U.S. Department of Energy

Builders Challenge

RECOGNIZING ENERGY LEADERSHIP IN HOMEBUILDING

Builders Challenge Quality Criteria Support Document

Building America Best Practices Series Volume 8 | Version 1.2 | November 2009 | PNNL-18009

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

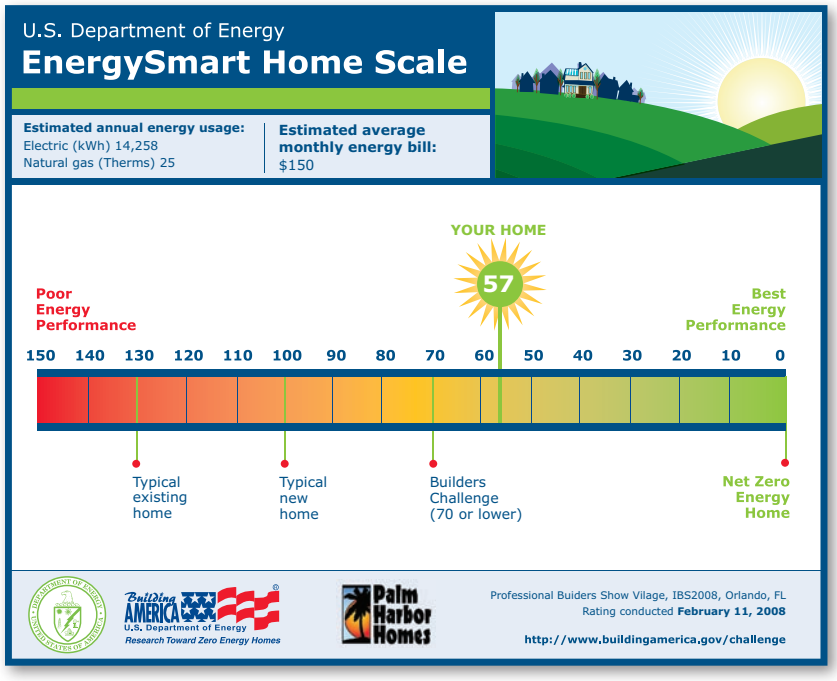
Building AMERICA U.S. Department of Energy Research Toward Zero Energy Homes | Builders Challenge: Recognizing Energy Leadership in Homebuilding

Summary

The U.S. Department of Energy (DOE) has posed a challenge to the homebuilding industry—to build a new generation of high-performance homes using proven innovations and to work toward the ultimate goal of providing cost-neutral, net-zero energy homes by 2030. Through the Builders Challenge, participating homebuilders will have an easy way to differentiate their best energy-performing homes from other products in the marketplace, and to make the benefits clear to buyers. This document provides guidance to U.S. home builders who want to accept the challenge.

To qualify for the Builders Challenge, a home must score 70 or less on the EnergySmart Home Scale (E-Scale). The E-Scale is based on the well-established Home Energy Rating System (HERS) index, developed by the Residential Energy Services Network (RESNET). The E-scale allows homebuyers to understand—at a glance—how the energy performance of a particular home compares with the performance of others. To learn more about the index and HERS Raters, visit www.natresnet.org. The Criteria are intended to ensure that qualifying homes not only are the most energy-efficient homes available, but also address issues of building durability, indoor air quality, and occupant health, safety, and comfort.

Figure S.1. The first EnergySmart Home label was awarded to Palm Harbor Homes in February 2008, which earned a score of 57, or 43 points better than typical new construction.



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BUILDING AMERICA
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From Version 1.3, published June 4, 2008.

Building America U.S. Department of Energy Research Toward Zero Energy Homes | Builders Challenge
Recognizing Energy Leadership in Homebuilding

Summary

Homes also must meet the Builders Challenge Quality Criteria described in this document. To help builders meet the Challenge, guidance is provided in this report for each of the 29 criteria. The 29 criteria, which include 15 requirements and 14 recommendations that builders must meet to qualify for the Builders Challenge, are listed in the sidebar. Included with guidance for each criteria are resources for more information including references cited in the text and lists of relevant codes and standards. Builders should always check with authoritative code officials before implementing changes in building techniques and measures.

Two appendices are attached to this guidance. The first, entitled *Other Considerations for Marketing and Resources*, is a summary of opportunities and other resources not tied to specific criteria that will be of interest to builders. The second is the full Builders Challenge Quality Criteria.

To learn more about the Builders Challenge and find tools to help market your Builders Challenge-certified homes, visit www.buildingamerica.gov/challenge.

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1 REQUIRED

Project Documentation

BUILDERS CHALLENGE QUALITY CRITERIA	BUILDER DOCUMENTATION & VERIFICATION REQUIREMENTS	THIRD-PARTY VERIFICATION REQUIREMENTS
1. Project Documentation – Required: Construction/design documentation (e.g., plans, details, specifications, job ready and job complete checklists, and trade scopes of work and/or agreements) will include energy and quality provisions needed to meet the Builders Challenge criteria.	Develop and store construction/design and energy rating documentation in project records. The builder (or builder's representative) shall review the adequacy of the construction/design documentation for implementing the energy and quality provisions, and shall sign the completed checklists.	The third-party rater shall review the construction documentation and signed checklists.

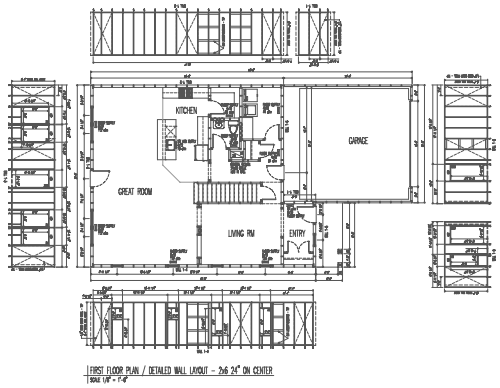
Good plans, showing features such as duct sizing and layout, framing details, and flashing specifications, are critical to building high-performance homes. Plans are important because they show where building elements are to be located and how those elements tie together with other building components. But construction documents should be more than a set of plans and accompanying specifications needed to get building permits and planning approval. Scopes of work are needed to communicate expectations with trades contractors. Job-ready and job-complete checklists are needed to ensure that each trade contractor is handing off a project that is ready for the next trade and that jobs are completed as specified.

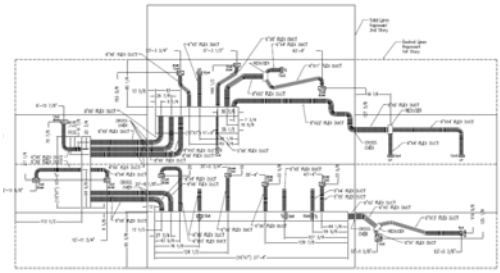
Plans and Specifications

Plans and specifications are the most familiar parts of construction documents. Plans provide elevations, floor plans, and details of many elements needed to show codes officials that projects meet code minimums. Construction managers and field crews often refer to plans during the building process. Plans and materials schedules are important for ordering materials. Plans and specifications should address the following building features related to energy efficiency:

- Provide framing diagrams and details to spell out advanced framing techniques and the placement of all framing members, an example is shown in ***Criteria 3. Material-Efficient Framing - Recommended***.
- Show duct sizes and layouts on floor plans and elevations, an example is shown in ***Criteria 6. Space Conditioning Design - Recommended***.
- Indicate methods, materials, and locations where sealing is needed to form the house air pressure barrier, as discussed in ***Criteria 16. Air Barrier and Insulation Integrity – Required***. Specify the approach to be taken to meet vapor barrier code requirements.
- Indicate methods, materials, and locations where liquid moisture barriers will be installed. Examples may include house wrap, sealing materials, flashing systems, gutter systems, and grading requirements as discussed in ***Criteria 23. Building Envelope Moisture Management – Field Verification – Required***.

Figure 1.1.
Full size versions of these examples of plan documents can be found in the sections on material-efficient framing (Criteria 3) and space-conditioning design (Criteria 6)





Building America U.S. Department of Energy Research Toward Zero Energy Homes | Builders Challenge Recognizing Energy Leadership in Homebuilding

- Provide plans and details for all specialized building features, such as sealed and conditioned attics and crawlspaces, sealed and insulated air handler closets in garages, and radon control measures.

These recommended elements that should be included with construction documents are consistent with the 2009 IECC, which states in section 103.2:

Construction documents shall be of sufficient clarity to indicate the location, nature, and extent of the work proposed, and show in sufficient detail, pertinent data and features of the building, systems and equipment as herein governed. Details shall include, but are not limited to, as applicable, insulation materials and their R-values; fenestration U-factors and SHGCs; area-weighted U-factor and SHGC calculations; mechanical system design criteria; mechanical and service water heating system and equipment types, sizes and efficiencies; economizer description; equipment and systems controls, fan motor horsepower (hp) and controls; duct sealing, duct and pipe insulation and location; lighting fixture schedule with wattage and control narrative; and air sealing details.

Scopes of Work

A scope of work is a description of the specific work that builders expect trade contractors to perform. Every contract, including those executed with only a nod and a handshake, incorporates a scope of work. After all, if a builder didn't need a task accomplished and didn't describe that task to a trade contractor, there would be no basis to initiate a deal. The issue is that, without a clear understanding of the task that can be conveyed to many trade contractors, and specifically the installer, the expectations for what a task entails can be all over the map. The bottom line is that builders and consumers should get what they pay for.

As materials change and techniques evolve, scopes of work must change to keep up. Front offices should give construction managers, trade contractors, and designers plenty of opportunity to review and update scopes of work. These reviews can happen any time but are especially important before big trade contracts are initiated and just after projects are completed.

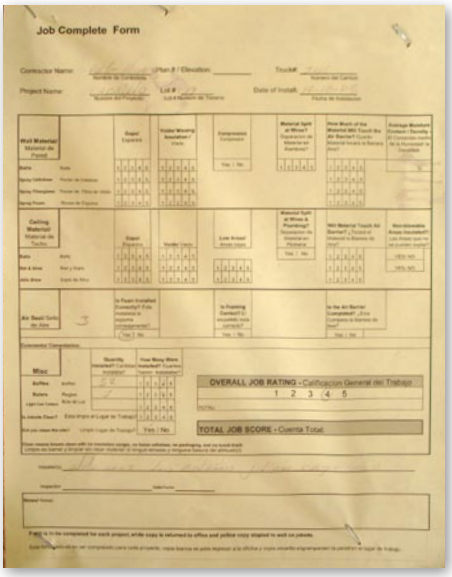
Scopes of work should take into account sequences of work that are unfamiliar to trade contractors. A good example of this situation is the installation of duct chases (see ***Criteria 15. Duct Leakage – Required***).

Job-Ready and Job-Complete Checklists

The job-ready checklist (see example on pages 1.4 – 1.7), to be completed jointly by the site supervisor and trade contractor, includes all items that must be installed or prepared on the jobsite—by other trade contractors—before work can begin. Items in the job-ready checklist are not directly under the control of the trade contractor getting ready to work, but they directly affect his or her ability to successfully and efficiently complete the job. The job-ready checklist should be part of the scope of work because it highlights the ways in which one trade contractor's work is connected to another's and encourages trade contractors to think of their individual work as part of a larger whole.

The job-complete checklist (Figure 1.2) is the mechanism by which the trade contractor certifies that the work has been completed to the

Figure 1.2.
Example of "Job Complete" form used for insulation. Samples of job ready and job complete checklists are included on pages 1.3 – 1.6.


Job Complete Form

OVERALL JOB RATING - Calificacion General del Trabajo
1 2 3 4 5

TOTAL JOB SCORE - Cuenta Total

Project Documentation

high standard expected and the site supervisor agrees that the work was completed satisfactorily. To verify that the high-performance features of the home were constructed correctly according to the scope of work, performance testing is often part of a job-complete checklist. The job-complete checklist holds both the builder and the trade contractor responsible for proper implementation and appropriate inspection of the scope of work. Properly defined and implemented, the job-complete checklist functions both as a part of the job-ready checklist for subsequent trade contractors and as a field authorization of payment for the completed work.

Related Quality Criteria

See *Criteria* referenced in text above.

Want to Learn More?

Sources for developing quality management programs include:

NAHBRC. 2000. *Quality Assurance System for Wood Framing Contractors: National Quality Housing*. National Association of Home Builders Research Center. www.pathnet.org/si.asp?id=478

NAHBRC 2008. *Scopes of Work for High Performance Homes*. Prepared for the National Renewable Energy Laboratory by the NAHB Research Center, Upper Marlboro, MD.

3D Building Solutions. *High Performance Scopes of Work*. Available at www.3-d-buildingsolutions.com/projects/hp_scopes.htm

IBACOS. *High Performance Scopes of Work*, Prepared for the U.S. Department of Energy. Available at www.ibacos.com/pubs/High_Performance_Scopes.doc

Related Standards & Procedures

ISO 9000, *Quality Management Systems*, www.iso.org

2009 International Energy Conservation Code, Section 103.2 “Information on Construction Documents,” International Code Council (ICC), Falls Church, Virginia. Available for purchase as www.iccsafe.org/dyn/prod/3810S06.html

Building America Best Practices

The U.S. Department of Energy has produced a series of builders guides that provide instructions for construction “best practices” that can help builders achieve high-performance homes. These guides can be found at www.eere.energy.gov/buildings/building_america/

HIGH PERFORMANCE SCOPE OF WORK FOR FRAMING

FRAMING

Job Ready Checklist

Prior to commencement of work, the trade contractor and site supervisor must complete this form together. The trade contractor shall forward the completed checklist to the Builder, the Construction Manager, or other designated representative of the Builder's management team.

