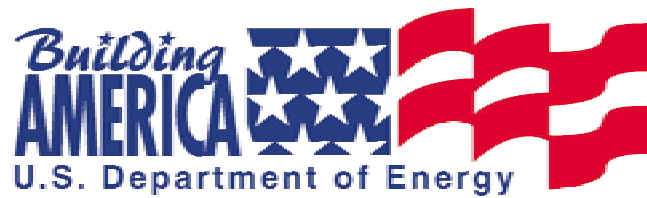


Building America IBACOS Consortium



Conference or Journal Paper: Results from Community-Scale Projects

Report Prepared For:
U.S. Department of Energy
National Renewable Energy Laboratory

Task #: KAR-8-18608-17.A.4

Report Prepared By:
Duncan Prahel and Eric Newhouse
IBACOS, Inc.
(IBACOS, Inc. is the managing organization of the Building America IBACOS Consortium.)

Date: January 31, 2003

NOTICE: Neither the United States government nor any agency thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States government or any agency thereof.

The information contained within this report is the property of The Department of Energy and IBACOS and may not be reproduced or used without written permission.

Integrated Building and Construction Solutions

*IBACOS, Inc.
2214 Liberty Avenue
Pittsburgh, PA 15222-4502
412.765.3664
Fax 412.765.3738*

Building America Program Overview



The Building America Program is an industry-driven, cost-shared program sponsored by the U.S. Department of Energy (DOE) through the National Renewable Energy Laboratory for applying systems engineering approaches that accelerate the development and adoption of innovative building processes and technologies. The goal of the program is to produce energy-efficient, environmentally sensitive, affordable and adaptable residences on a community scale.



The Building America teams bring together all segments of the housing industry (designers, builders, developers, financial institutions, material suppliers and equipment manufacturers). These industry groups have traditionally worked independently of one another, slowing development and adoption of new technologies. By working together using a systems engineering approach, decisions previously made independently can quickly be made with consideration for the entire design, manufacturing and construction process, thereby increasing quality and performance without increasing cost.



In 1993, Building America's first phase established a partnership between DOE and the IBACOS (Integrated Building and Construction Solutions) consortium. These reports are in partial fulfillment of Innovative Building Technologies, Advanced Systems Development and Testing—a program between IBACOS and the National Renewable Energy Laboratory Division of Midwest Research Institute.

Contents

Abstract	1
Summerset at Frick Park: Overview	1
<i>The Creation of Performance Standards</i>	1
<i>Development Team Objectives and Criteria for Housing</i>	2
<i>Education and Compliance Verification</i>	3
Description of House Types	4
<i>Cottage Homes</i>	4
<i>Estate Homes</i>	5
<i>Rental Town Homes</i>	6
High Performance Building Strategies	8
<i>Framing Systems</i>	11
<i>Foundation Systems</i>	12
<i>Envelope Air Barrier Systems</i>	17
<i>Mechanical Ventilation Systems</i>	21
<i>Thermal Envelope Systems</i>	22
<i>Mechanical Equipment and Duct Systems</i>	23
Repercussions of Building Performance Standards	28
<i>Is a single standard practical for a wide range of building sizes?</i>	28
Analysis of Energy Consumption, Rating Score, and House Size	
<i>Shell Area and Occupancy Factors</i>	33
<i>Methodology for Calibrating Rating Score to House Size and Occupancy</i>	35
<i>Conclusion</i>	49
References	50
Appendix A	51

Abstract

Abstract

Summerset at Frick Park is a master planned community development in Pittsburgh, PA, which incorporates various sized single-family and multifamily dwelling units. The master developer has implemented a set of housing performance standards created by IBACOS that all builders must follow. These standards cover topic areas such as improved energy performance, detailing for moisture control and long term durability, and provisions to help maintain good indoor air quality. IBACOS has been working to perform design integration and systems engineering for the various builders at Summerset. The different approaches taken, the rationale behind the approaches, and the results will be described in this paper. Three housing types will be discussed: smaller single-family homes being built by Summerset Cottage Associates, multifamily rental town house units being built by Mistick Construction, and large custom homes being built by Roger Glunt. Each of these builders has taken a slightly different approach to meeting the performance standards. The strategies discussed in this paper will include: framing systems to facilitate fully ducted supply and return air distribution systems, insulated conditioned crawlspaces and basements, overall building envelope air tightening, controlled mechanical ventilation, achieving higher insulation levels, and high performance heating and air conditioning systems (equipment and distribution systems). Finally, an analysis of Home Energy Rating (HERS) scores compared with house size will be presented, with a proposed methodology for normalizing energy ratings with house size for use in master planned communities with a wide range of house sizes and for use with Green Building Programs that wish to include house size as a factor in their point systems. The use of a single point score as a threshold of performance is on the surface a simple and equitable standard. As the housing industry is maturing to evaluate not simply the relative energy efficiency of housing but the total environmental impact, new methods for defining performance and encouraging lower energy and resource use are necessary. Duncan Prahl will present the details of this report at the Greenprints Conference in February of 2003.

Summerset at Frick Park: Overview

Summerset at Frick Park: Overview

Summerset at Frick Park, a planned new landmark community of over 700 homes located 3 miles from downtown Pittsburgh, is transforming an abandoned slag heap into a new traditional neighborhood overlooking reforested hillsides, the riverfront, and an expanded city park system. The 244-acre brownfield site is the largest parcel of undeveloped land in the city of Pittsburgh, and is the first large-scale residential development to occur within the city of Pittsburgh in 30 years. The developer is Summerset Land Development Associates (SLDA), which is a partnership of The Rubinoff Company, Montgomery & Rust, Inc., Pennrose Falbo Associates, and EQA Landmark Communities. The housing being built in the project consists of various sized single-family homes, attached for-sale town house units, rental town houses and multifamily rental apartments.

IBACOS has been working with the development team over the past several years to create an overall process by which higher performance housing is realized in all housing types built at Summerset, and to assess the ways in which master planned community developers can regulate the quality, and performance of the housing that is built in their community.

IBACOS has identified three fundamental activities that need to be implemented within a master planned community: the creation of performance standards, the education process with the designers and builders, and the compliance verification process to assure the performance standards are being met. Without the implementation of any one of these activities, it is unlikely that the developer can ensure that higher performance homes are being built within their community. The following sections outline an overview of the activities undertaken at Summerset that laid the groundwork for the specific construction solutions that are discussed in this report. More detail on the community development-related activities that have been implemented at Summerset has been documented by IBACOS (2001).

The Creation of Performance Standards

As a first step in the path to higher performance housing at Summerset, IBACOS worked with the development team to create a set of performance standards that all housing will be required to meet. As single-family homes are the predominant building

Summerset at Frick Park: Overview

type in this particular community, the primary focus was to create standards for this building type. As is discussed in the sections on the specific strategies for the Rental Town Homes, certain adjustments to the standards for first cost reasons were needed; however, to date all single-family detached homes and for-sale town home units are being built according to the same set of performance standards.

Development Team Objectives and Criteria for Housing

In order to communicate the intent and specifics of the performance requirements at Summerset, IBACOS supported the development team in the creation of the Summerset Home Performance Standards. The development team classified objectives and criteria for the project. These were listed in the Home Performance Standards as follows:

The Home Performance Standards for Summerset at Frick Park were created to ensure one of the core values of Summerset is achieved: provide high quality homes for the residents. High quality construction for Summerset at Frick Park is defined to embody the following qualitative objectives:

- Improve occupant comfort
- Conserve energy and natural resources
- Increase building durability
- Improve occupant health and safety

The Summerset Home Performance Standards have been developed based on a study of traditional construction methods used in the Pittsburgh region. The intent has been to define criteria that will significantly improve the quality of the homes at Summerset, and create standards to assure those criteria are met. To that end, careful consideration has been given to the following criteria:

1. Water management and exterior drainage plane, for control of storm water conditions.
2. Air barrier systems, to control high exchange rates of indoor air for outside air and the movement of moisture through construction assemblies.
3. Thermal insulation and interior moisture management, to establish a durable, well-insulated shell that improves occupant comfort and controls heat loss.
4. Mechanical systems and indoor air quality, to ensure comfortable and efficient space conditioning and integration of fresh air for the occupants.

Summerset at Frick Park: Overview

5. Lighting and communications, to ensure high quality and efficient lighting strategies and adequate ability to benefit from current and future communications technology.

From these five criteria, the following performance standards were developed:

- Site and buildings designed to minimize percolation of water through soil.
- Homes incorporate integrated gutter, flashing, exterior drainage plane, and foundation drainage strategy.
- Homes will all be certified as EPA Energy Star® Homes (30% more energy efficient than the 1993 CABO Model Energy Code).
- A building airtightness of 2.5 Air Changes per Hour at 50 Pascal pressure difference (2.5 ACH @ 50 Pa), as measured by a blower door test.
- Vapor barrier on the interior surface of approximately 1 perm to allow drying to the inside.
- Fresh air ventilation system to be installed in all homes.
- Homes will be designed and wired to facilitate future expansion and utilization of computer-connected technologies.
- Combustion appliances (except ranges, cook tops, ovens) are vented to the outdoors and selected so as not to allow combustion by-products into the home.
- Radon and carbon dioxide pre-mitigation systems installed.

These standards were further augmented with prescriptive measures to assure compliance, and recommended best practices were included as part of the finished Summerset Home Performance Standards booklet (1999).

Education and Compliance Verification

IBACOS has worked with the development team and the builders throughout the design and construction process and has developed a high-level process map for the community that identifies the major steps that need to be taken. This has further been reduced to a generic process map, which is a template for other community developers. This process map follows the general process presented by IBACOS in KAR-8-18608-13.A.2, Community Scale Building System Test and Evaluation Results (2001). A more detailed process map has been included in Appendix A.

Description of House Types

Description of House Types

The housing being built at Summerset falls into three different categories: single-family detached, attached town homes, and low rise multifamily. The single-family detached products are offered as Cottage Homes, Village Homes and Estate Homes. One attached town home product is being offered as for-sale and another smaller product is being developed for the rental market. The low rise multifamily will be offered as garden style rental apartments. This report will discuss the Cottage Homes, Estate Homes, and Rental Town Homes, all of which are currently under construction or have been completed and occupied.

Cottage Homes

The Cottage Homes are the smallest single-family detached houses being constructed in the community of Summerset at Frick Park. A photo of the completed Cottage Homes is presented in Figure 1. All of the Cottage Homes are two-story buildings, with a two-car attached garage in the rear and a porch on the front. The houses are built on crawlspace foundations. The Cottage Homes range in size from 1,920 square feet to 2,200 square feet of living space. The Cottage Homes have two to three bedrooms, two and a half to three bathrooms, 10-foot first floor ceilings and 9-foot second floor ceilings. Summerset Cottage Associates (SCA) is constructing the Cottage Homes.

Description of House Types



Figure 1. Two Cottage Homes at Summerset

Estate Homes

The Estate Homes are the largest single-family detached houses being constructed in the community of Summerset at Frick Park. All of the Estate Homes are customized to meet the desires of the homebuyer; therefore, each Estate Home is unique. All of the Estate Homes are two story buildings with an attached garage in the rear and a porch on the front. The houses are typically built on basement foundations, and in most instances, the homebuyers choose to finish a portion of the basement as living space. Generally speaking, the Estate Homes have about 4,000 or more square feet of living space. A photo of an Estate Home is presented in Figure 2. Jayar Construction, Inc. is constructing the Estate Homes that are discussed in this report.

