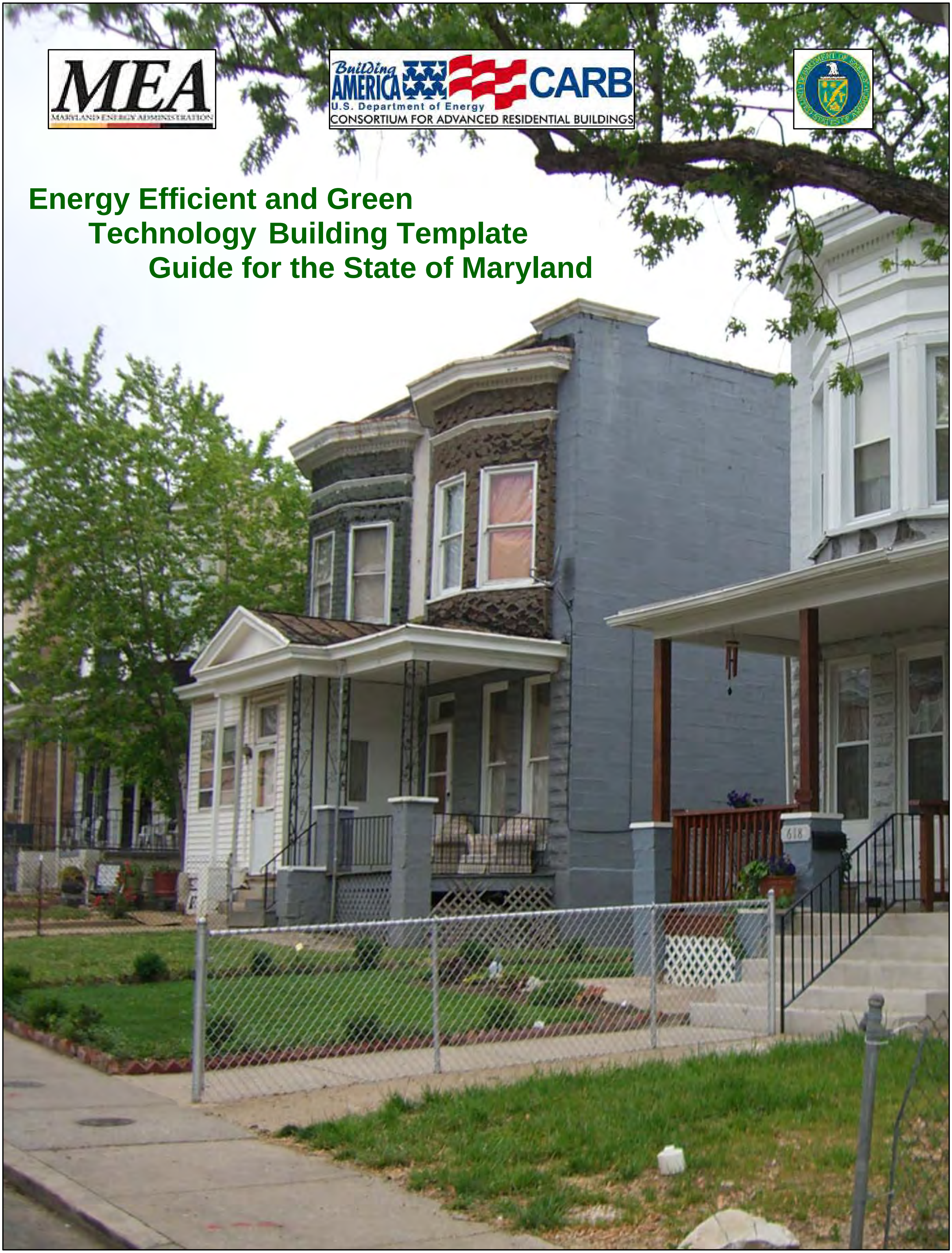
Energy Efficient and Green Technology Building Template Guide for the State of Maryland



MEA
MARYLAND ENERGY ADMINISTRATION
Building AMERICA CARB
U.S. Department of Energy
CONSORTIUM FOR ADVANCED RESIDENTIAL BUILDINGS

Energy Efficient and Green Technology Building Template Guide for the State of Maryland

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CREDITS

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TABLE OF CONTENTS

Background

The Maryland Energy Administration (MEA) promotes energy efficiency and conservation, which in turn facilitates economic development, reduces reliance on foreign fuel supply, and improves the environment. MEA provides technical and financial assistance to private, non-profit, and governmental entities for the purposes of furthering energy conservation, efficiency, and renewable energy.

With energy costs rising and increasing public concern for the environment, the building science community has the opportunity and responsibility of incorporating energy efficiency and green building strategies into mainstream residential construction. In response to a 2002 U.S. Department of Energy's (DOE) solicitation for State Energy Program Special Projects under the Building America Program, MEA submitted a proposal to implement an "Energy Efficient and Green Technology Building Templates Program".

Technical assistance was provided by DOE's Building America (BA) Program. The BA program develops innovative system engineering approaches to advanced housing that enable the U.S. housing industry to deliver affordable and environmentally sensitive housing while maintaining profitability and competitiveness of homebuilders and product suppliers in domestic and overseas markets.

The Consortium for Advanced Residential Buildings (CARB) was chosen to provide Building America technical support for this Maryland State Energy Project (SEP) grant. CARB, led by Steven Winter Associates, Inc. (SWA), is one of several teams that are working to achieve the Building America program goal of attaining zero net energy use in marketable production homes by the year 2020. CARB works with scores of professionals throughout the homebuilding industry to design, engineer, construct, and test energy-efficient homes. The systems-engineering strategies used to build the houses assure the highest level of performance, while maintaining market appeal.

Project Scope

The purpose of this SEP grant was to implement an "Energy Efficient and Green Technology Building Template" in partnership with selected Maryland Homebuilders. There were two primary initiatives in this project. The first task was the construction of 3 new townhouses, using Building America energy-efficiency guidelines, to reduce total energy consumption by 50% compared to the 1993 Model Energy Code (MEC) or 30% total source energy consumption when compared to the typical 1990's construction (*Building America Benchmark Definition 12/29/04)*. Struever Bros. Eccles & Rouse (SBER) provided the 3 townhouses for the case study utilized within this report.

The second component was the rehabilitation of 5 rowhouses that exceed the total energy performance of the 1993 MEC by 30%. This equates to a total source-energy savings of 20% when compared to the 1990's construction. A case study of 5 rowhouses rehabilitated by the Chesapeake Habitat for Humanity (CHfH) will be discussed within this report.

Each of the builder partners was responsible for providing the land, materials, and labor necessary to complete the project. CARB performed energy modeling and made recommendations for meeting the target energy goals. Based on the options presented by CARB, the builder chose the most cost-effective strategy for achieving the program goals. Technical assistance was also provided by CARB for the implementation of these strategies.

CARB was also responsible for recommending green features to be included in both the rehab and new construction prototypes. For the rehabs, the green recommendations were based upon the *Green Building Template: A Guide to Sustainable Design Renovating for Baltimore Rowhouses*. This document was prepared by TerraLogos for The Maryland Department of Natural Resources in December of 2001. This template lays out several packages to "increase energy efficiency and comfort, create a healthy indoor environment, and reduce resource consumption by specifying earth-friendly materials and water-saving fixtures, and instituting a program to recycle demolition and construction waste." The packages are referred to as "light, medium, and deep green" and the major features of each package are shown below.

Feature	Base Case	Light Green	Medium Green	Deep Green
Insulation				
- Roof	R-30 FGB	R-24 LB cellulose	R-38 "dense pack"	R-31 AirKrete
- Walls	R-11	R-11 Stab cellu'	R-19 steel stud	R-19 AirKrete
- Basement wall	Un-insulated	R-11 FSB	R-11 FSB	AirKrete 2"
- Party Walls	Un-insulated	sheetrocked	Firing, cellulose	R-5.5 AK, GWB
Roof surface	BUR recoat	BUR White acry	Mod Bit. Light color	"Green Roof"
Windows	DP vinyl	Vinyl Low-E	Alum TB Low-E	FG Low-E Argon
Skylights	Clean up	Retro dbl Pane	Retro dbl Pane	Solar Tubes
Doors	Standard	R-4 improved	R-4 improved	R-5 super-insul
HVAC				
- Heating	AFUE 78	AFUE 84	AFUE 91	Combo-unit FA
- Cooling	SEER 11	SEER 11	SEER 13	SEER 15
- Hot Water	Standard	"Efficient" gas	Demand htr, gas	Combo/solar HW
- Ducts	Sheet mtl,	Duct seal, good	Duct seal <10% lkg	Tight sealed
- Ventilation	Bath fans	Bath fans	Bath fans, timers	Bath & Kit / timers
Thermostat	Standard	Digital	Digital (2)	Digital (2)
Ceiling Fans	Pre-wired	LR, DR, Kitchen	LR, DR, Kitchen	LR, DR, Kitchen
Appliances				
- Stove	Std	Outside venting	Elect. Ignition, OV	Elect. Ignition, OV
- Refrigerator	Std	EnergyStar	EnergyStar	"Eco-Fridge"
- Microwave	By owner	By owner	By owner	E*/range hood
- Dishwasher	Std	Std	EnergyStar	EnergyStar
- Laundry	Std	Std	EnergyStar	EnergyStar
Lighting package	Standard pkg	Some flouresnt'	Pin-base CFL's	Pin-base CFL's
Water Savings	NAECA	LF Shower head	Better toilet, LF SH	Dual flush toilet

During the course of the project, CARB did several inspections of the prototype homes to ensure proper implementation of the recommended strategies: an initial inspection during framing, an inspection prior to drywall to inspect the insulation installation and mechanical ductwork rough-in, and a final inspection during the performance testing.

The lessons learned from these two case studies, along with technical experience from the BA program, were utilized by CARB to develop this Energy Efficient and Green Technology Building Template Guide for builders throughout the state of Maryland.

Chapter One: New Construction

The new construction builder partner was Struever Bros. Eccles & Rouse, Inc. (SBER), a pioneer of Baltimore's real estate landscape. For thirty years, SBER has been creating communities in Baltimore neighborhoods. SBER is committed to an enduring legacy of building homes and neighborhoods that exemplify the finest urban living options available in today's marketplace. They were awarded a redevelopment opportunity by the City of Baltimore to transform Moravia Park, a neighborhood in northeast Baltimore. Working with Doracon Contracting, SBER began the re-development of an 18 acre property that was to be completed in 2006. The development, Frankford Estates, will have up to 170 new homes and was designed as a "Green-Friendly" community. The community includes townhomes, duplexes, and single-family homes. Three attached townhomes in this community served as the prototypes for this project.

SBER worked with CARB to incorporate energy efficient strategies into three townhomes and to expand the green options SBER offers to prospective homeowners. Although the recommendations require a few extra steps and some additional first costs, the increased energy-efficiency and sustainability of these homes allow for increased market differentiation due to the reduction in the homeowner's utility bills, improved comfort, and enhanced environmental awareness. With many development opportunities available in Maryland, new construction has the responsibility of raising the standards in energy efficient housing.

Energy Modeling

EnergyGauge USA v2.59 (EGUSA), an hourly energy simulation tool, was used to perform a cost-benefit analysis and generate the optimal package of measures to improve the energy performance of the prototype homes. CARB determined that the energy performance of the current builder homes was 16% better than the *Building America Benchmark Reference Home (definition 12/29/2004).* Once this "standard practice" energy performance was established, CARB simulated the impact of alternative specifications on the energy performance of the home. CARB developed specifications that would meet or exceed the Building America goal of 30% whole house source-energy savings.

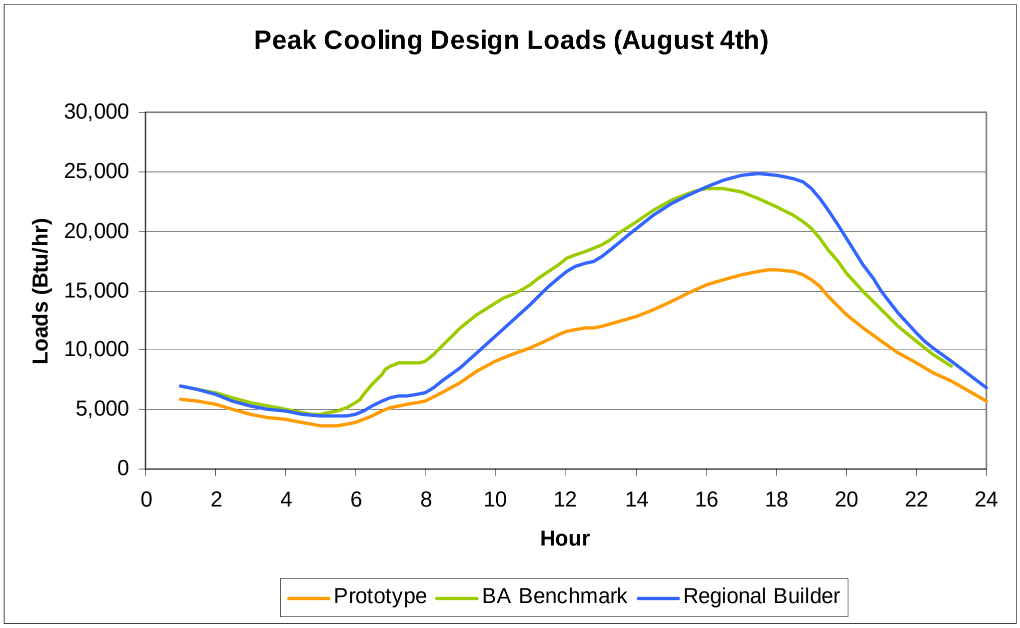
The immediate priority for the energy efficiency/green industry should be on developing and packaging environmentally-friendly products that are cost-competitive, have a range of benefits, and minimize the tradeoffs in terms of style and functionality. This can be reinforced by connecting products to specific environmental outcomes and highlighting the full array of benefits that environmentally friendly housing can offer. SBER offers various energy-efficient and green features as a buy-up option, but these are typically overlooked by homeowners in the end. A more aggressive marketing campaign is needed or better yet, directly incorporating these features into the builder standard practice. The table below summarizes the building's energy-efficiency specifications for these prototype townhouses.

Struever Rouse Prototype Specifications

Foundation Walls	2" Polyiso, foil-faced rigid insulation board (R-13), full height, interior
Rim/Band Joists	Spray-in-place polyurethane foam insulation (R-6.75/inch)
Exterior Walls	2x6, 24" OC, framed walls
Wall Insulation	Blown-in fiberglass insulation (R-21)
Floor System	Open web trusses
Windows	Insulated glass, low-e, argon-filled (U = 0.35, SHGC = 0.29)
Ceiling Insulation	Fiberglass insulation (R-40)
Duct System	Compact system sealed with mastic
Transfer Grilles	R.A.P. transfer grilles, 8"x8" over the doors of each secondary bedroom
Space Heating	2 Bryant Plus 90i gas furnaces, 93% AFUE, direct vent
Space Cooling	2 Bryant air conditioners, SEER 13
Thermostat	Programmable
Water Heating	Noritz tankless gas water heater, EF = 0.82
Lighting	100% fluorescent
Appliances	Energy Star® refrigerator and dishwasher
Ventilation	Upgraded Energy Star® bath fan controlled by Grasslin pin timer

When compared to SBER's standard practice that meets Energy Star requirements, overall source energy consumption is reduced by 23%. At current energy prices in Baltimore of approximately 14¢ per kWh and $1.30 per therm of natural gas, this translates to $533 in energy savings each year over standard builder practice.

In addition to reducing overall electrical usage, HVAC systems are prime candidates for reducing peak demand load. Almost all heating and cooling systems tend to be "oversized". This means that they have more capacity than they need. The idea behind installing higher capacity systems is to ensure that no matter how cold or hot it gets (or how leaky the ducts are) the homeowners will remain comfortable. The furnace or air conditioning equipment takes some time to reach its optimum operating temperature and shorter cycles mean that the equipment is operating less efficiently. Lastly, oversized equipment uses more power which creates a bigger peak demand for the utility. Properly sizing the equipment, making sure that the conditioned air gets to where it was intended, and utilizing high efficiency equipment results in a design peak cooling load reduction of 33% and a design peak heating load reduction of 30% over the current builder standard practice.



Energy Efficient Strategies and Green Technologies

CARB's recommendations to SBER focused on improving energy efficiency and the health and safety of occupants while minimizing the impact on the environment. These strategies are applicable to new construction projects throughout the state.

