1. HAMILTON WAY, FARMINGTON, CT

1.1 Executive Summary

G3 - Hamilton Way

Overview

Hamilton Way is a ten-lot subdivision located just outside of Hartford in Farmington, CT. It is a community designed and constructed through a partnership between Landworks Realty and Nelson Construction. The homes are single-family detached residences of approximately 3,000 ft^2 to 3,700 ft^2 with basements. The community is located in DOE Climate Zone 5A, and given the cold climate location of the project, focus was placed on conductance (high R-Value) and air tightness of the enclosure as well as efficiency of the heating system.

Key Results

The Building America energy consumption reduction goals (minimum 40% source energy consumption reduction compared to the Building America benchmark protocol) were exceeded for the community. The homes were modeled at around 48% savings, and achieved over of 50% based on measured system performance. These efficiency goals were achieved entirely from energy consumption reduction strategies and not through the addition of renewable strategies to offset energy use. However, photovoltaic panels are offered by Nelson Construction as an option and were installed on a few homes in the community.

Gate Status

Table 1.1: Stage Gate Status Summary

"Must Meet" Gate Criteria	Status	Summary
Source Energy Savings	Pass	The BA performance target was to a reach a minimum 40% source energy savings compared to the BA benchmark. The homes were modeled at around 48% savings, and achieved over of 50% based on measured system performance.
Market Coverage	Pass	Hamilton Way consists of 10 homes. The subdivision was completed in April 2009.
Neutral Cost Target	Pass	All of the homes met the neutral cost target. The homes increase in cost for each home was approximately $21,900 resulting in an additional mortgage of $1,923/year. This was compared to an annual utility bill savings of approximately $2,900/year to $4,000/year (depending on the plan type) yielding an annual net cash flow between $1,000/year to $2,000/year to the consumer.

"Should Meet" Gate Criteria	Status	Summary
Marketability	Pass	Consumer feedback indicated a strong interest in the energy efficiency aspects of the design and the importance of this on the decision to buy a home at Hamilton Way. This interest is also demonstrated through the decision of some homeowners to purchase the PV package that was offered as an addition to the home.

Market Coverage	Pass	Nelson Construction is a semi-custom/production home builder in climate zone 5A building around 15 to 50 homes a year (market dependant). The type of construction provided ranges from large (4000 ft^2) semi-custom luxury homes, to smaller (1500 ft^2) multi-family condominium complexes. Being just outside of Hartford, CT, larger homes (2500 ft^2 to 4000 ft^2) are common for the area.
Builder Commitment	Pass	The success at Hamilton Way has led to a restructuring of the business model for the Landworks/Nelson Construction team. The Development team now intends to place energy efficiency as a center point to the design and marketing strategy of future subdivisions and developments.
Gaps Analysis	Pass	Air leakage due to traditional wood burning fireplaces lead to increased infiltration rates. Performance testing of one home with factory glass doors "as is" and with the fireplace taped and air sealed was completed. The resulting performance difference was substantial with a reduction in air infiltration from 1658 CFM50 down to 1387 CFM50. Some work was done to examine gasketed custom doors; however th design is still being worked out.
Quality Assurance	Pass	Nelson Construction provides quality assurance and quality control through construction site management. A site/construction manager typically reviews the progress of construction on a regular basis. The smaller size of the subdivision lends itself to frequent inspection and construction monitoring.

Conclusions

The Hamilton Way development is a successful energy efficient community. The homes are designed with efficient enclosure and mechanical systems allowing for the designs to reach high levels of source energy consumption reduction without the addition of renewable energy technologies to offset energy use.

The success at Hamilton Way was also reported to have been influential in restructuring the Landworks/Nelson Construction business model. The Development team now intends to place energy efficiency as a center point to the design and marketing strategy of future subdivisions and developments.

BSC and Nelson Construction intend to continue working together on future projects. The goal is to keep pushing for greater energy savings. Future work will try to look to further optimize the enclosure design (increased air tightness such as addressing fireplace issues, moving to more efficient windows, increased thermal insulation, etc.) as well as looking towards integration of more advanced technologies as standard packages to the homes (solar hot water, photovoltaic panels, alternate heating and cooling systems, etc.)

1.2 Introduction

1.2.1. Project Overview

Hamilton Way is a ten-lot subdivision located just outside of Hartford in Farmington, CT. It is a community designed and constructed through a partnership between Landworks Realty and Nelson Construction. BSC began working with Landworks/Nelson Construction in December 2007 after a meeting at the 2007 EEBA conference between Chris Nelson (owner of Nelson Construction) and Armin Rudd (Principal at BSC) connected the goals of the Building America program with the desires of Nelson Construction to build an energy efficient showcase community in the Hartford area.

Chris Nelson as an active member in his local homebuilders association, and current president, has a desire to help advance energy efficient design in the local building community. Bringing an already high quality baseline of their standard home package to the beginning design phase for Hamilton Way, Nelson Construction worked with BSC to optimize the design and increase the efficiency through examining benefits of various strategies weighed against the energy consumption reduction, cost, and potential value in marketability.

The homes are single-family detached residences of approximately 3,000 ft^2 to 3,700 ft^2 with basements. The community is located in DOE Climate Zone 5A, and given the cold climate location of the project, focus was placed on conductance (high R-Value) and air tightness of the enclosure as well as efficiency of the heating system.

The Building America energy consumption reduction goals (minimum 40% source energy consumption reduction compared to the Building America benchmark protocol) were exceeded for the community. The homes were modeled at around 48% savings, and achieving over of 50% based on measured system performance. These efficiency goals were achieved entirely from energy consumption reduction strategies and not through the addition of renewable strategies to offset energy use. However, photovoltaic panels are offered by Nelson Construction as an option and are being installed on a few homes in the community.

In addition to the Building America Program, the community is also being certified under the EPA Energy Star® Program as well as the DOE Builder's Challenge, and has won awards from the Home Builders Association of Connecticut for "Best Energy-Efficient Community" and "Best Energy Efficient Spec Home"

Figure 1.2.1: Completed houses at Hamilton Way

1.2.2. Project Information Summary Sheet

PROJECT SUMMARY	
Company	Landworks Realty/Nelson Construction
Company Profile	Developer Ron Janeczko and builder Chris Nelson are partners in Landworks Development, LLC. Together they combine land planning and site development skills with the construction experience and knowledge of a second-generation builder. The results have been a series of highly successful communities in the Farmington Valley. The Landworks / Nelson Construction team has garnered many awards from the Connecticut Home Builders Association.
Contact Information	Chris Nelson Nelson Construction 77 Tolland Turnpike Manchester, CT 06042 860-646-0442
Division Name	N/A
Company Type	Developer/Builder Partnership
Community Name	Hamilton Way
City, State	Farmington, CT
Climate Region	Climate Zone 5A

SPECIFICATIONS	
Number of Houses	10
Municipal Address(es)	#1 to #4 Ingelside, #3 to #8 Hamilton Way Farmington, CT 06032
House Style(s)	single family

Number of Stories	2
Number of Bedrooms	4
Plan Number(s)	Sedgwick (Standard/Walkout) Ridgewood (Standard/Walkout) Griswold (Standard/Walkout)
Floor Area	3000 to 3700
Basement Area	1300 to 1600
Estimated Energy Reduction	45% to 52% (based on predicted performance) 50 to 55% (based on measured performance)
Estimated Energy Savings	$2,600 to $3,800 (Gas $1.71/therm; Electricity $0.19/kWh)
Estimated Cost	$800,000
Construction Start	December 2007
Expected Buildout	March 2009

1.2.3. Targets and Goals

Building America Community houses must reach a minimum of 40% vs. the 2008 Building America Benchmark in cold climates. This is an energy efficiency target established by Building America to promote quality design and construction.

Specific goals for this project were focused around high efficiency enclosure design. Given the climate zone, effort was placed on reducing conductive transfer as well and air infiltration. To accomplish this, high R-value assemblies were used as well as a critical seal air seal approach to try to attain enclosure air tightness well below the target goal for the Building America Program.

1.3 Whole-House Performance and Systems Engineering

1.3.1. Energy Analysis Summary

Table 1.2: Estimated Whole House Energy Use for Hamilton Way, Farmington, CT

ESTIMATED WHOLE HOUSE ENERGY USE BY PLAN NUMBER					
Plan No.	Source (MMBtu/year)	Site (MMBtu/year)	Area + Bsmt (sq ft)	No. of Bedrooms	% Electric
Sedgwick (Standard)	228	137	3611 + 1616	4	25
Sedgwick (Walkout)	236	145	3695 + 1653	4	23
Ridgewood (Standard)	215	127	3337 + 1404	4	26
Ridgewood (Walkout)	221	132	3356 + 1410	4	26
Griswold (Standard)	211	124	3062 + 1255	4	27
Griswold (Walkout)	215	127	3299 + 1323	4	27

With the enclosure and mechanical characteristics presented in Table 1.6 and Table 1.7, these plans achieve a performance level of 45% to 52% reduction relative to the Building America Benchmark.

1.3.1.1. Parametric Energy Simulations

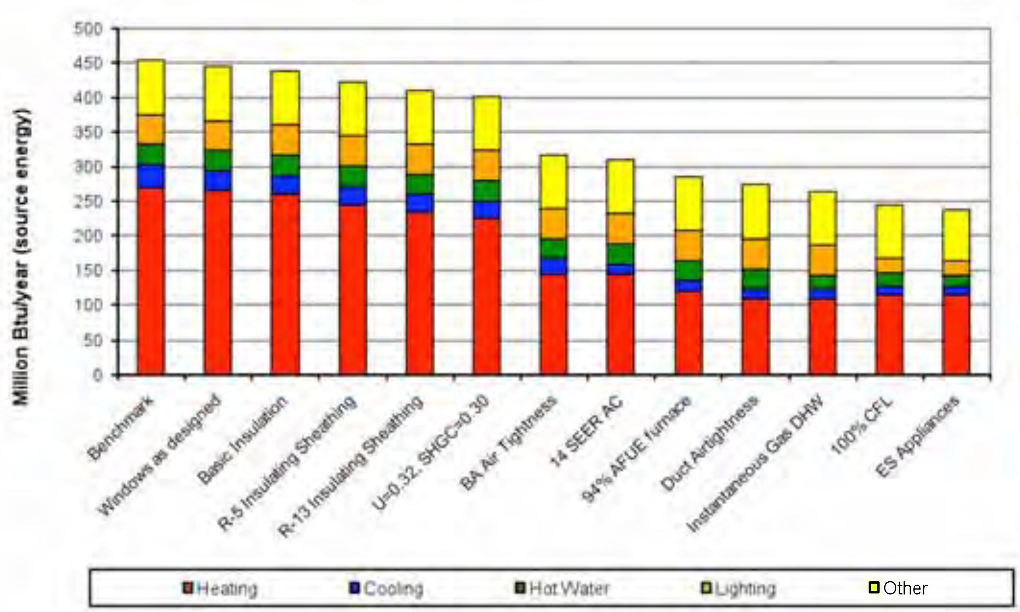


Figure 1.3.1: Parametric energy simulations for "Sedgwick Walkout" Plan

1.3.1.2. End-Use Site and Source Energy Summaries

Table 1.3.2: Summary of End-Use Site-Energy

	Annual Site Energy			
	BA Benchmark		Prototype 1	
End-Use	kWh	therms	kWh	therms
Space Heating	1752	2277	722	961
Space Cooling	2842		1119	
DHW	0	270	0	144
Lighting*	3781		1761	
Appliances + Plug	6810	0	6459	0
OA Ventilation**	15		18	
Total Usage	15199	2547	10079	1105
Site Generation	0	0	0	0
Net Energy Use	15199	2547	10079	1105

*Lighting end-use includes both interior and exterior lighting
**In EGUSA there are currently no hooks to disaggregate OA Ventilation, it is included in Space Heating and Cooling

Table 1.3.3: Summary of End-Use Source-Energy and Savings

			Source Energy Savings	
	Estimated Annual Source Energy		Percent of End-Use	Percent of Total
End-Use	BA Benchmark 106 BTU/yr	Prototype 1 106 BTU/yr	Prototype 1 savings	Prototype 1 savings
Space Heating	269	113	**58%**	**34%**
Space Cooling	33	13	**61%**	**4%**
DHW	29	16	**47%**	**3%**
Lighting*	43	20	**53%**	**5%**
Appliances + Plug	78	74	**5%**	**1%**
OA Ventilation**	0	0	**-24%**	**0%**
Total Usage	453	236	**48%**	**48%**
Site Generation	0	0		**0%**
Net Energy Use	453	236	**48%**	**48%**

The "Percent of End-Use" columns show how effective the prototype building is at reducing energy use in each end-use category.
The "Percent of Total" columns show how the energy reduction in each end-use category contributes to the overall savings.

All homes meet the minimum 40% source energy consumption reduction. As expected the primary savings were realized through increasing the thermal performance of the envelope (11.5% reduction), reducing the air infiltration (18.5% reduction), and high efficiency heating system (5.3% reduction). In addition to these savings, the use of compact fluorescent lighting throughout the house also had a significant impact (4.2% reduction).

1.3.2. Discussion

1.3.2.1. Enclosure Design

Table 1.3.4 (below) summarizes the building enclosure assemblies used for this project.

Table 1.3.4: Enclosure Specifications

ENCLOSURE	SPECIFICATIONS
Ceiling	
Description -	Truss/rafter framing with vented attic
Insulation -	R-50 cellulose at ceiling level
Walls	
Description -	2x6 Advanced Framing
Insulation -	R-13 2" polyisocyanurate sheathing with R-19 cellulose
Foundation	
Description -	Cast concrete basement
Insulation -	R-10 (2" XPS) below slab, R-10 (2” XPS) cast in walls (Thermomass)
Windows	
Description -	Double Pane Vinyl Spectrally Selective LoE²
Manufacturer -	Harvey Industries
U-value -	0.32
SHGC -	0.27

ENCLOSURE	SPECIFICATIONS
Infiltration	
Specification -	2.5 in^2 leakage area per 100 ft^2 envelope
Performance test -	2081 to 2470 CFM 50 (3.0 to 3.3 ACH 50)

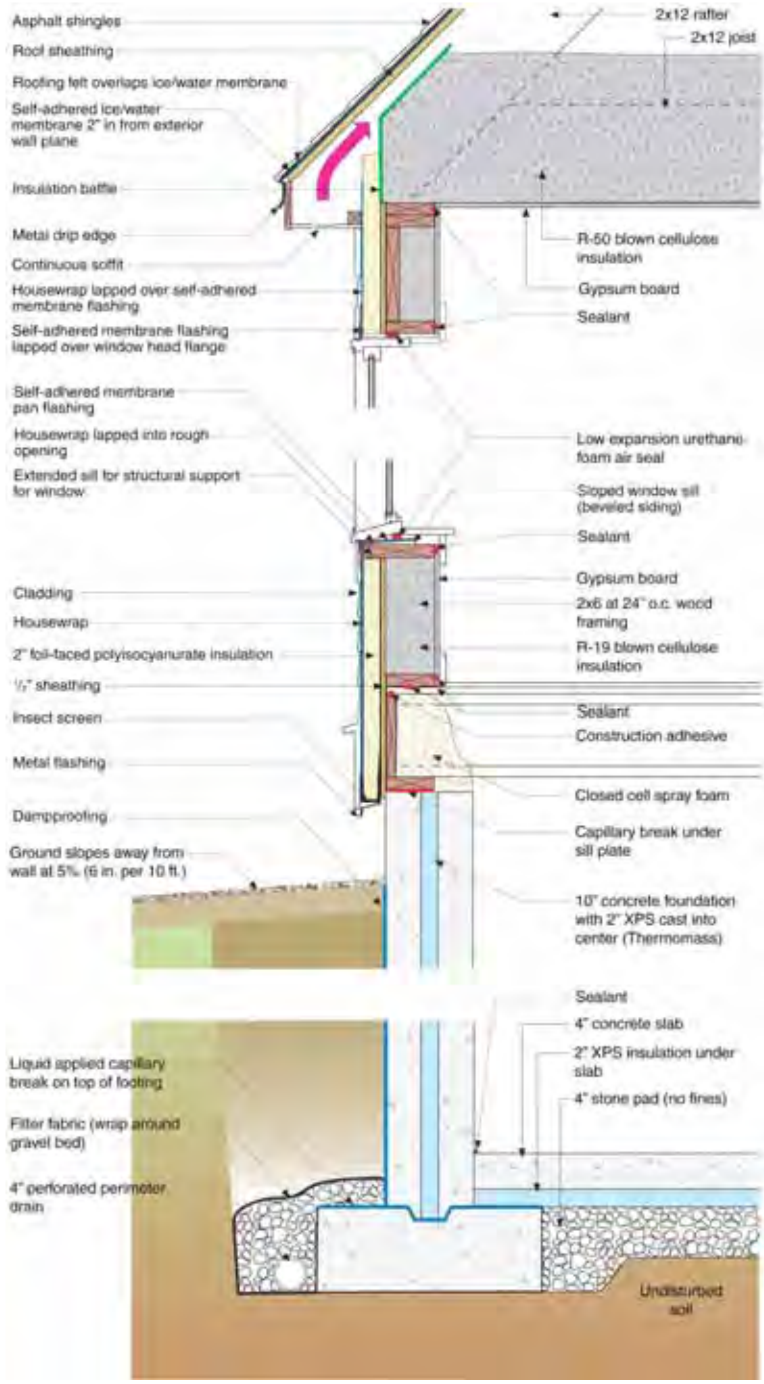


Figure 1.3.2: Enclosure Building Section

The roof is designed as a vented attic with R-50 blown in cellulose insulation on the ceiling plane. Strategies such as dropped perimeter ceiling soffits was used to maintain the thickness of the insulation near the perimeter and still be able to provide higher ceilings in areas such as the master bedroom.

Figure 1.3.3: Dropped ceiling soffit framing

Adding insulating sheathing was not common practice for Nelson Construction. The potential energy benefits were discussed as well as the design and construction implications and it was decided to incorporate 2" of foil-faced polyisocyanurate to the exterior of the wall assemblies. To help with this change, BSC provided details to C Nelson Homes illustrating how the insulating sheathing is incorporated into the design. These details were incorporated as an addendum to the framing package created for Lot 7 of Hamilton Way. The overall effective R-Value for this assembly is R-26 (twice the effective thermal resistance of a typical 2x6 framed wall). The application of 2" of foil-faced polyisocyanurate to the exterior is done through the use of large headed roof nails or cap nails. The housewrap drainage plane is installed exterior of the foam and the windows are flashed to the Tyvek® housewrap. The housewrap is taped with Tyvek® Tape to help with the durability of the installation from wind before the cladding is installed.

Figure 1.3.4: Tyvek® installed over 2" foil-faced polyisocyanurate

The foundation is designed with the Thermomass system. This system incorporates 2" of XPS insulation (R-10) cast into the center of the concrete foundation wall. This was a choice from the builder to allow for the basements to remain unfinished while still providing continuity of the thermal enclosure. The negative aspect of the system was related to the increased cost, however, given that the insulation does not need to be covered with a thermal barrier (Thermax™ was not considered from an aesthetic perspective), the cost trade off from not requiring to finish the basement with gypsum compared to the extra cost for the thermomass was thought to be nearly equal.

Figure 1.3.5: Thermomass foundation system

Figure 1.3.6: Insulation at bulkhead door opening

The windows are a Harvey Industries Vicon vinyl double paned Low-E2 with Argon. These windows have a U-Value of 0.32 and SHGC of 0.27. The coated glazing has superior insulating properties compared to clear glass. The glass coating allows transmission of most of the visible light (unlike tinted windows), while cutting ultraviolet light transmittance by approximately 90%. Therefore, they reduce cooling load from solar gain, increase comfort, and reduce UV damage to furnishings.

Air tightness is a concern particularly in cold climates as the temperature difference across the enclosure is much higher than in hot climates. The design incorporates the airtight drywall approach with a critical seal approach to reduce the potential for air infiltration. In this assembly, the interior gypsum is the primary plane of air tightness for the enclosure. To accommodate this, the perimeter of the gypsum is sealed to the framing. In addition, spray foam is applied in areas of known air infiltration (rim/band joists, around windows, at any mechanical/electrical penetrations). Particular care is taken at the ceiling plane to address leakage associated with lights and the intersection of partition walls. The floor over the garage is a flash and batt approach providing air tightness between the garage and the living space above.

Figure 1.3.7: Closed cell spray foam at rim joist

Figure 1.3.8: Closed cell spray foam floor over the garage

1.3.2.2. Mechanical System Design

Table 1.3.5 (below) summarizes the mechanical systems used by this project.

Table 1.3.5: Mechanical system specifications

MECHANICAL SYSTEMS	SPECIFICATIONS
Heating	
Description -	Seal combustion 94% gas furnace
Manufacturer & Model -	Lennox G61MP Series
Cooling (outdoor unit)	
Description -	14 SEER Condenser
Manufacturer & Model -	Lennox 14ACX
Cooling (indoor unit)	
Description -	Indoor Coil
Manufacturer & Model -	Lennox CX34
Domestic Hot Water	
Description -	0.82 EF instantaneous gas hot water heater
Manufacturer & Model -	Rinnai R94LSi
Distribution	
Description -	Single air handler with zone control dampers (2 zones) Insulated sheet metal trunks with insulated flex run-outs

MECHANICAL SYSTEMS	SPECIFICATIONS
Leakage -	none to outside (5% or less)
Ventilation	
Description -	Supply-only system integrated with AHU, 75 CFM 33% Duty Cycle: 20 minutes on; 40 minutes off
Manufacturer & Model -	Aprilaire Model 8126 Ventilation Control System
Return Pathways	
Description -	2 returns (low first floor, high second floor) Transfer grilles/jump ducts at bedrooms
Dehumidification	
Description -	none
Manufacturer & Model -	N/A
PV System	
Description -	7 kW array (Lot 4, Lot 5, and Lot 6)
Manufacturer & Model -	Sanyo HIT Power 200 Series Module
Solar Hot Water	
Description -	none
Manufacturer & Model -	N/A

The climate is a heating dominated climate increasing the importance of the efficiency of the heating system. The furnace for this project is designed as a 94% sealed combustion condensing gas furnace. Being sealed combustion the furnace is completely decoupled from the interior environment, addressing concerns relating to make up air (the energy penalty associated with the uncontrolled air infiltration required for naturally aspirating appliances) as well as the potential indoor air quality concerns from back drafting of appliances.