Description of House Types



Figure 2. First Estate Home at Summerset nears completion

Rental Town Homes

A group of 40 Rental Town Homes are being constructed at Summerset. These units are grouped into four separate buildings. In three of these buildings, all of the town homes are two-story units attached side-by-side. These units range in size from 1,100 to 1,500 square feet of living space, with two or three bedrooms and two full bathrooms. Most of these units have a garage located in the full basement under the unit, but a few units have slab-on-grade foundations with off-street parking spaces outside the unit.

The fourth building is three stories tall with a full basement and has units that are stacked vertically as well as horizontally. The building consists of four three-story modules located side-by-side and separated by firewalls. The first two floors of each module is a town home unit with two bedrooms and two full bathrooms in about 1,220 square feet of living space. The third floor is a separate loft town home unit, with one bedroom and one full bathroom in about 720 square feet of living space. A photo of one of the buildings of town homes near completion is presented in Figure 3.

The Rental Town Homes will be owned and managed by Ralph Falbo Inc. and Pennrose Properties, Inc. Mistick Construction, Inc. is constructing all of the Rental Town Homes.

Description of House Types



Figure 3. Building 1 of the Rental Town Homes at Summerset nearing completion

High Performance Building Strategies

High Performance Building Strategies

IBACOS worked closely with all of the design teams and the builders throughout the design and construction of the homes in order to use a systems integration engineering approach to meet the requirements of the Summerset Home Performance Standards. The requirements of the performance standards necessitate the use of high performance building strategies to deliver high quality buildings, and many of these strategies were new methods for the builders. Therefore, IBACOS also provided extensive field training for the builder's construction staff and sub-trades to facilitate high quality field implementation in all of the buildings.

The systems integration engineering for the various building types also had to meet the economic requirements associated with each building type. For example, the Cottage Homes are the smallest single-family houses at Summerset. Because they are being sold at a lower price point, the construction costs per square foot needed to be lower than the other single-family houses. Therefore, minimizing construction costs was a priority for these homes when creating the systems integration solutions to meet the performance standards. On the other hand, the Estate Homes are high-end custom homes. Jayar was committed to not only meeting the performance standards, but also providing optimal quality and performance for their homebuyers. Therefore, IBACOS was able to consider more expensive systems integration solutions that exceeded the requirements of the performance standards of these houses.

The economics and cost implications for the Rental Town Homes are substantially different than the single-family houses primarily because these units are to be rented rather than sold. The rental rates in the Pittsburgh market therefore determine the maximum construction costs for the project. The design team for the Rental Town Homes initially designed the products to meet the same Summerset Home Performance Standards and Architectural Standards as the single-family houses, but the construction costs for the buildings came in too high. Therefore, a set of revised Summerset Home Performance Standards and Architectural Standards were developed for the rental units, so that the project would still represent outstanding quality and building performance in the Pittsburgh region, while still being cost competitive. The revised performance standards required the Rental Town Homes to be 20% better than the 1993 Model Energy Code (compared to 30% better required for

High Performance Building Strategies

the for-sale single-family housing), with a building air tightness of 6.0 ACH @ 50 Pa (compared to 4.0 ACH @ 50 Pa required for the for-sale single-family housing). The design team and Mistick Construction both agreed to these revised performance standards, and have been working hard to meet these requirements.

Table 1 outlines all of the high performance building strategies being implemented on the various building types at Summerset. More detailed discussion of these building strategies follows in the next section of this report.

Table 1. Comparison of Energy features (R- Value in ft²•h•°F / Btu).

System	Cottage Homes	Estate Homes	Rental Town Homes
Floor Framing System	12 in. engineered wood I-joists	16 in. wood floor trusses	12 in. wood floor trusses
Foundation system	Unvented, conditioned crawlspace	Full basement, part of conditioned space	Full basement, part unconditioned garage, part finished & conditioned
	Tuff-N-Dri® exterior below grade insulation (R-3) and water management system	Tuff-N- Dri® exterior below and above grade insulation (R-10) and water management system	Tuff-N- Dri® exterior below grade insulation (R-5) and water management system
	R-10 interior fiberglass batt blanket	R-15 Icynene® interior insulation at finished basement	R-13 interior stud wall with fiberglass cavity batts
Above Grade Walls	R-13 fiberglass cavity batts R-5 insulation sheathing	R-13 Icynene® cavity insulation R-5 insulation sheathing	R-13 fiberglass cavity batts ½ in. OSB sheathing
Floor over Ext. or Garage	R-19 fiberglass cavity batts R-5 insulation sheathing	R-20 Icynene® cavity	R-30 fiberglass cavity batts
Ceiling	R-30 Blown-in fiberglass	R-20 Icynene® cavity insulation in roof rafters	R-30 Blown-in fiberglass at attic floor R-30 batts at vaulted ceilings
Windows	Double-glazed low-E, U-value = 0.33 SHGC = 0.31	Double-glazed low-E, U-value = 0.33 SHGC = 0.31	Double-glazed low-E, U-value = 0.33 SHGC = 0.31
Air Barrier System	Airtight Drywall Assembly, Taped insulation sheathing, subtrades seal penetrations as they make the holes 4.0ACH @ 50Pa max	Icynene® insulation air barrier; wood-to-wood connections, windows & doors openings sealed by Icynene® contractor 4.0ACH @ 50Pa max	Airtight Drywall Assembly, Exterior sheathing & all penetrations sealed by air tightness contractor 6.0ACH @ 50Pa max
Duct System	Sheet metal ducts in conditioned space, sealed with duct mastic	Sheet metal ducts in conditioned space, sealed with duct mastic	Ducts in conditioned space, sealed with UL 181 duct tape and duct mastic
Space Conditioning System	Direct vent, 93% AFUE gas furnace with fixed capacity fan; 12 SEER air conditioning system (AC)	(2) Direct vent, 94% AFUE gas furnaces with variable speed fans; 13 SEER AC; first floor/ basement zoned system	Air handler with hydronic heating coil & fixed capacity fan; combo hot water heater w/ 78% recovery efficiency; 12 SEER AC
Ventilation System	Low sone, energy efficient, 2-speed bath exhaust fan	Heat Recovery Ventilator	Low sone, energy efficient, 2-speed bath exhaust fan; Fresh air intake into return
Domestic Water Heating	Power-vented gas water heater; EF = 0.57	Power-vented gas water heater; EF = 0.56	Power-vented gas water heater; EF = 0.54
HERS Score	85.5 to 87.2	87.0	84.5 to 88.6

Framing Systems

IBACOS worked with all of the builders to use a floor framing system that would enable the duct system to be integrated into the structure. One of the basic principles of systems integration design for higher performance is bringing the ductwork inside the thermal envelope of the house, centralizing the duct system in order to shorten duct lengths, and then integrating the ductwork with the structural systems and plumbing systems to avoid spatial conflicts among them. This approach is essentially mandated by the Summerset Home Performance Standards, which require the furnace/air handler and 90% or more of the ductwork to be in conditioned space. Also, the standards prohibit any ductwork from being located in exterior walls. Therefore, the ductwork must be located in interior walls and structural floor systems, and also in duct chases and bulkheads when necessary. The duct system configuration must be considered when designing the home and when deciding what framing system will be used for the floor structure.

Cottage Homes

The floor framing system for the Cottage Homes consists of engineered wood I-joists. In order to allow for ductwork to be integrated into the wood I-joists, 11 7/8 in. deep floor joists at 16 in. on center (O.C.) were specified. These deeper joists were not necessary to meet the structural spanning requirements for the house (9½ in. joists at 16 in. O.C. met the structural requirements), but they allow for holes to be cut through the OSB web of the I-joist at center span, which enable some ductwork to be integrated into the floor system. This created just enough flexibility in the structural system to accommodate the HVAC system, while keeping all of the ductwork in conditioned space and out of the exterior walls. IBACOS also discussed with SCA the possibility of using open web floor trusses in order to facilitate the integration of the duct system with the floor structure. The open web floor trusses create many more optional paths for ductwork within the floor system, offering much more design flexibility when integrating the ductwork into the floor structure. However, the duct system could be integrated into the 12 in. deep wood I-joists, and the open web floor trusses were found to be more expensive than the wood I-joists. Given that keeping costs to a minimum while still meeting the Summerset Home Performance Standard was a top priority, the wood I-joists proved to be the most cost-effective integrated solution for the Cottage Homes.

High Performance Building Strategies

Estate Homes

The floor framing system for the Estate Homes consists of open web wood trusses. The top and bottom chords as well as the diagonal bracing of the floor trusses are made with 2x4's connected by metal plate fasteners. In order to allow for ductwork to be easily integrated into the floor trusses, 16 in. deep floor trusses were specified. The open web floor trusses create many optional paths for ductwork within the floor system, offering design flexibility when integrating the ductwork into the floor structure. In fact, these 16 in. deep floor trusses have a large enough rectangular opening at center span to integrate a duct trunk into the floor system running perpendicular to the trusses. Jayar placed the floor trusses at 16 in. O.C., even though they were designed for 24 in. O.C., so that they would feel more confident in the "stoutness" of the house that they were building.

Rental Town Homes

The Rental Town Homes also used open web wood trusses for the floor framing system, although they used trusses with 2x2 diagonal wood braces finger-jointed into 2x3 top and bottom chords. Twelve-inch deep floor trusses were specified. The ductwork was integrated into the open web floor structure. Vertical duct chases and horizontal duct bulkheads were also incorporated into the architectural design where necessary to enable the ductwork to be integrated into the structure within the conditioned space of each unit.

Foundation Systems

IBACOS worked with each of the builders' design teams to ensure that all of the buildings would have a well-insulated foundation system, which properly managed water and moisture. All of the builders constructed the foundation walls with concrete block, and they all decided to use Tuff-N-Dri® as the primary means of controlling ground water on the below grade portions of the foundation walls. This system consists of dampproofing material spray-applied to the exterior of the foundation wall, and semi-rigid fiberglass insulation board on the exterior of the wall, held in place by the dampproofing material. The fiberglass insulation board has small voids between the fibers, which create a drainage cavity for ground water. The Tuff-N-Dri® system was extended to the bottom of the foundation wall, where it connected to a gravel bed with a perforated drainpipe installed along the entire exterior perimeter of the foundation footer. This drainpipe was connected to the storm sewer for proper drainage. On all the buildings, the downspouts from the roof were piped separately into the storm sewer system.

High Performance Building Strategies

The unique attributes of the foundation systems for the various building types are discussed below.

Cottage Homes

All of the Cottage Homes are constructed upon crawlspace foundations. One of the main improvements in the Cottage Homes at Summerset is that the crawlspace was unvented, insulated and conditioned, as compared to typical crawlspaces in Pittsburgh, which are vented to the outside. Building an unvented, insulated crawlspace enabled the furnace and primary duct plenums and trunks to be located in the crawlspace and still be within the thermal envelope and air barrier of the house. The unvented crawlspace also facilitates making the exterior envelope of the house more airtight, as the crawlspace foundation walls and slab floor are easier to make airtight than the frame floor between the house and the crawlspace. Such a crawlspace also can improve the control of moisture in the building and make the home more comfortable (the frame floor above the crawlspace will be warmer in the wintertime). Therefore, the unvented, insulated crawlspace is a key element of the overall strategy for improving the energy efficiency, comfort and durability of the Cottage Homes.