Trade	Builder	
❑	❑	Building permit is clearly posted
❑	❑	Readable sign identifying lot number and street address is in place
❑	❑	Full accessibility to the site is established, including gravel pad or clear driveway
❑	❑	Silt fence is in place
❑	❑	Site is clear of debris
❑	❑	Concrete basement, slab, garage and porches are complete
❑	❑	Foundation/slab has been checked for level and square. Any foundation or slab more than ¼ inch out of level must be repaired by concrete contractor before work can continue. (No shimming exceeding ¼ inch is permitted.)
❑	❑	Form boards have been removed
❑	❑	Plans are complete and show critical dimensions. Any red-line changes have been incorporated into a final plan set. Verify that last revision to plans, specs, and options is current
❑	❑	Manufacturer's garage door installation instructions are onsite and available to trade contractor
❑	❑	Placement of sub-slab plumbing or drainage pipes, anchor bolts, and hold down layouts match the plans
❑	❑	Any anchor hold downs mistakenly placed in doorways have been removed without damaging the foundation wall
❑	❑	Temporary electrical service is available
❑	❑	Sewer, water, electrical, and gas laterals are complete
❑	❑	An area has been designated for lumber delivery and stacking
❑	❑	Lumber drop is located so as to be easily accessible to the framer, about 5 to 6 feet from the house foundation, and out of the way of other work in progress
❑	❑	Enough lumber has been delivered for framer to work for at least 1 to 2 days

HIGH PERFORMANCE SCOPE OF WORK FOR FRAMING

Trade	Builder	
❑	❑	Stockpiled lumber and other framing materials are protected from damage, theft, and weather. Top sheets of plywood may be nailed or bundled together to prevent theft
❑	❑	An area designated for trash and debris has been identified
❑	❑	Construction waste management plan has been consulted and proper handling of clean wood waste is known
❑	❑	There is no damage to curb/road or existing foundation/utilities

Incomplete Items	Date Completed

By signing below, builder and trade contractor acknowledge that all above items have been completed and the job is ready to start.

Builder/Superintendent Signature	Date:
Builder Company Name	Date:
Trade Contractor Signature	Date
Trade Contractor Company Name	
Site Address	

HIGH PERFORMANCE SCOPE OF WORK FOR FRAMING

FRAMING
Job Complete Checklist

This list is to be reviewed by the Builder/Superintendent and the Framing Contractor to verify that the job site is ready for Trade Contractor work–subsequent to the Framing Contractor work–to begin.

NOTE: Many if not most of the items called out below would be accomplished by following the plans or the building code. Items are called out in the Job Complete Checklist as further verification of proper completion because many of these items have proven to be problematic and, therefore, require a double check.

Trade	Builder	
❑	❑	All loads are fully transferred to the concrete foundation or basement floor footer pads as indicated on the plans
❑	❑	Any and all basement load bearing walls are located per the plans
❑	❑	Any and all basement load bearing walls have a capillary break, such as rubber membrane, 15# felt, 6-mil poly, between the bottom plate and the concrete slab including wherever vertical studs are in contact with concrete at steps in foundation wall
❑	❑	All piers have proper shimming; i.e., shimming that has at least the compressive strength as the beam bearing on the shim
❑	❑	All headers are sized per the framing plan; i.e., as large as is required for the load but no larger than is required
❑	❑	All headers are at correct height for rough opening
❑	❑	All walls are flush with floor systems at two-story foyers and stairs
❑	❑	The EPA Thermal Bypass Checklist has been completed for the job
❑	❑	All fire stops, particularly at the chimney, have been installed
❑	❑	All garage door openings have double jacks
❑	❑	Any garage stairs are in place and clearance for cars is verified
❑	❑	Shear bracing (structural panels or other techniques as indicated on the plans) is in place and nailed off per the pattern required on the plans
❑	❑	All structural flooring is sufficiently planar to meet the needs of finish flooring with underlayment, particularly at direction changes in the floor framing
❑	❑	All kitchen and bath wall framing is plumb within a 1/8" in 8' tolerance for cabinets
❑	❑	Any kitchen windows are centerlined correctly in terms of subsequent cabinetry and finish plumbing layout
❑	❑	Stairs have finished uniform riser heights, taking into consideration finished treads and flooring

HIGH PERFORMANCE SCOPE OF WORK FOR FRAMING

Trade	Builder	
❑	❑	Stair stringers are fully supported per the plans
❑	❑	Full finished head height at stairs is a minimum of 6'-8"
❑	❑	All capillary breaks called out on the plans have been installed
❑	❑	No unapproved material substitutions have been made in the frame of the building

Incomplete Items	Date Completed

By signing below, builder and trade contractor acknowledge that all above items have been completed and the job is ready to start.

Builder/Superintendent Signature	Date:
Builder Company Name	Date:
Trade Contractor Signature	Date
Trade Contractor Company Name	
Site Address	

2
REQUIRED

Building Envelope Moisture Management – Design Phase

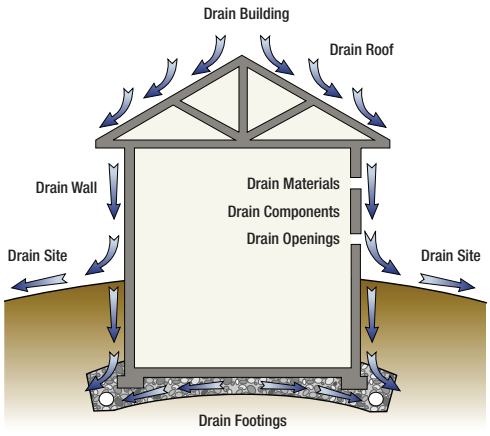
BUILDERS CHALLENGE QUALITY CRITERIA	BUILDER DOCUMENTATION & VERIFICATION REQUIREMENTS	THIRD-PARTY VERIFICATION REQUIREMENTS
2. Building Envelope Moisture Management – Design Phase – Required: In the design phase, include details for integrating the weather barrier system with flashing components in the construction plans. Specify window and door flashing based on the Building America Best Practices (Trades section), or such references as the Water Management Guide (EEBA), the latest version of ASTM E-2112, the AAMA Installation Standard, or manufacturer's recommendations. Provide details to provide adequate site and below-grade drainage, and to prevent moisture from entering the building from below grade by capillary flow. Typically, this would require the builder to specify a foundation drainage system with capillary breaks below the slab, between the footer and foundation, and between the foundation wall and sill plate. Specify climate-appropriate vapor retarder or barrier per locally applicable IECC (reference 2006 IECC, Section 402.5.) When using water absorptive cladding, including brick, stone (real or manufactured), stucco, and fiber cement, provide a pathway for bulk water that enters the wall assembly from the exterior to drain to the exterior. Typically this involves specifying a drainage space or pathway provided by furring strips, an air gap, contoured house wrap, or other products that create a vertical drainage channel behind the cladding and exit the wall horizontally. Cladding installation per manufacturer's recommendations is also permitted.	Develop construction plans with flashing details, foundation details, vapor retarder specification, and drainage space specification (if applicable). Include requirements for flashing, foundation details, and wall system details in contractor's construction/design documentation.	Verify that construction plans contain specifications.

Builders can develop construction plans with flashing details, foundation details, vapor retarder specifications, and drainage space specifications (if applicable). The following flashing, foundation, and wall system details should be included in contractors' construction/design documentation.

Recommended Excavation, Grading, and Landscaping Measures

- Maintain a surface grade of at least 5% (½ inch per foot) for at least 10 feet around and away from the entire structure.
- Slope driveways, garage slabs, patios, stoops, and walkways a minimum of ¼ inch per foot away from the structure.
- Position irrigation systems so that sprinklers do not spray walls, foundations, or the ground near the foundations.
- Plantings should be 18 to 36 inches away from the foundation.
- Choose drought-tolerant plants near the house to minimize irrigation.
- Decorative ground cover, such as mulch or pea stone, should be no more than 2 inches thick in the first 18 inches from the house.

Figure 2.1. Optimal drainage patterns



Adapted from Lstiburek 2003

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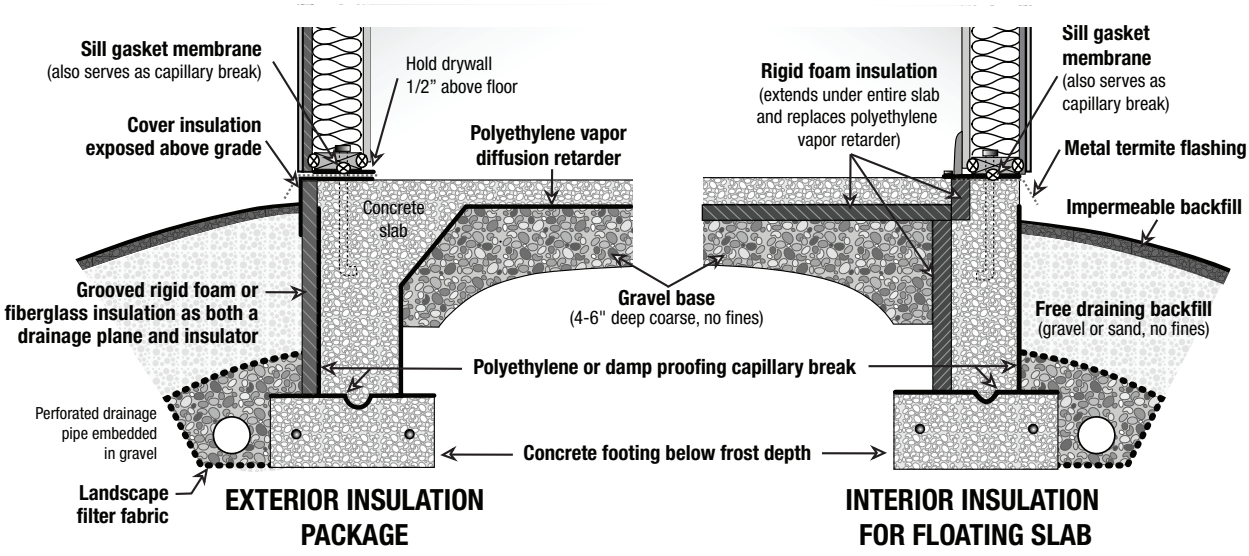
Building Envelope Moisture Management – Design Phase

Figure 2.2. Examples of slab insulation and moisture management.



Foundation Systems

- Moisture control practices are especially important wherever building components touch the ground. Liquid can wick from the ground and be carried into building assemblies through capillary flow.
- Specify and show in details that 6-ml polyethylene sheeting is to be placed directly beneath concrete slabs. The sheeting should continuously wrap the slab as well as footings up to grade. Seams in the sheathing should be overlapped 6 to 12 inches.
- Place a 4-inch-deep, ¾-inch gravel bed directly beneath the polyethylene sheeting to act as a capillary break and drainage pad.
- Do not place a sand layer between the vapor retarder and the concrete slab. Differential drying and cracking is better handled with a low water-to-concrete ratio and wetted burlap covering during initial curing.
- Specify that footings poured independent of slabs or foundation walls are to be treated with a bituminous damp-proof coating, masonry capillary-break paint, or a layer of 6-ml polyethylene sheeting to isolate the footing from the remainder of the assembly.
- Place a continuous drainage plane over the damp proofing or exterior insulation on foundation walls to channel water to the foundation drain and relieve hydrostatic pressure. Drainage plane materials include washed gravel, sand, special mats, high-density fiberglass insulation, dimpled sheets, and grooved rigid insulation. Protect foundation drains and gravel drainage backfill with geotextile landscape filter fabric to prevent dirt from clogging the drainage channels.
- Exterior foundation wall insulation requires a protective coating at above-grade applications. Examples of protective coverings for exterior, above-grade insulation include flashing, fiber-cement board, parging (stucco type material), treated plywood, or membrane material (EPDM - ethylene propylene diene terpolymer flexible roofing).

Figure 2.3. This appraoch uses a dimpled-plastic drainage plane and damp proofing on the wall. Landscape filter fabric, horizontal to the foundation, keeps soil from clogging the gravel around the perforated drainage pipe. A gasket blocks moisture from enterring the treated sill plate.

Figure 2.4. Example of damp proofing and exterior insulation below grade

Building Envelope Moisture Management – Design Phase

- Damp proof the exposed portion of the foundation with latex paint or other sealants.
- Use a sill gasket for air sealing and to block wicking.
- Install a protective shield such as metal flashing, a plastic L bracket, or a membrane to block capillary water wicking into the wall from the foundation. This material can also serve as a termite shield.
- Design the house structure with overhangs, gutters, drainage planes, and flashing to shed rainwater and conduct it away from the house.
- Because of it's fire rating, exposure rated foil-faced polyisocyanurate insulation can be installed uncovered on the interior of basement walls but should terminate at least 6 inches above the slab floor to allow for moisture dissipation. Expanded and extruded polystyrene used on interior basement walls must be covered with 0.5 inch gypsum board for thermal protection. This gypsum board should be held 0.5 inches above the slab to help prevent wetting from small leaks. Seams on all rigid foams should be sealed with foil tape or fiberglass web tape and mastic.

Walls

Rainwater management is provided by using a weather-resistive barrier behind the cladding as a drainage plane and integrating this with flashing and sheathing to provide drainage plane continuity. A graphic guide to installing house wrap is included at the end of this information.

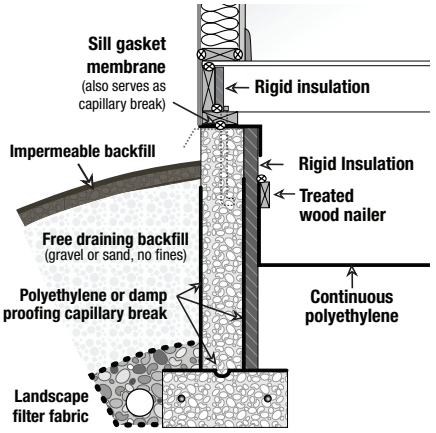
BE CAREFUL WITH VAPOR BARRIERS

Walls must be able to dry to at least one surface, the inside or the outside, or to both surfaces. The placement of a vapor barrier (such as polyethylene plastic sheeting, foil or kraft-faced batt insulation, reflective radiant-barrier foil insulation, etc) should be in a location to facilitate drying to the proper surface. Generally speaking, vapor barriers should be installed on the interior side of walls in cold climates; on the exterior side of walls in hot climates; and eliminated in mixed climates. Do not specify impermeable coverings, such as vinyl wallpaper, on interior walls.