Figure 1.3.9: Lennox 94% AFUE Furnace

Figure 1.3.10: Rinnai 0.82EF Instantaneous Gas Water Heater

While not as critical as the heating system, high efficiency appliances were used for all other aspects of the mechanical design including a 14 SEER central air conditioning system and a 0.82EF natural gas instantaneous hot water system.

As a cost savings and system efficiency measure, the mechanical design was modified from 2 furnace air handlers (one in the attic and one in the basement) to a single furnace air handler in the basement with 2 zones. This removed all of the ductwork from the attic and placed it within the conditioned space. BSC worked closely with Nelson Construction to help modify the house plans to re-route the ductwork in the structure to provide conditioning to the second floor. This required a few framing modifications and the addition of some dropped soffits to accommodate the supply trunks. As a strategy to provide better mixing of the interior air, two returns were designed into the system (low on the first floor and high on the second floor). The intent was to help counter the effects of stratification. These efforts were successful in bringing all of the ductwork inside the conditioned space.

New to Nelson Construction designs was the use of a ventilation control system. Given the airtight nature of the building enclosure, providing ventilation air to the home is important. The ventilation system chosen is central fan integrated system controlled with an Aprilaire 8126 controller. The system includes an outside air duct is run from the outside to the return side of the air handler. The running air handler pulls outside air into the return system, and an electrically operated damper prevents excess ventilation during peak load usage. This damper automatically closes the fresh air duct to prevent outside air from diluting the conditioned air too much.

Figure 1.3.11: Aprilaire motorized damper installed on outdoor air intake duct

1.3.2.3. Lighting and Miscellaneous Electrical Loads

The houses are fitted with compact fluorescent lights in all of the fixtures. As part of the delivery of the home, information is passed on to the homeowner regarding the potential energy and utility savings that can be realized through the use of efficient lamps.

Figure 1.3.12: Compact fluorescent lamps installed in the lighting fixture

Nelson construction also provides appliances as part of the home package. The appliances are all Energy Star® rated as applicable (washing machine, dishwasher, refrigerator).

1.3.2.4. Site-generated Renewable Energy

No renewable strategies were included as standard on the homes, however, Nelson Construction is offering Photovoltaic systems as an option for the homes. One homeowner elected to have a 7kW photovoltaic system installed on the home as part of the purchase and sale of the home. Nelson Construction also made available to the homeowners contact information with a PV installer should the homeowners decide to have PV systems installed at a later date. To additional homes were fitted with similar PV systems after the final purchase and sale was complete totally 3 homes in the community with 7kW PV systems installed.

Figure 1.3.13: Lot 4 with 7kW PV array installed on the South facing roof

1.4 Construction Support

1.4.1. Construction Overview

Construction began in late 2007 on Lot 7 of the community. Lot 7 was the model home for Hamilton Way and provided the steepest learning curve for construction. BSC worked closely with Nelson construction to help with the adoption of new construction details and practices needed to integrate the new enclosure elements and new technologies.

As experienced with other subdivisions and research homes, the integration of insulating sheathing into the enclosure design often provides some of the greatest challenges for a builder. Early site meetings discussed installation methods, particularly for windows (cantilevered over the 2” foam thickness and installed with a pan flashed and sloped sill), and other requirements for the insulating sheathing (insect control, fastener requirements, cladding attachment). Nelson Construction was able to adopt these details very easily and construction proceeded very smoothly.

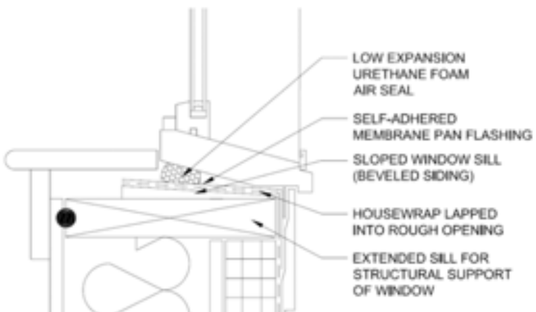


Figure 1.4.1: Provided window detail section

Figure 1.4.2: Window installation at sill

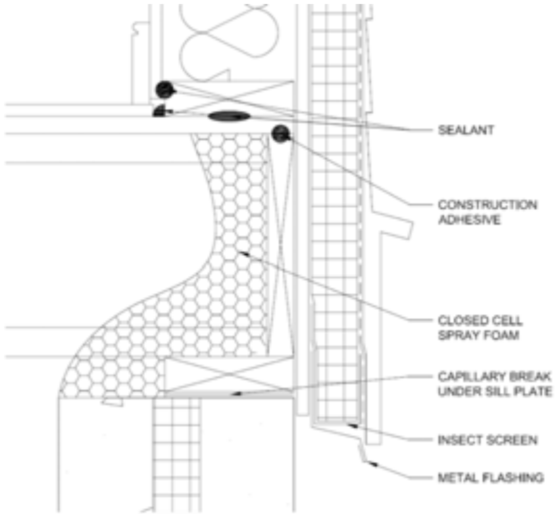


Figure 1.4.3: Provided foundation interface detail

Figure 1.4.4: Installation of insect screen at foundation

The mechanical contractor integrated the changes to the mechanical design and no significant issues arose. The design was ever evolving during the construction process, and duct layouts were changed in the community to reflect the high efficiency enclosure. Floor registers out at the exterior walls were installed in the first few homes as is common practice for cold climate homes. BSC concerns relating to registers being covered by furniture impeding the efficient delivery of conditioned air to the space were relayed to Nelson Construction. Based on this a decision was made to change the locations to high wall registers closer to the interior core to shorten duct run-out length and provide unobstructed locations for the registers.

Figure 1.4.5: High wall register roughed in

Periodic site visits for construction monitoring and performance testing were completed from December 2007 through to February 2009. Construction proceeded very smoothly with few issues noted during site visits.

1.4.2. Educational Events and Training

Dr. Lstiburek of BSC was asked to come and present at the NAHB Builder 20 Club that Nelson Construction is a member of. The presentation covered new construction techniques and energy efficiency and technologies that are available to builders. This presentation sparked the interest of Moser Builders (another member of the Builder 20 Club) in the benefits of the Building America Program. Subsequently, Moser Builders became a Building America Partner, constructing a high efficiency prototype home in Chester County, PA.

1.4.3. Systems Testing

As each home neared completion, BSC scheduled a site visit to perform the standard battery of performance testing, including overall air infiltration (blower door), duct leakage (total and to exterior), HVAC system static pressure and overall flow, HVAC register flows, room pressurization, and ventilation system flows.

The performance of the homes exceeded the minimum standards set out by the Building America Program. Some of the results are highlighted in Table 2.4.1 below.

Table 1.4.1: Performance Testing Results

Address	Plan	CFM 50 Measured	CFM 50 Goal	Pass/Fail 2.5 in^2	Duct25 Outside Measured	Duct25 Outside Goal	Pass/Fail 5% out
1 Ingelside	Griswold (Walkout)	1544	2368	Pass	40	60	Pass
2 Ingelside	Sedgwick (Standard)	1813	2431	Pass	28	60	Pass
3 Ingelside	Ridgewood (Walkout)	1387	2221	Pass	35	60	Pass
4 Ingelside	Sedgwick (Standard)	1779	2431	Pass	30	60	Pass
3 Hamilton Way	Ridgewood (Standard)	1473	2195	Pass	29	60	Pass
4 Hamilton Way	Sedgwick (Walkout)	1713	2470	Pass	25	60	Pass
5 Hamilton Way	Sedgwick (Standard)	1946	2431	Pass	51	60	Pass
6 Hamilton Way	Griswold (Walkout)	1645	2368	Pass	50	60	Pass
7 Hamilton Way	Griswold (Standard)	1252	2081	Pass	57	60	Pass
8 Hamilton Way	Sedgwick (Walkout)	1891	2470	Pass	40	60	Pass

1.4.4. Monitoring

As part of a follow up to the energy performance for the homes it is intended to collect utility bills from each of the homeowners to compare predicted use and actual consumption. In addition, bills are intended to be collected from other similar subdivisions built by Nelson Construction to see if there is a notable difference in the performance of the homes at Hamilton Way.

1.5 Project Evaluation

The following sections evaluate the performance of the final production building designs using energy simulations and targeted field tests, if needed. References are made to the results from field tests and energy simulations, which are included as an appendix to this report.

1.5.1. Source Energy Savings

Requirement:	*Final production home designs must provide targeted whole house source energy efficiency savings based on BA performance analysis procedures and prior stage energy performance measurements.*
Conclusion:	***Pass***

The homes at Hamilton Way exceeded the minimum whole house source energy savings based on BA performance analysis and energy performance measurements. The Building America goal for communities is 40% savings and the houses are reaching above 50% savings (based on the performance testing results).

Table 2.5.1: Source Energy Savings Evaluation Results

Lot #	Address	Plan Name	Source Energy Consumption Reduction (%)	HERS	Benchmark Estimated Annual Utility Costs	Prototype Estimated Annual Utility Costs	Estimated Annual Utility Savings
1	2 Ingelside	Sedgwick (Standard)	56%	45	$7,651	$3,166	$4,485
2	4 Ingelside	Sedgwick (Standard)	55%	48	$7,552	$3,462	$4,090
3	3 Ingelside	Ridgewood (Walkout)	51%	48	$6,857	$3,364	$3,493
4	1 Ingelside	Griswold (Walkout)	72%	31	$6,922	$1,906	$5,015
5	4 Hamilton Way	Sedgwick (Walkout)	52%	48	$7,243	$3,547	$3,696
6	6 Hamilton Way	Griswold (Walkout)	50%	49	$6,922	$3,514	$3,408
7	8 Hamilton Way	Sedgwick (Walkout)	50%	48	$7,114	$3,588	$3,526
8	7 Hamilton Way	Griswold (Standard)	52%	50	$6,135	$3,241	$2,894
9	5 Hamilton Way	Sedgwick (Standard)	51%	46	$7,034	$3,289	$3,745
10	3 Hamilton Way	Ridgewood (Standard)	50%	46	$5,972	$2,747	$3,225

1.5.2. Market Coverage

Requirement:	*Must have a minimum of 10 homes per project (including projects from all teams). At least five homes must be completed by March/April to be used as a case study in the annual Joule* report.*
Conclusion:	***Pass***

Hamilton Way is a small subdivision consisting of 10 homes. Final build out of the subdivision was completed in April 2009.

1.5.3. Neutral Cost Target

Requirement:	*The incremental annual cost† of energy improvements, when financed as part of a 30 year mortgage, must be less than or equal to the annual reduction in utility bill costs relative to the BA benchmark house.*
Conclusion:	***Pass***

The cost of the energy efficiency upgrades to the home compared to the incremental annual cost† of energy improvements, when financed as part of a 30 year mortgage results in a positive annual cash flow. The results demonstrated that the additional mortgage costs would be approximately 2/3 the annual utility bill costs relative to the BA benchmark house. The analysis took into account the fees required for third party testing as well as the benefits back to the builder relative to the federal tax credit.

The estimated annual utility savings were based on local utility rates provided by Nelson Construction (Gas $1.71/therm; Electricity $0.19/kWh)

Neutral Cost Analysis Worksheet

Updated January 16, 2009

bhendron:
New tab added for neutral cost calculations

	Annual Electric Energy (Site)			Annual Gas Energy (Site)					
	Benchmark	Builder Standard Practice (Optional)	Prototype House	Benchmark	Builder Standard Practice (Optional)	Prototype House	Annual Utility Bill Reduction vs Benchmark	Local Marginal Electricity Price	Local Marginal Gas Price
End Use	**(kWh/yr)**	**(kWh/yr)**	**(kWh/yr)**	**(therms/yr)**	**(therms/yr)**	**(therms/yr)**	**($/yr)**	**($/kWh)**	**($/therm)**
Space Heating	2061.75		578	2768		837	$3,584	$0.19	$1.71
Space Cooling	2900.75		1393				$286		
DHW	0		0	291		152	$238		
Lighting	3715		1732				$377		
Appliances and MELs	6770		6419	0		0	$67		
Ventilation	98.75		95				$1		
Total Usage	**15546.25**	**0**	**10217**	**3059**	**0**	**989**	**$4,552**		
Site Generation							$0		
Net Energy Use	**15546.25**	**0**	**10217**	**3059**	**0**	**989**	**$4,552**		
Added Annual Mortgage Cost w/o Site Gen.							**$2,055**		
Net Cash Flow to Consumer w/o Site Gen.							**$2,497**		
Added Annual Mortgage Cost with Site Gen.							**$2,055**		
Net Cash Flow to Consumer with Site Gen.							**$2,497**	**Neutral Cost Criteria Met?**	**Yes**

Figure 1.5.1: Neutral Cost Analysis Summary - Lot 1 Hamilton Way

† Mature market incremental first cost evaluated relative to builder standard practice.

Measure	Builder Standard Practice (Optional)	Code Minimum House*	Prototype House*	Total Incremental Cost + 10% markup)	Amortized Annual Cost (30 year mortgage, 7% interest)	Footnotes
Thermal Enclosure:	**$0**	**$0**	**$19,400**	**$21,340**	**$1,704**	
Roof / Attic	$0	$0	$750	**$825**	**$66**	
Cathedral Roof	$0	$0	$0	**$0**	**$0**	
Flat Ceiling	$0	$0	$750	**$825**	**$66**	
Radiant Barrier	$0	$0	$0	**$0**	**$0**	
Other Roof Attic Measure	$0	$0	$0	**$0**	**$0**	
Wall	$0	$0	$7,750	**$8,525**	**$681**	
Cavity Insulation	$0	$0	$750	**$825**	**$66**	
Insulating Sheathing	$0	$0	$6,500	**$7,150**	**$571**	
Advanced Framing	$0	$0	$0	**$0**	**$0**	
Other Wall Measure	$0	$0	$500	**$550**	**$44**	
Foundation	$0	$0	$10,600	**$11,660**	**$931**	
Slab	$0	$0	$1,600	**$1,760**	**$141**	
Crawlspace	$0	$0	$0	**$0**	**$0**	
Basement	$0	$0	$9,000	**$9,900**	**$790**	
Air Infiltration Reduction	$0	$0	$300	**$330**	**$26**	
Other Enclosure Measures	$0	$0	$0	**$0**	**$0**	
Windows:	**$0**	**$0**	**$0**	**$0**	**$0**	
Glazing: *U-Factor / SHGC*	$0	$0	$0	**$0**	**$0**	
Slider (horz)	$0	$0	$0	**$0**	**$0**	
Slider (vert)	$0	$0	$0	**$0**	**$0**	
Fixed	$0	$0	$0	**$0**	**$0**	
Patio	$0	$0	$0	**$0**	**$0**	
French	$0	$0	$0	**$0**	**$0**	
Other Window Measures	$0	$0	$0	**$0**	**$0**	
HVAC System:	**$0**	**$0**	**$850**	**$935**	**$75**	
Furnace: AFUE	$0	$0	$500	**$550**	**$44**	
A/C: SEER	$0	$0	$350	**$385**	**$31**	
Ducts	$0	$0		**$0**	**$0**	
Ventilation	$0	$0	$0	**$0**	**$0**	
Other HVAC Measures	$0	$0	$0	**$0**	**$0**	
Water Heating:	**$0**	**$0**	**$750**	**$825**	**$66**	
Water Heater Size	$0	$0	$0	**$0**	**$0**	
Solar System	$0	$0	$0	**$0**	**$0**	
Tankless	$0	$0	$750	**$825**	**$66**	
Distribution Type	$0	$0	$0	**$0**	**$0**	
Other Water Heating	$0	$0	$0	**$0**	**$0**	
Lighting:	**$0**	**$0**	**$150**	**$165**	**$13**	
Hard Wired Fluorescents	$0	$0	$0	**$0**	**$0**	
Compact Fluorescents	$0	$0	$150	**$165**	**$13**	
Other Lighting Measures	$0	$0	$0	**$0**	**$0**	
Appliances:	**$0**	**$0**	**$750**	**$825**	**$66**	
Energy Star	$0	$0	$750	**$825**	**$66**	
Other Appliance Measures	$0	$0	$0	**$0**	**$0**	
Misc Electric Loads:	**$0**	**$0**	**$0**	**$0**	**$0**	
Home Automation	$0	$0	$0	**$0**	**$0**	
Other MEL Measures	$0	$0	$0	**$0**	**$0**	
Other Measures	**$0**	**$0**	**$0**	**$0**	**$0**	
3rd Party Inspections and QA Testing	**$0**	**$0**	**$1,500**	**$1,650**	**$132**	
Total Energy Efficiency Investment	**$0**	**$0**	**$23,400**	**$25,740**	**$2,055**	
Site Generation	**$0**	**$0**	**$0**	**$0**	**$0**	
Total with Site Generation	**$0**	**$0**	**$23,400**	**$25,740**	**$2,055**	
REBATES / INCENTIVES	**$0**	**$0**	**$2,000**	**$2,200**	**$176**	
SMUD Rule 15 Hook Up Fee Discount	$0	$0	$0	**$0**	**$0**	
Incentive for Lighting and Energy Star	$0	$0	$0	**$0**	**$0**	
SMUD PV Buydown	$0	$0	$0	**$0**	**$0**	
Other	$0	$0	$2,000	**$2,200**	**$176**	
Total Incremental Cost to Buyer Including Incentives	**$0**	**$0**	**$25,400**	**$27,940**	**$2,231**	

Figure 1.5.2: Neutral Cost Analysis Worksheet - Lot 1 Hamilton Way

1.5.4. Marketability

Requirement:	*Based on initial response from model homes, should be marketable relative to the value-*

	added benefit seen by consumers at increased or neutral cost.
Conclusion:	***Pass***

Hamilton Way experienced a high volume of sales in a market that had almost completely stopped in competing areas. The subdivision completely sold in less than one year.

Initial consumer feedback to Nelson Construction through the first few sales did not necessarily indicate a strong market value for the energy efficiency upgrades that were designed into the community. However, later consumer feedback did show a strong interest in the energy efficiency aspects of the design and the importance of this on the decision to buy a home at Hamilton Way. This interest is also demonstrated through the decision of some homeowners to purchase the PV package that was offered as an addition to the home.

1.5.5. Market Coverage

Requirement:	*Project case studies should cover a representative range of weather conditions and construction practices in major metropolitan areas in the targeted climate region.*
Conclusion:	***Pass***

Nelson Construction is a semi-custom/production home builder in climate zone 5A, building around 15 to 50 homes a year (market dependant). The type of construction provided ranges from large (4000 ft^2) semi-custom luxury homes, to smaller (1500 ft^2) multi-family condominium complexes. Being just outside of Hartford, CT, larger homes (2500 ft^2 to 4000 ft^2) are common and would be considered representative for the area.

1.5.6. Builder Commitment

Requirement:	*Should demonstrate strong builder commitment to continued construction at current or future BA performance targets.*
Conclusion:	***Pass***

The initial driving force behind the project and the creation of a high efficiency community was from a desire to "move in the right direction". Energy efficiency was an ethic that Chris Nelson simply wanted to include in the design. Landworks has since talked with BSC stating that the success at Hamilton Way has led to a restructuring of the business model for the Landworks/Nelson Construction team. The Development team now intends to place energy efficiency as a center point to the design and marketing strategy of future subdivisions and developments.

1.5.7. Gaps Analysis

Requirement:	*Should include a summary of builder technical support requirements, gaps analysis, lessons learned, optimal builder business practices, what not to do, documentation of failures, recommendations for policy improvements, and remaining technical and market barriers to achieving current and future performance levels.*
Conclusion:	***Pass***

While a slight learning curve was needed in the adoption if the new envelope and mechanical systems, none of the changes amounted to very significant hurdles for Nelson Construction.

One aspect of the design that affected the overall performance of the homes was the inclusion of traditional masonry fireplaces in the construction of the homes. Early discussions between BSC and Landworks/Nelson Construction discussed the potential energy performance implications of the fireplace design uncontrolled air leakage). BSC recommended the use of sealed combustion natural gas fireplace inserts to decouple the combustion process from interior environment and address the air infiltration impacts of a traditional masonry fireplace design. Ultimately, the decision to keep the traditional fireplace design was made based on perceived market benefits (value added to the home from a consumer perspective).

Steps were taken to try to minimize the air infiltration effects of the fireplace design through the use of custom made doors for the fireplace covers. The intention was to create a door system that would be gasketed to reduce air leakage though the chimney. The design is still being worked out.

Performance testing of one home with factory glass doors "as is" and with the fireplace taped and air sealed was completed. The resulting performance difference was substantial with a reduction in air infiltration from 1658 CFM50 down to 1387 CFM50. Additional work on addressing fireplace air infiltration issues is required.

1.5.8. Quality Assurance

Requirement:	Should provide documentation of builder's energy related QA and QC processes.
Conclusion:	***Pass***

Nelson Construction provides quality assurance and quality control through construction site management. A site/construction manager typically reviews the progress of construction on a regular basis. The smaller size of the subdivision lends itself to frequent inspection and construction monitoring.

1.6 Conclusions/Remarks

The Hamilton Way development is a successful energy efficient community. The homes are designed with efficient enclosure and mechanical systems allowing for the designs to reach high levels of source energy consumption reduction without the addition of renewable energy technologies to offset energy use.

Due to the high quality of construction from Nelson Construction the performance of the homes is exceeding the expected performance of the earlier energy analysis. The homes reach an estimated 50% or greater source energy consumption reduction when compared to the 2008 Building America Benchmark.

