HIGH PERFORMANCE RESIDENTIAL DESIGN CHALLENGE

FINAL REPORT 10-25
JULY 2010

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HIGH PERFORMANCE RESIDENTIAL DESIGN CHALLENGE

Final Report

Prepared for the
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ENERGY RESEARCH AND
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ABSTRACT and KEY WORDS

The New York State Energy Research and Development Authority (NYSERDA) developed the High Performance Residential Development Challenge (HPRDC) program to increase the homebuilding industry's knowledge of and experience in building cost-effective, energy efficient homes. The program requires homes to meet the challenging energy efficiency benchmark of performing at least 60 percent better than homes built to the 2004 International Energy Conservation Code (IECC). This report documents the activities and results of seven homes on which Newport Ventures served as the contractor. Newport Ventures recruited the builders, modeled the Challenge and reference homes, and worked with builders to redesign home plans to improve energy efficiency. Additionally, the incremental costs associated with energy efficiency improvements were quantified to help the builder and project team make cost-effective decisions. Finally, to help compare the Challenge home to the builder's typical home, short-term energy tests and long-term utility bill tracking monitoring were conducted.

Key words: energy efficiency, high performance homes, energy efficient products and systems, NYSERDA.

ACKNOWLEDGEMENTS

Newport Ventures thank Greg Pedrick for his accessibility and interest in the program and his commitment to advancing energy efficiency in housing.

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Section 1

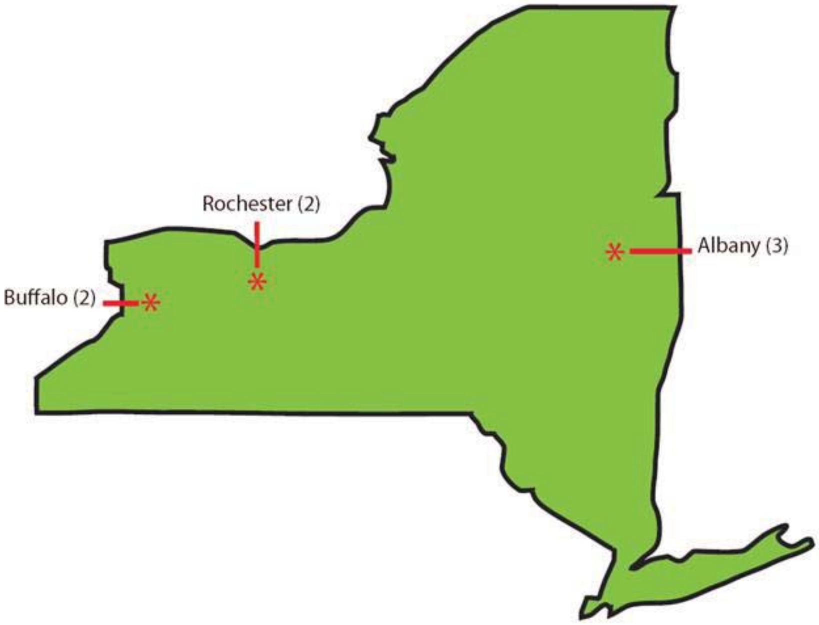
EXECUTIVE SUMMARY

The New York State Energy Research and Development Authority (NYSERDA) developed the high performance residential development challenge (HPRDC) program to increase the homebuilding industry's knowledge and experience in building cost-effective, energy efficient homes. The program established a goal for participating homes to meet the challenging energy efficiency benchmark of performing at least 60 percent better than homes built to the 2004 international energy conservation code (IECC). To ensure that the homes were comparable to typical homes in NY, homes were not to be larger than 2,500 square feet. Throughout this report, homes participating in the program are referred to as "challenge" homes.

Newport Ventures served as the building consultant on the project, qualifying builders and providing technical support on energy efficiency and new technology. Once a builder was selected and approved by NYSERDA, Newport created building energy simulation models of both the typical builder home that served as a reference home, and the redesigned challenge home, and worked with builders to redesign home plans to improve energy efficiency. Additionally, Newport ventures quantified the incremental costs associated with energy efficiency improvements to help the builder and project team make cost-effective decisions. Finally, short-term energy tests and long-term utility bill tracking were conducted to help compare the challenge home to the builders' typical home.

Selecting and qualifying builders proved to be more time consuming than was originally envisioned as the timing of the project coincided with a downturn in the economy and a severe downturn in housing. Newport interviewed and reviewed plans of over 20 builders in the process of selecting six builders and seven homes across New York as shown on the map below. Builders were offered the following benefits:

- Evaluation of current practices
- Design assistance in energy efficiency
- Public relations outreach
  - Press: newspaper, trade journals, and/or multi-media
  - Opportunity to be one of an exclusive group of builders
- Funding to help offset incremental cost of approved energy efficient systems
- A competitive edge and head start on what's coming – build above ENERGY STAR® and ahead of the curve



Although all of the items listed above helped to encourage participation, builders seemed most drawn to the educational aspects of the project. They were most interested in exploring modifications that they could then incorporate into other homes. There was significantly less interest in pursuing a technology or system that wouldn't fit into their building practice long-term; even if the technology could be supplied at a greatly reduced cost. Thus, to provide the greatest opportunity for long-term impact with the builders, Newport focused on incorporating energy efficiency measures that could be easily integrated within builders' current practices.

Energy efficiency measures that were commonly specified and achieved within the challenge homes included:

- Building air tightness: less than 2.0 ach 50
- Below grade wall insulation: r-25 or greater
- Above grade wall insulation: whole wall r-value average of r-28, range from r-22 to r-35
- Window u-factor: average of u-0.32, range from u-0.27 to u-0.35
- Ceiling insulation: average insulation r-value of r-50, range from r-41 to r-60
- Space heating: three dual fuel heat pumps (14 seer/9.0 HSPF or better + 95 AFUE furnace), one ground source heat pump, four stand-alone 95 AFUE furnaces
- Space cooling: air conditioners or air source heat pumps with seer 13-15
- Domestic hot water: natural gas fired, tankless units, from 0.82 EF non-condensing to 0.95 EF condensing
- Whole-building ventilation: ASHRAE 62.2 compliant; 4 HRVS, three exhaust-based systems (either multiport or multi-fan)
- Lighting: typically 100% CFL
- Appliances: typically ENERGY STAR rated

By employing these and other energy efficiency measures, the project team was able to greatly increase the performance of each Challenge Home as shown in the table below:

BUILDER PARTICIPANTS	**HERS SCORE, BUILDER'S TYPICAL CONSTRUCTION**	**HERS SCORE, CHALLENGE HOME**
BELMONTE BUILDERS	**86.2**	**91.4**
ROSEWOOD HOME BUILDERS	**84.6**	**91.8**
STEWART CONSTRUCTION	**86.4**	**91.8**
GERBER HOMES	**85.8**	**92.4**
VIOLA HOMES	**86.6**	**91.6**
MARRANO I	**86.6**	**92.4**
MARRANO II	**86.8**	**93.4**

After the homes were completed, Newport conducted builder and homeowner surveys to help determine the effectiveness of the techniques and technologies used in those homes. The surveys were conducted by phone and via e-mail.

Questions in the builder survey were targeted at:

- determining builder satisfaction with the project;
- gathering builder impressions of the customer's satisfaction with the high performance features;
- gauging the level of difficulty and the learning curve associated with using the new technologies and practices in the project; and,
- identifying the parts of the project they are likely to use in future homes.

Questions in the homeowner survey covered:

- the homeowner’s satisfaction with the overall home;
- the specific benefits from the project, such as comfort, performance, and cost savings;
- the homeowners understanding of the technologies used in the home; and,
- the homeowners likelihood to buy energy efficient homes in the future.

Of the upgrades over builders’ standard practices used during these projects, the most common technologies listed as likely to be used again by the builders were ducts in conditioned space (all builders); tankless gas water heaters; heat recovery ventilators (HRV); and CFL lighting (all builders). The homeowners’ comparisons to previous homes were always favorable and builders’ impressions were that their customers were more satisfied than in previous homes. The homeowners all recognized added comfort, quality, durability and a better living environment as additional benefits to living in energy efficient homes.

This report includes the following: a full case study on all seven Challenge Homes; a chapter on project findings that discusses lessons learned from the project; a chapter that analyzes the utility bills for each home over a two-year period; and, a final chapter describing the builder and homeowner evaluation survey. The overall project makes a significant contribution to the practice of building high performance homes.

Section 2

CASE STUDIES

BELMONTE BUILDERS

Belmonte Builders, a family-owned and -operated business, has been building custom homes for over 30 years. Belmonte focuses on offering quality custom homes at affordable prices and providing energy efficient features. About 90% of Belmonte's homes are designed and built to receive ENERGY STAR certification. Belmonte's ENERGY STAR labeled homes include a 95% efficient natural gas furnace, R-19 insulation in above grade walls, and R-38 insulation in the ceiling. Because of Belmonte's custom approach to home building, prospective buyers are able to go beyond Belmonte's standard energy package and select additional features that will reduce a home's electric and natural gas bills.

Belmonte's Challenge Home

The Belmonte Challenge

This case study highlights the high performance Belmonte Challenge home, which combines multiple energy efficiency strategies that are expected to reduce whole-house energy use by approximately 51% compared to a new home built to the 2007 New York Energy Conservation Construction Code (NYECCC).

Besides serving as a demonstration home for the NYSERDA HPRDC, Belmonte's Challenge home was part of the 2008 Showcase of Homes presented by the Saratoga Builders Association and held in Mechanicville, New York. As part of the Showcase of Homes, the association judged and presented a series of awards to the homes featured in the Showcase. The Belmonte Challenge home swept the competition, receiving first place in every category for a home with a selling price under $600,000. The categories included Best Exterior, Best Floor Plan, Best Kitchen, Best Master Bath, Best Workmanship, Best Interior Design, Best Landscaping, and the coveted Realtor's Choice Award. These awards demonstrate that, with the right design, a home can be both elegant and energy efficient. Further, the Belmonte Challenge home achieved the distinction of becoming the first Leadership in Energy and Environmental Design (LEED) Gold certified home in New York's Capital Region.

Belmonte's 2,036 square foot Challenge home contained three bedrooms and an attached garage. The overall Home Energy Rating System (HERS*)* Score[1] for this home was 91.4. As a point of reference, ENERGY STAR® homes built by Belmonte generally achieve a HERS Score of 86.2. Analysts applied REM/Rate residential modeling

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[1] New York State uses the "HERS Score" rating system based on industry standards that are produced by energy simulation software. Under this system, the "Reference Home" is scored at 80, and every point above 80 represents a 5% improvement in energy efficiency. To convert a HERS Score to a HERS Index, and vice-versa, see http://www.energystar.gov/index.cfm?c=bldrs_lenders_raters.nh_HERS

software to calculate the HERS Score, energy usage, and cost savings estimates used throughout this case study. Figure 2-1 details the building shell and mechanical system improvements made to Belmonte's reference home to create the Challenge home. The last column, titled 'Duplication Costs to Builder,' quantifies the builder's incremental costs associated with improved measures if Belmonte were to replicate the improvements on additional homes. On the Challenge home itself, manufacturer and supplier discounts made it possible to reduce some of these additional costs. Those discounts are disregarded, however, in reporting the duplication costs.

Measure	Belmonte Reference Home	Challenge Home	Duplication Cost to Builder
Below Grade Walls	R-11 Fiberglass Blanket Draped 4 Feet	R-30 Full Length, Perforated, FSK Fiberglass Blanket	$1,892
Above Grade Walls & Rim/Band Joists	R-21 Fiberglass Batt	R-3 Exterior Insulation R-12 of BASF SPRAYTITE Spray Foam Insulation R-15 Fiberglass Batt	$5,008
Ceiling/Attic Insulation	R-30 Fiberglass Batt	R-6 of BASF SPRAYTITE Spray Foam Insulation R-54 Blown Fiberglass	$1,554
Shell Tightness	3.0 ACH at 50 Pascals	1.5 ACH at 50 Pascals	Captured in Above Grade Wall Costs
Mechanical Ventilation	Continuous Exhaust Fan; 110 cfm 108 Watts	Continuous HRV; 76 cfm, 78 Watts 67% Sensible Recovery Efficiency	$2,850
Space Heating and Cooling	95 AFUE Furnace SEER 13 AC	Dual Fuel Heat Pump: 16 SEER/9.5 HSPF Heat Pump with 95 AFUE backup Furnace	$1,490
Domestic Water Heating	Gas-fired 50 Gallon Tank 0.64 Energy Factor	Condensing Tankless 0.95 Energy Factor	$490
Lighting & Appliances	10% Fluorescent ENERGY STAR Refrigerator, 487 kWh/year; ENERGY STAR Dishwasher, 0.72 Energy Factor	100% CFL or Fluorescent Same Refrigerator and Dishwasher	Not Captured
Enhanced Feedback and Controls	N/A	In2's "Energy ICM", enabling Internet-based control and energy use reporting of mechanical systems	$600
Total Incremental Costs			$13,884
HERS Score	86.2	91.4	

Figure 2-1 - Belmonte Reference Home and Challenge Home Comparisons

The package of energy efficient systems is expected to save the home buyer $98/month in year-one utility costs. At an incremental first cost of $13,884 for the package, the average monthly energy savings outpaces the monthly fixed amortized costs for these items in year-one. An explanation of these energy efficient systems and their benefits follows.

Review of Efficiency Upgrades

Beyond their energy and cost impacts, analysts also assessed the upgrade measures in terms of their impacts on estimated energy savings and compatibility with other building systems. The sections that follow discuss notable findings.

Basement Walls. The Challenge home's improved basement wall system is projected to save 7% of the whole house energy use of Belmonte's reference home. Belmonte's reference home has four feet long R-11 insulation blankets draped on the basement walls, leaving the bottom half of the basement wall uninsulated. Newport Ventures recommended the Challenge home install full-length blanket insulation on the below grade walls. Additionally, Newport recommended increasing the insulation value of the blanket from R-11 to R-30. Although other insulation products are available, the project team selected fiberglass blanket insulation for the basement because it is relatively inexpensive, and insulation crews are experienced and comfortable working with blanket insulation. Performance of blanket insulation is highly dependent on proper foundation drainage and water management, so it was crucial that the builder employ best practices in this area.

The basement wall insulation will result in an incremental cost to the builder of approximately $1,900 to replicate in the future. The ease of installation and the energy reductions that result make this measure a viable option for both new homes and existing homes with unfinished basements.

Full length blanket insulation being installed on below grade wall.

Above Grade Walls. Energy losses through above grade walls account for roughly 15-25% of the heating load of a NYECCC compliant home; therefore, when improving a home's energy performance, the above grade wall deserves serious attention. Newport Ventures and Belmonte worked together to develop an energy performance improvement strategy for the above grade walls, which used multiple measures to improve the building shell and reduce the energy use of the Challenge home. Builders applied two inches of BASF's SPRAYTITE spray foam inside the wall cavities to reduce air infiltration through the walls. This insulative foam not only helps seal the home but also provides an insulative value of R-12. After the spray foam in the wall cavities was dry, they installed a high density fiberglass batt rated at R-15, for a total cavity insulation value of R-27.

In order to reduce construction costs, the design team decided not to fill the entire 5.5" wall cavity with spray foam. This material is

Exterior insulation that seamlessly integrates with vinyl siding more expensive than traditional batt insulation. Spray foam insulation, however, expands and fills holes, effectively sealing the home from air infiltration and moisture penetration. By specifying a combination spray foam and fiberglass batt insulation system, the designers of the Belmonte Challenge home took advantage of the sealing benefits of spray foam and the reduced costs of traditional fiberglass insulation.

The award winning Challenge home has a remarkable curb appeal, and a person looking at the outside of the home would not be able to tell the house has additional insulation on the exterior. To increase the R-value of the wall, builders installed a layer of Progressive Foam's Fullback Thermal Support System EPS insulation on the outside of the home, beneath the vinyl siding. Based on testing results of similar assemblies supplied by the Vinyl Siding Institute, the combined R-value of the Fullback and vinyl siding was assumed to have an R-value of R-2.6. This R-value was based on thermal hot box tests that simulated wind effects on heat transfer across insulated vinyl siding. Builders installed the expanded polystyrene Fullback Thermal Support System over the moisture resistant membrane that was specially designed to match the profile of the vinyl siding.

The windows chosen for the Challenge home had a U-factor of 0.33, a Solar Heat Gain Coefficient of 0.30, and ENERGY STAR certification. The project team evaluated higher performance windows, but did not specify them due to high initial costs and low return on investment. Instead of spending money on higher performance windows, the project team successfully reduced the amount of heat loss through the windows by reducing the window-to-wall area of the Challenge home by 5%. This was accomplished through turning a flex room on the rear of the home into an outdoor porch, which also reduced the conditioned square footage by 100 sq. ft.

In total, above grade wall insulation measures provided a whole wall insulation value of R-23. As a stand-alone measure, the upgraded above grade wall system had the potential to save as much as 19% of the energy use of a baseline NYECCC compliant home.

Ceiling Insulation. Ceilings also used the dual-material insulation method. The ceiling insulation in the Challenge home comprises one inch of BASF SPRAYTITE spray polyurethane foam (SPF) covered with blown fiberglass insulation. SPRAYTITE has an R-value of six and provides a "critical seal" over any air penetrations resulting from utilities, chases, and recessed lights. Blown fiberglass insulation provides an additional R-54, for a total R-value of R-60. It is expected that, without counting the reduced air leakage from the spray foam, the insulation value of the spray foam and blown fiberglass will provide an energy savings of 6% beyond a baseline NYECCC compliant home.

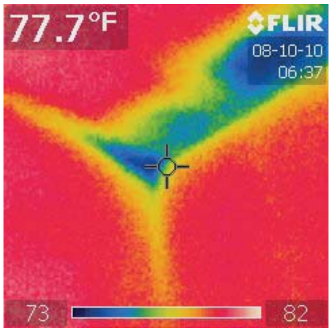
To ensure installation of the full depth of insulation across the entire ceiling plane, a raised heel truss was specified. A raised heel or "elevated" truss allowed the installation of full depth insulation at the eaves, while still maintaining clearance for ventilation. The following photographs show the raised heel truss above the master bedroom before and after insulation.

Ceiling and raised heel trusses

Ceiling after application of spray foam

Wall-to-roof connections can create tight corners that are difficult to insulate. A raised heel truss helps to cope with these hard-to-reach areas, as does spray foam insulation, which can typically be used to reach into tight corners. The Belmonte Challenge home had one ceiling corner where spray foam was not installed due to difficulty in accessing this small area at the junction of the house and garage roof line (see photos). Instead, insulators decided to try to reach the difficult corner with blown in cellulose from the attic. The thermal image below shows that, despite careful efforts, the insulator was unable to blow the fiberglass insulation into this small area. Without the assistance of thermal imaging equipment, this insulation gap would not likely have been identified.

Tight corner at intersection of house and garage roof lines



Thermal image of tight corner, indicating very little, if any, insulation reached this junction

Small air leaks caused by envelope penetrations at multiple locations can produce a large cumulative effect on the energy performance of high performance buildings. One of the more common locations for air leakage to occur is around recessed lights. Recessed lights can provide conditioned air with a direct path to an unconditioned attic, either through the inside of the light fixture or around the outside of the fixture itself. Still, because typical recessed light fixtures get hot during operation, there are restrictions on how close insulation can be placed to them. The Challenge home installed enclosed recessed lights that had been especially tested and rated for direct contact with insulation. The project team specified compact fluorescent lights (CFL) recessed lights to increase the lighting efficacy of the fixtures, as well as maintain lower temperatures in the fixture. Then builders applied spray foam around the entire recessed light fixture in the attic, greatly reducing the chances of conditioned air seeping out of the home and into the attic (see photos).

Enclosed recessed lights before spray foam application from the ground

Recessed lights after spray foam was applied from inside the attic

Further, the Belmonte Challenge home used only lights that were CFL, pin-based fluorescent, or LED. Improvements in the lighting package alone were projected to reduce the home's energy use by 3% from a baseline NYECCC compliant home, while resulting in significantly longer bulb life.

Mechanical Ventilation. All the ducts in the Belmonte Challenge home were located in conditioned space. This measure not only improves energy efficiency but also helps reduce the volume of dust and chemicals entering the home. Leaky ducts located in an attic, for example, can pick up dust and other air-borne particles from the attic and transport them into the home. Tight, energy efficient homes require ventilation systems designed to maintain optimal indoor air quality. Fresh air ventilation systems that use heat exchangers can use less energy than exhaust-only systems; therefore, the Belmonte Challenge home used an energy recovery ventilator due to its high energy efficiency and ability to satisfy industry-recommended fresh air ventilation rates.

Branch elbow before being attached

Builders sealed all the duct seams and joints with UL-181A-P/UL-181B-FX tape. When branching from the ventilation trunk, duct elbows with pre-applied foam tape were used to help seal the duct to the ventilation branch. The elbow was mechanically fastened using screws, while the foam adhesive helped to seal air gaps and ensure the delivery of more fresh air to the intended locations (see photos).

Branch elbow, after attachment to the ventilation trunk

Heating and Cooling. In a climate where heating days outnumber cooling days, an efficient heating and ventilation system is a foundational component of an energy efficient home. The Belmonte Challenge home installed a high efficiency, dual fuel heat pump to provide space heating and cooling. This dual fuel system consisted of an air source heat pump (AHSP) with a backup fossil-fuel fired furnace. The AHSP cools the home in the summer with an Air-Conditioning and Refrigeration Institute (ARI) rated seasonal energy efficiency ratio (SEER) of 16 and heats the home in the winter with a Region IV heating season performance factor (HSPF) of 9.5. Unlike a gas fired furnace, which can maintain constant heating capacity, regardless of outdoor temperature, or an air source heat pump's heating capacity and efficiency decline with decreasing outdoor temperatures. The colder it is outside, the more energy the heat pump uses and the less able the heat pump is able to keep the home at the thermostat set point. If the heat pump is installed without a back-up system, electric resistance heaters are employed to make up the difference between what the heat pump is able to provide and the heating demands of the home. In the case of a dual fuel system, however, a forced air furnace is brought on-line when the air source heat pump's efficiency and capacity decrease below an acceptable level. The advantages of a dual fuel system include the ability to:

- Minimize carbon foot print
- Minimize utility bills

Some calculations are required to find the optimum outdoor temperature at which responsibility for primary heating should shift from the heat pump to the gas-fired furnace. Unless the unit is equipped with controls that can do this automatically, the first step is to determine the efficiency of the heat pump at various outdoor temperatures. These data can be sourced from the equipment manufacturer. It is important to ensure that this efficiency calculation includes the operation of

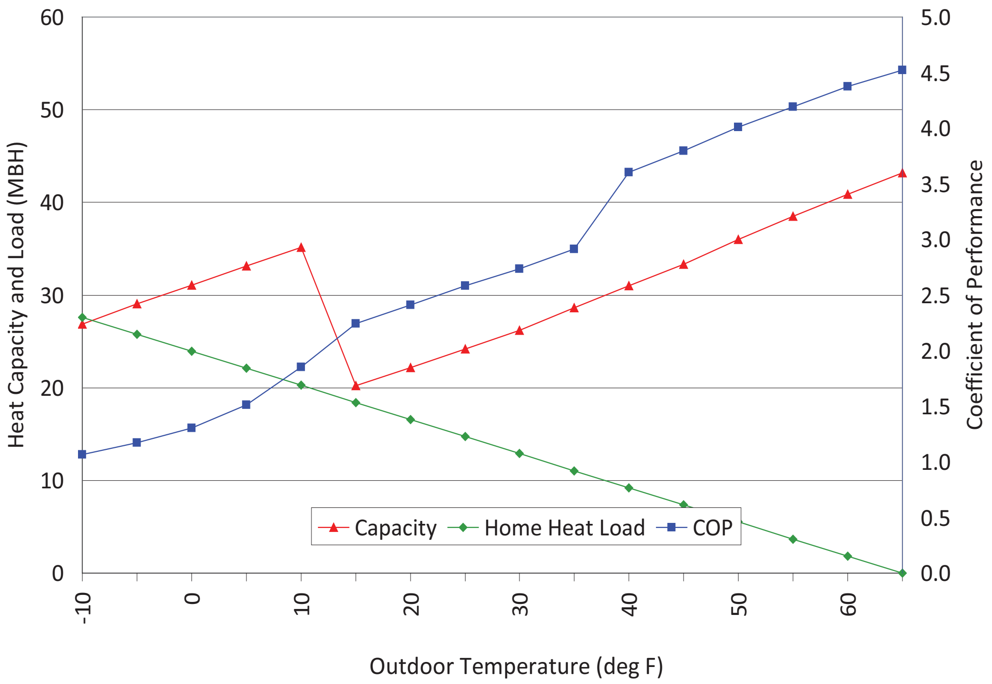


Figure 2-2 – Belmonte Heat Pump Capacity and Load electric resistance at colder temperatures. A bin data analysis can then be conducted at various outdoor temperatures to identify the costs, energy consumption, and emissions of the heat pump and furnace.

As Figure 2-2 shows, the heat pump's heating capacity and the coefficient of performance (COP) decrease with outdoor temperature. It is assumed that defrost cycles occur for five minutes of every hour when outdoor dry bulb temperature is at or below 35 degrees F (hence the sudden drop in COP below 35 degrees F). When the heating capacity falls below the home heat load (in this case, expected to occur at 15 degrees F), electric resistance heating is brought on-line in blocks of five kW, producing the saw-tooth effect of the graph of heating capacity. Dividing the cost of electricity by the COP of the heat pump produces a plot of the cost of heat delivered to the home as a function of outdoor temperature. For natural gas furnaces with essentially constant efficiencies, the cost per Btu of heat delivered can be represented by a straight line. The intersection of these two functions determines the economic balance point of the system – the temperature at which it costs the same to heat the home with a heat pump or a furnace (see Figure 2-3). Below this temperature, it is cheaper to heat with the furnace; above this temperature, it is cheaper to heat with the heat pump. The economic balance point for the Belmonte Challenge home was estimated at 15 degrees F.

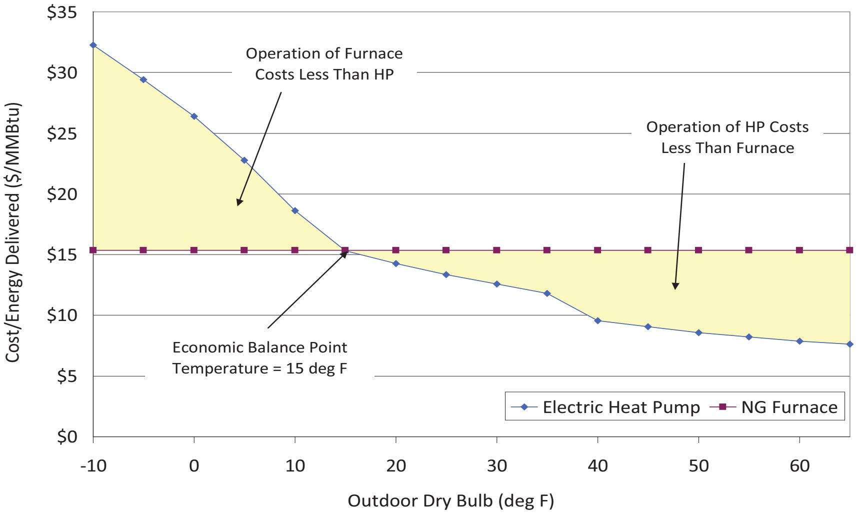


Figure 2-3 – Belmonte Economic Balance Point

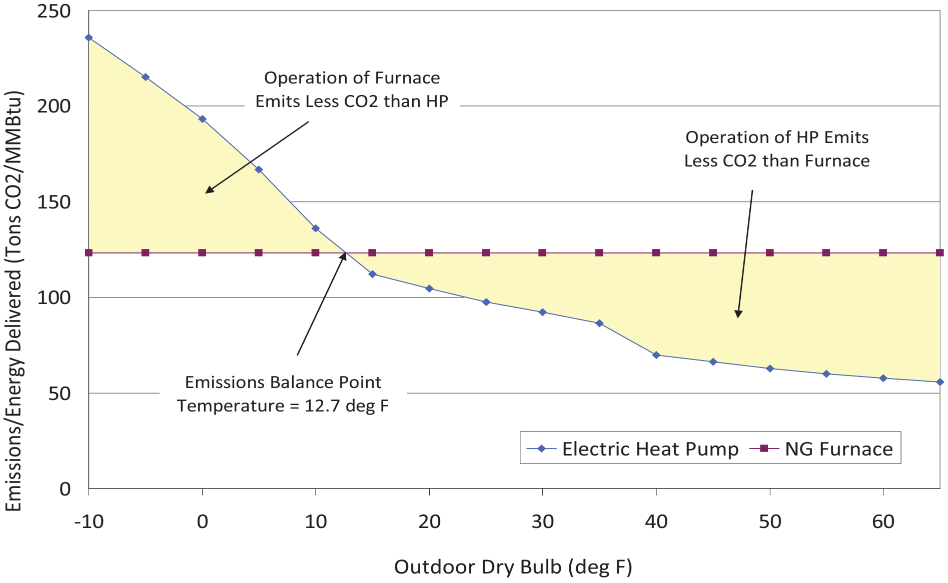


Figure 2-4 – Belmonte Emissions Balance Point

A similar analysis identified the emissions balance point of the heating system— that outdoor temperature at which operation of the AHSP and operation of the natural gas fired furnace produce equivalent emissions per unit of heat generated. Below this point, operation of the furnace produces fewer emissions; above this point, operation of the AHSP produces fewer emissions (see Figure 2-4). To perform this analysis, the state level emission factor for electricity generation in New York was sourced from the Environmental Protection Agency (EPA) as 252 lbs of CO2 per MMBtu of electricity consumed. The natural gas emission rate was set at 117 lbs CO2 per MMBtu of natural gas consumed. Based on equipment efficiencies and emission rates as a function of outdoor temperatures, analysts determined the emissions balance point temperature to be 12.7 degrees F.

According to these analyses, the homeowner would set the switchover temperature at 12.7 degrees F if basing the decision on 100% environmental analysis, or at 15.0 degrees if basing the decision on a 100% economics analysis. Nevertheless, in this case, the point where science and spreadsheets meet reality is at the intersection of comfort. Because the air delivery temperature of air source heat pumps decreases with decreasing outdoor temperatures, occupants are less comfortable when the heat pump is operating under cold conditions. Based on their experience with air source heat pumps in the area, the contractors who installed the system selected a switch-over temperature of 38 degrees F for the system. This temperature did not optimize either economics or emissions, but did deliver an acceptable solution that would provide comfort, energy savings, and dollar savings over the operation of traditional systems.