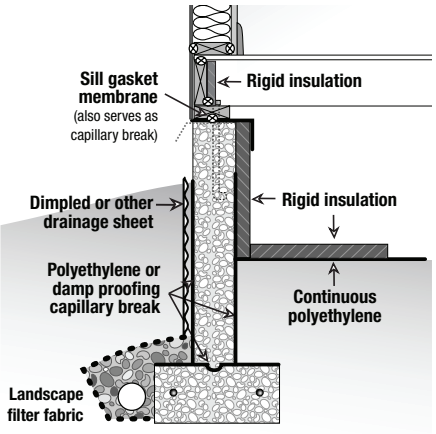
The 2006 International Energy Conservation Code provides the following guidance on installing vapor barriers. According to Section 402.5 "Moisture Control (Mandatory)," above-grade frame walls, floors, and ceilings that are not ventilated to allow moisture to escape should have a vapor retarder that is applied on the warm-in-winter side of the thermal insulation. The IECC includes some exceptions to this requirement: for instance if the wall is located where moisture and freezing won't damage the materials; if the house is located in climate zones 1 through 4 (see *Criteria 7* for a map of climate zones); or if some other method for avoiding condensation is used. Vapor barrier requirements will be incorporated into the 2009 International Residential Code, which was unavailable at the time of publication of this document. Crawl space floor vapor retarders are always required over soil.

Figure 2.5. Examples of damp proofing, interior insulation below grade, and drainage options.

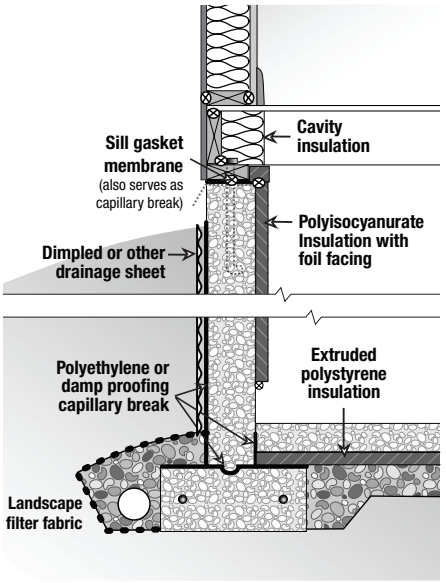
INTERIOR CRAWLSPACE INSULATION



If depth does not extend two feet below grade, place remaining insulation horizontally along the ground.



INTERIOR BASEMENT INSULATION



Building Envelope Moisture Management – Design Phase

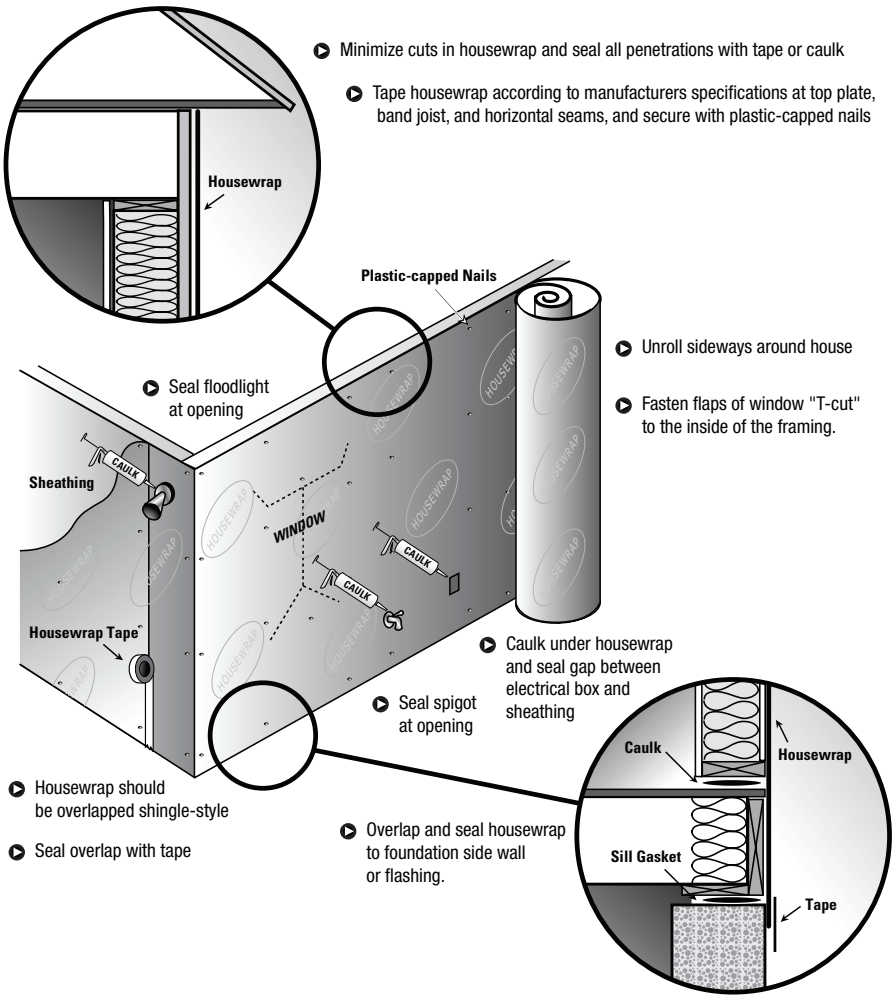
HOUSE WRAP AND DRAINAGE SPACES

Specify and show in elevations building paper, house wrap, or taped insulated sheathing (rigid foam insulation) behind the exterior cladding to serve as a drainage plane. This drainage plane can also serve as an exterior air barrier.

House wrap, building paper, or impregnated felt should be part of the exterior wall system that protects the building from water penetration. A water resistant barrier over studs or sheathing is a code requirement (2006 IRC, section 703.2). None of the materials are waterproof, but they are intended to shed rainwater that penetrates exterior cladding. The surface formed by these materials is called a drainage plane, house membrane, or rain barrier. It's used to shed liquid water that may penetrate siding or roofing and to prevent liquid water from wicking through, while remaining sufficiently vapor permeable ("breathable") for outward drying (Straube 2001). By helping to keep building materials dry, these membranes improve building durability, decrease maintenance costs, and reduce the risk of moisture-related problems such as pests, mold, and rot.

Most building paper is UV-resistant, whereas recommended house wrap exposure limits may vary by manufacturer. Check with manufacturers if outdoor exposure will exceed a month. One person can usually install building paper, while house wrap requires two people. However, house wrap is available in wide sheets that can cover an entire one-story wall surface in a single pass.

Figure 2.6. Example of housewrap strategies



Want to Learn More?

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IBACOS. 2002. "Moisture Issues in Homes with Brick Veneer" article available at www.eere.energy.gov/buildings/building_america/pdfs/db/36397.pdf

Building Science Corporation. Homeowner Information Resources. Available at www.buildingscienceconsulting.com/resources/homeowner.htm

HGTVpro.com. Improved Stucco Systems. Article available at www.hgtvpro.com/hpro/bp_exterior_finishes/article/0,,hpro_20149_4243887,00.html

"House wrap Felt or Paper: Comparing specs on weather barriers," *Buildernews Magazine*, May 2004, www.buildernewsmag.com/viewnews.pl?id=21

U.S. Environmental Protection Agency. 2007. *ENERGY STAR Indoor Air Package Specifications*, version 2, April 19, 2007, available at www.energystar.gov/index.cfm?c=bldrs_lenders_raters.nh_iap

Aldrich, Robb and Marc Zuluaga. 2006 "The Challenge of Basement Insulation," *Home Energy* Jan/Feb 2006.

Zuluanga, Marc. 2006. "Brainy Membrane," *Home Energy* July/Aug 2006.

Building Envelope Moisture Management – Design Phase

During construction and operation it is important that house wraps remain clean. Surface contaminants interfere with the wrap's ability to hold out water. Once wetting of the house wrap or building paper surface occurs, material pores in the house wrap or building paper become filled allowing transport of liquid phase water across the house wrap or building paper via capillarity or hydrostatic pressure (gravity).

Some cladding can contaminate wraps if the two are in direct contact. For example, water-soluble extractives in wood, such as tannins and wood sugars in redwood and cedar, can contaminate the surface of house wraps and building papers. Back-priming or back-coating wood clapboards and trim helps to isolate the surfactants in the wood from the house wrap or building paper surface. Back-priming is also recommended on all wood and cementatious cladding systems to avoid water uptake and possible warping.

Stucco should never be installed in direct contact with any of the plastic-based house wraps. A drainage space between stucco and plastic house wraps is essential to control liquid phase water penetration. Two layers of building paper behind stucco are needed for drainage.

If building paper is used as a drainage plane behind any cladding in areas prone to severe storms, use two layers to increase resistance to leakage at fasteners and allow for more flexible installation.

Use spacer strips (1x4 furring strips) to create a ¾-inch air space to act as a drainage gap behind cladding. Drainage gaps can help stop some materials from contaminating house wraps. Gaps are also important in some wall assemblies to control vapor. Brick cladding must have a drainage space. Bricks and other masonry absorb liquid water from rain and irrigation. Solar energy will then drive this moisture in the form of vapor into the wall assembly. The gap allows the vapor to dissipate before entering wall cavities.

SEALING

Tightly seal wall assemblies to avoid vapor movement into walls through infiltration. Air sealing is described in greater detail in ***Criteria 16***.

WINDOWS

One critical point of concern is water leakage around windows. Window flashing is a code requirement, (2006 IRC, Section 703.8) but durability and performance are products of careful installation and compliance with standards. The *EEBA Water Management Guide* offers examples of many window flashing applications. The window flashing examples included on the following page (p.2.5) are for homes with house wrap and plywood or OSB sheathing. Window and door flashing details should be designed to match specific wall assemblies and claddings. Flashing systems should be designed in accordance with the ASTM standard entitled *Standard Practice for Installation of Exterior Windows, Doors, and Skylights* (ASTM 2007).

Related Quality Criteria

See ***Criteria*** referenced in text above.

Related Standards & Procedures

FMA/AAMA 100-07. "Standard Practice for the Installation of Windows with Flanges or Mounting Fins in Wood Frame Construction." Available from AAMA's online store at www.aamanetstore.org/pubstore/ProductResults.asp

ASTM E-2112-07. "Standard Practice for Installation of Exterior Windows, Doors and Skylights." Available from ASTM at www.astm.org/Standards/E2112.htm

2006 International Energy Conservation Code, International Code Council (ICC), Falls Church, Virginia. Available for purchase at www.iccsafe.org/dyn/prod/3810S06.html. 2006 International Residential Code, available for purchase at www.iccsafe.org.

ASTM E 2266 "Standard Guide for Design and Construction of Low-Rise Frame Building Wall Systems to Resist Water Intrusion." Available for purchase at www.astm.org/Standards/E2266.htm

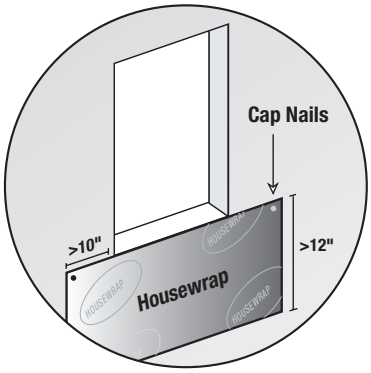
Building America Best Practices

The U.S. Department of Energy has produced a series of builders guides that provide instructions for construction "best practices" that can help builders achieve high-performance homes. These guides can be found at www.eere.energy.gov/buildings/building_america/

Building Envelope Moisture Management – Design Phase

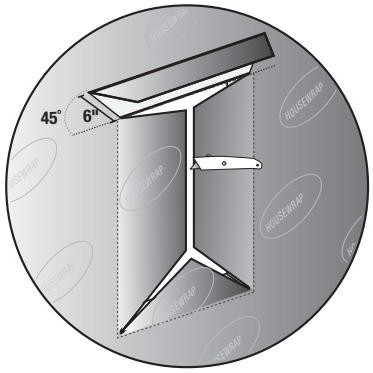
Figure 2.7. Window Flashing prevents leakage around windows

STEP 1 - If Housewrap Has **Not** Been Installed



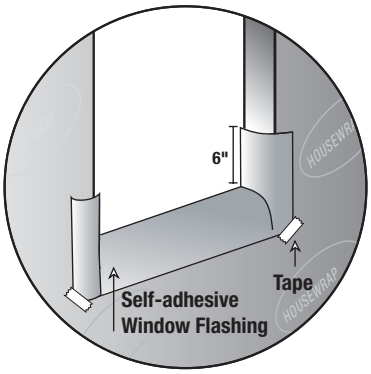
- Apply at least a 12-inch flap, or apron, of building paper or housewrap just below the windows sill.
- If the window sill is close to the sill plate, the apron can extend all the way to the sill plate.
- The apron should extend at least 10 inches past the sides of the window opening, or to the first stud in open wall construction.
- Attach only the apron's top edge with cap nails.

STEP 1 - If Housewrap Has Been Installed



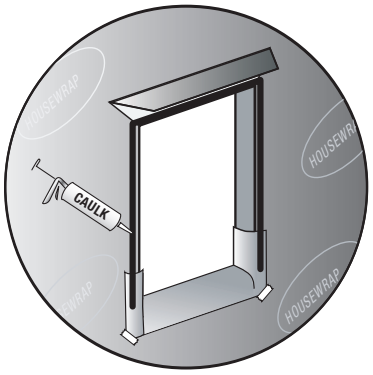
- Cut the housewrap covering the rough opening in the shape of a modified "Y."
- Fold the side and bottom flaps into the window opening and secure.
- Above the window opening, cut a head flap and flip up to expose sheathing, and loosely tape in place out of the way.