Sales in the community were high compared to other similar price point communities in the area. The entire ten-lot subdivision has been sold with the final closing in February of 2009. Reports from the Landworks Realty indicated that the energy efficiency aspects of the designs were a key aspect in homebuyers' interest.

The success at Hamilton Way also reported to have been influential in restructuring the Landworks/Nelson Construction business model. The Development team now intends to place energy efficiency as a center point to the design and marketing strategy of future subdivisions and developments.

BSC and Nelson Construction intend to continue working together on future projects. The goal is to keep pushing for greater energy savings. Future work will try to look to further optimize the enclosure design (increased air tightness such as addressing fireplace issues, moving to more efficient windows, increased thermal insulation, etc.) as well as looking towards integration of more advanced technologies as standard packages to the homes (solar hot water, photovoltaic panels, alternate heating and cooling systems, etc.)

1.7 Appendices

1.7.1. BSC Project Case Study-Hamilton Way Community Prototype

1.7.2. 2008-01-23 Hamilton Way Lot 7 Analysis

1.7.3. 2008-05-28 Hamilton Way Analysis

1.7.4. 2008-09-01 Hamilton Way Site Visit Summary

1.7.5. 2008-10-10 Hamilton Way Site Visit Summary

Appendix E.1.7.1
BSC Project Case Study: Hamilton Way Community Prototype

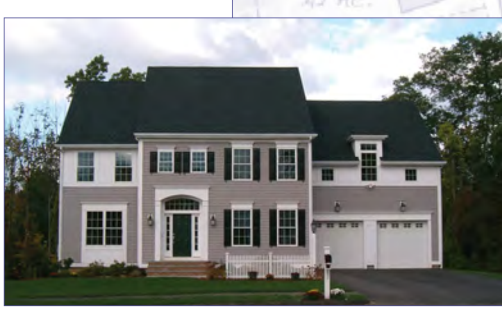
Case Study

Hamilton Way Community Prototype

Farmington, Connecticut

Overview

Hamilton Way is a ten-lot subdivision located just outside of Hartford in Farmington, Connecticut. It is a community designed and constructed through a partnership between Landworks Realty and Nelson Construction. Building Science Corporation (BSC) began working with Landworks/Nelson Construction in December 2007 after a meeting at the 2007 EEBA conference between Chris Nelson (owner of Nelson Construction) and Armin Rudd (Principal at BSC) connected the goals of the Building America program with the desires of Nelson Construction to build an energy efficient showcase community in the Hartford area.



Chris Nelson, as an active member and current president of his local homebuilders' association, has a desire to help advance energy efficient design in the local building community. Bringing an already high quality baseline of their standard home package to the beginning design phase for Hamilton Way, Nelson Construction worked with BSC to optimize the design and increase the efficiency through examining benefits of various strategies weighed against the energy consumption reduction, cost, and potential value in marketability.

U.S. Department of Energy
Energy Efficiency and Renewable Energy
Bringing you a prosperous future where energy is clean, abundant, reliable, and affordable

Project Profile

Project Team:
C. Nelson Construction, Inc.

Location:
Hamilton Way, Farmington, Connecticut

Description:
10 single family 4-bedroom homes with basements ranging from 3,000 ft^2 to 3,700 ft^2

Completion Date:
February 2009

Estimated Annual Energy Savings:
50% savings over the Building America benchmark; $2,600 to $3,800

Building Science Corporation
30 Forest Street
Somerville, MA 02143
www.buildingscience.com

Builder Profile

Developer Ron Janeczko and builder Chris Nelson are partners in Landworks Development, LLC. Together they combine land planning and site development skills with the construction experience and knowledge of a second-generation builder.

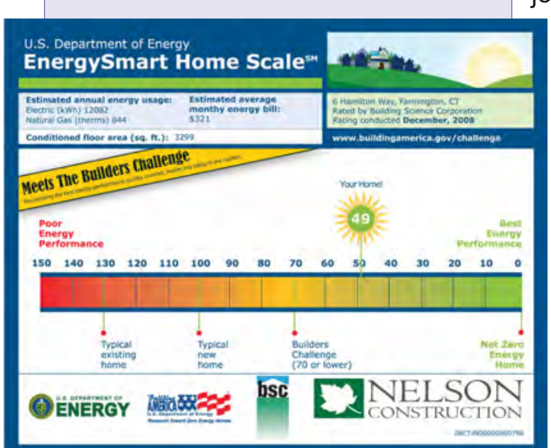
The results have been a series of highly successful communities in the Farmington Valley. The Landworks / Nelson Construction team has garnered many awards from the Connecticut Home Builders Association.

Participating Programs & Certifications

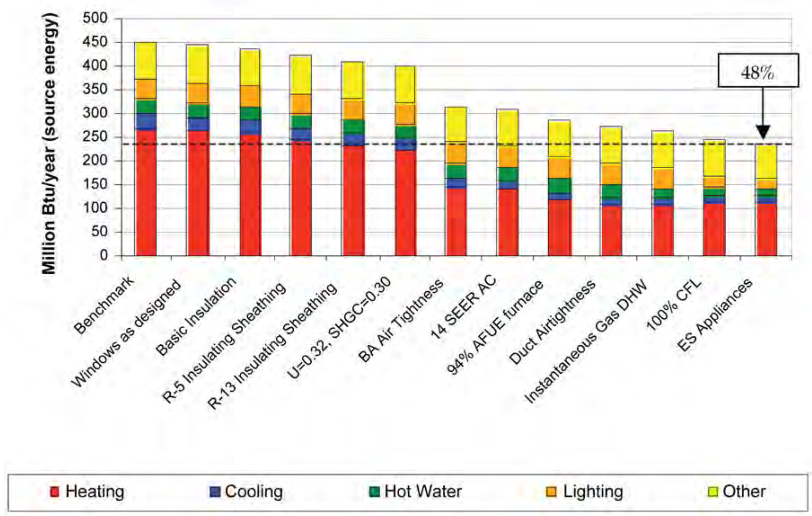
U.S. Department of Energy's Building America Program

U.S. Environmental Protection Agency ENERGY STAR® Program

Home Builders Association of Connecticut: Best Energy-Efficient Community and Best Energy-Efficient Spec Home



Design

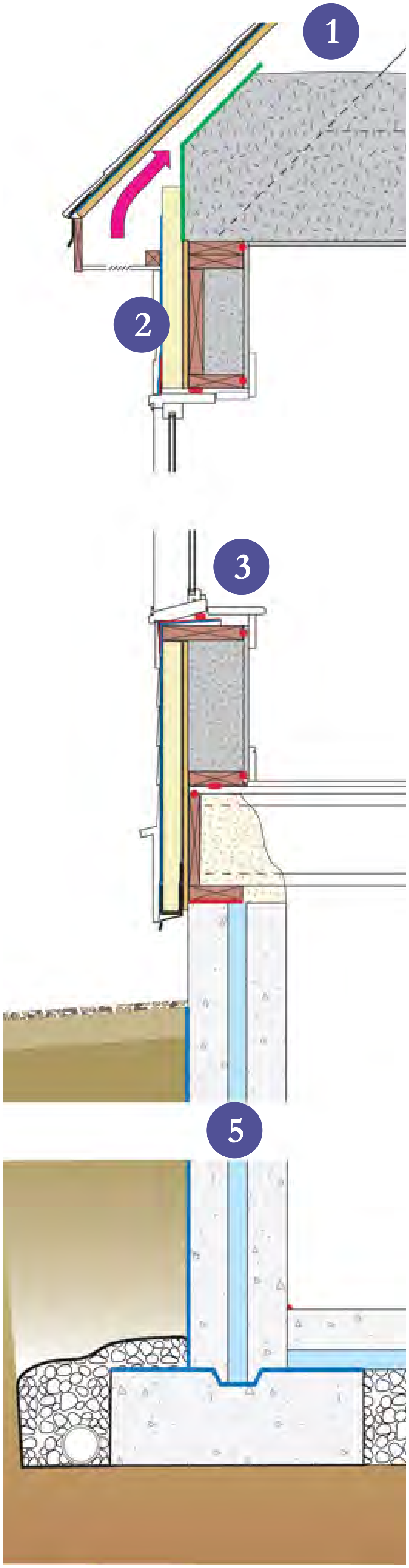


Parametric Study

The Building America target goals for the community were to achieve a minimum 40% source energy consumption reduction when compared to the Building America benchmark protocol. Since the community was located in a cold climate, special focus was placed on the efficiency of the thermal enclosure and air tightness of the homes. The basements were designed with insulation cast into the concrete foundation walls (Thermomass® system) and the above grade walls were covered with 2" of foil-faced polyisocyanurate. To achieve the air tightness goals for the project, a critical seal approach was used that targeted known common air leakage areas such as rim boards and band joists as well as the tops of partition walls and mechanical penetrations and sealed them using closed cell spray foam.

In the heating dominated climate a high efficiency natural gas furnace (94% AFUE) was included in the design, along with a 14 SEER air conditioner and an instantaneous gas domestic hot water heater. As a cost savings and system efficiency measure, the mechanical design was modified from 2 furnace air handlers (one in the attic and one in the basement) to a single furnace air handler in the basement with 2 zones. This removed all of the ductwork from the attic and placed it within the conditioned space. The house plans were modified to reroute the ductwork in the structure to provide conditioning to the second floor. This required a few framing modifications and the addition of some dropped soffits to accommodate the supply trunks. To provide better mixing of the interior air, two returns were designed into the system (low on the first floor and high on the second floor). The intent was to help counter the effects of stratification. These efforts were successful in bringing all of the ductwork inside the conditioned space.

All of these strategies were modeled through a parametric annual load study that examined the individual effect of each strategy as well as the total cumulative effect of all of the strategies. The results of the analysis indicated that the homes would well exceed the Building America minimum target and achieve a source energy consumption reduction between 45% and 48%. These efficiency goals were achieved entirely from energy consumption reduction strategies and not through the addition of renewable strategies to offset energy use. However, photovoltaic panels were offered by Nelson Construction as an option and are being installed on a few homes in the community.



Enclosure Design

❶ **Roof Assembly:** Rafter framed vented attic with R-50 blown cellulose insulation. Dropped perimeter ceiling soffits were used to maintain the thickness of the insulation near the perimeter and still be able to provide higher ceilings in areas such as the master bedroom.

❷ **Wall Assembly:** 2x6 wall at 24” O.C. with R-19 damp spray cellulose cavity insulation and 2” (R-13) of foil-faced polyisocyanurate insulating sheathing. The wall drainage plane was provided by Tyvek homewrap installed over the insulating sheathing.

❸ **Window Specifications:** Harvey Vicon double hung vinyl Low-E Argon with contour grid windows (U=0.32, SHGC = 0.27). Windows were installed in a pan flashed and drained manner with a sloped sill drained to the exterior and the head and jambs integrated into the drainage plane through the use membrane flashing.

❹ **Floor Assembly:** TJI floor framing with 1” closed cell spray foam flash seal with the remaining cavity filled with fiberglass batts.

❺ **Foundation Assembly:** Conditioned basement with 2” (R-10) XPS cast into 10” concrete walls (Thermomass® System). 2” (R-10) XPS insulation installed below the concrete slab.

Infiltration: Maximum 2.5 in^2 of leakage areas per 100ft^2 of enclosure area. Critical seal air sealing approach with primary air barrier maintained at interior gypsum walls and ceiling. Closed cell spray foam installed at rim joists and band joists, under floors over unconditioned areas, in the attic on top of partition walls and electrical penetrations through the ceiling plane, around windows and doors, and at any mechanical and electrical penetration through the enclosure.

Mechanical Design

❶ **Heating:** 94% AFUE sealed combustion gas furnace in conditioned space

Cooling: 14 SEER split system air conditioning

Ventilation: Central fan integrated supply (CFIS) only ventilation operated with ❷ Aprilaire controller.

❸ **Space Conditioning Distribution:** Single air handler furnace with zone controlled dampers (zone 1: first floor and basement, zone 2: second floor). Insulated sheet metal trunks with insulated flex run-outs. Two ducted returns (first and second floor), with jump ducts/transfer grilles at bedrooms. Filter minimum MERV 12.

❹ **DHW:** 0.82 EF instantaneous gas water heater

❺ **Lighting:** ENERGY STAR® CFLs

Appliances: ENERGY STAR® dishwasher, refrigerator and clothes washer

❻ **Site Generated Power:** Optional photovoltaic system offered by builder.

Construction

At the beginning of the project a start up meeting was held to discuss detail changes from current builder practice. Each change was discussed and where required, details to illustrate the changes were provided by BSC. This initial work was effective in heading off common problem areas for the construction trades encounter when adapting to new techniques, assemblies, and systems.

Specific areas that were addressed related to the installation of the windows in a wall with 2" of insulating foam sheathing, as well as careful examination of air sealing details for the enclosure.

During the construction progress, site visits by BSC personnel as well as conference calls and photo review allowed for quick troubleshooting of concerns as they arose on site

This combined with the high quality of construction and site supervision provided by Nelson Construction resulted in a smooth transition and adoption of new technologies.

The construction of the subdivision took place from January 2008 with final build out in March 2009.

Testing

Over the course of construction BSC tested the homes as they were completed to ensure that the actual performance of the homes is meeting the predicted minimum performance targets of the Building America Program.

As part of the testing requirement, each home was blower door tested to measure the air tightness of the enclosure. All of the homes tested approximately 25% below the maximum air leakage threshold set out in the Building America program.

In addition to overall air tightness, the mechanical systems were also tested to measure the potential duct leakage to the outside. Since the design moved all of the ducts inside the conditioned space, the leakage to outside was also below the maximum threshold target.

The measured performance values were input into the energy models and final simulations were completed. Based on the actual measured performance of the homes, the estimated source energy consumption reduction was over 50% for every home (some as high as 55%) when compared to the Building America benchmark protocol.

Moving Forward

Nelson Construction is working with the homeowners in order to collect utility bills over the next year or more. These bills will be examined and compared to the predicted use of the energy model.

The success of Hamilton Way has encouraged the Landworks/Nelson Construction team to continue to pursue high energy efficient designs for future subdivisions. Already new plans for a final build out of the Somersby subdivision are being examined. The intention is to provided even higher efficiency homes as well as the potential for a near zero energy showcase home.

Design Highlight: Thermomass® Foundation System

A special feature of this subdivision was the use of the Thermomass® foundation system. Thermomass® uses XPS insulation cast into the middle of the concrete foundation wall. This provides a unique solution to common basement insulation problems. Insulating a basement on the exterior brings with it durability on contractibility concerns. Insulating on the interior is much simpler and can be less expensive if left exposed, however; this may not meet the aesthetic desires of the homeowner and would have additional costs associated with covering it. With the foam cast into the middle of the foundation wall, the concrete can be left exposed, and if at some point later on the homeowner should desire to finish out the basement, it can be done with little risk of common cold surface condensation problems that can occur with un-insulated concrete foundation walls.

This case study has been prepared by Building Science Corporation for the Department of Energy's Building America Program, a private/public partnership that develops energy solutions for new and existing homes. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States government or any agency thereof.

For more information about Building America go to www.buildingamerica.gov.

Building America U.S. Department of Energy Research Toward Zero Energy Homes

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30 Forest Street
Somerville, MA 02143
www.buildingscience.com

For more information about this or other case studies by Building Science Corporation and the Building America Program go to: www.buildingscienceconsulting.com/buildingamerica.

Appendix E.1.7.2
2008-01-23 Hamilton Way Lot 7 Analysis

2008.01.23

Chris Nelson
C. Nelson Construction, Inc
77 Tolland Turnpike
Manchester CT, 06042

(860) 646-0442

Re: Plan Review and Energy Analysis of Lot 7 Hamilton Way, Farmington, CT

Dear Mr. Nelson:

We have completed the energy analysis for the Lot 7 plans of the Hamilton Way development in Farmington, CT. The results of the analysis show that the plan has a source energy consumption reduction of 48% when compared to the Building America Benchmark Protocol and a HERS rating of 54. Based on local utility rates of approximately $0.16/kWh and $1.60/therm, the estimated annual utility cost for the house is approximately $3,000. Compared to the Building America Benchmark house utility cost of $6,070/year this represents an annual utility savings of $3,070 per year. The following is a detailed break down of the analysis and results as well as a discussion on the various attributes of the plan.

Sincerely,

Peter Baker, P.Eng.

Building Science Corporation

Building Plan and Specifications

Lot 7 of the Hamilton Way development is a two-story plan with a walk out basement. The floor area is approximately 3700ft2 (not including the basement).

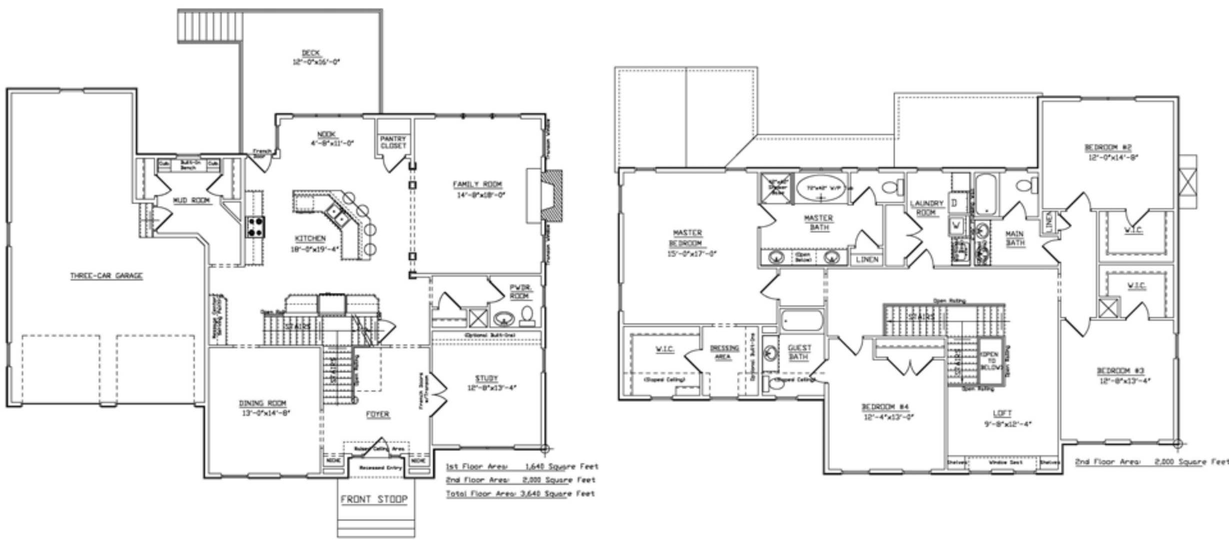

Figure 1: Lot 7 First and Second Floor Plans

Hamilton Way Lot 7, Farmington, CT

Specifications

Building envelope

Ceiling	R-50 blown cellulose
Walls	2" Foil Face Polyiso (R-13) 2x6 OVE Framed with R-19 Blown Cellulose
Frame Floors	1" spray foam insulation remaining filled with cellulose
Foundation	Basement + R-10 XPS cast in concrete walls (Thermomass System) R-10 XPS below slab
Windows	Harvey Industries Vicon Low-E with Argon Weighted Average U=~0.32, SHGC=~0.30
Infiltration	2.5 sq in leakage area per 100 sf of envelope area

Mechanical systems

Heat	Lennox G61V sealed combustion 95% AFUE gas furnace in conditioned space (basement)
Cooling	14 SEER split system in conditioned space
DHW	0.82 EF instantaneous gas water heater in conditioned space
Ducts	R-6 flex runouts in dropped ceiling or in floor joists leak free to outside (5% or less)
Ventilation	Aprilaire VCS 8126 Supply-only system integrated with AHU 33% Duty Cycle: 10 minutes on; 20 minutes off 74 CFM continuous average flow
Return Pathways	Transfer grilles/jump ducts at bedrooms

Design Review

Insulation: The recommended building design is a very high efficiency enclosure. This includes a fully insulated basement with R-10 XPS insulation beow the slab and R-10 XP insulation cast into the foundation wall (Thermomass System). The house designed is for 2x6 stack framing spaced 24" o.c. The wall cavities are filled with R-19 blown cellulose or fiberglass batts with 2" foil faced polyisocyanurate insulating-sheathing (R-13) installed on the exterior. The roof is designed as a vented attic with R-50 blown cellulose of fiberglass insulation. (Building sections representing recommended enclosure design attached).

Spectrally selective windows: The specified windows are Harvey Industries spectrally selective Low-E^2 units in vinyl frames. The glass coating allows transmission of most of the visible light (unlike tinted windows), while cutting ultraviolet light transmittance by approximately 90%. Therefore, they reduce cooling load from solar gain, increase comfort, and reduce UV damage to furnishings. Furthermore, the coated glazing has superior insulating properties compared to clear glass (U=0.32, SHGC=0.3).

For cold climates, some benefit can be gained by increasing the SHGC of the window. If possible an SHGC between 0.3 and 0.4 would be recommended to offset some of the heating load.

Infiltration/air flow retarder (a.k.a. air barrier): Air tightness is a concern particularly in cold climates as the temperature difference across the enclosure is much higher than in hot climates. The recommended design incorporates the air-tight drywall approach with a critical seal approach to reduce the potential for air infiltration. In this assembly, the interior gypsum is considered the primary plane of air tightness for the enclosure. To accommodate this, the perimeter of the gypsum is sealed to the framing. In addition, spray foam is applied in areas of known air infiltration (rim/band joists, around windows, at any mechanical/electrical penetrations). Particular care is taken at the ceiling lane to address leakage associated with lights and the intersection of partition walls.

The model envelope is tightened to a target based on the surface area of the house (including floor slab). The Building America target is 2.5 square inches of equivalent leakage area per 100 square feet of envelope area.

The air tightness of the test house will be measured with a blower door test. The targets are shown in the table below, in CFM 50 (cubic feet per minute at a test pressure of 50 Pascals) and in ACH 50 (air changes per hour at 50 Pascals). Note that ACH 50 is not the same as natural air changes per hour (nACH).