The Cottage Homes used the fiberglass insulation/drainage board water management system only on the below grade portion of the crawlspace wall. Three-quarter-inch thick (R-3) semi-rigid fiberglass insulation board was used. The crawlspace floor was constructed with a 2 in. slab of low grade concrete over a continuous 6 mil polyethylene vapor barrier. A continuous bed of uniform-sized crushed stone with no fines, about 4 in. thick, was installed under the poly vapor barrier. The stone bed was thickened along the inside edge of the footer and a continuous perforated drainpipe was installed along the footer. This interior drainpipe was connected to the exterior drainpipe with drainpipe leaders through the foundation footer to create positive drainage from below the crawlspace slab to the storm sewer system. Together, these elements comprised the ground water and moisture management system for the Cottage Homes.

Because the crawlspace is unvented and air tight, construction moisture can accumulate in the crawlspace. As soon as the first floor deck is in place, little air circulates through the crawlspace. At this point in time, the 2 in. concrete slab is still full of moisture. As well, rainwater can still enter the crawlspace until the roof framing is

High Performance Building Strategies

complete. The capacity for the crawlspace to get wet during construction is much greater than its ability to dry because there is no air circulation. To resolve this issue, measures were taken to increase the drying capacity of the crawlspace, in order to avoid problems with moisture and mold. Fans were used to circulate air between the crawlspace and the house, and dehumidifiers were used if necessary. The builder uses the mechanical system for space conditioning during construction; so once this system is installed, the other temporary air circulation measures are eliminated. It is important to note that during seasons where no mechanical space conditioning is necessary during construction that either the furnace fan be operated to circulate air or the other temporary system should be left operational. IBACOS recommends using the temporary system to minimize the entrainment of construction dust in the permanent mechanical system.

The majority of the Cottage Homes have fiber-cement siding as the exterior cladding on the above grade framed walls, with the above grade portion of the crawlspace wall constructed with split-face concrete block. Because the split-face block functions as both the structural wall and the exterior finish, the crawlspace walls had to be insulated on the interior to R-10 or more. IBACOS recommended extruded polystyrene insulation board systems for the interior insulation, with fiberglass batt blankets with a perforated vinyl facing being a viable alternative. SCA selected the R-10 fiberglass batt blankets due to the ease of installation and the lower material costs. The width of the blankets was cut to the height of the crawlspace wall and then the blankets were installed horizontally along the wall. The blanket was fastened to the mudsill plate at the top of the wall and to the pressure treated wood plate installed along the bottom of the wall.

Estate Homes

All of the Estate Homes are constructed upon full basement foundations. In order to meet the overall energy efficiency goals for the house, IBACOS determined that basement walls needed to be insulated to R-10 for the full height of the wall. Jayar desired to use semi-rigid fiberglass insulation/drainage boards on the below grade portion of the walls to provide insulation performance and drainage capabilities. The challenge was how to insulate the above grade portion of the foundation walls. Given that the Estate Homes are high-end homes, the exterior of the houses are almost exclusively brick veneer. The construction detail that was developed used a progression of foundation block sizes from 12 in. for the below grade portion of the wall, diminishing to 6 in. block just below grade to create a brick shelf and space for the

High Performance Building Strategies

semi-rigid fiberglass insulation board sandwiched between the brick veneer. This resulted in R-10 full height insulation to the exterior of the block wall as shown in Figure 4 and Figure 5.

In the finished areas of the basement, a 2x4 stud wall was constructed on the inside of the basement walls, with a 1 in. space between the wood and concrete block. This 1 in. cavity and the stud wall cavities were filled with open-cell expanding foam insulation. This construction method resulted in an R-25 foundation wall at the finished basement.

Because of concerns regarding potential expansion of the slag soil beneath the basement floor, it's constructed with a 4 in. concrete slab on a corrugated stainless steel deck, elevated 10 in. above the slag ground surface. A continuous polyethylene vapor barrier was placed on the ground below this 10 in. air cavity, and turned up the interior side of the footer. Together with the fiberglass insulation/drainage board system, these elements comprise the ground water and moisture management system for the Estate Homes.



Figure 4. Insulation of foundations below grade at Estate Homes showing brick ledge



Figure 5. Insulation of foundations below grade at Estate Homes. Brick ledge is created by stepping from a 12 in. block to 6 in. block

Rental Town Homes

The water management system and insulation strategy for the Rental Town Homes is similar to the Cottage Homes, except that the town homes mostly have full basements rather than crawlspaces. The majority of the area in all the basements is used as an unconditioned garage. However, most of the basements have a small entryway that leads to the stairs, a mechanical room, and sometimes a laundry room - all finished and conditioned spaces. One-inch thick (R-5) fiberglass insulation/drainage board water management system was installed on the below grade portion of the basement walls. The basement floor was constructed with a 4 in. slab of concrete over a continuous 6 mil poly vapor barrier. A continuous bed of uniform-sized crushed stone with no fines, about 4 in. thick, was installed under the polyethylene vapor barrier. The stone bed was thickened along the inside edge of the footer, and a continuous perforated drainpipe was installed along the footer. This interior drainpipe was connected to the exterior drainpipe with drainpipe leaders through the foundation footer

High Performance Building Strategies

to create positive drainage from below the basement slab to the storm sewer system. Together, these elements comprise the ground water and moisture management system for the town homes.

In the conditioned portions of the basement, the block walls were also insulated on the interior. Because interior stud walls were built to accommodate the electrical wiring and drywall finish, the insulation was accomplished by insulating the stud cavities with R-13 fiberglass batts. These walls were also sealed for air tightness to minimize the contact of warm indoor air on the concrete block wall.

Envelope Air Barrier Systems

The Summerset Home Performance Standards set fairly stringent airtightness requirements for all the buildings at Summerset. The air leakage of the single-family houses must not exceed 4.0 ACH at 50 Pa when tested with a blower door. The air leakage of the Rental Town Homes must not exceed 6.0 ACH at 50 Pa when tested with a blower door. All of the single-family houses and most of the Rental Town Homes constructed in the first phase of the project will be tested upon completion. Given this testing protocol for compliance verification, the builders knew from the outset that they would need to make their buildings airtight. For all of the builders, meeting an airtightness requirement was a new experience. Interestingly, all of the builders opted for a different approach to achieving this goal, both in terms of how to seal their buildings, and in terms of who would be hired to complete this new scope of work. The approach taken by each builder, and the experience of learning how to implement the various strategies in the field, are described below.

Cottage Homes

IBACOS worked closely with SCA to develop strategies for increasing the airtightness of all the Cottage Homes. The above grade walls and band joists had two air barriers: an airtight drywall assembly and exterior foam insulation board installed as a secondary air barrier. All areas in exterior walls without drywall (areas behind showers, bath tubs, fireplaces, etc.) were pre-insulated and sealed with thin-profile building sheathing caulked to the framing, installed by the framer. The insulated ceilings were sealed from the attic above before insulation was blown into the attic. To complete the airtightness package, all penetrations in the walls and ceiling, including windows, doors, attic hatch, electrical utilities and plumbing utilities, were to be sealed with expanding foam.

High Performance Building Strategies

The question of who would complete this airtightness work is often more challenging to resolve than the process of defining the actual airtightness work. IBACOS discussed with SCA the possibility of hiring a separate air tightness contractor to seal all the penetrations in the walls, floors and ceilings of the houses. Even in this scenario, however, the framer and the drywall crews still play a significant role in properly achieving the airtightness target. Given that multiple trades are inherently involved in making the building air tight, SCA preferred to not introduce a separate airtightness contractor into the equation, but instead to make each of the existing contractors responsible for sealing their own penetrations and doing their part to make the building air tight. It is often more difficult to achieve improved airtightness with this approach, as it requires more site coordination and scrupulous supervision of multiple trades for airtightness compliance. SCA accepted this challenge and moved forward with this approach.

Much of the airtightness work needed to be completed by the framing contractor. Therefore, IBACOS created a scope of work outline for the framing contractors and conducted training sessions to educate the framers and the site supervisors on each airtightness measure. IBACOS conducted the primary training for the framer on their first day on the job site. IBACOS then visited the site throughout the framing process to ensure that these measures were being properly implemented in the field, and that any lingering questions were answered. IBACOS conducted similar training sessions for all of the trades people involved in implementing airtightness measures.

Even with all this effort, the process of implementing the airtightness measures did not proceed without some glitches. The first home to be constructed just met the airtightness requirements of the Summerset Home Performance Standard. The second house had a few building assemblies that were difficult to seal, including a conditioned floor assembly over the front porch and several bulkheads connected to the attics of the house. Due to some confusion over which trade was responsible for the work, these items were not properly sealed, and the results of the airtightness test was 4.2 ACH at 50 Pa. IBACOS provided a detailed list of areas to address to the builder. In addition, IBACOS conducted further training with the builder and their trades, this time with their full recognition that the task at hand was not simple. In the process of building the first few Cottage Homes, SCA and their various trades learned the new scope of work for each contractor and the revised construction process for properly

High Performance Building Strategies

implementing the airtightness measures. With a clearer understanding of this process, they have built 10 more Cottage Homes at Summerset, all of which have met the airtightness requirements of the Summerset Home Performance Standards.

Estate Homes

Jayar opted to use an open-cell, spray-applied polyisocyanurate insulation to create the thermal envelope and air barrier system in the exterior shell of the Estate Homes. This expanding foam insulation adheres to the surfaces onto which it is sprayed, and expands into the building cavities to create an insulation layer. In the process, it fills all the gaps in the building cavities where it is applied, and therefore creates an air barrier in the exterior shell of the house. Because the product is spray-applied and expands to fill building cavities, it can be used to easily insulate and air seal cavities that would be difficult to make airtight otherwise. Homes which use this product often perform extremely well with respect to overall house airtightness. The spray foam insulation was applied at the finished basement walls, and then in the entire exterior envelope from the band joist at the foundation up to the ridge beams in the roof system. Because the spray foam is installed between the roof rafters, the attic space becomes part of the conditioned envelope of the house. For the Estate Homes, the spray foam contractor also sealed the rough openings around windows and doors with low expansion polyurethane foam insulation. This contractor also sealed all gaps between wood structural elements in the exterior envelope. For example, all bottom plates at exterior walls were caulked to the subfloor, the crack between plates at double top plates were sealed, and jack studs were caulked to king and cripple studs and headers at the window rough openings.

For the Estate Homes, the spray foam contractor conducted all of the airtightness work. This makes coordinating the airtightness work much simpler for the builder. As well, the spray foam contractor also performs all of the airtightness work at one stage in the construction process, after the mechanical systems are roughed in and before the drywall is installed. This makes scheduling the airtightness work much simpler for the builder as the typical construction process does not need to be altered to accommodate the airtightness work. Given these realities, IBACOS did not need to conduct airtightness training for Jayar and their construction crews, and the result of the airtightness test on the first Estate Home was 1.48 ACH at 50 Pa in a preliminary blower door test conducted after the drywall was complete, which far exceeds the airtightness requirements of the Summerset Home Performance Standards.

High Performance Building Strategies

Rental Town Homes

IBACOS worked closely with Mistick and the project architect to develop strategies for achieving the airtightness goals for the Rental Town Homes. The overall airtightness strategy for the town homes ended up being similar to the strategies employed in the Cottage Homes. The above grade walls and band joists had two air barriers: exterior structural sheathing installed as an air barrier and an airtight drywall assembly installed as a secondary air barrier. The areas behind showers and bathtubs without drywall were to be sealed by the framer. This was accomplished with rigid foam insulation caulked into each stud cavity, and covered with thin-profile building sheathing for flame spread protection. The thin-profile sheathing was slightly recessed into each cavity, so that the drywall finish would remain flush to the studs. The party walls were to be sealed with expanding foam and blocking as required. The insulated ceilings were to be sealed from the attic above before insulation was blown into the attic. Additionally, all penetrations in the walls and ceiling, including windows, doors, attic hatch, electrical utilities and plumbing utilities, were to be sealed with expanding foam.