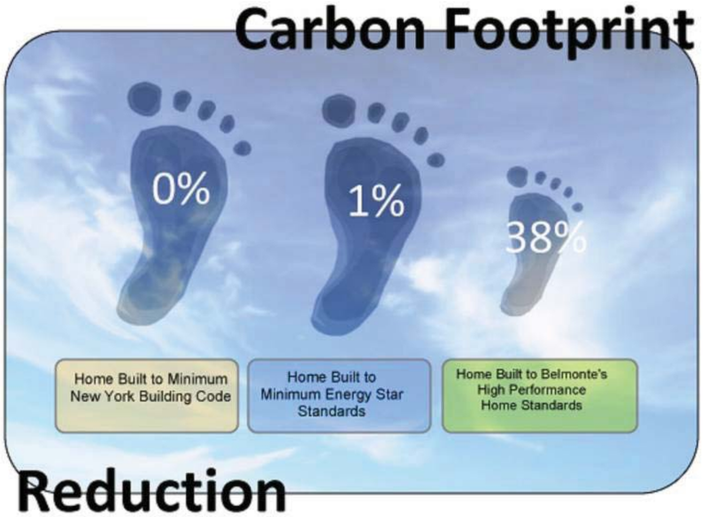
It is expected that, if it were the only energy efficiency improvement installed in Belmonte's reference home, this dual fuel system would result in 29% heating energy savings and 16% cooling energy savings. At an incremental cost to the builder of $1,490, the dual fuel system is a very affordable energy efficiency improvement.

Controls and Energy Monitoring. The more information that homeowners have about their energy use, the more able they will be to act on that information to manage and conserve energy. Therefore, builders installed an Internet-enabled thermostat control and energy use feedback meter to provide future homeowners with a greater level of information about their space heating and cooling system. In2 Network's "Energy ICM" (internet connection module), specified for this application, enabled a homeowner to monitor instantaneous heating and cooling energy use as well as energy use aggregated on daily, monthly, and annual bases. One study has documented energy savings from feedback metering as ranging between five and 15%. Because these expected savings are dependent on the behavior of the future homeowners and their interaction with their home, however, the cost and anticipated savings associated with this unit were not included in the economic analysis of home energy conservation measures.

Tankless water heater

Domestic Hot Water. Traditional natural gas hot water storage tanks have inefficiencies associated with heating a volume of water and maintaining it at a constant temperature until use. Tankless water heaters, which only heat water as it is needed, eliminate these standby heat losses. The builders selected the Navien tankless water heater, the first condensing, tankless water heater available in the United States, and is 15% more efficient than typical tankless units. Using roughly 26% less energy to heat water than the unit specified in Belmonte's reference home, the Navien is expected to achieve whole house energy savings of about four%

Carbon Emissions. Newport Ventures conducted a whole building energy modeling analysis to estimate the emissions associated with the same home footprint built to three different standards: the NYECCC, EPA's ENERGY STAR, and the NYSERDA Challenge. This simulation projected the Challenge home to emit roughly 38% less carbon than the NYECCC compliant home. Interestingly, the analysis also revealed that a NYECCC compliant home and New York ENERGY STAR home are very close in expected performance – at least on paper. Even though utility rates will fluctuate, the Challenge home will continue to use less energy and emit less carbon into the atmosphere throughout the home's lifetime than a baseline NYECCC compliant home or ENERGY STAR home.



Economic Analysis of Efficiency Upgrades

A major component of the NYSERDA Challenge is demonstration of cost-effective solutions towards 60% savings. In keeping with this goal, Newport Ventures conducted an economic analysis to evaluate the first and operational costs to be expected by both the builder and future homeowner. Currently, builders in New York State are heavily incentivized to build energy efficient homes. Between the Federal Energy Tax Credit and the New York ENERGY STAR Homes program, builders are eligible to receive between $2,750 and $5,000 for very high performance home that they construct.

The current analysis assumes that the significant financial incentives available to builders are passed on to the homeowner at the builder's cost. The replication cost of the energy efficient measures for the Belmonte Challenge home, was $13,284.2 The analysis rolls this incremental cost into the mortgage of the future homeowner, who, it is assumed, finances the home using a conventional, conforming 30-year fixed-rate mortgage with an interest rate of 6.2% (the average monthly rate at the home's completion in October 2008).

If the homeowner finances the energy efficient upgrades in this manner, the most relevant indicator of affordability is the net monthly expense of the amortized energy efficient measures after accounting for utility savings. Newport Ventures conducted whole building energy simulations using REM/Rate software to estimate the energy use of Belmonte's reference home and Belmonte's Challenge home. Based on these simulations, the Belmonte Challenge home was projected to use 79.9 MMBtu of energy per year (or 18 kBtu/conditioned square foot), while Belmonte's reference home was projected to use roughly 135.7 MMBtu of energy per year (or 31 kBtu/conditioned square foot). Referencing local utility rates, analysts valued the electricity savings of the Challenge home at $0.1175/kWh, and valued the natural gas savings at $1.46/therm. Analysts assumed a 5% annual appreciation rate for electric and natural gas utility rates (see Figure 2-5).

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[2] Analysts expect a 51% savings are expected compared to a minimum NYECCC compliant home. Also, the analysis uses $13,284 as the incremental cost instead of $13,884, because the expected savings from the $600 In2 Energy ICM were not included in the energy and economic analysis.

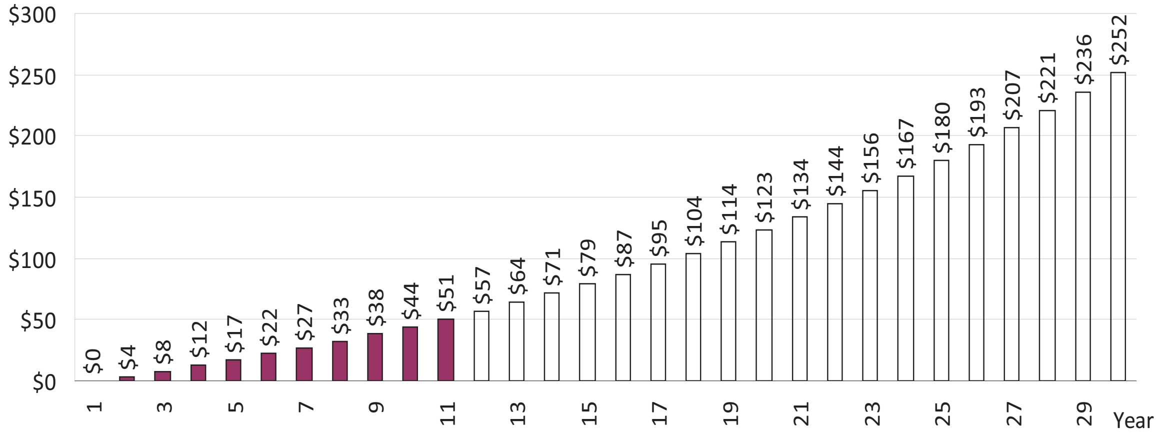


Figure 2-5 – Belmonte Projected Net Monthly Saving

Based on these assumptions, analysts undertook a monthly cash flow analysis to examine the cost-benefits of the efficiency package. Once amortized over a 30 year loan at 6.2%, the monthly cost of the $13,284 energy efficiency package is $81. In year-one, the average monthly electricity and natural gas savings (benefits) are also expected to be $81, meaning that the net savings for the first months are projected to be $0. As annual utility rates continue to increase (assume 5% per year) and the amortized cost of the energy efficient package remains fixed, the net savings continue to increase, so that by year-10, the average net monthly savings are projected to be $44. By year-20, the average net monthly savings are projected to be $123, and by year-30, they are expected to reach $252. In total, over a 30 year mortgage, the cumulative net savings are expected to reach $35,282.

Utility Bill Analysis

See Section 4 of this report for the results of the utility analysis.

GERBER HOMES

Gerber Homes, Inc., a family owned and operated home building business, has been building and renovating homes in the Greater Rochester area for more than 45 years. Having built over 2,000 homes, with at least 250 of those rated as ENERGY STAR, Gerber Homes prides itself on being on the cutting edge of energy efficiency.

Gerber's focus on energy efficiency started in the 1970s, when the company was trying to find a way to lower customers' high electric heating bills. Gerber suspected that if they could build a better insulated home, the heating bills costs would fall. Gerber began increasing the insulation in the homes and tracking the effects on their customers' monthly utility bills. The extra insulation they put in the attics and walls during this time resulted in significant utility cost savings, and extra insulation is still used as one of the company's many standards in all of their home building.

Once word of the results spread, many were eager to build their own "extra insulated home." It was not long before other area builders were making similar changes to meet the new demand. Gerber Homes has continued this innovative thinking over the last 45 years, assessing obstacles, researching and testing options, and collaboratively sharing their results. Gerber's target market includes first time home buyers, empty nesters, retirees, and those moving up to a larger home. They are now moving to meet an emerging demand from their target market for 'in-law'-capable ranch homes, to enable care of elderly family members, homes that are also low maintenance, and highly energy efficient. Most of the homes they build are ranch style and between 1,400 and 3,500 square feet. Gerber is considered a custom builder of affordable housing for those of all ages and circumstances.

Marketing

Energy efficient features that are behind the wall or tucked away in mechanical rooms can be hard to sell. That is why Gerber decided to show an unfinished home at the Rochester HBA Homearama. While other builders were focusing on finishes, Gerber was showing off their super-insulated building envelope. Letting potential home buyers touch and feel a product really makes a difference. Gerber believes that effective market penetration of energy efficient technologies for the home can only come about by involving both the manufacturer and the builder in marketing directly to the consumer.

A press conference was held in conjunction with the Homearama on June 17, 2008. The Governor proclaimed the day Energy Efficiency Day.

Peter Douglas of NYSERDA, (left), presents the Governor's proclamation to Gerber Homes founder, Bruce Gerber.

The Design Home

Front elevation of Gerber's Build Green, Live Green Homerama Home

Gerber Homes responded enthusiastically to the HPRDC challenge. They identified this as an opportunity to learn more about energy efficient home construction systems and their associated costs and benefits. For this project, Gerber selected a 2004 sq. ft. model that was to be showcased in the Rochester Homebuilders Association's 2008 Homearama. Newport Ventures provided design and energy consulting services.

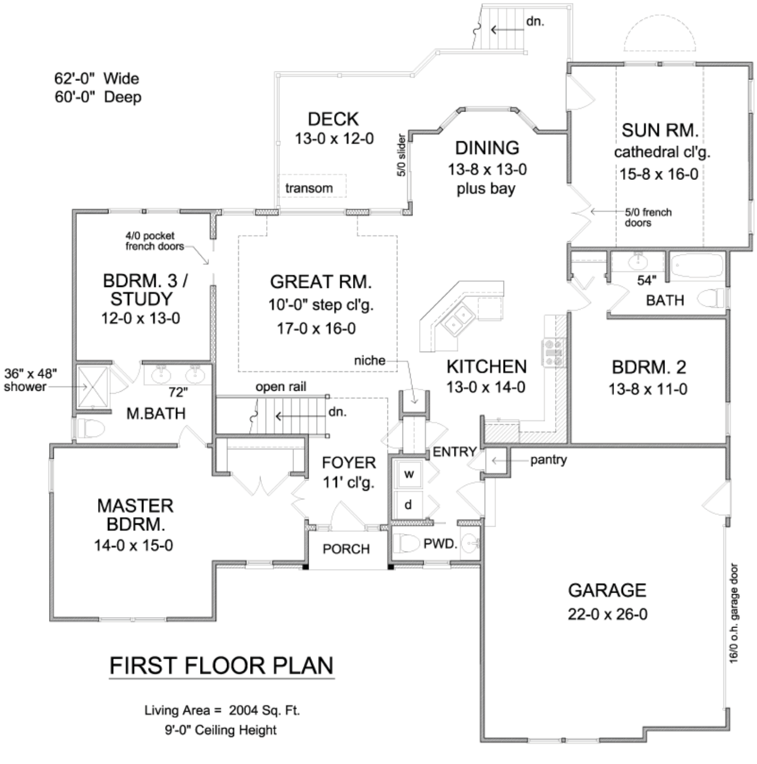
Starting with Gerber's baseline systems, Newport recommended multiple building systems to result in a design that modeled to be 61% more energy efficient than a home built to the 2007 New York Energy Conservation Construction Code. Primarily, the design focused on improving the energy performance of the walls and ceiling ensuring lifetime good performance. Secondarily, the super-insulated home incorporates a very energy-efficient mechanical ventilation system, and heating and cooling system. The house finishes out its energy efficiency package through specification of high efficiency appliances and lighting. (See Figure 2-6.) The resulting Gerber's Build Green, Live Green home is one of seven homes throughout the state built in partnership with Newport Ventures and NYSERDA as models of advanced energy efficient homes.

Measure	Gerber's Reference Home	Gerber's Build Green, Live Green Design Home	Incremental Cost	Expected Single Measure Savings
Ceiling Insulation	R-42 blown cellulose	R-50 blown cellulose + raised heel truss	$500	$19
Above Grade Walls	2x4, 19.2 inches on center, R-13 cavity	2x4, 19.2 inches on center, R-18 closed cell spray foam cavity insulation, 2" R-10 exterior continuous foam insulation	$7295	$149
Below Grade Walls	Precast concrete walls with integral R-5 continuous interior foam insulation	Precast concrete walls with integral R-12.5 continuous interior foam insulation + R-21 cavity insulation	$2400	$267
Domestic Water Heating	40 gallon, 62% EF, natural gas-fired tank	82% EF natural gas-fired tankless unit	$721	$62

Figure 2-6 - Gerber Baseline Home and Design Home Comparisons

Space Heating and Cooling	92 AFUE furnace, SEER 13 AC	Ground Source Heat Pump	$16,520	$722
Mechanical Ventilation	Exhaust MV at 100 cfm, 110 Watts	ASHRAE 62.2 compliant Heat Recovery Ventilator	$2,800	$59
Lighting	10% fluorescents	63% fluorescents	$300	$56
Total Incremental Costs & Expected Savings			$30,536	$1128
HERS Score	85.8	92.4		

Figure 2-6 - Gerber Baseline Home and Design Home Comparisons (Continued)



First Floor Plan Gerber's Build Green, Live Green Home

Gerber's targeted several systems for energy-efficiency improvements.

Superior Walls basement walls

Basement Walls. Energy simulation modeling shows that in New York State, the typical new home's standard basement wall system can account for as much as 20-30% of the home's heat loss. The Build Green, Live Green home's advanced basement wall system is projected to save 14% of the entire home's energy use compared with Gerber's standard basement wall system. To achieve a super-insulated basement, Superior Walls' pre-cast concrete walls with integrated R-12.5 continuous insulation provided the support. Then, builders installed Owens Corning's high-density R-21 fiberglass insulation in the wall cavities. For the unfinished basement, the design team specified Owens Corning's permeable house wrap, PINKWRAP® as the interior finish, for its clean and non-abrasive surface that far outperforms code requirements for flame spread and smoke developed index.

Constructability Issues. Typically, unfinished basements of new homes in New York State contain several supply registers to at least semi-condition a storage space. What starts as a storage space, however, generally becomes a fully conditioned, finished space at some point in the future. With only two choices for characterizing the space within energy modeling software (conditioned or unconditioned), the most logical choice was to treat the basement as conditioned. This modeling assumption revealed that there were significant efficiency gains to be had over standard insulation practice in the basement — up to 14% energy savings in this case by going from an R-5 Superior Wall to a whole wall R-value of R-33.5. While this may seem to be low-hanging fruit on the energy efficiency tree, there turned out to be a wide chasm between specifying a system and actually achieving it.

Insulating and air sealing an unfinished basement can be a challenge. When a contractor thinks basement insulation, he typically pictures R-11, hanging 4' down from the sill plate of a poured concrete or concrete masonry foundation wall. The Gerber home called for precast concrete walls with integrated and continuous polyisocyanurate foam at R-12.5. To boost the whole wall R-value to R-33.5, the specification called for installation of R-21 in the 2x6 cavities of the precast concrete wall. What seemed as if it should take a couple of simple steps turned into several. Un-faced fiberglass batts had to be used to meet the smoke density and flame spread requirements of code. Although the un-faced batts conformed to code, local building code inspectors asked that a finish layer be applied over the batts due to concerns about ambient fibers. Because kraft faced batts would not meet smoke and flame requirements of code, a foil or poly scrim kraft is generally used for this application. Non-perforated scrim kraft finishes have a very low permeability (~0.02 perms) that do not permit the wall to dry to the interior when there is bulk moisture penetration. Owens Corning, who supplied the R-21 batt, suggested their PINKWRAP housewrap product for the finish.

It provides a higher perm while performing far better than code requirements as related to smoke and flame. Ultimately, however, because the product was not labeled as an interior wrap, code officials rejected the house wrap as an interior finish, and the builder was forced to settle for a PSK finish for the below grade walls.

When it came time to actually install the batts, insulation installers were faced with highly irregular stud spacing in the precast concrete walls. “Standard” stud spacing within the walls was given as 24 inches on center, meaning the standard cavity was 19.75 inches wide, accounting for stud width and foam board insulation. A large number of the cavities were much smaller than the 19.75 inches – at dimensions of 11 or nine or seven inches, which would require trimming all batts to various dimensions to avoid compression and to maintain their rated R-value. All told, the supposed low-hanging fruit of basement insulation required coordination between manufacturers, code official, builder, and contractor — with the final installed system unable to provide the same performance as the specified system, due to building official concerns over product labeling.

BASF Comfort Foam cavity insulation

Above Grade Walls. Energy losses through above grade walls account for about 15-25% of the heat load of a typical home in New York State. To reduce expected heat loss, designers first reduced the amount of framing in the wall by spacing the studs at 19.2 inches on center (the diamond mark on a tape measurer), and using ladder blocking and two stud corners. Reducing the framing members in this fashion makes it possible to install more insulation in the walls. The Gerber home has both continuous exterior insulation and interior wall-cavity insulation on above-grade walls (see photos). Insulation installers placed 2” Dow Styrofoam, rated at R-10, on the outside of the oriented strand board (OSB) structural sheathing. To help produce a tighter wall assembly while increasing insulation, BASF Comfort Foam was sprayed in all cavities and along band joists, providing a cavity insulation R-value of 18.3. The design team estimated that, taken together, these measures are projected to reduce the home’s total energy use by eight %. Improved air sealing resulting from these measures could increase the projected energy savings by another three %.

Dow Styrofoam for exterior continuous insulation

In specifying that above grade walls have continuous extruded polystyrene on the exterior and high density spray foam in the interior cavities, it was crucial to detail the flashing around windows and penetrations to avoid future problems with bulk water movement through the assembly (see photo). Joints and seams of exterior foam board were taped to create a code compliant weather barrier, and a Dow representative was on site to ensure that builders followed the manufacturer’s flashing instructions explicitly.

Domestic Hot Water. Standard natural gas fired hot water storage tanks produce inefficiencies associated with heating a volume of water and maintaining it at a constant temperature until use. Tankless water heaters, which heat water only as it is used, eliminate these standby heat losses. The design team selected the Takagi TK3 tankless water heater in order to decrease energy consumption and costs. With an Energy Factor of 0.83, energy savings are expected to account for three % of whole-house energy use, saving approximately $62 annually on natural gas bills. The unit was mounted on an exterior wall to avoid incremental costs associated with long gas line runs and venting.

Mechanical Ventilation. Tight, energy efficient homes need to have ventilation systems that ensure that adequate indoor air quality is maintained. Fresh air ventilation systems that use heat exchangers can use less energy than typical exhaust-only systems. Gerber's Build-Green, Live-Green Home used Broan's Heat Recovery Ventilation (HRV) HRV-100 system because it is extremely energy efficient and satisfies fresh indoor air quality needs. The Broan HRV100 is expected to save three% of the home's total energy use compared to a typical exhaust-only system,

A builder has several options for installing an HRV, including the supply and return streams, setting ventilation rates and times, and providing variable controls. The simplest installation typically involves pulling from the central duct return plenum and supplying fresh air to the supply plenum of the furnace. It is also possible to pull from the furnace's return plenum and supply to the return plenum, but this method generally requires that the central blower operates in tandem with the HRV to avoid short-circuiting ventilation air. This approach can result in severe energy penalties, especially if configured to run continuously.


Broan HRV100h for indoor air quality

The Gerber Challenge home used the "Cadillac" of all HRV installations – a system configured to pull from the three bathrooms in the home and supply to the return plenum of the central duct (see photo). Though the design team could have selected a smaller model HRV to provide the target ventilation rate (based on ASHRAE 62.2 levels), they selected a larger volume unit to permit the HRV to operate at lower speeds and higher efficacies. Builders installed variable fan speed and placed humidistat controls in the bathrooms to boost the HRV from low to high speed during high demand events. It was expected that the unit, sized to pull over twice the targeted air flow of the home, would operate on medium speed. Field measurements of air flow taken with a digital thermo anemometer (Dwyer Series 471), resulted in fan speeds that fell short of design levels. Although the digital thermo anemometer was selected for its reputed high accuracy, field measurements showed a high degree of variability based on position within the duct. For this reason, the analysis reports no measurements here. Nevertheless, based on low numbers that the anemometer reported, the HRV was left on the high speed setting to maximize flow through the ducts.

It is suspected that the layout of the HRV supply and return ducts contributed to the low flow measurements recorded. This was especially true of the return side of the HRV, which consisted of a six inch flex duct with runs from three bathrooms. The longest of these runs was 80 feet and included eight 90 degree bends, one 180 degree bend, and one tee. The HRV's supply duct was characterized by 32 feet of six inch flex duct, two 90 degree bends, and two 45 degree bends.

The lesson learned from this install is that what looks good on paper does not always play well in the field. The simple solution may be the best, and placement of the HRV and its ducting system should be done through balancing considerations of both anticipated expansion/basement finishing as well as performance of the unit. Further, actual supply and return flow rates of these units can be expected to fall far short of manufacturer's published data due to high static pressure associated with typical installations.

CFLs for Lighting. Changing inefficient incandescent lights for fluorescent lights can be one of the most cost-effective methods for saving energy. The Gerber Build Green, Live Green home exclusively uses compact fluorescents and pin-based fluorescent lighting. This single measure is expected to reduce the home's energy use by three%.

Though this project did not focus on lighting, specification of energy efficient lighting can provide an excellent return on investment for homeowners. home energy Rating systems (HERS) modeling showed that the effect on the HERS score of specifying a 100% fluorescent and compact fluorescent package for the Gerber home came to an increase of one full point over the base case of 10% fluorescent and compact fluorescent package. The builder agreed to specify a 100% CFL and fluorescent package for the home and Newport did not provide any further support in this area, as NYSERDA stressed that lighting and appliances should not be the focus of the project. When the final walk-through was carried out, there was only one CFL in the home. When alerted to this, the builder sent a punch-list employee to buy and install CFL bulbs. Screw-in CFLs were placed in all fixtures that were easily reachable and that would accommodate the standard base sizing. This amounted to 63% of all lighting for the home. Unfortunately, no consideration had been given to placing dimmable CFLs in dimmable light switches, so the CFLs in these circuits performed poorly, flickering regularly. The CFL bulbs installed in pendant lighting over the kitchen island were longer than their shades, resulting in an uncomfortable glare. CFLs in recessed cans were not of the flood-light variety, and their appearance could be described as awkward at best. Finally, no CFLs were installed in the candelabra light fixtures, as the punch-list employee was unable to locate these at the local hardware store. All told, a little planning would have gone a long way in specifying the CFLs. It is possible to create a 100% fluorescent lighting package, but this outcome would require specification of the right bulb for the right fixture.

Heating and Cooling. The minimum code compliant furnace in New York has an efficiency of 80 percent, while the minimum efficiency air conditioner is rated as a SEER 13. The Gerber home uses a ground source heat pump to improve the home's heating and cooling energy efficiency. WaterFurnace Envision's high efficiency ground source heat pump is expected to provide between 40 percent and 45 percent reductions in total energy use, compared with a baseline code-compliant home. To install a ground source heat pump (GSHP), Gerber needed to look beyond typical HVAC contractors. In established relationships with contractors, both builders and contractors have mutual expectations of responsibilities, regardless of what is stated in a contract. Gerber was surprised to learn that a few items that were typically provided by its HVAC contractor were not considered to be within the scope of services offered by the geothermal contractor. For example, Gerber expected that the geothermal HVAC contractor would vent the range hood and also run gas lines. These items were not in the HVAC contractor's contract, and the cost to Gerber was approximately $600 for these services. The lesson here is that to ensure a fair comparison between alternate technologies and contractors, contracts should outline a full scope of services. Identifying responsibilities up front can save headaches and budget overruns down the road.

Excavating for the horizontal geothermal loop field

Attic Insulation. For this high performance home, the attic's insulation value was specified at R-50. Builders achieved this level by using blown cellulose and raised heel trusses, which permit the blowing of insulation all the way to the eaves, providing excellent coverage of the top plate. This measure is expected to result in a savings in whole-house energy use of 0.4%. Further, a weather-stripped foam board cover, specified for the attic access, reduced infiltration and improved thermal performance.

An on-site inspection revealed that attic insulation, which should be about 14.5 inches deep at a typical value of R-3.5/inch, was installed in many areas at 13" deep or less – based on the rulers provided along the trusses. This means that some areas are an R-7 to R-10 less that specified, unless this blow is of higher density than typical. The HERS rater said that this kind of variation is typical, and that an average number is taken for the install. Based on the average depth of the insulation, the rater listed the R-value at R-50. Also, inspection revealed that no foam cover or weather stripping had been provided at the attic hatch. The home managed to score 2.5 ACH @ 50 Pa without this and several other air sealing measures − implying that a lower score could have been possible with better follow-through on specified measures. Ultimately, the rater adjusted the blower door infiltration number to 2.0 ACH @ 50 Pa, once these measures had been addressed.

Assessing the Home’s Performance

Short term energy monitoring (STEM) tests can be an effective tool to estimate the heating energy use or thermal performance of homes. The resources, effort, and associated expense of these tests vary greatly. The NYSERDA HPRDC project emphasizes identification of cost-effective means to demonstrate energy conservation measures in homes. The study thus used cost-effective, non-invasive STEM testing methods to measure the effectiveness of these measures.

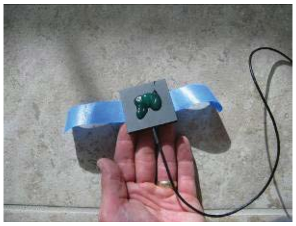
The first STEM test on the Gerber home included four testing points

- Envelope heat flux measurements
- Duct distribution system effectiveness
- Envelope air infiltration
- Infrared imagery

Test Conditions

The Gerber home was completed and sold in July 2008. Because the homeowners planned to move in during July, it was necessary to perform the STEM test during the summer – resulting in less than ideal conditions. Due to weather constraints (for example, high outdoor ambient temperatures), the home was heated to 90 degrees to ensure that a significant temperature gradient, necessary to produce meaningful infrared imagery and heat flux measurements, existed across the envelope. Testers maintained a delta T of at least 20 degrees across the envelope for the STEM test. Wind was negligible.

Envelope Heat Flux Measurements. To compare actual values versus expected values of envelope performance, testers took heat flux measurements at various locations to obtain real-time data on the heat transfer performance of the walls and ceiling. ASTM standards C1046[3] and C1155[4] offer standard practices for this method and were used to guide the measurement and calculation procedures.



Heat flux sensor with conductive paste

Results. In theory, heat flux measurements should be useful in assessing the thermal resistance of the building envelope, but, in this case, test results were highly variable and problematic. Sensors were affected by convective currents and even proximity to radiant heat emitted by technicians. Further, these sensors require steady state, one-dimensional flows of heat, or extended periods of measurements if these flows are not steady-state. Given program constraints and due to the variability of the results, the heat flux sensors were determined to be an inappropriate method for quantifying envelope performance.

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[3] ASTM C 1046-95(2007) Standard Practice for In-Situ Measurement of Heat Flux and Temperature on Building Envelope Components

[4] ASTM C 1155-95(2007) Standard Practice for Determining Thermal Resistance of Building Envelope Components from the In-Situ Data

Duct System Distribution Effectiveness. For the Gerber home, as for each home in the NYSERDA HPRDC project, duct location was restricted to conditioned space only because all leakage occurred within conditioned space, with negligible duct leakage to the outside. To assess the overall performance of the duct system, technicians took pressure differentials between rooms and common areas with doors shut and open to gauge air distribution effectiveness.

DeltaP (Pascals)	Room
1.9	Master Bedroom
0.1	Master Bathroom
0	Bedroom 3
0.1	Powder Room
-0.3	Bedroom 2
0.4	Bath in BDRM 2
0.1	Sun Room
-1.8	Basement

Figure 2-7 – Gerber Pressure Differentials

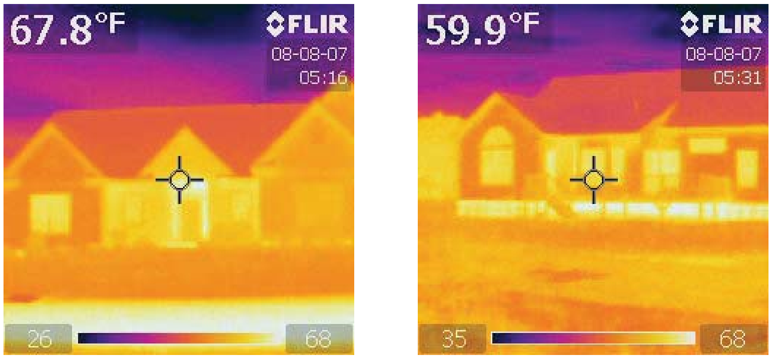
Results. Differences in pressure measurements between rooms and common areas were small, suggesting that the distribution effectiveness was satisfactory. Figure 2-7 shows pressure differentials between individual rooms and the first floor common area (kitchen/living room/dining room). Pressure differentials were measured with the HRV operating.

Blower door test

Envelope Air Infiltration. Tighter homes consume less energy through reduction of unwanted convective heat loss and gain. Technicians conducted a blower door test on the Gerber home to quantify air infiltration (see photo). This value can used to calibrate models of the home to better estimate expected heating and cooling energy use.

Results. Typically, new single family detached construction produces infiltration levels of 5-7 air changes per hour (ACH) at 50 Pascal. With high density spray foam used to seal the above grade walls, band joists, and penetrations, the Gerber Challenge home was expected to perform much better than a standard house. The blower door test subcontracted to a HERS rater, scored an infiltration rate of 2.0 ACH at 50 Pa for the home.

Infrared Thermography. Infrared imagery can help gauge the quality of insulation installation and air sealing of a home. For the infrared imagery to be useful, it is necessary to maintain a significant temperature gradient across the envelope (for example, 20 degrees F or greater). ASTM C 1060[5] provides guidance for producing and interpreting thermal imagery of buildings.