Plan	Nominal floor area	Stories	Surface area	Volume (cu ft)	Goal CFM 50	Goal ACH 50
Lot 7	3695	2	9,967	50,000	2492	3.0

Mechanical Systems

Furnace: The use of a high efficiency sealed combustion furnace is an important aspect of this design. The climate is a heating dominated climate increasing the importance of the efficiency of the heating system. In addition, being sealed combustion the furnace is completely decoupled from the exterior environment. Concerns relating to make up air and the energy penalty associated with the uncontrolled air infiltration as well as the potential indoor air quality concerns from back drafting of appliances is eliminated.

Air Conditioner Right-Sizing: The leak-free nature of the building envelope, the high-performance window system, and the increased levels of thermal insulation allow a considerable simplification and reduction in size of the duct distribution system for heating and cooling.

A 14 SEER unit will save money on electricity and increase the Energy Star score; they also run quieter because they are constructed better. 14 SEER units do cost more than 13 SEER, but the utilization of a TXV will better control the refrigerant charge levels if a leak is present, and the right sizing of the equipment will also help to offset the additional cost.

Duct system: The ductwork system will be tested for tightness in the completed house with a duct blaster test. The goal is a CFM 25 (cubic feet per minute at 25 Pascals test pressure) equal to 5% of the high-speed air handler nominal flow, at 400 CFM per ton. For instance, a 3-ton unit has a nominal 1200 CFM flow, with a 60 CFM 25 goal. The requirement is for duct leakage to the outside, not total duct leakage.

The HVAC equipment is recommended to always be located in the conditioned space. This is done because the air handler is one of the most leaky parts of the HVAC system; this move eliminates much of the leakage to the outside.

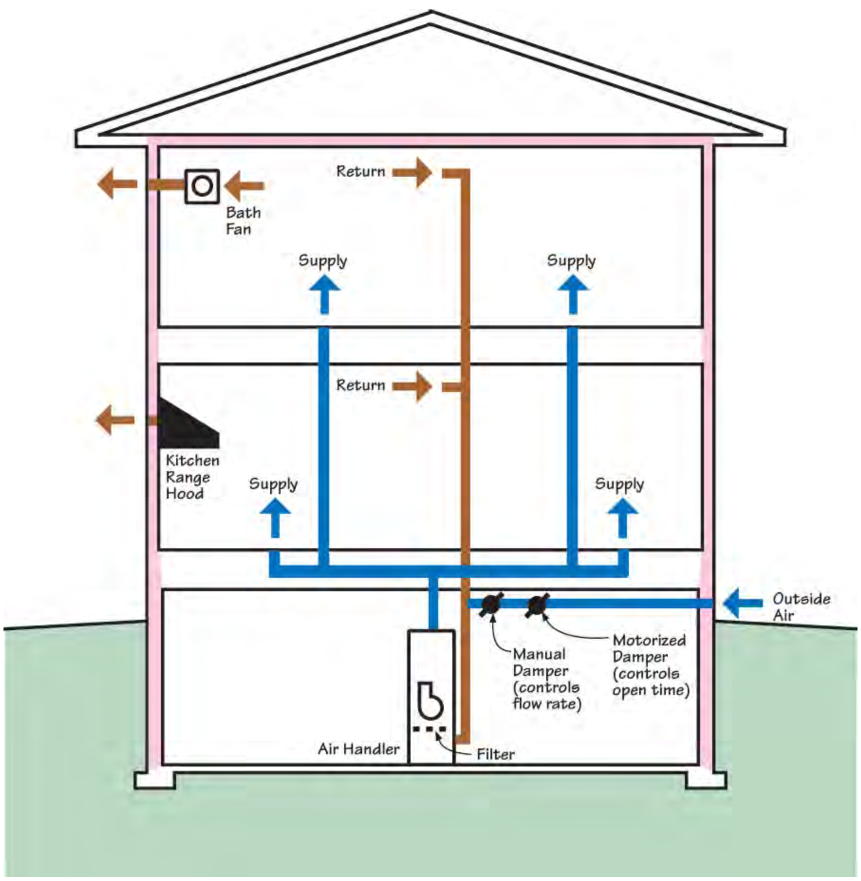

Figure 2: Recommended HVAC and ventilation system layout

Ventilation System Calculations and Rates

BSC modeled these homes with ASHRAE 62.2 specified ventilation rates. Below is the new ventilation rate, Equation (1), dependant on the number of occupants and the size of the conditioned area:

$$\dot{Q}_{cont} = 7.5P + 0.01Area \quad (1)$$

where: $\dot{Q}_{cont}$ = Continuous ventilation rate in CFMs.

P = # of occupants = # Bedrooms + 1

Area = Nominal sf area

The ventilation rates for this house is in the range of 74 CFM according to ASHRAE 62.2.

Ventilation System Specifications

The ventilation system in this house will be a combination of supply and exhaust systems (a.k.a. a "semi-balanced system." This system uses both the fan cycling controller with a duct to the return side of the air handler, as well as a dedicated ventilation exhaust fan.

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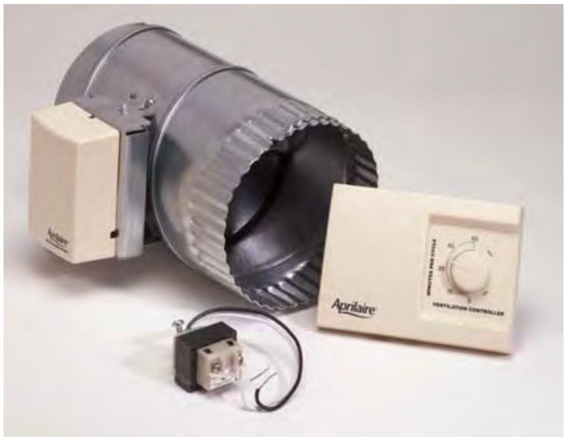
Continuous running of the air handler in order to draw ventilation air is not recommended. An Aprilaire VCS 8126 controller is suggested, to run air handler periodically; it operates the fan only after a selected amount of time following last operation. Furthermore, this system reduces stagnation in the house by providing mixing of house air and controls the electrically operated damper to prevent over mixing. The Aprilaire VCS 8126 fan cycler is available on www.aprilaire.com. Below is a picture of the controller and electrically operated damper.

The outside air duct will be set up to draw 74 CFM at a fan cycling run time of 10 min on/20 min (33% duty cycle). A 6" outside air duct tapped at the return box should provide enough negative pressures to reach this flow rate. The manual damper shall be used to adjust and "dial in" the correct flow.

Exhaust ventilation system: The exhaust fan for whole house ventilation should be placed in a powder room or bathroom near the main space of the house. It should be connected to the main space with a 6" jump duct.

To meet the ASHRAE 62.2 rate, a Broan S80LU Soltaire Ultra Silent® Series fan is recommended to be installed as the ventilation fan (80 CFM at 0.1" WIC static; 75 CFM at 0.25" WIC, 1 sone rating)

The dedicated exhaust ventilation fan should be run continuously for the first 90 days after completion to exhaust volatile organic compounds (VOCs) and other construction related contaminants from the living space.



Aprilaire VCS 8126 controller and electrically operated damper

Broan S80LU Soltaire Ultra Silent® Series 80 CFM Ceiling Mounted low-sone exhaust fan

Potential Cold Air Complaints (Supply System)

Building Science Corporation recommends that not more than 125 CFM be supplied at one location in bedrooms and not more than 500 ft/min at the supply register anywhere. Most often that means that an 8" to 10" supply to the master bedroom needs to be split up to two 6" or 7" supplies. The reason for this is when the fan cycler turns on without the furnace in the wintertime; room air temperature will be blown very fast in an area where people are sedentary. Air moving faster than 500ft/min can feel cool and be uncomfortable. Besides delivering too much air too fast from a given supply, the problem is worse when people let their setpoint drop too low (e.g. below 70° F). That may save a few pennies in energy efficient houses, but comfort is adversely affected. Another concern is to make sure that air isn't being directed right on the bed. Careful location of registers and/or making sure the vanes point the flow away from the bed can minimize this problem.

Laundry Room Pressure Relief

The laundry room shall have a 10"x12" transfer grille installed to provide pressure relief during dryer operation. Typical dryers exhaust 150-200 CFM: although a supply duct is making up for some of that air, when the door is closed during dryer operation a return pathway must be present to keep the pressure within the +/- 3 Pa range.

Energy Analysis

Baseline Energy Efficiency Package: A whole house hourly energy consumption parametric simulation was completed comparing the incremental energy consumption reduction for various energy efficiency strategies compared to the Building America Benchmark Protocol created by the Department of Energy. The simulation was run using EnergyGauge USA USRCBB v2.7.02 software developed by the Florida Solar Energy Center (FSEC).

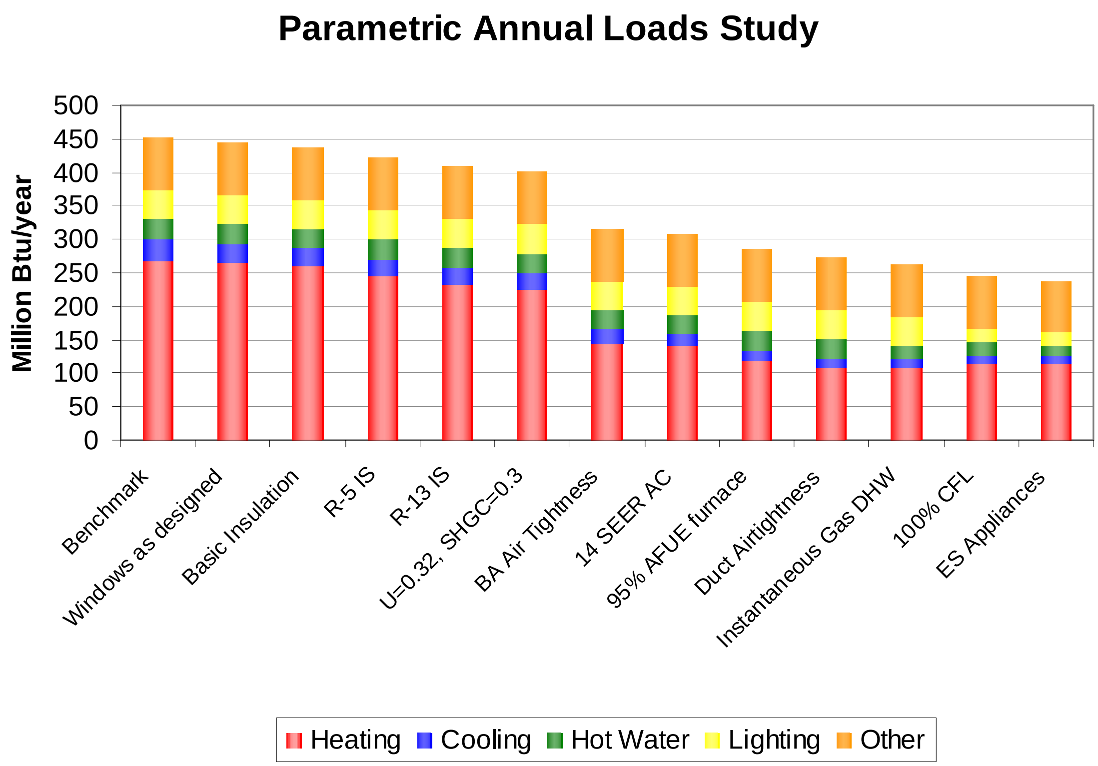


Figure 3: Parametric Analysis Results

Each parametric step shows an increment over source energy use (IOSEU) over the Building America Benchmark Protocol for the change to the model. This can be used to evaluate the relative effects of each performance upgrade made to the model. The step is described below and the results are discussed.

1. Window configuration changes: In this step, the house plan was oriented in the worstcase scenario orientation and the window sizes were changed to match the layout of the prototype house. The plan orientation and change of the window sizes resulted in an IOSEU of 2.0% for this step.
2. 1 + Insulation: The standard insulation package was added to the model (not including insulating sheathing). The result did not show a significant improvement primarily due to the BA Benchmark insulation levels already being close to the levels used in the prototype design. This resulted in an IOSEU of 1.3% for this step.
3. 2 + R-5 Insulating sheathing: The energy consumption reduction shown in this step is due to the installation of 1" of XPS sheathing to the exterior of the wall assembly. This resulted in an IOSEU of 3.5% for this step.
4. 3 + R-13 Insulating sheathing: The insulating sheathing was increased to 2" of Polyisocyanurate (R-13) to the exterior. The item savings was based on the increment from R-5 to R-13, This resulted in an IOSEU of 2.6% for this step (however it is an increase of 4.1% from step 2).

5. 4 + U=0.32, SHGC=0.3 Windows: The window systems were set to the performance rating of Harvey Industries vinyl windows. The result did not show a significant improvement primarily due to the BA Benchmark window specifications already being close to the levels used in the prototype design. This resulted in an IOSEU of 2.1 % for this step.
6. 5 + BA air tightness): The model infiltration was set to the BA goal stated earlier in the report. Past reports were that this air leakage target has been achieved in the past. Due to the large enclosure area and climate zone, air infiltration is a significant factor for energy efficiency. This can be seen with the resulted IOSEU of 18.5% for this step.
7. 6 + 14 SEER AC: The air conditioning efficiency was increase up from 10 SEER to 14 SEER. With the cooling load being relatively small, this resulted in an IOSEU of 1.7% for this step.
8. 7 + 0.95 AFUE gas furnace: The gas furnace efficiency was increased from 0.78 to 0.95. With the heating load being pretty high for the area, this resulted in an IOSEU of 5.3% for this step.
9. 8 + Duct tightness: The overall duct leakage was reduced from 15% down to 5%. This has been shown to be achievable goal in the past. This resulted in an IOSEU of 2.7% for this step.
10. 9 + 0.82 EF Instantaneous gas hot water: A gas hot water tank with an EF rating of 0.53 was replaced with a high efficiency instantaneous gas hot water system. This resulted in an IOSEU of 2.1% for this step.
11. 10+ 100% Compact fluorescent lighting: The lighting scheme was changed from a 14% CFL lighting package to a complete 100% CFL package for all hard wired lights. This resulted in a IOSEU of 4.2% for this step.
12. 11+ Energy Star Appliances: The regular appliances modeled in the home were replaced with energy star appliances. The appliances were based on performance ratings from GE appliances, as they are the preferred appliance manufacturer for the builder. This resulted in a IOSEU of 1.8% for this step.

Additional Strategies: In addition to the standard efficiency package, three alternate strategies were examined to see how the design could be brought to 50% whole house energy consumption reduction. These alternate strategies were using higher SHGC glazing, triple glazed windows, or a solar hot water system.

1. 12 + U=0.32, SHGC=0.4 Windows: The SHGC was increased to allow for some benefit to be gained from passive solar heating for the house. This resulted in an IOSEU of 0.7 % for this step.
2. 12+ U=0.19, SHGC=0.3 Windows: Triple glazed high efficiency windows were modeled. This resulted in an IOSEU of 3.3% for this step.
3. 12+ 40 ft2 solar hot water system: A 40ft2 drain back solar hot water system was included in the model. The tilt of the panel was set to the slope of the roof. This resulted in an IOSEU of 1.9% for this step.

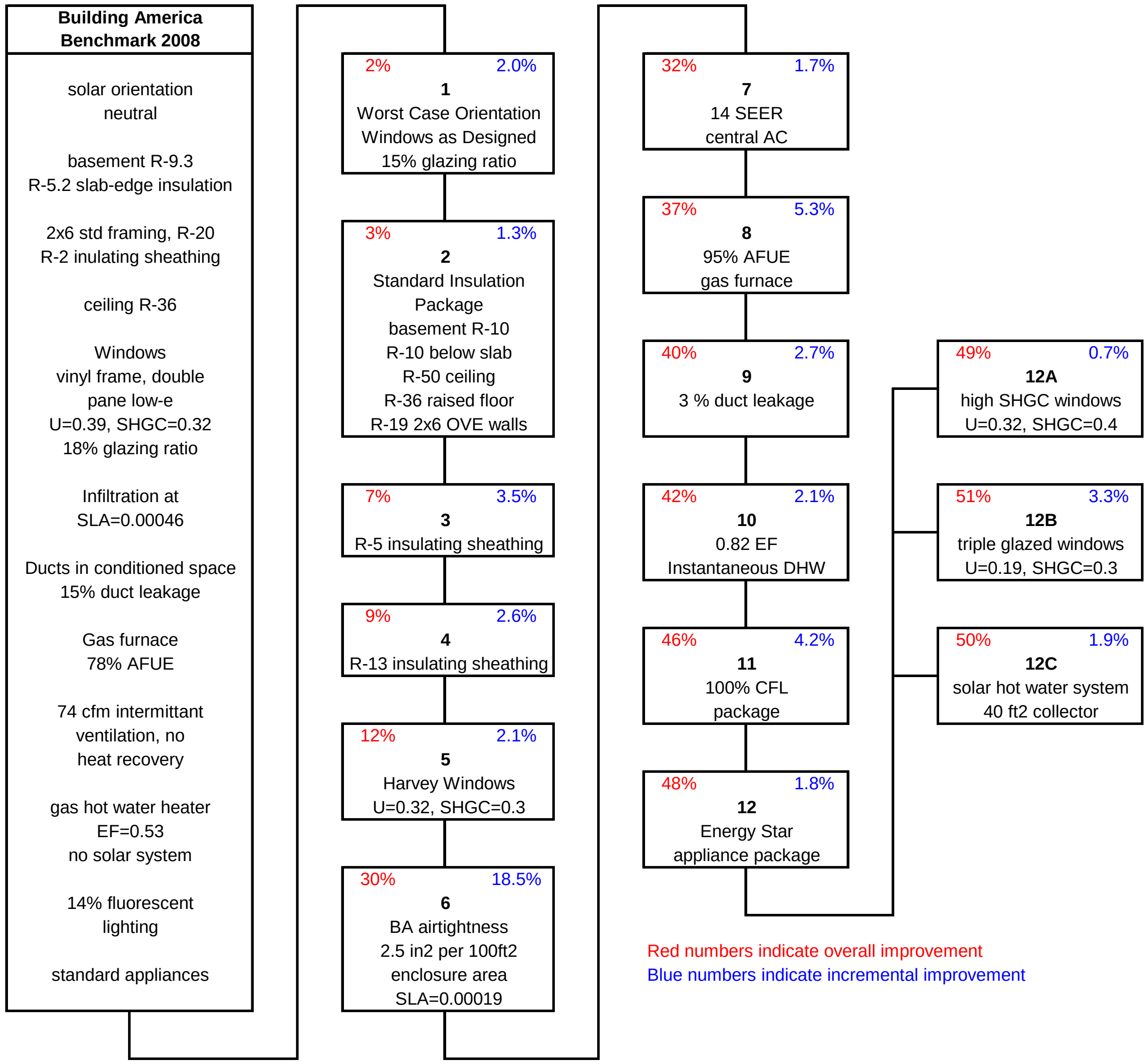


Figure 4: Flow chart of parametric analysis and additional strategies

Utility Analysis

The total annual energy costs were predicted using local utility rates:

Connecticut Light and Power: ~$0.11/kWh – generation

~$0.05/kWh – delivery and service

~$0.16/kWh – total

Connecticut Natural Gas: ***~$1.60/therm – total***

Hamilton Way Lot 7, Farmington, CT

Parametric Run ID	Description of change	Total Source Energy Savings (H/C/DHW/Lights/Appliances/Plug): over BA Benchmark[1]	Incremental Over Bmrk	Annual energy cost	Item Savings
0	Benchmark	n/a	n/a	$6,070	n/a
1	0 + Windows as designed	2.0%	n/a	$5,944	$126
2	1 + Basic Insulation	3.3%	1.3%	$5,858	$86
3	2 + R-5 IS	6.8%	3.5%	$5,625	$233
4	3 + R-13 IS	9.4%	2.6%	$5,451	$174
5	4 + U=0.32, SHGC=0.3	11.5%	2.1%	$5,314	$136
6	5 + BA Air Tightness	30.1%	18.5%	$4,091	$1,224
7	6 + 14 SEER AC	31.7%	1.7%	$3,986	$105
8	7 + 95% AFUE furnace	37.0%	5.3%	$3,634	$352
9	8 + Duct Airtightness	39.7%	2.7%	$3,457	$177
10	9 + Instantaneous Gas DHW	41.8%	2.1%	$3,320	$138
11	10 + 100% CFL	46.0%	4.2%	$3,056	$264
12	11 + ES Appliances	**47.8%**	1.8%	$3,000	$56
12a	12 + U=0.32, SHGC=0.4	**48.5%**	0.7%	$2,952	$48
12b	12 + U=0.19, SHGC=0.3	**51.1%**	3.3%	$2,781	$219
12c	12 + Solar Hot Water System	**49.7%**	1.9%	$2,875	$125

Total Utility Costs:

Benchmark: ***$6,070/year***

Prototype: ***$3,000/year***

Utility savings: ***$3,070/year***

End Use Site Energy and Source Energy Savings Summary Tables

Table 1. Summary of End-Use Site-Energy

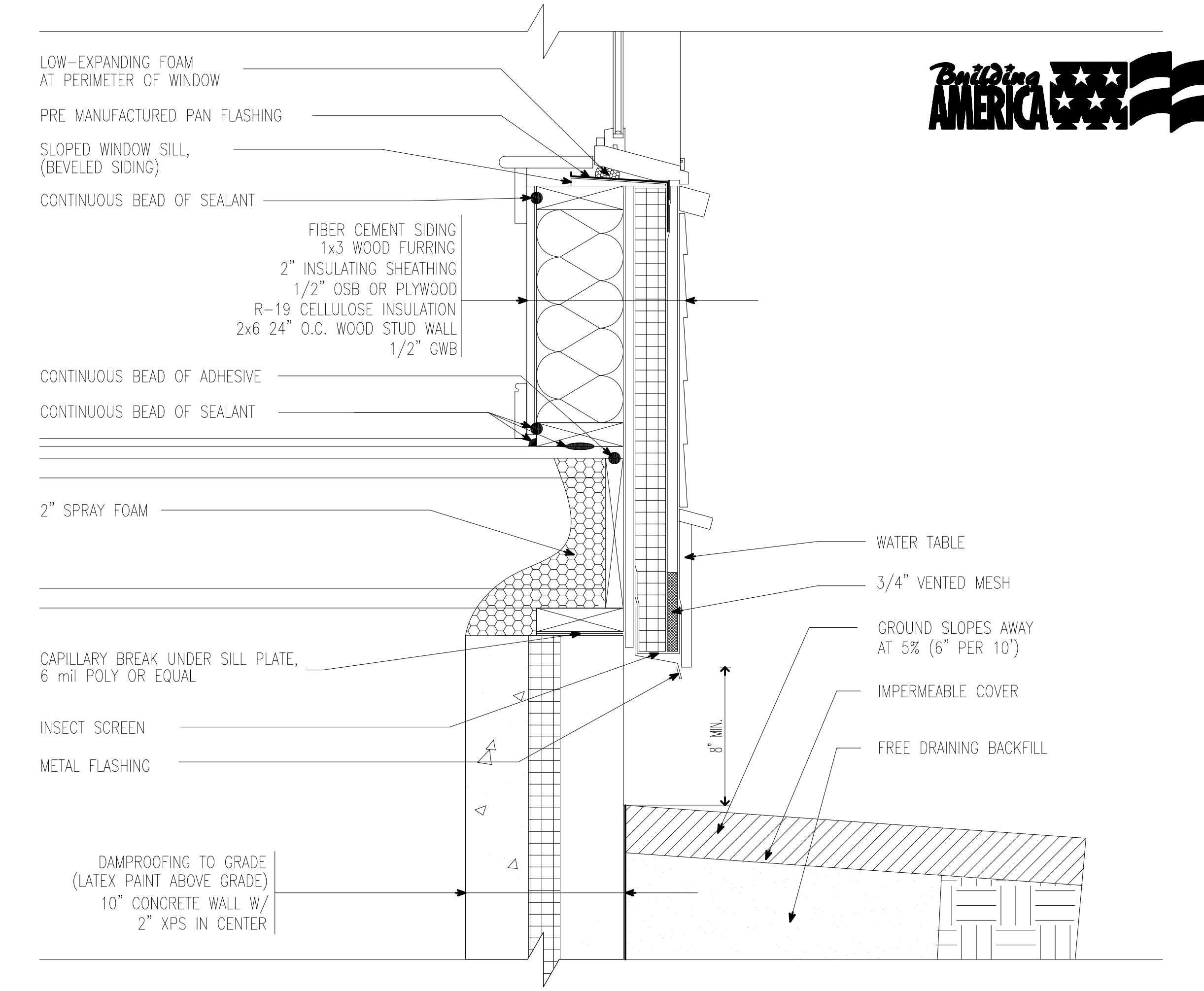
End-Use	Annual Site Energy: BA Benchmark kWh	BA Benchmark therms	Prototype 1 kWh	Prototype 1 therms
Space Heating	1763	2277	736	961
Space Cooling	2845		1123	
DHW	0	270	0	144
Lighting*	3781		1761	
Appliances + Plug	6810	0	6459	0
OA Ventilation**				
Total Usage	15199	2546.75	10079	1105
Site Generation	0	0	0	0
Net Energy Use	15199	2546.75	10079	1105

*Lighting end-use includes both interior and exterior lighting
**In EGUSA there are currently no hooks to disaggregate OA Ventilation, it is included in Space Heating and Cooling

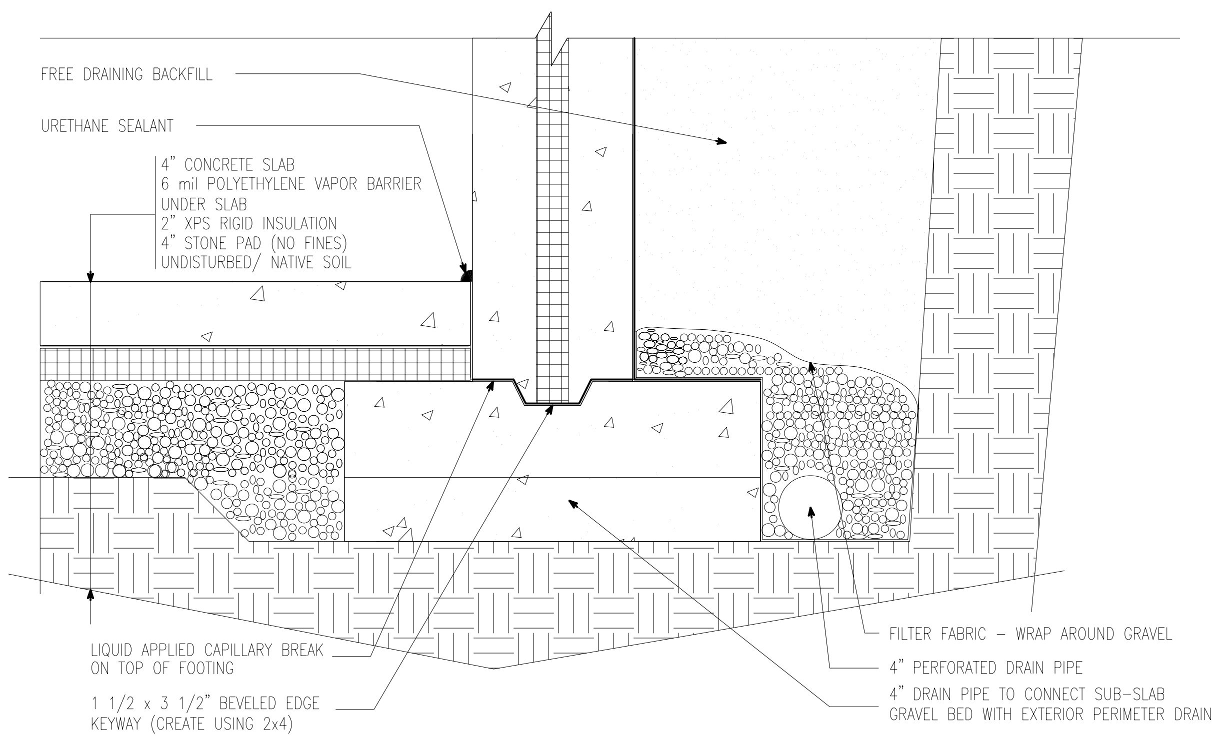
Table 2. Summary of End-Use Source-Energy and Savings

	Estimated Annual Source Energy		Source Energy Savings	
			Percent of End-Use	Percent of Total
	BA Benchmark	Prototype 1	Prototype 1 savings	Prototype 1 savings
End-Use	106 BTU/yr	106 BTU/yr		
Space Heating	269	113	**58%**	**34%**
Space Cooling	33	13	**61%**	**4%**
DHW	29	16	**47%**	**3%**
Lighting*	43	20	**53%**	**5%**
Appliances + Plug	78	74	**5%**	**1%**
OA Ventilation**	0	0	**0%**	**0%**
Total Usage	453	236	**48%**	**48%**
Site Generation	0	0		**0%**
Net Energy Use	453	233	**48%**	**48%**

The "Percent of End-Use" columns show how effective the prototype building is at reducing energy use in each end-use category.
The "Percent of Total" columns show how the energy reduction in each end-use category contributes to the overall savings.

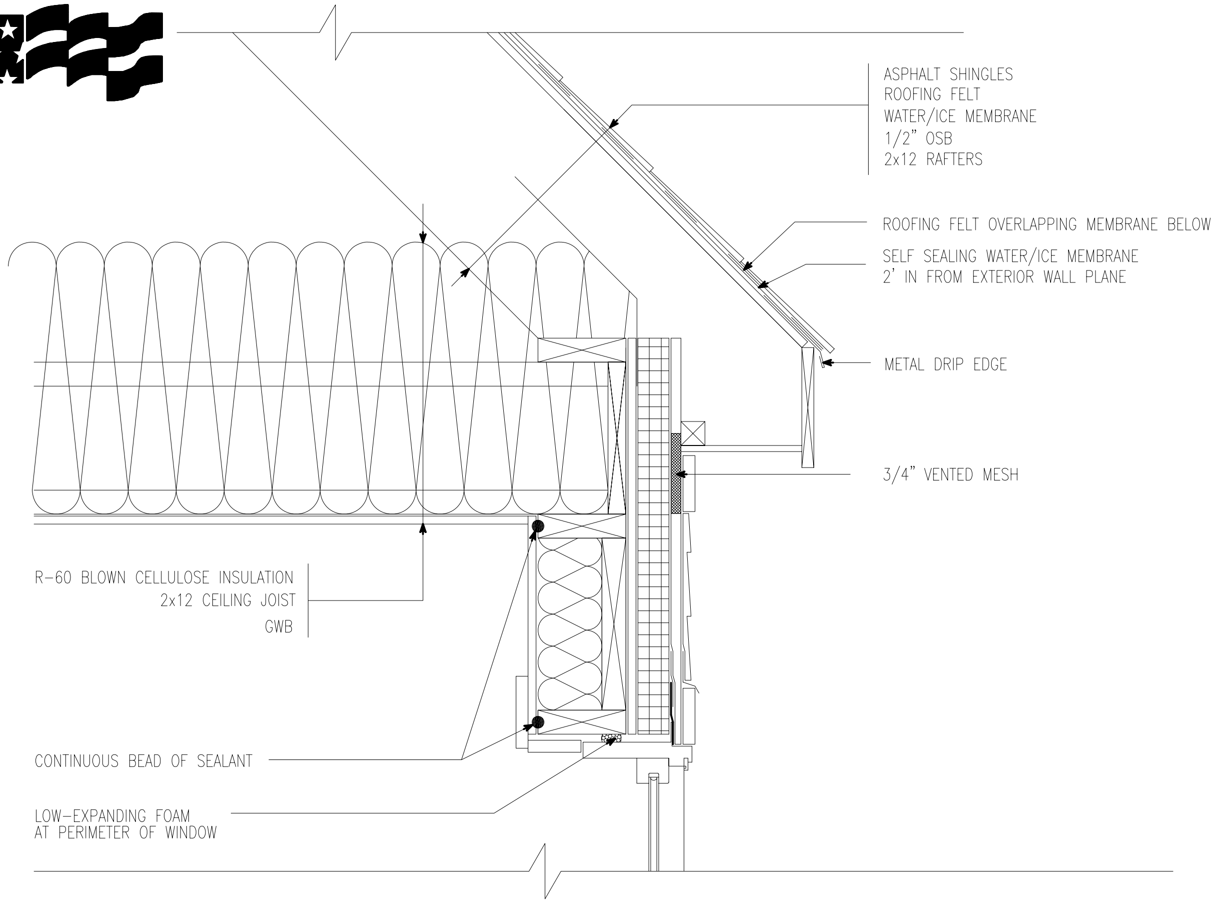


2 | WALL DETAIL SECTION
SCALE 1" = 1'-0"

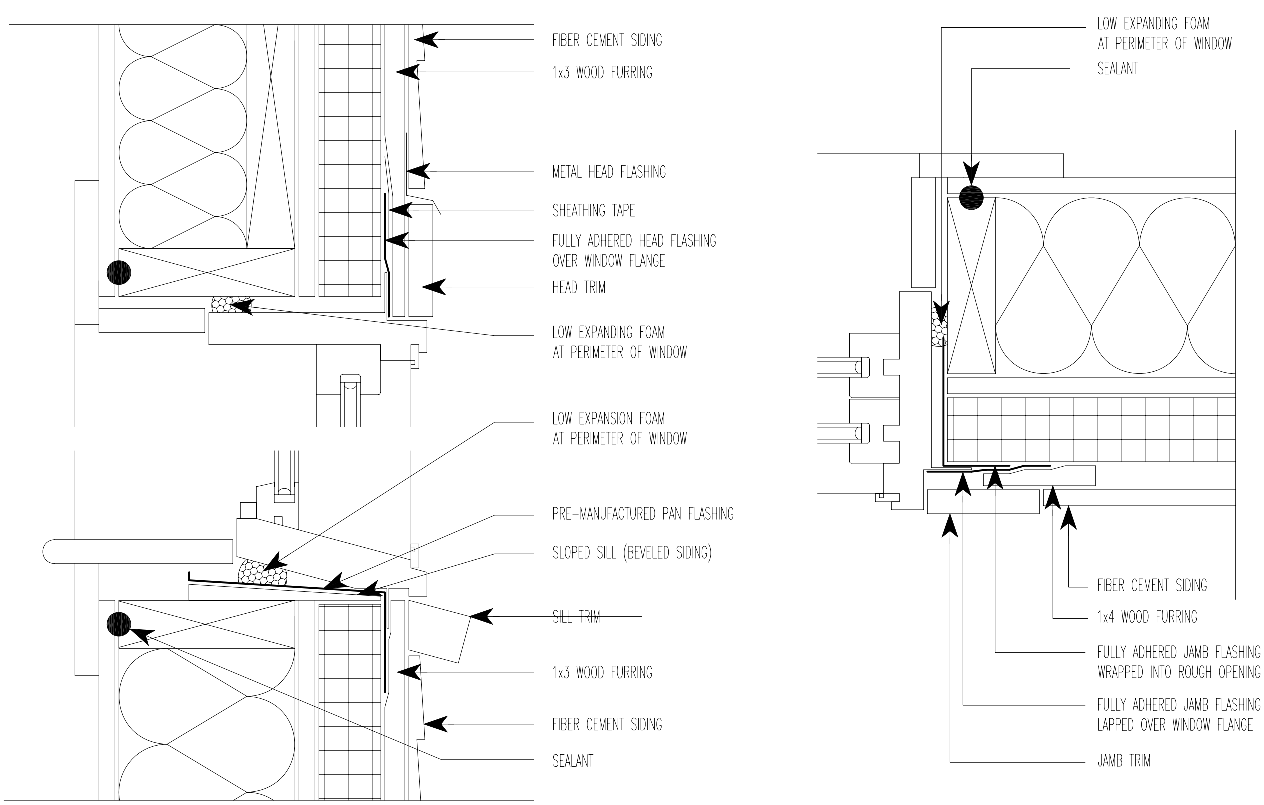


1 | FOUNDATION DETAIL SECTION
SCALE 1" = 1'-0"

FILE: 07219 H-Way.DWG	**SK-1**		**Building Section Details** SCALE AS NOTED	PROJECT: C. NELSON BUILDERS HAMILTON WAY Farmington, CT	ARCHITECT: BUILDING SCIENCE CORPORATION 30 FOREST STREET SOMERVILLE, MASSACHUSETTS 02143 PH: 978-589-5100



2 | ROOF DETAIL SECTION
SCALE 1" = 1'-0"



1 | WINDOW DETAILS
SCALE 1" = 6"

FILE: 07219 H-Way.DWG

SK-2

Building Section Details

SCALE AS NOTED

PROJECT:
C. NELSON BUILDERS
HAMILTON WAY
Farmington, CT

ARCHITECT:
BUILDING SCIENCE CORPORATION
30 FOREST STREET SOMERVILLE, MASSACHUSETTS 02143 PH: 978-589-5100

Appendix E.1.7.3
2008-05-28 Hamilton Way Analysis

2008.05.28

Chris Nelson
C. Nelson Construction, Inc
77 Tolland Turnpike
Manchester CT, 06042
860-646-0442

Re: Plan Review and Energy Analysis of Hamilton Way, Farmington, CT

Dear Mr. Nelson:

We have completed the energy analysis for all three plans for the Hamilton Way development in Farmington, CT. The results of the analysis are summarized in the table below. The estimated annual utility costs were estimated based on local utility rates of approximately $0.16/kWh and $1.60/therm.

Plan	Source Energy Consumption Reduction (%)	HERS	Benchmark Estimated Annual Utility Costs	Prototype Estimated Annual Utility Cost	Estimated Annual Utility Savings
Sedgwick	48	54	$6,070	$3,000	$3,070
Griswold	45	54	$5,062	$2,633	$2,429
Ridgewood	47	53	$5,383	$2,683	$2,700

The following is a detailed break down of the analysis and results as well as a discussion on the various attributes of the subdivision.

Sincerely,

Peter Baker, P.Eng.
Building Science Corporation

Building Plan Specifications

The Hamilton Way development consists of 10 homes with three different floor plans.

Plan	Finish Floor Area (not including basement)	Basement Area	Number of Stories	Bedrooms
Sedgwick	3695	1653	2	4
Griswold	3062	1255	2	4
Ridgewood	3337	1404	2	4

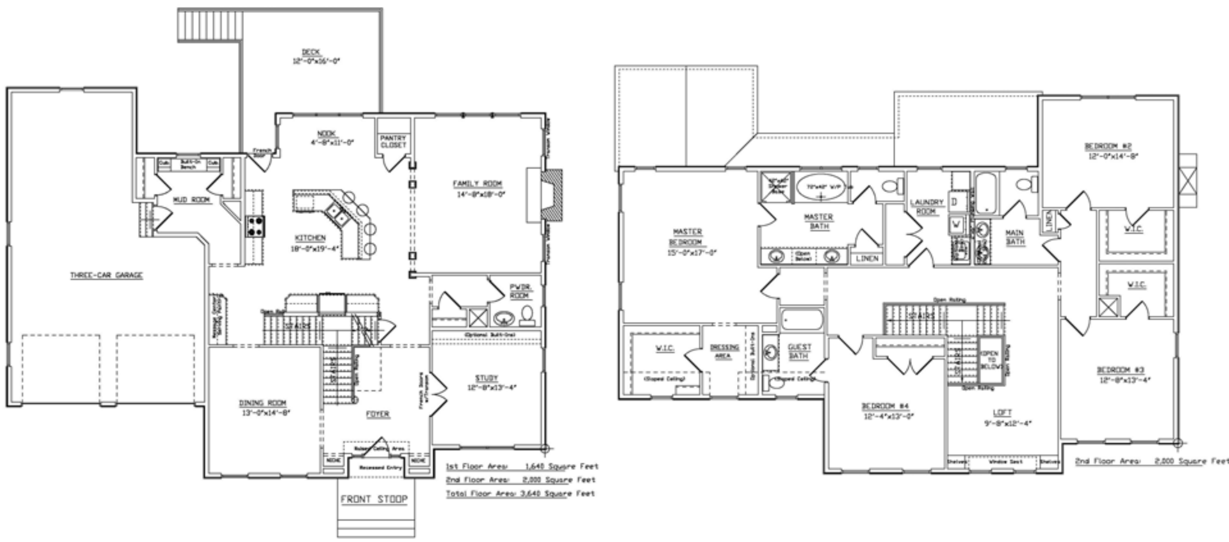


Figure 1: Sedgwick First and Second Floor Plans

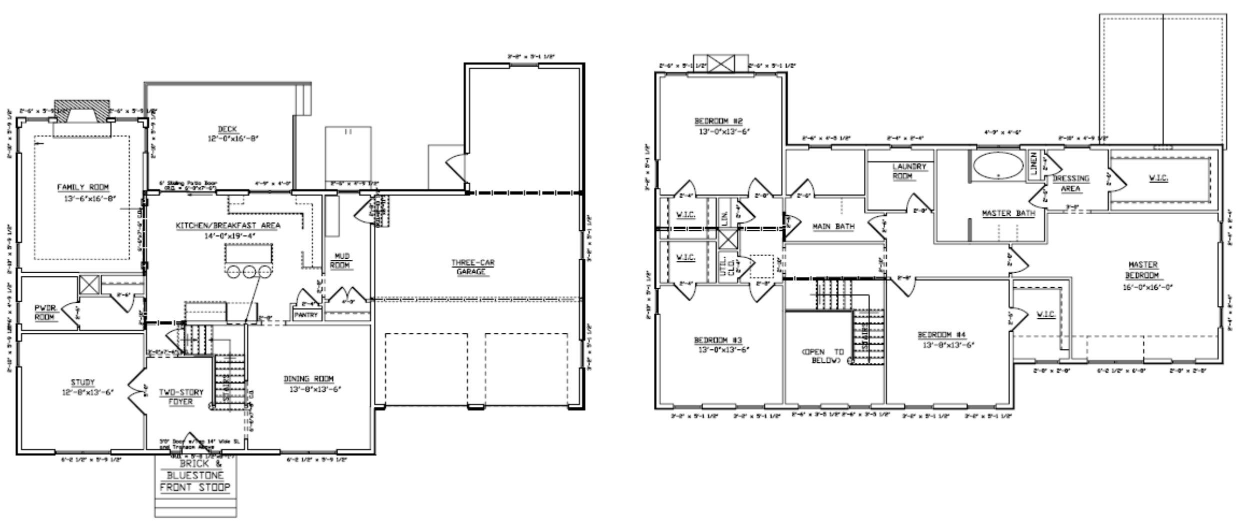


Figure 2: Griswold First and Second Floor Plans

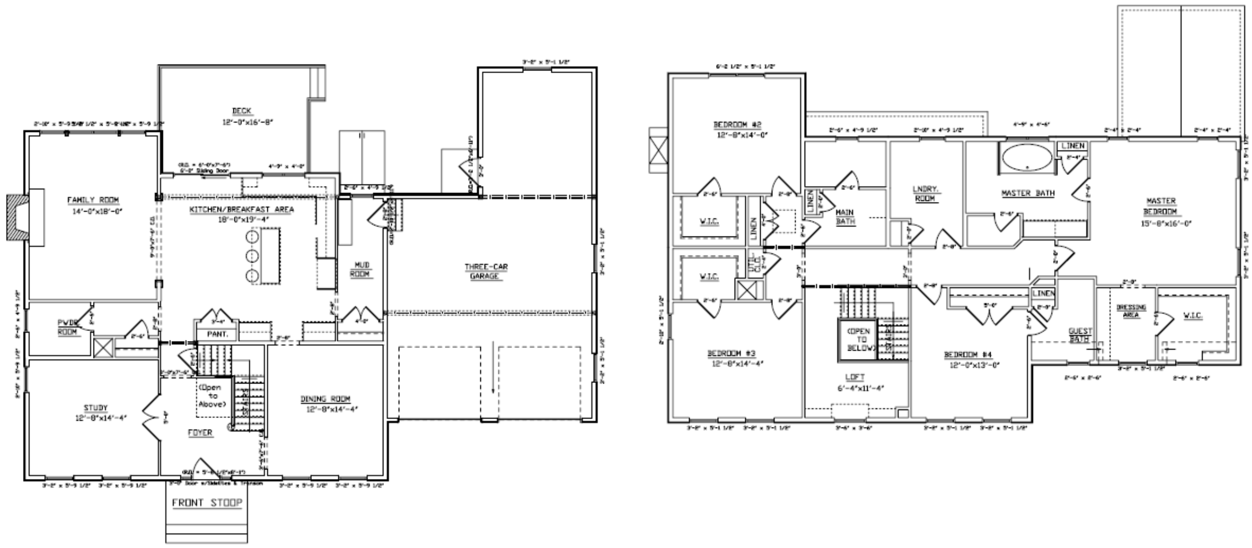


Figure 3: Ridgewood First and Second Floor Plans

Each home is being built with the following specifications.