STEP 2 - Sill Flashing



- Install self-adhesive flashing to the sill, ensuring that flashing extends up jambs at least 6 inches.
- One commercial product comes with two removable strips over the adhesive. Remove the first strip to expose half the adhesive and apply this area to the sill. Begin pressing in the middle of the sill and work towards the sides. Remove the second strip to expose the adhesive that will be used to apply the flashing below the window to the outside wall.
- Tape down the bottom corners of the flashing

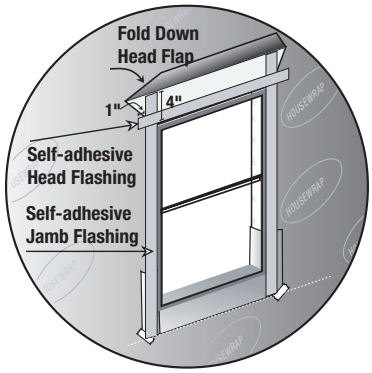
STEP 3 - Jamb Caulking



- Caulk the outside edges of the head and side jambs
- Do not caulk across the sill
- Install the window using corrosion-resistant nails and following manufacturer's specifications.

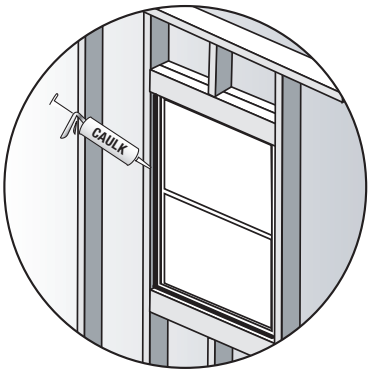
Figure 2.7. Window Flashing prevents leakage around windows, *Continued*

STEP 4 - Jamb and Head Flashing



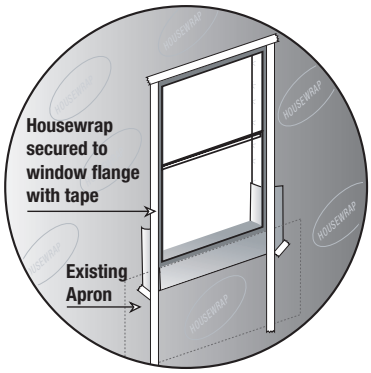
- Install self-adhesive jamb flashing extending 4 inches above the top of the head flange and even with the bottom of the sill flashing.
- Install self-adhesive head flashing extending 1 inch beyond the jamb flashing.
- If housewrap has been installed, be sure that the head flap, when it is folded down, will cover the top of the flashing.

STEP 5 - Seal Rough Opening Gap



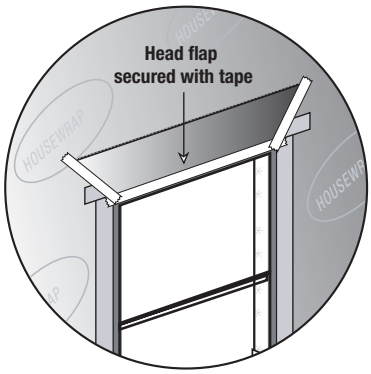
- On the interior side of the window, seal gap between the window and the rough opening with appropriate sealant.

STEP 6 - If Apron was Installed



- If an apron was installed under the window, slip the housewrap or building paper under the apron.
- Tape the edges where the housewrap meets the window flange if housewrap is installed after flashing.
- If building paper is used, embed the edges in a bead of sealant where the paper meets the window flange.

STEP 6 - If Head Flap was Created



- If headflap was created, fold it over the head flashing and tape across the top window flange and the 45º angle seams.

3
RECOMMENDED

Material-Efficient Framing

BUILDERS CHALLENGE QUALITY CRITERIA	BUILDER DOCUMENTATION & VERIFICATION REQUIREMENTS	THIRD-PARTY VERIFICATION REQUIREMENTS
3. Material-Efficient Framing – Recommended: Design building dimensions and layouts to minimize material cuts and waste for wall, floor, and roof system structural components and sheathing. Size all headers for actual structural loads and insulate to the fullest extent possible. To the extent possible, use building systems which minimize on-site waste, such as panelized walls, pre-cut framing packages, and engineered wood products. Incorporate these measures in the framing layout plan.	Develop framing layout plan and keep in project records.	

Optimal value engineering or advanced framing refers to framing techniques that require less lumber than standard framing practices but provide all the needed structural strength. These strategies require simple modifications to framing practices. By using less framing material, these strategies make room for more insulation to be installed while saving resources and reducing waste. This recommendation applies to standard framing using dimensional lumber. However other techniques, not explored here, such as structural insulated panels or steel framing, could also possibly be used to build more efficient frames.

Figure 3.1. Attic trusses aligned with 24-inch wall framing creates more space for insulation and reduces framing material cost and waste. *(photo courtesy of Artistic Homes)*

Designers take note that construction documents should include a detailed framing plan that illustrates where framing members are to be placed and the type of corners, window jacks, header size and type, and other features to be incorporated. Examples of advanced framing techniques include:

- **Two-foot module design:** Starting with the foundation, the house footprint should be based on 2-foot increments; this can result in significant savings in both framing members and sheathing, with a lot less waste. Sheet goods come in 4 ft by 8 ft dimensions. Layouts should be based on the fundamental unit dimensions of the materials used.

Material-Efficient Framing

- **Frame 24-inch on center:** Current practice is to frame walls, floors, and often roofs at 16-inch on center. However, 24-inch on center are structurally adequate for most residential applications. Even when the stud size must be increased from 2x4 to 2x6, changing spacing from 16 to 24 inch can significantly reduce the amount of framing lumber needed.
- **Align framing members and use a single top plate:** Double top plates are used to distribute loads from framing members that are not aligned above studs and joists. By aligning framing members vertically throughout the structure, the second plate can be eliminated. Plate sections are cleated together using flat plate connectors. For multi-story homes that are framed with 2x4s, this may increase the stud size on lower floors to 2x6; however, there is still typically a net decrease in lumber used.
- **Size headers for actual loading conditions:** Headers are often oversized for the structural work that they do – doubled-up 2x6 (or 4x6) headers end up in non-load-bearing walls; doubled-up 2x12 (or 4x12) headers end up in all-load-bearing walls, regardless of specific loading conditions. Nonbearing walls do not need structural headers. Proper sizing may allow for the use of insulated headers in which foam insulation is sandwiched between lumber.
- **Ladder-block exterior wall intersections.** Where interior partitions intersect exterior walls, three-stud "partition post" or stud-block-stud configurations are typically inserted. Except where expressly engineered, these are unnecessary. Partitions can be nailed either directly to a single exterior wall stud or to flat blocks inserted between studs. This technique is called "ladder blocking" or "ladder framing." This also creates room for more insulation.
- **Use two-stud corners.** Exterior wall corners are typically framed with three studs. The third stud generally only provides a nailing edge for interior gypsum board and can be eliminated. Drywall clips, a 1x nailer strip, or a recycled plastic nailing strip can be used instead. Using drywall clips also reduces opportunities for drywall cracking and nail popping, frequent causes of builder callbacks.
- **Eliminate redundant floor joists.** Double floor joists are often installed unnecessarily below non-load-bearing partitions. Nailing directly to the sub-floor provides adequate attachment and support. Partitions parallel to overhead floor or roof framing can be attached to 2x3 or 2x4 flat blocking.
- **Use 2x3s for partitions.** Interior, non-load-bearing partition walls can be framed with 2x3 (51mm x 76mm) studs at 24-inch on center or 2x4 "flat studs" at 16-inch on center (2009 IRC, section R602.5).

Want to Learn More?

NAHB Resource Center. "Advanced Framing Techniques: Optimum Value Engineering (OVE)," Available at www.toolbase.org/Construction-Methods/Wood-Framing/advance-framing-techniques, accessed 6-4-08.

IBACOS. 2003. "Best Practices: Optimum Value Engineering." Available on the Building America website at www.eere.energy.gov/buildings/building_america/pdfs/db/35380.pdf accessed 6-4-08.

Natural Resources Defense Council. 1998. Efficient Use of Wood in Residential Construction. Washington, DC. www.nrdc.org/cities/building/rwoodus.asp.

Lstiburek, Joseph, "The Future of Framing Is Here," *Fine Homebuilding*, November 2005, No. 174, p. 50-55.

U.S. DOE. 2002. "Advanced Wall Framing," 6-page fact sheet by the U.S. Department of Energy www.nrel.gov/docs/fy01osti/26449.pdf.

National Home Builders Association (NAHB) Green Building Program website: nahbgreen.org

U.S. Green Building Council LEED for Homes website: www.usgbc.org/LEED/homes/

Related Standards & Procedures

2006 International Residential Code, International Code Council (ICC), Falls Church, Virginia. Available for purchase at www.iccsafe.org/dyn/prod/3110S061.html

2009 International Residential Code, section R602.5, "Interior non-bearing walls." International Code Council (ICC), Falls Church, Virginia. Available for purchase at www.iccsafe.org/e/prodshow.html?prodid=3100L09

Building America Best Practices

The U.S. Department of Energy has produced a series of builders guides that provide instructions for construction "best practices" that can help builders achieve high-performance homes. These guides can be found at www.eere.energy.gov/buildings/building_america/

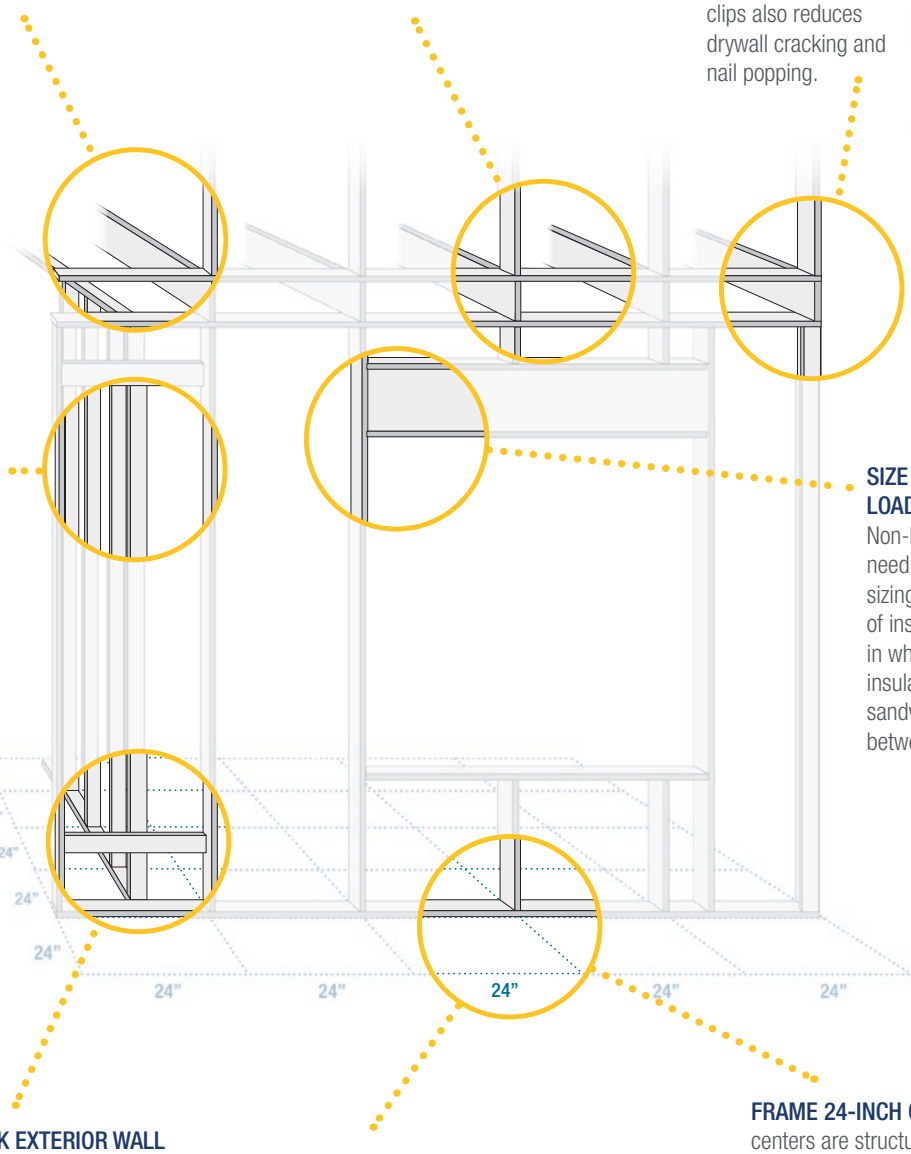
Material-Efficient Framing

Figure 3.2. Advanced framing techniques can reduce lumber costs while providing more space for insulation

ELIMINATE REDUNDANT FLOOR JOISTS: Nailing directly to the sub-floor provides adequate attachment and support below non-load-bearing partitions.

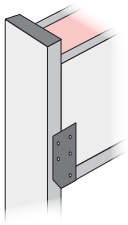
ALIGN FRAMING MEMBERS AND USE A SINGLE TOP PLATE: Plate sections are cleated together using flat plate connectors. For multistory homes, this may increase the stud size on lower floors to 2x6.

USE TWO-STUD CORNERS: Rather than using a third stud as a nailing edge for interior gypsum board, use drywall clips, a 1x nailer strip, or a recycled plastic nailing strip. Using drywall clips also reduces drywall cracking and nail popping.



USE 2X3s FOR PARTITIONS: Interior, non-load-bearing partition walls can be framed with 2x3s at 24-inch on center or 2x4 "flat studs" at 16-inch on center.

SIZE HEADERS FOR ACTUAL LOADING CONDITIONS: Non-load-bearing walls do not need structural headers. Proper sizing may allow for the use of insulated headers in which foam insulation is sandwiched between lumber.