Infrared images of the Gerber home

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[5] ASTM C 1060-90(2003) – Standard Practice for Thermographic Inspection of Insulation Installations in Envelope Cavities of Frame Buildings.

Results. Because the Gerber home STEM test was conducted in July, the thermostat was set to 90 deg, to maintain a delta T of at least 20 degrees across the envelope (see photo). Technicians held the home at this temperature for several hours before taking the thermal images at five a.m. Taking the pictures at night helped reduce the effect of solar gain on the envelope.

The image on the left is of the front of the home, the rear image is on the right. Notice the higher temperatures of the then uninsulated basement wall (insulated the morning after the test). The light color around the front door comes from the sidelites and transom windows. These images reveal as much by what is *not seen* as by what is seen. We do not see framing members in the walls, gaps in insulation, or cold corners. At the time of the STEM test, the basement insulation was not yet complete, so the rear view of the house clearly demonstrates higher temperatures on the foundation wall than on the above grade wall. We can also see warmer temperatures along the top plate of the above grade wall and at windows. Overall, the images reveal no insulation deficiencies in the areas where insulation is complete. There were no occupied homes near the Gerber home that would permit heating to 90 degree F, so there was no control home for comparison.

Utility Bill Analysis

See Section 4 for the results of the utility analysis.

MARRANO HOMES, CHALLENGE HOME #1

Founded in 1956, Marrano Homes/Marc Equity Corporation, headquartered in West Seneca, New York, is a leading homebuilder in western New York. Marrano Homes builds entry level to luxury custom single-family residential homes, townhouses, and patio homes throughout the metropolitan Buffalo area. Under the leadership of Patrick A. Marrano, president, Marrano Homes has seen its sales triple over the past decade.

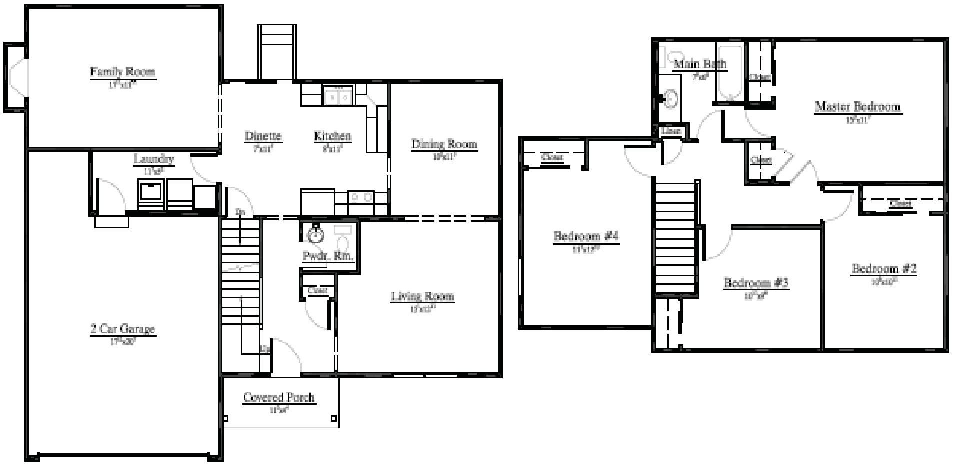
One of the reasons Marrano was selected to participate in the HPRDC was its corporate commitment to building energy efficient homes. Marrano was one of the first builders in western New York to build an ENERGY STAR® home and has been installing ENERGY STAR products in homes since the EPA extended the label to cover categories such as residential heating and cooling equipment and major appliances.

Marrano's Challenge Home #1

As a side note, following Marrano's first high performance home (completed in the fall of 2008), a second high performance Marrano home also became part of this project. This case study refers throughout to Marrano's first home in the program, "Marrano #1" in the text. The case study that follows discusses Maranno's Challenge home #2.

Marrano's Challenge Home #1 – Overview of Efficiency Upgrades

The Marrano Challenge home #1 is located in Lancaster, New York, a suburb of Buffalo, which is located in IECC Climate Zone 5 with 6,799 Heating Degree Days and 3,044 Cooling Degree Hours. The house is laid out according to a traditional two-story colonial floor plan, with about 2,000 sq. ft. of living space, four bedrooms, and an attached two-car garage with living space above (see photo). The basement area is insulated and heated, but not finished. Newport used REM/Rate residential modeling software (Version 12.6) to assess a multitude of design scenarios and technology options. As part of the re-design



Marrano Challenge #1: first and second floor plans process, the project team also examined incremental costs, work sequencing impacts, installation issues, code/regulatory issues, and the compatibility of various building technologies. As an ENERGY STAR home builder, Marrano's typical home has a HERS Score[6] of roughly 86.6, while the Marrano Challenge home #1 achieved a HERS Score of 92.4.

Figure 2-8 details the building shell and system changes made to Marrano's typical home to create the Challenge home. The last column, titled 'Duplication Costs to Builder,' quantifies the builder's costs associated with these changes if they were to replicate the changes on additional homes. On the actual test home, some upgrade costs were reduced due to manufacturer and supplier discounts. It should also be noted that 'Duplication Costs' reflect the marginal cost increase relative to the baseline practice or system.

Building System / Component	Marrano's Typical Home	Marrano's Challenge Home #1	Duplication Cost (Marginal) to Builder ($)
Below Grade Walls	R-11 full height blanket insulation	R-26 full height blanket insulation	$778
Above Grade Walls & Rim/Band Joists	2x4 framing @ 16" on-center R-13 fiberglass (FG) batts in wall cavity R-13 FG batts in rim/band joists	2x6 @ 16" on-center R-21 FG batts in wall cavity + R-9.8 exterior polyisocyanurate foam insulation board (1.5" thick) Expanding spray foam insulation on rim/band joists	$8,792
Ceiling/Attic Insulation	R-38 FG batts	R-50 blown cellulose	$178
Garage Ceiling/ Bedroom-4 Floor	R-26 FG batts	R-30 FG batts + critical air seal with spray foam	Cost included in the $178 for Ceiling/Attic Insulation
Windows	U = 0.32; SHGC = 0.34 almost all double hung	U = 0.27 SHGC = 0.21 almost all double hung	$1,003
Shell Tightness	3.5 air changes per hour at 50 Pascals (ACH50)	Target: 1.5 ACH50 As Tested: 1.8 ACH50	$1,962 (includes mechanical ventilation)
Mechanical Ventilation	Exhaust fan at 110 CFM for 15 hours per day; 38 Watts	Heat Recovery Ventilator (HRV) @ 67 CFM continuous with 75% Sensible Recovery Efficiency; 54 Watts	Costs included in the $1,962 for Mechanical Ventilation

Figure 2-8 – Marrano #1. Efficiency Upgrade Measures Relative to Typical Practice

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[6] New York State uses the "HERS Score" rating system, while many other parts of the U.S. have adopted the "HERS Index" system to rate a home's energy performance. Both systems are based on industry standards. With the HERS Score, the "Reference Home" is scored at 80, and every point above 80 represents a 5% improvement in energy efficiency beyond a basic code compliant home. A HERS Index is scaled from 100 (reference home) to 0 (net-zero energy home). To convert, use HERS Index = 100 – ((HERS Score – 80)*5)

Duct Leakage	80 CFM leakage to outdoors at 25 Pascals (CFM25) Multiple returns with panned building cavities for return ducts	0 CFM25 leakage to outdoors - all ducts in conditioned space Central, hard-ducted returns with jump ducts in bedrooms	$300
Space Heating and Cooling	90 AFUE, 60 kBtu furnace; No air conditioner	95 AFUE, 45 kBtu furnace with sealed combustion; No air conditioner	$975
Domestic Water Heating	Gas-fired 50 gallon tank water heater; 0.62 Efficiency Factor (EF)	Gas-fired tankless WH with 0.95 EF; fiberglass tempering tank upstream of tankless WH	$2,434
Lighting & Appliances	10% fluorescent lighting; ENERGY STAR dishwasher: 0.65 EF Refrigerator @ 775 kWh/year	100% CFL and fluorescent lighting; ENERGY STAR Dishwasher 0.65 EF ENERGY STAR Refrigerator at 474 kWh per year	$1,650
Total Incremental Costs to Builder			$18,072
HERS Score	86.6	92.4	

Figure 2-8 – Marrano #1. Efficiency Upgrade Measures Relative to Typical Practice (continued)

In terms of the home's energy consumption, Figures 2-9 and 2-10 show key performance data based on energy simulations.

Energy Use Component	Marrano's Typical Home (MMBtu/yr)	Marrano's Challenge Home #1 (MMBtu/yr)	% Reduction Relative to Marrano's Typical Home
Heating	74.1	28.1	62%
Water Heating	21.7	14.8	32%
Lighting & Appliances	34.7	30.0	14%
Total	130.6	73.0	44%

Figure 2-9 – Marrano #1. Efficiency Upgrade Measures Relative to Typical Practice

As a comparative metric with other homes, the Marrano Challenge home #1 is projected to consume 24.5 kBtus per square foot per year, or 7.2 kWh per square foot per year. This metric includes the heated and insulated square footage in the basement.

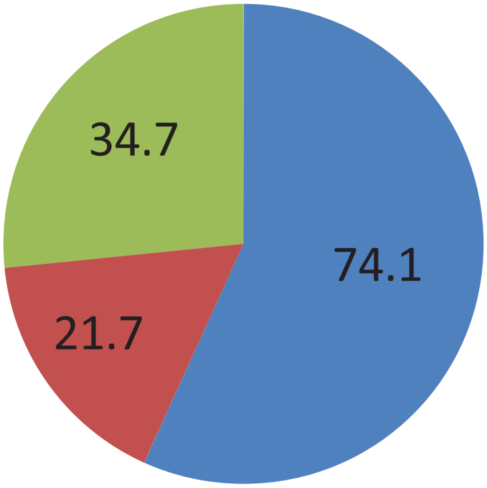


Figure 2-10 – Marrano #1. Energy Use Comparison between Marrano Typical Home and Challenge Home(MMBtus/year)

Below grade walls' moisture membrane before backfill

In the Challenge home, heating energy represents roughly 39% of whole-house energy use, while in the typical Marrano home it represented about 57%. While the relative proportion of heating energy was greatly reduced in the Challenge home, lighting and appliances increased from 27% of total energy in the baseline home to about 41% in the Challenge home.

It should also be noted the Challenge home shows about a 44% reduction in whole-house energy use relative to Marrano's typical home of this same model (see Figure 2-10). At the same time, based on the HERS Score, the Challenge home performs about 62% better than a reference home based on the 2004 IECC. Most of the analysis in this case study focuses on the Marrano Challenge home #1 relative to Marrano's typical home of the same model, taking this as the true reference point for the builder to make decisions about efficiency upgrades to the Marrano product.

Review of Efficiency Upgrades

Beyond their energy and cost impacts, the analysis assessed upgrade measures in terms of their impacts on work sequencing, code/regulatory issues, installation issues, and compatibility with other building systems. The sections that follow discuss notable findings.

Below Grade Walls. Marrano constructed the basement slab and below grade walls of the Challenge home #1 using the company's normal construction process.

For the basement slab, Marrano installed 4" of crushed stone, a vapor barrier, and then the 3.5" thick slab. The builder evaluated below-slab and perimeter insulation, but found it to provide only modest energy benefits compared with the implementation costs.

The basement walls were form-poured and reinforced with rebar. These walls were eight-feet tall and eight-inches thick, with approximately two feet of exposed surface above-grade. The initial insulation recommendation was to install one R-25 insulation blanket with a perforated PSK facing. The final as-built system changed somewhat, with the insulation contractor installing two R-13 blankets on the inside face of the walls. The insulation contractor recommended this change, believing that they could better seal the blanket seams with two R-13 blankets, then with of one thicker blanket.

R-26 blanket insulation installed in basement

During the initial design discussions, the project team evaluated the possibility of insulating basement walls with exterior foam board insulation. While this approach frees interior square footage, which can be used when the basement is finished, it also introduces production complications, including the necessity for vertically matching the basement wall profile (concrete + exterior foam) with the above-grade wall surface, as well as protecting the above-grade portions of the foam. While these production issues could have been dealt with, using an R-25 interior blanket provided significantly better energy savings compared to realistic exterior insulation strategies.

Above Grade Walls. Significant changes were made to the above-grade walls of Marrano's typical home to meet the HRPDC's performance goals. Such modifications are attractive in that they will be permanent upgrades to the building over its entire useful life. The paragraphs that follow discuss details on exterior foam board insulation, windows, cavity and attic insulation, and framing details.

Exterior insulation being installed by the window installation contractor

Exterior Insulation. The home's exterior has 1.5" thick insulating foam board attached to the OSB sheathing panels (see photo). This thickness of Dow's Tuff-R polyisocyanurate foam has an R-value of 9.8. This measure alone improved the insulating value of Marrano's baseline walls by nearly 50%.

Exterior insulation can dramatically improve a home's energy performance. Thermal bridging occurs when thermal energy (hot or cold) travels through lower R-Value materials in an assembly, such as the wall studs in an exterior wall. By taking the path of least resistance, thermal bridging reduces the effectiveness of better-insulated parts of an assembly, such as the insulated wall cavities in an exterior wall. Exterior insulation helps to add insulation to these "short circuits" for thermal conduction by placing a layer of insulation between studs and the outdoors. This measure reduces heat transfer through the studs and improves the overall performance of the building shell.

Besides reducing thermal bridging, the Tuff-R foam boards also served as the home's weather barrier behind the wall cladding. Although the seams of the foam board needed to be taped in order for it to serve as the weather barrier, this measure permitted the builder to avoid the cost and time associated with applying both a building wrap product and exterior insulation.

Exterior insulation with cap nails and seam tape

Construction Issues. The 1.5" thick exterior foam presented two immediate challenges to the builder (1) fastening details and (2) window integration details. Fastening concerns centered on the length of nails needed for attaching the foam to the home's framing and also attaching exterior accessories, such as vent caps, to the foam. Through consultation and reviewing installation details, the project team selected pneumatically driven 2.5" button cap as the foam fastener. The pneumatic nail guns needed to be set at the right pressure to prevent over- and under-driving. The project team also determined to attach the exterior accessories with 3.5" long siding nails, providing approximately 1.5" of nail penetration into the wood framing.

Sealant was applied before setting windows. Note the 2" x 2" board around rough opening perimeter.

Window jambs and installation details were adjusted to accommodate the exterior foam. At the window openings, installers initially cut the foam flush to the rough opening (from inside the house), a step that speeded the installation of the foam board. Then, before installing the windows, the foam was cut back farther from the window rough opening, and a 2" x 2" strip of wood was placed around the opening as a nailing backer for the window.

Once having installed the wood backer strip around the opening perimeter, the first step in flashing the opening was to install the pan flashing component, a two-piece element sized to fit the opening width. Installers used a strip of flashing tape to cover the pan component seam and both jambs; the bottom of the flashing tape strip overlapped the sill pan edge.

Prior to setting a window unit, installers ran a bead of sealant along all sides of the rough opening, sealing all framing gaps to prevent water intrusion or air leakage (see photo). The windows were set into the opening and mounted flush against the sealant (see photo).

On the inside, the window units had two pine wood jamb extensions (one factory installed and one installed by the distributor) to accommodate the wall framing thickness (2" x 6" wood framing + 1.5" of foam). The total jamb extensions were 8 $^{1}/_{16}$" deep. This depth of jamb extension represented an upper limit for these windows, and was a key factor in determining just how much foam could be added to the exterior walls. Earlier in the design process, the project team had considered a 2” exterior foam layer at R-10, but, due to the window jamb extension issue, opted for the 1.5” polyiso foam at R-9.8.

Installers leveled the windows as they nailed them into the rough opening. They did not want to rely on using shims to level the windows, because the deep jamb extensions would make the shims less effective in influencing the window’s position. Once the windows were in place, installers fashioned a series of flashing tape applications on the jambs and head creating a shingle-style detail to channel water over and around the unit.

On the inside of the rough opening, spray-foam was used to fill in gaps around the frame from inside the home. Still, the installer made sure the gap was of an adequate size to accommodate expanding spray-foam, otherwise a caulk product was used to seal potential air leaks.


Window is set flush against the sealant. Note the extended jambs

Windows. The windows installed in the Marrano Challenge home #1 have a U-factor of 0.27 and a Solar Heat Gain Coefficient (SHGC) rating of 0.21. By contrast, these ratings for Marrano’s baseline home window were U = 0.32 and a SHGC = 0.34.

The primary issues concerning the upgraded windows in the high performance home were:

- Integrating the windows with the 2x6 plus 1.5” foam exterior walls;
- Obtaining accurate specifications.


Flashing tape and weather resistant tape

The project team used the above-discussed techniques to integrate the windows with the wall system (see photo). One additional note on this topic concerns the installation of windows and exterior foam. The builder elected to have the window installation contractor handle both the window and foam insulation. This arrangement worked fairly well, as the four-man crew could ensure a clean integration of the windows with the exterior foam insulation.

In terms of window specifications, the National Fenestration Rating Council (NFRC) ratings for U factor and SHGC offered by manufacturers and window distributors are often applicable to a general line of windows (for example, insulated vinyl frame) with a particular type of glass. The specific ratings for a given window (for example, a 3’0” x 5’6” double hung unit) may vary somewhat from these more generalized specifications. While the difference may be fairly small, such as a U factor of 0.27 instead of 0.25, these details become increasingly important as builders and designers continue to prioritize energy upgrades. It is therefore recommended that builders and designers obtain NFRC rating data for the specific window units they are considering for a project.

Cavity Insulation. Marrano framed its Challenge home #1 with wood 2x6s @ 16” on-center, and filled the wall cavities with R-21 fiberglass batts. This practice represented a significant upgrade from the baseline practice of 2x4 framing with R-13 batts.

The rim joist detail in the Challenge home was an area of special focus, as this detail can allow air leakage, thermal conduction, and even wetness/condensation when surface temperatures dip below the indoor dew point. To air seal and insulate this location in the first- and second-floor framing, builders applied 1” of DOW’s Froth Pack polyurethane spray foam (~ R-4.5), along with R-21 batts behind the foam. This detail optimized the use of the spray foam to limit air leakage and relied upon the R-21 batt to provide additional R-value at this point in the envelope.


R-50 (16”) blown cellulose in attic


Isolating the ceiling system of garage from adjacent family room with spray foam

Air Sealing. Builders air-sealed all joints and penetrations in the exterior walls with either caulk or spray foam. The project team targeted air sealing of the envelope as one of the most cost-effective measures for reducing household heating energy use, and placed extra emphasis on these details (see photos). In fact, a diagnostic blower door test was conducted prior to wall close-in (but with ceiling drywall installed so the building could be pressurized) in order to identify and seal remaining leakage sites.

While Marrano’s typical shell tightness is already good, the use of spray foam and close attention to detail – particularly by the insulation contractor who had overall responsibility for air sealing – resulted in a nearly 50% reduction in the shell leakage in this home at 1.8 ACH50.


Spray foam was used at the rim joist detail on both floors (above left) and building shell penetrations (dryer vent – above right), while caulks were used in all top plate penetrations (bottom left). The insulation contractor’s scope of work included air sealing all of these details, so the responsibility for air sealing the shell was clearly defined.

Ceiling and Attic Insulation. Marrano typically uses batt insulation in attics and garage ceilings with an R-value of 38 and 26, respectively. In this house, builders increased insulation values to R-50 in the attic (blown cellulose) and R-30 in the garage ceiling. Additionally, the garage space received extra attention to air-seal it from the adjacent space on the first floor and the bedroom above.

On top of the attic hatch, located in the master closet, are 12” of rigid foam insulation and a 10” thick fiberglass batt, along with weather-stripping along the perimeter of the hatch. This insulation helps prevent warn house air from escaping into the attic.

Framing Details. The Marrano Challenge home #1 is a four-bedroom, two-story rectangular footprint home with an attached garage. A portion of the garage ceiling serves as the floor for one of the second floor bedrooms.

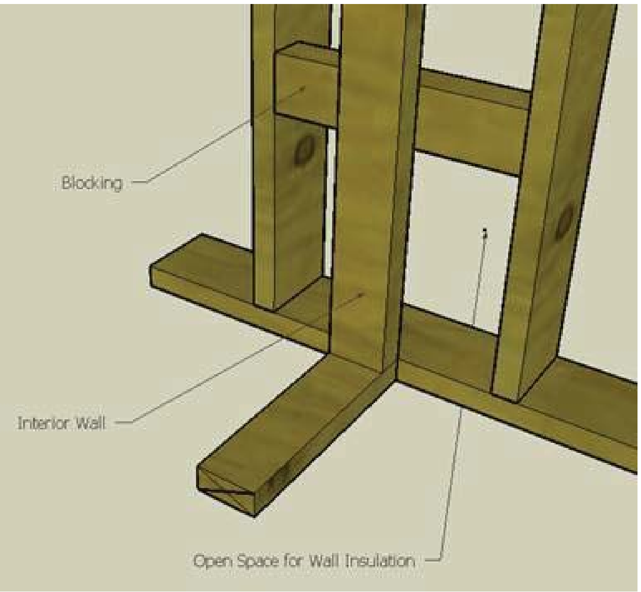
Builders framed the home with wood 2x6 exterior walls, spaced at 16” on-center, sheathing the framing with OSB sheathing panels, covered with 1.5” thick insulative foam that also served as the home’s weather barrier.

For the floor joists (see photo), builders used wood 2x10s, spaced at 16” on-center, insulating rim/band joists with both spray foam and fiberglass batts.

First floor joist system

They framed the roof with 2x8 wood rafters, spaced at 16” on-center and used a wood 2x10 at the ridge line.

In terms of energy-related details, builders used open partition framing at interior wall T-intersections with exterior walls. They used blocking to help secure the T-intersection, and the open space created by this detail then allowed more space in the wall cavity for insulation. While computer simulations for the home do not necessarily capture them, details such as these can contribute significantly to the thermal performance of the building envelope and will increase the home’s energy performance.



Open partition framing at interior/exterior wall T-intersections allows for additional insulation

Mechanical Ventilation. The Marrano Challenge home #1 is located in IECC's Climate Zone 5, with 6,799 heating degree days. This is certainly a heating-dominated climate, as evidenced by the fact that Marrano's baseline home expends almost 57% of the total energy usage on heating. As with many existing and new homes in the region, Marrano Challenge home #1 has no air-conditioning system.

In the effort to identify and implement cost-effective energy upgrades, the building shell underwent extensive air sealing efforts. While sealing is an effective energy-savings measure (especially in a cold climate), it reduces natural air infiltration, necessitating the use of a whole-house mechanical ventilation system to ensure an adequate supply of fresh air to the home. And in fact, the New York ENERGY STAR Homes program carries a requirement for whole-house ventilation with a flow rate based on the square footage and the number of bedrooms.

HRV unit in the basement, which distributes fresh air throughout the house through the central duct system

To provide whole-house ventilation to comply with this requirement, the Challenge home uses a Broan HRV 100 fresh-air ventilation system to continuously introduce outside air into the home. This system is equipped with a heat recovery system to improve energy performance. Before exhausting stale inside air to the outdoors, this air first passes through a cross-flow heat exchanger where it adds heat to incoming fresh air (although the two air streams do not directly mix with each other). Thus, instead of adding fresh air at approximately outdoor temperature, the HRV system warms this air before introducing it to the living space.

Construction Issues. The design layout for the HRV relies on the home's central duct system to both draw in household air and distribute fresh air throughout the house (see photo). An important installation consideration for an HRV is the layout and length of the ducts that feed into it. An ideal layout involves short and direct duct runs. This type of layout presents less resistance to airflow, allowing the HRV to move more air with less fan power. At the other extreme, duct runs that are long and full of elbows and bends, add airflow resistance and constrict airflow. In this home the HRV installation was adequate. Given the location of the HRV unit, the placements of its inlet and outlet ports, and the desire to route the fresh air intake to the side of the house and stale air exhaust to the rear, the ducts for the unit had several elbows. The duct runs were fairly short, but the resistance from these elbows did reduce flow to some extent.

The main recommendation coming out of this experience is to pre-plan the HRV unit's location, keeping in mind the location of the inlet/outlet ports on the unit and the points of fresh air intake and stale air exhaust through the building envelope. In many cases it is necessary for one or two of the ducts to the HRV to incorporate at least one elbow (and possibly a 180 degree turn). To the extent possible, however, all duct runs should be as short as practicable. Attention to these details can also allow operating the unit on a lower fan speed setting, and consume less energy.

Central Duct System. Marrano's typical home uses a central reducing plenum duct system to distribute heated/cooled air throughout the house, with a multiple return system partially constructed with panned building cavities. In a typical floor plan, a few of the supply takeoffs are located in exterior wall cavities.

The Challenge home made two major modifications:

- Constructing the return system of central returns (hard-ducted) with jump ducts to each bedroom (see photo)
- Not locating any supply takeoffs in exterior wall cavities

Builders implemented the change to the return air system to improve the reliability of air distribution, since hard ducted returns will be far less leaky than panned building cavities. While return duct air leakage within the building envelope may not carry the energy penalty associated with duct leakage in unconditioned spaces, such leakage can still create pressure imbalances and affect air flows and comfort within the home.

In making the change to central returns, Marrano actually realized a cost saving relative to a multiple return system by eliminating the labor to pan and seal the building cavities. Since this change was made after finalizing the floor plan, the builder had to alter first-floor framing plans to accommodate a larger return air trunk running vertically through the first level.

Jump duct grilles

Also, the use of 6" round jump ducts to the bedrooms, providing a pathway for return air when bedroom doors are closed, added back some cost. These jump ducts were fairly simple to install, with a short length of insulated duct running from one ceiling grille in the bedroom to another ceiling grille in the hallway, where it could communicate with the central return. Two of the four bedrooms had pressure levels of less than 2- Pascals relative to the hallway with the central blower on and the bedroom door closed, while the other two bedrooms were at pressure levels greater than 3.5-Pascals. The recommendation to the builder is to use a sizing criteria for the jump ducts which would result in 8" ducts for the bedrooms with more supply airflow.

Total duct leakage, in CFM at 25-Pascals duct pressure, was measured at less than 9% of the conditioned floor area.

Space Heating. The heating furnace typically specified by Marrano is a 90 Annual Fuel Utilization Efficiency (AFUE) unit with a 60 kBtu capacity. While this unit is a good baseline furnace, the Challenge home #1 instead used an even higher efficiency unit – a two-stage Rheem 95 AFUE furnace. The two firing rates of this sealed combustion gas furnace are 45 kBtu input (100% of capacity) and 31.5 kBtu input (70% of capacity). In addition to the higher efficiency of this furnace, its operating capacities are much better aligned with the design heating load for the home, which was about 24 kBtu.

As a side note, the furnace capacity in this home highlights a trend in high performance homes in general, where the building envelope is improved to such an extent that the design heating load is greatly reduced. So instead of a design load of 50 kBtus or greater, these homes have design loads of half this amount or even less. It can be a problem, however, to obtain high efficiency centralized heating and cooling systems with capacities in this range.

Tankless hot water heater

Domestic Hot Water. The Marrano Challenge home #1 has a gas-fired Navien tankless water heater with a 0.95 energy factor, along with a Wellmate UT-80 fiberglass tempering tank. This tempering storage tank serves as a reservoir to allow incoming water to pick up a small amount of heat in the basement prior to flowing to the water heater. The underlying concern of the builder was the ability of the tankless system to provide adequate heat gain to hot water, especially in the winter when inlet water temperatures can be around 40 degrees F in Buffalo.

This system was plumbed in a manner that will allow bypassing the tempering tank. In this configuration, inlet water will go directly to the tankless heater. During February 2009 the builder and homeowner were scheduled to reconfigure the system to bypass the tempering tank and then assess if the occupants notice any impacts on hot water delivery.

CFLs

CFLs for Lighting. Marrano Homes installed CFLs or fluorescent lights in all the interior light fixtures in the Challenge home (see photo). The builder reported $158 of additional costs associated with this measure.

During the final inspection, the project team noted that the recessed lights in the kitchen and light fixtures in the basement did not have CFLs. The team informed the builder, who switched the lights before the occupants moved in.

Appliances. An ENERGY STAR qualified refrigerator in the Challenge home will use 474 kWh/year, while the ENERGY STAR dishwasher is expected to use 365 kWh/year and cost $30 annually. The builder’s typical home uses this same dishwasher and a standard refrigerator that consumes about 64% more energy.

Economic Analysis of Efficiency Upgrades

By implementing this package of efficiency upgrade measures as part of new home construction, the homeowner has the advantage of being able to add the incremental cost of the efficiency package to the home mortgage and pay for it slowly over time. The utility bill savings, however, will soon begin accruing to the homeowner and increase over time. Further, as energy rates for electricity or natural gas increase over time, the energy saved by the efficiency measures will result in greater dollar savings to the homeowner.

Given this dynamic of paying for efficiency upgrades and the resultant savings, a monthly cash flow analysis is used to examine the cost-benefit of the efficiency package. This cash flow analysis compares the builder’s typical home of the same model to the high performance home, which will include the added costs for the upgrade measures along with lower monthly energy costs. Figure 2-11 shows the inputs, assumptions, and results of this analysis.

Analysis Component	Value	Comments
Inputs		
Cost of Upgrade Package to Builder	$18,072	Reflects duplication costs of all measures.
Utility Costs	$1.55/therm (NG) $0.11/kWh (electric) Monthly fees: $15	Based on residential rate estimates taken from local utility providers in Buffalo.
Assumptions		
30-year Fixed Mortgage Rate	6.04%	Based on September 2008 (month home was completed) average from Freddie Mac Weekly Primary Mortgage Market Survey.
Utility Cost Escalation	5%	Uniform escalation rate is assumed. Short-term escalation rates, such as from U.S. EIA, were overly volatile.
Term of Analysis	30 years	Aligns with mortgage term. Allowances for equipment replacement or efficiency changes over time not considered.
Results		
Monthly Amortized Cost of Efficiency Package	$108.82	What the efficiency package costs on a monthly basis over the duration of a 30-year fixed mortgage.
Year-1 Monthly Energy Cost Savings	$86.97	
Year-1 Net Monthly Cash Flow	-$22.03	
Monthly Amortized Cost of Efficiency Package	$108.82	
Year-6 Monthly Energy Cost Savings	$110.77	
Year-6 Net Monthly Cash Flow	$1.95	
Monthly Amortized Cost of Efficiency Package	$108.82	
Year-10 Monthly Energy Cost Savings	$134.64	
Year-10 Net Monthly Cash Flow	$25.82	
Total Projected Savings over 30-year Term	$30,019	Includes The net sum of annual cash flows resulting from the added costs for the efficiency package and the added savings.