Hamilton Way, Farmington, CT

Specifications

Building envelope

Ceiling	R-50 blown cellulose
Walls	2" Foil Face Polyiso (R-13) 2x6 OVE Framed with R-19 Blown Cellulose
Frame Floors	1" spray foam insulation remaining filled with cellulose
Foundation	Basement + R-10 XPS cast in concrete walls (Thermomass System) R-10 XPS below slab
Windows	Harvey Industries Vicon Low-E with Argon Weighted Average U=~0.32, SHGC=~0.30
Infiltration	2.5 sq in leakage area per 100 sf of envelope area

Mechanical systems

Heat	Lennox G61V sealed combustion 95% AFUE gas furnace in conditioned space (basement)
Cooling	14 SEER split system in conditioned space
DHW	0.82 EF instantaneous gas water heater in conditioned space
Ducts	R-6 flex runouts in dropped ceiling or in floor joists leak free to outside (5% or less)
Ventilation	Aprilaire VCS 8126 Supply-only system integrated with AHU 33% Duty Cycle: 10 minutes on; 20 minutes off 74 CFM continuous average flow
Return Pathways	Transfer grilles/jump ducts at bedrooms

Design Review

Insulation: The recommended building design is a very high efficiency enclosure. This includes a fully insulated basement with R-10 XPS insulation below the slab and R-10 XP insulation cast into the foundation wall (Thermomass System). The house designed is for 2x6 stack framing spaced 24" o.c. The wall cavities are filled with R-19 blown cellulose or fiberglass batts with 2" foil faced polyisocyanurate insulating-sheathing (R-13) installed on the exterior. The roof is designed as a vented attic with R-50 blown cellulose of fiberglass insulation.

Spectrally selective windows: The specified windows are Harvey Industries spectrally selective Low-E^2 units in vinyl frames. The glass coating allows transmission of most of the visible light (unlike tinted windows), while cutting ultraviolet light transmittance by approximately 90%. Therefore, they reduce cooling load from solar gain, increase comfort, and reduce UV damage to furnishings. Furthermore, the coated glazing has superior insulating properties compared to clear glass (U=0.32, SHGC=0.3).

For cold climates, some benefit can be gained by increasing the SHGC of the window. If possible an SHGC between 0.3 and 0.4 would be recommended to offset some of the heating load.

Infiltration/air flow retarder (a.k.a. air barrier): Air tightness is a concern particularly in cold climates as the temperature difference across the enclosure is much higher than in hot climates. The recommended design incorporates the air-tight drywall approach with a critical seal approach to reduce the potential for air infiltration. In this assembly, the interior gypsum is considered the primary plane of air tightness for the enclosure. To accommodate this, the perimeter of the gypsum is sealed to the framing. In addition, spray foam is applied in areas of known air infiltration (rim/band joists, around windows, at any mechanical/electrical penetrations). Particular care is taken at the ceiling lane to address leakage associated with lights and the intersection of partition walls.

The model envelope is tightened to a target based on the surface area of the house (including floor slab). The Building America target is 2.5 square inches of equivalent leakage area per 100 square feet of envelope area.

The air tightness of the test houses will be measured with a blower door test. The targets are shown in the table below, in CFM 50 (cubic feet per minute at a test pressure of 50 Pascals) and in ACH 50 (air changes per hour at 50 Pascals). Note that ACH 50 is not the same as natural air changes per hour (nACH).

Plan	Nominal floor area (ft2)	Surface Area (ft2)	Volume (ft3)	Goal CFM 50	Goal ACH 50
Sedgwick	3695	9,967	49,969	2492	3.0
Griswold	3062	8,325	40,263	2081	3.1
Ridgewood	3337	8,781	44,259	2195	3.0

Mechanical Systems

Furnace: The use of a high efficiency sealed combustion furnace is an important aspect of this design. The climate is a heating dominated climate increasing the importance of the efficiency of the heating system. In addition, being sealed combustion the furnace is completely decoupled from the exterior environment. Concerns relating to make up air and the energy penalty associated with the uncontrolled air infiltration as well as the potential indoor air quality concerns from back drafting of appliances is eliminated.

Air Conditioner Right-Sizing: The leak-free nature of the building envelope, the high-performance window system, and the increased levels of thermal insulation allow a considerable simplification and reduction in size of the duct distribution system for heating and cooling.

A 14 SEER unit will save money on electricity and increase the Energy Star score; they also run quieter because they are constructed better. 14 SEER units do cost more than 13 SEER, but the utilization of a TXV will better control the refrigerant charge levels if a leak is present, and the right sizing of the equipment will also help to offset the additional cost.

Duct system: The ductwork system will be tested for tightness in the completed house with a duct blaster test. The goal is a CFM 25 (cubic feet per minute at 25 Pascals test pressure) equal to 5% of the high-speed air handler nominal flow, at 400 CFM per ton. For instance, a 3-ton unit has a nominal 1200 CFM flow, with a 60 CFM 25 goal. The requirement is for duct leakage to the outside, not total duct leakage.

The HVAC equipment is recommended to always be located in the conditioned space. This is done because the air handler is one of the most leaky parts of the HVAC system; this move eliminates much of the leakage to the outside.

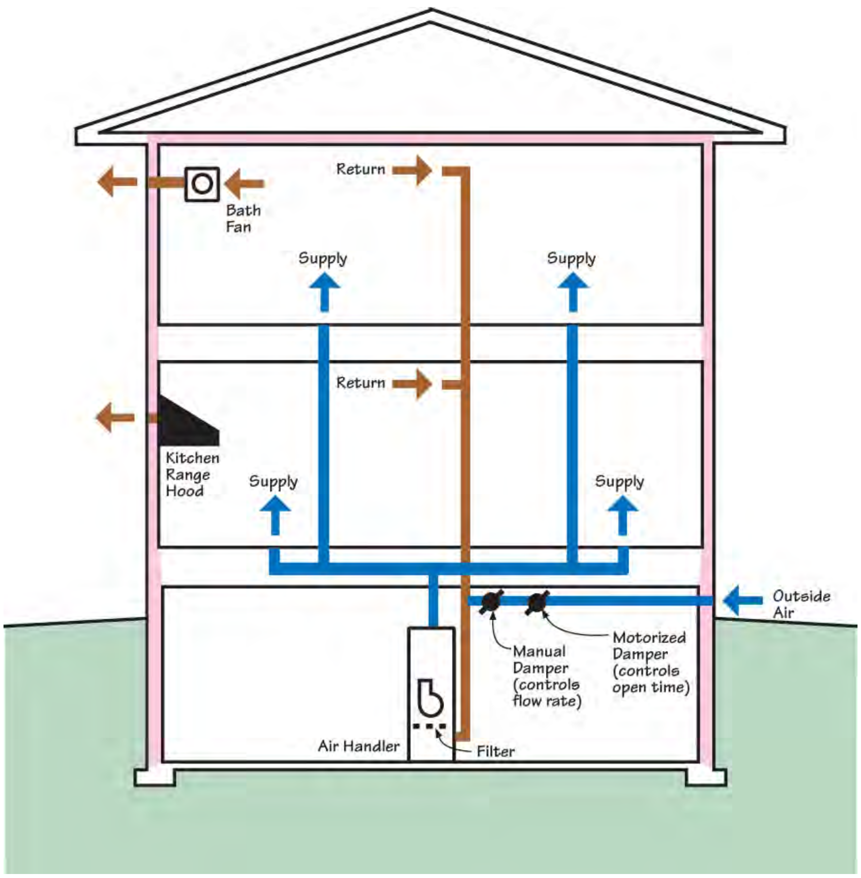


Figure 4: Recommended HVAC and ventilation system layout

Ventilation System Calculations and Rates

BSC modeled these homes with ASHRAE 62.2 specified ventilation rates. Below is the new ventilation rate, Equation (1), dependant on the number of occupants and the size of the conditioned area:

$$\dot{Q}_{cont} = 7.5P + 0.01Area \quad (1)$$

where: $\dot{Q}_{cont}$ = Continuous ventilation rate in CFMs.

P = # of occupants = # Bedrooms + 1

Area = Nominal sf area

The ventilation rates for these homes are in the range of 68 CFM to 75 CFM according to ASHRAE 62.2.

Ventilation System Specifications

The ventilation system in this house will be a combination of supply and exhaust systems (a.k.a. a "semi-balanced system." This system uses both the fan cycling controller with a duct to the return side of the air handler, as well as a dedicated ventilation exhaust fan.

Supply Ventilation system: A central fan integrated with exhaust control ventilation strategy is specified. An outside air duct is run from the outside to the return side of the air handler. The running air handler pulls outside air into the return system. A flow regulator or adjustable damper provides fixed outside air supply quantities independent of air handler blower speed, and the HVAC system provides circulation and tempering. In addition to the flow regulator, an electrically operated damper will be installed to prevent excess ventilation during peak load usage. This damper will automatically close the fresh air duct to prevent outside air from diluting the conditioned air too much. The Aprilaire fan controller mentioned below comes with an electrically operated damper.

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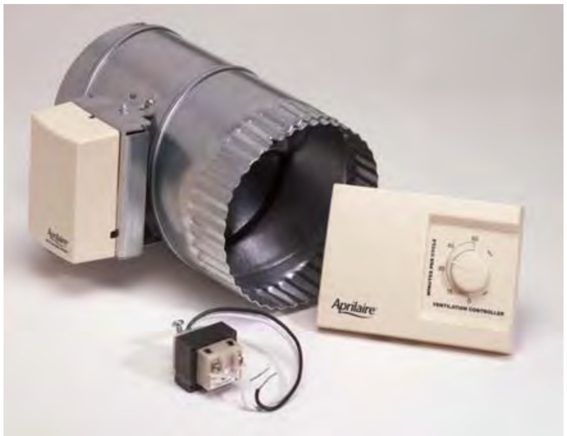
The outside air duct will be set up to draw the recommended ASHRAE 62.2 ventilation rate at a fan cycling run time of 10 min on/20 min (33% duty cycle). A 6" outside air duct tapped at the return box should provide enough negative pressures to reach this flow rate. The manual damper shall be used to adjust and "dial in" the correct flow.

Exhaust ventilation system: The exhaust fan for whole house ventilation should be placed in a powder room or bathroom near the main space of the house. It should be connected to the main space with a 6" jump duct.

To meet the ASHRAE 62.2 rate, a Broan S80LU Soltaire Ultra Silent® Series fan is recommended to be installed as the ventilation fan (80 CFM at 0.1" WIC static; 75 CFM at 0.25" WIC, 1 sone rating)

The dedicated exhaust ventilation fan should be run continuously for the first 90 days after completion to exhaust volatile organic compounds (VOCs) and other construction related contaminants from the living space.



Aprilaire VCS 8126 controller and electrically operated damper

Broan S80LU Soltaire Ultra Silent® Series 80 CFM Ceiling Mounted low-sone exhaust fan

Potential Cold Air Complaints (Supply System)

Building Science Corporation recommends that not more than 125 CFM be supplied at one location in bedrooms and not more than 500 ft/min at the supply register anywhere. Most often that means that an 8" to 10" supply to the master bedroom needs to be split up to two 6" or 7" supplies. The reason for this is when the fan cycler turns on without the furnace in the wintertime; room air temperature will be blown very fast in an area where people are sedentary. Air moving faster than 500ft/min can feel cool and be uncomfortable. Besides delivering too much air too fast from a given supply, the problem is worse when people let their setpoint drop too low (e.g. below 70° F). That may save a few pennies in energy efficient houses, but comfort is adversely affected. Another concern is to make sure that air isn't being directed right on the bed. Careful location of registers and/or making sure the vanes point the flow away from the bed can minimize this problem.

Laundry Room Pressure Relief

The laundry room shall have a 10"x12" transfer grille installed to provide pressure relief during dryer operation. Typical dryers exhaust 150-200 CFM: although a supply duct is making up for some of that air, when the door is closed during dryer operation a return pathway must be present to keep the pressure within the +/- 3 Pa range.

Energy Analysis

Baseline Energy Efficiency Package: Whole house hourly energy consumption parametric simulations were completed comparing the incremental energy consumption reduction for various energy efficiency strategies compared to the Building America Benchmark Protocol created by the Department of Energy. The simulations were run using EnergyGauge USA USRCBB v2.7.02 software developed by the Florida Solar Energy Center (FSEC).

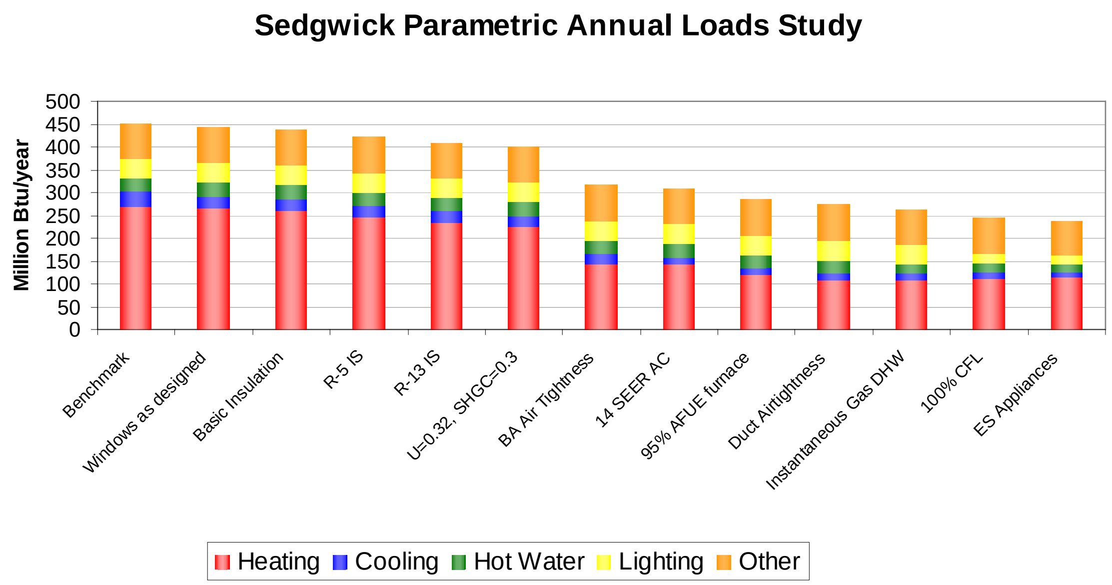


Figure 5: Sedgwick Parametric Analysis Results

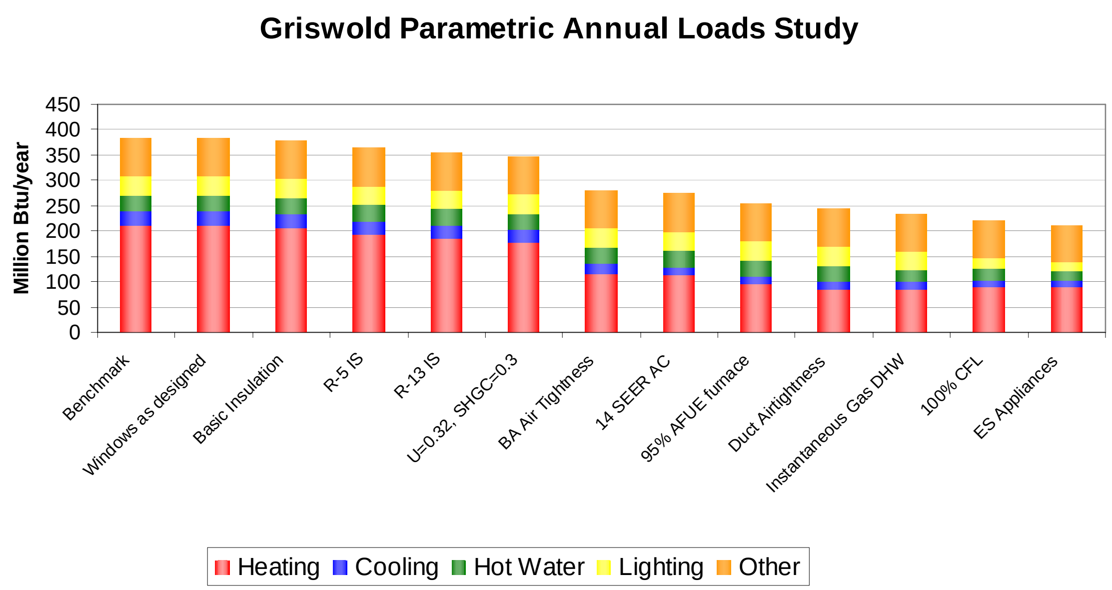


Figure 6: Griswold Parametric Analysis Results

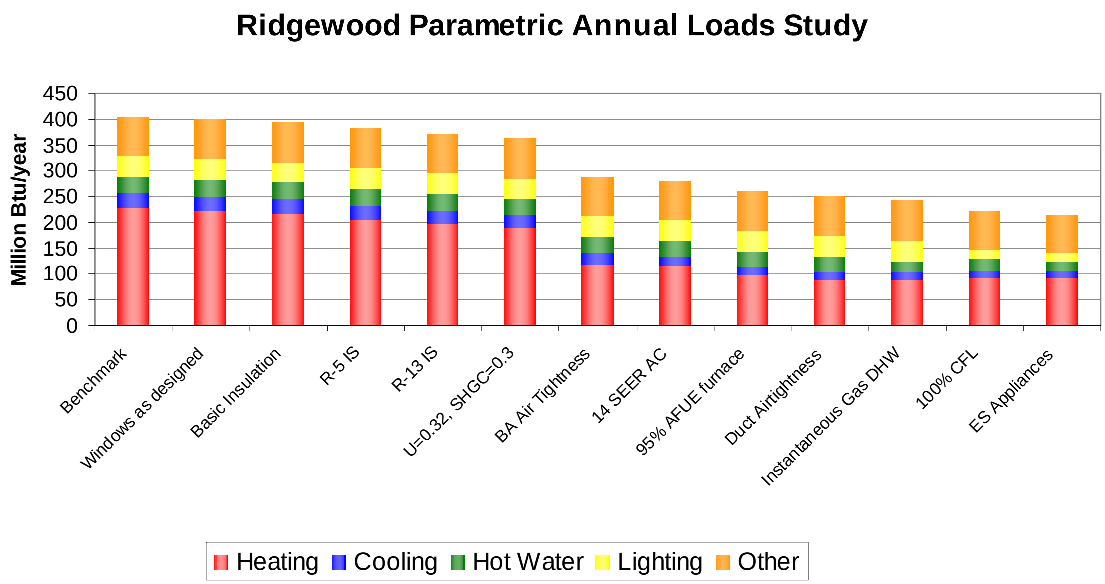


Figure 7: Ridgewood Parametric Analysis Results

Each parametric step shows an increment over source energy use (IOSEU) over the Building America Benchmark Protocol for the change to the model. This can be used to evaluate the relative effects of each performance upgrade made to the model. The step is described below and the results are discussed.