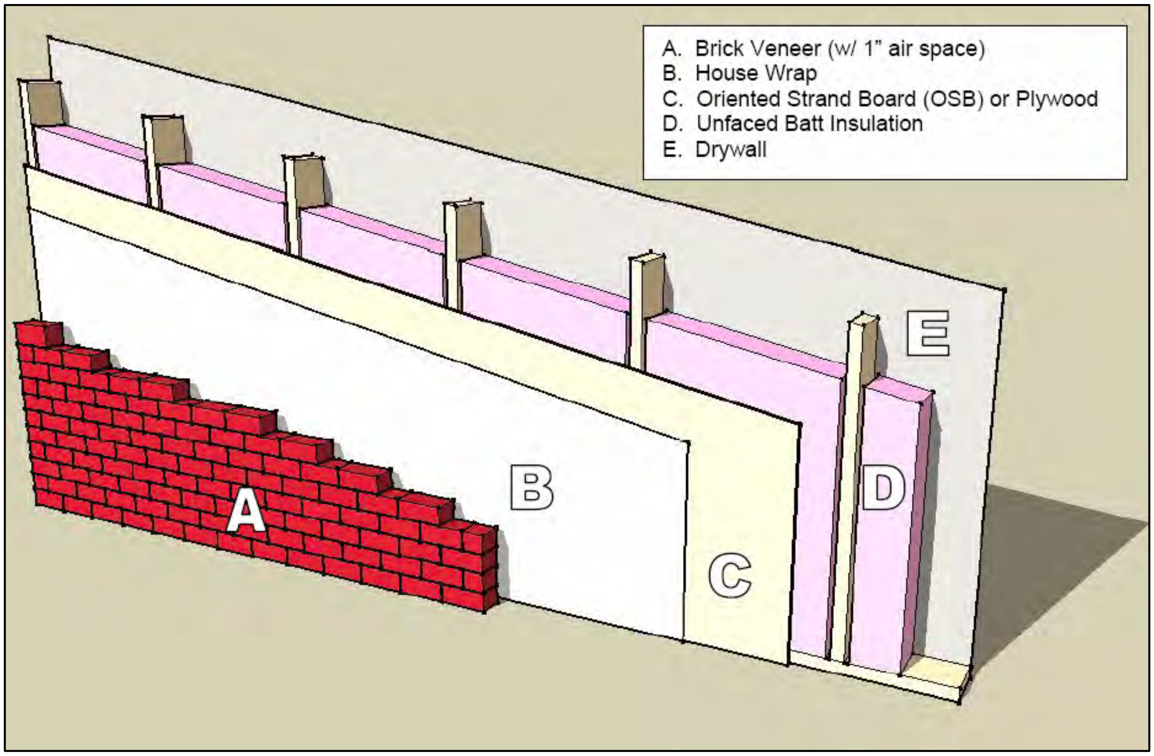
Improved Building Envelope – Construction

In order to reduce the overall energy consumption of a building, it is best to first minimize the building load on the building. This can be effectively done by increasing the thermal resistance of your building envelope. A common practice is to use 2x4 stick or panelized construction at 16" on center with Thermo-ply insulated sheathing on the exterior. This sheathing provides minimal thermal benefits (R-0.20), but can help in minimizing building infiltration. CARB recommended switching to 2x6 panelized walls at 24" on center (OC) with ½" oriented strand board (OSB) on the exterior.

Panelized wall systems consist of prefabricated, or factory-manufactured, panels that form a structural envelope, and significantly expedite on-site framing. Panels are manufactured in a factory, which ensures their quality and consistency, but may limit flexibility. For example, concrete foundations must be placed precisely, and on-site design changes can be costly and difficult. The initial cost of prefabricated panels may be higher than that of conventional framing materials. However, labor savings are often significant enough to offset the initial cost difference.

Panelized construction offers several benefits for this climate region. Because they are prefabricated in an indoor factory setting, they can be constructed any time of year, and are not subject to weather delays. Panelized systems can be designed to offer a uniform and continuous air barrier that improves insulation and helps homeowners stay comfortable while reducing their heating and cooling costs. Panel systems have gained popularity among production builders because of their ability to reduce framing errors (quality control) and maintain construction schedules.

Specifying 24" OC stud framing reduces thermal bridging while 2x6 studs maintain structural integrity and maximizes the insulation that can be installed in the wall cavity.

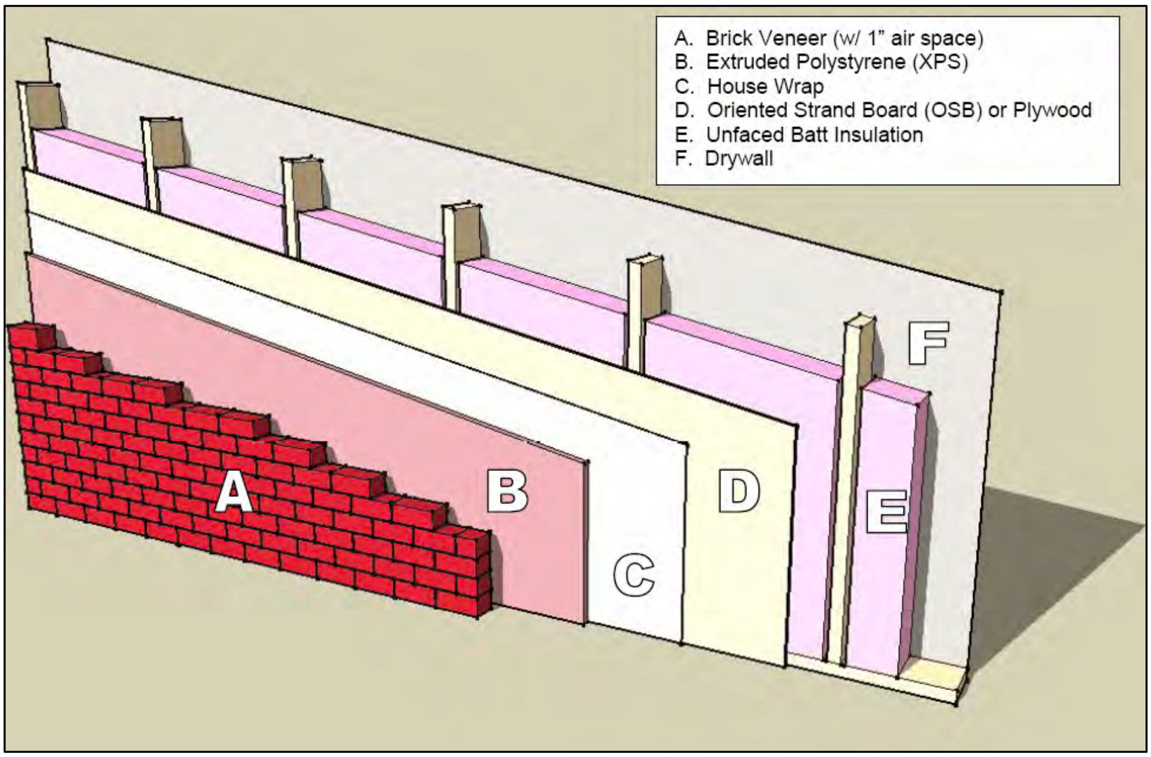


Increased insulation levels help homeowners reduce energy costs, and provide builders with an additional selling point. Blown-in insulation systems provide improved air sealing and achieve the rated R-value more consistently than batt insulation. There are green insulating products available that are certified by the Greenguard Program. This certification helps identify products that have been tested for emissions of formaldehyde, volatile organic compounds (VOCs), respirable particles, and other pollutants.

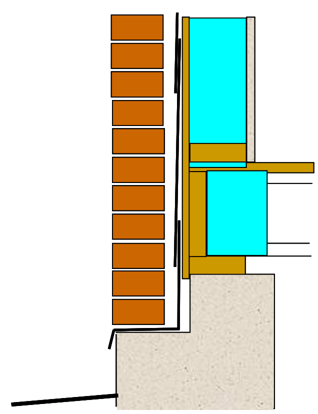
In terms of cost, 2x6 at 24" OC should have a negligible incremental cost over 2x4 at 16" OC, except for the additional insulation that will be needed to fill the larger wall cavity. Even this added cost for insulation should not affect the first cost, as the HVAC system sizing should be reduced sufficiently to allow for cost-shifting. Most of the savings will be seen on the cooling side due to the larger availability of incremental sizes for cooling equipment.

SBER's incremental cost for additional insulation was $1,795 for end units, and $535 for the middle unit. The wider foundation required for the 2x6 panels cost an additional $566. Theoretically, the savings in lumber by switching from 16" to 24" OC pays for the incremental cost of switching from 2x4's to 2x6's. Depending on your panelizing company's familiarity with this framing technique, cost might be slightly higher or lower.

Other options:
CARB would highly recommend the following wall assembly that uses rigid insulation on the exterior of the sheathing as an additional method to increase the overall thermal resistance of the wall system and to provide a thermal break in the wall assembly. One inch or more of extruded polystyrene (XPS) with a R-value of 5 per inch can be used. This strategy can be used regardless of framing type and spacing. It should be noted that window details may be affected due to the added thickness of the insulation.

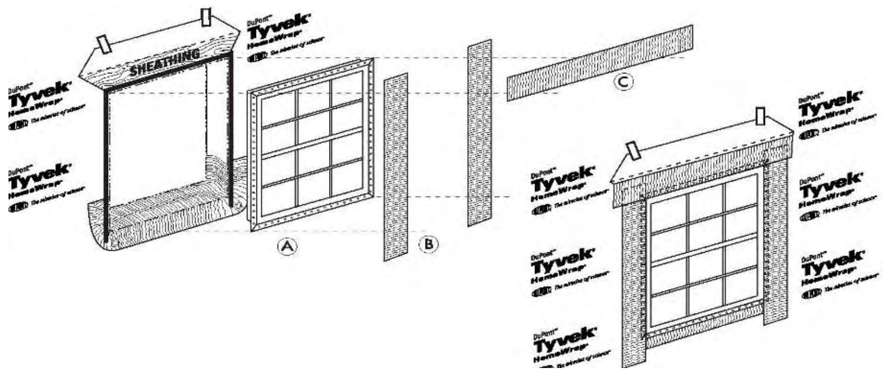


Improved Building Envelope – Moisture Barrier



When considering water management for the building envelope, it is important to not only consider the materials used (house wrap, flashing, etc.), but how they are installed. The most common method of "waterproofing" the walls of a home is to provide a drainage plane using house wrap. This material should be installed from the bottom up to ensure overlapping of the previous row. Overlaps should be a minimum of 3-inches horizontally and 6-inches vertically. The seams should be either taped or the appropriate fasteners specified by the manufacturer should be used.

As a best practice, CARB recommends the flashing approach specified by one house wrap manufacturer, which prevents moisture intrusion by shingling. As shown in the following manufacturer's detail: butyl tape is applied to the bottom of the window opening, the window is installed, the sides are sealed with butyl tape, the house wrap is folded over the top of the window and secured in place. This creates a weather-resistive barrier.



XPS and polyisocyanurate have commonly been utilized as a moisture barrier, but recent building science research has shown that these products may not be as dimensionally stable as initially thought. There is some evidence that the insulation boards shrink enough (up to $^{5}/_{8}$") that simply taping the joints may not be sufficient to maintain the drainage plane long term. Though manufacturers are continually improving their products, CARB recommends installing an added level of protection using housewrap or building paper behind the foam sheathing.

In addition to controlling water in its liquid form, it must be controlled in its vapor form. The region of the mixed, humid climate that Maryland falls in makes any vapor barrier strategy more complicated. It is typically recommended to place the vapor barrier on the warm side of the wall, in order to prevent the moisture from warm interior air condensing inside the wall. In the South, this would be on the exterior of the wall. In the North, this would be on the interior of the wall.

As Maryland falls in a climate region that is fairly balanced between heating and cooling, this poses a dilemma. One answer is to place a vapor barrier on both sides of the wall assembly. This option can lead to more problems than having no vapor barrier, as it can result in moisture being trapped within the wall assembly. Local building codes require it to be located on the interior of the wall assembly. This is commonly satisfied by using kraft-faced batt insulation. Installation of kraft-faced batts is tricky and often is improperly installed. A vapor retarder paint primer is a better alternative for adhering to the intent of the building code.

It is actually CARB's opinion that a vapor retarder is not required on the interior surface in Maryland's climate. In fact, Maryland will be adopting the 2006 International Energy Conservation Code (IECC) in March 2007, which allows for the exclusion of the vapor barrier requirements that are currently required in Zone 4. The majority of water vapor is introduced into the wall assembly through the moisture transport mechanism of air infiltration/exfiltration, not diffusion. By paying close attention to air sealing, much of the concern that building codes are trying to address is eliminated. Once air sealing has been addressed, simply using a latex paint will provide some resistance to vapor diffusion from interior conditions, while still allowing any moisture trapped within the wall assembly to dry to the inside.

Improved Building Envelope – Air Sealing

The next efficiency strategy is geared towards controlling air infiltration. As a first step for home builders, the U.S. Environmental Protection Agency (EPA) provides a useful resource: the thermal bypass checklist guide. Though geared towards minimizing the movement of heat around or through insulation, it also results in improved air sealing by attempting to maintain a contiguous and continuous air barrier over the entire building envelope.

A commonly overlooked air bypass location is the rim/band joists. These areas are not typically insulated and are only designed for structural purposes. SBER originally tried to seal this area using spray foam, but found quality control installation issues with maintaining a uniform thickness. Therefore, CARB recommended switching to rigid insulation cut-outs that are sealed around the edges with low-expansion foam. Air sealing was taken one step further by applying a bead of spray foam at all the seams between the wood studs and the plywood, and around penetrations in the envelope from plumbing and electrical systems. This later strategy is not necessary in all cases, but will ensure a tight building envelope.

Improved Building Envelope – Basement

It is common in this climate region for basements to be unconditioned with insulation on the underside of the 1st floor. This insulating strategy becomes an issue when the HVAC system is also located in the basement. By extending the thermal envelope to include the basement walls, the performance of the HVAC system will be improved. By insulating the walls, even if not actively conditioning the space, the basement will have a smaller temperature swing. These basements are typically considered to be semi-conditioned due to the internal heat gain provided by the mechanical equipment and from the 10-15% duct leakage that is commonly found in standard duct installations. Though duct sealing strategies will be discussed later, it is worthy to note that basement duct leakage is typically not leakage that is lost to the exterior (because the basement is now within the building envelope). It still may result in comfort issues due to insufficient air flows at the supply, but doesn't result in a whole-house energy penalty.

For the prototypes, the insulation strategy was to use 2-inches of foil-faced polyisocyanurate rigid insulation (Thermax or similar product with equivalent fire rating) adhered to the upper half of the walls using construction adhesive. With an insulating value of R-6.5 per inch, this closed-cell insulation is better suited to moist basement conditions than standard fiberglass blanket insulation. Since the majority of the heat loss is through the above-grade portion of the foundation, CARB was primarily concerned with insulating the top four feet of the foundation, but SBER insulated the complete wall. CARB specified a 4" gap at the bottom to allow any moisture that may be present to dry out to the space. The added cost of this insulation strategy was $500 per unit.

Other options:
One insulation strategy is to place expanded polystyrene (EPS) or extruded polystyrene (XPS) insulation against the exterior of the foundation wall. This is advantageous due to the creation of a capillary break to moisture intrusion and also protects the foundation from the freeze-thaw cycle. There are some downsides to this method as it is typically more expensive than installing the insulation to the interior of the foundation wall. In addition, though not a food source, the rigid insulation is still susceptible to insect infestation (tunneling, nesting, etc.). The finishing detail for the portion of the foundation wall that is above grade can also be cumbersome.

EPS and XPS can be used on the interior of the basement walls, but the walls must be finished (drywall) due to fire code requirements. The insulation should be left 4 to 6-inches above the slab floor to allow for drying out of the wall to the inside for any moisture that may be present in the wall assembly.

Encapsulated batts and fiberglass blankets can also be utilized but do not provide the same level of performance of the rigid insulations. This is primarily due to poor installation that results in air movement behind the insulation. This will result in a reduction in the thermal performance of the insulation and may allow for condensation on the cool foundation wall.

Improved HVAC Equipment – Heating

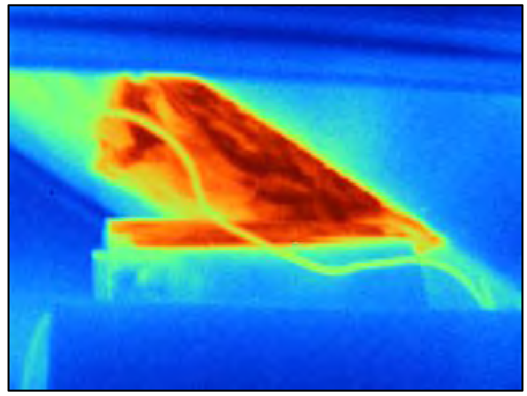
To complement the improvements to the building envelope, it was also necessary to make improvements to the mechanical equipment and to control duct leakage. A high efficiency (92+ % AFUE) direct-vent furnace was recommended by CARB that, combined with the improved envelope, would reduce space heating costs by one-third, compared to SBER's standard practice. The use of an air handler with a variable speed electronically commutated motor (ECM) will substantially reduce fan energy consumption. Another benefit of an ECM is its ability to maintain proper airflow rates over a larger range of system pressure drops. If the air handler fan is used for a significant period of time to provide air circulation or fresh air ventilation, CARB recommends upgrading the air handler to an ECM.

The heating, ventilating, and air conditioning (HVAC) systems were designed to have all the ductwork and equipment located within the conditioned envelope. This was done to minimize duct leakage to the outside and to prevent unconditioned attic air from entering the system. All ductwork was sealed with mastic to prevent leakage around seams and joints. The highest pressures within the system are seen at the air handler, so it is a good practice, though an added cost, to specify factory sealed air handlers to minimize leakage at this point. The incremental cost of the higher efficiency furnace and mastic sealed ductwork was $2,880. This is significantly higher than would be anticipated on a production scale. If high efficiency furnaces are specified for the entire development, there will likely be a significant discount on the equipment versus a couple individual installations. In addition, there is a learning curve for the HVAC contractor to be trained in properly sealing the ducts with mastic. As the duct crews become more comfortable with the sealing strategy, there should be no increase in labor cost. When contracting with your HVAC subs, the use of UL-rated mastic or butyl tape should be specified. It is also highly recommended that duct leakage targets be specified (i.e. less than 4 cfm/100ft^2 or 5% duct leakage to the outside per system) and verified by a third-party.

There were two HVAC systems in each of these townhouses. The main unit was located in the basement and served the first and second floor living areas. The secondary unit was for the master suite loft. A mechanical closet was located in the loft to bring the system within the conditioned envelope. Typically, this unit would be located in one of the corner attic spaces with a service door in the kneewall. Once again, by bringing the system within the building envelope, the potential energy penalty is reduced.

Builder Lessons Learned:
The tight quarters of the mechanical space in the loft caused some problems during the installation of the ductwork that lead to higher building infiltration and duct leakage. When the door to the mechanical room was opened, it was evident that there was a major source of leakage, as the closet was cooler than the rest of the master suite. An inverted U-bend was positioned over the air handler supply outlet. Unfortunately, the inner curve of this U-bend was not properly constructed and sealed at installation. The HVAC contractor sealed this area later, and improved the layout for future installations.