Figure 2-11 – Marrano #1. Cash Flow Analysis of Efficiency Upgrade Package

According to this cash flow analysis, the homeowner pays a little over $20 per month "extra" in Year-1, after considering a higher monthly mortgage payment (to cover the cost of the upgrades) and a lower monthly energy bill. This out-of-pocket amount diminishes gradually until, in Year-6, the monthly cash flow becomes positive. By the end of a 30 year term, the net total of the monthly cash flows is more than $30,000.

The cost of the upgrade package in this analysis is taken as the builder's cost without a mark-up applied. This approach was used for several reasons. First, builder mark-ups on upgrades can vary from nothing to 50% or higher. Some builders view energy upgrades that do not complicate their production in terms of time or money as added-value opportunities and will apply little or no mark-up. An example of this would be simply passing along the added cost without mark-up of a 95 AFUE furnace compared to a 90 AFUE furnace. These two units are installed in the same manner, and substituting the 95 AFUE furnace does not change the production routine or impact other building systems, therefore no added mark-up would be applied.

At the other end of the spectrum, major changes to the building envelope can introduce scheduling complications and impacts to other building systems, so such items may be applied with a higher mark-up. As a third scenario, some building firms simply apply a uniform mark-up to changes or upgrades without consideration of the nature of the change.

Because of the range of possible mark-up scenarios, the analysis in this case study simply uses the cost of the upgrade package to the builder without mark-up. While this procedure will reduce the cost basis for the upgrade package, it should be noted that the analysis does not account for additional New York State ENERGY STAR Homes rebates ($500 for this house), to be realized as a result of the higher HERS Score. Nor does the analysis account for the fact that the efficiency package allows the house to qualify for the federal energy efficient home tax credit, worth up to $2,000 to the builder. The baseline home of this same model would not qualify for this credit. Depending on the level of mark-up a builder would apply to upgrades, and the applicability of additional incentives and tax credits that come into play as a result of the efficiency upgrades, these factors could increase, decrease, or have no impact on the cost basis for the package. In this example, if the builder mark-up on the package was about 14%, then this mark-up compared to the added incentives and credits would be equal.

Finally, this analysis is sensitive to several inputs – especially the assumed mortgage rate. With the volatile behavior of mortgage rates over the last year, and the current level of rates near historic lows, it is worth exploring this analysis using a more current mortgage rate (as of early 2009). Using all of the same inputs and assumptions, except for a mortgage rate of 5.05% 30-year fixed[7], the homeowners would realize a positive cash flow by Year-4 and a net total cash flow of over $34,000.

This analysis could also incorporate several other factors that could influence the results in either direction. Factors that would delay the positive cash flow point and make the efficiency package seem less effective would include higher property tax valuations and more modest energy cost increases over time. Factors that would increase the effectiveness and payback of the efficiency package include more aggressive energy costs increases (driven by Renewable Portfolio Standards and carbon emissions regulations), as well as preferential loan terms for highly efficient homes.

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[7] Average for January 2009, based on Freddie Mac Weekly Primary Mortgage Market Survey

Finally, beyond the financial results of this analysis it is also essential to recognize that a high performance home will provide better energy performance along with improved comfort for occupants. The measures used in Marrano’s Challenge home will reduce drafts, ensure the steady introduction of fresh air into the home, and provide a quiet and even temperature indoor environment.

Utility Bill Analysis

See Section 4 for the results of the utility analysis.

MARRANO HOMES, CHALLENGE HOME #2

After completing its first high performance home in the fall of 2008 (see photo), Marrano Homes/Marc Equity Corporation also made a second high performance home part of this project. The current case study discusses this second home, referred to as Marrano's Challenge Home #2 or Marrano #2 (see photo).

Marrano's Challenge Home #2 – Overview of Efficiency Upgrades

Marrano's Challenge Home #2

The Marrano #2 home is located in West Seneca, New York, a suburb of Buffalo, a city located in IECC Climate Zone 5 with 6,799 Heating Degree Days and 3,044 Cooling Degree Hours. The house is laid out according to a fairly typical 2-story colonial floor plan, with 2489 ft^2 of living space, 4-bedrooms, and an attached two-car garage with living space above. The basement walls are fully insulated, but the basement is not finished. Newport used REM/Rate residential modeling software (Version 12.6) to assess a multitude of design scenarios and technology options. As part of the re-design process, the project team also examined incremental costs, work sequencing impacts, installation issues, code/regulatory issues, and the compatibility of various building technologies. As an ENERGY STAR home builder, Marrano's typical home has a HERS Score[8] of roughly 86.8, while the Marrano Challenge home #2 achieved a HERS Score of 93.4. This translates to an improvement of roughly 33% over the company's typical home, and 67% over a standard built-to-code home.

Figure 2-12 below details the building shell and system changes made to Marrano's typical home to create Marrano's Challenge home #2. The right hand column titled 'Duplication Costs to Builder' quantifies the builder's costs associated with these changes if they were to replicate the changes on additional homes. On the actual test home some upgrade costs were reduced due to manufacturer and supplier discounts. Such discounts are not reflected in the 'Duplication Cost' column, which reflects the marginal cost increase relative to the baseline practice or system.

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[8] New York State uses the "HERS Score" rating system, while many other parts of the U.S. have adopted the "HERS Index" system to rate a home's energy performance. Both systems are based on industry standards. With the HERS Score, the "Reference Home" is scored at 80, and every point above 80 represents a 5% improvement in energy efficiency beyond a basic code compliant home. A HERS Index is scaled from 100 (reference home) to 0 (net-zero energy home). To convert, use HERS Index = 100 – ((HERS Score – 80)*5)

Building System / Component	Marrano's Typical Home	Marrano's Challenge Home #2	Duplication Cost to Builder (marginal)
Below Grade Walls	R-11 full height blanket insulation	R-25 full height blanket insulation with FSK foil paper	$690.00
Above Grade Walls & Rim/Band Joists	2x4 framing @ 16" on-center; R-13 fiberglass (FG) batts in wall cavity R-13 FG batts in rim/band joists	2x6 @ 16" on-center ½" of spray foam (R-3), with R-21 FG batt (flash & batt) 1" spray foam insulation with R-21 FG batt on the rim/band joists Insulated Vinyl Siding	$9,239.00
Attic Insulation	R-38 FG batts	R-19 batt with R-31 blown cellulose	$666.00
Garage Ceiling/ Bedroom # 4 Floor Under Dinette Window/Sliding Door Bump Out	R-26 FG batts	R-30 FG batts plus critical air seal with 1" of spray foam 4" of Guardian ATS foam + R-13 FG batt	$324.00
Mechanical Ventilation	Exhaust fan at 110 CFM for 16 hours per day; 38 Watts	Broan SmartSense @ 80 CFM, 24/7 operation; 35 Watts w/ make-up air damper	$636.00
Duct Leakage	80 CFM Leakage to Outdoors at 25 Pascals (CFM25) Multiple returns with panned building cavities for return ducts	0 CFM25 leakage to outdoors ; all ducts in conditioned space Mostly central, hard-ducted returns with jump ducts in bedrooms	$475.00

Figure 2-12 – Marrano #2. Efficiency Upgrade Measures Relative to Typical Practice

Space Heating and Cooling	90 AFUE, 60 kBtu furnace; 13 SEER, 3 Ton	95 AFUE, 45 kBtu furnace with sealed combustion; AC, 14 SEER, 2 Ton AirScape 1.7 Whole House Fan,1700 CFM	$2,191
Domestic Water Heating	Gas-fired 50 gallon tank water heater; 0.62 Efficiency Factor (EF)	Gas-fired tankless WH with 0.95 EF	$1,257.00
Lighting	10% fluorescent lighting	100% CFL and fluorescent lighting	$158.00
Appliances	ENERGY STAR dishwasher: 0.65 EF Refrigerator @ 775 kWh/year	ENERGY STAR Dishwasher 0.65 EF ENERGY STAR Refrigerator @ 451 kWh per/year	$1,450.00
Photovoltaics	None	3KW PV Solar System	$5,963.00
Total Incremental Costs to Builder			$23,049
HERS Score	86.8	93.4	

Figure 2-12 – Marrano #2. Efficiency Upgrade Measures Relative to Typical Practice (continued)

In terms of the home’s energy consumption, Figures 2-13 and 2-14 show key performance data based on energy simulations.

Energy Use Component	Marrano's Typical Home (MMBtu/yr)	Marrano's Challenge Home #2 (MMBtu/yr)	% Reduction Relative to Marrano's Typical Home
Heating	83.4	50.7	39%
Cooling	3.4	1.6	53%
Water Heating	21.5	14.8	31%
Lighting & Appliances	41.0	22.0[9]	46%
Total	149.3	89.1	40%

Figure 2-13 – Marrano #2. Summary of Efficiency Upgrade Measures relative to Typical Practice

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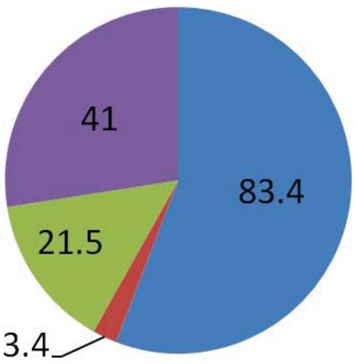
[9] The actual modeled number was 33.5 MMBtu/yr for the Challenge Home’s lights and appliances prior to the reduction of 11.5 MMBtu/yr provided by the home’s photovoltaic system.

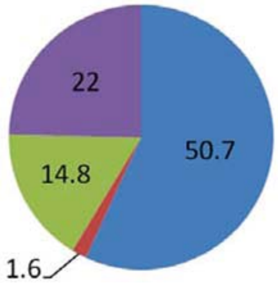
Figure 2-14 – Marrano #2. Energy Use Comparison

Between Marrano's Typical Home and Challenge Home (MMBtus/year)

- 🟦 Heating
- 🟥 Cooling
- 🟩 Water Heating
- 🟪 Lighting & Appliances



Typical Home: 149.3 MMBtus/Year



Challenge Home: 89.1 MMBtus/Year

Figure 2-14 shows a 40% reduction in the Challenge home’s whole-house energy use relative to Marrano’s typical home of this same model. At the same time, based on the HERS Score, the Marrano Challenge home #2 performs about 55% better than a reference home based on the 2004 IECC. Most of the analysis in this case study focuses on the Challenge home relative to Marrano’s typical home of the same model, taking this as the true reference point for the builder to make decisions about efficiency upgrades to the product.

Energy modeling results of Marrano’s typical ENERGY STAR home project a need for 83.4 MMBtu of energy to heat the home over the course of a typical year. After implementing the energy efficient measures listed above, the home is projected to use 50.7 MMBtu of energy for the same task. These measures should result in a 39% decrease in energy used to heat the home compared to Marrano’s typical home.

On the cooling side, the just described measures are expected to reduce the energy needed to cool the home by 53% compared to the typical Marrano home. Projections state that, in total, Marrano’s typical ENERGY STAR home will use roughly 149.3 MMBtu per year to operate, while the Challenge home is expected to use approximately 89.1 MMBtu over the same time period. This comparison reveals a total energy use reduction of 40%. Contributing to this reduction are the Photovoltaic panels that reduced the overall electrical load of the Marrano Challenge home #2 by 35%, an impressive 47% reduction from the baseline home.

Review of Efficiency Upgrades

Beyond their energy and cost impacts, the analysis assessed upgrade measures in terms of their impacts on work sequencing, code/regulatory issues, installation issues, and compatibility with other building systems. The sections that follow discuss notable findings.

Below Grade Walls. The builder constructed the basement slab and below grade walls of the Marrano #2, using the company's normal construction process. For the basement slab, Marrano installed 4" of crushed stone, a vapor barrier, and then the 3.5" thick slab. The builder evaluated using below-slab and perimeter insulation, but found that these items would have provided only modest energy benefits compared with the implementation costs.

Basement Walls: R-25 fiberglass insulation blanket with perforated FSK facing

The basement walls are poured in place concrete and reinforced with rebar (see photos). The walls are 8' tall and 8" thick, with approximately 2' of exposed surface above-grade. The interior of the concrete walls were insulated with an R-25 fiberglass insulation blanket with perforated FSK facing. Builders installed the insulation from the sill plate down to the concrete slab. They installed the mechanical systems such as the tankless water heater, power inverter for the solar panels, and the fuse panel away from the foundation wall, in order to allow for a continuous blanket of insulation behind the equipment.

Above Grade Walls. For exterior insulation, builders first covered the exterior of the home with a weather barrier home wrap, in order to stop air infiltration and the elements from entering the sheathing and wall cavities of the exterior wall. The product is a polyolefin based wrap that allows the home to dissipate moisture from beneath the wrap to the outside. The reduction of air infiltration improves the home's energy performance and comfort level.

Next, builders added insulated vinyl siding to the exterior of the home (see photo). The insulated vinyl siding product came with the foam insulation already integrated to the back side of the profile. This product feature reduces the installation time compared with a typical two-part installation method. The continuous insulation on the back side of the vinyl improves the overall performance of the walls by adding to R-value of the walls' cavity insulation.

Insulated Vinyl Siding

Windows. The windows installed in the Marrano Challenge home #2 have a U-factor of 0.32 and a SHGC rating of 0.34 (see photo). These ratings match with what Marrano typically installs in a number of its homes. Multiple window configurations were modeled showing minimal gains to the overall performance of the house. The project team determined that better performing windows could not be justified because of the higher cost involved.

The performance of the windows, however, exceeds the minimum requirement set by ENERGY STAR. The minimum requirement is a U-factor of .35 in western New York. It is useful for builders to visually inspect the NFRC sticker on each window before installing them, to verify that the numbers match with specifications.


Windows


Exterior walls – "flash and batt" method

Cavity Insulation. Marrano's Challenge home #2 was framed with wood 2x6s @ 16" on-center. The wall cavities were filled using a "flash and batt" method. This practice represented a significant upgrade from the baseline practice of 2x4 framing with R-13 batts. Builders first sprayed the above grade exterior walls with ½" of foam and then placed an R-21 fiberglass batt into the wall cavity. These two components combined to increase the total wall cavity insulation above an R-21.

They then added ½" of spray foam to create an air barrier that prevents air leaks, but saves the cost of filling the whole cavity with foam. This approach also prevents the movement of moisture through the wall. The decision to use fiberglass the rest of the way was simply a cost savings measure, with the fiberglass providing its maximum efficiency due to the air sealing properties of foam.

Air Sealing. All joints and penetrations in the exterior walls were air-sealed with either caulk or spray foam (see photo). The project team targeted air sealing of the envelope as one of the most cost-effective measures for reducing heating energy use in the home, so extra emphasis was placed on these details.

While Marrano's typical shell tightness is already good, the use of spray foam and close attention to detail – particularly by the insulation contractor who had overall responsibility for air sealing – resulted in a 44% reduction in the shell leakage in this home at 1.97 ACH50.


Overhang sealed with spray foam

Ceiling and Attic Insulation. Marrano typically uses batt insulation in attics and garage ceilings with R-values of 38 and 26, respectively. In this house, insulation values were increased to R-50 in the attic (R-31 blown cellulose with an R-19 fiberglass batt) and R-30 in the garage ceiling. In addition to the R-30, the garage ceiling also received a 1" application of spray foam to better separate the two spaces.

The attic hatch, located in the master closet, had foam board stacked and glued together to match the R-50 rating desired for the entire attic space. Weather-stripping was also added along the perimeter of the hatch. These two steps help prevent warm house air from escaping into the attic or cold winter-time air from blowing in.


95% AFUE furnace

Mechanical Ventilation. Energy efficient homes with extensive air sealing need ventilation systems to ensure the maintenance of adequate indoor air quality. Options for residential mechanical ventilation include heat and energy recovery ventilators (HRVs and ERVs), central-fan integrated systems, and exhaust. HRVs and ERVs are known for their ability to efficiently exchange air without producing pressure imbalances across the envelope. These systems, however, come with a large first cost premium. Exhaust-based ventilation can provide economic, energy efficient ventilation, but can create pressure imbalances across the envelope if not coupled with a fresh air intake vent.

The whole house mechanical ventilation system installed in the Marrano Challenge home #2 consisted of four Broan SmartSense bathroom fans. The four fans operate at separate times to achieve the required amount of ventilation in the home throughout a 24 hour period. When the fans are actively venting, a make-up air damper located on the return plenum of the home's duct work automatically opens to allow fresh outside air to come in. This approach allows for a controlled measure of air to replace the air removed during ventilation. This system is used in place of an HRV or ERV to keep costs low.

Space Heating. The Marrano Challenge home #2 uses a high-efficiency forced air furnace. The two-stage unit is labeled as 90 plus, but is rated at 95% AFUE furnace. The two firing rates of this sealed combustion gas furnace are 45 kBtu input (100% of capacity) and 31.5 kBtu input (70% of capacity). In addition to the higher efficiency of this furnace, its operating capacities are much better aligned with the design heating load for the home, which was modeled at 29.1 kBtu. The home's original baseline called for a furnace that burned at 105 kBtus.


AC unit

Space Cooling. Marrano #2 has two cooling options in place. The first is a whole house fan. The AirScape 1.7 WHF was specified to reduce the need of using a whole house air conditioner to cool the home. Homeowners can use the whole house fan to create a comfortable breeze in the home and remove hot air without using energy to run the air conditioner. The convection-based cooling system of the whole house fan uses less energy than the traditional vapor compression cycle of an air conditioning unit, providing an attractive option for saving.

The AirScape unit, installed in the attic above the second floor hallway, uses a wireless remote control to operate. An optional 2-speed wall switch was not used in this home. The whole-house fan draws 140 watts and 1700 CFM on high speed and operates at 82 watts and 1000 CFM on low speed. This low power draw and high flow rate result in an excellent overall efficacy of 12.1 CFM/Watt. The insulated doors operate automatically and seal against a gasket to prevent any leakage from conditioned to unconditioned spaces.

The energy modeling showed a HERS score improvement of 0.4 when implementing a whole house fan, making this one of the most cost-effective ways to introduce alternative cooling methods for a home while also reducing electricity usage.

The second system installed was central air conditioning. Modeling for the baseline home called for a 13 SEER, 3-ton unit. Taking into account the improvements made to the home's envelope and the sealed duct work, the builders installed a 14 SEER, 2-ton unit. This simple change, along with the whole-house fan, accounted for a 53% reduction in cooling loads for the home. The air conditioning is most energy efficient when temperatures are the highest during the daytime, but at night the whole house fan can take its place, saving energy.

Domestic Hot Water. Standard gas-fired hot water storage tanks produce inefficiencies associated with heating a volume of water and maintaining it at a constant temperature until use. Tankless water heaters, which heat water only as it is used, eliminate these standby heat losses. The design team selected the Navien 240 tankless water heater to decrease energy consumption and water costs.

This 95% efficient unit is expected to reduce the home's water heating annual consumption by almost 31%, saving approximately $100 off of the annual natural gas bills compared with Marrano's typical ENERGY STAR home. The tankless water heater will need to perform well. since winter time inlet water temperatures can be down around 40^{o} F. This one change is predicted to reduce the annual gas consumption by 6.7 MMBtu/yr.

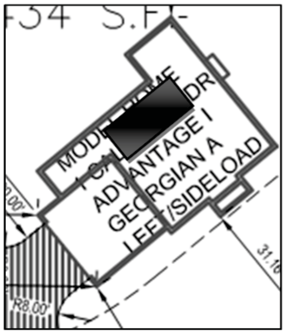
Tankless water heater

Ceiling fan with CFL bulbs

CFLs for Lighting. Marrano Homes switched from incandescent to fluorescent lights in a cost-effective move for saving energy (see photo). The Marrano Challenge home #2 uses only CFLs. This simple change reduces the home's modeled lighting consumption from 3385 kWh/yr to 1409 kWh/yr, changing the annual energy cost for lighting the home from $508 on the baseline home to $211. The change to fluorescent helps to substantially reduce the home's electrical consumption, and is one of the most cost-effective energy efficiency upgrades.

Appliances. An ENERGY STAR qualified refrigerator in the Marrano Challenge home #2 (see photo) will use 451 kWh/year, while the ENERGY STAR dishwasher is expected to use 330 kWh/year. The total cost for operating these two appliances for the year should be about $86. It was a requirement that the model home use ENERGY STAR appliances.

ENERGY STAR Refrigerator



Photovoltaics. The Marrano Challenge home #2 received a 3KW PV Solar System located on the southwest rooftop of the project home, determined to be the most suitable place for maximizing the efficiency of the system. The system does not have battery backup for storage capability, but it is integrated into the home and provides Net Metering.

This system received the maximum reimbursement allowed for a new residential home, and so cost the builder only $1,500 out of pocket. The PV system as modeled shows a reduction 11.5 MMBtu/yr in annual consumption. This in turn has the potential to save the homeowners $504 in annual energy cost the very first year.

Solar panels

The system includes 187 ft^2 of panels, facing southwest, installed on the back side of the roof. Peak power is expected to reach 2,940 watts, which is accessible through a 95% efficient inverter.

Economic Analysis of Efficiency Upgrades. A major component of the NYSERDA Challenge is demonstration of cost-effective solutions toward 60% savings. In keeping with this goal, Newport Ventures conducted an economic analysis to evaluate the first and operational costs that were experienced and expected by both the builder and future homeowner. Currently, builders are heavily incentivized in New York State to build energy efficient homes. Between the Federal Energy Tax Credit and the New York ENERGY STAR Homes program, builders are eligible to receive between $2,750 and $5,000 for constructing a very high performance home.

The current analysis assumes that the significant financial incentives available to builders are passed on to the homeowner at the builder's cost. The replication cost of the energy efficient measures for the Marrano Challenge home #2, was $17,124[10]. The analysis rolls this incremental cost into the mortgage of the future homeowner, who, it is assumed, finances the home using a conventional, conforming 30-year fixed-rate mortgage with an interest rate of 4.86% (the average monthly rate at the home's completion in May 2009).

If the homeowner finances the energy efficient upgrades in this manner, the most relevant indicator of affordability is the net monthly expense of the amortized energy efficient measures after accounting for utility savings. Whole building energy simulations were conducted using REM/Rate software to estimate the energy use of Marrano's second reference home and Marrano's #2 Challenge home. Based on these simulations, analysts projected the Marrano Challenge home #2 to use 89.1 MMBtu of energy per year (or 24.3 kBtu/conditioned square foot). They

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[10] The price of $17,124 does not include the cost of the Photovoltaic's mentioned in Figure 2-12.

projected Marrano's #2 reference home to use roughly 149.3 MMBtu of energy per year (or 40.7 kBtu/conditioned square foot). Referencing local utility rates, analysts valued electricity savings of the Challenge #2 home at $0.11/kWh, and natural gas savings at $1.55/therm. A 4% annual appreciation rate was assumed for electric and natural gas utility rates .

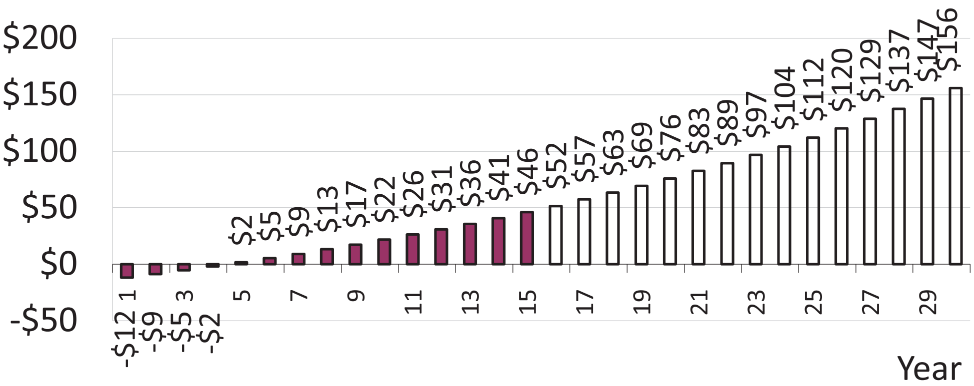

Figure 2-15 – Marrano #2. Projected Net Monthly Savings due to Energy Efficiency Measures

Based on these assumptions, a monthly cash flow analysis was used to examine the cost-benefit of the efficiency package. Once amortized over a 30-year loan at 4.86%, the monthly cost of the $17,124 energy efficiency package is $90.47. As annual utility rates continue to increase (assume 4% per year) and the amortized cost of the energy efficient package remains fixed, the net savings continue to increase. By year-10, the average net monthly savings are projected to be $22. By year-20, the average net monthly savings are projected to be $76, and by year-30, they are expected to reach $156. In total, over a 30-year mortgage, the cumulative net savings are expected to reach $19,540.

The photovoltaics installed in the home are expected to reduce the home's electric load by 3359 kWh/yr, creating even greater homeowner savings on the home's improvements. Also benefitting the homeowner is the net metering law in place in New York State, which credits the homeowner for excess electricity sent out to the grid on the following month's bill. The homeowner may claim a maximum of $5,000.00 in tax credits.

Utility Bill Analysis

See Section 4 for the results of the utility analysis.

ROSEWOOD HOME BUILDERS

For three generations, Rosewood Home Builders has been creating homes in New York's Capital Region. The company's President, Richard G. Rosetti, learned about home construction and the pride of craftsmanship at an early age, while working under the direction of both his grandfather and father.

The company's main office and 4,000 square foot design center are located in Latham, New York. Home designs include ranch and colonial. Rosewood Home Builders was selected to participate in the HPRDC because of its high sales volume and desire to learn more about providing an ultra-energy efficient home in a cost-effective manner. Ultimately, the Rosewood Challenge home will provide a better understanding of the most effective energy efficiency measures to deploy in high-performance New York homes.

This energy efficient, innovative home has pursued a Silver rating under the U.S. Green Building Council's LEED for Homes program. The home was also featured in Albany's *Business Review Journal* October 17, 2008 and appeared on a broadcast of the local CBS affiliate in Albany, New York.

The Challenge Home

Rosewood's typical ENERGY STAR home package includes wood wall studs at 16" on-center, attic trusses at 24" on-center, R-19 fiberglass batt insulation in wall cavities, R-30 fiberglass insulation in the attic, and an AFUE 90 furnace. Builders commonly hang four feet of R-11 FSK-faced fiberglass blankets on basement walls, and ENERGY STAR exhaust fans on timers supply mechanical ventilation. Rosewood's typical ENERGY STAR home has a HERS Score of 86.0[11].

Newport Ventures used REM/Rate residential modeling software (Version 12.6) to assess a multitude of design scenarios and options, with the project team simultaneously examining incremental costs, work sequencing impacts, code/regulatory issues, and the compatibility of various building technologies.

Rosewood's High Performance Challenge Home received a 91.8 HERS score.

Rosewood's HPRDC Challenge home was designed as a four bedroom, two-story single-family colonial home located in the Archmont Knolls development of North Colonie, New York. Termed the "Lexington," the Rosewood Challenge home has 2,446 square feet of finished space and 1,225 square feet of unfinished but conditioned basement.

Figure 2-16 details the building shell and system changes made to Rosewood's typical home to create the Challenge home. The last column titled 'Duplication Costs to Builder' quantifies the builder's costs associated with these

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[11] New York State uses the "HERS Score" rating system based on industry standards. Under this system, the "Reference Home" is scored at 80, and every point above 80 represents a 5% improvement in energy efficiency beyond a basic code compliant home. A "HERS Index" is equal to 100 – ((HERS Score – 80)*5)

changes if they were to replicate the changes on additional homes. It should also be noted that 'Duplication Costs' reflect the marginal cost increase relative to the baseline practice or system.

Building System / Component	Rosewood's Typical Home	Rosewood's Design Home	Duplication Costs to Builder (Marginal)
Ceiling Insulation	R-30 Fiberglass batts	R-50 Blown cellulose	$750
Above Grade Walls	Wood 2x6, 16 inches on-center, R-19 Fiberglass batt	Wood 2x6, 16 inches on-center R-21 Fiberglass batt, 1.5" R-9.8, continuous exterior foam insulation	$8237
Below Grade Walls	R-11 Fiberglass blanket draped 4'	R-30 Full-height fiberglass blanket	$1,663
Air Sealing	Code minimums	Foam jambs, caulk light fixtures, foam insulators	$1,230
Domestic Water Heating	50 gallon tank, 62% EF, natural gas-fired	Navien 240: Tankless,95% EF, Condensing, natural gas-fired	$607
Heating & Cooling	90 AFUE gas furnace, 13 SEER AC	Primary: Air Source Heat Pump at 9.0 HSPF and 14 SEER Secondary: 95 AFUE gas furnace	$1,000– furnace $1,450 – air source heat pump
Whole House Fan	Natural ventilation only	Whole House Ventilation Fan	$1,569
Mechanical Ventilation	Standard bath fans	Broan SmartSense System with fresh air vent	$551
Lighting	10% fluorescents	100% fluorescents	$300
Total Costs			$17,357
HERS Score	84.6	91.8	
Annual Energy Use (MMBtu)	158.8	75.6	

Figure 2-16 – Rosewood. Efficiency Upgrade Measures Relative to Typical Practice

Energy modeling results of Rosewood's typical ENERGY STAR home show a heating energy use of 89.8 MMBtu over the course of one year. Analysts project that, after implementing the energy efficient measures listed earlier, the home will use a total of 24.2 MMBtu for heat over the course of a year. Combined, the above measures should result in a 73% decrease in energy used to heat the home compared to Rosewood's typical home. Analysts expect that the measures described earlier will reduce the home's annual cooling energy use by 38%, compared with the typical Rosewood home.