IBACOS encouraged Mistick Construction to hire an airtightness contractor to conduct the majority of the airtightness work on these town homes. Mistick heeded this advice, and contracted with a local airtightness contractor to complete the work. IBACOS coordinated sites visits between the airtightness contractor and Mistick to outline the scope of work to be completed for these units. IBACOS also worked closely with Mistick to coordinate the airtightness work to be completed by other trades, particularly the framer and the drywall crews. The main challenge encountered during construction so far has been properly sealing the party walls, while still satisfying the requirements of the local building code inspectors and the rated fire separation assembly details. Tested assembly details require mineral wool insulation placed in the gap between the building structure and the 2 in. thick gypsum board firewall assembly. However, the mineral wool does not create an air barrier. The local building official was opposed to the use of rigid insulation blocking with expanding foam sealant instead of mineral wool, as these products are not fire-rated. After struggling through these issues on the first building, an alternative solution was developed and will be tested on the other buildings under construction. This alternative approach will use mineral wool as a thermal break between the firewall and building structure, and a rubber gasket and expanding foam sealant will be used to create an air barrier from the attic. The intersection of the fire separation wall and the exterior wall at the front and back of the building will be sealed with expanding foam. IBACOS will continue to investigate methods for creating a fire-rated air barrier at fire separation walls, as it is critical to

achieving good airtightness in multifamily buildings.

Mechanical Ventilation Systems

Given that all of the buildings were going to be made as airtight as possible, the builders recognized the need for mechanical ventilation in these houses. IBACOS presented several options for mechanical ventilation systems to all of the builders. The systems they selected are described below.

Cottage Homes

Installing a mechanical ventilation system and developing an indoor air quality strategy for a home was a new effort for SCA. Most of the homes they have built over the years have not had a mechanical ventilation system, and have relied upon random air leakage to provide fresh air. Given the pressures to keep costs to a minimum for the Cottage Homes, SCA did not want the ventilation system to be expensive. With these criteria set, IBACOS developed an exhaust only ventilation system using an energy efficient, low speed, two-speed bath exhaust fan. The fan is intended to run continuously on low speed, exhausting about 60 cfm of air. The occupants can turn the fan up to high speed when using the bathroom at which point the fan should move about 110 cfm of air. SCA has had difficulty sourcing the two-speed bath fan, as their supplier does not typically stock them. While these fans were on backorder, a typical bath fan was installed, but it was pre-wired in such a way that the two-speed fan could be easily installed when the shipment arrived.

Estate Homes

In keeping with their commitment to use high quality systems, which provide improved comfort and performance, Jayar selected a heat recovery ventilator for the mechanical system in the Estate Homes. One ventilator was located in the basement, and the fresh air from the system was ducted into the return duct system of both furnaces. The ventilator was ducted to draw stale air from the hallway near the kitchen in the house. In addition, bathrooms are provided with individual exhaust fans for spot ventilation.

Rental Town Homes

Given the construction cost pressures on the Rental Town Homes, a cost-effective mechanical ventilation system was needed for these buildings. The mechanical ventilation specified for the town homes is similar to the Cottage Homes' system, where first costs were also a primary design consideration. An exhaust-only ventilation

High Performance Building Strategies

system was employed using an energy efficient, low speed, two-speed bathroom exhaust fan. The fan is intended to run continuously on low speed, exhausting about 60 cfm of air. The occupants can turn the fan up to high speed when using the bathroom, at which point the fan should move about 110 cfm of air. A 5 in. fresh air intake duct was also installed from the first floor band joist to the return plenum with a balancing damper so that the flow could be adjusted to around 50 to 60 cfm of outdoor air. Therefore, whenever the central system is operating, the ventilation system will be balanced, and fresh air will be filtered and distributed throughout the house. When the central system is not operating, the fresh air duct serves as a controlled opening for make-up air for the exhaust fan.

Thermal Envelope Systems

High performance thermal envelope systems were implemented on all of the buildings at Summerset in order to meet the Summerset Home Performance Standards. Insulated foundation systems were used on all of the buildings as described earlier in this report. All of the buildings also used double glazed, low-E windows to improve the performance of the thermal envelope. These windows represent a major improvement in the energy efficiency, comfort, and durability of these houses. These windows have an overall heat transfer coefficient (U-x) of 0.33 Btu/ft²•h•°F and a solar heat gain coefficient (SHGC) of 0.31 Btu/ft²•h•°F. IBACOS was able to provide some calculations as well to show each builder the relationship between the improved thermal envelope and improved windows to the reduced mechanical equipment sizing. This has helped the builders reduce costs while also having an improved product to market to homebuyers.

The unique attributes of the thermal envelope systems for the various building types are discussed below:

Cottage Homes

One-inch of extruded polystyrene insulation board exterior sheathing was used to improve the thermal effectiveness of the above grade portions of the wall. This insulation is continuous along the entire wall surface, thus minimizing thermal bridging through framing members. More importantly, this insulated sheathing keeps the wall cavities and framing members warmer during the winter, which reduces the potential for condensation in the wall. Discussions about this product and the appropriate thickness to be used in the walls enabled SCA to gain a better understanding of the

High Performance Building Strategies

movement of moisture in above grade walls and how to avoid moisture problems. SCA uses panelized stud walls in the construction of their homes, so the extruded polystyrene board was included in the manufacturing process of the wall panels. In order to have added strength and abuse-resistance to withstand the shipment from the factory to the site, extruded polystyrene board with reinforced laminate on both sides of the board was used.

SCA also uses manufactured roof trusses for all the houses that they build. IBACOS worked closely with SCA to ensure that wedge heel trusses were used in all the Cottage Homes at Summerset. These trusses reduce the amount of ceiling insulation displaced by the roof sheathing and insulation baffle at the eave, resulting in better energy efficiency and reduced possibility for ice dams.

Estate Homes

Similar to the Cottage Homes, 1 in. thick extruded polystyrene insulation board exterior sheathing was used to improve the thermal effectiveness of the above grade walls in the Estate Homes. The insulation board has an R-value of 5.0. Together with the R-13 provided by the spray foam insulation in the 2x4 stud wall cavity, the Estate Homes had a nominal R-18 exterior wall system.

The roof was framed with 2x10s, and insulated with about 5 in. of Icynene® insulation. Floors over the exterior and floors over the garage were also insulated with about 5 in. of spray foam insulation. Therefore, these building assemblies have an R-value of about 20.

Rental Town Homes

All of the above grade portions of the town homes use fiberglass batt insulation. Because many of the units have a large amount of floor area over the unconditioned garage in the basement, these floors were insulated to R-30 and made to be as airtight as possible in order to improve comfort and energy efficiency. The exterior walls used R-13 cavity batts with continuous OSB structural sheathing, and the attic floor and vaulted ceilings were insulated to R-30.

Mechanical Equipment and Duct Systems

High efficiency mechanical equipment was installed in all the buildings at Summerset to increase energy efficiency and combustion safety. For example, all of the homes

High Performance Building Strategies

used seasonal energy efficiency ratio (SEER) 12 Btu/Wh condensing units for the cooling system, and all the single-family houses used environmentally friendly refrigerant with no CFCs. As well, all of the buildings used an energy efficient, power-vented water heater. Most of the Cottage Homes have a water heater with a 40-gallon storage tank and an Energy Factor (EF) of 0.57 (the minimum EF for this type of water heater is 0.54). Most of the Rental Town Homes have a water heater with a 65-gallon storage tank and an EF of 0.55 (the minimum EF for this type of water heater is 0.50). The Estate Homes will have a 75-gallon water heater with an EF of 0.56 (the minimum EF for this type of water heater is 0.48).

All of the buildings also used an engineered duct system to provide calculated amounts of conditioned air to each room to maintain desired temperatures. The entire duct system was fully ducted (no panned return duct cavities) located within conditioned space, and sealed with duct mastic to increase energy efficiency and air delivery to the conditioned spaces. All of the duct systems were engineered so that the various duct branches would roughly balance at the calculated airflow for each room, given the different lengths and number of duct transitions in the various duct branches. For example, duct branches serving first floor diffusers close to the furnace were slightly undersized, otherwise they would receive too much air because there is little resistance to airflow between the furnace fan and the diffuser in the room. On the other hand, duct branches for the second floor are slightly oversized; otherwise they would receive too little air given the large resistance to airflow in the longer duct with numerous elbows. The engineered duct sizes enable the duct system to roughly balance at the appropriate airflows, and then the HVAC contractor can fine-tune the balance of the system using balancing dampers when the home is complete.

The unique attributes of the mechanical equipment and duct systems for the various building types are discussed below:

Cottage Homes

In all the Cottage Homes, a 93% annual fuel utilization efficiency (AFUE), direct-vent horizontal flow furnace with a fixed capacity fan was located in the crawlspace. The duct system was integrated with the framing system and plumbing system to maximize performance. The main duct plenums and trunks were located in the crawlspace below the floor structure and steel beams. Individual take-offs and duct branches were installed from the main trunks in the crawlspace to each of the supply and return

High Performance Building Strategies

registers throughout the house. All of these duct branches were sized to roughly balance at the calculated airflow for each room, given the varying length and number of duct fittings in the various duct branches.

Estate Homes

All of the Estate Homes have two heating and cooling systems, one in the basement serving the basement and first floor, and one in the attic serving the second floor and any loft spaces. For both systems, a 94% AFUE, direct-vent furnace with 2-stage heating and a variable speed fan was used. Condensing units rated at 12 SEER were also used, although when combined with the variable speed furnace fan, the cooling system is rated at 13 SEER.

The duct system for the first floor/basement system was integrated with the first floor framing system and plumbing system to maximize performance. For this system, an upflow furnace was located in the basement, and the main duct trunks were run just below the floor trusses parallel to a steel beam in the basement. A zoned system was used on this system, with the first floor and basement being separate zones. Therefore, the first floor and basement have separate supply and return trunks and thermostats so that each can be conditioned separately. Individual take-offs and duct branches were installed from the main trunks to each of the supply and return registers in the respective zones.

For the second floor system, a horizontal flow furnace was located in the attic. The main duct trunks were also located in the attic. All of this mechanical equipment and ductwork is still within conditioned space because the spray foam insulation is installed in the roof rafters enclosing the entire attic within the thermal envelope of the house. Individual take-offs and duct branches were installed from the main trunks to each of the supply and return registers located in the ceiling or high sidewalls of the second floor.

Rental Town Homes

The Rental Town Homes are smaller than all of the single-family detached houses, and they have less exterior wall area per square foot of living space because the units share common walls. Given these factors, in addition to the well-insulated, airsealed exterior shell, the units have relatively small heating and cooling loads. At the same time, most of the town homes have just as many bedrooms as the small to mid-size

High Performance Building Strategies

single-family houses, so the number of occupants and the corresponding domestic water heating load will be just as high for the town homes as these single-family houses. Therefore, the domestic water heating load becomes a more significant factor in the Rental Town Homes meeting the overall energy efficiency requirements set by the Summerset Home Performance Standards. Because of this, an energy-efficient, power-vented domestic water heater was a key piece of the mechanical equipment strategy for the Rental Town Homes. Since this higher efficiency domestic water heater was a necessity, IBACOS recommended to the design and engineering team for the project that they consider using an air handler with a hydronic heating coil to heat the town homes. Given the small heating loads and the necessity for the higher efficiency water heater, the mechanical engineer agreed that the hydronic system was ideal for this project. In order to minimize construction costs, a wall-mounted air handler with a standard fixed-capacity fan was specified and installed.