In addition, there was a height issue that the HVAC contractor solved by cutting out a portion of the ceiling drywall, leaving a one foot square hole for air to leak between the roof rafters. The infrared picture below shows the impact of this cut out when the house is depressurized (result of exhaust-only ventilation strategy). By cutting the drywall, the air barrier at the ceiling plane has been compromised. The hot ambient air is being drawn through the attic insulation and into the conditioned space. The ceiling was patched prior to CARB's secondary inspection, but details like this would typically go unchecked in standard practice. These problems all lead to the equipment being subjected to conditions that affect its performance and efficiency.



Improved HVAC Equipment – Ventilation

Since these homes were well-sealed, the use of mechanical ventilation was specified. CARB recommended an "Exhaust-Only" strategy, which is the most affordable solution for this climate zone. This approach requires one bath fan in each of the homes be upgraded to a model that has been rated for: energy-efficient operation, continuous use, and quiet running. These three features are fundamental to the success of this strategy. An efficient fan will not cost the homeowner a lot to operate. A fan rated for longer run times will not fail after a few months of operation. And lastly, the homeowner is less likely to disable the fan if it runs quietly.

This was accomplished by installing one ENERGY STAR® bath fan that operated in conjunction with a pin-timer control. The upgraded bath fan was wired to allow occupant control via a manual switch within the bathroom. The timer control was also tied into the fan wiring and remote-wired to a nearby closet to prevent tampering. The timer was setup by CARB to comply with the guidelines set forth by the American Society of Heating, Refrigerating and Air Conditioning Engineers (ASHRAE) in *Standard 62.2, Ventilation and Acceptable Indoor Air Quality in Low-rise Residential Buildings*. This standard recommends continuous ventilation equal to:

$$Q_{fan} = 0.01A_{floor} + 7.5(N_{br} + 1)$$

where,

Q_{fan} = fan flow rate (cfm)
A_{floor} = floor area (ft^2)
N_{br} = # of bedrooms

The timer ensures that the fan operates for long enough periods to provide the equivalent recommended air exchange rate. As fan noise is a concern, CARB specified a “low-sone” fan be purchased. The ENERGY STAR® bath fan cost $130 (versus $80 for a standard contractor grade fan) and the Grasslin timer control cost $31.

All other bathrooms and the kitchen range still have exhaust fans for local humidity control. CARB required that all exhaust fans be vented directly to the outside. No recirculating kitchen exhaust fans were installed in these prototypes.

Other options:
There are also two other ventilation strategies to consider: supply-only and balanced ventilation. A supply-only ventilation strategy is commonly recommended for hot, humid climates. The simplest version of this is a 4”-6” outdoor air intake ducted to the return plenum.

This provides a mix of outdoor air to the return air when the air handler is running. For more flexibility with controls, an air cycler can be used to provide additional ventilation when the air conditioner is not running. This system would work, but will increase the latent load of the building.

The other alternative is a balanced ventilation system in which an equivalent amount of air that is being introduced to the conditioned spaced is exhausted as well. This can be accomplished through the use of heat recovery ventilators (HRV) or energy recovery ventilators (ERV). An HRV uses the exhausted air to partially condition (pre-cool or pre-heat) the incoming outdoor ventilation air. An ERV allows for the additional transfer of moisture across the heat exchange media. Additional controls that monitor interior CO_2 levels can be utilized to ensure optimal indoor ventilation.

Tankless Water Heater

Tankless water heaters are compact units that provide hot water as needed, but do not store hot water like traditional tank-type water heaters. When a hot water tap is opened, water enters the tankless water heater. A sensor detects the water flow, and activates a gas heating device, which quickly raises the water temperature to a preset level through the use of a low-mass heat exchanger. When water flow stops, the heating element shuts off. Thermostatically-controlled tankless water heaters vary their output temperature according to water flow rate and inlet water temperature.

Unlike traditional storage tank water heaters, tankless water heaters do not store a reservoir of hot water. As a result, standby losses are eliminated, which makes them an energy-efficient alternative to traditional water heating. Tankless units can reduce water heating bills by 10 to 20% – a significant savings for homeowners, considering the average household spends 14% of its energy budget on water heating.
Gas tankless water heaters are available in a variety of capacities by numerous manufacturers. They can be used for supplementary heat, such as a booster to a solar hot water system, or to meet all of a home’s hot water needs. The maximum flow rate and temperature rise are determined by the capacity of the heater. In general, gas tankless heaters have larger capacities than their electric counterparts. Residential gas

models are available that can heat more than five gallons per minute with a temperature rise of 60°F, generally more than enough for two showers to be run simultaneously.

Because tankless heaters do not store water, they are less subject to corrosion than tank-type heaters. As a result, their expected equipment life is longer – more than 20 years, compared with 10 to 15 years for traditional heaters.

Gas tankless water heaters are more expensive than typical tank systems but similar in cost to high efficiency tank systems. Standard tank systems may cost around $300, whereas gas tankless systems cost closer to $1,000. Gas tankless water heaters are more desirable than electric tankless systems, due to electric tankless systems having lower heating capacities and the higher capacity electrical panel required (high amperage draw) for these units.

Noritz tankless water heaters provided domestic hot water for these townhouses. The energy analysis shows a 25% decrease in annual domestic hot water energy use. The incremental cost for this DHW improvement was about $650.

Other Energy Savers

ENERGY STAR® appliances reduce energy consumption and save occupants money on their energy bills. ENERGY STAR® appliances provided by SBER include a refrigerator, dishwasher and a bath exhaust fan. Homeowners are responsible for installing their own clothes washers, and many ENERGY STAR® models are available. Energy savings from these upgraded appliances generally pay for themselves in just a few years.

Lighting in all rooms and hallways are compact fluorescent, accounting for 100% of all lighting and saving homeowners an estimated $172 annually. CFLs last up to seven times longer than incandescent lamps, thus reducing maintenance and replacement costs. Fluorescents generate less waste heat than incandescent lamps and fixtures. As CFLs use about one-quarter of the energy of conventional incandescent light bulbs, they justify their slightly higher incremental cost.

When used properly, programmable thermostats save heating and cooling energy when the house is unoccupied or occupants are sleeping. The cost to upgrade is $30.

Green Features

All buildings can incorporate sustainable or ‘green’ practices. Green building revolves around principles of site planning, improved air quality, water conservation, and energy and resource efficiency. To build green means to prioritize any strategy that conserves natural resources and minimizes impacts on the environment, either during project demolition, new construction, operation and maintenance, or manufacturing and delivery of building products. Selecting environmentally preferable materials is a simple way to build 'green'. These products are durable, renewable, use energy and natural resources sparingly, and incorporate recycled materials whenever possible.

At Frankford Estates, SBER offers a package of green options to homeowners. CARB pushed for the incorporation of many of these features, but the final decision was left to the homeowner. Among the options that selected in at least one of the townhouses were: dual flush toilets (*$300 premium*), bamboo floors (*$695 premium*), and no VOC paints (*$35/gal*). Wool carpeting (*$40/yd^2*) is another option that is available, but was not selected. CARB encouraged the use of low VOC paints, sealants, and caulks as a standard practice to minimize the off-gassing that is typically found in new construction. Other green options explored are summarized below.

Green Floor Options
An attractive alternative to traditional wood flooring, bamboo is a rapidly renewable resource. Ceramic tile lasts far longer than vinyl flooring, are low-toxic, waterproof and available with recycled-content. Other durable, low-toxic options: natural linoleum, finished concrete, & carpets made from natural fibers, like wool or jute.

Recycled Content
Recycled content building materials reduce waste and conserve resources, and can be included throughout a home: composite wood and plastic decking, polystyrene trim and moldings, PET carpet (manufactured with yarn created from reclaimed polyester resins of two-liter soda bottles and ketchup containers), fiberglass and cellulose insulation, concrete aggregate and fly ash, floor tile, fiberboard, and even drywall are all prime examples of recycled content materials.

Forest Conservation
Instead of using plywood and solid sawn lumber, the use of oriented strand board (OSB) and engineered lumber preserves old-growth forests. Some other environmentally conscious sheathing products are straw board and recycled paperboard. Traditional wood cabinets can be replaced by ones made with wheat straw, an abundant resource that is generally burned as waste. Preference should be given to wood that is sustainably grown and harvested, as certified by the Forest Stewardship Council (FSC).

Water Conservation
Although 70% of the planet is covered in water, less than half a percent of this water is fresh and accessible. Efforts must be made to conserve this precious resource. Low-flow faucets and showerheads reduce water usage by about 40% and low-flow toilets can save a family of four an estimated 22,000 gallons per year. Dual-flush toilets offer half-flush and full-flush options, saving even more water. Low-water use dishwashers and front-loading clothes washers provide additional water savings.

Indoor Air Quality
Volatile organic compounds (VOCs) contribute to urban smog and poor indoor air quality, exacerbating human health conditions such as asthma and chemical sensitivities. VOCs and formaldehyde (a suspected carcinogen) are present in many conventional building materials. These chemicals are released into homes for years after new materials are installed. Indoor air quality can be improved by specifying low or no-VOC paints, finishes, glues and sealants, and no-added-urea-formaldehyde or formaldehyde-free insulation, flooring, and medium density fiberboard.

Green Template Matrix
The net result of the builder's improved building specs and the green features selected by homeowners results in a classification of *"medium green"* in terms of the *Green Building Template: A Guide to Sustainable Design Renovating for Baltimore Rowhouses.* In terms of the building envelope, high efficiency equipment, and moisture control, there townhouses exceed the recommendations specified by the green template. Earth-friendly materials and low VOC products were used wherever possible. Water conservation was taken to the furthest limits without incorporating a solar thermal system. Elements such as aluminum thermally-broken low-e windows, light color roof, and pin-based CFLs were not included in these prototypes, so the units do not meet the *"medium green"* level based on the 4B.2 Summary Alternatives Table (prescriptive method). Still the overall prototype building specifications result in an equivalent energy performance level (30% better for heat, A/C, and hot water energy use over a similar home meeting 1992 Model Energy Code levels) to achieve the *"medium green"* level.

Cost-Benefit Analysis

The builder provided a cost summary for this project, shown below. The standard Frankford Estates townhouse was selling in the mid to high $200,000s during the start of this project. The efficiency upgrades cost an additional $5.81/ft^2$ for the builder. The last townhouse will not likely see the same mark-up due to the turn in the housing market. Though, SBER is still confident that they can recoup their expenses for this last unit. By the end of the project, the housing market slowdown had reduced that sale price to just under $200,000. Even at cost neutral pricing, these homes provide significant benefit to the builder due to the marketability and quality (typically fewer call backs) of the homes. With the high cost of energy, homeowners may not be more educated about energy efficiency, but they are becoming more conscious of it. What may have been previously an after thought in the homebuyer's decision process is now moving up in terms of priority.

COMPONENTS	UPGRADE COST	REGULAR COST
APPLIANCES	$1,031.00	$440.00
Refrigerator	$591.00	
Dishwasher	-	
ENERGY STAR	$1,050.00	$550.00
Rigid Insulation	$500.00	
HVAC	$9,030.00	$6,150.00
Furnace + Mastic sealed	$2,880.00	
INSULATION	$3,920.00	$2,125.00
Blown-in Fiberglass	$1,795.00	
PLUMBING	$7,025.00	$6,075.00
Dual Flush Toilet	$300.00	
Tankless Water Heater	$650.00	
POURED WALLS	$5,044.00	$4,478.00
Wider Foundation	$566.00	
WALL PANELS	$8,485.00	$4,823.00
2x6 @24" o.c.	$3,662.00	
Stainless Flue H/W/H	$435.00	
TOTAL	$36,020.00	$24,641.00
Difference	$11,379.00	
*Estimated Annual Energy Savings**	$533.00	

** assuming electricity at $0.14/kWh and natural gas at $1.30/therm*

A number of factors contributed to a higher than expected first cost of this project, including: spacing error by panelizer (16" OC rather than 24" OC), one-off pricing for prototypes (rather than production scale pricing), and a steep learning curve due to a lack of familiarity with HVAC sealing strategies by HVAC contractor. The up charge for these items should not be as significant on a production scale. There is an added cost for more efficient HVAC equipment, but a portion of this can be offset by downsizing and/or proper sizing of the HVAC equipment. Future HVAC contractor bids should specifically call out for sealing of the ductwork in the work order.

Performance Testing

Despite what may have been specified or inspected in a home, the only true way to know how well a house is performing is through verification. Performance testing ensures both the builder and homeowner are getting what they pay for.

Building Infiltration:

A blower door test quantifies infiltration through the building envelope. By depressurizing the house, outdoor air is induced to enter the house through cracks and holes found in the exterior house surface. This test simulates the driving forces that naturally occur as a result of stack effect, wind pressure, ventilation fans, and duct system pressures. To isolate infiltration through only the exterior walls, blower doors should be run simultaneously in adjoining townhouse to eliminate leakage through party walls.

Duct Leakage:

A duct blaster test entails sealing all the supply registers and return grilles. Then a small fan is connected to the individual duct systems at the air handler to pressurize the ductwork to 25 Pascals. The fan flow measured at this pressure is referred to as the cfm_{25}. Based on an actual flow measurement at the air handler or an assumed 400 cfm/ton air handler flow rate, the total duct leakage for an HVAC system can be determined by dividing the cfm_{25} (from the duct blaster fan) by the total system flow rate. Total duct leakage includes conditioned air that is being lost to both conditioned and unconditioned space through the ductwork. Conditioned air that is leaking to other conditioned spaces does not result in an energy penalty, but it means that the design flowrate of air to each room is not being satisfied.

This test method is intended to simulate the average pressure that the system faces during normal operation. Though a beneficial method of testing, this can be somewhat misleading of normal operation. In normal operation, the pressure profile will be significantly higher at the air handler and negligible at the supply registers, rather than uniform throughout. Essentially leakage at the air handler will be deemphasized and leakage at the supply boots will be overemphasized. As long as you are aware of the short comings of the test, this method can be used effectively to ensure the ductwork is properly sealed.

More important is duct leakage to the outside, which can be measured through a combination of the blower door and a duct blaster test. The house and ductwork are both brought up to a pressurization of 25 Pascals, isolating duct leakage to the outside. Ideally, duct leakage to the outside should be negligible (below measurable levels). As a guide, a duct leakage to the outside of 4 cfm/100 ft^2 should be the maximum allowed by your contractor. This level of duct sealing meets the Energy Star homes requirement when using the prescriptive method. Alternatively, locating ducts and the air handler within the conditioned envelope is a simple way to reduce duct leakage to the outside to negligible levels.

Distribution System:
In terms of optimizing comfort, a low-flow balometer should be used to measure all supply register flow rates. Supply register dampers should be adjusted to meet the design flow rates (from Manual J analysis) for each room. It is naive to assume that the ductwork, without balancing, will operate properly. Ductwork is sized to help proportion the air properly to each room, but a duct size can correlate to a multitude of flow rates, flow velocities, and duct pressures. Only through testing of the supply registers can a system be properly balanced to optimize the performance.

It is simple to overlook items during the construction and many of these items are not easily detectable during visual inspections, but verification will help catch these errors prior to homeowners moving in. This quality control not only reduces homeowner complaints/callbacks, but is a marketable commodity that a homebuilder can use to distinguish themselves from the masses.

Chapter Two: Existing Construction

Row houses have been prominent in Baltimore's architecture for centuries, with over 140,000 still standing today. Many are abandoned and are being renovated in an attempt to improve the quality of life in these urban neighborhoods. Over 17,000 permits were issued in 2005 for residential rehabilitation projects, indicating a significant opportunity to improve the quality of existing housing in Baltimore, in a sustainable and energy-efficient way.

The Chesapeake Habitat for Humanity (CHfH) was the builder partner for the rehabilitation project. CHfH works in Baltimore, rehabilitating vacant houses to provide home ownership opportunities to low-income families. Relying on a large volunteer staff, they have already completed 103 homes in various Baltimore City neighborhoods, and eight additional units are currently under construction.

Incorporating CARB's recommendations, Chesapeake Habitat rehabilitated five 2-story row houses into energy-efficient, affordable housing. Although the recommendations required a few extra steps during construction and some additional first costs, the increased energy-efficiency of these homes reduce the utility bills homeowners will face, making them truly affordable for low-income families. Many of the strategies that were discussed for the new construction prototypes work for these gut rehabs, but there are a few slight differences/priorities when dealing with existing buildings.

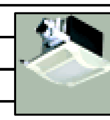


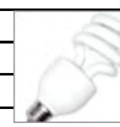

Energy Modeling

EGUSA v2.59 was once again used to perform a cost-benefit analysis and generate the optimal package of measures to improve the energy performance of the prototype homes selected. CARB's energy modeling demonstrated that the energy performance of the current builder homes was actually 27% worse than typical 1990's construction (*Building America Benchmark Reference Home Definition 12/29/2004*), primarily due to excessive air infiltration. Once this "standard practice" energy performance was established, CARB simulated the impact of alternative specifications on the home's energy performance. CARB developed specifications that would meet the Building America goal of 20% whole house source-energy (The sum of the energy consumed at a residence and the energy required to extract, convert, and transmit that energy to the residence) energy that is savings. One of the prototypes also included a third bedroom addition off the back of the unit. This addition was built on a crawlspace foundation.