Energy Consumption Component	Rosewood's Typical Home (MMBtu/yr)	Rosewood's Challenge (MMBtu/yr)	% Reduction
Heating	89.8	24.2	74%
Cooling	4	2.5	42%
Water Heating	23.3	14.8	36%
Lighting & Appliances	41.6	34.1	16%
Total Energy Use	158.8	75.6	52%

Figure 2-17 – Rosewood. Efficiency Upgrade Measures Relative to Typical Practice

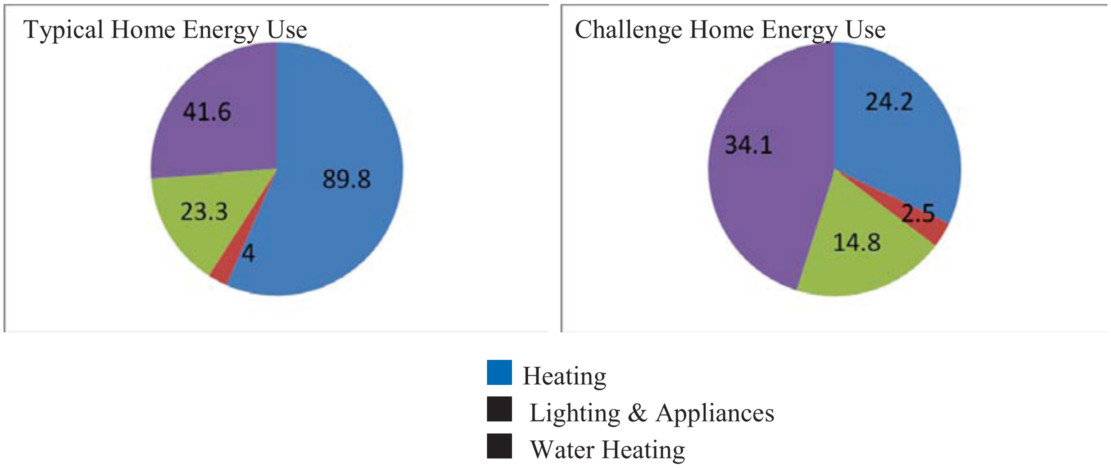


Figure 2-18 – Rosewood. Energy Use Comparison

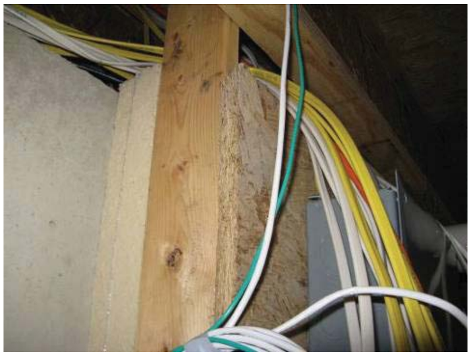
In terms of the whole house energy consumption, Figure 2-17 shows key performance data derived from energy simulations. In total, Rosewood's typical home is expected to use roughly 158.8 MMBtu per year to operate (43 kBtu/conditioned sq. ft.), while the Challenge home should use approximately 75.6 MMBtu (21 kBtu/conditioned sq. ft.) over the same period, resulting in a whole house energy use reduction of 52%. Utility bill data, which is being tracked over the home's first year of occupancy, will be used to refine these projections. Figure 2-18 compares energy use in the Rosewood Challenge home and the reference home.

Basement Walls. Most new homes in New York State have unfinished basements, which builders tend to treat as storage space, installing a handful of air vents to provide a low level of comfort and air exchanges. Yet, after a home has been occupied, the basement usually transforms into a work room, play area, or recreation room, becoming livable space.

Most energy modeling software programs, however, only offer two options for categorizing rooms within a home: conditioned or unconditioned space. In this project, Newport Ventures classified the basement as conditioned space when conducting energy modeling, reflecting the fact that, over time, most basements eventually become finished space. This modeling assumption revealed the need to take measures to improve the energy efficiency of the basement. Further influencing the decision to improve the basement's insulation is that a typical new New York State home's standard basement wall system accounts for approximately 20-30% of the home's heat loss (assuming the basement is conditioned space).

The Challenge home replaced Rosewood's traditional R-11 fiberglass 4' blankets with R-30 FSK-faced, perforated full-length blankets (see photos). The full-length blankets cover the entire basement wall while the 4' blankets leave the bottom portion of the basement wall exposed and un-insulated. This measure cost about $1,663 more than installing the 4' blankets.

In cold climate areas, builders often place vapor retarders toward the heated or conditioned side of the wall. This is done to reduce water vapor penetration into the wall from the building interior. The facing also acts as a fire retarder as required by local building codes. The perforated blanket allows any moisture in the foundation out to dry to the interior of the basement. Permitting the blanket to remain dry is beneficial to thermal performance.



Insulation foam board behind the electrical panel.

Full length blanket insulation with spray foam and fiberglass batted rim joist in the basement.

Installers insulated the rim joists by first applying 1-2" of SPF to provide air sealing benefits and then stuffing fiberglass batts on the interior of the SPF to provide a total insulation value of R-21. SPF helps create a tightly sealed building envelope by filling in small gaps in the wood framing. SPF can also easily reach the tight corners of the rim joists without much effort on the part of the installer.

Sometimes mechanical components and electrical panels are attached directly to the basement wall, which can create a break in the insulation. The Rosewood Challenge home attached four layers of Dow's Tuff-R rigid foam board to the basement wall where the insulation blanket would otherwise be interrupted. This strategy was used for the electrical panel, where the wood framing was built on top of 6" of insulation foam board.

Construction Issues

In the Capital Region of New York, as explained earlier, builders typically insulate basements with 4' long insulation blankets draped from the sill plate at the top of the basement wall. The larger, full-length fiberglass blankets required two people to install; some additional preplanning was needed since the builder and construction crew do not regularly use full-length blankets. Installers first stapled the insulation blankets to 1"x2" wood strips, screwing the strips into the first floor joists. At the bottom of the wall they tucked the insulation into a steel track and then taped the entire perimeter of each blanket to create a clean, finished look.

Spray foam in rim joists that shrank instead of expanding

Replacement spray foam that has properly expanded

One issue that arose was the application of spray foam to the rim joist (see photos). Throughout the entire basement, the foam shrank and peeled away from the framing instead of expanding and filling the rim joists. The contractor attributed the shrinking to a clog in the supply line of the applicator that prevented the two part mixture from mixing. A consultation with a distributor provided more guidance as to why this may have occurred. The distributor stated that call-backs for spray foam can be very common beginning in fall and lasting through the winter. Two-part SPF is very sensitive to the temperature at which it is applied, and the distributor recommend that their tanks be maintained at 85 degrees F. The SPF should still mix and flow down to 70 or 65 degrees F, but, beyond this, the yield of the two-part mix will fall off very quickly. Expected issues below this temperature include inability for the foam to flow from the nozzle, or inability for the foam to expand or adhere correctly. The contractor had to completely remove the "bad batch" to allow for a 100% adherence of a properly mixed second batch.

Exterior insulation and weather barrier tape

Above Grade Walls. Modeled heat loss through the above grade walls accounted for nearly 24% of the heating energy consumption of Rosewood's typical ENERGY STAR home. In comparison, heat loss through the ceiling accounts for just 9% of total heating energy consumption. One of the most cost-effective methods of improving the above grade wall's thermal performance would have been transitioning from traditional 16” on-center stud spacing to 19.2” or 24” on-center stud spacing and optimizing framing plans by lining up doors and windows with sheathing material sizes. Additionally, builders can further reduce the amount of framing material used by employing ladder blocking and two-stud corners. Besides reducing material usage and costs, wider spaced studs allow for more insulation in the wall cavity. Rosewood, however, elected to stay with 16” on-center studs based on the framing crew’s preference with this spacing as well as concern that consumer perception would categorize 24” on-center framing as inferior construction.


Wall cavity insulation
and sealant

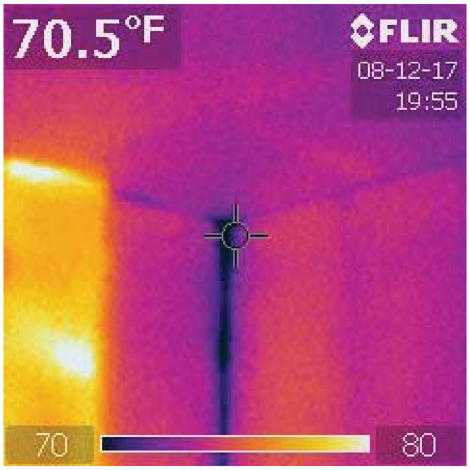
To improve the thermal performance of the above grade walls, the Rosewood Challenge home employs both cavity and continuous exterior insulation on these walls. Newport Ventures recommended exterior insulation because it can both improve a home’s insulation value and help create a tighter building shell. The exterior insulation consisted of 1.5” of Dow’s Tuff-R, with a total exterior insulation R-value of 9.8 (see photo). Builders installed the exterior insulation between the OSB structural sheathing and vinyl siding. They taped all the seams with a code compliant tape, which allows the insulation to serve double duty as a weather barrier; therefore, the home did not require a traditional house wrap. Similar to the basement, builders first applied low density expanding spray along the above grade band joists to provide a critical seal. After curing, they stuffed fiberglass batts in the band joists to provide a total R-value of 21. The wall cavities were filled with R-21 fiberglass batts to achieve a whole wall R-value of 28.6, once the R-value of the Tuff-R was considered (see photo). This procedure produced an 80% improvement in the R-value of Rosewood’s Challenge home over Rosewood’s typical ENERGY STAR home with R-19 fiberglass batts and no exterior insulation.

Location of ducts in exterior walls was discouraged by the project team, but where this was done, the Rosewood Challenge home also applied SPF between the duct work and framing members. The SPF served to simultaneously insulate the duct and reduce duct leakage and heat loss.

Prior to construction, the project team set an aggressive goal of achieving a whole house infiltration rate of 1.5 ACH at 50 Pascal. After the home was constructed, but prior to occupancy, they tested the home’s tightness using a blower door test. The infiltration rate measured by this test was 1.9 ACH at 50 Pascal. Although the initial target was not achieved, the home achieved tightness levels rarely seen in new construction. Paying close attention to air sealing measures in the above grade wall made reaching this degree of tightness possible. Measures employed included caulking the seam between the bottom plate and floor, SPF in the band and rim joists, caulking around all recessed lights, and foaming and caulking around windows.

Construction Issues, Wall Framing. Because the builder did not use ladder blocking, increase stud spacing, or optimize the framing plans, the Challenge home had one wall section where five studs were very close to each other (see photo on page 6-7). Further, it could not be verified that any fiberglass insulation was stuffed into the tight spots between the studs. The infrared picture below highlights the importance of limiting framing and increasing insulation. The picture on the right shows a nice, even temperature across the walls and ceiling, except for the corner. The dark section represents a cold spot in the wall cavity, produced by this five-stud corner. The yellow portion to the left of the infrared picture is produced by a duct return. The better method for framing this area would have been to use ladder framing, which would have reduced the amount of lumber and reduced the tight spots, allowing for increased use of insulation in this specific spot.

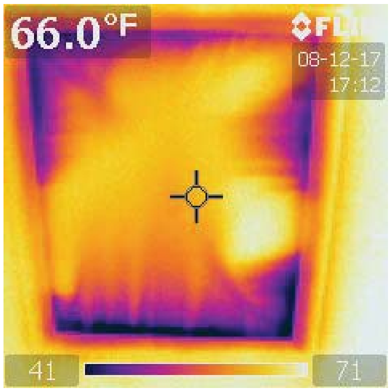
One corner in the home with five studs next each other



A thermal image of the same corner showing cold air in this section (Note: Yellow section on left is a duct return)

Ceiling Insulation. A typical Rosewood home uses a single layer of R-38 fiberglass batts as ceiling insulation. To increase the R-value of the ceiling, Rosewood's high performance home received blown-in cellulose resulting in an R-50. Raised heel trusses permited insulation to be blown all the way to the eaves, providing excellent coverage of the top plate. This measure cost $750 more than the builder's typical insulation specifications and is expected to reduce the Rosewood's typical home's heating energy use by 4%.

Construction Issues, Sealing the Attic Hatch. Building a high performance home requires that the home be tightly sealed, to reduce undesirable infiltration and exfiltration levels. During the blower door test, Newport Ventures used a handheld smoke puffer to discover potential air leaks. The most air infiltration was discovered at the attic hatch.



Thermal image of attic hatch. Notice middle of hatch is 71°F while edges are in the low 40s

Attic hatch with four layers of insulation foam board

Creating a tight seal between the attic and conditioned space requires attention to details that are easily overlooked during construction. A weather-stripping gasket or another sealing device can be used to reduce air leakage through the attic hatch. An infared image depicts the energy loss through the attic hatch.

The attic access hatch was adequately insulated, but not sealed. Prior to a gasket being installed, the infrared picture shows that the center of the attic hatch maintains an adequate temperature, while the edges maintain a 30 degree F lower temperature. This pattern indicates that heat is being lost at a higher rate through gaps around the edges of the attic hatch, not that the hatch is inadequately insulated (see photo). Starting with a tight building shell makes finding leakage areas much easier.

Mechanical Ventilation. In other Challenge homes, heat or energy recovery ventilators have been demonstrated to be energy-efficient and effective methods for providing whole house mechanical ventilation. Still, the high price of these units can make their specification cost prohibitive for some builders. For the Rosewood Challenge home, Newport Ventures focused on identifying more cost-effective ventilation options to satisfy indoor air quality design objectives. Ultimately, Newport specified a Broan SmartSense system with a pressure-activated fresh air make-up damper. This system allowed for a decrease in first costs of around $1,500 versus the installation of an HRV or ERV. The make-up vent used in conjunction with Broan's SmartSense exhaust system was specified to assist in balancing exhaust rates with supply rates into the home.

Builders installed Broan's SmartSense fans in two of the home's three bathrooms. The fans are "ultra-silent" – operating at less than 1-sone while exhausting up to 110 cfm and drawing less than 34 Watts. The fans are programmed to ventilate the home as required to meet ASHRAE 62.2, the standard for "Ventilation and Acceptable Indoor Air Quality in Low-Rise Residential Buildings." These 'smart' fans can communicate with each other in achieving targeted whole house ventilation volumes. The SmartSense fans are normally set at "off," but occupants can turn them on as desired for spot ventilation (just like any other exhaust fan). When occupants run the fans, a record is kept of the run time, counting this exhaust ventilation toward the total targeted ventilation for the hour. If at the end of the hour, occupants have not run the fans enough to satisfy the ventilation target, the fans will automatically cycle on to ensure meeting the differential ventilation requirements. This system provides an economical and energy efficient method for meeting targeted ventilation rates.


Whole house fan

Heating and Cooling. With building codes continuing to increase the insulation requirements of the building envelope, improvements in heating and cooling mechanical equipment efficiencies remain opportunities for reducing whole house energy use. The Rosewood Challenge home employs high efficiency and redundant heating and cooling equipment to optimize energy savings and system performance.

The project team selected an ASHP as the primary heat source and chose a natural gas fired furnace as the secondary heat source. This system is often referred to as a dual fuel heat pump system. The team specified high efficiency equipment, with the ASHP rated with a heating season performance factor of 9.0 and the forced air furnace maintaining an AFUE of 95. They paired this equipment with a fan driven by a highly efficient electronically commutating motor (ECM).

Though the ASHP is highly efficient to operate, its efficiency and supply air temperature decrease with decreasing outdoor temperature. At lower outdoor temperatures, the ASHP becomes more expensive and less comfortable to operate. Because of this, the project ran an analysis of engineering performance data and utility costs, in order to identify the economic balance point temperature (or the targeted outdoor temperature at which switching from the ASHP to the natural gas furnace makes the most economic sense). Because the ASHP was slightly oversized, it is not expected to use much resistance heat at lower temperatures, and so the economic balance point for this unit was very low: 11 degrees F. The emissions balance point (or the targeted outdoor temperature at which switching from the ASHP to the natural gas furnace results in minimized CO2 pollution), was found to be 26.4 degrees F.[12]. Based on the contractor's experience in addressing homeowner complaints in the operation of ASHPs when outdoor temperatures fall below 30 degrees F, however, a switch over temperature of 32 degrees F was selected as a compromise, balancing concerns of economics, emissions, energy use, and comfort.

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[12] For a detailed explanation of the methodology used to calculate economic and emissions balance point temperatures, see the Belmonte High Performance Homes Case Study.

For cooling, the Rosewood Challenge home also employs two systems. The first is a whole house fan that is capable of providing cooling especially well under moderate outdoor humidity levels and dry bulb temperatures. At low speed, the whole house fan will move 1,000 CFM of air, and at high speed it can move up to 1,700 CFM while only drawing 140 Watts of power (see photos). Unlike older generations of whole house fans, which were known to rattle the rafters, the AirScape 1.7 is relatively quiet, operating at 2.0 sones at low speed and 3.5 sones at high speed. The low power draw will result in a substantial reduction of power that would otherwise be demanded by the operation of the air conditioner and central fan. Installed, the fan costs $1,569.

It is expected that the homeowner will typically operate the fan at night to draw warm air out of the home. Specification of the whole house fan improved the HERS score by 0.8 points, a significant jump in the score for such a low cost. Although Rosewood does not usually install whole house ventilation fans, no major construction issues arose. Prior to installing it, the project team discussed the whole house fan to avoid any delays during construction. A method to note for future insulating solutions around the whole house fan would be the use of spray foam or a boxed area of foam board around the fan. The rest of the attic could then have blown cellulose.

Sealed duct work and sprayed around section – great work

Spray foam used to seal around forced air registers

When the whole house fan is unable to adequately cool the home due to high outdoor temperatures and/or humidity levels, homeowners can employ the ASHP to produce a traditional vapor compression cycle. In cooling mode, the air source heat pump is rated at a 14 SEER.

The combination 9.0 HSPF/14 SEER heat pump, 95 AFUE furnace, and whole house fan will supplant Rosewood's typical 13 SEER AC and 90 AFUE furnace. The incremental cost for this package came to $4,019. Once these highly efficient mechanical systems are combined with all the targeted building envelope efficiency measures, analysts expect to reduce the Challenge home's energy use for heating and cooling by 72% compared with Rosewood's traditional ENERGY STAR home. As utility costs continue to rise, homeowners will increasingly appreciate the energy efficiency improvements made in heating and cooling., Just as Rosewood wanted to keep conditioned or heated air inside the home, they also wanted to keep conditioned or heated air in the ducts. The construction crew did an excellent job of properly sealing the duct work (see photo). Not only were duct seams or joints properly sealed, but also expanding foam was used to seal framing penetrations as well. Spray foam was used to seal the vent openings. Often there are little gaps between the duct work and the wood flooring, which allow air to escape into floor cavities or under the flooring material. The use of spray foam, by contrast, helps ensure that all the heated air makes its way to the intended areas.

Domestic Hot Water. Traditional natural gas hot water storage tanks produce inefficiencies associated with heating volume of water and maintaining it at a constant temperature until use. Tankless water heaters, which only heat water as it is needed, eliminate these standby heat losses. The builders selected the Navien 240 tankless water heater to decrease energy consumption and costs. This 95% efficient unit is expected to reduce whole house energy use by 5%, and reduce water heating energy use by 35% compared to Rosewood's typical ENERGY STAR home.

Sealing with expanding foam

Additionally, builders sealed all framing penetrations associated with plumbing the home (see photo). This measure limits the flow of air within the wall cavity, which improves energy efficiency and inhibits the spread of fire, should one occur.

The layout of mechanical systems is also important. Builders placed the tankless water heater, along with the furnace, centrally located in the middle of the basement, reducing the supply line runs.

CFLs for Lighting. Replacing inefficient incandescent lights with fluorescent lights is a cost-effective method for saving energy. The Rosewood Challenge home's lights are 100% compact fluorescents and pin-based fluorescent lighting. This single measure is expected to reduce the home's lighting and appliance energy use by 16%, whole house energy use by 3%, and cost roughly $300 more than Rosewood's traditional 10% CFL lighting package.

Utility Bill Analysis

See Section 4 for the results of the utility analysis.

STEWART CONSTRUCTION, INC.

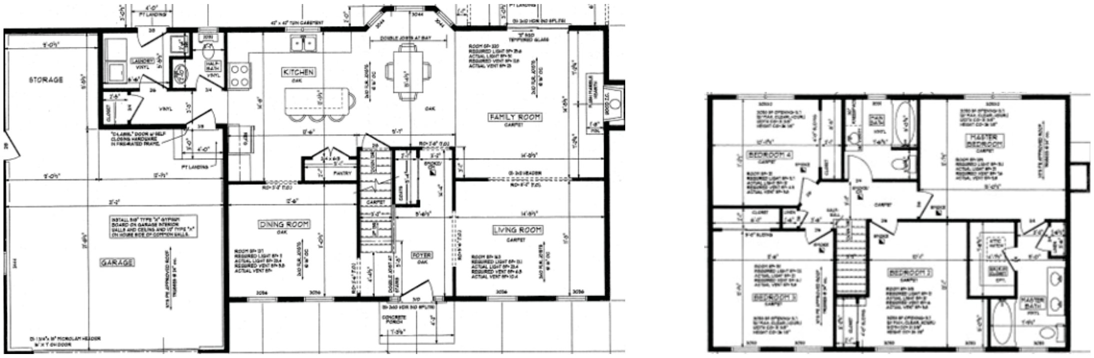
STEWART CONSTRUCTION, INC.
Professional Home Builders

Stewart Construction Inc. is a second generation, family-owned and operated business that has been building and remodeling homes in the Capital Region for 40 years. A small-volume company, Stewart Construction takes a hands-on approach to projects and prides itself on personal service and customer satisfaction. The company is owned by Todd Stewart, the current president of Capital Region Builders and Remodelers Association.

Stewart's typical or "reference" home was modeled with building energy simulation software to have a HERS score of 86.4. The minimum HERS score for ENERGY STAR compliance in New York State is 84.0, so Stewart's reference home exceeds the baseline criterion for ENERGY STAR qualification. Through participation in the NYSERDA HPRDC Challenge, Stewart Construction hopes to improve upon the company's reference design, taking it beyond ENERGY STAR, as far as a 60% improvement over a minimum code compliant home.

The Challenge Home

Stewart Construction's Challenge home is a two-story, four bedroom colonial home built in the existing Burnt Hills neighborhood in Saratoga County (see diagram). Starting with Stewart's typical ENERGY STAR home design, Newport Ventures recommended multiple building and mechanical system enhancements to produce a design that modeled to be roughly 60% more energy efficient than a home built to the 2004 International Energy Conservation Code. Primarily, the design emphasizes improving the energy performance of the walls and ceiling to ensure that the home performs well for its entire life. Secondarily, the super-insulated home incorporates energy efficient mechanical ventilation and heating/cooling systems. The house completes its energy efficiency package through specification of high efficiency appliances and lighting.



Stewart Construction's first and second floor high performance home

This case study discusses the rationale for recommending these energy efficiency measures and the construction issues related to their implementation. Stewart's typical ENERGY STAR home was modeled to have a HERS Score of 86.413. Figure 2-19 details the recommended building shell and mechanical system changes made to Stewart's typical home to create Stewart's Challenge home. The 2,134 square foot Challenge home achieved a HERS Score of 91.8. The column on the right, titled 'Duplication Costs' quantifies builders' costs associated with these changes if they were to replicate the changes on additional homes. Manufacturer or supplier discounts reduced some of these costs on the actual Challenge home.

Measure	Typical Stewart Home	Stewart HPRDC Home	Duplication Costs to Builder (Marginal)
Ceiling Insulation	R-30 blown cellulose insulation	R-41 open cell spray foam insulation (raised heel truss)	$4,109
Above Grade Walls	R-19 cavity insulation	R-23 open cell spray foam cavity insulation, R-3.5 exterior rigid foam insulation, R-23 open cell spray foam in band joists	$3,937
	Vinyl siding	CertainTeed's CedarBoards Insulated Siding	$1,170
Below Grade Walls	Poured concrete foundation wall, interior 2x4 stud wall insulated with R-11 fiberglass batts with foil scrim kraft facing	Poured concrete foundation wall with full length R-25 fiberglass perforated foil scrim kraft blanket insulation (framed areas received R-30 batts with poly-scrim kraft facing)	$1,279
Air Sealing	Code minimums	Foam band joists and jambs, caulk light fixtures, and foam tape attic hatch	Included in spray foam costs
Domestic Water Heating	50 gallon, 62% EF, natural gas-fired tank	95 % EF Navien 210 condensing gas-fired tankless unit	$1,367
Space Heating and Cooling	13 SEER AC unit, cooling only	14 SEER,9 HSPF, 3-ton air source heat pump, acts as the primary heating and cooling system for the home	$1,800

Figure 2-19 – Stewart. Summary of Efficiency Upgrade Measures Relative to Typical Practice

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[13] New York State uses the "HERS Score" rating system based on industry standards and produced by energy simulation software. Under this system, the "Reference Home" is scored at 80, and every point above 80 represents a 5% improvement in energy efficiency. To convert a HERS Score to a HERS Index, and vice-versa, see http://www.energystar.gov/index.cfm?c=bldrs_lenders_raters.nh_HERS

	92 AFUE furnace, heating only	95 AFUE furnace is used as a back-up heating system when outdoor air temperature is low	$1,020
Whole House Ventilation	Natural ventilation	Whole house fan for space cooling and ventilation, 230 CFM multi-port exhaust fan with fresh air make-up for mechanical ventilation	$2,178
Total Costs			$16,860
HERS Score	86.4	91.8	
Projected Annual Energy Use (MMBtu)	126.8	72.7	

Figure 2-19 – Stewart. Summary of Efficiency Upgrade Measures Relative to Typical Practice (continued)

Energy modeling projects that Stewart’s typical ENERGY STAR home requires 59.8 MMBtu of energy to heat the home over the course of a typical year. After implementing the energy efficient measures listed above, the home is projected to use 26 MMBtu of energy for the same task. The measures cited in Figure 2-19 result in a 57% decrease in energy used to heat the home compared with Stewart’s typical home.

These measures are expected to reduce the energy needed to cool the home by 64%, compared with the typical Stewart home. In total, Stewart’s typical ENERGY STAR home is projected to operate on roughly 127 MMBtu per year, while the Stuart Challenge home is expected to use approximately 73 MMBtu over the same period, producing a total energy use reduction of 43%.

Figure 2-20 shows key performance data based on energy simulations. Utility bill data, which are being tracked over the home’s first year of occupancy, will be used to refine these projections. Figure 2-21 shows another comparison on energy use.

Energy Consumption Component	Stewart's Typical Home (MMBtu/yr)	Stewart's Challenge Home (MMBtu/yr)	% Reduction
Heating	59.8	26.0	57%
Cooling	3.3	1.2	64%
Water Heating	24.7	14.8	40%
Lighting & Appliances	39.0	30.7	21%
Total Energy Use Projections	126.8	72.7	43%

Figure 2-20 – Stewart. Summary of Efficiency Upgrade Measures Relative to Typical Practice

Typical Home Projected Energy Use

Challenge Home Projected Energy Use

Figure 2-21 – Stewart. Energy Use Comparison

Analysts used REM/Rate's (Version 12.51) residential modeling software to assess a multitude of design scenarios and options, with the project team simultaneously examining incremental costs and the compatibility of various building technologies. The modeling software allowed the researchers to calculate the HERS Score and energy usage information as discussed throughout this case study, unless otherwise noted.

Basement Walls. Because a standard basement wall system in New York State can account for 27% of a home's heat loss, when Newport Ventures and Stewart Construction began designing this high performance home, they knew they would have to make changes in the basement. Stewart typically builds a wood framed wall to cover the poured concrete walls in the basement. Then they fill the wall cavity with R-11 fiberglass insulation and cover the framing with drywall; but in order to achieve the project's energy goals the project team decided that the unfinished portion of the basement (comprising 60% of the basement) would receive an R-25 poly scrim-kraft, perforated full length insulation blankets. They decided to frame the remaining 40% of the basement with 2x4s and insulate with R-30 kraft faced batt insulation with FSK scrim-coating, to be held in place with a friction fit and staples. This section is intended for future home expansion.

One of the factors to consider when finishing a basement is that it is much easier to add insulation during construction than after the home is built. By investing in increased basement insulation prior to fully finishing the basement, homebuyers can realize energy cost savings while they decide how and when to finish the basement. This strategy is particularly attractive to homeowners who expect to grow into their new homes or cannot afford to finish the basement during construction.

Installers sprayed the basement rim joist with insulation foam. The foam was applied to a level of R-23. Rim joists are relatively small and traditionally have a lot of framing penetrations and tight corners. These factors make expanding spray foam a good option to consider when building a high performance home. The spray foam will fill framing penetrations and make it possible to efficiently reach into tight, difficult-to-reach corners.

Constructability Issues. During the planning stages the project team decided to install the electric panel away from the foundation wall to allow for the placement of blanket insulation behind the panel (see photos). Typical construction mounts the electric panel to a piece of OSB and then attaches it directly to the foundation wall. With a little preplanning, building the electrical panel away from the foundation wall is a quick, easy way to allow for 100% coverage in the basement, increasing the energy performance of the home.

The builder also added insulated foam board to the inside of the window sill. This detail not only provides insulation value to what would otherwise be exposed concrete but also creates a nice finishing detail that ties the blanket insulation with the window opening. Builders added foam board after framing the window and walls, taping up all joints for a clean appearance.

Electrical panel built away from wall to allow for insulation behind it

Above Grade Walls. Energy losses through above-grade walls account for about 14% of the heat load of a typical New York ENERGY STAR home. Exterior walls of new single family homes in New York State are commonly framed with 2x6" studs, which enables the builder to stuff R-19 fiberglass insulation batts into the wall cavities to meet building code insulation requirements. The Stewart Challenge home used typical 2x6 wall framing at 16" on-center. Because the builder wanted this home to exceed code requirements for insulation, however, the home used 2x6" walls that employed both cavity and continuous insulation. (see photos)

Insulated Vinyl Siding: Before and after images of the Stewart challenge with CertainTeed's insulated vinyl siding

Builders first covered the exterior of the home with a weather barrier home wrap. Next, they attached CertainTeed's insulated vinyl siding, which can increase an exterior wall R-value by 22%[14]. The insulated vinyl siding came with

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[14] Based on a wall construction of 2x4 wood studs spaced 16" O.C. with R-13 insulation, non-insulated siding, standard 1/2" gypsum board and 7/16" OSB.

the foam attached to the back side of the vinyl. Some siding products come in two pieces, rigid exterior foam, and vinyl siding. The home's elevations, however, lent themselves to the single piece insulated vinyl siding. The one-piece product permitted builders to side and insulate the home in one process, instead of two. Because of the weight of the product, the installation involves two people, potentially increasing the cost of labor for a house.

On the inside of the home, installers insulated the above-grade walls with spray foam in the wall cavities. A total of 5.5" of open cell expanding spray foam was applied to provide an R-value of 23. Besides providing insulation value, expanding spray foam fills small gaps and holes in the framing to provide additional air sealing. Small gaps in the framing can come from sheathing and siding fasteners, normal cracks in wood sheathing, and the installation of exterior junction boxes, often used for lights and electrical outlets. Notice the sunlight shining through the junction box on the right in this photo, a prime example of a gap in framing that would benefit from expanding spray foam. The photo also indicates how important it is to seal all framing penetrations when using traditional fiberglass batts in wall cavities. For example, if Stewart used the traditional R-19 batt insulation, but did not seal the framing penetrations with caulk or spray foam, outside air would have direct access to this wall cavity through the junction box and to adjacent wall cavities by following the yellow electrical wire. Through reducing cold-air drafts, enhanced air sealing, which improves both energy efficiency and comfort, is one of the biggest and most noticeable benefits of building a tight envelope.