As an option to further increase the energy efficiency of this system, IBACOS also recommend that a tankless gas water heater with a modulating gas valve be considered. However, the building owner/manager was not confident of the effectiveness and long-term durability of these products, so an energy efficient storage tank-type water heater was used. IBACOS feels that due to the significantly higher EF of these tankless, gas-fired water heaters, further research should be conducted to validate if they will meet long term durability and hot water generation needs for low load houses. This research could be undertaken at one of the DOE's National Labs looking at an accelerated aging test using water with a high mineral content to assess heat exchanger scaling potential, long-term loss of efficiency, and overall system durability.

In the town homes, duct mastic was used to seal all of the round take-offs and round duct elbows, and UL 181 foil faced duct tape was used to seal all other joints in the system. When necessary on the field fabricated trunk connections, two side-by-side strips of UL 181 duct tape were used to ensure proper coverage and air tightness of the duct joints.

The duct system for each town home was integrated with the floor framing system and plumbing system to maximize performance. The main supply trunks were routed through the floor trusses, dropped ceilings, duct chases and bulkheads near the center of the building. Individual take-offs and duct branches were installed from the main

High Performance Building Strategies

trunks to each of the supply diffusers, located in the floor or baseboard near the exterior wall. In order to minimize duct length and simplify the duct system, a central return duct system was used in the town homes. The return ducts were integrated into duct chases, bulkheads and the floor framing near the center of the building.

Repercussions of Building Performance Standards

Repercussions of Building Performance Standards

Is a single standard practical for a wide range of building sizes?

The experience at Summerset and developments in Green Building Programs has lead IBACOS to begin to investigate the impact of a single energy performance standard for a range of house sizes. In the current method used to determine Home Energy Rating Scores (HERS), the thermal shell and component areas of the reference home (i.e. walls, windows, ceilings, etc,) from which the point score is derived are the same as to the rated home, except for windows. This factor gives an indication of the relative energy efficiency of the home compared to a 1993 Model Energy Code version of itself, and in theory allows for the comparison of homes across a range of sizes. The rating method uses the loads for space heating, space cooling and water heating to generate the score. The method is shown below from the Mortgage Industry National Home Energy Rating Systems Accreditation Standard (RESNET, 2002)

Rating point score and star rating.

Point score. The Reference Home shall have a point score of 80 points on a 0 to 100 point scale. Each 5% increase or decrease in the relative energy efficiency potential of the Rated Home with respect to the Reference Home shall constitute a 1-point increase or decrease, respectively (from 80), in the Rated Home's score. The method used to calculate the score shall be approved by the accrediting body and be consistent for each HERS provider operating within a state. Except in states or territories whose laws or regulations require a specific alternative method, which shall control, equations 1 and 2 shall be used in a 2-step process to calculate the point score for the Rated Home, as follows:

Step (1) Calculate the individual normalized Modified End Use Loads (nMEUL) for heating, cooling, and hot water using equation 1:

$$\text{nMEUL} = \text{REUL} * (\text{nEC}_x / \text{EC}_r) \quad (\text{Eq. 1})$$

where:

nMEUL = normalized Modified End Use Loads (for heating, cooling or hot water).

Repercussions of Building Performance Standards

REUL = Reference Home End Use Loads (for heating, cooling or hot water) as computed using accredited simulation tools.

nEC_x = normalized Energy Consumption for Rated Home's end uses (for heating, cooling or hot water).

EC_r = estimated Energy Consumption for Reference Home's end uses (for heating, cooling or hot water) as computed using accredited simulation tools.

and where:

$$\mathbf{nEC_x = (a * EEC_x - b) * (EC_x * EC_r * DSE_r) / (EEC_x * REUL)}$$

where:

EC_x = estimated Energy Consumption for the Rated Home's end uses (for heating, cooling or hot water) as computed using accredited simulation tools.

EEC_x = Equipment Efficiency Coefficient for the Rated Home's equipment, such that EEC_x equals the energy consumption per unit load in like units as the load, and as derived from the Manufacturer's Equipment Performance Rating (MEPR) such that EEC_x equals 1.0 / MEPR for AFUE, COP or EF ratings, or such that EEC_x equals 3.413 / MEPR for HSPF, EER or SEER ratings.

$$DSE_r = REUL / EC_r * EEC_r$$

For simplified system performance methods, DSE_r equals 0.80 for heating and cooling systems and 1.00 for hot water systems. [see Section B.4.a.(17)]. However, for detailed modeling of heating and cooling systems, DSE_r may be less than 0.80 as a result of part load performance degradation, coil air flow degradation, improper system charge and auxiliary resistance heating for heat pumps. Except as otherwise provided by these Guidelines, where

Repercussions of Building Performance Standards

detailed systems modeling is employed, it must be applied equally to both the Reference and the Rated Homes.

EEC_r = Equipment Efficiency Coefficient for the Reference Home's equipment, such that EEC_r equals the energy consumption per unit load in like units as the load, and as derived from the Manufacturer's Equipment Performance Rating (MEPR) such that EEC_x equals 1.0 / MEPR for AFUE, COP or EF ratings, or such that EEC_x equals 3.413 / MEPR for HSPF, EER or SEER ratings.

and where the coefficients 'a' and 'b' are as defined by Table 1 below:

Table 1. Coefficients 'a' and 'b'

Fuel type and End Use	a	b
Electric space heating	1.9924	0
Natural gas space heating	1.2544	0.6082
Fuel oil space heating	2.4321	2.1180
Electric air conditioning	2.9301	0
Electric water heating	0.8800	0
Natural gas water heating	0.9404	0.7415
Fuel Oil water heating	1.5569	1.9376

Step (2) Determine the point score using equation 2:

$$\text{Point score} = 100 - ((\text{TnML} / \text{TRL}) * 20) \quad (\text{Eq. 2})$$

where:

TnML = nMEUL_{HEAT} + nMEUL_{COOL} + nMEUL_{HW} (Total of all normalized Modified End Use Loads as calculated using equation 1).

TRL = REUL_{HEAT} + REUL_{COOL} + REUL_{HW} (Total of all Reference Home End Use Loads).

One artifact of this method is that as houses of a given occupancy get smaller, the energy consumption for space heating and cooling is lowered, and domestic water

Repercussions of Building Performance Standards

heating becomes a larger relative component in the final rating score. This has the tendency to make it more difficult for smaller homes to achieve the same score as a larger home provided both houses have the same number of bedrooms.

While setting a performance standard based on a rating score does allow a significant amount of flexibility to the designer and builder, the variety of houses at Summerset has shown that two different size houses with the same number of bedrooms will likely have to incorporate different energy features to reach the same HERS score. Generally as house size decreases for a given number of bedrooms, larger relative investments in energy improvements need to be made to achieve a given HERS score. This potentially has serious impacts in a number of areas. First, smaller homes are typically targeted to the more affordable sectors of the housing market. If indeed smaller houses need more costly energy efficiency features to achieve a given score that can prevent the adoption of energy efficient construction practices in smaller homes where long-term energy affordability is perhaps most critical. In addition, while HERS scores demonstrate the relative levels of energy efficiency across house sizes, the reality is that given the same envelope and mechanical system characteristics smaller houses inherently use less energy than larger houses for a given occupancy. As such, smaller more efficient house designs for a certain occupancy or number of bedrooms can be a method of encouraging energy efficiency. Between 1987 and 2001 the average size of a new house in the United States increased from 1,905 square feet to 2,324 square feet (2003). While energy codes have improved over that period of time, the growth in the size of the home seems to be a fairly well established trend. The overall percentage of new homes 1,200 square feet or less has also been decreasing over that time period, and the percentage of new homes 2,400 square feet or greater has increased from 21% to 38% (2003). At the same time, household size in the United States has decreased from 2.66 to 2.62 (2002b). Smaller homes will also generally use less material, so there should be less volume of waste generated and a lower overall embodied energy content for the project.

Green Building Programs and House Size

Several emerging Green Building Programs have been exploring the concept of house size in their systems. The Vermont Built Green Program has developed a matrix that in essence allows smaller houses with a certain number of bedrooms to be certified by meeting the minimum program requirements, whereas larger houses with the same number of bedrooms will have to meet the program minimums and get a certain

Repercussions of Building Performance Standards

number of points from the checklist to be certified. As the house size increases for a given number of bedrooms, the number of points needed for certification also increases. The Florida Green Home Standard awards points based on smaller house sizes; however, it is not keyed to number of bedrooms, which is a factor that should probably be included to consider all houses equitably. The City of Austin's Green Builder Program gives a fixed number of points for houses that meet a certain threshold of size for a given number of bedrooms.

All of these programs are beginning to grapple with the difficult issue relating to house size in the context of environmentally responsible construction. In part this issue is a technical one, in that some basis needs to be made for how to allocate points for various sizes of houses. This is also a social policy and regional economics issue, in that there is currently no universally accepted definition of how big a house should be. In some parts of the country, a 1,200 square foot home may have five or more occupants. In another part of the country (or another part of the county), 1,200 square foot homes are being torn down in order to build a 4,000+ square foot home that will be lived in by two people. Much of this is driven by the economics of the region, however the success of Sarah Susankas' book *The Not So Big House* (1998) indicates that a growing number of consumers are looking for smaller, higher quality alternatives to what many builders and designers are providing in the marketplace.

Analysis of Energy Consumption, Rating Score, and House Size

Analysis of Energy Consumption, Rating Score, and House Size

Shell Area and Occupancy Factors

To begin the process of understanding the technical energy issues surrounding house size and occupancy, IBACOS has performed a limited analysis on several home sizes built to meet the Summerset Home Performance Standards. The HERS rating score is driven by space heating, space cooling and domestic hot water energy consumption and loads, and as such, there are two primary factors to look at when trying to understand the relationship between energy and house size: surface area of the shell of the building and number of bedrooms (as a surrogate for occupancy). The surface area of the building is a driving force in the space heating and cooling loads, and while the various characteristics of the thermal shell (such as window to wall area ratio or overall U-value of the envelope) will impact how energy efficient a house is, these do not necessarily reflect changes in the overall size of the house. The number of bedrooms in a house is what home energy rating tools use to estimate the domestic hot water consumption and associated energy use in the rated and reference home.

In order to develop a methodology for community scale design standards or for use with Green Building Programs that allocates energy use according to house size and occupancy, IBACOS has studied the effects of normalizing energy consumption based on shell area and occupancy. IBACOS has performed energy modeling on a number of homes built to the Summerset Home Performance Standards from the Summerset at Frick Park community in Pittsburgh, PA using IBACOS' in-house energy simulation and rating tool (QuEST). For this analysis, the domestic water heating efficiency was kept constant at an EF of 0.56, and the above grade envelope insulation characteristics were modified to achieve as close to a HERS score of 86 as was possible. All homes were modeled with conditioned basements or crawlspaces, all ducts were modeled inside the conditioned envelope, and all homes were modeled with an estimated air change rate of 0.2 ACH under natural conditions. The primary characteristics of each home and its associated rating score are shown in Table 2.

Analysis of Energy Consumption, Rating Score, and House Size

Table 2. House characteristics to achieve a HERS 86 score in Pittsburgh, PA (R- Value in ft²•h•°F / Btu).