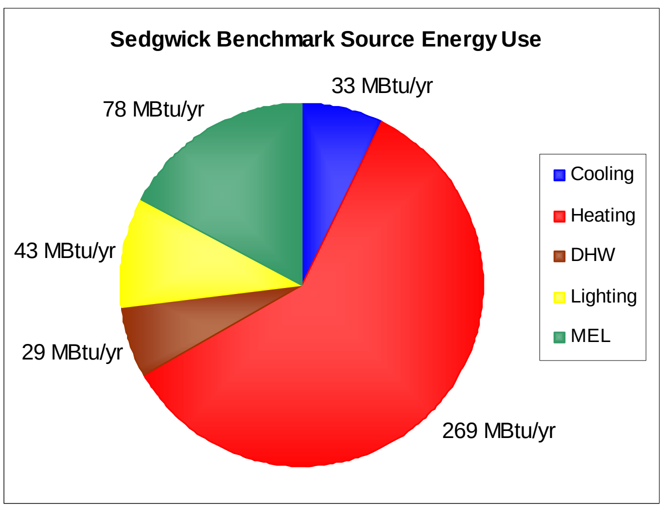
Parametric Step	Description	Sedgwick (IOSEU)	Griswold (IOSEU)	Ridgewood (IOSEU)
0 + Window configuration changes	In this step, the house plan was oriented in the worst-case scenario orientation and the window sizes were changed to match the layout of the prototype house.	2.0%	0.0%	1.5%
1 + Insulation	The standard insulation package was added to the model (not including insulating sheathing). The result did not show a significant improvement primarily due to the BA Benchmark insulation levels already being close to the levels used in the prototype design	1.3%	1.3%	1.4%
2 + R-5 Insulating sheathing	The energy consumption reduction shown in this step is due to the installation of 1” of XPS sheathing to the exterior of the wall assembly.	3.5%	3.5%	3.0%
3 + R-13 Insulating sheathing	The insulating sheathing was increased to 2” of Polyisocyanurate (R-13) to the exterior. The item savings was based on the increment from R-5 to R-13	2.6%	2.2%	2.4%

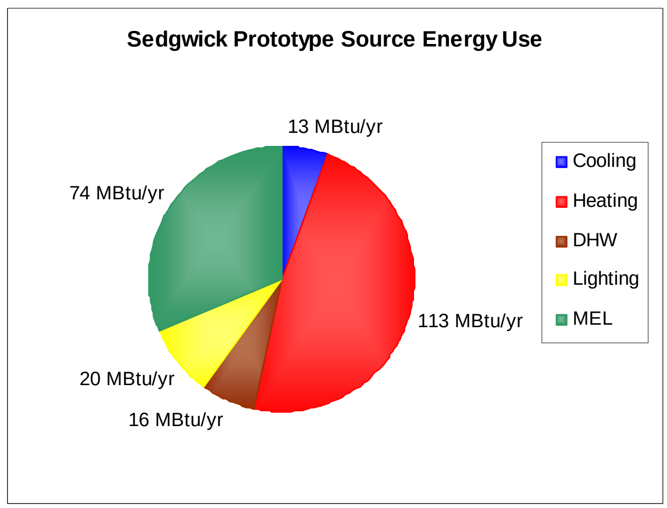
4 + U=0.32, SHGC=0.3 Windows	The window systems were set to the performance rating of Harvey Industries vinyl windows. The result did not show a significant improvement primarily due to the BA Benchmark window specifications already being close to the levels used in the prototype design.	2.1%	2.3%	2.1%
5 + BA air tightness	The model infiltration was set to the BA goal stated earlier in the report. Past reports were that this air leakage target has been achieved in the past. Due to the large enclosure area and climate zone, air infiltration is a significant factor for energy efficiency.	18.5%	17.2%	18.3%
6 + 14 SEER AC	The air conditioning efficiency was increase up from 10 SEER to 14 SEER. The incremental change was relatively small due to the small overall cooling load for this climate	1.7%	1.9%	1.9%
7 + 0.95 AFUE gas furnace	The gas furnace efficiency was increased from 0.78 to 0.95.	5.3%	5.0%	4.9%
8 + Duct tightness	The overall duct leakage was reduced from 15% down to 5%. This has been shown to be achievable goal in the past	2.7%	2.7%	2.6%
9 + 0.82 EF Instantaneous gas hot water	A gas hot water tank with an EF rating of 0.53 was replaced with a high efficiency instantaneous gas hot water system.	2.1%	2.5%	2.3%
10+ 100% Compact fluorescent lighting	The lighting scheme was changed from a 14% CFL lighting package to a complete 100% CFL package for all hard wired lights	4.2%	3.8%	4.4%
11+ Energy Star Appliances	The regular appliances modeled in the home were replaced with energy star appliances. The appliances were based on performance ratings from GE appliances, as they are the preferred appliance manufacturer for the builder.	1.8%	2.5%	2.3%
Total		**47.8%**	**44.9%**	**47.1%**

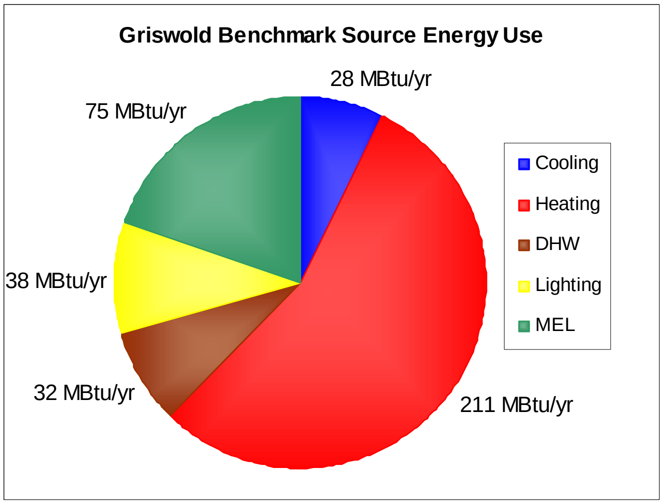
Additional Strategies: In addition to the standard efficiency package, three alternate strategies were examined to see the effects on the overall energy performance. Based on consumer interest, the use of geothermal heat pumps, solar hot water systems, and PV systems were examined.

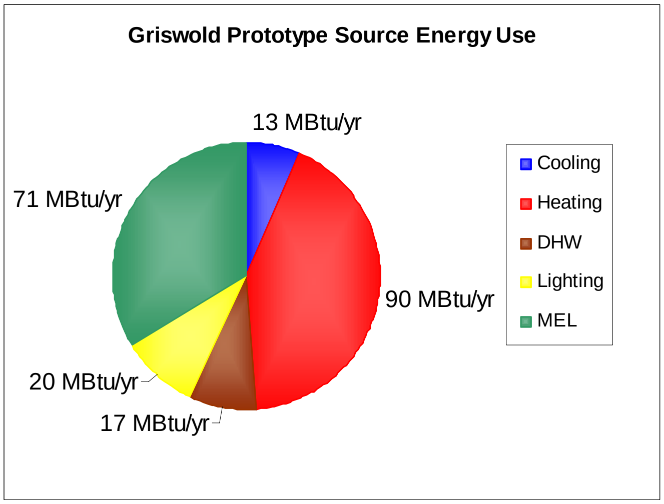
Parametric Step	Description	Sedgwick IOSEU (total)	Griswold IOSEU (total)	Ridgewood IOSEU (total)
12 + GSHP (3.8 COP, 19 EER)	In this step, the mechanical system was changed to a Geothermal Heat Pump System.	6.9% (54.7%)	7.0% (51.8%)	6.8% (53.9%)
12 + 40 ft2 Solar Hot Water System	In this step a 40 ft2 closed loop solar hot water system with a 80 gallon storage tank was added to the homes.	1.8% (49.5%)	1.1% (46.0%)	1.1% (48.1%)
12 + 2kW PV System	In this step, a 2kW PV grid-tied photovoltaic array was added to the homes.	6.0% (53.8%)	7.1% (52.0%)	6.7% (53.8%)

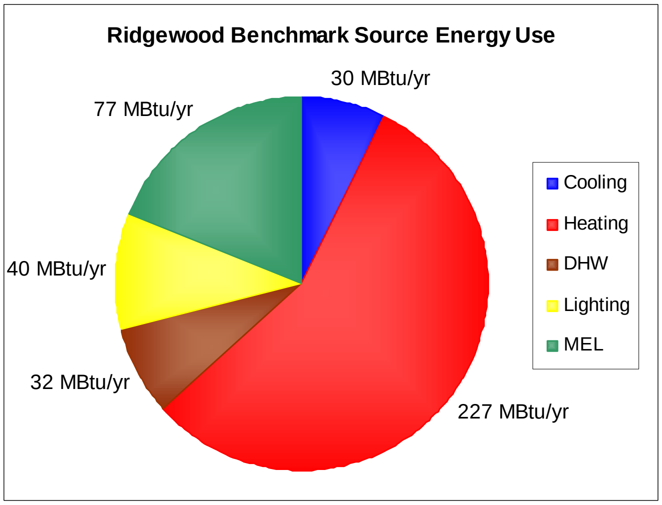
The following charts illustrate the component annual energy use for each plan.

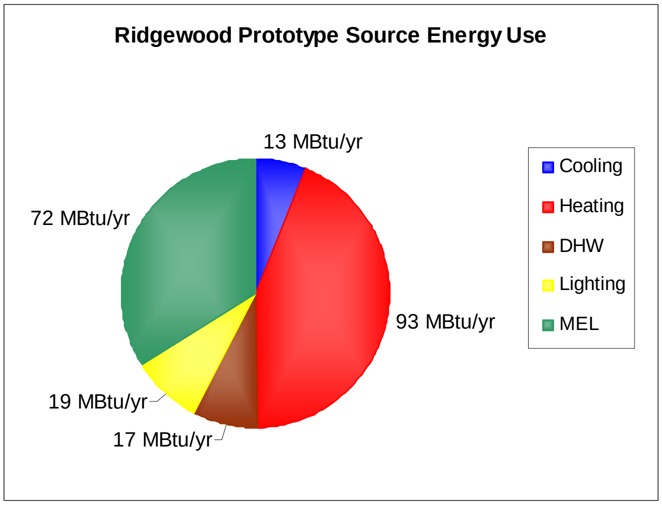












Utility Analysis

The total annual energy costs were predicted using local utility rates:

Connecticut Light and Power: ~$0.11/kWh – generation
~$0.05/kWh – delivery and service
~$0.16/kWh – total

Connecticut Natural Gas: ***~$1.60/therm – total***

Parametric Run ID	Description of change	Total Source Energy Savings (H/C/DHW/Lights/Appliances/Plug) over BA Benchmark[1]	Incremental Over Bmrk	Annual energy cost	Item Savings
0	Benchmark	n/a	n/a	$6,070	n/a
1	0 + Windows as designed	2.0%	n/a	$5,944	$126
2	1 + Basic Insulation	3.3%	1.3%	$5,858	$86
3	2 + R-5 IS	6.8%	3.5%	$5,625	$233
4	3 + R-13 IS	9.4%	2.6%	$5,451	$174
5	4 + U=0.32, SHGC=0.3	11.5%	2.1%	$5,314	$136
6	5 + BA Air Tightness	30.1%	18.5%	$4,091	$1,224
7	6 + 14 SEER AC	31.7%	1.7%	$3,986	$105
8	7 + 95% AFUE furnace	37.0%	5.3%	$3,634	$352
9	8 + Duct Airtightness	39.7%	2.7%	$3,457	$177
10	9 + Instantaneous Gas DHW	41.8%	2.1%	$3,320	$138
11	10 + 100% CFL	46.0%	4.2%	$3,056	$264
12	11 + ES Appliances	**47.8%**	1.8%	$3,000	$56
12a	12 + GSHP (19 EER, 3.8 COP)	**54.7%**	6.9%	$2,491	$509
12b	12 + 40 sqft Solar Hot Water	**49.5%**	1.8%	$2,883	$117
12c	12 + 2 kW PV systems	**53.8%**	6.0%	$2,621	$379

Figure 8: Sedgwick Parametric Summary Table

Parametric Run ID	Description of change	Total Source Energy Savings (H/C/DHW/Lights/Appliances/Plug) over BA Benchmark[1]	Incremental Over Bmrk	Annual energy cost	Item Savings
0	Benchmark	n/a	n/a	$5,062	n/a
1	0 + Windows as designed	0.0%	n/a	$5,060	$1
2	1 + Basic Insulation	1.4%	1.3%	$4,986	$74
3	2 + R-5 IS	4.9%	3.5%	$4,789	$197
4	3 + R-13 IS	7.1%	2.2%	$4,669	$120
5	4 + U=0.32, SHGC=0.3	9.3%	2.3%	$4,542	$127
6	5 + BA Air Tightness	26.6%	17.2%	$3,580	$961
7	6 + 14 SEER AC	28.5%	1.9%	$3,479	$102
8	7 + 95% AFUE furnace	33.5%	5.0%	$3,197	$282
9	8 + Duct Airtightness	36.2%	2.7%	$3,048	$149
10	9 + Instantaneous Gas DHW	38.6%	2.5%	$2,910	$138
11	10 + 100% CFL	42.4%	3.8%	$2,712	$198
12	11 + ES Appliances	**44.9%**	2.5%	$2,633	$79
12a	12 + GSHP (19 EER, 3.8 COP)	**51.8%**	7.0%	$2,201	$432
12a	12a + 40 sqft Solar Hot Water	**46.0%**	1.1%	$2,513	$120
12a	12a + 2 kW PV systems	**52.0%**	7.1%	$2,254	$379

Figure 9: Griswold Parametric Summary Table

Parametric Run ID	Description of change	Total Source Energy Savings (H/C/DHW/Lights/Appliances/Plug) over BA Benchmark[1]	Incremental Over Bmrk	Annual energy cost	Item Savings
0	Benchmark	n/a	n/a	$5,383	n/a
1	0 + Windows as designed	1.5%	n/a	$5,296	$87
2	1 + Basic Insulation	2.9%	1.4%	$5,214	$82
3	2 + R-5 IS	5.9%	3.0%	$5,035	$180
4	3 + R-13 IS	8.3%	2.4%	$4,894	$141
5	4 + U=0.32, SHGC=0.3	10.4%	2.1%	$4,770	$123
6	5 + BA Air Tightness	28.7%	18.3%	$3,688	$1,082
7	6 + 14 SEER AC	30.6%	1.9%	$3,584	$104
8	7 + 95% AFUE furnace	35.5%	4.9%	$3,295	$290
9	8 + Duct Airtightness	38.1%	2.6%	$3,140	$155
10	9 + Instantaneous Gas DHW	40.4%	2.3%	$3,002	$138
11	10 + 100% CFL	44.8%	4.4%	$2,757	$245
12	11 + ES Appliances	**47.1%**	2.3%	$2,683	$74
12a	12 + GSHP (19 EER, 3.8 COP)	**53.9%**	6.8%	$2,237	$446
12a	12a + 40 sqft Solar Hot Water	**48.1%**	1.1%	$2,563	$120
12a	12a + 2 kW PV systems	**53.8%**	6.7%	$2,304	$379

Figure 10: Ridgewood Parametric Summary Table

Plan	Source Energy Consumption Reduction (%)	HERS	Benchmark Estimated Annual Utility Costs	Prototype Estimated Annual Utility Cost	Estimated Annual Utility Savings
Sedgwick	48	54	$6,070	$3,000	$3,070
Griswold	45	54	$5,062	$2,633	$2,429
Ridgewood	47	53	$5,383	$2,683	$2,700

End Use Site Energy and Source Energy Savings Summary Tables

Table 1: Sedgwick Summary of End-Use Site Energy

	Annual Site Energy			
	BA Benchmark		**Prototype 1**	
End-Use	kWh	therms	kWh	therms
Space Heating	1763	2277	736	961
Space Cooling	2845		1123	
DHW	0	270	0	144
Lighting*	3781		1761	
Appliances + Plug	6810	0	6459	0
OA Ventilation**				
Total Usage	15199	2547	10079	1105
Site Generation	0	0	0	0
Net Energy Use	15199	2547	10079	1105

*Lighting end-use includes both interior and exterior lighting
**In EGUSA there are currently no hooks to disaggregate OA Ventilation, it is included in Space Heating and Cooling

Table 2: Sedgwick Summary of End-Use Source-Energy and Savings

			Source Energy Savings	
	Estimated Annual Source Energy		Percent of End-Use	Percent of Total
	BA Benchmark	**Prototype 1**	**Prototype 1 savings**	**Prototype 1 savings**
End-Use	106 BTU/yr	106 BTU/yr		
Space Heating	269	113	**58%**	**34%**
Space Cooling	33	13	**61%**	**4%**
DHW	29	16	**47%**	**3%**
Lighting*	43	20	**53%**	**5%**
Appliances + Plug	78	74	**5%**	**1%**
OA Ventilation**	0	0	**0%**	**0%**
Total Usage	453	236	**48%**	**48%**
Site Generation	0	0		**0%**
Net Energy Use	453	236	**48%**	**48%**

The "Percent of End-Use" columns show how effective the prototype building is at reducing energy use in each end-use category.
The "Percent of Total" columns show how the energy reduction in each end-use category contributes to the overall savings.

Table 3: Griswold Summary of End-Use Site Energy

	Annual Site Energy			
	BA Benchmark		**Prototype 1**	
End-Use	kWh	therms	kWh	therms
Space Heating	1390	1783	593	761
Space Cooling	2428		1174	
DHW	0	290	0	152
Lighting*	3273		1739	
Appliances + Plug	6546	0	6195	0
OA Ventilation**				
Total Usage	13636	2073	9701	913
Site Generation	0	0	0	0
Net Energy Use	13636	2073	9701	913

*Lighting end-use includes both interior and exterior lighting
**In EGUSA there are currently no hooks to disaggregate OA Ventilation, it is included in Space Heating and Cooling

Table 4: Griswold Summary of End-Use Source-Energy and Savings

	Estimated Annual Source Energy		Source Energy Savings	
			Percent of End-Use	Percent of Total
End-Use	BA Benchmark 106 BTU/yr	Prototype 1 106 BTU/yr	Prototype 1 savings	Prototype 1 savings
Space Heating	211	90	**57%**	**32%**
Space Cooling	28	13	**52%**	**4%**
DHW	32	17	**48%**	**4%**
Lighting*	38	20	**47%**	**5%**
Appliances + Plug	75	71	**5%**	**1%**
OA Ventilation**	0	0	**0%**	**0%**
Total Usage	383	211	**45%**	**45%**
Site Generation	0	0		**0%**
Net Energy Use	383	211	**45%**	**45%**

The "Percent of End-Use" columns show how effective the prototype building is at reducing energy use in each end-use category.
The "Percent of Total" columns show how the energy reduction in each end-use category contributes to the overall savings.

Table 5: Ridgewood Summary of End-Use Site Energy

	Annual Site Energy			
	BA Benchmark		Prototype 1	
End-Use	kWh	therms	kWh	therms
Space Heating	1496	1923	614	790
Space Cooling	2592		1166	
DHW	0	290	0	152
Lighting*	3494		1639	
Appliances + Plug	6658	0	6307	0
OA Ventilation**				
Total Usage	14240	2213	9726	942
Site Generation	0	0	0	0
Net Energy Use	14240	2213	9726	942

*Lighting end-use includes both interior and exterior lighting
**In EGUSA there are currently no hooks to disaggregate OA Ventilation, it is included in Space Heating and Cooling

Table 6: Ridgewood Summary of End-Use Source-Energy and Savings

	Estimated Annual Source Energy		Source Energy Savings	
			Percent of End-Use	Percent of Total
End-Use	BA Benchmark 106 BTU/yr	Prototype 1 106 BTU/yr	Prototype 1 savings	Prototype 1 savings
Space Heating	227	93	**59%**	**33%**
Space Cooling	30	13	**55%**	**4%**
DHW	32	17	**48%**	**4%**
Lighting*	40	19	**53%**	**5%**
Appliances + Plug	76	72	**5%**	**1%**
OA Ventilation**	0	0	**0%**	**0%**
Total Usage	405	215	**47%**	**47%**
Site Generation	0	0		**0%**
Net Energy Use	405	215	**47%**	**47%**

The "Percent of End-Use" columns show how effective the prototype building is at reducing energy use in each end-use category.
The "Percent of Total" columns show how the energy reduction in each end-use category contributes to the overall savings.

Appendix E.1.7.4
2008-09-01 Hamilton Way Site Visit Summary

2008.09.01

Chris Nelson
C. Nelson Construction, Inc
77 Tolland Turnpike
Manchester CT, 06042
860-646-0442

Re: 080813 Site Visit – Hamilton Way Development, Farmington, CT

Mr. Nelson:

The following is a summary of our observations and comments during our site visit on August 13, 2008, to the Hamilton Way Development in Farmington, CT. At the time of our site visit, 7 homes were under construction.

Lot Number	Plan Type	Address
2	Sedgwick (Standard Basement)	4 Ingelside, Farmington, CT
3	Ridgewood (Walkout Basement)	3 Ingelside, Farmington, CT
4	Griswold (Walkout Basement)	2 Ingelside, Farmington, CT
5	Sedgwick (Walkout Basement)	4 Hamilton Way, Farmington, CT
6	Griswold (Walkout Basement)	6 Hamilton Way, Farmington, CT
7	Sedgwick (Walkout Basement)	8 Hamilton Way, Farmington, CT
8	Griswold (Standard Basement)	7 Hamilton Way, Farmington, CT

The main focus of the site visit was to complete a series of performance tests on the Lot 7 model home in the community. Please see the attached report relating to the results of the performance testing and site review.

Sincerely,

Peter Baker, P.Eng.
Building Science Corporation

CC: Betsy Pettit, FAIA Building Science Corporation

Performance Testing

Lot 7 - #8 Hamilton Way (Model Home)

Figure 1: Lot 7 exterior elevation

Lot 7 was substantially complete at the time of the site visit. During the visit the home was tested for overall enclosure air infiltration levels as well as duct system leakage and conditioning system register flows.

The home tested at 1891 CFM @ 50Pa or 2.3 ACH @ 50Pa. The Building America target for this model is 2492 CFM @ 50Pa or 3.0 ACH @ 50Pa (representing approximately 2.5 in2 of leakage area for every 100 ft2 of enclosure area). This house achieved a very tight enclosure using the critical seal approach.

Table 1: Lot 7 House Performance Testing Results

Address	Plan	CFM 50 Measured	CFM 50 Goal	Pass/Fail 2.5 in^2	Leak Ratio	Duct 25 Total	Duct25 Outside	Pass/Fail 5% out
8 Hamilton Way	Sedgwick (Walkout)	1891	2492	**Pass**	1.9	335	40	**Pass**

During the air infiltration test, the fan was set to cruise at –50Pa. During this time, the house was surveyed for areas of air infiltration. The infiltration to the inside was noted mostly at exterior wall outlet boxes, though infiltration at interior partition wall boxes as well as a few other locations was also noted.

The exterior outlet boxes that were used have a gasket seal behind the faceplate that seals the faceplate to the wall. Leakage through the outlet openings was still present.

A few options exist for reducing the infiltration through the electrical outlet boxes.

One option is to use an air tight electrical box that comes complete with a flange that can be sealed to the back of the gypsum and seals around all the wire penetrations.

A similar concept uses a perform pan that houses standard electrical boxes to maintain the seal.