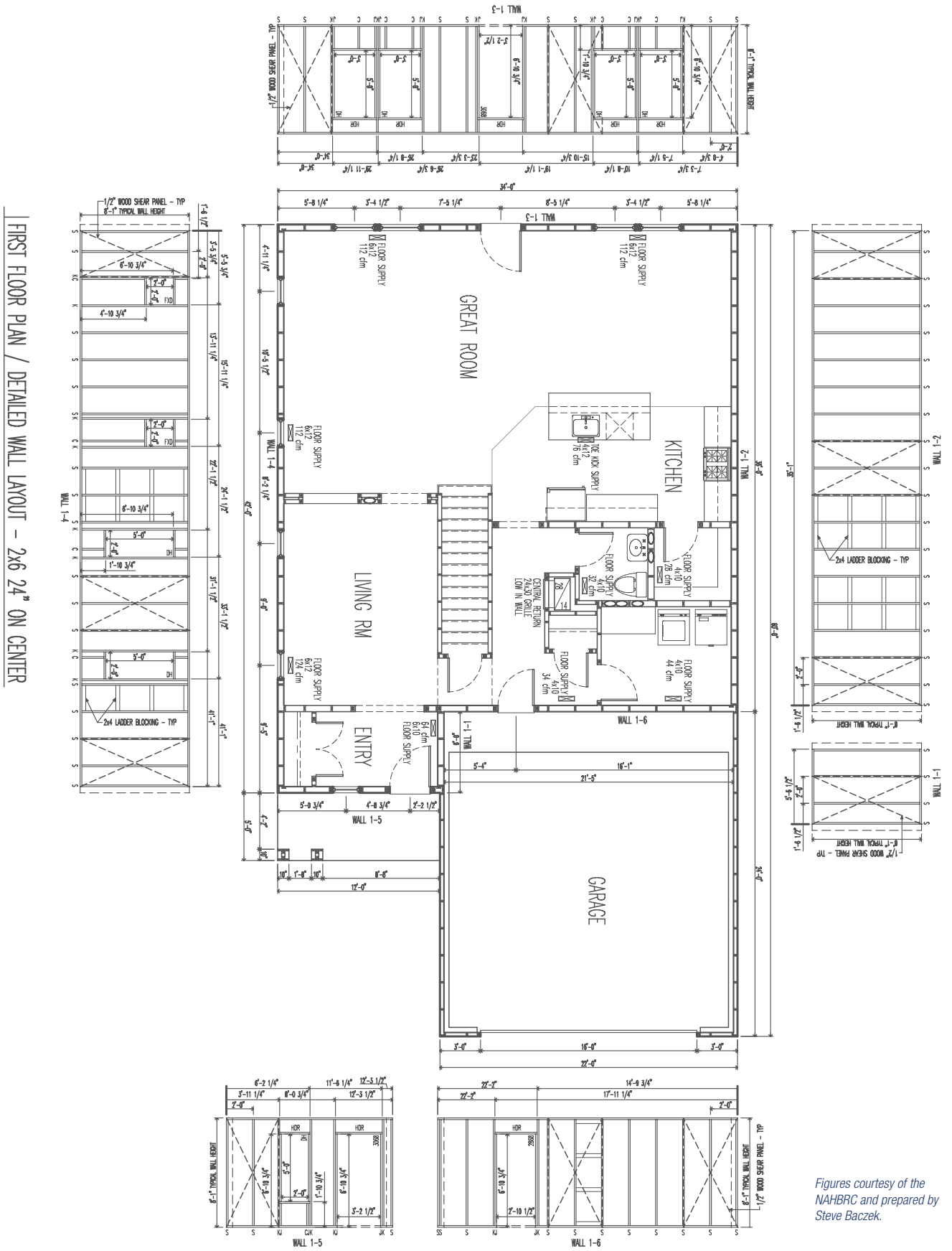


LADDER-BLOCK EXTERIOR WALL INTERSECTIONS: Partitions can be nailed either directly to a single exterior wall stud or to flat blocks inserted between studs.

TWO-FOOT MODULE DESIGN: Starting with the foundation, the house footprint should be based on 2-foot increments. Layouts should be based on the fundamental unit dimensions of the materials used.

FRAME 24-INCH ON CENTER: 24-inch centers are structurally adequate for most residential applications. Even when the stud size must be increased from 2x4 to 2x6, 24-inch spacing can reduce framing lumber needs significantly.

Figure 3.3. Detailed wall framing layout example



Figures courtesy of the NAHBRC and prepared by Steve Baczek.

4
RECOMMENDED

Construction Waste Management

BUILDERS CHALLENGE QUALITY CRITERIA	BUILDER DOCUMENTATION & VERIFICATION REQUIREMENTS	THIRD-PARTY VERIFICATION REQUIREMENTS
4. Construction Waste Management – Recommended: Develop, post at the jobsite, and implement a Construction Waste Management Plan. The plan should document the diversion pathways for major waste stream components including cardboard, lumber, land-clearing debris, and drywall. The plan should also document efforts to request minimized packaging from suppliers. Goals for waste diversion should be at least 25% (by weight) for construction and land-clearing waste.	Develop Construction Waste Management Plan and keep in project records.	

The National Association of Home Builders Research Center's "Residential Construction Waste Management: A Builder's Field Guide" recommends that a waste management plan include details on waste reduction, contract structure (who will haul construction waste—the builder or subcontractors), and waste recycling responsibilities.

NAHB's Model Green Home Building Guidelines include points for the following: 1) posting the construction waste management plan at the jobsite, 2) recycling construction waste on-site, e.g., grinding or shredding for use on site to reduce transportation-related costs, 3) recycling offsite, e.g., sorting and hauling wood, cardboard, metals, drywall, plastics, asphalt roofing shingles, concrete, etc., and 4) providing on-site bins for sorting scrap building materials for recycle or reuse.

Want to Learn More?

Information on developing a Construction Waste Management Plan is available in the NAHB Research Center's "Residential Construction Waste Management: A Builder's Field Guide" Available at www.toolbase.org/PDF/BestPractices/wastemngmnt_buildersguide.pdf accessed 6-4-08

NAHB's Model Green Home Building Guidelines, available at www.nahb.org/publication_details.aspx?publicationID=1994&SectionID-155

LEED for Homes MR3: Waste Management, www.greenhomeguide.org/documents/leed_for_homes_rating_system.pdf, page 83

Local and state organizations sponsor green building programs and can help with construction waste management tips. Examples of these programs are listed in the Building America Best Practices and Builders Challenge Guides.

National Home Builders Association (NAHB) Green Building Program website: nahbgreen.org

U.S. Green Building Council LEED for Homes website: www.usgbc.org/LEED/homes/

Related Standards & Procedures

LEED for Homes and NAHB criteria are referenced above.

Building America Best Practices

The U.S. Department of Energy has produced a series of builders guides that provide instructions for construction "best practices" that can help builders achieve high-performance homes. These guides can be found at www.eere.energy.gov/buildings/building_america/

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5 REQUIRED

Space Conditioning Design

BUILDERS CHALLENGE QUALITY CRITERIA	BUILDER DOCUMENTATION & VERIFICATION REQUIREMENTS	THIRD-PARTY VERIFICATION REQUIREMENTS
5. Space Conditioning Design – Required: Right-size space conditioning system for heating/cooling loads based on ACCA Manual J Version 8 or comparable load sizing analysis (reference IRC M1401.3, 2006 IECC Section 403.6). The maximum over-sizing limit for cooling equipment is 15%, with the exception of heat pumps in Climate Zones 5-8 where the maximum over-sizing limit is 25%. Outdoor temperatures shall be the 99.0% design temperatures as published in the ASHRAE Handbook of Fundamentals for the home's location or most representative city for which design temperature data are available. Note that a higher outdoor air design temperature may be used if it represents prevailing local practice by the HVAC industry and reflects extreme climate conditions that can be documented with recorded weather data; Indoor temperatures shall be 75°F for cooling; Infiltration rate shall be selected as "tight", or the equivalent term. In specifying equipment, the next available size may be used. In addition, indoor and outdoor coils shall be matched in accordance with AHRI standards. Identify the whole building ventilation strategy and equipment in the mechanical system design (see the two other Quality Criteria: Whole Building Ventilation I and II for requirements).	Analyze load-sizing and duct-sizing and keep in project records.	Review the load-sizing and duct-sizing analyses to ensure that sizing criteria stated in the requirements were used for the home.

A well-designed house should have an HVAC system properly sized to its demands. Equipment sizing ensures a comfortable environment and provides opportunities to recapture some of the expense of constructing an efficient building envelope. Rules of thumb for equipment sizing do not work in modern homes and should not be used.

The Air Conditioning Contractors of America (ACCA) has published simple but effective methods for determining loads and sizing ductwork and heating and cooling equipment. *Manual J* tells you how to calculate heating and cooling loads. *Manual D* tells you

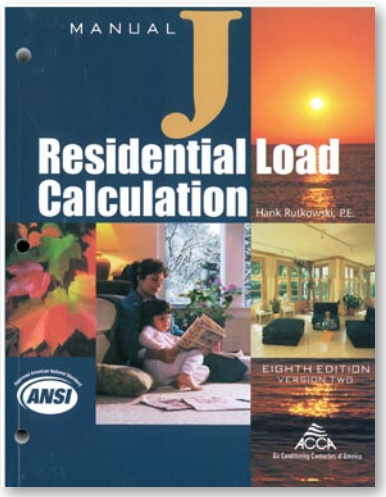

Figure 5.1. Right sizing of HVAC equipment using *Manual J* calculations can minimize energy use and save upfront costs

Building America U.S. Department of Energy Research Toward Zero Energy Homes | Builders Challenge Recognizing Energy Leadership in Homebuilding

Space Conditioning Design

how to size ducts. Manual S guides you through the selection of appropriate heating and cooling equipment to meet identified loads. Manual T gives you air distribution basics for small buildings.

Related Quality Criteria

See guidance and references for ***Criteria 6. Space Conditioning Design***.

Want to Learn More?

Air Conditioning Contractors of America (ACCA). Descriptions of Manuals D, J, and S, available at www.socalgas.com/construction/builders/Builders%20Resource%20Guide/Air%20Conditioning%20Contractors%20of%20America.htm. For more information or to purchase these documents, go to www.acca.org

Air-conditioning Heating and Refrigeration Institute (AHRI). Directory of Certified Product Performance. www.ahridirectory.org/trustedsource/

DOE. "Right-Size Heating and Cooling Equipment," U.S. Department of Energy Technology Fact Sheet, available at www.toolbase.org/PDF/DesignGuides/doe_hvacsizing.pdf

DOE Building Energy Codes Resource Center. "How to Size HVAC Systems Correctly," Article available at http://resourcecenter.pnl.gov/cocoon/morf/ResourceCenter/article/137

Related Standards & Procedures

Air Conditioning Contractors of America. *Manual J, Version 8*, ACCA, Arlington, VA, available for purchase at www.acca.org/store/product.php?pid=30

American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE). 2005. *ASHRAE Handbook of Fundamentals*. Available at www.ashrae.org/publications/page/158

2006 International Residential Code, International Code Council (ICC), Falls Church, Virginia. Available for purchase at www.iccsafe.org/dyn/prod/3110S061.html

2006 International Energy Conservation Code, Section 403.6, International Code Council (ICC), Falls Church, Virginia. Available for purchase at www.iccsafe.org/dyn/prod/3810S06.html

Consortium for Energy Efficiency. *Residential HVAC: CEE-AHRI HVAC Directory*. Available at www.cee1.org/resid/rs-ac/rs-ac-main.php3

The Building Industry Institute. *Procedures for HVAC System Installation*. Available at www.thebii.org/hvac.pdf

U.S. Environmental Protection Agency. 2007. *ENERGY STAR Indoor Air Package Specifications*, version 2, April 19, 2007, available at www.energystar.gov/index.cfm?c=bldrs_lenders_raters.nh_iap

Building America Best Practices

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6
RECOMMENDED

Space Conditioning Design

BUILDERS CHALLENGE QUALITY CRITERIA	BUILDER DOCUMENTATION & VERIFICATION REQUIREMENTS	THIRD-PARTY VERIFICATION REQUIREMENTS
6. Space Conditioning Design – Recommended: Design and install duct system(s) using ACCA Manual D or equivalent. Integrate HVAC duct layout with construction documentation. Select heating/cooling equipment using ACCA Manual S or equivalent.		

Duct layout and air handler location should be shown on construction drawings. Ducts and air handlers should be placed in conditioned spaces whenever possible, either in the living space, in an insulated and sealed crawlspace or attic, or in a sealed conditioned closet in the garage. As an alternative to placing ductwork in conditioned space, Building America research has shown that in the hot-dry and mixed-dry climates, burying attic ducts in insulation is acceptable. California code (Title 24) includes provisions for this approach and does not restrict the use of buried ducts in that state's climate. Burying ducts in insulation is not recommended in areas of high humidity, because cool air flowing through the ducts can cause condensation to form on duct surfaces in hot unconditioned attics and crawlspaces. See ***Criteria 15*** for more information.

Make Duct Runs As Short As Possible

An efficient building envelope and efficient HVAC equipment allow for a compact air distribution system. Conditioned air may be discharged from inside walls or from ceiling diffusers up to 12 feet from the window wall in most cases without compromising comfort. Such "inside throw" layouts cut ductwork runs, saving money and reducing the amount of ductwork that may run in unconditioned space.

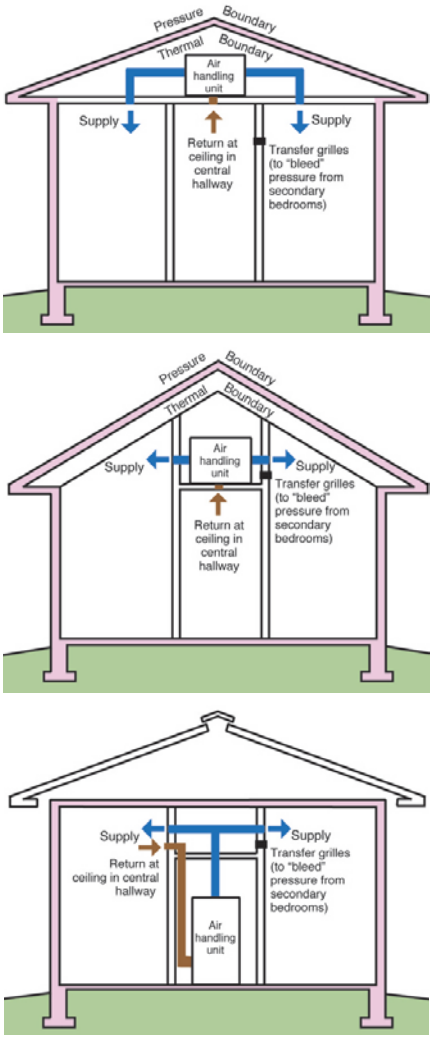
Integrate Duct Layout with Construction Documentation

Clearly identify on plans and drawings the locations, sizes, and types for all duct work and registers, including the heating and cooling supply ducts, passive return air ducts or transfers, the locations for the mechanical ventilation air inlet (at least 8 feet away from any exhausts or condensers), and all exhaust outlets. If chases or other spaces are to be dedicated to duct runs, indicate this on the plans.