Spray foam in rim joists and tight corner, and caulk sealing gaps in framing members

Spray foam is also beneficial in filling gaps around window framing, rim joists and corners. By reducing air infiltration through the walls, the homeowner can save on energy bills while the builder realizes a time-saving benefit when using spray foam. It would have been time consuming to stuff the small gap between the framing studs with a cut piece of fiberglass insulation. The homeowner has the security of knowing that the builders has minimized gaps in insulation, providing this level of efficiency in a few minutes' time. Also, notice the left side of the window header on the right. Stewart's construction crew did an excellent job of filling gaps in the framing with caulk (see photo). This is an example of the little details that are necessary to produce a high efficiency home.

Wall cavities filled with spray foam before being trimmed

Wall cavities filled with spray foam that has been trimmed

Stuart builders also used spray foam to place insulation into the rim joists at a level of R-23. As noted on the below-grade section, it would be difficult for many crew members to stuff traditional fiberglass into these joist bays without compressing and degrading the insulation value.

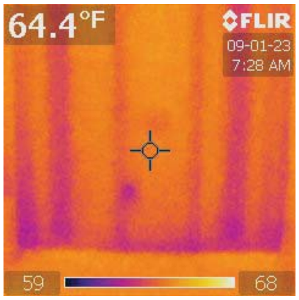
Then, all window and door headers were built on site and pre-stuffed with fiberglass insulation. Other available options include pre-ordering insulated headers or cutting laminated beams on site and foaming the remaining cavity. If builders are going to spend money on ENERGY STAR windows and high insulation values, they should make sure all the headers and footers have adequate insulation, as well.

Ceiling Insulation. Builders continued the application of spray foam insulation into the attic. Stewart most often specifies R-30 blown-in cellulose for ceiling insulation. To improve the energy performance of the home, Newport Ventures recommended spray foam to provide air sealing and insulation to a level of R-41. For example, expanding spray foam helps seal holes associated with missed nails, gaps between ceiling fixtures, and the drywall.

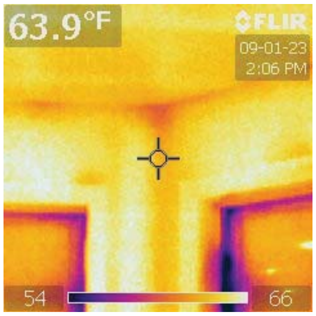
Because there were no ducts or mechanical equipment in the attic, there was no energy savings advantage to be gained by insulating the roof sheathing versus the ceiling. Hence, builders applied spray foam to the ceiling side of the attic, rather than to the roof sheathing. This procedure allowed the attic to be vented, rather than conditioned. The resultant application allows for 7.5” of continuous foam insulation to be applied above the trusses’ bottom chords. The application of continuous insulation in the attic represents a major improvement over standard homes that may simply use R-38 batts, which are interrupted every 24” by trusses.

Constructability Issues. To ensure that the spray foam thoroughly covers the roof-wall connections in the attic, the builder upgraded trusses at a cost of $365 to a raised heel model. The few extra inches of clearance provided by raised heel trusses over wall top plates improve the chances that insulation will reach deep into corners.

Air Sealing. Using 5.5” of spray foam insulation in the exterior wall and 10” of spray foam in the attic was very effective in air sealing the envelope. The home achieved a remarkable 1.4 ACH50 during the blower door test. As a point of reference, ENERGY STAR homes in New York are permitted to have an infiltration rates as high as 5.5 ACH50. Even more impressive, this level of performance was achieved without masking off the whole house cooling fan, which sealed very effectively with its internal damper.



With the home depressurized to 50 Pascal with the blower door, several electrical outlets in the exterior walls were barely visible with the infrared camera and an indoor-outdoor Delta T of 350F (see photos). This is not the case, typically, with a standard home, where infiltration is more likely to occur, resulting in highly visible outlets.



Another area of distinguished improvement was the kitchen bay window ceiling area. Typically small areas like this are overlooked and do not receive a thorough insulating and air sealing detail. This area appears to be very well sealed.

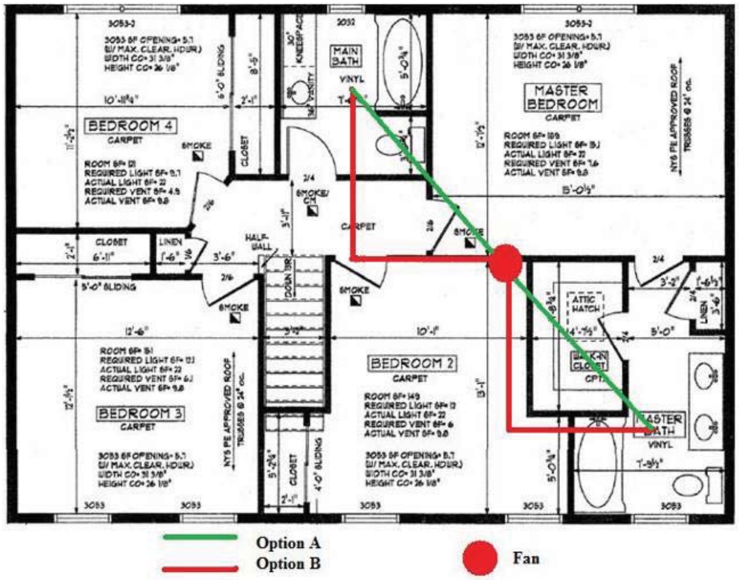
The builder used air tight IC rated housings for recessed lighting. This choice helps keep conditioned air from escaping into ceiling cavities or unconditioned air from seeping into the home.

Windows. Prior to joining the NYSERDA Challenge, Stewart Construction specified Anderson’s Silver Line 3900 Series U-Value 0.35 and SHGC 0.47. These windows meet the minimum requirement for ENERGY STAR in New York. Other windows with better U-values are available, but at an increased cost to the builder. Since these windows were already ordered, and modeling showed only slight gains in scoring through specification of higher performance windows, the project team decided that these windows would remain a sound choice for this project.

Constructability Issues. Manufacturer-sourced window data and the final NFRC rating taken from the NFRC sticker were not in agreement. This was a common story for most homes that participated in the Challenge. In this instance, the NFRC sticker rating pointed toward a better value than what was initially expected. The U-value was still 0.35, but the SHGC was 0.30 instead of the 0.47 originally modeled.

As it turned out, a majority of the windows in the Stewart Challenge Home have a U-Value of 0.35 and SHGC value of 0.30, but a small number had other values. Basement windows were particularly likely to vary. When ordering windows, builders should be sure to check if the desired performance factors are available in all window types and sizes required.

To save cost on windows, builders can choose higher performance windows to be placed in specific walls around the home. Though this practice is sound in theory, the implementation of it can be difficult without strict supervision. Carpenters on site typically will not check the labels but just look at the size of the windows to be placed.



Mechanical Ventilation. Tight, energy efficient homes need to have ventilation systems that ensure the maintenance of adequate indoor air quality (see diagram). Options for residential mechanical ventilation include heat and energy recovery ventilators (HRV and ERV), central-fan integrated systems, exhaust, and supply systems. HRVs and ERVs are known for their ability to efficiently exchange air without producing pressure imbalances across the envelope. Still, these systems come with a large first cost premium. Exhaust-based ventilation can provide economic, energy efficient ventilation, but also can create pressure imbalances across the envelope if not coupled with a fresh air intake vent.

In an effort to balance energy efficiency, performance, and economics, the project team specified a multi-port exhaust system with a passive fresh air intake vent. The team located the 6" diameter fresh air intake vent in the basement to decrease the likelihood that the make-up air would be perceived as a draft. This system allowed for a significant decrease in cost compared with an HRV or ERV. It was noted to the builder that a bug/insect screen should be installed over the inlet port to the make-up air damper in the basement.

Installed in the attic, the multi-port fan draws out air from two separate bathrooms simultaneously. The fan operates with a rated efficacy of 3.43 cfm/Watt (67 watts @ 230 CFM). The ceiling grille housings include 14 watt instant-on fluorescent bulbs, and the unit is ENERGY STAR qualified.

The fan connects to an after-market switch programmed to run a total of seven hours intermittently during a 24 hour period in order to meet the ASHRAE 62.2 standard. Option A (see diagram) was chosen for installation of the fan and the flexible duct to both bathrooms. This layout created the shortest duct runs possible with minimal bends that would reduce performance of the fan. The remote location of the fan motor almost nullifies the noise level of the fan in the conditioned part of the home. A third bathroom contained a typical exhaust vented to the outdoors.

Heating and Cooling. Stewart Construction upgraded the standard 92 AFUE furnace and 13 SEER air-conditioning unit to a dual fuel heating and cooling system. Within this system, an ASHP with a 9.0 HSPF and 14 SEER rating is being used as the primary heating system. The ASHP will help cool the home as well. While ASHPs provide a cost-effective and efficient mode of heating the home under moderately cool outdoor conditions, the efficiency and performance of the unit degrades as outdoor air temperatures fall below freezing. To ensure that the home's heating load can continue to be met efficiently, economically, and comfortably when outdoor temperatures fall, the project team specified a two-stage 95 AFUE furnace to provide back-up heat.

Giving consideration to equipment efficiencies and electricity and gas utility rates and emissions rates, Newport Ventures conducted an analysis to identify the optimum outdoor dry bulb switch-over temperature between the ASHP and the natural gas furnace (see Figure 2-22). A pure economic analysis identified an optimized economic switch-over (or "balance point") temperature of 41.4 degrees F, a temperature that is higher than other Challenge homes with more favorable electricity to natural gas utility price ratios. Figure 2-22 shows that the economic advantage of operating the ASHP above 41.4 degrees F is slight under the current utility rates. Utility rates have proven to be highly variable in the past several years, however, and with the dual fuel system installed, future homeowners will have a security policy in place as a hedge against future price volatility.

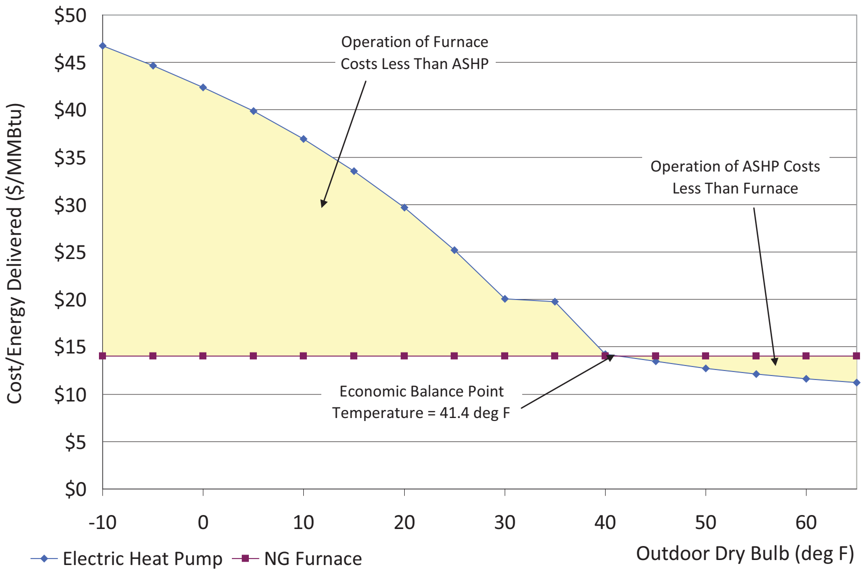


Figure 2-22 – Stewart. Economic balance point of dual fuel fired heating system

A pure emissions analysis identified an optimized balance point temperature of 27.2 degrees F, meaning that above this temperature, use of the ASHP will result in fewer emissions, while below this temperature, use of the natural gas furnace will result in fewer emissions. Ultimately, a switch-over temperature of 35 degrees F was selected as a good balance between optimizing emissions and economics without sacrificing occupant comfort, which tends to decrease as outdoor temperatures fall during operation of the ASHP.

A whole house fan was specified to reduce the need to use the ASHP to cool the home. Homeowners can use the whole house fan to create a comfortable breeze in the home and remove hot air from the attic, using less energy than it takes to run the air conditioner. The convection-based cooling of the whole house fan is less energy intensive than the traditional vapor compression cycle of the ASHP, and so provides an attractive option for saving.

The unit comes with a 2-speed wall switch, drawing 140 watts and 1700 CFM on high speed and operating at 82 watts and 1000 CFM on low speed. This low power draw and high flow rate result in an excellent overall efficacy of

12.1 CFM/Watt. The insulated doors operate automatically and seal against a gasket, preventing any leakage from conditioned to unconditioned spaces.

The energy modeling showed a HERS score improvement of 0.4 when implementing a whole house fan, making this one of the most cost-effective ways to introduce alternative cooling methods for a home while also reducing electricity usage.

Craftsmanship was evident in sealing all duct work to reduce duct losses to unconditioned space (see photos). The construction crew did an excellent job, properly sealing the duct work. They sealed duct seams and joints properly with mastic and used expanding foam to seal framing penetrations as well. Often times there are little gaps between the duct work and the wood flooring that can allow air to escape into floor cavities or under the flooring material. The use of spray foam helps ensure that all the heated air makes its way out of the duct and into the home.

Domestic Hot Water. Traditional gas-fired hot water storage tanks produce inefficiencies associated with heating a volume of water and maintaining it at a constant temperature until use. Tankless water heaters, which heat water only as it is needed, eliminate these standby heat losses. The project team selected the Navien 240 condensing tankless water heater in order to decrease energy consumption and water costs. This 95% efficient unit is expected to reduce the Stewart Challenge home's water heating annual consumption by almost 40%, saving approximately $153 off of the annual natural gas bills compared to Stewart's typical ENERGY STAR home.

Because this locality has hard water, the homeowners decided to have the water softener added. This decision agreed with the plumber's request to include such a unit.

Although tankless water heater warranty literature does not typically identify the water hardness level at which water treatment should be used, it generally does warn of warranty violations if used with untreated hard water. The plumber stood behind the decision to install a water softener upstream of the tankless water heater, citing a hardness of 14 grains/gallon. Without the water softener, the homeowner would run the risk of calcium scale accumulation on the heat exchanger, which could quickly render it ineffective.

In this case, the necessity for and the incremental cost of the water softener was a moot point, because the builder specified a water softener in response to the homeowner's request –a decision that was not based on whether or not the water heater was a tankless unit. Regardless, it is recommended that if selecting a tankless water heater, water hardness be considered in system specification.

CFLs for Lighting. Switching from incandescent lights to fluorescent lights is a cost-effective method for saving energy. The Stewart Challenge Home uses only compact fluorescent light bulbs (CFLs). This simple change reduces the home's modeled lighting consumption from 3074 kWh/yr to 1280 kWh/yr. The change to fluorescent helps to substantially reduce the home's electrical consumption, and is one of the most cost-effective energy efficiency upgrades.

The builder considered the cost to be minimal and the energy-efficient bulbs to be a good selling point, so they performed this installation upon Newport's recommendation.

Economic Analysis of Efficiency Upgrades

A major component of the NYSERDA Challenge is to demonstrate cost-effective solutions toward 60% savings. In keeping with this goal, Newport Ventures conducted an economic analysis to evaluate the first and operational costs that were experienced and expected by both the builder and future homeowner. Currently, builders in New York State are heavily incentivized to build energy efficient homes. Between the Federal Energy Tax Credit and the New York ENERGY STAR Homes program, builders are eligible to receive between $2,750 and $5,000 for constructing a very high performance home.

Because of the significant financial incentives available to builders, it is assumed that builders pass on the energy conservation measures to the homebuyer at the builder's own cost. For the Stewart Challenge home, the replication cost of the energy efficient measures was $16,860. The analysis rolls this incremental cost into the mortgage of the future homeowner who, it is assumed, finances the home using a conventional, conforming 30-year fixed-rate mortgage with an interest rate of 5.05% (the average monthly rate at the home's completion in January 2009).

If the homeowner finances the energy efficient upgrades in this manner, the most relevant indicator of affordability is the net monthly expense of the amortized energy efficient measures after accounting for utility savings. Newport Ventures conducted whole building energy simulations using REM/Rate software to estimate the energy use of the Stewart reference home and the Stewart Challenge home. Based on these simulations, the Stewart Challenge home was projected to use 72.6 MMBtu of energy per year (or 22 kBtu/conditioned square foot15), while Stewart's reference home was projected to use 126.8 MMBtu of energy per year (or 39 kBtu/conditioned square foot). Referencing local utility rates, electricity savings of the Challenge home were valued at $0.16/kWh, and natural gas savings were valued at $1.33/therm. A 4% annual appreciation rate was assumed for electric and natural gas utility rates.

Based on these assumptions, a monthly cash flow analysis examined the cost-benefit of the efficiency package (see Figure 2-23). Once amortized over a 30-year loan at 5.05%, the monthly cost of the $16,860 energy efficiency package is $91. In year-one, the average monthly electricity and natural gas savings (benefits) are also expected to be $79, meaning that the net savings per month are projected to be -$12. As annual utility rates continue to increase (assume 5% per year) and the amortized cost of the energy efficient package remains fixed, the net savings continue to increase. By year-five, the net savings are cash positive and by year-10, the average net monthly savings are

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[15] Conditioned square feet also include conditioned basement floor area.

projected to be $22. By year 20, the average net monthly savings are projected to be $76, and by year-30, they are expected to reach $156. In total, over a 30 year mortgage, the cumulative net savings are expected to reach $20,544.

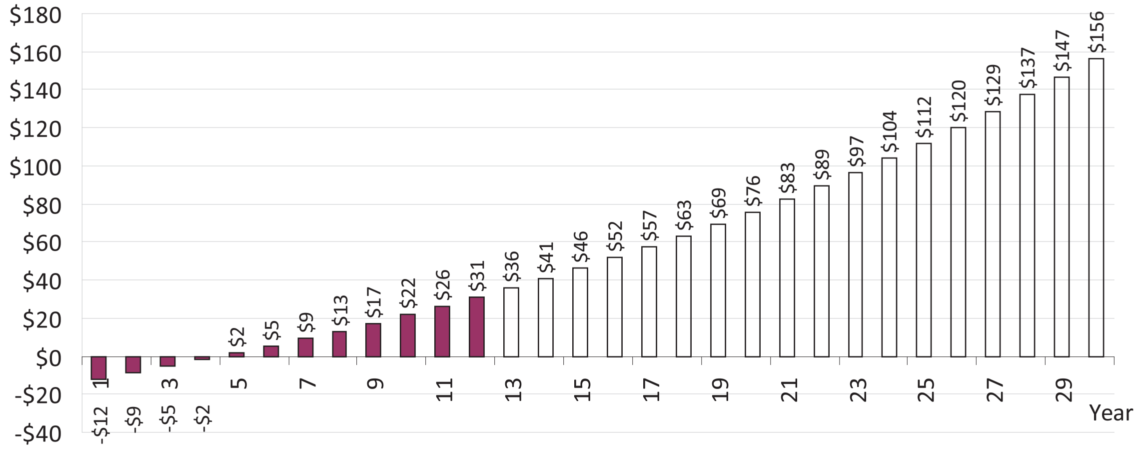

Figure 2-23 – Stewart. Projected Net Monthly Savings due to Energy Efficiency Measures – Net savings due to energy efficiency are expected to increase with increasing utility prices. A 4% escalation rate is assumed for this study.

Utility Bill Analysis

See Section 4 for the results of the utility analysis.

VIOLA

Viola Homes Inc.
585-787-9824

Operating as a semi-custom residential and commercial builder in Rochester, New York, Viola Homes builds approximately 12 to 16 homes per year, varying in square footage. Most of these are ENERGY STAR qualified homes. Viola has operated in the greater Rochester area since 1958, and has established a reputation as a builder dedicated to quality and energy efficiency. In addition to constructing the NYSERDA HPRDC home, Viola is also performing a substantial remodel on an office building that will seek LEED Platinum certification.

The Challenge Home

Viola's Challenge home is located in the Town of Penfield, New York, just outside of Rochester, which is situated in IECC climate Zone 5A and typically experiences 6,718 heating degree days and 3,764 cooling degree hours annually. The house is a two-story, four bedroom home, built in an existing neighborhood. Initially the home plan exceeded the NYSERDA HPRDC maximum above-grade square footage of 2,500 square feet. Alterations to the floor plan, however, helped to reduce this number to within the programmatic requirements.

Starting with Viola's typical ENERGY STAR home systems, Newport Ventures recommended multiple building systems to result in a design that modeled to be 58% more energy efficient than a home built to the 2004 International Energy Conservation Code. The design primarily emphasized improving the energy performance of the walls and ceiling to ensure that the home performs well for its entire life. Secondarily, the super-insulated home incorporates energy efficient mechanical ventilation and heating/cooling systems. The house finishes out its energy efficiency package through specification of high efficiency appliances and lighting.

This case study discusses the rationale for and the construction issues related to their implementation. As part of the re-design process, the project team also examined incremental costs, work sequencing impacts, installation issues, code/regulatory issues, and the compatibility of various building technologies. Newport used REM/Rate residential modeling software (Version 12.6) to assess a multitude of design scenarios and technology options. Viola's typical ENERGY STAR home was modeled to have a HERS Score of 86.6[16]. The 2,499 square foot Viola Challenge home achieved a HERS Score of 91.6.

Figure 2-24 details the recommended building shell and mechanical system changes made to Viola's typical home to create Viola's NYSERDA Challenge home. The right-hand column, titled 'Duplication Costs', quantifies the builder's costs associated with these changes if they were to replicate the changes on additional homes. Manufacturer or supplier discounts reduced some of these costs on the actual Challenge home.

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[16] New York State uses the "HERS Score" rating system, based on industry standards, that is produced by energy simulation software. Under this system, the "Reference Home" is scored at 80, and every point above 80 represents a 5% improvement in energy efficiency. To convert a HERS Score to a HERS Index, and vice-versa, see http://www.energystar.gov/index.cfm?c=bldrs_lenders_raters.nh_HERS

Building System / Component	Viola’s Typical Home	Viola’s Challenge Home	Duplication Cost to Builder (Marginal)
Below Grade Walls	R-11 FG insulation blanket draped 4’ 4”	R-25, full length FSK perforated FG insulation blanket	$1,870
Above Grade Walls & Rim/Band Joists	2x6 framing @ 16” on-center	2x6 @ 24” on-center	$17,443
	R-19 FG batts in wall cavity	R-31 closed cell SPF insulation in cavity, R-9.8 polyisocyanurate continuous insulation	
	R-19 FG batts in rim/band joists	Expanding SPF insulation on rim/band joists	
Ceiling/Attic Insulation	R-38 FG batts	R-22 SPF cavity insulation R-30 blown cellulose continuous insulation	$3,185
Windows	U = 0.33; SHGC = 0.47 Double Pane	U = 0.28 SHGC = 0.39 Triple Pane	$1,833
Mechanical Ventilation	Bathroom fans vented to the outside	HRV 68% SRE, 76 cfm continuous, 78 watts	$1,800
Space Heating and Cooling	90 AFUE, 89 kBtu/h furnace; 2.5 ton, 13 SEER AC	95 AFUE, 2 stage 45 kBtu/h, sealed combustion furnace 1.5 ton, 13 SEER AC	$500
Duct Leakage	80 CFM Leakage to Outdoors at 25 Pascals (CFM25)	0 CFM25 leakage to outdoors; all ducts in conditioned space	
Domestic Water Heating	Gas-fired 50 gallon tank; 0.62 Efficiency Factor (EF)	Gas-fired tankless; 0.95 EF	$680
Lighting	10% fluorescent lighting;	100% CFL and fluorescent lighting	$523
Total Incremental Costs to Builder:			$27,835
HERS Score	86.6	91.6	
Annual Energy Use (MMBtu)	152.3	93.1	

Figure 2-24 – Viola. Summary of Efficiency Upgrade Measures Relative to Typical Practice

In terms of the home’s energy consumption, Figure 2-25 shows key performance data based on energy simulations. Utility bill data, which are being tracked over the home’s first year of occupancy, will be used to refine these projections.

Energy Consumption Component	Viola’s Typical Home	Viola's Challenge Home	% Reduction
Heating	81.8	37.7	54%
Cooling	4.7	4.2	11%
Water Heating	22.2	14.8	33%
Lighting & Appliances	43.6	36.3	17%
Total Energy Use	152.3	93.1	39%

Figure 2-25 – Viola. Summary of Efficiency Upgrade Measures Relative to Typical Practice

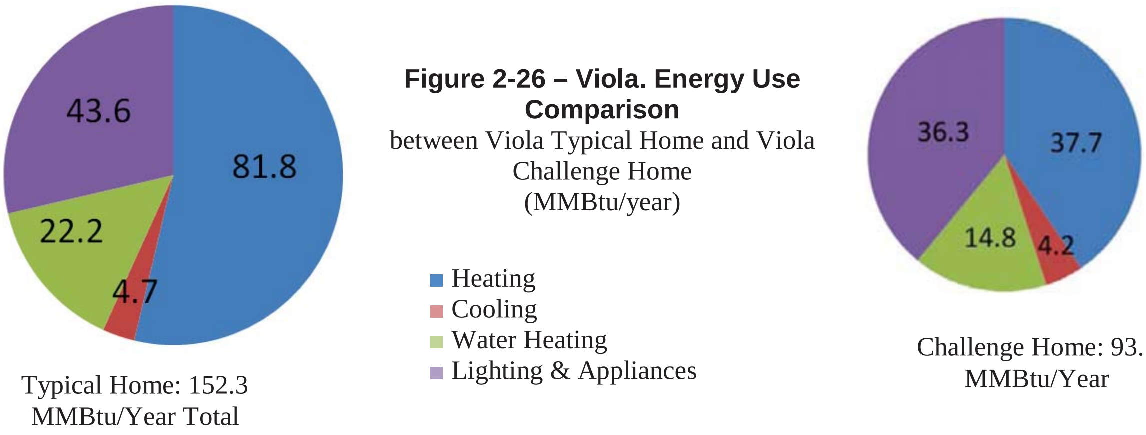


Figure 2-26 – Viola. Energy Use Comparison
between Viola Typical Home and Viola Challenge Home
(MMBtu/year)

Energy modeling results showed that Viola’s typical ENERGY STAR home required 81.8 MMBtu of energy to heat the home over the course of one year. After implementing the energy efficient measures listed above, the home is projected to use 37.7 MMBtu of energy to heat the home over the course of a year. This differential will result in a 54% reduction to the home’s heating energy use.

In total, Viola’s typical ENERGY STAR home uses roughly 152 MMBtu per year to operate while the Challenge home will use approximately 93 MMBtu over the same period, resulting in a total energy use reduction of 39%.

Review of Efficiency Upgrades

Beyond their energy and cost impacts, Newport Ventures also assessed the upgrade measures in terms of their impacts on work sequencing, code/regulatory issues, installation issues, and compatibility with other building systems. The sections that follow discuss notable findings.

Basement Walls, Because a standard basement wall system in New York can account for 27% of a home’s heat loss, when Newport Ventures and Viola Homes began designing this high performance home, they knew they would have to make adjustments in the basement (see photo).

The standard Viola foundation is 12" hollow concrete block stacked to 8' in height. The exterior is damp-proofed with parging and tarred below grade. The inside wall receives R-11 fiberglass insulation at least 4' down from the top of the foundation.

The Viola Challenge home foundation was eight inches of poured-in-place concrete. The exterior received a water resistant membrane that creates an air gap between the two surfaces, allowing for any water behind the membrane to find its way down to the foundation drain. The interior foundation wall received an R-25 full-height, continuous, FSK fiberglass insulation blanket, perforated to permit drying to the interior in case moisture might accumulate within the wall. Specifying the R-25 blanket alone improved the HERS score by almost a full point (0.8).

The basement rim joist received closed cell spray foam, with an R-value of 6.4 per inch. Builders applied the foam to a level of R-31. Because rim joists are relatively small and traditionally have a lot of framing penetrations and tight corners, expanding spray foam is a good option to consider when building a high performance home. The spray foam will fill framing penetrations and difficult-to-reach, tight corners, and do so in a short period of time.

Electrical panel built away from wall to allow for continuous insulation

__Constructability Issues__. During the planning stages, it was decided to erect the electric panel away from the foundation wall to allow the placement of blanket insulation behind the panel. In typical construction builders mount the electric panel to a piece of plywood and then attach it directly to the foundation wall. With a little preplanning, however, building the electrical panel away from the foundation wall can be a quick, easy way to allow for 100% insulation coverage in the basement, increasing the energy performance of the home.

The Viola challenge home before attaching continuous foam insulation

__Above Grade Walls__. Energy losses through above grade walls account for about 14% of the heat load of a typical New York ENERGY STAR home. Most ENERGY STAR Homes, like other single family homes in New York State, generally use 2x6 wall framing at 16" on-center.

To improve the performance of the above grade walls (AGW), 24" on-center spacing was used. This method helps reduce the amount of lumber used to frame the home and increases the insulation levels in the wall cavities. Builders then sprayed the wall cavities with 5" of closed cell spray foam, providing an R-31 in a wall cavity that typically holds an R-19 or R-21 fiberglass batt.

The Viola Challenge home employs both cavity and

continuous exterior insulation on the above-grade walls. Newport Ventures recommended polyisocyanurate exterior insulation because it can help improve a home's insulation value, form a water drainage plane, and assist in creating a tighter building shell. The exterior insulation consisted of 1.5" of Dow Tuff-R foam board, with a total R-value of 9.8. Builders taped all of the seams with a code compliant tape, which allows the insulation to serve double duty as a weather barrier. Therefore, the home did not require a traditional house wrap.

Prior to construction, the project team set an aggressive goal of achieving a whole house infiltration rate of 1.5 ACH at 50 Pascals. Technicians conducted a blower door test after the home was constructed, but before total completion, to assess the tightness. The infiltration rate measured by this test was 1.77 ACH at 50 Pascals.

As the home was not yet completed, builders improved on some infiltration areas. They sealed mechanical penetrations to the outside and added foam gaskets to the attic hatch. These measures brought the home air tightness level to 1.52 ACH at 50 Pascals, just missing the initial target. This home, however, achieved tightness levels rarely seen in new construction. Paying close attention to air sealing measures throughout the house, including the above grade wall, made reaching this level of tightness possible.

Constructability Issues. Two items of interest in the home's AGW were the enlarged wall cavity for the master bathroom shower's water supply lines and the movement of the gas fireplace.

This feature (see photo) has the supply lines and shower valve installed in an expanded exterior wall cavity. The wall cavity measures 7 ½" deep. This outcome is accomplished by using a standard 2x6 for wall framing which was furred out with an additional ½" of OSB and 1 ½" of framing lumber. This additional depth allows for greater insulation in the wall cavity, providing greater freeze protection of the pipes and improved thermal performance of the building shell. This particular home has closed cell spray foam applied in the wall cavities.