CHfH Prototype Specifications

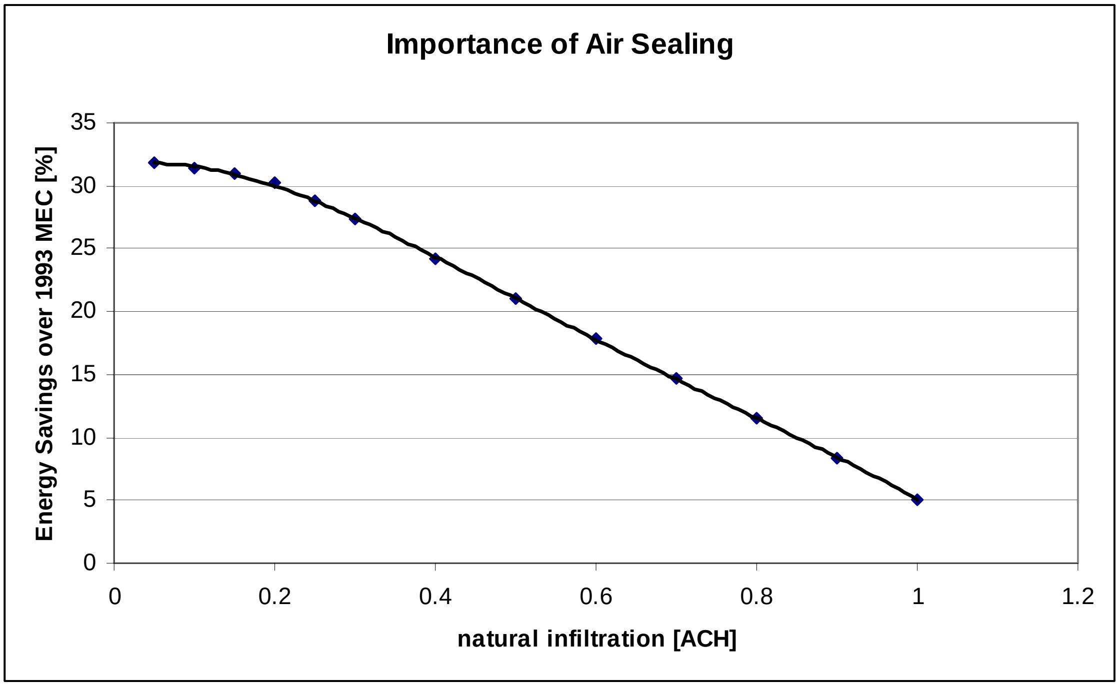
Basement Wall	1.5" polyiso (foil-faced both sides) @ top 4' of basement walls R-10.5
Crawlspace	Insulated Concrete Forms R-20
Exterior Wall	Brick wall with 3/4" XPS on interior surface, 2x6 stud wall with R-19 fiberglass batts
Party Wall	Brick wall with 3/4" XPS on interior surface, 2x4 stud wall with R-13 fiberglass batts
Windows	Vinyl insulated windows with low-e (U ≤ 0.30 / SHGC ≤ 0.48)
Roof/Ceiling	R-30 FGB
Duct System	Uninsulated sheet metal. Mastic at all joints, including return
Air Handler Unit	Located in basement
Space Heating	Direct Vent 90+ AFUE Natural Gas Furnace
Space Cooling	*[optional to homeowner with A-coil]*
Thermostat	Programmable
Hot Water Heating	40 gal power vented 0.61 EF NG tank water heater or NG tankless water heater (0.78 EF)
Ventilation	Energy Star fan/light unit with control timer
Lighting	70-100% fluorescent lighting package
Appliances	EnergyStar refrigerator
	EnergyStar clothes washer
	Gas dryer
	Gas range w/ electronic ignition
Green	low-VOC paints, adhesives, caulks
	low flow faucets & toilet
	central location of DHW unit
	waste management (separation and recycling as required)
	fire/CO protection
	locally manufactured products (windows, flooring, cabinets, paints, etc.)





These specifications result in the rowhouses exceeding the 1993 Model Energy Code (MEC) with an estimated overall annual energy consumption savings of 30%-34% over a 1993 MEC compliant home. Energy analyses showed that if all the recommendations were implemented, there could be a 22% annual savings in cooling energy, a 17% savings in annual heating energy, and a 25% savings in annual domestic hot water heating savings (compared to typical 1990's construction). Energy consumption from lights would be reduced by over 60% and 6% for appliances.

The biggest obstacle to realizing these savings would be to successfully air-seal the building envelope. By paying close attention to details during the reconstruction process, the target natural infiltration rate was 0.20 $ACH_{natural}$ (Natural air changes per hour, $ACH_{natural}$, is essentially a measure of how much air is flowing into and out of a home as a result of wind, pressure imbalances, and the stack effect. If the air volume of house is replaced every hour, this would equate to an ACH of 1.0). This was very optimistic due to the conditions of the rowhouses. Without proper air sealing of the units, the savings would be less than the 20% annual source energy consumption reduction over 1990's construction.



Based on the final inspections and test results, the prototype buildings averaged only 14% source energy savings over 1990's construction, though this is still 32% source energy savings versus Habitat's standard practice. The primary culprit was the lack of air sealing in the basement at the floor joists and the chimneys (though capped at the top, interior conditions of the chimney brickwork is unknown). CARB was unable to get access to the adjoining rowhouses to isolate building infiltration only through the exterior walls and not the party walls. Therefore, the measured infiltration that was used in the final modeling is conservatively high.

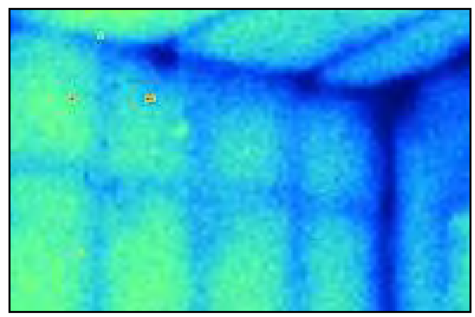
Energy Efficient Strategies and Technologies

Row houses are a large majority of the housing stock in Baltimore and offer a big opportunity to improve energy efficiency of existing housing. Much like other row houses in Baltimore, these prototype units were 2-story, brick construction, with two bedrooms, one bath and a basement. This template builds off previous work done for The reHABITAT Guide.

Improved Building Envelope – Continuous Thermal & Air Barrier

The original walls of these Baltimore rowhouses were uninsulated brick that were cleaned of all plaster and debris. In order to increase the energy efficiency of these five rehabilitation projects, improvements to the building envelope needed to be made. Once deconstruction was complete, the builder's standard practice was to stud out the walls (exterior and party) 5" away from the brick walls and insulate with fiberglass batts. This is done to account for the uneven wall surface. This method allowed for a significant amount of heat loss through the framing and convective loops behind the batt insulation due to no air barrier being present.

Common practice in new and rehab construction is to insulate the wall cavities with fiberglass batt insulation. The use of R-13 batts does not result in an R-13 wall assembly. Every stud marks the absence of insulation and therefore the opportunity for heat loss or "thermal bridging". As seen in the thermograph to the right, heat can use stud framing to bypass insulation, effectively reducing the R-value of the wall assembly.



To avoid this, CARB recommended installing 1" XPS rigid insulation between the brick and stud framing, which could be done without a significant change to the current construction practice. All remaining edges and seams were filled with a low-expansion foam insulation. The rigid insulation provides a continuous thermal break and acts as an air barrier. CARB provided on-site training on how and what to air seal to properly prevent air leakage bypasses. Fiberglass batts were still installed in the stud cavities for additional wall R-value. CHfH had not previously obtained DOW Styrofoam rigid insulation through the international partnership between Dow and Habitat for Humanity. CARB worked with the CHfH to procure the necessary rigid insulation for these rehabs and to instruct on the proper application of this wall detail. Other builders could expect to pay around $0.52 per square foot for this rigid insulation.

A layer of rigid insulation board was attached to the brick surface with a low-VOC foam adhesive. The walls were then framed with the studs right against the rigid insulation board and the cavities were filled with fiberglass batt insulation. An installation guide was created by CARB for use by CHfH for future training of its volunteers.

Building America U.S. Department of Energy CARB CONSORTIUM FOR ADVANCED RESIDENTIAL BUILDINGS
MEA MARYLAND ENERGY ADMINISTRATION
Chesapeake Habitat for Humanity

Wall Insulation Strategy

Step-by-Step Guidelines

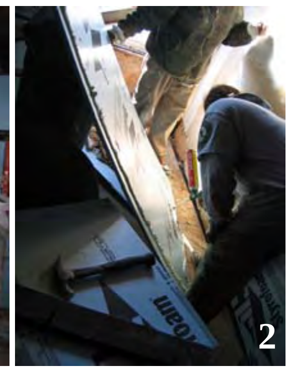
1. Clear walls of plaster and debris that affect how flush the rigid insulation will be. Using a 4x8 sheet of insulation, vertically dry-fit the board to the wall.

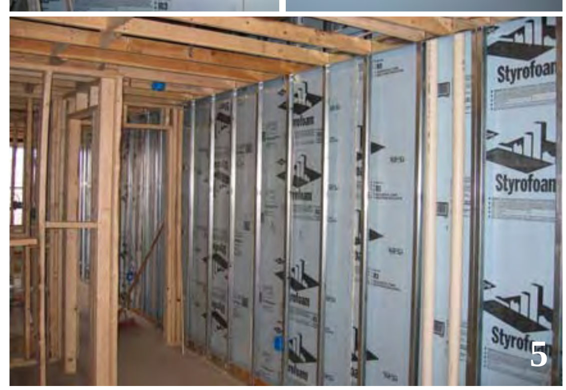
2. Remove the board and apply a 1/2" bead of foam adhesive along the outer rim of the rigid board and in the center, in the shape of an "X".

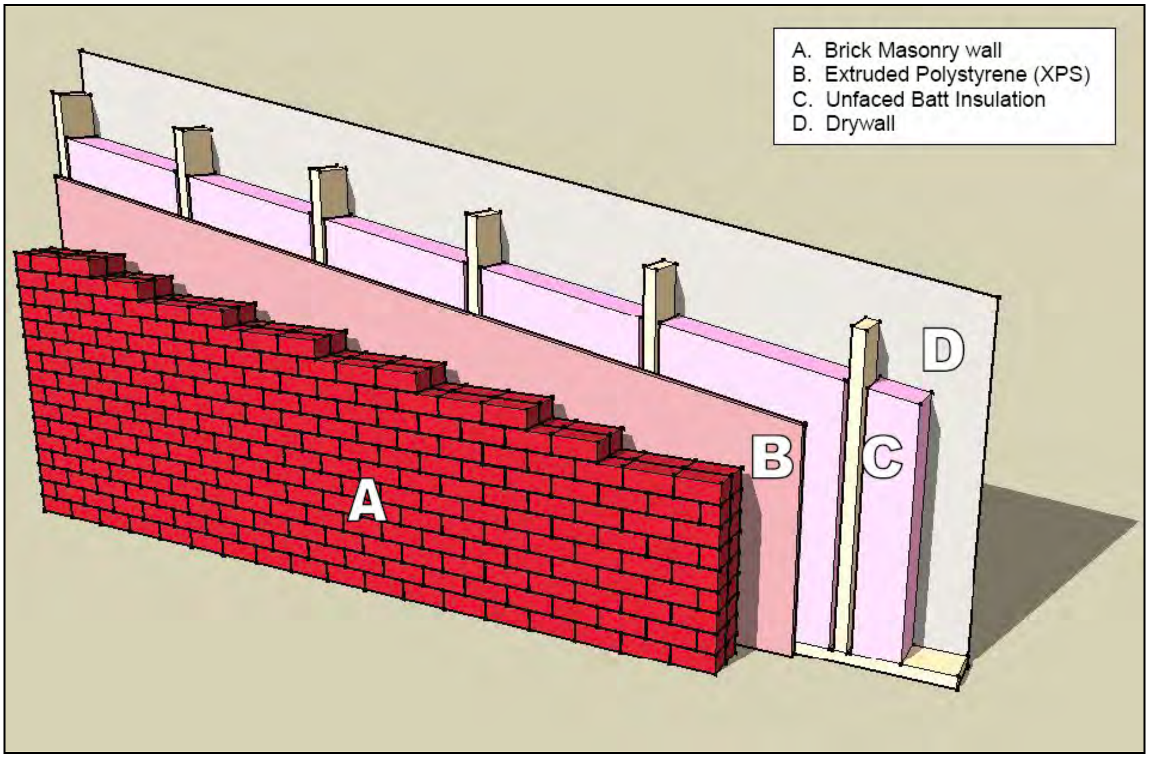
3. Press the board against the selected wall, using continuous pressure. For example, in narrow width row houses, place a 2x4 brace against the seam of the rigid boards and use an extension pole to hold the wood and insulation in place for at least 5 minutes. Save time by doing opposite walls at the same time.

4. Use cutouts to fill in spaces between floor joists and other remaining wall area. Rigid insulation should extend at least 6" above the ceiling plane, so that a tight air seal can be formed with the ceiling drywall. Once rigid insulation is adhered to the walls, use low expansion foam to fill any cracks, seams, or openings where rigid insulation could not be used. Areas to pay special attention to: the seam between the floor and insulation, the space between rigid boards, the area around the floor joists, and the top edge of rigid insulation that extends above the ceiling plane.

5. When studding out the walls, press the studs against the insulation. In many rehab projects, the original walls may be too far out of alignment. In that case, keeps studs as close to the wall as possible, while maintaining a straight profile. If a wall has already been studded out, cut pieces of insulation to a workable size so that they can be slid in behind the stud wall. Fill stud cavities with batt or blown-in insulation. On exterior walls, try 2x6 studs to allow for higher R-value insulation.







Improved Building Envelope – Foundations

Another major change to the current builder practice was the insulating of the basement. Currently the basements are not insulated at the exterior walls or in between the floor joists. CHfH has simply been providing a small amount of conditioned air to this space. Without a clear definition of the building envelope, much of this is just wasted energy. This is an issue that must be addressed to obtain a 'tight" home. As the mechanical equipment (furnace and water heater) and the laundry machines are located in the basement, it is best to insulate at the basement walls. As the basement height varies in each of these units, insulating the top 4 feet of the basement wall with 2 inches of foil-faced polyisocyanurate rigid insulation (Thermax or equivalent) should be sufficient. XPS should not be used in the basement, as it can not be left unfinished (fire hazard). To save on cost, it would be possible to only insulate the front wall, rear wall, and just the first 8' of the party walls extending inward from the front and rear wall. The main objective is to insulate any portion of the exterior brick walls that are above grade. The incremental cost incurred for the foil-faced basement insulation totaled $0.76 per square foot.

In terms of the crawlspace for the bonus third bedroom in one of the rowhouses, CARB recommended the use of insulated concrete blocks, as they are easy for volunteers to install and they are the most cost-effective method to construct the unvented crawlspace. Some conditioned air was supplied to this space using the duct run that supplies the addition. Constructing a vented crawlspace from CMU block and insulating at the floor joists with a combination of rigid insulation and fiberglass batts would be harder in terms of labor and cost.

Improved Building Envelope – Low Emissivity Windows

To further improve the building envelope, CARB recommended upgrading the windows commonly used by Habitat to low-e, insulated glass. Higher performing double pane windows have lower U-values, indicating less heat transfer through this building component. The low-emittance glass coating is a thin film applied to the glass that keeps heat inside during the winter and outside during the summer.

Because Maryland has both cold winters and hot summers, a low-e glass with a moderate solar heat gain coefficient is desired, such that the house is kept cooler in the summer but a good amount of sun is still let in during the winter. The incremental cost to upgrade the windows: $32 per window or a total cost of $259 per home.

Improved HVAC Equipment

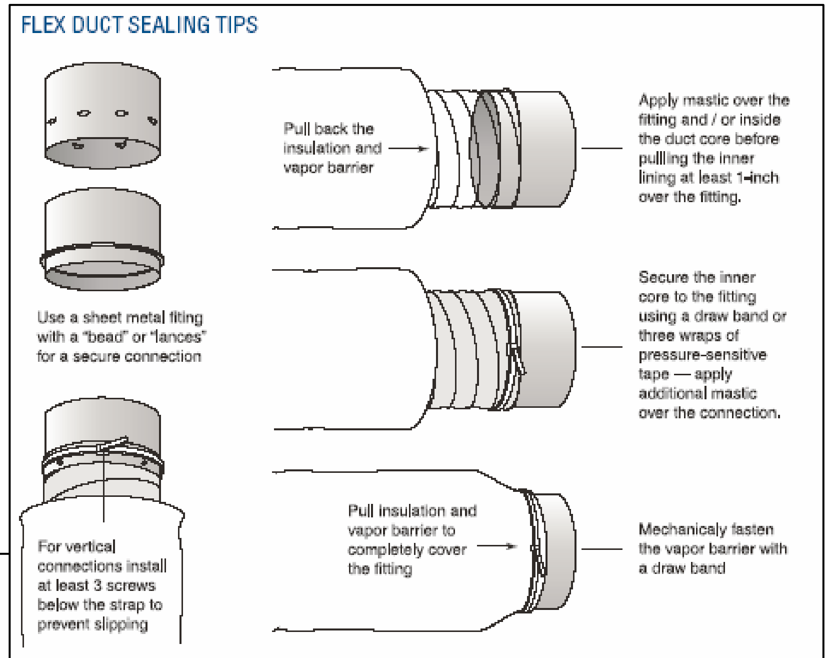
Affordable housing is only truly affordable if the homeowner can afford the utility bills. To complement the improvements to the building envelope, it was also necessary to make improvements to the mechanical equipment. Habitat does not provide central air conditioning, but provides the necessary equipment and connections so that the homeowner has the option of installing it at a later date.

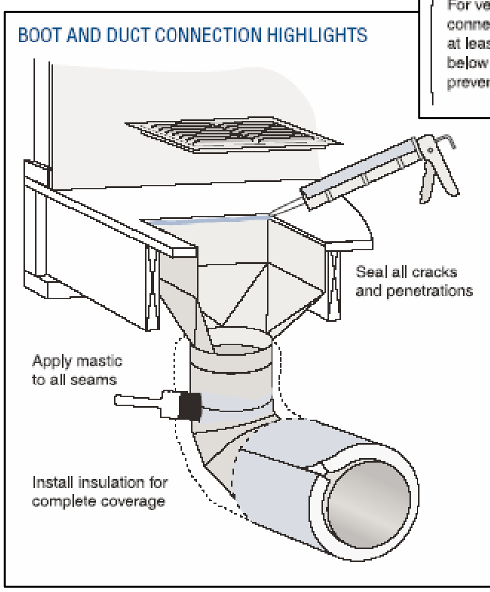
A high efficiency furnace was recommended by CARB that would reduce space heating costs by approximately 10% per year. A direct-vent Goodman natural gas furnace (93% AFUE) was installed to improve indoor air quality and reduce gas bills.