Related Quality Criteria

See guidance and references for ***Criteria 5. Space Conditioning Design*** and ***Criteria 15. Duct Leakage***, and ***Criteria 26. Pressure Balancing***.

Figure 6.1. Duct Run Configurations

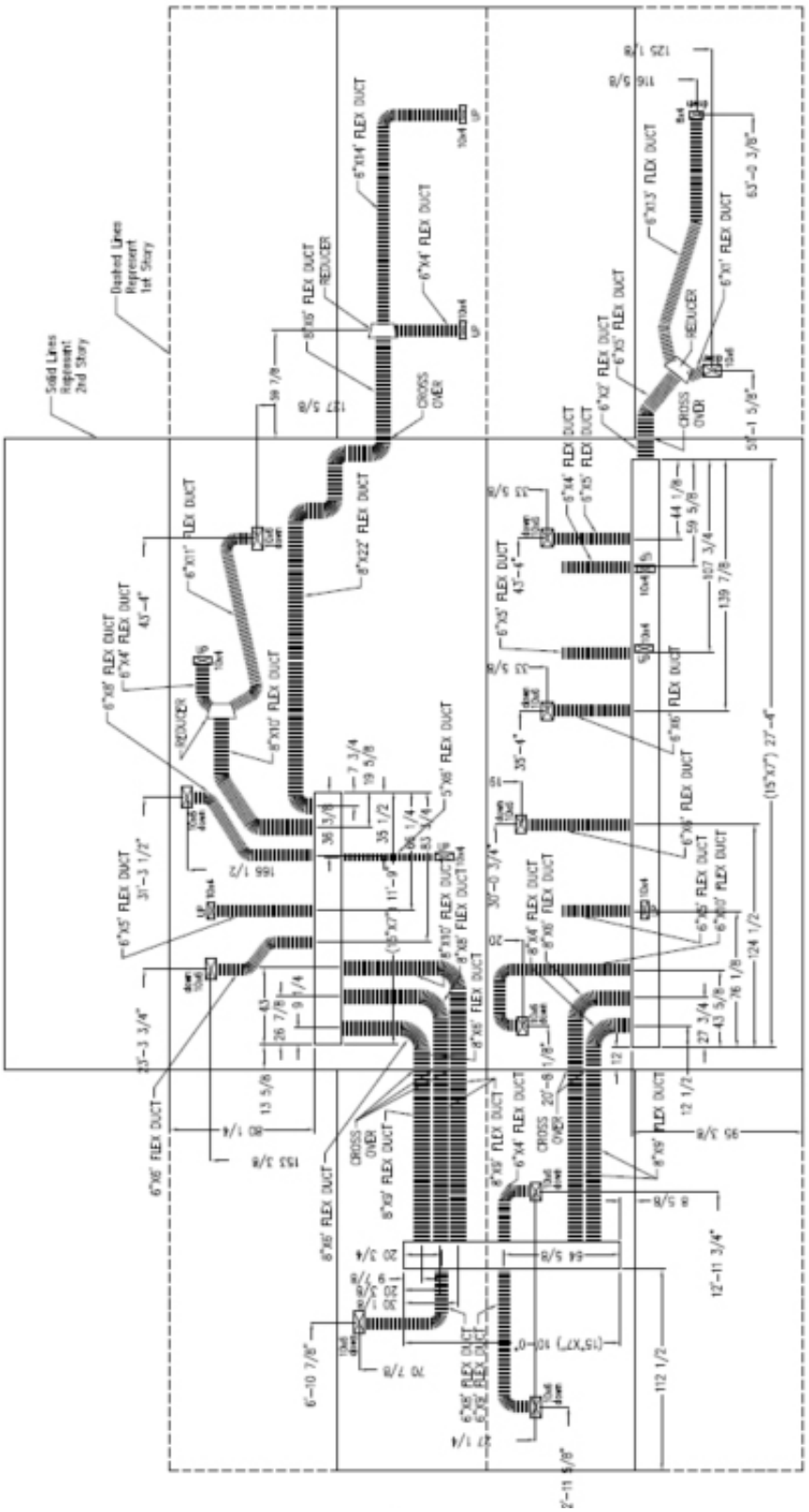


Source: Building Science Corporation

Building America U.S. Department of Energy Research Toward Zero Energy Homes | Builders Challenge Recognizing Energy Leadership in Homebuilding

Space Conditioning Design

Figure 6.2. Thoughtful duct design that includes shorter duct runs and properly sealed ducts in conditioned space can greatly improve energy savings. Show duct sizing and layout on construction documents.



Want to Learn More?

Air Conditioning Contractors of America (ACCA). Descriptions of Manuals D, J, and S, available at www.socalgas.com/construction/builders/Builders%20Resource%20Guide/Air%20Conditioning%20Contractors%20of%20America.htm

California Energy Commission. *2005 Building Energy Efficiency Standards Residential Compliance Manual*, CEC-400-2005-005-CMF, published: April 2005, Third Quarter Revision October 21, 2005, Fourth Quarter Revision May 26, 2006. Available at www.energy.ca.gov/title24/2005standards/residential_manual.html

Related Standards & Procedures

Air Conditioning Contractors of America (ACCA). *Manual D: Residential Duct Systems*, ACCA, Arlington, VA. www.acca.org

Building America Best Practices

The U.S. Department of Energy has produced a series of builders guides that provide instructions for construction "best practices" that can help builders achieve high-performance homes. These guides can be found at www.eere.energy.gov/buildings/building_america/

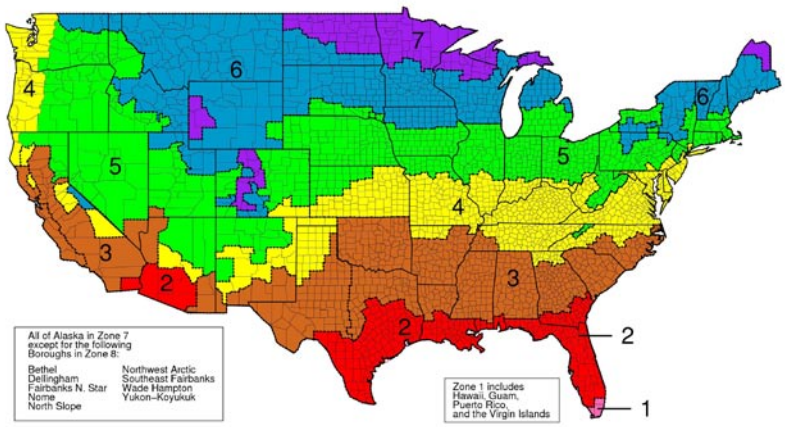
7 RECOMMENDED

Dehumidification

BUILDERS CHALLENGE QUALITY CRITERIA	BUILDER DOCUMENTATION & VERIFICATION REQUIREMENTS	THIRD-PARTY VERIFICATION REQUIREMENTS
7. Dehumidification – Recommended: Install equipment with sufficient latent capacity to maintain indoor relative humidity at or below 60% in Climate Zones 1A, 2A, 3A and 4A, as defined by the 2006 IECC Figure 301.1. This requirement can be met with an additional dehumidification system or a central HVAC system equipped with additional controls to operate in dehumidification mode.	Include mechanical specifications for dehumidification in construction documents and keep in project records.	

The desirable range of indoor relative humidity is from 20% in winter to 65% in summer, with a preferable range of 40% to 50%. One way that humidity has been managed in homes is through the inefficient operation of air conditioners. The more inefficient the air conditioner, the more it operates, and the more moisture it takes out of the air. Building America research suggests that energy efficiency measures, combined with controlled mechanical ventilation, change the ability of air conditioners to control humidity; thus, supplemental dehumidification is suggested for humid climates. Research suggests the dehumidification system providing the best value involved a standard dehumidifier located in a hall closet with a louvered door, in combination with a central fan-integrated supply ventilation system with a fan cycling control.

Figure 7.1. Map of U.S. climate zones
(Climate zones 1A, 2A, 3A and 4A are as defined by the 2006 IECC, Figure 301.1.)



Related Quality Criteria

See guidance and references for ***Criteria 5. Space Conditioning Design***.

Want to Learn More?

Rudd, A.F., J.W. Lstiburek, P. Eng, and K. Ueno. 2005. *Residential Dehumidification Systems Research for Hot-Humid Climates*, Building Science Consortium, NREL/SR-550-36643. Prepared by the Building Science Corporation for the U.S. Department of Energy. Available at www.buildingamerica.gov

NAHB Research Center. *Central Air Purification/ Ventilation/Dehumidification Systems*, available at www.toolbase.org/Home-Building-Topics/Indoor-Air-Quality/central-air-purification-ventilation-dehumidification

Related Standards & Procedures

2006 International Energy Conservation Code, International Code Council (ICC), Falls Church, Virginia. Available for purchase at www.iccsafe.org/dyn/prod/3810S06.html

Rudd, Armin. 2006. *Ventilation Guide*. Building Science Press Inc., Energy & Environmental Building Association, Minneapolis, MN, available for purchase at www.eeba.org/bookstore/default.asp.

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8 RECOMMENDED

Space-Conditioning System Installation

BUILDERS CHALLENGE QUALITY CRITERIA	BUILDER DOCUMENTATION & VERIFICATION REQUIREMENTS	THIRD-PARTY VERIFICATION REQUIREMENTS
8. Space-Conditioning System Installation – Recommended: Space-conditioning system installation meets ACCA Quality Installation Specification.		

The Air Conditioning Contractors of America's Quality Installation Specification is available at www.acca.org/quality/. This ANSI-approved standard provides precise steps for a quality HVAC installation. According to ACCA, proper installation includes correct selection of equipment and controls and following all the steps for correct installation. In this specification, five core areas are characterized: equipment design, equipment installation, duct distribution, system documentation, and owner education.

Figure 8.1. Space-conditioning systems should meet the ACCA Quality Installation Specification

Related Quality Criteria

See guidance and references for ***Criteria 5. Space Conditioning Design*** and ***Criteria 15. Duct Leakage***

Want to Learn More?

Designing and Building Interior Duct Systems, FSEC-PF-365-01. Available from the Florida Solar Energy Center at http://securedb.fsec.ucf.edu/pub/pub_show_detail?v_pub_id=4013

Better Duct Systems for Home Heating and Cooling, NREL/BR-550-30506; DOE/GO-102004-1606. Available from Building America at www.buildingamerica.gov

Thermal Energy Distribution Website at http://ducts.lbl.gov

Related Standards & Procedures

Air Conditioning Contractors of America. 2007. ACCA Standard 5, *HVAC Quality Installation Specification*, ANSI/ACCA 5 QI-2007, Air Conditioning Contractors of America, 2800 Shirlington Road, Suite 300, Arlington, Virginia. Available at www.acca.org

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9 RECOMMENDED

Building Envelope Pressurization Testing

BUILDERS CHALLENGE QUALITY CRITERIA	BUILDER DOCUMENTATION & VERIFICATION REQUIREMENTS	THIRD-PARTY VERIFICATION REQUIREMENTS
9. Building Envelope Pressurization Testing – Recommended Test envelope leakage to ≤ 0.35 cfm per square foot of building envelope area at a pressure differential of 50 Pascals between the house interior and outdoors. (See QC provision: Air Barrier and Insulation Integrity).		Test envelope leakage to be below specified limit, using a RESNET-approved testing protocol.

The Residential Energy Services Network (RESNET) provides a database of certified home energy raters who are trained and qualified to perform whole house air leakage ("blower door") tests. To find a RESNET certified home energy rater near you, see www.resnet.us/directory/raters_builders.aspx. Energy raters must also be approved to certify homes as meeting the Builders Challenge criteria. For more information on Builders Challenge, see www1.eere.energy.gov/buildings/challenge/.

Figure 9.1. A Building America team member conducting a blower door air leakage test of a new home in Gainesville, Florida

Related Quality Criteria

See guidance and references for ***Criteria 16. Air Barrier and Insulation Integrity***

Want to Learn More?

The Air Conditioning, Heating and Refrigeration NEWS. 2006. "Blower Doors: The Next Most Important Contribution to HVAC," available online at www.achrnews.com/Articles/Technical/d9aaa7bc7126a010VgnVCM100000f932a8c0

Blower Door Testing, Builder Brief BB0201, The Pennsylvania Housing Research/Resource Center; www.pct.edu/wdce/wtc/pdf/Blower-Door-FINAL.pdf

Related Standards & Procedures

RESNET Standard 2004-03 "Blower Door Test Procedures", http://resnet.us/rater/roundtable/Gauge_Calibration.ppt

ASHRAE Standard 62.2-2007 *Ventilation for Acceptable Indoor Air Quality in Low-Rise Residential Buildings* can be previewed at www.ashrae.org/technology/page/548

Building America Best Practices

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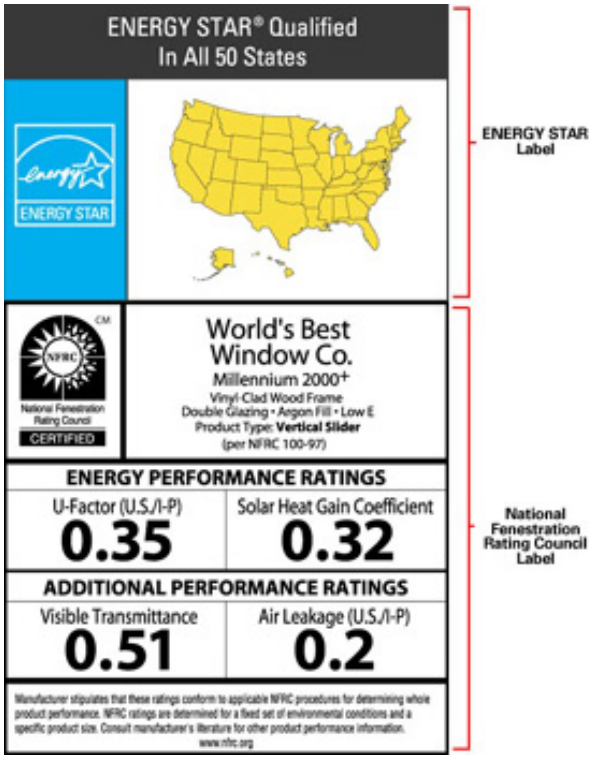
10 REQUIRED

Windows

BUILDERS CHALLENGE QUALITY CRITERIA	BUILDER DOCUMENTATION & VERIFICATION REQUIREMENTS	THIRD-PARTY VERIFICATION REQUIREMENTS
10. Windows – Required: Specify ENERGY STAR qualified windows or better.	Include in specification and keep in project records.	Verify installation of ENERGY STAR-qualified windows.