Many builders install gas fireplaces in exterior walls framed outside of a building's foundation and frame a box to carry the exhaust flue up and out over the home's roof top. In this case, the project team decided to bring the gas fireplace inside of the home's envelope to allow for a tighter building shell (see photo). The fireplace was placed at a 45 degree angle and was vented to the outside via a side wall vent.

Ceiling Insulation Viola's typical ENERGY STAR homes are outfitted with R-38 fiberglass batts fitted between the trusses. The Viola Challenge home used a "flash and blow" method in the attic to reduce air leakage and increase insulation. NCFI's Insulstar, a high density spray polyurethane foam, was applied directly to the attic side of the ceiling gypsum board to create an airtight seal between conditioned and unconditioned spaces (see photo). Above the foam, builders blew in cellulose insulation to reach a clear cavity insulation value of R-50.

Another benefit for this type of installation method is the continuous application of the insulation over the bottom chord of the truss. Typically, homes using fiberglass batts will meet the requirement of an R-30 or R-38 attic, but with gaps in insulation for framing every 16" or 24" depending on truss or ceiling joist layout. The continuous insulation measure is another detail that increases the thermal performance of the home. The builder also used raised heel trusses to permit blowing of insulation all the way to the eaves, providing excellent coverage of the top plate. Builders applied the spray foam to the ceiling side of the attic, not to the bottom of the roof sheathing, allowing the attic to be vented, rather than being conditioned. This application strategy reduces the amount of spray foam used, and therefore, costs.

Constructability Issues. The original house plans called for two skylights (8 sq. ft.) to be located in the morning room. Removal of these two skylights increased the HERS score by 0.2 points. Had the skylights remained it would have been necessary to ensure that insulation encompassed the skylight shaft to reduce heat loss into the attic space. The use of spray foam insulation would have been an effective measure for sealing and insulating around the skylights in this case.

Windows The windows chosen for the Viola Challenge home had a U-factor of 0.28, a solar heat gain coefficient of 0.39, and were ENERGY STAR certified. These high performing windows are triple pane with a krypton gas mix. The original windows specified for the home had a U-factor of 0.31 and a SHGC of 0.34. Modeling showed that with the switch to the higher performing windows, the home's overall HERS score would gain 0.4.

Constructability Issues Windows delivered to job sites should have a label on them provided by the National Fenestration Rating Council. The NFRC label shows the energy performance ratings of the window. In some instances, window labels may not match what was specified for the home. It is important to address this situation so as to make corrections in a timely way. A change in energy performance can affect the home's overall HERS score. In some applications, builders may want to specify different energy performance values on windows, depending on which direction the installed window may face.

Mechanical Ventilation. Tight, energy efficient homes need to have ventilation systems that ensure the maintenance of adequate indoor air quality. Fresh air ventilation systems with heat exchangers can use less energy than typical exhaust-only

systems. The Viola Challenge home uses Honeywell's heat recovery ventilator (HRV) because it surpasses the minimum ventilation requirement for new homes and satisfies the fresh indoor air quality needs of the home. Compared to a typical exhaust only system, the Honeywell HRV is expected to save 2% of the home's total energy use.

Speed Setting	Watts	Supply Flow (cfm)	Exhaust Flow (cfm)
1	83	66	75
2	100	92	100
3	117	110	123
4	127	126	134

Figure 2-27 – Viola. HRVs Four Speed Settings

An HRV is designed to pull fresh air into the home while it exhausts stale air to the outside, heating or cooling the incoming air depending on the time of year. Recapturing this conditioned air before it escapes the home is key to reducing home energy costs.

One of two flow meters installed near the HRV unit

Builders installed this partially dedicated system in the basement area of the home. This installation involved connecting to the central duct return plenum and supplying fresh air further down the return, before the blower in the furnace. This installation method was one of three options recommended by the manufacturer. This particular unit can be set to four different fan speeds depending on the preferences of the occupants. At its lowest setting, the unit met the minimum ASHRAE 62.2 ventilation requirements for the home. By providing the unit with short supply and return runs, the installers were able to deliver maximum air flow at minimum fan energy consumption levels. They permanently installed two flow meters within the duct work to compare actual flow measurements with manufacturer's specifications (see photos). Field tests of flow rates resulted in lower rates than published, but the rates were still sufficient to achieve target ventilation, even at the lowest speed setting. It is important to remember that, in the field, rates are greatly affected by supply and return ducting. To maintain performance, installers should keep runs short, straight, and clean as possible. Figure 2-27 shows the HRV's four speed settings and the watts used to operate the system as measured in the field.

Heating and Cooling. Viola's reference home's heating energy use modeled at 71.8 MMBtu/yr. With its tighter envelope, increased insulation, and higher performance mechanical systems, the Viola Challenge home's annual heating energy load dropped to 35.1 MMBtu/yr, a reduction of 54%.

Contributing to this reduction is the use of a two stage, sealed combustion, 95% AFUE furnace, with all of the home's duct work sealed and located in conditioned space. The furnace itself is centrally located in the basement of the home, allowing for short, even runs of supply and return lines throughout the home. This placement also contributes to more even heating and cooling effects. The home's programmable thermostat is located just off the kitchen, adjacent to the dining room. Zoning would have been another measure that could have contributed to reduced energy use in the home, but the software package was unable to model this improvement.

The tightness of the home's envelope and the increased insulation levels made it possible to reduce the size of the home's cooling system. The AC specified for the reference home was a 13 SEER 2.5 ton unit, while the new home showed that a 13 SEER 1.5 ton unit could handle the load of the Challenge home. The smaller unit is expected to have longer cycle times, which will help to reduce the humidity levels in the home and provide a more comfortable environment. Additionally, smaller air conditioner units can contribute to financial savings.

Domestic Hot Water Traditional natural gas hot water storage tanks produce inefficiencies associated with heating a volume of water and maintaining it at a constant temperature until use. Tankless water heaters, which only heat water as it is needed, eliminate these standby heat losses (see photo).

The project team selected the Navien CR-240 NG condensing tankless water heater for this project in order to decrease energy consumption and water heating costs. This 95% efficient unit is expected to reduce hot water energy use by 33%, compared to a typical gas-fired 50 gallon tank. Additionally, builders sealed all framing penetrations associated with plumbing the home. This measure limits the flow of air within the wall cavity, which improves energy efficiency and inhibits the spread of fire, should one occur.

CFLs for Lighting Switching from incandescent lights to fluorescent lights is a cost-effective method for saving energy. The Viola Challenge home uses only compact fluorescent light bulbs. This simple change reduces the home's modeled lighting consumption from 3665 kWh/yr to 1472 kWh/yr. The change to fluorescent helps to substantially reduce the home's electrical consumption, and is one of the most cost-effective energy efficiency upgrades.

Economic Analysis of Efficiency Upgrades

While the NYSERDA conceived the HPRDC to identify paths towards designing and building homes with greater energy efficiency, the Challenge also emphasizes evaluating the cost effectiveness of these measures. In keeping with this objective, Newport Ventures conducted an economic analysis to evaluate the first and operational costs that were experienced and expected by both the builder and future homeowner. Currently, New York State heavily encourages, through incentives, builders to produce energy efficient homes. Between the Federal Energy Tax Credit and the New York ENERGY STAR Homes program, builders are eligible to receive between $2,750 and $5,000 for constructing a very high performance home.

The current analysis assumes that the significant financial incentives available to builders for energy conservation measures are passed on to the homeowner at the builder's cost. For the Viola Challenge home, the replication cost of the energy efficient measures was $27,835. A significant portion of this cost was associated with the above grade walls, which used full cavity SPF and R-9.8 of continuous exterior insulation. While both of these applications represent excellent products, several thousand dollars could have been saved by the builder by specifying a lower cost cavity insulation, such as 1-2" of SPF complemented with R-15 fiberglass. Such a system would have delivered comparable, if slightly lower, performance, while reducing the incremental cost of the above grade wall by almost half. Regardless, the builder's decision to use a full cavity of SPF was based upon the desire to specify a durable, energy efficient product that is expected to provide high performance throughout the life of the home. It is assumed that the incremental cost of the above grade wall and all other measures is absorbed into the mortgage of the future homeowner, who finances the home using a conventional, conforming 30 year fixed-rate mortgage with an interest rate of 5.4% (the average monthly rate at the home's completion in June 2009).

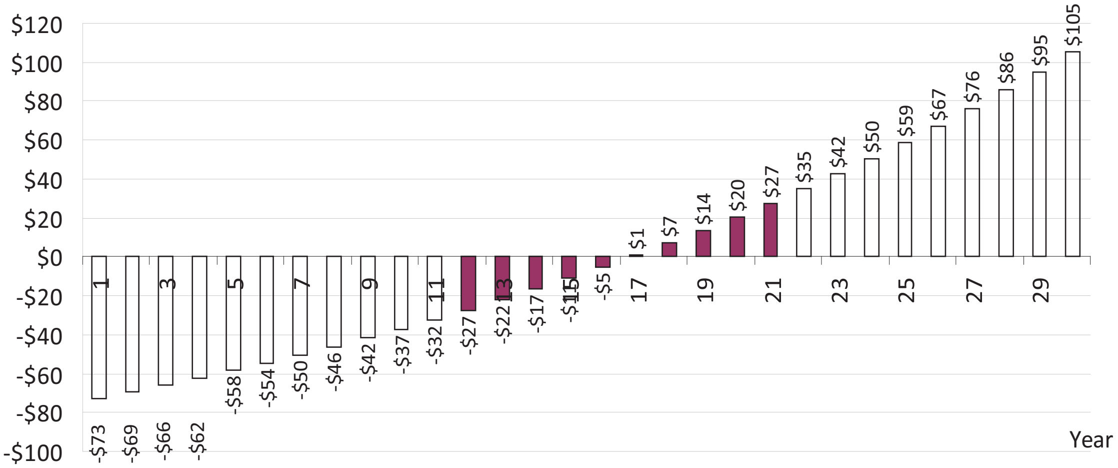


Figure 2-28 – Viola. Projected Net Monthly Savings Due to Energy Efficiency Measures

Net savings due to energy efficiency are expected to increase with increasing utility prices. This study assumes a 4% escalation rate.

If the homeowner finances the energy efficient upgrades in this manner, the most relevant indicator of affordability is the net monthly expense of the amortized energy efficient measures after accounting for utility savings. The project team conducted whole building energy simulations using REM/Rate software to estimate the energy use of

Viola’s reference home and Viola’s Challenge home. Based on these simulations, analysts projected that the Viola Challenge home would use 93.1 MMBtu of energy per year (or 24 kBtu/conditioned square foot). By comparison, they projected that Viola’s reference home would use roughly 152.3 MMBtu of energy per year (or 40 kBtu/conditioned square foot). Referencing local utility rates, they valued the electricity savings of the Challenge home at $0.1629/kWh, and valued natural gas savings at $1.14/therm. A 4% annual appreciation rate was assumed for electric and natural gas utility rates.

Using these rates, analysts used a monthly cash flow analysis to examine the cost-benefit of the efficiency package (see Figure 2-28). Once amortized over the life of a 30 year loan at 5.4%, the monthly cost of the $27,835 energy efficiency package is $157. In year-1, the average monthly electricity and natural gas savings (benefits) are expected to be $84, meaning that there are no projected net savings in year-1. As annual utility rates continue to increase (assume 4% per year) and the amortized cost of the energy efficient package remains fixed, however, the net savings continue to increase, so that by year-30, the average net monthly savings are projected to be $105. In total, over a 30 year mortgage, the cumulative net savings are expected to be cost-neutral. Again, these savings could have been far greater if the incremental costs of the above grade wall were reduced by a more cost-effective application of SPF.

Utility Bill Analysis

See Section 4 for the results of the utility analysis.

Section 3

PROJECT FINDINGS

The following discussion highlights lessons learned and related recommendations for improving the energy efficiency of single family homes in New York State. While the specific circumstances for a given project may dictate different methods or approaches, these findings are generally representative of effective practices for high performance homes in a heating dominated climate such as New York State.

GENERAL

- It is essential for a good outcome to engage in deliberate planning on how best to integrate new materials or methods. For example, when striving to minimize building shell air leakage effectively, successful builders determined what additional steps would be taken (for example, 1" of spray foam in band joist) and also assigned direct responsibility for this task (for example, insulator would apply the spray foam after mechanical rough-in).
- Whenever a new material or method is under consideration, identify all of the affected trades to anticipate what they may have to do differently. Discussions at the pre-construction phase are the best time to identify changes and account for them in work scopes and construction plans and specifications.

BUILDING SHELL

Walls

Take advantage of the opportunity to cost-effectively add higher-than-code levels of interior insulation on basement walls. Typical builder practice in New York State is installing R-11 PSK fiberglass blankets draped 4' from the sill plate. The majority of high performance homes in this study specified full length fiberglass blankets of R-25 to R-30 with perforated PSK facing, producing lower costs than alternative materials and high projected energy savings. Mounting systems (for example, push pins or nailing strips) should be designed to support the insulation and also minimize compression of the blanket. The perforated facing allows vapor diffusion out of the wall assembly to prevent moisture build-up. Builders must closely observe site grading, drainage, and exterior foundation water proofing details.

R-26 Fiberglass batts with a perforated facing mounted on basement foundation walls

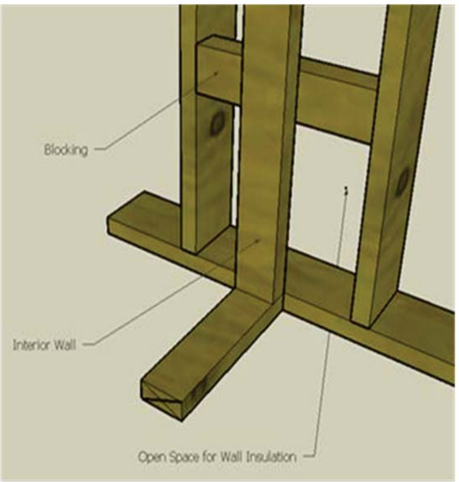
Window with jamb extensions being installed into a wall with 1.5" of exterior foam insulation. Flashing tape already installed on sides and sill, with head flashing to follow window installation.

When considering the use of exterior foam insulation for above-grade walls, consider several key issues. First, the thickness of the exterior foam will affect window jamb extensions, so ensure that windows will accommodate the added wall thickness. Next, in determining how much foam to add, note that adding more foam beyond ~1" will typically bring the wall to the point of diminishing returns for energy benefits. Next, the integration of the exterior foam with the window flashing and other roof flashing components (for example, step flashing) should be determined in advance. It is also critical to determine the most effective subcontractor to install the foam. Many window installers will install the foam, windows, and the window flashing in an integrated process. Also, consider opportunities for the exterior foam to double as the code-required weather barrier for the shell. Some manufacturer's exterior foam systems are rated for this application when seams are taped. Attach cladding over the foam according to manufacturer's installation instructions. When using nails to attach the cladding, a minimum penetration of 1¼" into the wood framing is recommended.

- Fiiberglass or blown cellulose, plus spray polyurethane foam insulated cavities for above grade walls can offer comparable air sealing and insulation performance to a full-depth (that is, 5.5") low density spray foam cavity at reduced first costs.
- Use framing techniques that decrease the amount of lumber in the wall, thereby allowing for more insulation in the wall cavities.

Windows

ENERGY STAR qualified windows are a good starting point for high performance homes. Specifying windows beyond this level may not be the most cost-effective application of energy efficiency dollars, depending on what other opportunities are available in other building systems. Based on product availability at the time of the design stage, the standard window installed had a U-factor of 0.32 to 0.35. Increasing the thermal performance of the windows (for example, to U=0.27 or U=0.28) came at a much higher cost per square foot than increasing the thermal performance of other parts of the building envelope.



Open partition framing at interior/exterior wall T-intersections allows for additional insulation

When large amounts of glazing faces south (in a heating dominated climate like New York State), look for the opportunity to use windows of equal U value as the other windows in the home but with a higher SHGC value. This step can help increase the contribution of passive solar heating to meet the home's heating load.

Since windows represent a "soft spot" in the building shell's thermal resistance, optimizing their extent can help energy performance. Unless it is possible to optimize the home's windows for beneficial solar gain, consider keeping window-to- wall area ratios at less than 20% to improve the envelope's overall thermal performance.

Air Sealing

Air sealing using spray foam in band joist (which will also be insulated with a fiberglass batt), and caulk and foam at penetrations and framing joints.

Attention to detail, proper sequencing, and clear assignments of responsibility are the keys to effective air sealing of the building shell. Various materials − such as caulk, spray foam, and sealed weather barrier systems − all have a role in air sealing. It can also be effective to strategically use spray foam for air sealing areas such as band joists, penetrations, and complicated framing details. It is critical to clearly assign responsibility for air sealing of specific assemblies or components, along with assuring the performance of these tasks at a point in the schedule when subsequent tasks by other trades will not damage air sealing efforts or create new leakage sites.

A standard air sealing package that shows good results for reasonable effort and cost includes

- using spray polyurethane foam (SPF) at the band joists for a critical air seal
- using caulk and/or SPF at all building shell penetrations
- using caulk or non-expanding foam around windows
- applying caulk to top plate penetrations

A more aggressive air sealing package would also include using SPF for a critical air seal in exterior wall cavities and floor bays over exterior space (for example, cantilevered bay windows, bonus room over garage); caulking gypsum to wall bottom plates for all partitions; and using exterior foam board insulation with taped seams.

With attention to detail, builders can reach high levels of air tightness, regardless of cavity insulation type. The air tightness of the seven Challenge homes ranged from 1.40-1.97 ACH 50. The homes used fiberglass batts, fiberglass batts + spray polyurethane foam, or spray polyurethane foam only in the wall cavities. All homes used spray polyurethane foam in the band joists, a problematic area for air leakage.

Builders should provide a critical seal for all IC-rated recessed lights in accordance with the 2009 IRC (which does not prohibit direct insulation contact) or eliminate recessed lights altogether. Also note that recessed lights can require more lumens to provide equivalent lighting to a space than does a typical light flush-mounted ceiling fixture.

If building a large volume of homes, consider conducting a diagnostic blower door test as soon as possible after installation of windows and doors on a representative home. This precaution could help identify air penetrations while there is still an opportunity to seal them and apply lessons learned to future homes.

HVAC

Builders should scrutinize the home’s Manual J load calculation. With an upgraded building envelope, chances are very good there will be an opportunity to significantly downsize equipment capacity. In homes with very well insulated and air-sealed envelopes, traditional heating equipment (boilers, furnaces) will often possess capacities much greater (as much as double) for the design heating load - even for the smallest unit sizes available. This consideration makes it important to assure that the equipment has good efficiency ratings at part-load conditions, and can encourage the use of two-stage or variable output systems. If design loads are low enough and the floor plan lends itself to this approach, non-centralized systems such as mini-splits may be used.

Smaller loads and small equipment will result in smaller duct sizes and lower air flows. This increases the importance of duct sealing to make sure of the delivery of conditioned air where it is intended to go. Therefore – even for ducts within conditioned space – use mastic to air-seal duct joints and seams. A reasonable target for total duct leakage is less than 10% of conditioned floor area when measured at 25 Pascals using a duct blaster test. Switching from 1) return air systems containing multiple returns with panned building cavities returns to 2) hard-ducted, central duct systems with jump ducts between bedrooms and central hallways proved to be a cost-effective change that also reduced duct system leakage. Room pressurization levels were well controlled by the jump ducts, even with bedroom doors closed and the central blower operating. Finding the space to run the return air trunk vertically through the first floor to the second floor return grille emerged as the main challenge with going to the central, hard-ducted return system.. In a multiple return system, returns are hidden inside wall cavities whereas the central, hard-ducted system requires a vertical chase to accommodate the larger trunk size. Builders accommodated this chase, but it would be easier to plan for this feature in the initial floor plan design phase than to re-design an existing floor plan.

Dual fuel heating systems, which use an air-source heat pump (ASHP) during moderate outdoor temperature conditions and a natural gas fired forced air furnace during cold outdoor conditions, can offer a good opportunity to reduce energy use, utility bills, and CO2 emissions while also satisfying consumer wishes for high delivery temperatures during cold weather. The monetary savings potential for dual fuel heating systems depends on the relative pricing of natural gas versus electricity. Analysts found the highest savings (compared with a furnace-only approach) in those areas with relatively cheap electric rates (< 8 cents/kWh) and gas rates around $1.20/therm or higher. Considering economics and emissions, the ideal switch-over outdoor dry bulb temperature for these systems was typically below 15 degrees F, although for comfort reasons, contractors generally elected to switch over around 38 deg degrees F.

Consider the use of a high efficacy whole house cooling fan, which can offset the air conditioning load of the compressor in the summer. For areas with modest cooling loads like much of New York State, this type of system can complement or potentially replace a traditional forced-air central A/C system. Effective operation of a whole house cooling fan, however, will require engaged residents who know to operate the system when outdoor conditions are cool and dry.

MECHANICAL VENTILATION

Whole house mechanical ventilation was very important for these well-sealed, tight Challenge homes. Therefore, whole-house mechanical ventilation systems meeting ASHRAE 62.2 were specified. Following this standard involved designing systems to meet requirements for minimum air flow rates, sound rating of fans, and system controls.

The majority of the homes used exhaust-based ventilation systems using high efficacy (ENERGY STAR rated) and quiet bath fans (< 1 sone). Despite the tight building shells, operation of these systems did not create significant depressurization levels. This outcome also indicates that fresh air was entering the building in response to the exhaust flow. Two of the homes used make-up air dampers as well, to aid in providing fresh air.

A few of the homes used HRV systems with heat exchange as well. While the HRV’s heat exchange capability was helpful in reducing the energy impact of ventilation air, it was a challenge to duct these systems for effective airflow and fresh air distribution. When using HRV to help deliver fresh air to the home, it is recommended that builders select properly sized, independent ducts for these systems (for example, not tying into the central duct system or into the regular cycling of the central air handler unit (which ideally has an ECM motor). . The cost increase for the HRV systems was also significant compared to exhaust-based systems.

Conducting air flow measurements of installed systems is highly recommended, both for whole-house ventilation and for bath exhaust fans. For some systems, good flow measurements are best acquired by installing a flow collar or similar device in-line with ducting when initially installing the system. Bath exhaust fans with larger 6” ducts were found to more reliably provide the nominal ventilation rate of the fan, compared to 4” ducted units. Straight and direct duct runs also proved to be crucial for installed systems to match design flow rates.

HOT WATER

High efficiency tankless hot water heaters can be used to achieve energy savings of roughly 30% compared to standard tank units. Tankless units eliminate standby losses, and units are available that still heat water at low flows. Some tankless units also make use of buffer tanks to prevent “cold plugs” which can result if hot water flow is briefly interrupted by turning off a fixture. Before committing to a tankless unit, however, builders should check the manufacturer’s requirements for upstream water softening or annual flushing of units. Depending on local water supply hardness, a manufacturer may require a water softener, a plug-in cartridge, and/or annual scale flush-out maintenance.

Centrally located, manifold-fed water delivery systems can speed the delivery of hot water through shorter runs and also reduce pipe diameters for dedicated supply lines.

Low-flow showerheads and faucets may also help to curb hot water demand.

LIGHTING & APPLIANCES

Builders should maximize the use of CFL lighting throughout the home. This lighting is typically the most cost-effective energy upgrade over standard systems in a new home. For fixtures on dimmer switches, builders should make sure to use a CFL rated for dimmable operation. For lights in exterior locations or other cold locations (such as a garage), note that CFL's light output declines at cold temperatures. Given this fact, consider using higher wattage CFLs in these applications. In extremely cold conditions (~ 0 F), some CFLs may not light. In such extreme climates, builders should seek CFLs rated to start at -20 F. In areas where the bulb might be broken, such as a workshop or an area where children play, recommend a light fixture that protects the bulb.

Select ENERGY STAR qualified appliances for the refrigerator and dishwasher. The use of ENERGY STAR bath fans is recommended where these fixtures are used for meet the whole house ventilation requirements of ASHRAE 62.2, and provide for quieter operation as well as lower energy consumption.

Section 4

UTILITY BILL ANALYSES

Utility bill data was collected for each home during a twelve month period after completion of construction. The charts below show the energy and dollar savings relative to each builder's typical practice, e.g. construction practice that meets or exceeds the requirements of the NYS Energy Conservation Construction Code 2007 and the NYS Residential Building Code 2007. Figure 4-1 illustrates the annual whole house energy savings of each builder's high performance home relative to the same home with its typical energy package (the reference home). To derive Figure 4-1, annual energy use for each reference home was estimated, using REM/Rate software. These results were then adjusted for the actual temperature conditions in each locale during the analysis period. The estimated annual energy use of each reference home was then compared with the high performance home's actual electricity and natural gas consumption over the analysis period. The results are shown on a Btu/square foot basis in order to provide a comparison across homes that account for differences in the homes'conditioned floor areas.

Three of the high performance homes (Rochester B, Buffalo B, and Capital Region A) were used as model homes during the entire analysis period. Because the energy use of model homes is managed differently than occupied homes, the results for these homes do not necessarily track with the owner occupied homes in this study. For example, the Buffalo B house actually had a higher annual energy use than the reference home, which is likely due to more lights being turned on for a longer time and to the models being kept warmer in the winter and cooler in the summer than a typical occupied home.

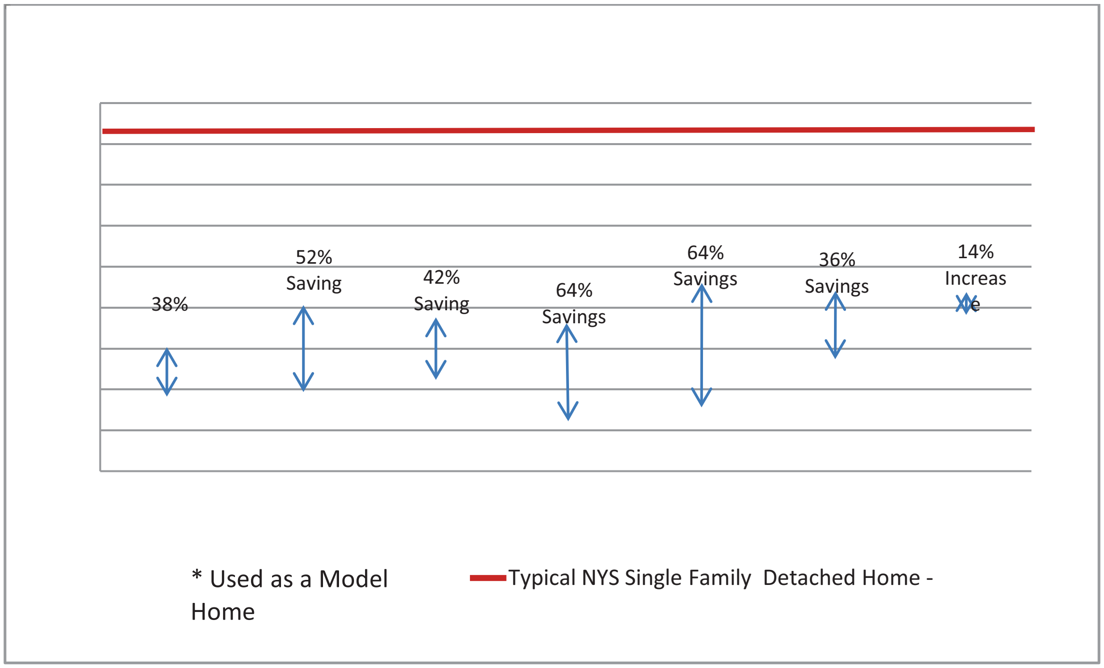


Figure 4-1 Annual Whole House Energy Use

Figure 4-2 shows the projected whole house energy savings relative to the builder's typical construction package in five year increments, out to 20 years. The projected savings are based on actual first year savings that are assumed to remain constant over time. Energy consumed at the site is reported rather than source energy. In most cases, at least one billion Btus per home could be saved over 20 years if new NY single family homes were constructed with energy packages equivalent to those used in these high performance homes. This is equivalent to approximately 293 thousand kWh or 10,000 therms of natural gas.

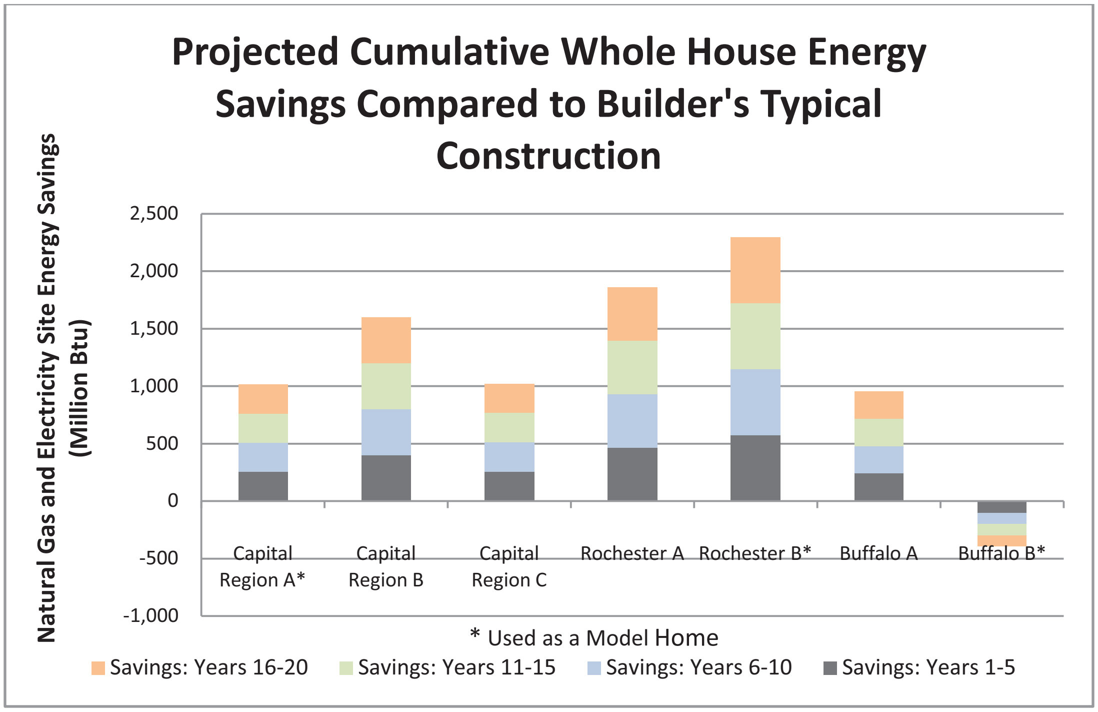


Figure 4-2 Projected Cumulative Whole House Energy Savings

The energy savings for each home were translated into cost savings using prices of $0.18/kWh for electricity and $1.52/therm for natural gas. These prices were based on year 2009 NY State average data from the U.S. Department of Energy's Energy Information Administration. Figure 4-3 shows projected cumulative dollar savings over 20 years relative to each builder's standard practice. Price escalation of 4% per year was assumed over the twenty year period.[17] The incremental construction costs for each builder are also indicated. In three of the seven homes, the added costs for the high performance energy packages are expected to be paid for in less than ten years. In two of the homes, the costs are offset in less than 20 years. As is indicated in this chart, the payback period for the high performance measures is not necessarily dependent upon the amount of additional first costs.