Mechanical ventilation was specified by CARB in order to meet the indoor air quality requirements of ASHRAE 62.2. This was accomplished by installing one ENERGY STAR® bath fan that operated on a timer to ensure a certain number of air changes each day (in this case the equivalent of 40 cfm continuously). The incremental cost of the upgraded exhaust fan was $58 and an additional $31 for the timer control.

Hard ducted returns were specified by CARB to reduce energy losses due to duct leakage. Using existing cavities between studs and joists as return pathways is ineffective and can lead to pressure imbalances within the home. These pressure imbalances affect the air distribution and can possibly lead to backdrafting of flue gases. Hard ducted returns were properly sealed, using mastic or UL-181 rated butyl tape with aluminum backing, to allow the flow of air to be better controlled.

In addition to the panned returns, duct leakage can occur at many places, such as the flex duct to boot/junction box connection, the supply register to ceiling connection, and at the air handler unit. It is common for duct board junction boxes that have been attached with foil-backed duct tape to come apart over time, and thus are a potential source of leakage. Metal collars leak between the collar and the sheet metal cut-out, unless they are properly sealed with mastic. CARB recommends adhering to the following procedure for all flex duct connections.

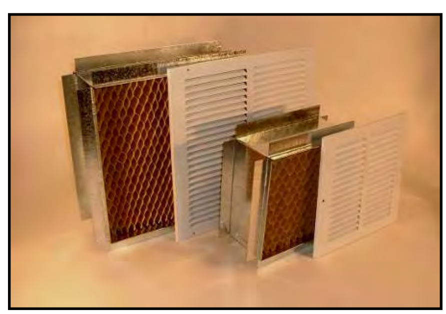




Courtesy of Building Technologies Program, Office of Energy Efficiency and Renewable Energy • U.S. Department of Energy

Other options:

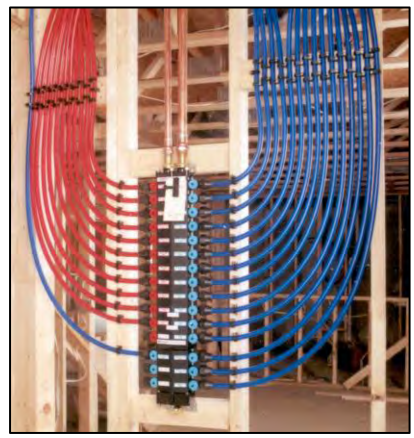
Rather than hard ducting returns from each bedroom, a central return and transfer grilles provide a more balanced air distribution system. In addition, this strategy reduces return duct lengths and the potential for excessive duct leakage. However, even in affordable housing, there is often resistance from contractors accustomed to installing individual returns from each bedroom. To mitigate concerns over privacy, CARB specifies Return Air Pathway (R.A.P.) transfer grilles. These grilles have a baffle to reduce noise and light transmission. The Master Suite can remain separately ducted for added privacy.



Tankless Water Heater

A Rinnai tankless water heater provides domestic hot water on demand. Similar to the Noritz installed in the SBER townhouses, this gas-fired equipment offers a substantial improvement in water-heating efficiency compared to a conventional storage tank water heater. Storage tank systems have to deal with standby losses. Tankless systems provide hot water, at the desired temperature, when needed. For these rehab units, the energy analysis shows a 25% decrease in annual domestic hot water energy use and an estimated annual savings of $66. Savings would be higher if there were more than a single bathroom in these units. Energy savings are also based on typical national homeowner water usage. If homeowners use an excessive amount of water, the savings potential of this technology is improved. The incremental cost for this improvement for Habitat was approximately $1,000.

Other options:



CARB is finding more and more builders and contractors expressing interest in the plastic manifold plumbing piping system, commonly referred to as the “home-run” system. The general concept of the installation is that a plastic plumbing manifold is used to connect individual flexible supply lines to each fixture. This strategy works best when combined with a floor design that allows for all water closets to be centrally located.

Directly routing piping from the manifold to fixtures minimizes potential failure points as there are no connections or elbows located behind drywall. The manifold has a separate shut-off valve for hot and cold water that allows for individual fixture control, shutoff, and maintenance. In addition, dedicated distribution lines provide balanced pressure and temperature to each fixture. Even if several fixtures are used simultaneously, the “home-run” system provides quiet delivery of water and lower pressure losses than a conventional plumbing installation.

With the increased cost of copper in today’s market, a “home-run” installation, including labor, can cost anywhere from $500-1000 less than a conventional copper plumbing installation. For first time installers, labor time may be higher as there is a learning curve to the system, but it should take roughly half the time to install a “home-run” system for an experienced crew. A “home-run” system can be installed by any licensed plumber. Typically, there are no problems with procuring materials, which are readily available from most plumbing wholesalers and distributors.

CARB is seeking to verify the water and energy saving benefits of a “home-run” system. The faster delivery time should result in decreased water consumption. Conventional systems can have wait times up to 60 seconds or more (depending on plumbing layout) before hot water reaches a fixture. Theoretically, these systems deliver hot water to fixtures faster than conventional systems. It’s estimated that the average family of four wastes as much as 14,000-gallons of water a year waiting for hot water after turning on the faucet, so this isn't a trivial issue. Another benefit of PEX piping includes the lower heat transfer coefficient than copper plumbing, which means that water does not condense as much on PEX as on copper piping and should improve the decay constant of the distribution lines. In addition, PEX does not require a large diameter pipe size (3/8" tubing versus ½" copper) due to the lower pressure drop associated with fewer connections and angled bends. Not only will this reduce water wasted while waiting for hot water, but with less heated water in the plumbing, distribution losses should be reduced.

Other Energy Savers

ENERGY STAR® appliances provided by Habitat include a refrigerator and a bath exhaust fan. Homeowners are responsible for installing their own clothes washers.

Lighting in all rooms and hallways are compact fluorescent, accounting for 100% of all lighting, at an incremental cost of $25 per home.

A programmable thermostat was installed to allow for temperature setbacks to save heating energy when the house is unoccupied and when occupants are sleeping.

Green Features

As part of the grant, MEA strongly promoted the use of green materials and technologies. Building 'green' means using sustainable products and being environmentally sensitive before, during, and after construction. In one row house, bamboo floors were installed and low-VOC paints and adhesives were used. Non-vinyl, Hardi plank fiber cement board was used in the rear exterior wall and low flow faucets and dual flush toilets (incremental cost of $125) were installed in the bathroom and kitchen.

Low-VOC paints, sealants, and adhesives can substantially reduce the indoor air pollution that causes irritations of the eyes, lungs, and skin and respiratory and internal organ problems. Nationally, these products are often cost-competitive with traditional counterparts. Bamboo floors utilize a rapidly renewable resource and Hardi plank recycled-content cement board is a durable low-maintenance alternative to traditional wood siding.

Green Template Matrix

The net result of the builder's improved building specs and the green features selected by homeowners results in a classification of *"light green"* and nearly *"medium green"* in terms of the *Green Building Template: A Guide to Sustainable Design Renovating for Baltimore Rowhouses.* Low VOC products and water conservation were taken to the furthest limits for affordable housing. Most of the waste from the deconstruction of these units was recycled. Through better air infiltration and duct sealing, these rehabs should be able to meet the performance levels for "medium green". Quality control on these two elements is hardest with HfHs due to the use of a volunteer workforce, but site supervisors just need to inspect and correct any deficiencies during construction.

Cost-Benefit Analysis

Chesapeake Habitat for Humanity, with a limited budget, is able to remain consistent with their mission of providing affordable housing to the local community while still being flexible and adaptive enough to quickly integrate new products and techniques into their product line. The final builder specifications are a result of a multi-tiered review process for each component of the current building standard practice. In all cases, our recommendations were for the optimal solution, balancing performance and cost.

While the objective for upgraded building specifications and the system engineering approach used to optimize them is improved performance and increased energy efficiency at manageable incremental cost levels, other factors were involved. Specifically, the building techniques used must be achievable by volunteers.

As shown in the table below, the overall cost for the selected components is higher for the prototype compared to standard practice, but there are added benefits (lower annual utility bills and improved comfort) that aren't accounted for in the first cost analysis. Looking at a simple payback analysis for the project, a payback of less than seven years is considered a viable option. In addition, as this is low-income housing, designing to minimize the annual utility bills is important.

Efficiency Items	Quanity	Cost Each	Incremental Cost Total	Notes
DOW 1" XPS (4'x8' sheet)		$16.50	donated	DOW & HfH international partnership
Foam Gun	1	$75.84	$75.84	
Pur Stick Adhesive (per 32 oz. can)	6	$14.40	$86.40	
Pur Fill Foam (per 32 oz. can)	5	$13.92	$69.60	
Gun Cleaner (per 32 oz. can)	4	$5.71	$22.84	
Foil-faced polyiso (4'x8' sheet)	4	$24.18	$96.72	
Low-e glass upgrade	8	$32.40	$259.20	
Insulated concrete forms			$900.55	labor time similar to block build
Concrete		$350.00	-	similar cost to block
tankless HW upgrade			$1,000.00	
90+ furnace upgrade w/ ducted returns			$400.00	
Energy Star bath fan + timer	1	$129.60	$89.60	contractor grade fan - $40
Programmable thermostats	1	$41.77	$29.77	standard thermostat - $12
Flourescent lights- 4 pk	2.5	$9.97	$24.93	
Subtotal			**$3,055.45**	
Green Items				
low VOC paint (per gal)	30	$19.16	$124.70	standard paint - $15/gal
Hardi-plank (per 12' length)	46	$6.29	$139.84	vinyl siding - $3.25
PVC trim boards	8	$22.99	$183.92	
bamboo flooring (20.56 ft^2 per box)	8	$70.06	$132.80	laminate plank - $53.46
flooring underlayment	3	$49.96	-	
dual flush toilet upgrade	1	$223.00	$125.00	standard toilet - $98
Subtotal			**$706.26**	
TOTAL			**$3,761.71**	
*Estimated Annual Energy Savings**			*$597.00*	*conservative savings estimate due to infiltration measurement*
Simple Payback for Efficiency Items			*5.1*	

** assuming electricity at $0.14/kWh and natural gas at $1.30/therm*

Final Thoughts

This building template lays out a method for economically incorporating efficiency and green design into production standards. These two case studies provide a good example of how various technologies and techniques can be incorporated into homes of all sizes and budgets. During a walkthrough of the home, it is easy to miss many of the key energy features of the home, and there in lies the beauty and the bane of the design. Through forethought and careful planning, builders can achieve the energy and performance benefits without sacrificing aesthetics. On the other hand, homeowners do not physically see the benefits of energy efficient homes when touring for potential homes. Not until they see the savings on their monthly utility bills or feel the consistent comfort all year round, will they truly appreciate the benefits of their home. This gap in the homeowner’s decision making process needs to be filled by aggressive marketing of the energy efficient products and education of the homeowners.

Appendix A: Energy Modeling

Building America Benchmark/Builder/Prototype Specifications

Project name: Frankford Estates
Model name: Homeplan C Loft
Location: Baltimore, MD

General Description	
Area of living space = 1,960 ft^2	Floors above grade = 3
Glazing Area = 287 ft^2	Attached Garage = N/A
Basement Area = 691 ft^2	TMY site: Baltimore, MD

Side-by-Side Study of Homes
Specifications of Standard and Energy Construction

Characteristic	Benchmark Home	Builder Home	Prototype Home
Foundation Construction	concrete basement wall	concrete basement wall	concrete basement wall
Foundation Insulation	U-0.099	R-11 fiberglass	2" polyiso (R-13)
Wall Construction:	2x4 wood framing - 16" o.c.	2x4 wood framing - 16" o.c.	2x6 wood framing - 16" o.c.
Wall Assembly:	U-0.085	R-13 kraft-faced fiberglass	R-22 blown fiberglass
Ceiling/Roof Construction	pre-engineered wood trusses @ 24" o.c.	pre-engineered wood trusses @ 24" o.c.	pre-engineered wood trusses @ 24" o.c.
Ceiling Assembly	U-0.032	R-30 insulation	R-38 insulation
Window Type	benchmark glazing	IG low-e w/ argon	Milgard IG low-e w/ argon
Window U-Value	0.53	0.35	0.35
Window SHGC	0.58	0.29	0.29
Interior Shading	drapes/blinds	drapes/blinds	drapes/blinds
Doors	U-0.20	U-0.20	U-0.20
Infiltration	ELA = 184 in^2	0.32 natural ACH	0.27 natural ACH
Heating System	NG Furnace 78 AFUE	NG Furnace 80 AFUE	NG Furnace 93 AFUE
Cooling System	Air Conditioner SEER 10 (SHR 0.7)	Air Conditioner SEER 13 (SHR 0.75)	Air Conditioner SEER 13 (SHR 0.75)
Water Heater	NG Water Heater EF 0.53	NG Water Heater EF 0.61	NG Tankless Water Heater EF 0.82
HW Tank Size	50 gals	50 gals	--
Water Heater Location	basement	basement	basement
Duct R-value	R-3.3	R-4.2	--
Supply Duct Location	65% basement	100% interior	100% interior
Return Duct Location	100% basement	50% attic	100% interior
AHU Location	interior	basement	basement
Duct Leakage To Outside	0.8%	5.0%	negligible to outside
Return Leakage Fraction	43% return	30% return / 5% AHU	--
mechanical ventilation	exhaust only	--	exhaust only w/ timer
	50 cfm/ Benchmark fan energy/ cont.	--	110 cfm/31 Watts/ 46% run-time
Temperature	cooling: 76°F	cooling: 76°F	cooling: 76°F
	heating: 71°F	heating: 71°F	heating: 71°F
Lighting	10% fluorescents	10% fluorescents	100% fluorescents
Energy Star Appliances	--	--	refrigerator and dishwasher
Miscellaneous	--	--	--

Struever Rouse - Frankford Estates Plan C

Summary of Energy Consumption by End-Use

	Annual Site Energy						Annual Site Cost		
	Benchmark		Builder		Prototype		Benchmark	Builder	Prototype
End-Use	kWh	Therms	kWh	Therms	kWh	Therms	$	$	$
Space Heating	540	752	386	550	308	366	$ 1,053	$ 769	$ 519
Space Cooling	2402	0	1629	0	1269	0	$ 336	$ 228	$ 178
DHW	0	234	0	202	0	152	$ 304	$ 263	$ 198
Fixed Lighting	1959		1959		726		$ 274	$ 274	$ 102
Appliances	1815	45	1815	45	1727	45	$ 313	$ 313	$ 300
Plug Load	3273		3273		3273		$ 458	$ 458	$ 458
Plug-in Lighting	405		405		405		$ 57	$ 57	$ 57
OA Ventilation	196		0		125		$ 27	$ -	$ 17
Total Usage	10589	1031	9467	797	7833	563	$ 2,823	$ 2,362	$ 1,828
Site Generation									
Net Energy Use	10589	1031	9467	797	7833	563	$ 2,823	$ 2,362	$ 1,828

Summary of End-Use Source-Energy and Savings

	Annual Source Energy			Source Energy Savings				Component %	
				Percent of End-Use		Percent of Total			
	Benchmark	Builder	Proto	Builder	Prototype	Builder	Prototype	Builder	Prototype
End-Use	MBtu/yr	MBtu/yr	MBtu/yr						
Space Heating	82.5	60.3	40.6	**27%**	**51%**	**10%**	**19%**	**61.9%**	**54.1%**
Space Cooling	25.9	17.6	13.7	**32%**	**47%**	**4%**	**6%**	**23.2%**	**15.8%**
DHW	23.9	20.6	15.5	**14%**	**35%**	**1%**	**4%**	**9.1%**	**10.8%**
Fixed Lighting	21.1	21.1	7.8	**0%**	**63%**	**0%**	**6%**	**0.0%**	**17.2%**
Appliances	24.2	24.2	23.2	**0%**	**4%**	**0%**	**0%**	**0.0%**	**1.2%**
Plug Load	35.3	35.3	35.3	**0%**	**0%**	**0%**	**0%**	**0.0%**	**0.0%**
Plug-in Lighting	4.4	4.4	4.4	**0%**	**0%**	**0%**	**0%**	**0.0%**	**0.0%**
OA Ventilation	2.1	0.0	1.3	**100%**	**36%**	**1%**	**0%**	**5.9%**	**1.0%**
Total	219.3	183.4	141.9	**16%**	**35%**	**16%**	**35%**	**100%**	**100%**
Site Generation			0.0		**0%**		**0%**		
Net Energy Usage	219.3	183.4	141.9	**16%**	**35%**	**16%**	**35%**		

Notes: The "Percent of End-Use" columns show how effective each building is in reducing energy use over the Benchmark in each end-use category.
The "Percent of Total" columns show how the energy reductions in each end-use category contribute to the overall savings.

energy costs	$0.1400	/kWh for electricity	Baltimore Gas & Electric
	$1.30	/therm for natural gas	Maryland Average

	equipment sizing		
Benchmark	63.9 kBtu/hr for heating		
	23.8 kBtu/hr for sensible cooling	-->	3.0 nominal tons
Builder	41.9 kBtu/hr for heating		
	19.0 kBtu/hr for sensible cooling	-->	2.5 nominal tons
Prototype	34.5 kBtu/hr for heating		
	15.9 kBtu/hr for sensible cooling	-->	2.0 nominal tons

*Sizing of cooling nominal tons is based on a SHR of 0.7, 0.75, 0.75, respectively