ENERGY STAR qualifies specific windows and makes distinctions based on climate zone. ENERGY STAR divides the United States into four climate zones, which are not identical to the climate zones of DOE's Building America and Building Codes programs. For ENERGY STAR's south/central climate region, all windows and doors qualifying for the ENERGY STAR label must have a U-factor rating of 0.40 or below and an SHGC rating of 0.40 or below; skylights must have a U-factor of 0.60 or below and an SHGC rating of 0.40 or less.

Figure 10.1. Example of a window label from the National Fenestration Rating Council and ENERGY STAR.



Want to Learn More?

ENERGY STAR Efficient Windows Collaborative www.efficientwindows.org/energystar.cfm

Carmody, John, Stephen Selkowitz, Dariush Arasteh, and Lisa Heschong. 2000. *Residential Windows: A Guide to New Technologies and Energy Performance.* W.W. Norton & Company, Inc., New York.

National Fenestration Rating Council. www.nfrc.org

ENERGY STAR. Residential Windows, Doors, and Skylights. www.energystar.gov/index.cfm?c=windows_doors.pr_windows

ASTM. *ASTM E2112 - 07 Standard Practice for Installation of Exterior Windows, Doors and Skylights*, www.astm.org/Standards/E2112.htm

Related Standards & Procedures

ENERGY STAR window product criteria www.energystar.gov/index.cfm?c=windows_doors.pr_crit_windows

American Architectural Manufacturers Association. "Product Certification. – Search now for AAMA-Certified Products (windows and doors)." Available at www.aamanet.org/general.asp?sect=2&id=127

Insulating Glass Manufacturers Alliance. www.igmaonline.org/content.php?sec=1 IGMA certified products.

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Figure 10.2. ENERGY STAR Qualified Windows, Doors and Skylights Eligibility Criteria

ENERGY STAR® Qualified Windows, Doors and Skylights Eligibility

Windows & Doors

Climate Zone	U-Factor[1]	SHGC[2]	
Northern	≤ 0.35	Any	
North/Central	≤ 0.40	≤ 0.55	
South/Central	≤ 0.40	≤ 0.40	Prescriptive
	≤ 0.41	≤ 0.36	Equivalent Performance *(Excluding CA)*
	≤ 0.42	≤ 0.31	
	≤ 0.43	≤ 0.24	
Southern	≤ 0.65	≤ 0.40	Prescriptive
	≤ 0.66	≤ 0.39	Equivalent Performance
	≤ 0.67		
	≤ 0.68	≤ 0.38	
	≤ 0.69	≤ 0.37	
	≤ 0.70		
	≤ 0.71	≤ 0.36	
	≤ 0.72	≤ 0.35	
	≤ 0.73		
	≤ 0.74	≤ 0.34	
	≤ 0.75	≤ 0.33	

Skylights

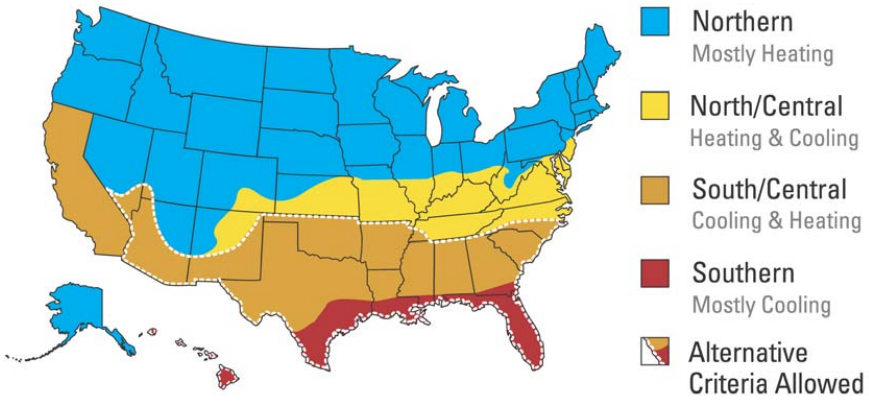
Climate Zone	U-Factor[1]		SHGC[2]
	2001 and 2004 NFRC rated at 20°[3]	*RES97 rated at 90°[4]*	
Northern	≤ 0.60	≤ 0.45	Any
North/Central	≤ 0.60	≤ 0.45	≤ 0.40
South/Central	≤ 0.60	≤ 0.45	≤ 0.40
Southern	≤ 0.75	≤ 0.75	≤ 0.40

[1] *Btu/h.ft².°F*

[2] *Fraction of incident solar radiation.*

[3] *U-Factor qualification criteria based on 2001 or 2004 NFRC simulation and certification procedures that rate skylights at a 20-degree angle. Although reported U-Factor is higher than RES97 rated products, energy performance at the ENERGY STAR minimum qualifying level is equivalent.*

[4] *NFRC certification using the 1997 NFRC procedures for residential windows (RES 97) that rated skylights at a 90-degree angle. Skylights rated under this procedure may be present in the marketplace until March 31, 2008. NFRC labels for products using this procedure state: "RES97 rated at 90 degrees."*



ENERGY STAR Program Requirements for Windows, Doors, and Skylights: Version 4.0 (5/14/2007) **5**

11
REQUIRED

Whole Building Mechanical Ventilation I

BUILDERS CHALLENGE QUALITY CRITERIA	BUILDER DOCUMENTATION & VERIFICATION REQUIREMENTS	THIRD-PARTY VERIFICATION REQUIREMENTS
11. Whole Building Mechanical Ventilation I – Required: Design and install a mechanical system(s) to provide outside air to the indoor environment through either exhaust, supply, or balanced ventilation. Equip outside air intakes for ventilation with filters and shutoff dampers. (Also see QC Provision: Whole Building Mechanical Ventilation II – which is a recommended measure).	Include in mechanical plans and keep in project records.	Verify the installation of a whole building MV system.

In 2007, the American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE) updated the standard for indoor ventilation in residences. The standard is ASHRAE 62.2, Ventilation for Acceptable Indoor Air Quality in Low-Rise Residential Buildings (ASHRAE 2007). The following is information adapted from the forward published with the standard:

> The three primary requirements in indoor air quality involve whole-house ventilation, local exhaust, and source control. Whole house ventilation is intended to dilute the unavoidable contaminant emissions from people, materials, and background processes. Local exhaust is intended to remove contaminants from specific rooms, such as kitchens and bathrooms. Source control measures are included to deal with other anticipated sources. The standard also includes secondary requirements that focus on properties of specific items, such as sound and flow ratings for fans and labeling requirements. While the standard may seem to be principally about mechanical ventilation, the purpose of ventilation is to provide acceptable indoor air quality.

To meet the whole-building ventilation requirement, ASHRAE 62.2 specifies a continuous ventilation rate of 1 cfm (cubic feet per minute) per 100 sq ft of building area plus 7.5 times the sum of the number of bedrooms plus 1 as indicated in the following equation:

> (Total house square footage/ 100) + (7.5 * (# bedrooms + 1)) = Specified ventilation rate (cfm)
>
> A compliant 1000 square foot house with 2 bedrooms would have the following ventilation rate:
>
> (1000/100) + (7.5 *3) = 32.5 cfm

For comparison, bath fan capacities tend to be from 30 cfm to 150 cfm.

An intermittent fan can meet this requirement if it operates at least one hour out of every twelve and provides the same volume of outdoor air as a continuous scenario plus an additional volume of air to make up for a loss in ventilation effectiveness by the intermittent fan.

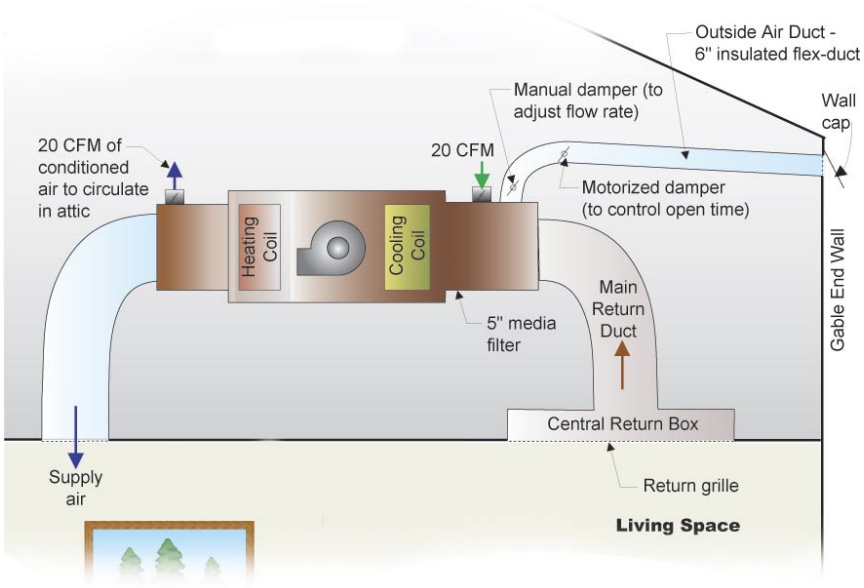
Exhaust fans help to improve indoor air quality by removing air contaminants near their source, such as moisture from a shower. However, be cautious about using exhaust-only ventilation systems. Exhaust systems, including bath fans, kitchen range fans, clothes dryers, and other exhaust fans, draw air out of the home and that air must be replaced.

Whole Building Mechanical Ventilation I

In an inefficient, leaky home, outside air is pulled in through cracks around doors and windows, etc. to repressurize the house. In a high-performance home, those air leaks have been sealed up so a fresh air intake must be added to the home to supply fresh air. Using exhaust equipment to expel air from indoors but failing to bring in outside air to replace (or make up) this air can cause air pressure to drop in the home. In a depressurized home, standard combustion (fuel-burning) equipment can backdraft dangerous gases (including carbon monoxide) into the house rather than letting them be expelled out the chimney. In humid climates, a depressurized house can draw in humid outside air, leading to moisture problems. For this reason, some building codes limit the conditions under which exhaust equipment can be used without bringing in an equal amount of fresh air, either through passive inlets or by powered intake.

Central fan-integrated supply ventilation can be an easy and inexpensive way to provide outside air to the HVAC unit. This system provides fresh, filtered, outside air in a controlled amount using the existing HVAC delivery unit for even distribution and mixing. The system involves exterior air intakes, ductwork running to the return air side of the HVAC air handler, dampers to allow control of the air intake, and electronic controls to ensure that the HVAC fans operate frequently enough to draw in adequate fresh air. These outdoor air inlets should be located at least 10 feet from any contamination sources. In humid climates care should be taken in drawing in outside air. Dehumidification may be needed to control relative humidity levels. See Criteria 7 for information on controlling humidity. Variable speed motors can be a significant source of energy savings.

Figure 11.1. Central fan-integrated supply ventilation



Related Quality Criteria

See guidance and references for ***Criteria 25. Whole Building Mechanical Ventilation II***.

Want to Learn More?

Aldrich, Robb and Gayathn: Vijaya Kumer, 2006. "Ventilating Small Chicago Houses," *Home Energy* Jan/Feb 2006.

Rudd, Armin. 1999. "Air Distribution Fan and Outside Air Damper Recycling Control," *Heating Air Conditioning and Refrigeration News*, 5 July 1999, pg. 45. Edited version of article available at www.buildingscience.com/resources/mechanical/fancycling/air_distribution.pdf

NAHB Research Center. "Whole-House Mechanical Ventilation Strategies," www.toolbase.org/Technology-Inventory/HVAC/whole-house-mechanical-ventilation

Building Energy Codes Resource Center "Whole-House Mechanical Ventilation – Code Notes," U.S. Department of Energy, http://resourcecenter.pnl.gov/cocoon/morf/ResourceCenter/article/1467

U.S. Department of Energy. 2002. "Whole-House Ventilation Systems," Technology Fact Sheet, December 2002. www.eere.energy.gov/buildings/info/documents/pdfs/26458.pdf

Rudd, Armin. 2006. *Ventilation Guide*. Building Science Press Inc., Energy & Environmental Building Association, Minneapolis, MN, available for purchase at www.eeba.org/bookstore/default.asp

Minnesota Department of Commerce Energy Information Center. June 23, 2008. "Maintain home ventilation systems to provide healthy air supply." Available at www.state.mn.us/portal/mn/jsp/content.do?id=-536881350&subchannel=-536881511&sc2=-536892313&sc3=null&contentid=536912088&contenttype=EDITORIAL&programid=536912110&agency=Commerce

Rudd, Armin, Joseph Lstiburek, 2001. "Clean Breathing in Production Homes." *Home Energy Magazine*, May/June, Energy Auditor & Retrofiter, Inc., Berkeley, CA.

U.S. Environmental Protection Agency. 2009. *Indoor airPLUS Construction Specifications*, available at www.epa.gov/indoorairplus/index.html

Related Standards & Procedures

ASHRAE Standard 62.2-2007 Ventilation for Acceptable Indoor Air Quality in Low-Rise Residential Buildings can be previewed at www.ashrae.org/technology/page/548

ENERGY STAR. Ventilating Fans Key Product Criteria. Available at www.energystar.gov/index.cfm?c=vent_fans.pr_crit_vent_fans

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12
REQUIRED

Kitchen Ventilation

BUILDERS CHALLENGE QUALITY CRITERIA	BUILDER DOCUMENTATION & VERIFICATION REQUIREMENTS	THIRD-PARTY VERIFICATION REQUIREMENTS
12. Kitchen Ventilation – Required: Provide mechanical kitchen ventilation with an exhaust fan(s) that can provide at least 100 cfm intermittent (reference 2006 IRC M1507.3) or airflow equivalent to 5 air changes per hour based on the kitchen volume (continuous use). Fans are vented to exhaust kitchen air to outdoors. Refer to Section 6.4 of ASHRAE 62.2-2007 "Combustion and Solid-Fuel Burning Appliances" for information on providing for adequate combustion air for combustion appliances.	Include kitchen ventilation requirements in construction documents.	Verify the installation of kitchen ventilation system which exhausts air to outdoors.