Component	House Size				
	912 sf	1537 sf	1922 sf	4060 sf	5564 sf
Walls	R-19 +R-5	R-19 +R-5	R-19+R-5	R-13+R-4	R-13
Ceilings	R-38	R-38	R-38	R-38	R-30
Windows & Glass Doors	R-3.1 SHGC 0.34	R-3.1 SHGC 0.34	R-3.1 SHGC 0.34	R-2.6 SHGC 0.34	R-2.4 SHGC 0.55
Doors	R- 2.2	R- 2.2	R- 2.2	R- 2.2	R- 2.2
Basement walls above grade	R- 11	R- 11	R- 11	R- 11	R- 11
Basement walls below grade	R- 11	R- 11	R-14	R- 11	R- 11
Duct location	Inside envelope	Inside envelope	Inside envelope	Inside envelope	Inside envelope
Heating efficiency (AFUE)	93%	96%	93%	80%	80%
Domestic water heating efficiency	40 gal, 0.56 EF	40 gal, 0.56 EF	40 gal, 0.56 EF	40 gal, 0.56 EF	40 gal, 0.56 EF
Air tightness	.2 ACH Nat	.2 ACH Nat	.2 ACH Nat	.2 ACH Nat	.2 ACH Nat
Air conditioning SEER	10	12	10	10	10
Floors over unconditioned space	N/A	N/A	N/A	19	N/A
HERS Score	85.7	85.7	85.9	85.9	86.0

In order for all houses to achieve similar scores, significant improvements need to be made to the insulation levels and mechanical equipment of the smaller houses (less than 2000 square feet) relative to the larger houses (greater than 2000 square feet). To some extent this is driven by the decision to keep domestic water heater efficiency held constant. While smaller houses could trade off water heater energy savings with other components if a more efficient domestic water heater was installed, the higher efficiency water heating would still represent additional costs. As can be seen in Figure 6, as house size decreases the difference between space conditioning loads (heating and cooling) and total loads (heating, cooling and hot water) used to calculate the rating score increases.

Analysis of Energy Consumption, Rating Score, and House Size

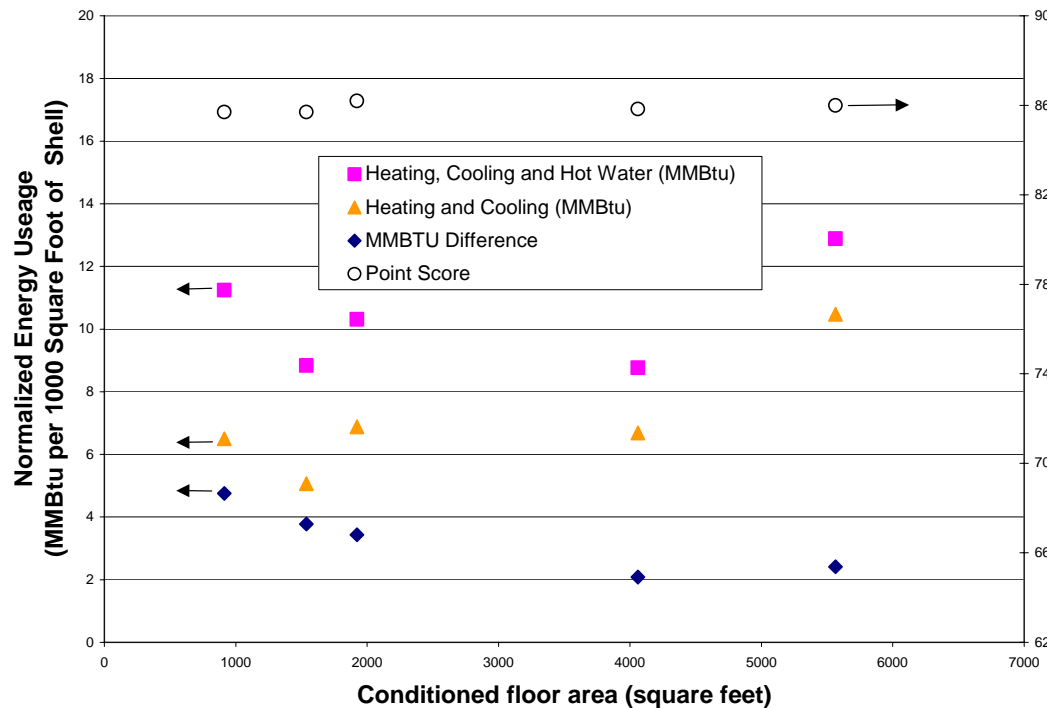


Figure 6. Comparison of Energy Consumption between Heating+Cooling and Heating+Cooling +Hot Water, as a function of thermal shell area of the house

Methodology for Calibrating Rating Score to House Size and Occupancy

A number of different normalization procedures were explored in this analysis to develop a methodology for adjusting rating score based on house size and occupancy. Normalization factors studied were 1000 square feet total shell area per occupant, 1000 square feet above grade shell area per occupant, and just occupancy. The two loads that were normalized were the sum of the normalized modified end use loads for heating and cooling for the rated house from the rating tool ($nMEUL_{HEAT} + nMEUL_{COOL}$), and the total normalized end use load (space heating and cooling and domestic hot water) from the rating tool ($TnML = nMEUL_{HEAT} + nMEUL_{COOL} + nMEUL_{HW}$.)

Once the houses had been modeled to meet the Summerset Home Performance Standard for a HERS 86 (actual scores ranged from 85.9 to 86.2), the first step was to create a Shell Occupancy Factor (SOF) for each house by dividing the thermal envelope shell area (in thousands of square feet) by the projected occupancy. This in

Analysis of Energy Consumption, Rating Score, and House Size

effect gives an occupancy-based measure of the shell area of the various sized houses. The occupancy was assumed as two for the first bedroom and one for each additional bedroom. Equation 1 was used to normalize total loads, Equation 2 was used to normalize just the space heating and cooling loads, and Equations 3 and 4 were used to normalize by occupancy. The normalized loads using shell area (Occupant•MMBtu/1000 sf shell) are shown in Table 3 and Table 4. The normalized loads just based on occupancy (MMBtu/occupant) are shown in Table 5.

$$TML_N = TnML / SOF \quad (1)$$

where

TML_N = total modified load normalized for shell area and occupancy

$TnML$ = total normalized modified load from rating tool

SOF = $\frac{\text{thermal envelope shell area (in thousands of square feet)}}{\text{Occupancy (\# bedrooms + 1)}}$

$$TML_{H\&CN} = \frac{(nMEUL_{HEAT} + nMEUL_{COOL})}{SOF} \quad (2)$$

where

$TML_{H\&CN}$ = total modified heating and cooling loads load normalized for shell area and occupancy

total normalized modified heating end use load from rating

$nMEUL_{HEAT}$ = tool

total normalized modified heating end use load from rating

$nMEUL_{COOL}$ = tool

SOF = $\frac{\text{thermal envelope shell area (in thousands of square feet)}}{\text{Occupancy (\# bedrooms + 1)}}$

Analysis of Energy Consumption, Rating Score, and House Size

$$TML_{OccN} = TnML / Occ \quad (3)$$

where

TML_{OccN} = total modified load normalized occupancy
 $TnML$ = total normalized modified load from rating tool
 Occ = number of bedrooms +1

$$TML_{OccH\&C} = \frac{(nMEUL_{HEAT} + nMEUL_{COOL})}{Occ} \quad (4)$$

where

$TML_{OccH\&C}$ = total modified heating and cooling loads load normalized occupancy
 $nMEUL_{HEAT}$ = total normalized modified heating end use load from rating tool
 $nMEUL_{COOL}$ = total normalized modified heating end use load from rating tool
 Occ = number of bedrooms +1

Table 3. TML (in Occupant•MMBtu/1000 sf shell), normalized using above grade shell area

House Size (sf)	TML_N	$TML_{H\&CN}$	Percent reduction in $TML_{H\&CN}$ compared to TML_N
912	52.0	31.4	39.5%
1537	79.0	46.2	41.6%
1922	59.4	39.8	32.9%
4060	89.8	64.3	28.4%
5564	102.5	82.5	19.5%

Analysis of Energy Consumption, Rating Score, and House Size

Table 4. TML (in Occupant•MMBtu/1000 sf shell), normalized using total shell area

House Size (sf)	TML_N	$TML_{H\&CN}$	Percent reduction in $TML_{H\&CN}$ compared to TML_N
912	32.6	19.7	39.5%
1537	36.0	21.1	41.6%
1922	41.7	27.9	32.9%
4060	45.7	32.7	28.4%
5564	64.2	51.7	19.5%

Table 5. TML (in MMBTU per occupant)

House Size (sf)	TML_{Occ}	$TML_{OccH\&CN}$	Percent reduction in TML_{Occ} compared to $TML_{OccH\&CN}$
912	12.9	7.4	42.2%
1537	11.5	6.6	42.7%
1922	15.3	10.2	33.3%
4060	17.2	13.1	23.7%
5564	26.1	21.2	18.7%

Table 3 and 4 show The TML_N (for both total and above grade shell area) of the 5564 square foot house is 1.97 times bigger than the TML_N 912 square foot house, and the $TML_{H\&CN}$ for the 5564 square foot house (for both total and above grade shell area) is 2.62 times bigger than the $TML_{H\&CN}$ the 912 square foot house. Table 5 shows when normalizing by occupancy, the TML_{Occ} of the largest house is 2.03 times the smallest house loads and the $TML_{OccH\&CN}$ of the largest house is 2.85 times the smallest house. This is demonstrating the magnitude of difference in loads for different sized houses with the same rating score. More importantly, the percentage difference between the TML_N and $TML_{H\&CN}$ in Table 3 and 4 range from 19.5% in the largest house to 41.6% in one of the smaller houses, showing the relative impact of the domestic water heating energy as a function of house size.

Analysis of Energy Consumption, Rating Score, and House Size

The next step was to create projected total loads (PTL) for each house using one of the normalized loads as the base. For this study, the three smallest houses (912 square foot, 1537 square foot and 1922 square foot) were each studied as the base for creating the normalized total modified load. The PTL was computed using Equations 5 and 6 for the total loads and the heating and cooling loads respectively. Equations 7 and 8 were used to normalize by occupancy.

$$PTL_{house} = TML_{Nbase} * SOF \quad (5)$$

where

PTL_{house} = projected total load of the house based on the TML_n of the base house

TML_{Nbase} = total normalized modified load normalized for shell area and occupancy of the base house

SOF = shell occupancy factor of the house for which the projected load is being calculated

$$PTL_{houseH\&C} = (TML_{H\&CNbase} + nMEUL_{DHW}) * SOF \quad (6)$$

where

$PTL_{houseH\&C}$ = projected total load of the house based on the $TML_{H\&CN}$ of the base house

$TML_{H\&CNbase}$ = total modified heating and cooling loads load normalized for shell area and occupancy

$nMEUL_{HW}$ = total normalized modified heating end use load from rating tool

SOF = shell occupancy factor of the house for which the projected load is being calculated

Analysis of Energy Consumption, Rating Score, and House Size

$$PTL_{houseOCC} = (TML_{Occbase} + nMEUL_{DHW}) * Occ_{house} \quad (7)$$

where

$PTL_{houseH\&C}$ = projected total load of the house based on the TML_{Occ} of the base house

$TML_{Occbase}$ = total modified loads load normalized for occupancy

$nMEUL_{DHW}$ = total normalized modified domestic water heating end use load from rating tool

Occ_e = occupancy of the house for which the projected load is being calculated (# Bedrooms +1)

$$PTL_{houseOccH\&C} = (TML_{H\&CNbase} + nMEUL_{DHW}) * Occ_{house} \quad (8)$$

where

$PTL_{houseOccH\&C}$ = projected total load of the house based on the $TML_{OccH\&CN}$ of the base house

$TML_{H\&CNbase}$ = total modified heating and cooling loads load normalized for occupancy

$nMEUL_{DHW}$ = total normalized modified domestic water heating end use load from rating tool

Occ_{house} = Occupancy of the house for which the projected load is being calculated (# Bedrooms +1)

Analysis of Energy Consumption, Rating Score, and House Size

From these projected total loads, rating scores using the were developed using the formula from the Mortgage Industry National Home Energy Rating Systems Accreditation Standard (RESNET 2002) shown in Equation 9.

$$\text{Point Score} = 100 - ((PTL/TRL) * 20) \quad (9)$$

where

PTL = projected total load from Equation 6, 7 or 8

TRL = total normalized modified load of the reference home from rating tool

The PTL and rating scores using the 1922 square foot house as the base are shown in Table 6, Table 7, and Table 8.