	HERS index
Builder	85
Prototype	64

EnergyGauge USA v2.6 SBER prototype .enb file

SBER prototype.enb

Building America Benchmark/Builder/Prototype Specifications

Project name: Chesapeake Habitat For Humanity
Model name: 1253 W. Cross Street
Location: Baltimore, MD

General Description	
Area of living space = 836 ft^2	Floors above grade = 2
Glazing Area = 86 ft^2	Attached Garage = N/A
Basement Area = 412 ft^2	TMY site: Baltimore, MD

Side-by-Side Study of Homes
Specifications of Standard and Energy Construction

Characteristic	Benchmark Home	Builder Home	Prototype Home
Basement Insulation	U-0.099	uninsulated	R-13 @ top 4 feet
Wall Construction:	2x4 wood framing - 16" o.c.	exterior: 2x4 wood framing / interior: 2x4 wood framing	exterior: 2x6 wood framing / interior: 2x2 wood framing
Wall Assembly:	U-0.085	exterior: R-13 insulation (FGB) / interior: R-13 insulation (FGB)	exterior: R-3 rigid (5/8" XPS) + R-19 FGB / interior: R-3 rigid (5/8" XPS) + R-11 FGB
Ceiling/Roof Construction	wood @ 24" o.c.	wood @ 24" o.c.	wood @ 24" o.c.
Ceiling Assembly	U-0.032	R-30 cathedral, R-38 attic, R-19 kneewall	R-30 cathedral, R-38 attic, R-19 kneewall
Window Type	benchmark glazing	vinyl double low-e	vinyl double low-e
Window U-Value	0.530	0.47	0.28
Window SHGC	0.580	0.50	0.43
Interior Shading	drapes/blinds	drapes/blinds	drapes/blinds
Doors	U-0.20	U-0.20	U-0.20
Infiltration	ELA = 79.09 in^2 (0.583 ACH_{nat})	0.92 natural ACH	0.82 natural ACH
Heating System	NG Furnace 78 AFUE	NG Furnace AFUE 90	NG Furnace AFUE 93
Cooling System	Air Conditioner SEER 10 (SHR 0.7)	Air Conditioner* SEER 10 (SHR 0.7)	Air Conditioner* SEER 10 (SHR 0.7)
Water Heater	NG Water Heater EF 0.62	NG Water Heater EF 0.60	Tankless NG Water Heater EF 0.82
HW Tank Size	40 gals	40 gals	0 gals
Water Heater Location	basement	basement	basement
Duct R-value	R-3.3	uninsulated sheet metal	uninsulated sheet metal
Supply Duct Area	250.8 ft^2	133.8 ft^2	133.8 ft^2
Return Duct Area	150.5 ft^2	33.4 ft^2	33.4 ft^2
Supply Duct Location	65% basement	65% basement	65% basement
Return Duct Location	100% basement	100% basement	100% basement
AHU Location	interior	basement	basement
Duct Leakage To Outside	0.8%	10.0%	66 CFM to outside
Return Leakage Fraction	43% return	30% return / 5% AHU	30% return / 5% AHU
mechanical ventilation	exhaust only	--	exhaust only
	40 cfm/ Benchmark fan energy/ cont.	--	40 cfm/24 Watts/ cont.
Temperature	cooling: 76°F	cooling: 76°F	cooling: 76°F
	heating: 71°F	heating: 71°F	heating: 71°F
Lighting	10% fluorescents	10% fluorescents	100% fluorescents
Energy Star Appliances	--	refrigerator	refrigerator
Miscellaneous	--	--	--

Chesapeake Habitat For Humanity - 1253 W. Cross Street

Summary of Energy Consumption by End-Use

	Annual Site Energy						Annual Site Cost		
	Benchmark		Builder		Prototype		Benchmark	Builder	Prototype
End-Use	kWh	Therms	kWh	Therms	kWh	Therms	$	$	$
Space Heating	244	171	393	447	275	170	$ 256	$ 636	$ 260
Space Cooling	891	0	839	0	765	0	$ 125	$ 117	$ 107
DHW	0	170	0	178	0	127	$ 221	$ 231	$ 165
Fixed Lighting	1508		1508		600		$ 211	$ 211	$ 84
Appliances	1624	45	1624	45	1505	45	$ 286	$ 286	$ 269
Plug Load	2094		2094		2094		$ 293	$ 293	$ 293
Plug-in Lighting	292		292		292		$ 41	$ 41	$ 41
OA Ventilation	138		210		210		$ 19	$ 29	$ 29
Total Usage	6790	386	6960	670	5741	342	$ 1,452	$ 1,845	$ 1,248
Site Generation									
Net Energy Use	6790	386	6960	670	5741	342	$ 1,452	$ 1,845	$ 1,248

Summary of End-Use Source-Energy and Savings

	Annual Source Energy			Source Energy Savings				Component %	
				Percent of End-Use		Percent of Total			
	Benchmark	Builder	Proto	Builder	Prototype	Builder	Prototype	Builder	Prototype
End-Use	MBtu/yr	MBtu/yr	MBtu/yr						
Space Heating	20.0	49.8	20.3	**-149%**	**-1%**	**-26%**	**0%**	**96.7%**	**-1.8%**
Space Cooling	9.6	9.0	8.2	**6%**	**14%**	**0%**	**1%**	**-1.8%**	**8.6%**
DHW	17.3	18.2	13.0	**-5%**	**25%**	**-1%**	**4%**	**2.6%**	**27.9%**
Fixed Lighting	16.3	16.3	6.5	**0%**	**60%**	**0%**	**9%**	**0.0%**	**62.1%**
Appliances	22.1	22.1	20.8	**0%**	**6%**	**0%**	**1%**	**0.0%**	**8.2%**
Plug Load	22.6	22.6	22.6	**0%**	**0%**	**0%**	**0%**	**0.0%**	**0.0%**
Plug-in Lighting	3.1	3.1	3.1	**0%**	**0%**	**0%**	**0%**	**0.0%**	**0.0%**
OA Ventilation	1.5	2.3	2.3	**-52%**	**-52%**	**-1%**	**-1%**	**2.5%**	**-4.9%**
Total	112.5	143.4	96.8	**-27%**	**14%**	**-27%**	**14%**	**100%**	**100%**
Site Generation			0.0		**0%**		**0%**		
Net Energy Usage	112.5	143.4	96.8	**-27%**	**14%**	**-27%**	**14%**		

Notes: The "Percent of End-Use" columns show how effective each building is in reducing energy use over the Benchmark in each end-use category.
The "Percent of Total" columns show how the energy reductions in each end-use category contribute to the overall savings.

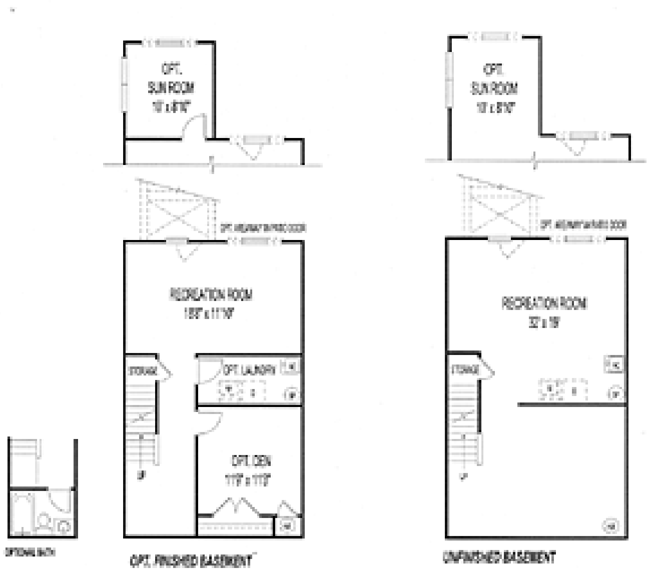
energy costs	$0.1400	/kWh for electricity	Baltimore Gas & Electric Co.
	$1.30	/therm for natural gas	Maryland Average

EnergyGauge USA v2.42 CHfH prototype .enb file

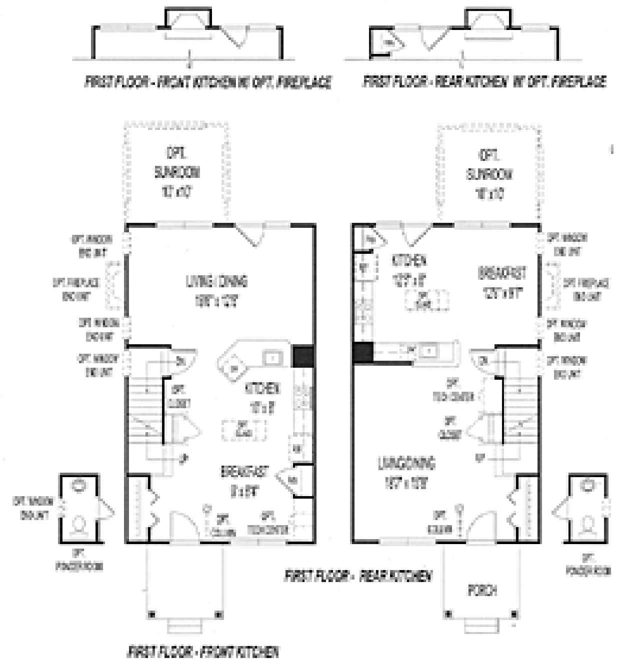
CHfH prototype.enb

Appendix B: Floor Plans

Struever Brothers Eccles & Rouse

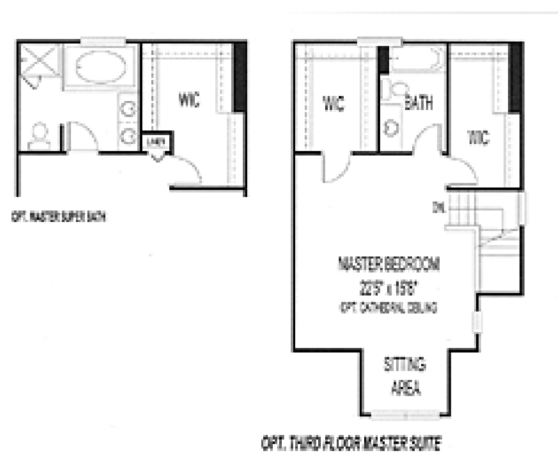


BASEMENT



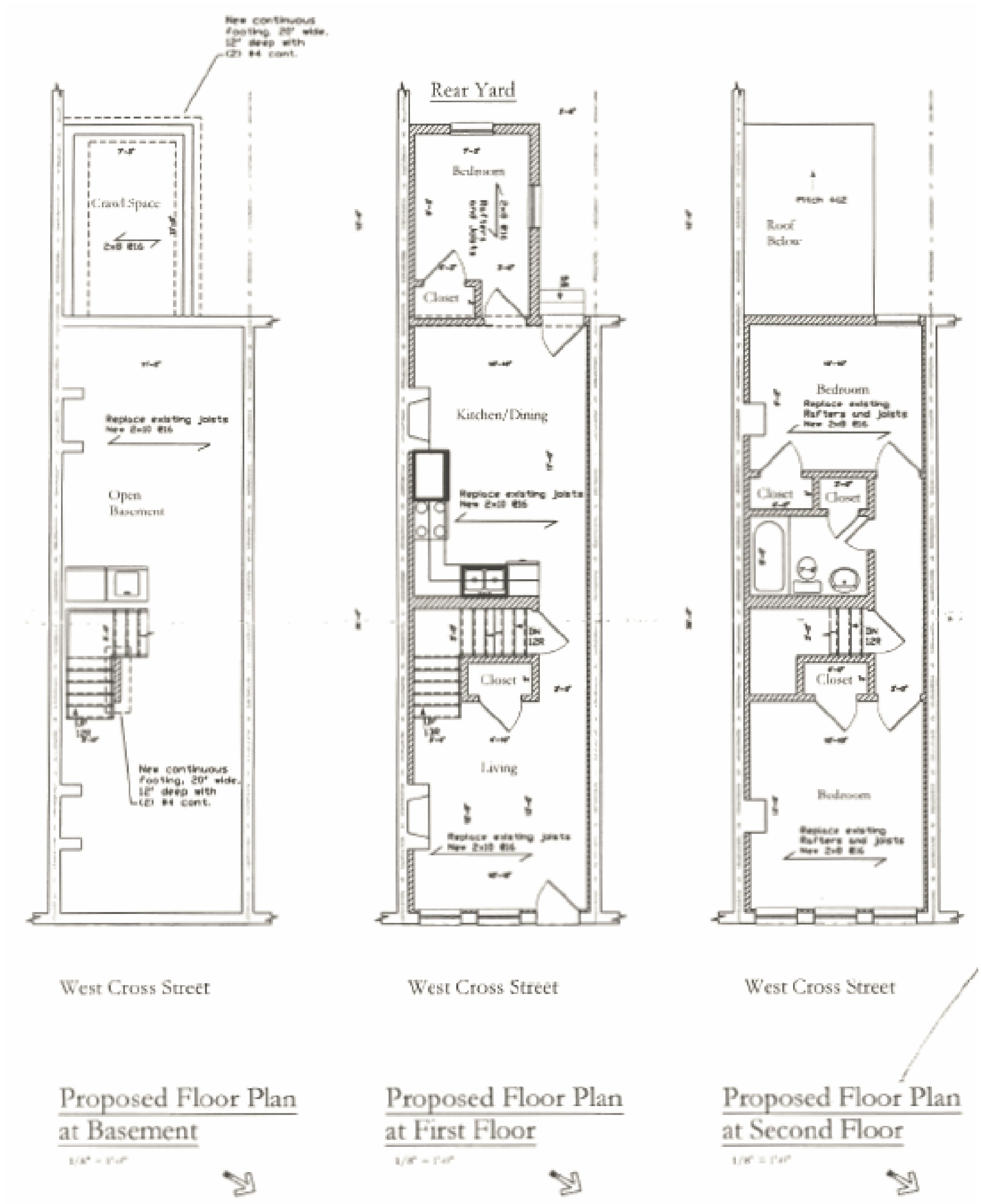
FIRST FLOOR

SECOND FLOOR



THIRD FLOOR

Chesapeake Habitat for Humanity

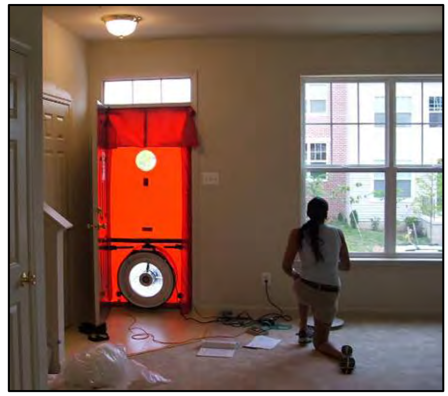


Appendix C: Performance Testing

SBER Performance Testing

CARB, with the assistance from the Energy Services Group, inspected/tested the townhouses to verify the final building specifications, to quantify the sealing of the building envelope and ductwork through perform testing, and to test the air distribution compared to design specifications. Performance data for the two end units is provided below.

Building Infiltration



A blower door test was performed to determine infiltration through the building envelope. This test induces outdoor air to enter the house through cracks and holes found in the exterior house surface by depressurizing the house. The blower door fan is used to simulate the driving forces that naturally occur as a result of the stack effect, wind pressure, ventilation fans, and duct system pressures. To isolate infiltration through only the exterior walls, blower doors were run simultaneously in each townhouse to eliminate leakage through the party walls.

The test showed that 1,604 cfm_{50} and 1,646 cfm_{50} were required to bring the two end units to a 50 Pascal depressurization. In terms of air changes per hour (ACH), this equates to an annual estimated natural infiltration of ~0.25 ACH_{nat}. This is higher than the originally anticipated 0.20 ACH_{nat} that was in the initial modeling, but better than the 2,043 cfm_{50} (0.32 ACH_{nat}) measured in the control house. As mentioned previously, there were a few problem issues in the mechanical closet in the loft at the time of the testing. In addition to the ceiling cut out, there were a couple other penetrations in this closet that were direct pathways to the attic spaces that were not sealed until later.

HVAC Duct Leakage

Duct blaster tests were performed on the two HVAC systems in each unit. This entails sealing all the supply registers and return grilles. Then a small fan is connected to the individual duct systems at the air handler to pressurize them. Based on a 400 cfm/ton air handler flow rate, the total duct leakage for the units servicing the main living space were 32% and 54% for the two end units. Testing was performed prior to the additional mastic sealing around the air handler. The loft units had a total duct leakage of 84% and 61%. This leakage can be attributed to the U-bend in the supply trunk and return plenum leakages. This is fairly leaky for a duct system and could lead to comfort issues. The control home had sufficient leakage to not allow for a proper pressurization to 25 Pascals for either unit. Total duct leakage includes conditioned air that is being lost to both conditioned and unconditioned space through the ductwork. Conditioned air that is leaking to other conditioned spaces does not result in an energy penalty, but it means that the design flowrate of air to each room is not being satisfied.

More important is duct leakage to the outside, this can be measured through a combination of the blower door and a duct blaster test. The house and ductwork are both brought up to a pressurization of 25 Pascals, this isolates the duct leakage only to the outside. If 400 cfm per ton of airflow is once again assumed, the main units both had unmeasurable (negligible) leakage to the outside. The loft units had a duct leakage to the outside of 51% and negligible. The 51% duct leakage to the outside was measured prior to the ceiling drywall cutout being repaired. What the contractor thought was a non-consequential drywall cutout would have actually lead to a significant energy penalty and likely comfort issues if not found during inspections. The control house was similar to the left end unit with negligible duct leakage in the main HVAC system and 43% for the loft unit.