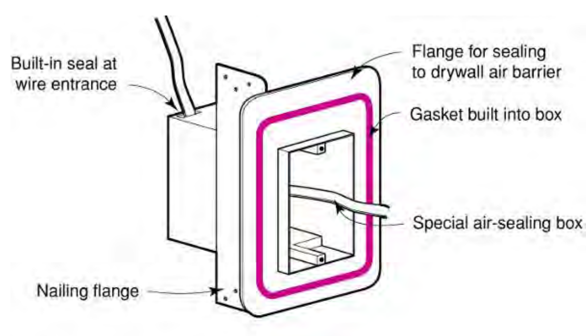


Figure 2: Airtight Electrical Box

A final option would be to use standard PVC boxes and caulk or foam all of the wire penetrations as well as any other hole in the box. After installation of the drywall, the face of the box will need to be caulked or sealed with a joint compound to the drywall

Figure 3: Airtight Electrical Box Pan (Photo courtesy of LESSCO)

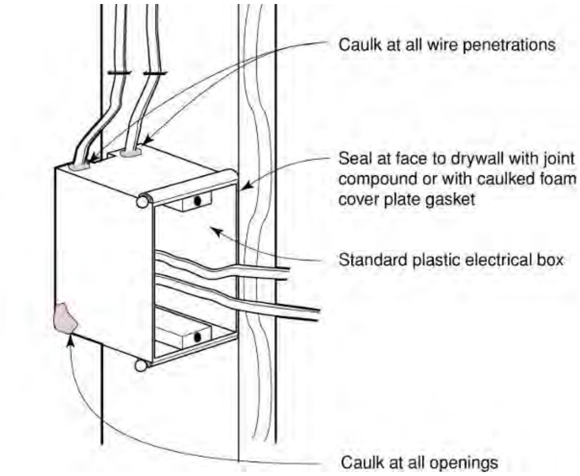


Figure 4: Air Sealed PVC Electrical Box

In the kitchen a significant amount of air seemed to be coming in from behind the cabinets over the range. It was suspected that the range hood duct might not have been well sealed as it penetrated the exterior wall.

In the basement, a small amount of leakage was noted coming in around the outdoor air duct where it penetrated the exterior wall. A few other small holes drilled through the foam were noted at the rim joist.

Figure 5: Leakage around exterior outdoor air intake duct

Figure 6: Leakage at small holes drilled through exterior foam seal

Other leakage was noted coming down the duct chase into the basement. This leakage is likely from the second floor framing.

In the attic a large hole in the enclosure was noted at the top of the return duct chase. No gypsum was installed at the top of the return duct leaving the duct chase open at the top to the exterior environment. As a retrofit, foil-faced polyisocyanurate cut and fit into the opening and the perimeter was sealed with spray foam sealant.

After the repair the air tightness did not change noticeably. This was likely due to the blocking that was installed in the duct chance between the first and second floor decoupling the duct chase from second story floor framing. While the duct chase was open at the top, the chase itself was well sealed from the rest of the house.

Figure 7: Open hole at top of duct chase

Figure 8: Blocking in duct chase at first to second floor interface

Figure 9: Polyiso cut and fit into opening

Figure 10: Foam seal around perimeter of polyiso

Figure 11: Un-sealed wire penetrations

In addition to the duct chase, other penetrations through the ceiling plane were noted such as at the drywall to partition wall framing and around electrical wire penetrations.

These areas should be sealed to help control air infiltration through the ceiling plane.

The duct system was first tested for overall system leakage. The test was completed using a duct depressurization test. The overall duct leakage was 335 CFM @ 25Pa. Given expected system airflow of 1400CFM (3.5 ton system at 400CFM/ton), this represents 23.9% of the total system flow. This amount of duct leakage, while high, is not uncommon for sheet metal duct systems. During the operation of the air handler, a significant amount of leakage was noted between the furnace and the cooling coil. In addition, leakage was also noted at the cooling coil to supply duct connection. The total duct leakage while not necessarily an energy concern, can affect the performance of the system to deliver the conditioned air to appropriate locations. Target duct system tightness would be less than 10% of the total system flow.

Some common leakage areas (in order of leakage potential):

1. Register boot to subfloor interface – the boot should be sealed to the subfloor to prevent air from leaking into the floor framing instead of being delivered to the room.
2. Flex duct to boot connection - the current flex duct to boot connection is made through the use of a zip tie at both the interior flex liner and the exterior flex liner. While this provides a moderate seal, variations due to the shape of the liner still allow for some leakage. It is recommended to apply mastic to the boot collar before sliding the interior liner over the boot collar. The liner should then be zip tied to the collar to hold it in place.
3. Round flex to rectangular sheet metal duct connection: The flanged collar connection are often fairly leaky and are recommended to be sealed with mastic.
4. Round metal articulating duct elbows and/or any seams in metal ductwork: Using foil tape can be effective in many cases however our experience has been that mastic is more effective in sealing these locations.
5. Air handler leakage: The connection between the furnace and the interior cooling coil is a common concern as well as air leakage from the furnace it self.

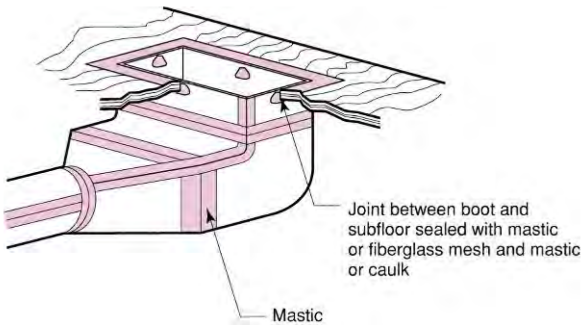


Figure 12: Sealing at register boot

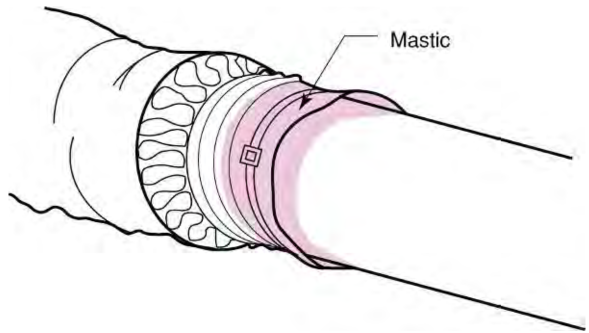


Figure 13: Sealing at flex to boot or round metal duct

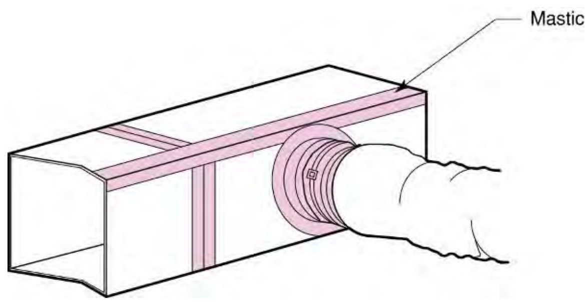


Figure 14: Sealing at flex to rectangular duct

From an energy efficiency perspective, the leakage potential to the exterior was also measured. The house was depressurizing to –25Pa with respect to the exterior and then the duct system was depressurized to be neutral with respect to the house and the flow out of the duct system was measured. The leakage to exterior was 40 CFM or 2.9% of the system flow. This is less than the Building America target of 5% or less.

In addition to the system leakage testing, the system flows were measured to examine the actual register flows compared to the Manual J design flows. Pressure measurements were also taken to examine the pressure relief from rooms that are more likely to have doors closed to ensure that return air pathway is not impeded.

The following table highlights the measured system flows compared to the design flows and the room pressure differentials with the doors closed when the system is operating.

Table 2: Register Flow and Room Pressure Testing Results

8 Hamilton Way - Sedgwick (Walkout)					
		Cool On (Both Zones)		Room Pressure	
Room	**Design (CFM)**	**Measured (CFM)**	**Delta (CFM)**	**Measured (Pa)**	**Comments**
Foyer	50	56	6		
Dining	70	*70*	0		Dinning Room Register not measured - default to design flow
Main_Hall	10		-10		No "Main Hall" register – flow combined with powder room
Mud-Room	50	49	-1		
Kitchen	150	142	-8		
Family	95	58	-37		
Powder_Room	20	44	24		Increased flow due to combined flow from "Main Hall"
Study	80	82	2		
Upper_Hall	55	43	-12		
Bedroom_4	70	44	-26	1.1	
Guest_Bath	20	18	-2		
Master_Closet	55	49	-6		
Master_Bedroom	110	78	-32	4.3	Pressure above recommended max of 3.0Pa
Master_Bath	55	30	-25		
Laundry	55	26	-29		
Main_Bath	25	17	-8		
Bedroom_2	85	96	11	3.1	combined measured flow from room + closet (80CFM + 16CFM)
Bedroom_3	95	102	7	2.8	combined measured flow from room + closet (69CFM + 33CFM)
Basement	130	*80*	-50		basement flows not measured due to lack of seal around registers
Total	**1280**	**1084**			

The flow to the family room on the main floor was lower than designed. If balancing the system can't increase the flow, it may be recommended that the duct size be increased or a second register added for this room.

The second floor registers appear to have lower flows compared to the design flows. The measurements were taken however with both zones calling. The system was not tested for register flows for individual zones calling. Under single zone demand conditions the second floor flows may be closer to the design flows.

Given the pressure differential with the master bedroom door closed, increasing the size of the jump duct to relieve the pressure on future installations is recommended. Given the total flow into the master bedroom (55 + 55 + 110 = 220 CFM), we would recommend a 12" flex jump duct be installed.

To help with future sizing of transfer grilles and jump ducts, the below tables provide a list of recommended jump duct sizes for given supply rates to the bedrooms.

Given:

Door width: 32 inch
Door undercut: 0.5 inch
Transfer grille width: 10, 12, or 14 inches
Net free area: 0.75 fraction of total grille area

Table 3: Transfer Grille and Jump Duct Sizing for Room Flow Rates

Room supply air flow	Net free area required	Area required after door undercut	Transfer grille height required for listed width in inches			Jump Duct Diameter Required
			10	12	14	
(CFM)	(in^2)	(in^2)	(in)	(in)	(in)	(in)
50	27.0	11.0	1.5	1.2	1.0	3.7
75	40.5	24.5	3.3	2.7	2.3	5.6
100	54.0	38.0	5.1	4.2	3.6	7.0
125	67.4	51.4	6.9	5.7	4.9	8.1
150	80.9	64.9	8.7	7.2	6.2	9.1
175	94.4	78.4	10.5	8.7	7.5	10.0
200	107.9	91.9	12.3	10.2	8.8	10.8
225	121.4	105.4	14.1	11.7	10.0	11.6
250	134.9	118.9	15.9	13.2	11.3	12.3
275	148.4	132.4	17.7	14.7	12.6	13.0
300	161.9	145.9	19.4	16.2	13.9	13.6
325	175.4	159.4	21.2	17.7	15.2	14.2
350	188.9	172.9	23.0	19.2	16.5	14.8

Based on $Q = 1.07 \times A \times \Delta P^{0.5}$ for square edged orifice flow

where: Q = room supply flow (CFM)
1.07 = constant, including unit conversions
A = free area (in^2)
ΔP = pressure difference between room and central area (Pa)

The measured values for overall enclosure leakage and duct leakage were entered into EnergyGauge USA – USRCBB - v2.7.0.3. The energy simulations were re-run based on the actual performance and orientation of the home. The home currently has a predicted Source

Energy Consumption Reduction of 50% when compared to the Building America Benchmark Protocol.

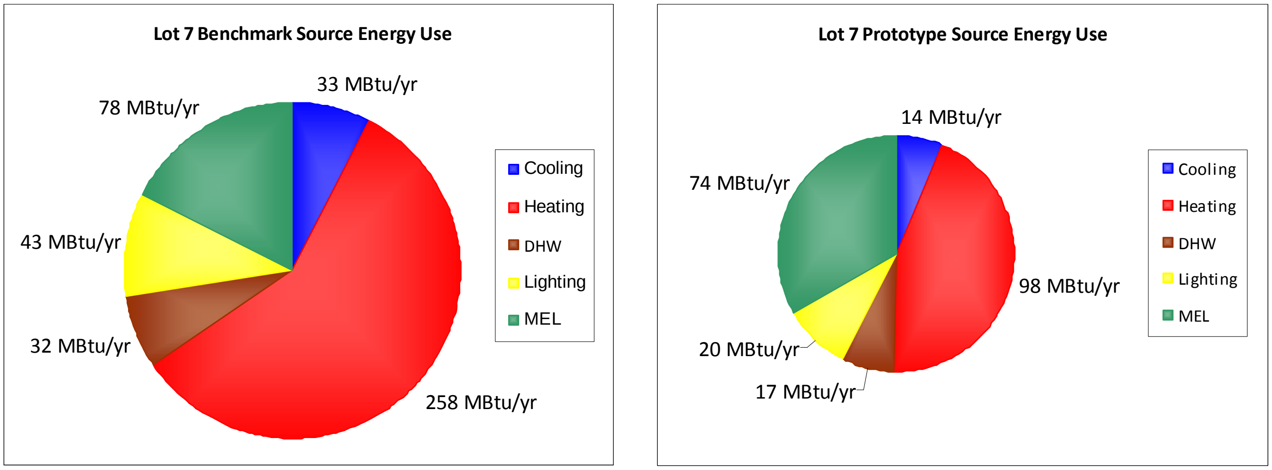


Figure 15: Source Energy Use by Component Load

Table 4: Summary of End-Use Site Energy

	Annual Site Energy			
	BA Benchmark		Prototype 1	
End-Use	kWh	therms	kWh	therms
Space Heating	1692	2182	645	826
Space Cooling	2910		1221	
DHW	0	291	0	152
Lighting*	3781		1761	
Appliances + Plug	6803	0	6453	0
OA Ventilation**				
Total Usage	15186	2473	10080	978
Site Generation	0	0	0	0
Net Energy Use	15186	2473	10080	978

*Lighting end-use includes both interior and exterior lighting
**In EGUSA there are currently no hooks to disaggregate OA Ventilation, it is included in Space Heating and Cooling

Table 5: Summary of End-Use Source Energy and Savings

			Source Energy Savings	
	Estimated Annual Source Energy		Percent of End-Use	Percent of Total
	BA Benchmark	Prototype 1	Prototype 1 savings	Prototype 1 savings
End-Use	106 BTU/yr	106 BTU/yr		
Space Heating	258	98	**62%**	**36%**
Space Cooling	33	14	**58%**	**4%**
DHW	32	17	**48%**	**3%**
Lighting*	43	20	**53%**	**5%**
Appliances + Plug	78	74	**5%**	**1%**
OA Ventilation**	0	0	**0%**	**0%**
Total Usage	444	223	**50%**	**50%**
Site Generation	0	0		**0%**
Net Energy Use	444	223	**50%**	**50%**

The "Percent of End-Use" columns show how effective the prototype building is at reducing energy use in each end-use category.
The "Percent of Total" columns show how the energy reduction in each end-use category contributes to the overall savings.

Development Progress

The following is a summary of the stage of construction for the remaining houses in the development.

Lot 2 - #4 Ingelside

Figure 16: Lot 2 exterior elevation

Lot 2 was nearing completion with the home at the being drywall stage at the time of the site visit. The exterior of the home was reviewed however, the house itself was not accessible and the interior was not reviewed.

Lot 3 - #3 Ingelside

Lot 3 was at the drywall stage of construction. This plan has a full finished basement. During the review, it did not appear that the drywall was caulked around the window rough opening. The gypsum should be sealed to the framing at the top and bottom plates as well as around any openings in the exterior gypsum.

Figure 17: Lot 3 exterior elevation

Figure 18: No caulk visible around window openings

Lot 4 - #2 Ingelside

Figure 19: Lot 4 exterior elevation

Lot 4 was at a similar stage of construction as Lot 2 and Lot 3 with the drywall being installed.

Lot 5 - #4 Hamilton Way

Figure 20: Lot 5 exterior elevation

Lot 5 had just finished framing and was beginning the installation of the exterior insulating sheathing.

At the base of the wall the trim flashing and insect screen was being installed behind the foam to cover and protect the exposed edges of the rigid insulation.

Figure 21: Flashing at base of wall following location of foam sheathing

Figure 22: Insect screen installed to wrap the exposed edge of the foam sheathing

Lot 6 - #6 Hamilton Way

Figure 23: Lot 6 exterior elevation

Lot 6 had the majority of the insulating sheathing installed and approximately half of the of the exterior WRB housewrap. No concerns were noted with the installation.

Lot 8 - #7 Hamilton Way

Figure 24: Foundation of Lot 8

Lot 8 has just finished pouring of the foundation.

Energy Analysis

A new set of energy simulations were run as reference to the site plan and orientation of the specific homes in the community. The specific homes were modeled using EnergyGauge USA – USRCBB - v2.7.0.3. The source energy consumption reduction for all the current homes in the community range from 45% to 52%.

Table 6: Estimated Source Energy Consumption Reduction and Utility Costs by Lot Number

Lot #	Address	Plan Name	Source Energy Consumption Reduction (%)	HERS	Benchmark Estimated Annual Utility Costs	Prototype Estimated Annual Utility Costs	Estimated Annual Utility Savings
1	Not Designated	Not Designated	n/a	n/a	n/a	n/a	n/a
2	4 Ingelside	Sedgwick (Standard)	52	54	$ 7,034	$ 3,215	$ 3,819
3	3 Ingelside	Ridgewood (Walkout)	48	53	$ 6,340	$ 3,117	$ 3,223
4	2 Ingelside	Griswold (Walkout)	46	55	$ 6,404	$ 3,297	$ 3,107
5	4 Hamilton Way	Sedgwick (Walkout)	48	53	$ 6,725	$ 3,306	$ 3,418
6	6 Hamilton Way	Griswold (Walkout)	46	55	$ 6,404	$ 3,297	$ 3,107
7	8 Hamilton Way	Sedgwick (Walkout)	50[1]	52	$ 6,596	$ 3,136	$ 3,460
8	7 Hamilton Way	Griswold (Standard)	45	54	$ 5,617	$ 2,953	$ 2,664
9	Not Designated	Not Designated	n/a	n/a	n/a	n/a	n/a
10	Not Designated	Not Designated	n/a	n/a	n/a	n/a	n/a

The utility data was based off of utility rates provided by C. Nelson. The estimated rates were:

Electricity: $0.19/kWh

Natural Gas[2]: $1.71/Therm

[1] Source Energy Consumption Reduction Based on measured performance of Lot 7. All others based on assumed air infiltration and duct system performance.

[2] Natural Gas rate does not include service charge – typical service charge is ~$10/month or ~$120/year.

The following table highlights the target goals for the system performance testing on each individual plan.

Table 7: Performance Testing Goals

Lot #	Address	Plan Name	Nominal Floor Area (ft2)	Enclosure Surface Area (ft2)	Volume (ft3)	Goal CFM 50	Goal ACH 50
1	Not Designated	Not Designated	n/a	n/a	n/a	n/a	n/a
2	4 Ingelside	Sedgwick (Standard)	3611	9723	48,900	2431	3.0
3	3 Ingelside	Ridgewood (Walkout)	3356	8883	44,500	2221	3.0
4	2 Ingelside	Griswold (Walkout)	3299	9472	43,100	2368	3.3
5	4 Hamilton Way	Sedgwick (Walkout)	3695	9880	50,000	2470	3.0
6	6 Hamilton Way	Griswold (Walkout)	3299	9472	43,100	2368	3.3
7	8 Hamilton Way	Sedgwick (Walkout)	3695	9880	50,000	1891[3]	2.3
8	7 Hamilton Way	Griswold (Standard)	3062	8325	40,300	2081	3.1
9	Not Designated	Not Designated	n/a	n/a	n/a	n/a	n/a
10	Not Designated	Not Designated	n/a	n/a	n/a	n/a	n/a

[3] Measured result

Appendix E.1.7.5
2008-10-10 Hamilton Way Site Visit Summary

2008.10.10

Chris Nelson
C. Nelson Construction, Inc
77 Tolland Turnpike
Manchester CT, 06042
860-646-0442

Re: 081002 Site Visit – Hamilton Way Development, Farmington, CT

Mr. Nelson:

The following is a summary of our testing results during our site visit on October 2, 2008. Two homes were tested for air tightness as well as duct tightness (8 Hamilton Way had been tested earlier). The table below is a summary of our testing results.

Table 1: House Performance Testing Results

		CFM 50	**CFM 50**	**Pass/Fail**	**Leak**	**Duct 25**	**Duct25**	**Pass/Fail**
Address	**Plan**	Measured	Goal	2.5 in^2	**Ratio**	**Total**	**Outside**	5% out
8 Hamilton Way	Sedgwick (Walkout)	1891	2492	**Pass**	1.9	335	40	**Pass**
4 Ingelside	Sedgwick (Standard)	1779	2431	**Pass**	1.9	307	30	**Pass**
3 Ingelside	Ridgewood (Walkout)	1658	2221	**Pass**	1.9	306	35	**Pass**

All of the homes have tested approximately 25% less leakage than the Building America target goal of less that 2.5in2 per 100ft2 of enclosure area.

A new set of energy simulations were run as reference to the site plan and orientation of the specific homes in the community and performance testing results. The specific homes were modeled using EnergyGauge USA – USRCBB - v2.7.0.3. The source energy consumption reduction for the current tested homes in the community range from 50% to 55%.

Table 2: Estimated Source Energy Consumption Reduction and Utility Costs by Lot Number

Lot #	Address	Plan Name	Source Energy Consumption Reduction (%)	HERS	Benchmark Estimated Annual Utility Costs	Prototype Estimated Annual Utility Costs	Estimated Annual Utility Savings
2	4 Ingelside	Sedgwick (Standard)	55	48	$ 7,034	$ 3,012	$ 4,022
3	3 Ingelside	Ridgewood (Walkout)	52	47	$ 6,340	$ 2,858	$ 3,482
7	8 Hamilton Way	Sedgwick (Walkout)	50	48	$ 6,596	$ 3,136	$ 3,460

The utility data was based off of utility rates provided by C. Nelson. The estimated rates were:

Electricity: $0.19/kWh

Natural Gas[1]: $1.71/Therm

After you have had a chance to review the results please fee free to contact me if you have any questions.

Sincerely,

Peter Baker, P.Eng.
Building Science Corporation

CC: Betsy Pettit, FAIA Building Science Corporation

[1] Natural Gas rate does not include service charge – typical service charge is ~$10/month or ~$120/year.