Table 6. Projected Total Load and Rating Score Normalized Using Above Grade Shell Area (1922 sf house base)

House Size (sf)	PTL_{house}	PTL_{house} Rating Score	$PTL_{houseH\&C}$	$PTL_{houseH\&C}$ Rating Score
912	42.17	84.4	44.46	82.6
1537	46.77	85.5	50.89	81.2
1922	61.32	86.2	61.32	86.2
4060	58.63	90.3	59.52	88.2
5564	74.68	92	74.31	91.9

Table 7. Projected Total Load and Rating Score Normalized Using Total Shell Area (1922 sf house base)

House Size (sf)	PTL_{house}	PTL_{house} Rating Score	$PTL_{houseH\&C}$	$PTL_{houseH\&C}$ Rating Score
912	47.25	82.5	47.85	82.3
1537	53.76	83.3	55.56	82.8
1922	61.32	86.2	61.32	86.2
4060	80.87	86.7	74.36	87.7
5564	83.67	91.1	80.32	91.4

Analysis of Energy Consumption, Rating Score, and House Size

Table 8. Projected Total Load and Rating Score Normalized by Occupancy Only (1922 sf house base)

House Size (sf)	$PTL_{houseOcc}$	$PTL_{houseOcc}$ Rating Score	$PTL_{houseOccH\&C}$	$PTL_{houseOccH\&C}$ Rating Score
912	45.99	83	30.69	82.6
1537	61.32	81	40.92	81.2
1922	61.32	86.2	40.92	86.2
4060	76.65	87.4	51.15	88.2
5564	76.65	91.8	51.15	91.9

In reviewing the data it became apparent that the normalization just by occupancy was creating something of a step function, in that rating scores were increasing dramatically for houses of different size with the same number of bedrooms, and that the range of scores were not following a logical progression, which if put into the market would likely cause confusion and the opportunity for gaming. This is most evident when comparing the rating scores in Table 8 of the smallest three homes, where the score of the 1537 square foot home is lower than the score of the 912 square foot home, and the jump between the 1537 and 1922 square foot homes is at least 5 points, or a 25% increase in energy efficiency.

The next step was to evaluate the rating score and loads of these houses if they all were built with the same energy features. The features necessary to make a small home meet the rating score according to the PTL method would not be significantly above code minimums, and in some cases could even fall below code minimum. We took the 1922 square foot house and developed an energy efficiency package that brought the house to a nominal HERS score of 86 (actual score is 86.3). The energy features of this house are shown in the “1922 sf” column in Table 10. This package was then applied to each of the other house sizes. Figure 7 shows the associated scores for each house and a Same Characteristics Curve (SCC) that represents the trend in score for that package.

Analysis of Energy Consumption, Rating Score, and House Size

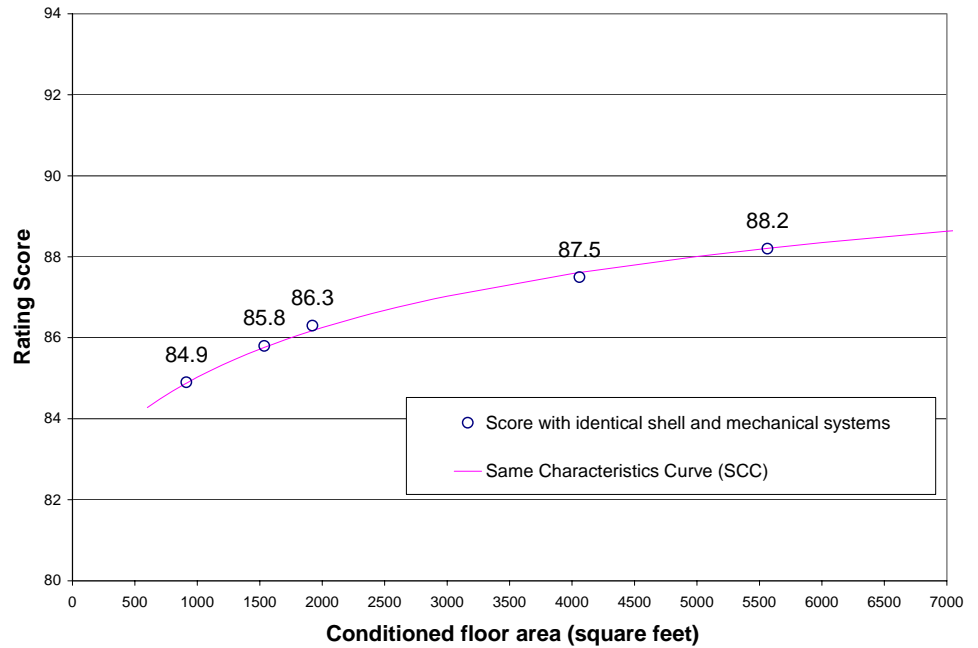


Figure 7. Same Characteristics Curve that represents the trend in score for houses with the 1922 sf house HERS 86.3 energy features.

Figure 8 shows the associated scores for the normalized loads in Table 6 and Table 7. From this data, a curve was generated (Proposed Rating Score Curve, or PRSC) that minimizes the lowering of the rating score for small houses below that of the 1922 square foot house with HERS 86 energy characteristics, and generally fits to the ratings of the larger houses with the normalized loads.

Analysis of Energy Consumption, Rating Score, and House Size

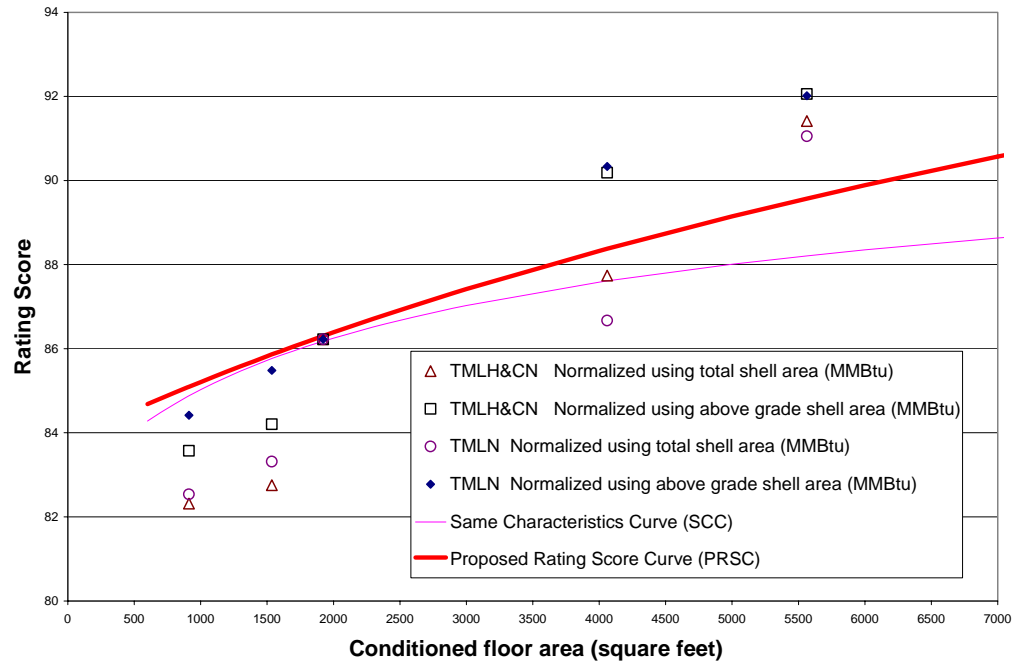


Figure 8. Rating Scores for Houses with normalized loads vs. SCC and Projected Rating Score Curve

A rating score was then assigned for each house size associated with the PRSC, and from that rating, the total modified load (TML) necessary to achieve that score was calculated. The original TML and the PRSC TML are compared in Figure 9 and Table 9 to evaluate the absolute energy impact of the PRSC method.

Analysis of Energy Consumption, Rating Score, and House Size

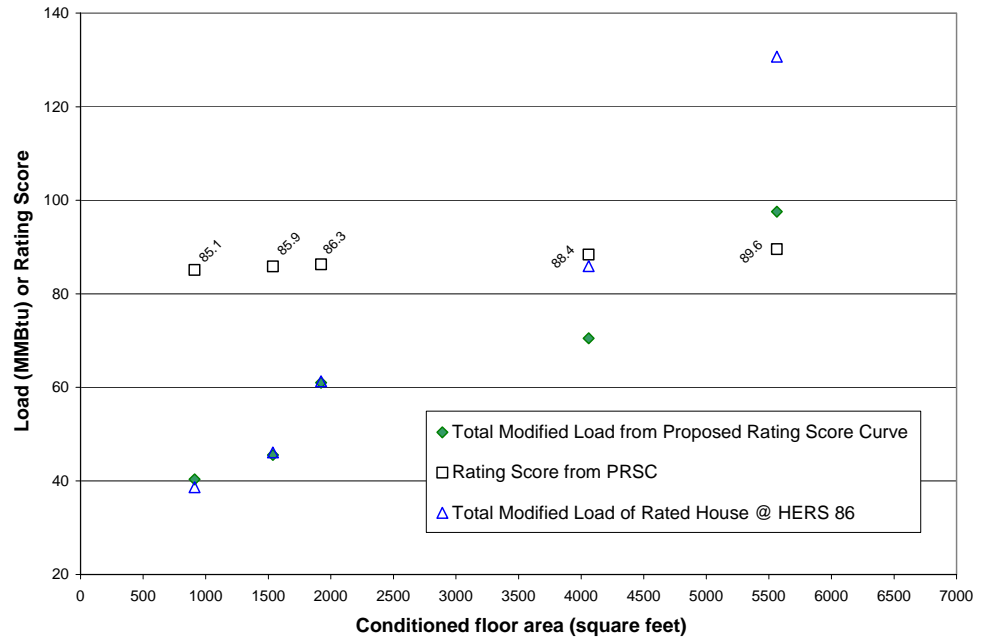


Figure 9. Comparison of total modified loads using PRSC methodology and total modified loads from all homes at HERS 86 rating

Table 9. Loads and scores associated with the PRSC

House Size (sf)	TML of HERS 86* (MMBtu)	TML from PRSC (MMBtu)	Relative Difference (%)	Absolute Difference (MMBtu)	Original Rating Score*	Rating Score from PRSC
912	38.64	40.33	-4%	-1.69	85.7	85.1
1537	46.08	45.55	1%	0.53	85.7	85.9
1922	61.32	60.98	1%	0.34	86.2	86.3
4060	85.92	70.49	22%	15.43	85.8	88.4
5564	130.68	97.54	34%	33.14	86	89.6

*House with energy features as shown in Table 2

Analysis of Energy Consumption, Rating Score, and House Size

While the smallest house decreased in energy efficiency by 4%, the absolute change in energy consumption is relatively small because its original energy consumption was already small to begin with. The largest houses see significant energy savings, both in percentages and in absolute values.