	Duct Leakage				Duct Leakage To Outside			
Test House	Lower Floor		Upper Floor		Lower Floor		Upper Floor	
4709 Moravia Run Way (left end unit)	645 cfm_{25}	54%	505 cfm_{25}	84%	negligible	-	304 cfm_{25}	51%
4705 Moravia Run Way (right end unit)	380 cfm_{25}	32%	368 cfm_{25}	61%	negligible	-	negligible	-
1403 Parkside Pl (control)	couldn't pressurize to 25 pascals				negligible	-	258 cfm_{25}	43%

Distribution System Performance
In terms of comfort, a low-flow balometer was used to measure all supply register flow rates. The two end units had slightly differing floor plans for the 1st floor (the living room and kitchen areas are reversed). The overall performance of the main HVAC system was fairly consistent. Overall flow at the air handlers was in the 900-1,000 cfm range and when summed up, the measured flow rates at the supply registers was in the 700 cfm range. This difference is due to duct leakage to the interior space and doesn't result in a energy penalty.

The loft HVAC systems measured lower air flowrates at the air handlers than anticipated (~500 cfm versus a design of 600 cfm). This is likely the result of the issues that were discussed previously with the installation of these units. The sum of the supply registers (in the 300 cfm range) is even lower due to the excessive leakage found at the U-bend in the supply trunk.

	Room Supply Airflows - measured cfm	
Rooms	4709 Moravia Run Way (lot 152)	4705 Moravia Run Way (lot 154)
Living Room 1	87	75
Living Room 2	81	103
Living Room 3	72	-
Breakfast 1	62	48
Breakfast 2	-	46
Kitchen	-	94
Bedroom 2 (rear)	76	86
Bedroom 3 (front 1)	67	59
Bedroom 3 (front 2)	72	68
Laundry	60	58
Powder Room	82	44
Common Bath	46	32
Master Bedroom 1	91	91
Master Bedroom 2	70	-
Master Sitting Room	89	88
Master WIC 1	-	40
Master Bath	37	90
Total	992	1,022

1,000 cfm total
measured @ AHU:
Lot 152 = 941 cfm
Lot 154 = 985 cfm

600 cfm total
measured @ AHU:
Lot 152 = 474 cfm
Lot 154 = 503 cfm

	Room Return Airflows - measured cfm	
Rooms	4709 Moravia Run Way (lot 152)	4705 Moravia Run Way (lot 154)
1st Floor central return	490	470
Bedroom 2	144	165
Bedroom 3	147	103
Master Suite	343	309
Total	1,124	1,047

Still, even with these issues, the house was able to maintain comfort throughout the house. The loft HVAC systems likely are running for a longer period than necessary due to the duct leakage but the efforts of the HVAC contractor to seal these units should help in the overall performance.

CHfH Performance Testing

CARB inspected/tested the rowhouses to verify the final building specifications, to quantify the sealing of the building envelope and ductwork through perform testing, and to test the air distribution compared to design specifications. Performance data for four of the rowhouses is provided below.

Building Infiltration

The blower door test results are conservative (higher) as access to the adjoining rowhouses was not able. Therefore, the values shown are total air infiltration, not only through the exterior walls, but also the party walls. This leakage to adjoining unit was particular noticeable in the basement at the floor joists.

	$ACH_{natural}$	
House Unit	whole house	w/o basement
1213 W. Cross St.	0.85	0.59
1239 W. Cross St.	1.03	0.79
1253 W. Cross St.	0.82	0.59
1231 Bayard St.	1.37	0.68

HVAC Duct Leakage

The duct blaster test showed minimal duct leakage to the outside (once again, leakage through party walls could not be isolated from leakage through exterior walls), but considerable total duct leakage. This leakage can be primarily attributed to the filter slot at the air handler. The filter slots are made on site by the HVAC contractor and do not have proper covers, so significant leakage is occurring. CARB worked with the HVAC contractor to change this design practice and seal the filter enclosure to avoid damp basement air from entering the distribution system. Still, when the supply side of the ductwork was isolated, there was enough total leakage for potential comfort issues. Once again, the HVAC contractor was trained in the use of mastic to seal the metal ductwork, rather than aluminum tape (which was used to hold sections of ductwork together and not installed for the intent of sealing the ducts).

	Duct Leakage (CFM_{25})			
Townhouse	total	supply only	total to outside	supply to outside
1213 W. Cross St.	382	154	65	24
1239 W. Cross St.	378	166	76	42
1253 W. Cross St.	450	152	66	23
1231 Bayard St.	403	150	96	36

Appendix D: Event Dates

Dissemination Events, Training Sessions, & Other Dates of Interest:

June 20th, 2005	– SBER initial meeting and site visit
Aug. 30th, 2006	– SBER follow up meeting on building recommendations
Dec. 1st, 2005	– CHfH initial meeting and site visit
Jan. 18th, 2006	– CHfH rigid insulation installation training
Feb. 21st, 2006	– CHfH site inspection of insulation strategy
Feb. 22nd, 2006	– SBER panelized wall installation
Mar. 21st, 2006	– SBER HVAC rough-in and duct sealing training
Mar. 23rd, 2006	– CHfH tours highlighting energy efficiency and green building techniques for interested local groups
Apr. 10th, 2006	– SBER blown insulation installation inspection
May 11th, 2006	– CHfH testing of first prototype and standard practice control house – SBER site inspection
June 22nd, 2006	– SBER performance testing of prototype end units and control townhouse
June 28th, 2006	– CHfH close on four prototype rowhouses (ribbon cutting)
July 12th, 2006	– CHfH testing of three prototype units – SBER verification of corrections from previous inspection
July 28th, 2006	– SBER close on two end units
Aug. 3rd, 2006	– CHfH foundation construction for addition
Aug. 29th, 2006	– CHfH final tours highlighting energy efficiency and green building techniques for interested local groups
Sept. 1st, 2006	– CHfH close of final prototype rowhouse
Sept. 15th, 2006	– SBER tours highlighting energy efficiency and green building techniques for interested local groups
Oct. 3rd, 2006	– CHfH debrief meeting

Appendix E: Informational Handouts

Struever Bros. Eccles & Rouse in Baltimore, MD

Energy Efficient and 'Green' Townhomes

MEA MARYLAND ENERGY ADMINISTRATION

ENERGY EFFICIENCY

- Improved Building Envelope
- Blown-In Insulation
- High Efficiency HVAC
- Tankless Water Heater
- ENERGY STAR® Appliances
- Compact Fluorescent Lighting

GREEN FEATURES

- No VOC paints
- Bamboo Flooring
- Formaldehyde-free insulation
- Dual flush toilets

Building AMERICA U.S. Department of Energy

FRANKFORD ESTATES

Introduction

With energy costs rising and increasing public concern for the environment, architects and builders have the opportunity and responsibility of incorporating energy efficiency and green building strategies into mainstream residential construction.

STRUEVER BROS. ECCLES & ROUSE
Transforming America's Cities

In order to facilitate this movement, the Maryland Energy Administration has been working with the US Department of Energy and Maryland builders, to develop a set of energy efficient and green building guidelines for new and rehab construction.

Background

The Maryland Energy Administration (MEA) provides technical and financial assistance to private, non-profit, and governmental entities for the purposes of furthering energy conservation, sustainability and renewable energy. The MEA received a grant from the US Department of Energy (DOE) for State Energy Program Special Projects under the Building America Program, to implement an "Energy Efficient and Green Technology Building Templates Program," for new and rehab construction. The Consortium for Advanced Residential Buildings (CARB), was chosen to provide Building America technical support to the MEA.

CARB, led by Steven Winter Associates (SWA), is one of the Building America teams working throughout the country to develop, test, and design advanced building energy systems for all major US climate regions. The goal of the Building America program is to develop innovative system engineering approaches to advanced housing that will enable the US housing industry to deliver affordable and environmentally sensitive housing while maintaining profitability and competitiveness of homebuilders and product suppliers.

To develop the program, MEA partnered with builder Struever Bros. Eccles & Rouse (SBER), to construct three energy efficient and sustainable homes. For thirty years, SBER has been creating communities in Baltimore neighborhoods. They were awarded a

redevelopment opportunity by the City of Baltimore to transform Moravia Park, a neighborhood in northeast Baltimore. Working with Doracon Contracting, SBER began the re-development of an 18 acre property, that will be completed in 2006. The development, Frankford Estates, has 170 new homes and is designed as a "Green-Friendly" community.

As a partner in this State Energy Project, SBER worked with CARB to incorporate energy efficient strategies into three townhomes and to expand the green options SBER offers to prospective homeowners. Although the recommendations require a few extra steps and some additional first costs, the increased energy-efficiency and sustainability of these homes reduce the utility bills homeowners will face and place less of a burden on the environment. With many development opportunities available in Maryland, new construction has the responsibility of raising the standards in energy efficient housing.

Energy Efficient Strategies and Green Technologies

CARB's recommendations to SBER focused on improving energy efficiency and the health and safety of occupants while minimizing the impact on the environment. When compared to a standard new home built to current code standards, the ENERGY STAR® SBER homes at Frankford Estates provide approximately 16 percent in energy savings. Improving upon SBER's already energy-efficient homes, the three Building America townhomes at Frankford Estates provide approximately 35 percent in energy savings when compared to a standard new home.

Improved Building Envelope

In order to increase the energy efficiency of these townhomes, improvements to the building envelope needed to be made. The builder's standard practice was to use 2x4 panelized construction at 16" on center with Thermo-ply insulated sheathing on the exterior. This sheathing provides minimal thermal benefits (R-0.20), but can help in minimizing building infiltration. CARB recommended switching to 2x6 panelized walls at 24" on center with oriented strand board (OSB) on the exterior. This strategy allows more insulation to be filled in exterior walls while remaining structurally sound and maintaining the same amount or less lumber usage. In terms of cost, this should be essentially a wash except for the additional insulation that will be needed to fill the larger wall cavity. Even this added cost for insulation should not affect the first cost, as the HVAC system sizing should be reduced sufficiently to allow for cost-shifting. Most of the savings will be seen on the cooling side due to the larger availability of sizes for cooling equipment.

Theoretically, the savings in lumber by switching from 16" to 24" on center pays for the incremental cost of switching from 2x4's to 2x6's.

The next energy efficient strategy was geared towards controlling air infiltration. A commonly overlooked air bypass location is the rim/band joists. These areas are not typically insulated and are only designed for structural purposes. SBER originally tried to seal this area using a spray foam, but found installation issues with maintaining a uniform thickness. CARB recommended switching to rigid insulation cut-outs that could be foamed around the edges. Air sealing was taken one step further by applying a bead of spray foam at all the seams between the wood studs and the plywood, and around penetrations in the envelope from plumbing and electrical systems.

For the basement, the insulation strategy was to use 2 inches of foil-faced polyiso-cyanurate rigid insulation (Thermax or equivalent product with suitable fire rating)

adhered to the upper half of the walls using construction adhesive. With an insulating

value of R-6.5 per inch, this closed-cell insulation is better suited to moist basement conditions than standard fiberglass blanket insulation. Since the majority of the heat loss is through the above-grade portion of the foundation, CARB was primarily concerned with insulating the top four feet of the foundation, but SBER insulated the complete wall. They allowed for a 4" gap at the bottom to allow any moisture that may occur to dry out to the space.

Improved HVAC Equipment

To complement the improvements to the building envelope, it was also necessary to make improvements to the mechanical equipment and to control duct leakage. A high efficiency (93% AFUE) direct-vent furnace was recommended by CARB that, combined with the improved envelope, would reduce space heating costs.

In terms of the ductwork, the HVAC systems were designed to have all the ductwork and equipment located within the conditioned envelope. This was done to minimize duct leakage to the outside and to prevent unconditioned attic air from entering the system. All ductwork was sealed with mastic to prevent leakage around seams and joints.

Mechanical ventilation was specified by CARB in order to meet the indoor air quality requirements of ASHRAE 62.2, a standard for ventilation and acceptable indoor air quality in low-rise residential buildings set by the American Society of Heating, Refrigerating and Air-Conditioning Engineers. This was accomplished by installing one ENERGY STAR® bath fan that operated on a timer to ensure a certain number of air changes each day. If fan noise is a concern, be sure to specify "low-sone" when purchasing.

Tankless Water Heater

A Noritz tankless water heater provides domestic hot water on demand. This gas-fired equipment offers a substantial improvement in water-heating efficiency compared to the conventional storage tank water heater used by SBER. Storage tank systems not only use more energy to heat water to higher temperatures than are actually needed, they also use more energy to keep the temperature hot all day long. Tankless systems provide hot water, at the temperature you need, when you need it. For these townhomes, the energy analysis shows a 35% decrease in annual domestic hot water energy use.

Other Energy Savers

ENERGY STAR® Appliances— Reduce energy consumption and save occupants money on their energy bills. ENERGY STAR® appliances provided by SBER as the basic package at Frankford Estates, include a refrigerator, dishwasher and a bath exhaust fan. Home-owners are responsible for installing their own clothes washers, and many ENERGY STAR® models are available. Energy savings from these upgraded appliances generally pay for themselves in just a few years.

Compact Fluorescent Lighting—Lighting in all rooms and hallways are compact fluorescent, accounting for 100% of all lighting and saving homeowners annually. Fluorescent fixtures reduce energy consumption by 50–75%, saving homeowners money on their energy bills. They also last up to seven times longer than incandescent lamps, thus reducing maintenance and replacement costs. Fluorescents generate less waste heat than incandescent lamps and fixtures. Fluorescent bulbs also use about one-quarter of the energy of conventional incandescent light bulbs, justifying their higher incremental cost.

Programmable Thermostat—When used properly, programmable thermostats save heating and cooling energy when the house is unoccupied.

Green Features

As part of the grant, MEA strongly promoted the use of green materials and technologies. Building 'green' means using sustainable products and being environmentally sensitive before, during, and after construction. Low-VOC paints, sealants, and adhesives can substantially reduce the indoor air pollution that causes irritations of the eyes, lungs, and skin and respiratory and internal organ problems. Nationally, these products are often cost-competitive with traditional counterparts. Bamboo floors utilize a rapidly renewable resource and recycled-content materials are available as alternatives to traditional construction products.

At Frankford Estates, homeowners are offered a package of green options, including dual flush toilets, bamboo floors and no-VOC paints.

CARB encouraged the use of low-VOC paints, sealants, and caulks as a standard practice to minimize the off-gassing that is typical in new construction. Other products, such as wool carpeting, tile or stone flooring, wheatboard cabinets, low flow fixtures, and recycled content plastic lumber were also discussed as possible options.

Energy efficiency and sustainable design can easily be applied to new construction to build better quality homes, conserve resources and to improve the environment.

For more information, contact the Maryland Energy Administration at 1-800-72-ENERGY or visit www.energy.state.md.us Visit Struever Bros. Eccles & Rouse at www.sber.com and CARB at www.swinter.com

STRUEVER BROS. ECCLES & ROUSE
Transforming America's Cities

MEA MARYLAND ENERGY ADMINISTRATION

Building America U.S. Department of Energy CARB CONSORTIUM FOR ADVANCED RESIDENTIAL BUILDINGS

Panelized Wall Construction

Improving Quality and Minimizing Resources

Panelized wall systems consist of prefabricated, or factory-manufactured, panels that form a structural envelope, and significantly expedite on-site framing, which can reduce labor costs. Panels are manufactured in a factory, which ensures their quality and consistency, but may limit flexibility. For example, concrete foundations must be placed precisely, and on-site design changes can be costly and difficult. The initial cost of prefabricated panels may be higher than that of conventional framing materials. However, labor savings are often significant enough to offset the initial cost difference.

Panelized construction offers benefits for many climates. Because they are prefabricated in an indoor factory setting, they can be constructed any time of year, and are not subject to weather delays. Panelized systems can be designed to offer a uniform and continuous air barrier that improves insulation and helps homeowners stay comfortable while reducing their heating and cooling costs. Specify 2X6 at 24" OC center stud framing to reduce thermal bridging while maintaining structural integrity and to maximize the insulation that can be installed in the wall cavity.

Improved insulation helps homeowners reduce energy costs, and provides builders with an additional selling point. Panel systems have gained popularity among production builders because of their ability to reduce framing errors and maintain construction schedules.

For more information on panelized wall systems, visit PATH's www.toolbase.org

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U.S. Department of Energy
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CONSORTIUM FOR ADVANCED RESIDENTIAL BUILDINGS

Tankless Water Heaters

Tankless water heaters are compact heating units that provide hot water as it is needed, and do not store hot water like traditional tank-type water heaters. When a hot water tap is turned on, water enters the tankless water heater. A sensor detects the water flow, and activates a gas heating device, which quickly raises the water temperature to a preset level. When water flow stops, the heating element shuts off. Thermostatically-controlled tankless water heaters vary their output temperature according to water flow rate and inlet water temperature.

Unlike traditional storage tank water heaters, tankless water heaters do not store a reservoir of hot water. As a result, standby losses are eliminated, which makes them an energy-efficient alternative to traditional water heating. Tankless units can reduce water heating bills by 10 to 20% – a significant savings for homeowners, considering the average household spends 14% of its energy budget on water heating.

Gas tankless water heaters are available in a variety of capacities by numerous manufacturers. They can be used for supplementary heat, such as a booster to a solar hot water system, or to meet all of a home's hot water needs. The maximum flow rate and temperature rise are determined by the capacity of the heater. In general, gas tankless heaters have larger capacities than their electric counterparts. Residential gas models are available that can heat more than five gallons per minute by 60°F, generally more than enough for two showers to be run simultaneously.

Because tankless heaters do not store water, they are less subject to corrosion than tank-type heaters. As a result, their expected equipment life is longer – more than 20 years, compared with 10 to 15 years for traditional heaters. Also, because they are not under pressure, tankless water heaters are less susceptible to leakage than tank-type water heaters.

Gas tankless water heaters are more expensive than typical tank systems but similar in cost to high efficiency tank systems. Standard tank systems may cost around $300, whereas gas tankless systems may cost closer to $1,000. Electric tankless systems are available, but due to low heating capacity and the higher capacity electrical panel required, these are not recommended.