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[17] Historical annual escalation rates for NY residential retail prices of electricity and natural gas were 4.8% and 6.3% over the period 1970-2009, based on U.S. DOE EIA data.

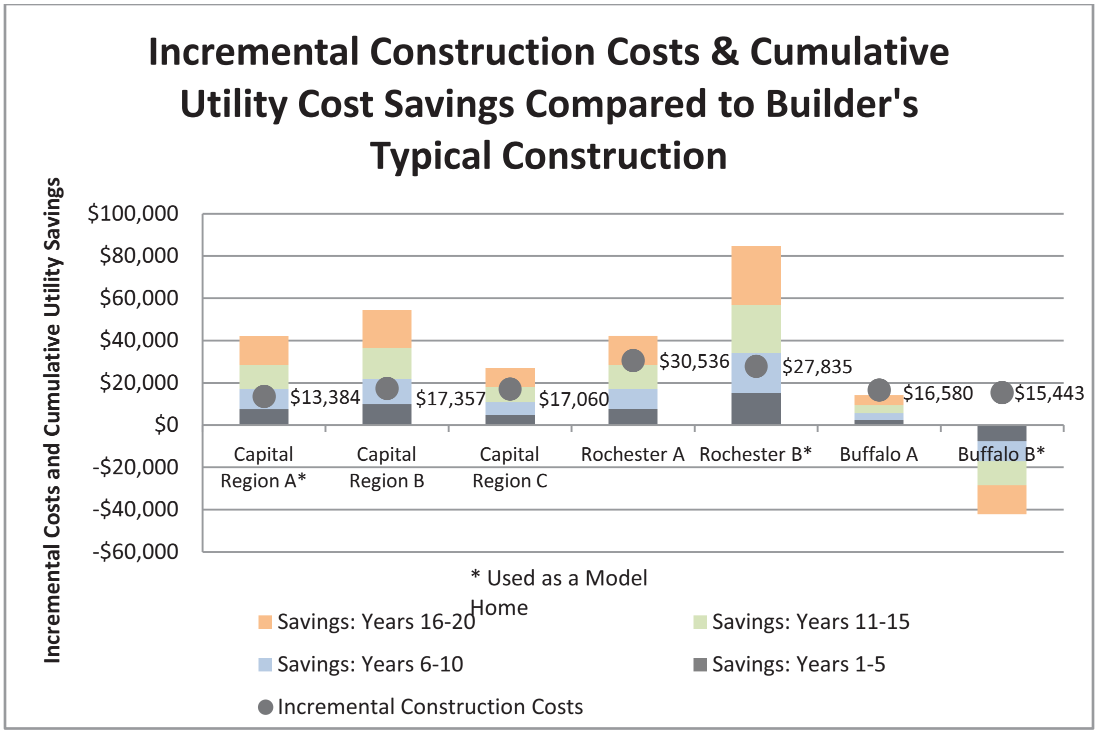

Figure 4-3 Incremental Construction Costs and Cumulative Energy Cost Savings

Section 5

BUILDER AND HOMEOWNER FEEDBACK

INTRODUCTION

Newport was tasked with conducting builder and homeowner (where possible) surveys for the seven high performance homes, to help determine the effectiveness of the techniques and technologies used in those homes. Below is a description of the methodology, as well as an analysis of survey results from each home. Figure 5-1 presents the Builder Survey Questionnaire; Figure 5-2 presents the Homeowner Survey Questionnaire.

Figure 5-1. Builder Survey Questionnaire

1. Compared to previous customers, please rate your customer's satisfaction with the NYSERDA project high performance house. (1=much less satisfied; 3= as satisfied; 5=much more satisfied).

   1 2 3 4 5

2. Please indicate which of the following technologies/systems you are likely to use in future homes. *[Interviewer: if answer to any of the following is yes, probe for reasons]*

Heating/Cooling

- High efficiency gas/propane furnace (90 AFUE or higher)
- Ground source heat pump
- High efficiency air-source heat pump (≥15 SEER)
- Dual fuel heat pump/furnace system
- In-floor hydronic radiant heating
- Central air handlers with ECM motors

Whole-Building Mechanical Ventilation

- Heat recovery ventilators (HRVs)
- High efficiency exhaust fans for whole-house ventilation
- Supply ventilation tied into the central air handler

Ducts

- Conditioned space duct systems
- Hard-ducted return ducts
- Ducts sealed with mastic

Hot Water

- ENERGY STAR rated tank water heaters
- Tankless water heaters

Renewables

- PV
- Solar hot water systems
- Wind turbines

Building Envelope

- 2x6 exterior wall construction
- Double-wall construction
- R-20 or greater basement wall insulation
- Exterior foam insulation
- Insulated vinyl siding
- ENERGY STAR rated windows
- High performance windows ($U \leq 0.25$)

Appliances and Lighting

- ENERGY STAR appliances
- CFL lighting
- LED lighting

3. For those technologies or techniques you do not plan on using in the future, which of these factors are reasons?
   a) there is not enough market demand
   b) would add too much cost
   c) would complicate other parts of the house too much
   d) the appraisal wouldn't value the upgrades
   e) it is hard to market energy efficiency
   f) not sure how to design the system

4. Please rate level of difficulty in using the building technologies and techniques for this project compared to your typical approach on other homes. Was the High Performance Home easier or more difficult (1= much more difficult; 3= same difficulty as usual; 5= much easier).

   1 2 3 4 5

5. What percent of the energy efficient technologies and techniques used in this project are you likely to use again?

   0%-25%

   26%-50%

   51%-75%

   75%-100%

6. Please compare the training needed to use new energy efficient technologies to the training needed to use other new building products. (1= much more training needed; 3= about the same amount of training; 5= much less training needed).

   1 2 3 4 5

7. Overall, has participating in the High Performance Homes project made it more likely that you will build more efficient homes in the future?
   - Yes – very likely
   - Maybe
   - No – not very likely

Figure 5-2. Homeowner Survey Questionnaire

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

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

1 2 3

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

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

A few questions about comfort and energy efficiency

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

1 2 3

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

1 2 3

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

1 2 3

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

1 2 3

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

1 2 3

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

1 2 3

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

1 2 3

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

1 2 3

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

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

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

Increased energy efficiency in a new home makes sense if the energy cost savings can pay for the added up-front costs on a monthly basis.

- ○ Agree
- ○ Disagree
- ○ Not sure

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

- ○ Agree
- ○ Disagree
- ○ Not sure

Increasing energy efficiency, even beyond the point where it pays for itself on a monthly basis, makes sense because of other benefits like indoor air quality and durability.

- ○ Agree
- ○ Disagree
- ○ Not sure

If I were to purchase another new home in the future, I would make the energy features of the home a high priority in the purchasing decision.

- ○ Agree
- ○ Disagree
- ○ Not sure

METHODOLOGY AND STRUCTURE

The overall objective of the surveys was to characterize the reactions and impacts for both the builders and residents of the high performance homes constructed under NYSERDA High Performance Residential Development Challenge (HPRDC) project. Newport Ventures administered the surveys by phone when possible, substituting e-mail surveys on request of the builder or homeowner due to scheduling constraints.

Questions in the builder survey were targeted at:

- determining their satisfaction with the project
- their impressions of their customers' satisfaction with the high performance features
- the level of difficulty and the learning curve associated with using the new technologies and practices in the project
- what parts of the project they are likely to use in future homes.

Questions in the homeowner survey covered:

- the homeowner’s satisfaction with the overall home
- the specific benefits from the project, such as comfort, performance, and cost savings
- the homeowner's understanding of the technologies used in the home
- the homeowner's likelihood to buy energy efficient homes in the future

In the cases of the Viola home, one of the two Marrano homes and the Belmonte home, the homes were being used as model homes, with no homeowner to survey. For the Gerber home, the homeowner only lived at the home seasonally. Despite repeated attempts to contact this homeowner, Newport was unable to do so in a timely matter for inclusion in this report.

Viola Homes

Figure 5-3. Viola Homes Builder Survey Summary

Technologies Likely to be Used in Future Homes			
Technology	Likely to be Used in Future Homes	Used in This Home	Currently Used in Builder's Typical Homes
Heating/Cooling			
High efficiency gas/propane furnace (90 AFUE or higher)	✓	✓	✓
Ground source heat pump	🟥	🟥	🟥
High efficiency air-source heat pump (≥15 SEER)	🟥	🟥	🟥
Dual fuel heat pump/furnace system	✓	🟥	🟥
In-floor hydronic radiant heating	✓	🟥	🟥
Central air handlers with ECM motors	✓	🟥	🟥
Whole-Building Mechanical Ventilation			
Heat recovery ventilators (HRVs)	✓	✓	🟥
High efficiency exhaust fans	🟥	🟥	🟥
Supply ventilation tied into the central air handler	✓	✓	🟥
Ducts			
Conditioned space duct systems	✓	✓	sometimes
Hard-ducted return ducts	✓	🟥	🟥
Ducts sealed with mastic	🟥	✓	✓
Hot Water			
ENERGY STAR rated tank water heaters	✓	🟥	sometimes
Tankless water heaters	✓	✓	🟥
Renewable Energy			
PV	Unsure	🟥	🟥
Solar hot water systems	Unsure	🟥	🟥
Wind turbines	Unsure	🟥	🟥
Building Envelope			
2x6 exterior wall construction	✓	✓	🟥
Double-wall construction	🟥	🟥	🟥
R-20 or greater basement wall insulation	✓	✓	🟥
Exterior foam insulation	✓	✓	🟥

Insulated vinyl siding	🟥	🟥	🟥
ENERGY STAR rated windows	✓	✓	✓
High performance windows (U≤ 0.25)	✓	🟥	🟥
Appliances & Lighting			
ENERGY STAR appliances	✓	✓	✓
CFL lighting	✓	✓	🟥
LED lighting	✓	🟥	🟥

Builder Responses Viola Homes' responses to the builder survey indicated the company's openness to a wide variety of energy efficient and high performance technologies, including some that were not incorporated into the Viola Challenge home. The company expects to use more than half of the technologies and strategies from this project in future homes, and to continue building energy efficient homes in the future.

As Figure 5-3 shows, upgrades to Viola's standard building practices used in this home that they plan to continue in the future include an HRV ventilation system, ducts in conditioned space, a tankless gas water heater, insulation and wall upgrades, and lighting upgrades. Of the technologies used in this home, Viola identified duct mastic as unlikely to be used again. Viola was unsure about using on site generation in future products, but recommended evacuation tubes for solar hot water as opposed to flat panels; and suggested that WindTamer was the only wind turbine they would use.

Viola impediments to energy efficient technologies or strategies that Viola cited included lack of market demand, added cost, difficulty in obtaining the necessary appraisal value, difficulty in marketing, and design difficulties. They indicated, however, that the building process for this home had the same level of difficulty as other homes that they have built, and the staff required about the same amount of training for using the new technologies as for other new building products.

Homeowner Responses. This project was a model home, and therefore no homeowner was surveyed.

Gerber Homes

Figure 5-4. Gerber Builder Survey Summary

Technologies Likely to be Used in Future Homes			
Technology	Likely to be Used in Future Homes	Used in this Home	Currently Used in Builder’s Typical Homes
Heating/Cooling			
High efficiency gas/propane furnace (90 AFUE or higher)	✓	🟥	✓
Ground source heat pump	✓	✓	🟥
High efficiency air-source heat pump (≥15 SEER)	✓	🟥	🟥
Dual fuel heat pump/furnace system	✓	🟥	🟥
In-floor hydronic radiant heating	🟥	🟥	🟥
Central air handlers with ECM motors	✓	🟥	🟥
Whole-Building Mechanical Ventilation			
Heat recovery ventilators (HRVs)	✓	✓	🟥
High efficiency exhaust fans	✓	🟥	🟥
Supply ventilation tied into the central air handler	✓	✓	🟥
Ducts			
Conditioned space duct systems	✓	✓	sometimes
Hard-ducted return ducts	🟥	🟥	🟥
Ducts sealed with mastic	✓	✓	✓
Hot Water			
ENERGY STAR rated tank water heaters	✓	🟥	sometimes
Tankless water heaters	✓	✓	🟥
Renewable Energy			
PV	🟥	🟥	🟥
Solar hot water systems	🟥	🟥	🟥
Wind turbines	🟥	🟥	🟥
Building Envelope			
2x6 exterior wall construction	🟥	🟥	🟥
Double-wall construction	🟥	🟥	🟥
R-20 or greater basement wall insulation	🟥	✓	🟥
Exterior foam insulation	🟥	✓	🟥
Insulated vinyl siding	✓	🟥	🟥
ENERGY STAR rated windows	✓	✓	✓

High performance windows (U≤ 0.25)	✓	🟥	🟥
Appliances & Lighting			
ENERGY STAR appliances	✓	✓	✓
CFL lighting	✓	✓	🟥
LED lighting	🟥	🟥	🟥

Builder Responses. Gerber Homes was open to using energy efficient technologies in the future, including some mechanical systems that were not used for this project. The builder reported that they expect to use more than half of the technologies and strategies from the Gerber Challenge home in future projects, and are likely to continue building energy efficient homes.

Upgrades not commonly included in Gerber's standard homes, that were used in the Challenge home and are likely to be used again, include ground source heat pump, HRV and other ventilation strategies, ducts in conditioned space, a tankless gas water heater, and upgraded lighting (see Figure 5-4). The builder had no interest in on site generation. Gerber said they would not continue to use the insulation upgrades from this project. These upgrades included basement insulation and exterior foam on above grade walls. Nevertheless, Gerber indicated that they would be using spray foam insulation in the cavity as an alternative to exterior foam. Gerber's responses indicated that they were more open to changes on mechanical systems than they were to changes in the walls.

As deterrents to the implementation of energy efficient technologies and strategies, Gerber listed added cost and lack of market demand, but indicated that the level of difficulty and the training needed to adapt to these products was no higher than usual.

Homeowner Responses. The Gerber home was purchased by a homebuyer, but is only seasonally occupied. Despite numerous attempts by Newport to contact the owner, there was no response. In order to give timely results of the project, the survey analysis was completed without responses from this owner. Nevertheless, Gerber's impression was that this customer's satisfaction level in the final product was the same level as Gerber's previous customers.

Stewart Construction

Figure 5-5. Stewart Builder Survey Summary

Technologies Likely to be Used in Future Homes			
Technology	Likely to be Used in Future Homes	Used in this Home	Currently Used in Builder's Typical Homes
Heating/Cooling			
High efficiency gas/propane furnace (90 AFUE or higher)	✓	✓	✓
Ground source heat pump	🟥	🟥	🟥
High efficiency air-source heat pump (≥15 SEER)	✓	🟥	🟥
Dual fuel heat pump/furnace system	✓	✓	🟥
In-floor hydronic radiant heating	🟥	🟥	🟥
Central air handlers with ECM motors	✓	🟥	🟥
Whole-Building Mechanical Ventilation			
Heat recovery ventilators (HRVs)	✓	🟥	🟥
High efficiency exhaust fans	🟥	✓	🟥
Supply ventilation tied into the central air handler	✓	🟥	🟥
Ducts			
Conditioned space duct systems	✓	✓	sometimes
Hard-ducted return ducts	🟥	🟥	🟥
Ducts sealed with mastic	✓	✓	✓
Hot Water			
ENERGY STAR rated tank water heaters	✓	🟥	sometimes
Tankless water heaters	🟥	✓	🟥
Renewable Energy			
PV	✓	🟥	🟥
Solar hot water systems	✓	🟥	🟥
Wind turbines	🟥	🟥	🟥
Building Envelope			
2x6 exterior wall construction	✓	✓	✓
Double-wall construction	🟥	🟥	🟥
R-20 or greater basement wall insulation	🟥	✓	🟥
Exterior foam insulation	✓	✓	🟥
Insulated vinyl siding	🟥	✓	🟥
ENERGY STAR rated windows	✓	✓	✓

High performance windows (U≤ 0.25)	✓	🟥	🟥
Appliances & Lighting			
ENERGY STAR appliances	✓	✓	sometimes
CFL lighting	✓	✓	🟥
LED lighting	🟥	🟥	🟥

Builder Responses. Stewart Construction expressed general openness to energy efficient technologies – mostly those that they tried in this project. They expect to use more than half of the technologies and strategies from this project in future homes and are very likely to continue building energy efficient homes.

Upgrades to their standard building practices used in the Stewart Challenge home, that they are likely to use again, include a dual fuel heat pump, ducts in conditioned space, exterior foam insulation, and lighting upgrades (see Figure 5.5).

Stewart also mentioned several upgrades used in this project that they were not likely to use again, including an energy efficient exhaust fan, tankless gas water heater, insulated vinyl siding, and basement insulation upgrades. Still, they did indicate they would likely use an HRV ventilation system instead of an exhaust fan.

Obstacles in implementing energy efficient technologies and strategies included lack of market demand, added cost, and achieving adequate appraisal value. Stewart indicated that this project presented a difficulty level equal to their standard homes. They found, however, that the training required for their new technologies was actually less than normal for new building products.

Homeowner Responses. The Stewart Challenge home was the second home purchased by the homeowners, who claimed much better performance out of this home than previous houses in which they had lived. The owners were most pleased with the lower utility bills, finding them to be much lower than expected. The homeowners felt that they were well informed about the energy efficient features of the home upon purchase.

The homeowners reported complete satisfaction and comfort related to all aspects of the home (HVAC, air sealing, lighting) except hot water for which they claimed only reasonable satisfaction. The owners noted that the hot water seemed to take longer than expected to get upstairs. Stewart also indicated that they would not use the tankless gas water heater again, but did not mention that this was due to a performance issue.

The owners' favorite components of the home included the HVAC system, the exterior foam insulation, and the lighting. The dual fuel heat pump system was not something the builder used in the standard home, and was noted as something they were likely to use again. Similarly both the builder and the owner had good impressions of the exterior foam insulation.

Although the homeowners liked the lower utility costs and agreed that adding efficiency makes sense if the up-front costs can be paid for by energy savings, they also saw additional benefits of energy efficiency. They agreed that side benefits, such as noise mitigation and indoor air quality, were additional benefits of energy efficiency and that these quality aspects, as well as durability, are reasons to increase efficiency even beyond what you can save on a monthly cash flow basis. They indicated that energy efficiency would be a high priority in future home purchasing decisions. Stewart agreed that the homeowner had a higher level of satisfaction than previous customers.

Rosewood Homes

Figure 5-6. Rosewood Builder Survey Summary

Technologies Likely to be Used in Future Homes			
Technology	Likely to be Used in Future Homes	Used in this Home	Currently Used in Builder's Typical Homes
Heating/Cooling			
High efficiency gas/propane furnace (90 AFUE or higher)	✓	✓	✓
Ground source heat pump	🟥	🟥	🟥
High efficiency air-source heat pump (≥15 SEER)	✓	🟥	🟥
Dual fuel heat pump/furnace system	✓	✓	🟥
In-floor hydronic radiant heating	🟥	🟥	🟥
Central air handlers with ECM motors	✓	✓	🟥
Whole-Building Mechanical Ventilation			
Heat recovery ventilators (HRVs)	✓	🟥	🟥
High efficiency exhaust fans	✓	✓	✓
Supply ventilation tied into the central air handler	✓	🟥	🟥
Ducts			
Conditioned space duct systems	✓	✓	sometimes
Hard-ducted return ducts	✓	🟥	🟥
Ducts sealed with mastic	✓	✓	✓
Hot Water			
ENERGY STAR rated tank water heaters	✓	🟥	sometimes
Tankless water heaters	✓	✓	🟥
Renewable Energy			
PV	🟥	🟥	🟥
Solar hot water systems	🟥	🟥	🟥
Wind turbines	🟥	🟥	🟥
Building Envelope			
2x6 exterior wall construction	✓	✓	✓
Double-wall construction	🟥	🟥	🟥
R-20 or greater basement wall insulation	🟥	✓	🟥

Exterior foam insulation	🟥	✓	🟥
Insulated vinyl siding	✓	🟥	🟥
ENERGY STAR rated windows	✓	✓	✓
High performance windows (U≤ 0.25)	🟥	🟥	🟥
Appliances & Lighting			
ENERGY STAR appliances	✓	✓	sometimes
CFL lighting	✓	✓	🟥
LED lighting	🟥	🟥	🟥

Builder Responses. Rosewood Home Builders was moderately open to energy efficiency moving forward, citing some technologies that it would likely use in the future (see Figure 5-6). Rosewood expects to use less than 25% of the technologies from this project in future homes. The explanation was that, while the project allowed it to develop a package with reasonable costs, customers would still pull options out of the whole package and choose what they specifically wanted in the home. The builder listed this as the biggest deterrent to energy efficient technology – people ask for energy efficiency, but opt for counter tops when they learn the cost. Rosewood did not think its customers thought about long term savings enough to appreciate utility bill savings over time.

Upgrades not used in Rosewood's standard homes, that were part of the Rosewood Challenge home and are likely to be used again, include a dual fuel heat pump, an air handler with an ECM motor, ducts in conditioned space, a tankless gas water heater, and lighting upgrades.

Rosewood indicated that it was unlikely to replicate the upgrades to the basement insulation or exterior foam insulation, which were used in the high performance home. The builder also had no interest in on site generation for future homes.

Although Rosewood found the construction process for this project more difficult, it reported needing the same amount of training for its staff as it would with other new building products.

Homeowner Responses. This Stewart Challenge home was the third house purchased by the homeowners. The aspect of the home they were most pleased with was the lowered utility bills. The homeowners said the utility bills were as expected, and that they were well informed about the energy efficient features of the house upon purchase. The owners were completely satisfied with all technologies and comfort levels in the home and specifically mentioned the hot water system (tankless gas water heater) as "awesome." They had nothing but good things to say about the home and recognized the comfort, lack of drafts, and overall aesthetic design as impressive features of the home. Rosewood agreed that its customer had a higher level of satisfaction than previous buyers.

Similar to the owners of the Stewart Challenge home, this homeowner agreed that added benefits of energy efficiency, such as indoor air quality, quiet, and durability, were substantial. The homeowner also indicated that these benefits were reasons to increase efficiency beyond a simple cash flow savings basis. The owners were likely to make energy efficiency a priority in any future home purchase.

Marrano Homes

Figure 5-7. Marrano Builder Survey Summary

Technologies Likely to be Used in Future Homes			
Technology	Likely to be Used in Future Homes	Used in this Home	Currently Used in Builder's Typical Homes
Heating/Cooling			
High efficiency gas/propane furnace (90 AFUE or higher)	✓	✓	✓
Ground source heat pump	🟥	🟥	🟥
High efficiency air-source heat pump (≥15 SEER)	🟥	🟥	🟥
Dual fuel heat pump/furnace system	🟥	🟥	🟥
In-floor hydronic radiant heating	🟥	🟥	🟥
Central air handlers with ECM motors	🟥	🟥	🟥
Whole-Building Mechanical Ventilation			
Heat recovery ventilators (HRVs)	✓	✓	🟥
High efficiency exhaust fans	✓	✓	🟥
Supply ventilation tied into the central air handler	✓	✓	🟥
Ducts			
Conditioned space duct systems	✓	✓	🟥
Hard-ducted return ducts	✓	✓	🟥
Ducts sealed with mastic	✓	✓	✓
Hot Water			
ENERGY STAR rated tank water heaters	✓	🟥	sometimes
Tankless water heaters	✓	✓	🟥
Renewable Energy			
PV	✓	✓	🟥
Solar hot water systems	✓	🟥	🟥
Wind turbines	✓	🟥	🟥
Building Envelope			
2x6 exterior wall construction	✓	✓	🟥
Double-wall construction	🟥	🟥	🟥
R-20 or greater basement wall insulation	🟥	✓	🟥
Exterior foam insulation	✓	✓	🟥
Insulated vinyl siding	✓	✓	🟥
ENERGY STAR rated windows	✓	✓	✓

High performance windows (U≤ 0.25)	🟥	🟥	🟥
Appliances & Lighting			
ENERGY STAR appliances	✓	✓	✓
CFL lighting	✓	✓	🟥
LED lighting	🟥	🟥	🟥

Builder Responses. As Marrano Homes built two homes under this project – Marrano Challenge home #1 and Marrano Challenge home #2 − analysts combined their survey answers into one set. Since one was a model home, only one homeowner was surveyed. Marrano was open to energy efficient technology and strategies and said that they were very likely to build energy efficient homes in the future. Figure 5-7 shows a wide variety of technologies that Marrano expects to use in future homes.

Upgrades from this project, not in Marrano's standard homes, that they were likely to use again included an HRV for whole-house ventilation as well as other ventilation solutions, ducts in conditioned space and hard-ducted returns, a tankless water heater, PV, a 2x6 wall, exterior foam, insulated vinyl siding, and lighting upgrades. Marrano said that they were unlikely to use basement insulation upgrades in the figure, citing cost and lack of market demand as significant barriers to the use of energy efficient technologies and strategies, with cost being the biggest deterrent. Nevertheless, Marrano felt that both the level of difficulty and the level of training needed for this project were equal to other projects.

Homeowner Responses. The occupied Marrano home was the third home that the buyers had purchased. Matching the other homeowners surveyed, they indicated that lower utility costs as the aspect of the home with which they were most pleased. They said these utility costs were lower than expected and that they felt reasonably informed about the energy efficient features of the home upon purchase.

The owners were completely satisfied with the technologies and comfort of the home and indicated that their utility bills were much lower than expected. Marrano judged the customer's satisfaction level as much higher than previous customers. The technologies they liked the most were the ventilation system and the varying stages of the furnace. Similar to the previous homeowners surveyed for this report, these owners agreed with the existence of additional benefits tied to energy efficiency and considered them a reason to increase efficiency beyond a simple cash flow savings basis. They said they were likely to make energy efficiency a high priority in future purchasing decisions.

Belmonte Builders

Figure 5-8. Belmonte Builder Survey Summary

Technologies Likely to be Used in Future Homes			
Technology	Likely to be Used in Future Homes	Used in this Home	Currently Used in Builder's Typical Homes
Heating/Cooling			
High efficiency gas/propane furnace (90 AFUE or higher)	✓	✓	✓
Ground source heat pump	🟥	🟥	🟥
High efficiency air-source heat pump (≥15 SEER)	🟥	✓	🟥
Dual fuel heat pump/furnace system	🟥	✓	🟥
In-floor hydronic radiant heating	✓	🟥	🟥
Central air handlers with ECM motors	✓	🟥	🟥
Whole-Building Mechanical Ventilation			
Heat recovery ventilators (HRVs)	✓	✓	🟥
High efficiency exhaust fans	🟥	🟥	🟥
Supply ventilation tied into the central air handler	✓	✓	🟥
Ducts			
Conditioned space duct systems	✓	✓	sometimes
Hard-ducted return ducts	✓	🟥	🟥
Ducts sealed with mastic	✓	🟥	🟥
Hot Water			
ENERGY STAR rated tank water heaters	✓	🟥	sometimes
Tankless water heaters	✓	✓	🟥
Renewable Energy			
PV	🟥	🟥	🟥
Solar hot water systems	🟥	🟥	🟥
Wind turbines	🟥	🟥	🟥
Building Envelope			
2x6 exterior wall construction	✓	✓	✓
Double-wall construction	🟥	🟥	🟥
R-20 or greater basement wall insulation	🟥	✓	🟥
Exterior foam insulation	🟥	✓	🟥
Insulated vinyl siding	🟥	✓	🟥
ENERGY STAR rated windows	✓	✓	✓

High performance windows (U≤ 0.25)	🟥	🟥	🟥
Appliances & Lighting			
ENERGY STAR appliances	✓	✓	✓
CFL lighting	✓	✓	🟥
LED lighting	🟥	🟥	🟥

Builder Responses. Since the Belmonte home was a model home, the builder was not able to give an estimate on the customer satisfaction level. Nevertheless, Belmonte said that its prospective buyers at open houses displayed a high level of interest in the energy efficiency of the home. Belmonte was open to some energy efficient technologies and strategies, but indicated that only up to a quarter of the technologies from this home were likely to be used in future homes.

Upgrades in this project that had not been included in Belmonte's standard homes, but that the company felt it is likely to use again, included an HRV and other ventilation systems, ducts in conditioned space, a tankless gas water heater, and lighting upgrades.

Upgrades that the builder considered were not likely to be used again included the dual fuel heat pump system, basement insulation upgrades, exterior foam insulation, and insulated vinyl siding. Belmonte had no interest in on site generation.

Belmonte indicated that lack of market demand was the biggest barrier to energy efficiency in homes, followed by cost, and then by marketing difficulties. The company found the process of incorporating high performance systems more difficult and time consuming for staff training than on other projects.

Homeowner Responses. This project was a model home. Therefore there was no homeowner to survey.

CONCLUSIONS

All builders participating in the project identified technologies and strategies that they were likely to use in future homes, and all homeowners interviewed indicated a high level of satisfaction with the final product.

Of the upgrades made during this project, the most common technologies listed as likely to be used again were:

- ducts in conditioned space (all builders)
- tankless gas water heaters
- heat recovery ventilator (HRV) ventilation systems
- CFL lighting (all builders).

The only builder that would not continue the tankless gas water heater was Stewart. Of the three homes that used dual fuel furnaces, two of the three builders were likely to use them again. Of the one home that used a ground source heat pump, that builder was likely to use one again. Exterior foam insulation was high on the list of upgrades to be repeated, but was also not likely to be continued by two builders. Of the upgrades not likely to be continued, basement wall insulation of R-20 or greater was the most common cut.

The technologies that received specific praise from homeowners included the tankless gas water heater, the two-stage feature of the high efficiency gas furnace, exterior foam insulation, and spray foam insulation. The homeowners' comparisons to previous homes were always favorable and builders' impressions were that their customers were more satisfied than in previous homes. The homeowners all recognized added comfort, quality, durability, and a better living environment as additional benefits to living in energy efficient homes.

Section 6

FOR MORE INFORMATION

For more information on this case study and NYSERDA's High Performance Residential Development Challenge (HPRDC) program please contact Newport Ventures at 518-377-9410.

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