The final analysis was to understand what the energy characteristics would be for these houses with the score created using the PRSC. The characteristics for each house are shown in Table 10.

Table 10. Comparison of energy features for homes meeting the PRSC (R-Value in ft²•h•°F / Btu).

Component	House Size				
	912 sf	1537 sf	1922 sf	4060 sf	5564 sf
Walls	R-13 +R-5	R-13 +R-3	R-13 +R-4	R-19 +R-5	R-20 +R-5
Ceilings	R-38	R-38	R-38	R-38	R-38
Windows & Glass Doors	R-3.1 SHGC 0.34	R-3.1 SHGC 0.34	R-3.1, SHGC 0.34	R-3.1 SHGC 0.34	R-3.1 SHGC 0.34
Doors	2.2	2.2	2.2	2.2	2.2
Basement walls above grade	R-11	R-11	R-11	R-11	R-11
Basement walls below grade	R-11	R-11	R-14	R-11	R-11
Duct location	Inside envelope	Inside envelope	Inside envelope	Inside envelope	Inside envelope
Heating efficiency (AFUE)	80%	96%	93%	96%	96%
Domestic water heating efficiency	30 gal, 0.58 EF	40 gal, 0.56 EF	30 gal, 0.58 EF	40 gal, 0.58 EF	40 gal, 0.84 EF
Air tightness	0.2 ACH Nat	0.2 ACH Nat	0.2 ACH Nat	0.2 ACH Nat	0.2 ACH Nat
Air Conditioning SEER	10	12	12	12	12
Floors over unconditioned space	N/A	N/A	N/A	19	N/A
HERS Score	85.4	85.9	86.3	88.4	89.6

Analysis of Energy Consumption, Rating Score, and House Size

Factors Impacting the Method

It needs to be noted that this method was developed using a cold climate example, where the largest end use load is space heating, followed by domestic hot water, then cooling. In other climates, decisions on what components to vary to come up with the energy characteristics for generating the SCC will likely differ from what was used in this analysis. The decision to set water heater efficiency as the one variable that would be set at a fixed efficiency was also somewhat arbitrary, however it is critical that the components chosen for the base house must be achievable by all house sizes. For example, if the base house is a one-story home and 2x4 framing at 24 in. O.C. is the framing characteristic, this cannot be achieved in a two-story home due to the requirements in Table 2308.9.1 in the International Building Code (2000) and other model codes that are still being used across the country.

In addition, the standards set to establish the SCC are critical. This in effect becomes the prescriptive package for many homes in the size range smaller than the base house. As such, it is important to make sure that not only the energy efficiency but also the health and safety of the occupants and the durability of the shell are assured. In this example, minimum efficiency water heating equipment was specified; however, the standards need to be written to eliminate the possibility that the by-products of combustion can be introduced into the home. This can be achieved by requiring either direct vent, power vent, or sealed combustion equipment, or by locating the equipment in conditioned space that is air sealed from the remainder of the house. In other climate zones, it may be possible to locate the water heater in unconditioned spaces; however, this is not feasible in cold climates.

One other factor that needs to be evaluated is the level of building envelope moisture tolerance that can be achieved cost effectively, and what impact that has on building durability. In smaller houses with higher occupant densities, the envelope will likely be subjected to higher internal moisture loading than the same occupancy in a larger home. Standards for air tightness and vapor permeability of the envelope need to be evaluated and decided upon to minimize the possibility of building envelope damage due to moisture movement through air leakage and vapor diffusion. Reductions in energy scores for smaller houses should not necessarily be interpreted as allowing for houses that are not well air sealed and do not have controlled mechanical ventilation.

Analysis of Energy Consumption, Rating Score, and House Size

Policy vs. Technical Decisions

It should be noted that there is no technical basis for the selection of the 1922 square foot house as the base for the development of the PRSC. The 912 square foot or 1537 square foot house could have been used as the HERS 86 home to generate the PRSC. Alternately, once the curve was generated, the scale could be shifted to make the HERS 86 score land at virtually any house size. This is where a community developer or Green Building Program must look at their goals and determine which house size should represent the appropriate size for a given occupancy, and use that as the base for this methodology. The smaller the base house, the higher the HERS scores will be for larger houses. IBACOS studied this using smaller houses as the base for the PRSC, however it had the tendency to push large home HERS scores up above a 93, which is the area that the Building America and Zero Energy Homes Programs are focusing research on. It does not appear practical to be suggesting that scores much above a HERS 90 would be acceptable to most of the industry at this point in time.

Using the smaller houses as the HERS 86 base will also likely have the impact of increasing the slope of the SCC, as achieving a HERS 86 in a small house will require improvements in the thermal envelope, advanced air sealing, and heating, cooling and domestic hot water equipment improvements. This package of “across the board” improvements will likely mean even greater improvements as the house size increases, which may not be cost effective. IBACOS will continue to study this issue in future work.

Community Scale Impact

Another issue that must be looked at in the use of this method is the variability in rating scores for the same house based on orientation, and for a product offering being built by a single builder. At Summerset and other communities IBACOS has worked with, builders have asked for a worst case package of building components in an integrated design that will get them to the energy performance standard. This single package allows them to simplify their purchasing and construction process. By using this worst case package, the “fleet average” across a given house size or group of house sizes within the builders offering will be higher than the standard. The rating scores shown for the Cottage Homes and the Rental Town Homes in Table 1 show that while the minimum rating score was used to set the energy package, the actual ratings for the larger group of homes that encompassed the entire product offering exceeded the minimum by up to 2.6 HERS points. While the worst-case package for smaller homes using the PRSC method may represent a slight decrease in energy efficiency, it is likely

Analysis of Energy Consumption, Rating Score, and House Size

that the fleet average will be higher, and may actually meet the HERS 86 level. IBACOS will be working to further explore this with a variety of consortium members throughout 2003.

Conclusion

The use of a single point score as a threshold of performance is on the surface a simple and equitable standard. As the housing industry is maturing to evaluate not simply the relative energy efficiency of housing but the total environmental impact, new methods for defining performance and encouraging lower energy and resource use are necessary. IBACOS will continue to evaluate this method in 2003 work with communities and initiatives to study local implementation of high performance homes.

References

References

IBACOS, Inc. KAR-8-18608-13.A.2, Community Scale Building System Test and Evaluation Results. Pittsburgh: IBACOS. October 2001.

RESNET. RESNET & The National Association of State Energy Officials Mortgage Industry National Home Energy Rating Systems Accreditation Standard, 2002. Oceanside, CA. RESNET 2002a.

U.S. Census Bureau, Table HH-4, Households by size, 1960 to Present, 2000 census.
<http://landview.census.gov/population/socdemo/hh-fam/tabHH-4.xls>.
2002b.

National Association of Homebuilders, Characteristics Of New Single-Family Homes (1987-2001). NAHB Website.
<http://www.nahb.org/generic.aspx?sectionID=130&genericContentID=374>.
2003.

International Code Council International Building Code: 2000 Edition. Falls Church, VA: International Code Council, 2000.

Susankas, Sarah. The Not So Big House: A Blueprint for the Way We Really Live. Newtown, CT: Taunton Press. 1998.

Council of American Building Officials. Model Energy Code: 1993 Edition. Falls Church, VA: Council of American Building Officials. 1993.

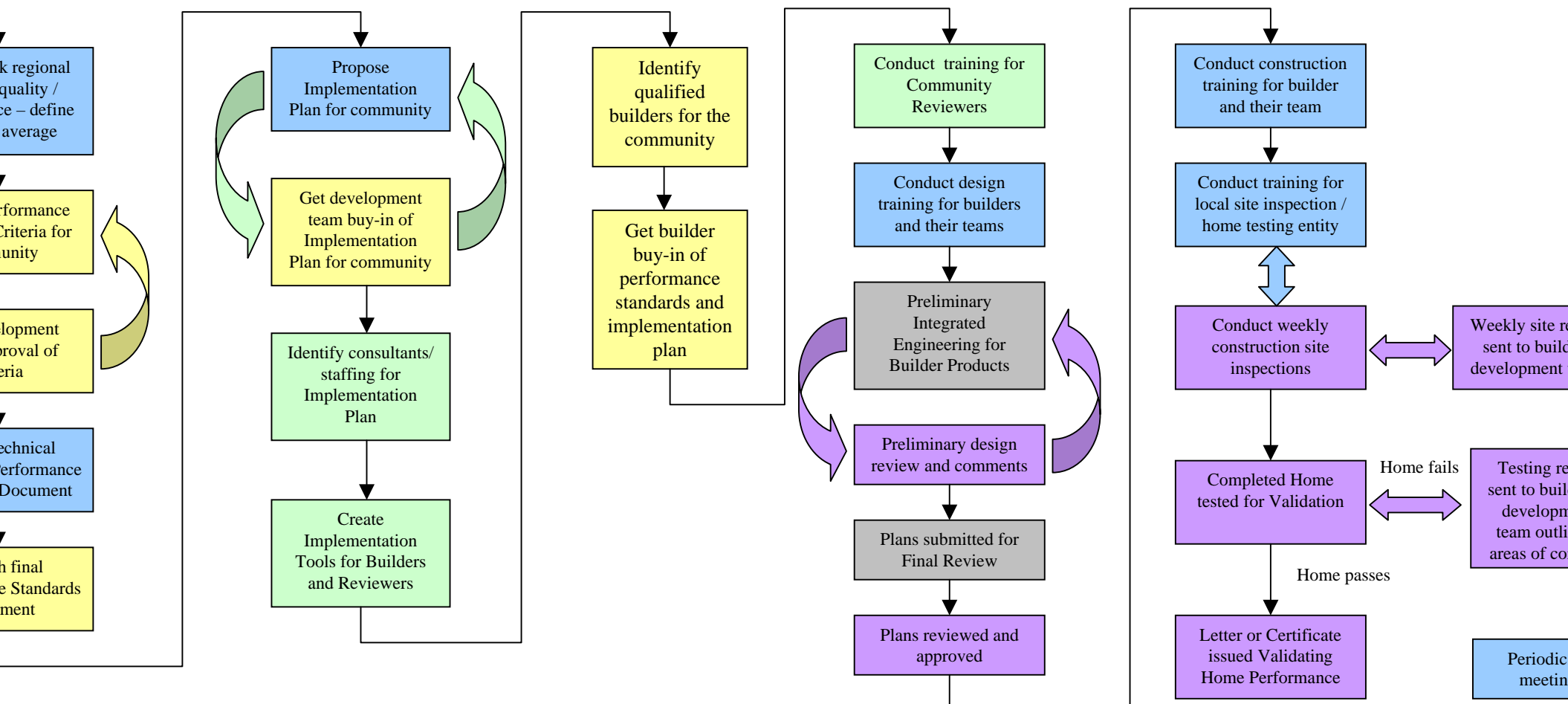
IBACOS. KAR-8-18608-06.C.2 Summerset Pilot Community Project Home Performance Standards and Approach. Pittsburgh: IBACOS. 1999.

Appendix A

Appendix A

Community Based Home Performance Process Map

Standards Development Phase Implementation Plan Development Phase Product Design and Engineering Phase Home Construction Phase



Weekly site report sent to building development

Home fails
Testing report sent to building development team outlining areas of concern

Home passes
Periodic meeting