For more information and tankless water heater case studies, visit PATH's www.toolbase.org

Chesapeake Habitat for Humanity Project in Baltimore, MD

Rowhouses Rehabbed for Energy Efficiency

MEA
MARYLAND
ENERGY ADMINISTRATION

ENERGY EFFICIENCY

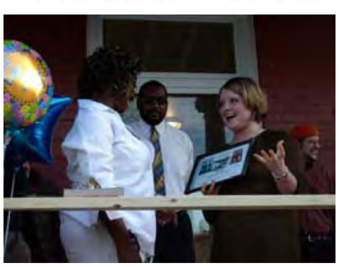
- Improved Building Envelope
- Improved HVAC
- Tankless Water Heater
- ENERGY STAR® Appliances
- Compact Fluorescent Lighting

GREEN FEATURES

- Low VOC paints and caulks
- Durable fiber-cement board siding
- Low flow faucets
- Dual flush toilets
- Bamboo flooring

Building AMERICA
U.S. Department of Energy

Chesapeake Habitat for Humanity



Introduction

Row houses have been prominent in Baltimore's architecture for centuries, with over 140,000 still standing today. Many are abandoned and are being renovated in an attempt to improve the quality of life in these urban neighborhoods. Over 17,000 permits were issued last year for residential rehabilitation projects, indicating a significant opportunity to improve the quality of existing housing in Baltimore, in a sustainable and energy-efficient way.

Background

The Maryland Energy Administration (MEA) provides technical and financial assistance to private, non-profit, and governmental entities for the purposes of furthering energy conservation, sustainability and renewable energy.

The MEA received a grant from the US Department of Energy (DOE) for State Energy Program Special Projects under the Building America Program, to implement an "Energy Efficient and Green Technology Building Templates Program," for new and rehab construction. The Consortium for Advanced Residential Buildings (CARB), was chosen to provide Building America technical support to the MEA.

CARB, led by Steven Winter Associates (SWA), is one of the Building America teams working throughout the country to develop, test, and design advanced building energy systems for all major US climate regions. The goal of the Building America program is to develop innovative system engineering approaches to advanced housing that will enable the US housing industry to deliver affordable and environmentally sensitive housing while maintaining profitability and competitiveness of homebuilders and product suppliers.

The Chesapeake Habitat for Humanity was selected as the builder for the rehabilitation projects. Chesapeake Habitat works in Baltimore, rehabilitating vacant houses to provide home ownership opportunities to low-income families. Relying on a large volunteer staff, they have already completed 103 homes in various Baltimore City neighborhoods, and eight additional units are currently under construction.

Low-income families may spend over 15% of their income on energy to operate their homes. Money saved on utility bills means more money for food, clothing, and other essentials.

Incorporating CARB's recommendations, Chesapeake Habitat has rehabilitated five 2-story row houses on West Cross Street and Bayard Street into energy-efficient, affordable housing. Although the recommendations require a few extra steps and some additional first costs, the increased energy-efficiency of these homes reduce the utility bills homeowners will face, making them truly affordable for low-income families.

Energy Efficient Strategies and Technologies

It is the goal of the Building America program to find energy-efficient solutions for new and existing housing that can be implemented on a production basis. Row houses are a large majority of construction in Baltimore and offer a big opportunity to improve energy efficiency of existing housing. Much like other row houses in Baltimore, these units are 2-story, brick construction, with two bedrooms, one bath and a basement.

CARB's recommendations for rehabilitations focused on improving energy efficiency and the health and safety of occupants while minimizing the impact on the environment. Energy analyses showed that if the recommendations were implemented, there could be a 22% annual savings in cooling energy, a 17% savings in annual heating energy, and a 25% savings in annual domestic hot water heating savings (compared to the Building America benchmark home). Energy consumption from lights and appliances could be reduced by over 60%. When compared to Habitat's standard practice, overall energy consumption is reduced by 32%. The biggest obstacle to realizing these savings would be to successfully air-seal the building envelope.

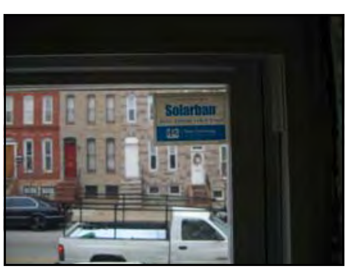
1

Improved Building Envelope

In order to increase the energy efficiency of these five rehabilitation projects, improvements to the building envelope needed to be made. Once deconstruction was complete, the builder's standard practice was to stud out the above grade walls and fill the cavities with fiberglass batts. This method allowed for a significant amount of heat loss through the framing. To avoid this "thermal-bridging," CARB recommended installing 1" XPS rigid insulation between the brick and stud framing (1) and provided on-site training on how to foam the seams to prevent any air pathways(2). The effectiveness of the air sealing determines how much energy is lost due to infiltration, which can be significant in these older brick row houses. For even greater R-value, fiberglass batts were installed within stud cavities and 2x6's were specified on exterior walls to accommodate R-19 batts.

2

Basements in typical row houses are unfinished and uninsulated, resulting in significant heat loss. Because the rehabilitated row houses would be directly conditioned, CARB recommended the installation of 2" foil-faced polyisocyanurate rigid insulation (R-13) on the front and rear basement walls, between the floor joists and on a portion of the party walls. Due to the international partnership between DOW and Habitat for Humanity, DOW Styrofoam rigid insulation was provided free of cost for the above grade walls. Other builders could expect to pay less than **$1 per square foot** for this improvement. Due to the potential fire hazard when left unfinished, this material could not be used in the basement. The incremental cost incurred for the foil-faced basement insulation totaled **75¢ per square foot**.



3

To further improve the building envelope, CARB recommended upgrading the windows commonly used by Habitat to low-e, insulated glass(3). Higher performing double pane windows have lower U-values, indicating less heat transfer through this building

4

5

6

component. The low-emittance glass coating is a thin film applied to the glass that keeps heat inside during the winter and outside during the summer.
Because Maryland has both cold winters and hot summers, a low-e glass with a moderate solar heat gain coefficient is desired, such that the house is kept cooler in the summer but a good amount of sun is still let in during the winter. The incremental cost to upgrade the windows: **$32 per window.**

Improved HVAC Equipment

Affordable housing is only truly affordable if the homeowner can afford the utility bills. To complement the improvements to the building envelope, it was also necessary to make improvements to the mechanical equipment. Habitat does not provide central air conditioning, so efficiencies of cooling equipment will be limited by window air conditioners installed by the homeowners.

A high efficiency furnace was recommended by CARB that would reduce space heating costs by approximately 10% per year. A direct-vent Goodman natural gas furnace (93% AFUE) was installed to improve indoor air quality and reduce gas bills(4). **Incremental cost: $400**

Mechanical ventilation was specified by CARB in order to meet the indoor air quality requirements of ASHRAE 62.2, a standard for ventilation and acceptable indoor air quality in low-rise residential buildings set by the American Society of Heating, Refrigerating and Air-Conditioning Engineers. This was accomplished by installing one ENERGY STAR® bath fan that operated on a timer to ensure a certain number of air changes each day. If fan noise is a concern, be sure to specify "low-sone" when purchasing. The cost to install one fan was **$130.**

Hard ducted returns were specified by CARB to reduce energy losses due to duct leakage(5). Using existing cavities between studs and joists as return pathways is ineffective and can lead to pressure imbalances within the home. These pressure imbalances affect the air distribution and can possibly lead to backdrafting of flue gases. Hard ducted returns can be properly sealed, using mastic or UL-181 rated butyl tape with aluminum backing, and the flow of air can be better controlled.

Tankless Water Heater

A Rinnai tankless water heater provides domestic hot water on demand (6). This gas-fired equipment offers a substantial improvement in water-heating efficiency compared to a conventional storage tank water heater. Storage tank systems not only use more energy to heat water to higher temperatures than are actually needed, they also use more energy to keep the temperature hot all day long. Tankless systems provide hot water, at the temperature you need, when you need it. For these rehab units, the energy analysis shows a 25% decrease in annual domestic hot water energy use and an estimated annual savings of $36. The incremental cost for this improvement for Habitat was approximately **$1,000.**

Other Energy Savers

ENERGY STAR® Appliances—ENERGY STAR® appliances reduce energy consumption and save occupants money on their energy bills. Appliances provided by Habitat include a refrigerator and a bath exhaust fan. Homeowners are responsible for installing their own clothes washers, and many ENERGY STAR® models are available. Energy savings from these upgraded appliances generally pay for themselves in just a few years.

7

Compact Fluorescent Lighting—Lighting in all rooms and hallways are compact fluorescent, accounting for 100% of all lighting. Fluorescent fixtures reduce energy consumption by 50–75%, saving homeowners money on their energy bills. They also last up to seven times longer than incandescent lamps, thus reducing maintenance and replacement costs. Fluorescents generate less waste heat than incandescent lamps and fixtures. Fluorescent bulbs also use about one-quarter of the energy of conventional incandescent light bulbs, justifying their higher incremental cost **($10 for a 4 pack of CFL's).**

Programmable Thermostat—When used properly, programmable thermostats (7) save heating and cooling energy when the house is unoccupied. **Cost to upgrade: $30**

Green Features

As part of the grant, MEA strongly promoted the use of green materials and technologies. Building 'green' means using sustainable products and being environmentally sensitive before, during, and after construction. In at least one row house, bamboo floors were installed on the first floor and low-VOC paints and adhesives were used. Non-vinyl, Hardi plank fiber cement board was used in the rear exterior wall and low flow faucets and dual flush toilets were installed in the bathroom and kitchen.

8

Low-VOC paints, sealants, and adhesives can substantially reduce the indoor air pollution that causes irritations of the eyes, lungs, and skin and respiratory and internal organ problems. Nationally, these products are often cost-competitive with traditional counterparts. **Bamboo floors(8)** utilize a rapidly renewable resource and **Hardi plank recycled-content cement board** is a durable low-maintenance alternative to traditional wood siding.

Energy efficiency and sustainable design can be applied to existing construction to build better quality homes, conserve resources and to improve the environment.

Chesapeake Habitat for Humanity volunteers gather in front of a recently deconstructed row house on West Cross Street.

Building Green

Simple ways to build 'Green'

From new construction to rehab projects, all buildings can incorporate sustainable or 'green' practices. Green building revolves around principles of site planning, improved air quality, water conservation, and energy and resource efficiency. To build green means to prioritize any strategy that conserves natural resources and minimizes impacts on the environment, either during project demolition, new construction, operation and maintenance, or manufacturing and delivery of building products. Selecting environmentally preferable materials is a simple way to build 'green'. These products are durable, renewable, use energy and natural resources sparingly, and incorporate recycled materials whenever possible.

Green Floor Options

An attractive alternative to traditional wood flooring, bamboo is a rapidly renewable resource. Ceramic tile lasts far longer than vinyl flooring, is low-toxic, waterproof and available with recycled-content. Other durable, low-toxic options: natural linoleum, finished concrete, & carpets made from natural fibers, like wool or jute.

Fiber-Cement Siding

Products such as Hardiplank® lap siding have the look of wood and the easy maintenance of vinyl, but this fiber-cement product has superior resistance to rotting, cracking, rain or hail damage, and fire (backed by a 50-year warranty).

Forest Conservation

Instead of using plywood and solid sawn lumber, use oriented strand board (OSB) and engineered lumber to help preserve old-growth forests. Traditional wood cabinets can be replaced by ones made with wheat straw, an abundant resource that is generally burned as waste. When stick framing, minimize use of wood by switching to 24" OC spacing. Give preference to wood that is sustainably grown and harvested, as certified by the Forest Stewardship Council (FSC).

Building Green

Water Conservation

Although 70% of our planet is covered in water, less than half a percent of this water is fresh and accessible. Efforts must be made to conserve this precious resource. Low-flow faucets and showerheads reduce water usage by about 40% and low-flow toilets can save a family of four an estimated 22,000 gallons per year. Dual-flush toilets offer half-flush and full-flush options, saving even more water. Choose low-water use dishwashers and front-loading clothes washers for additional water savings.

Recycled Content

Recycled content building materials reduce waste and conserve resources, and can be included throughout a home: composite wood and plastic decking, polystyrene trim and moulding, PET carpet, fiberglass and cellulose insulation, concrete aggregate and fly ash, floor tile, fiberboard, and even drywall are all prime examples of recycled content materials.

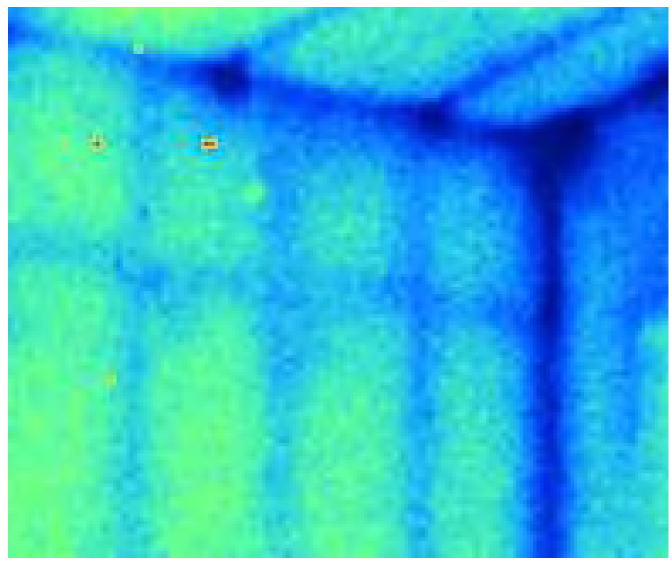
Indoor Air Quality

Volatile organic compounds (VOC's) contribute to urban smog and poor indoor air quality, exacerbating human health conditions such as asthma and chemical sensitivities. VOC's and formaldehyde (a suspected carcinogen) are present in many conventional building materials. These chemicals are released into homes for years after new materials are installed. Improve indoor air quality by specifying low or no-VOC paints, finishes, glues and sealants, and no-added-urea-formaldehyde or formaldehyde-free insulation, flooring, and medium density fiberboard.

Wall Insulation Strategy

Minimizing Thermal Bridging

Common practice in new and rehab construction is to insulate the wall cavities with fiberglass batt insulation. The use of R-13 batts does not result in an R-13 wall assembly. Every stud marks the absence of insulation and therefore the opportunity for heat loss or "thermal bridging". As seen in the thermograph to the right, heat can use stud framing to bypass insulation, effectively reducing the R-value of the wall assembly.



To avoid thermal bridging, a continuous layer of rigid insulation board should be placed between the studs and the exterior surface (sheathing, brick, etc.) This will minimize the amount of heat that is conducted through the studs. Cavity insulation should be installed as usual. Where feasible, framing should be switched to 24"OC, further reducing the number of "thermal bridges".

The wall section to the left shows a wall assembly of a sample gut rehab project. The original walls of this Baltimore row house were uninsulated brick that were cleaned of all plaster and debris. A layer of rigid insulation board was attached to this surface with a low-VOC foam adhesive. The walls were then framed with the studs right against the rigid insulation board and the cavities were filled with fiberglass batt insulation.

See the reverse side for step-by-step guidelines for implementing this cost-effective wall insulation strategy.

Building America U.S. Department of Energy CARB CONSORTIUM FOR ADVANCED RESIDENTIAL BUILDINGS

MEA MARYLAND ENERGY ADMINISTRATION

Chesapeake Habitat for Humanity

Wall Insulation Strategy

Step-by-Step Guidelines

1. **Clear walls of plaster and debris that affect how flush the rigid insulation will be. Using a 4x8 sheet of insulation, vertically dry-fit the board to the wall.**

2. **Remove the board and apply a 1/2" bead of foam adhesive along the outer rim of the rigid board and in the center, in the shape of an "X".**

3. **Press the board against the selected wall, using continuous pressure. For example, in narrow width row houses, place a 2x4 brace against the seam of the rigid boards and use an extension pole to hold the wood and insulation in place for at least 5 minutes. Save time by doing opposite walls at the same time.**

4. **Use cutouts to fill in spaces between floor joists and other remaining wall area. Rigid insulation should extend at least 6" above the ceiling plane, so that a tight air seal can be formed with the ceiling drywall. Once rigid insulation is adhered to the walls, use low expansion foam to fill any cracks, seams, or openings where rigid insulation could not be used. Areas to pay special attention to: the seam between the floor and insulation, the space between rigid boards, the area around the floor joists, and the top edge of rigid insulation that extends above the ceiling plane.**

5. **When studding out the walls, press the studs against the insulation. In many rehab projects, the original walls may be too far out of alignment. In that case, keeps studs as close to the wall as possible, while maintaining a straight profile. If a wall has already been studded out, cut pieces of insulation to a workable size so that they can be slid in behind the stud wall. Fill stud cavities with batt or blown-in insulation. On exterior walls, try 2x6 studs to allow for higher R-value insulation.**

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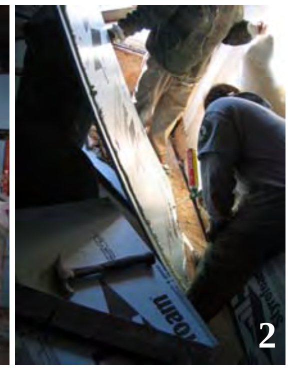
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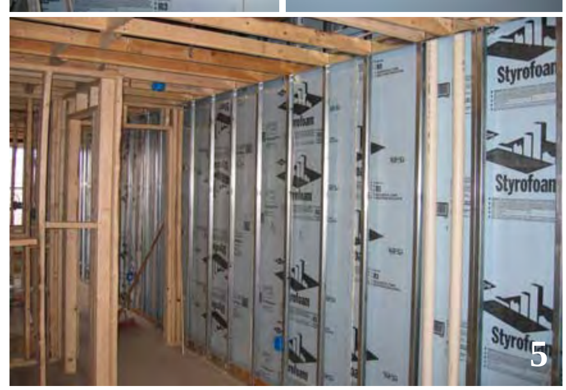

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