Builders should provide local exhaust fans for kitchen range hoods that are ducted to the outdoors via the most direct path. According to the 2006 IECC, Section 403.5 "Mechanical ventilation," outdoor air intakes and exhausts should be equipped with automatic or gravity dampers that close when the ventilation system is not in operation.

It is important for the ventilation system to operate quietly. A sone is a cumulative sound rating. Two sones is twice as loud as one sone. A noise level of 1.0 is equivalent to the sound of a newer refrigerator running. Some bathroom fans have a rating as low as 0.3. The maximum sone rating for an ENERGY STAR-rated exhaust fan, including bath, utility room, and kitchen exhausts, is 2 sones.

Related Quality Criteria

See guidance and references for ***Criteria 11. Whole Building Mechanical Ventilation I***.

Want to Learn More?

"Oversized Kitchen Fans – An Exhausting Problem" in *Home Energy Magazine Online*, January/February 1999. www.homeenergy.org/archive/hem.dis.anl.gov/eehem/99/990113.html

Rudd, Armin. 2006. *Ventilation Guide*. Building Science Press Inc., Energy & Environmental Building Association, Minneapolis, MN, available for purchase at www.eeba.org/bookstore/default.asp

HVI. 2006. "Fresh Ideas in Residential Ventilation." Home Ventilating Institute. Wauconda, IL.

Russell, Marion, Max Sherman and Armin Rudd, 2007. "Review of Residential Ventilation Technologies. "HVAC&R Research, Vol. 13, No. 2, March. ASHRAE.

Related Standards & Procedures

ASHRAE Standard 62.2-2007 *Ventilation for Acceptable Indoor Air Quality in Low-Rise Residential Buildings* can be previewed from www.ashrae.org/technology/page/548

2006 International Residential Code, International Code Council (ICC), Falls Church, Virginia. Available for purchase at www.iccsafe.org/dyn/prod/3110S061.html

2006 International Energy Conservation Code, Section 403.5 "Mechanical Ventilation," International Code Council (ICC), Falls Church, Virginia. Available for purchase at www.iccsafe.org/dyn/prod/3810S06.html

ENERGY STAR. *Ventilating Fans Key Product Criteria*. Available at www.energystar.gov/index.cfm?c=vent_fans.pr_crit_vent_fans

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13 REQUIRED

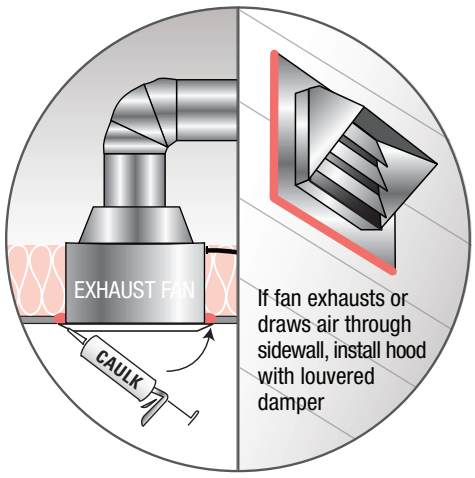
Bathroom Ventilation

BUILDERS CHALLENGE QUALITY CRITERIA	BUILDER DOCUMENTATION & VERIFICATION REQUIREMENTS	THIRD-PARTY VERIFICATION REQUIREMENTS
13. Bathroom Ventilation – Required: Include mechanical ventilation for all bathrooms with a bathtub, shower, spa, or similar source of moisture with an exhaust fan(s) that can provide at least 50 cfm (intermittent use) or 20 cfm (continuous use). For bathrooms without a bathtub, shower, spa, or similar source of moisture, exhaust ventilation is provided at these same rates, or the room has a window with an openable area of at least 4% of the floor area and no smaller than 1.5 square feet. All bathroom fans are vented to outdoors.	Include in construction documents.	Verify the installation of bathroom ventilation equipment which exhausts air to outdoors.

Provide local exhaust fans for bathrooms that are ducted to the outdoors via the most direct path.

According to 2006 IECC, Section 403.5 "Mechanical ventilation," outdoor air intakes and exhausts should be equipped with automatic or gravity dampers that close when the ventilation system is not in operation.

It is important for the ventilation system to operate quietly. A sone is a cumulative sound rating. Two sones is twice as loud as one sone. Exhaust fans with a sone rating of 1.0 or less are considered very quiet. Ventilation experts prefer quiet fans because they are less intrusive and occupants will be more likely to leave them on. Bathroom exhaust fans should have a maximum sound rating of 1.0 sone. A noise level of 1.0 is equivalent to the sound of a newer refrigerator running. Some fans have a rating as low as 0.3. The maximum sone rating for an ENERGY STAR-rated exhaust fan, including bath, utility room, and kitchen exhausts, is 2 sones.



Related Quality Criteria

See guidance and references for ***Criteria 11. Whole Building Mechanical Ventilation*** and ***Criteria 12. Kitchen Ventilation.***

Want to Learn More?

ENERGY STAR. "Ventilation Fans Purchasing and Procurement Language," www.energystar.gov/index.cfm?c=vent_fans.pr_proc_vent_fans

ENERGY STAR. "ENERGY STAR-Approved Ventilation Fans," available at www.energystar.gov/ia/products/prod_lists/vent_fan_prod_list.pdf

Rudd, Armin. 2006. *Ventilation Guide*. Building Science Press Inc., Energy & Environmental Building Association, Minneapolis, MN, available for purchase at www.eeba.org/bookstore/default.asp

Related Standards & Procedures

2006 International Energy Conservation Code, Section 403.5 "Mechanical Ventilation," International Code Council (ICC), Falls Church, Virginia. Available for purchase at www.iccsafe.org/dyn/prod/3810S06.html

ENERGY STAR. *Ventilating Fans Key Product Criteria*. Available at www.energystar.gov/index.cfm?c=vent_fans.pr_crit_vent_fans

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14 REQUIRED

Clothes Dryer Venting

BUILDERS CHALLENGE QUALITY CRITERIA	BUILDER DOCUMENTATION & VERIFICATION REQUIREMENTS	THIRD-PARTY VERIFICATION REQUIREMENTS
14. Clothes Dryer Venting – Required: Clothes dryer vented directly to the outdoors. (reference 2006 IRC M1502.1) Condensing dryers are exempt.	Provide for ducting to the outdoors for clothes dryers.	Verify the installation of a clothes dryer exhaust port to outdoors.

Vent clothes dryers and central vacuum cleaners directly outdoors. According to 2006 IECC, Section 403.5 "Mechanical ventilation," outdoor air intakes and exhausts should be equipped with automatic or gravity dampers that close when the ventilation system is not in operation. The IECC specifically covers clothes dryer exhausts in Section MIS-2.1

A fully loaded conventional clothes dryer exhausts several pounds of water vapor during a typical drying cycle. A 20-pound load of clothes coming out of a top-loading washer can hold as much as 8 pounds of water. Loads coming from ENERGY STAR washers tend to hold less water. Most dryers use heat to turn liquid water to vapor and fans to exhaust the vapor outdoors. The code requires that all conventional gas and electric dryers exhaust water vapor to the exterior of the house.

The dryer's fan can only move so much air. The amount of air that makes it outside is determined by the fan capacity, ducting type and layout, and vent type. Installers need to review manufacturers' specifications for specific dryers to know how well the fan will work with different ducting configurations. The more 90-degree turns (elbows) the vent duct has, the closer the dryer must be to the vent. Smooth metal ducts work better than flex metal. Louvered vents tend to have more clear area than a 2½-inch vent with a single hinged door.

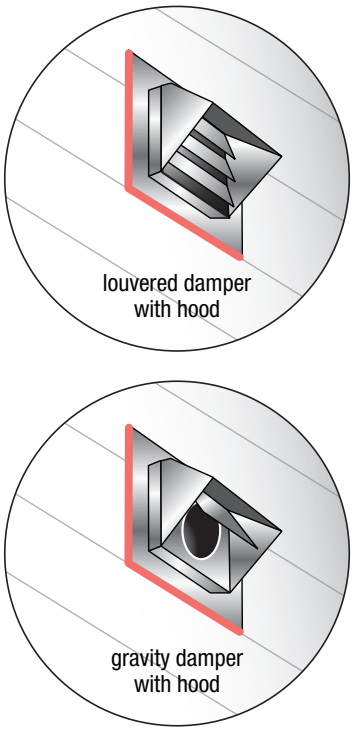
The following table shows how, on average, these factors work together. These numbers are based on average duct distances for several manufacturers and dryer models. More than two elbows can be used with most models, but manufacturer specifications must be consulted. In short, smooth, rigid metal ducts with louvered vents and straight runs provide the most efficient ducting systems. Vinyl, nylon, and foil ducts do not meet code. Code may limit the length of dryer vent duct runs.

Figure 14.2. Duct run distances averaged across several dryer manufacturers

DUCT & VENT HOOD COMBINATIONS	NO ELBOWS	1 ELBOW	2 ELBOWS
Rigid metal with louvered vent	57 feet	45 feet	35 feet
Rigid metal with 2½ inch hood vent	44 feet	34 feet	25 feet
Flex metal with louvered vent	30 feet	23 feet	16.5 feet
Flex metal with 2½ inch hood vent	28 feet	21 feet	15 feet*

**Some dryers cannot support 2 elbows with a 2½ inch hood vent.*

Figure 14.1. Dryer vent exhausts must have a gravity or other backdraft damper. A single hinged door with a 2½-inch effective opening is not as effective as a louvered damper.



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Clothes Dryer Venting

Other considerations when installing dryer vents include the following:

- In warm climates or in houses with air conditioning, insulate the ducts to avoid condensation forming on interior surfaces. Condensation can run back to the dryer or leak from duct joints.
- Mount ducts with no sags to avoid points where condensation can pool.
- Do not use screws to connect duct sections. Screws will catch lint that may build up and will make duct cleaning difficult. Use clamps and foil faced duct tape sold for heating and cooling ducts.
- Do not conceal flexible ducts inside walls or other framing.
- Flash and caulk penetrations through the building envelope for all vents.

Not all dryers require exhaust fans and ducts. Condensing dryers, common in Europe for years, are energy efficient and condense water into liquid rather than exhausting it to the outside. Some of these appliances use small blowers to circulate air across a heat-exchanger inside the dryer. Some draw in room air to cool the interior air and condense the water. Others use an internal water-cooling system to condense the water vapor. Whatever the particular design, the condensate is either pumped to a drain or is emptied by hand at the end of the drying cycle. Some condensing dryers are actually combination washers and dryers.

Condensing dryers can be useful in situations where the laundry room is located a significant distance from an exterior wall to which it can vent. If a condensing dryer is specified, verify that the proper drainage or an adjacent sink has been provided to remove the condensate.

Want to Learn More?

Building Energy Codes Resource Center "Ventilation Requirements for Condensing Clothes Dryers – Code Notes," U.S. Department of Energy, http://resourcecenter.pnl.gov/cocoon/morf/ResourceCenter/article/132

Related Standards & Procedures

2006 International Residential Code, "Section M1502.1 Clothes Dryer Exhaust – General," International Code Council (ICC), Falls Church, Virginia. Available for purchase at www.iccsafe.org/dyn/prod/3110S061.html

2006 International Energy Conservation Code, Section 403.5 "Mechanical Ventilation," International Code Council (ICC), Falls Church, Virginia. Available for purchase at www.iccsafe.org/dyn/prod/3810S06.html

Building America Best Practices

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15 REQUIRED

Duct Leakage

BUILDERS CHALLENGE QUALITY CRITERIA	BUILDER DOCUMENTATION & VERIFICATION REQUIREMENTS	THIRD-PARTY VERIFICATION REQUIREMENTS
15. Duct Leakage – Required: Comply with 15A or 15B, and 15C. 15A. Duct leakage to outdoors is less than 5% of conditioned floor area when measured at 25 Pascals using duct pressurization measures. OR 15B. All duct work is located within the conditioned envelope (meaning the air barrier and thermal barrier) of the house. AND 15C. Total duct leakage is less than 10% of conditioned floor area when measured at 25 Pascals using duct pressurization methods.		Test duct leakage to outdoors to be below specified leakage limits, using a RESNET-approved testing protocol. Verify that ducts are located within the thermal envelope of the house, if Option 15B is selected.

Leaky duct systems cause energy losses and may also result in indoor-outdoor pressure imbalances that force significant air leakage through the building envelope. Extensive duct sealing is typically required. The target for total duct leakage is 5% of conditiond floor area – cooling airflow in cfm, as tested at 25Pa reference pressure.

Duct Sealing

Seal all ductwork seams and connections to air handlers with UL181-approved water-based mastic and seal drywall connections with caulk or foam sealant.

Sealing ductwork is very important. Leaky ductwork in an unconditioned attic or crawlspace can draw unhealthy air into the air distribution system. Sealing ducts with mastic is desirable even for ducts located in conditioned spaces. Properly sealing ducts ensures air gets to the spaces intended, rather than leaking into a plenum space. It also minimizes the chances of creating pressure differentials from space to space that would induce airflow through the envelope. The process of sealing each joint also reduces the chances of unconnected ductwork, a surprisingly common mistake.

Mastic provides the most reliable duct sealing method for new construction. All ductwork, including fixed seams in the air handler compartment (which typically has many leaky joints), should be sealed with water-based mastic.

DOE research has found that some tapes perform adequately for sealing ducts, particularly fiberglass duct board. However, good performing tapes may be difficult to identify and traditional duct tape (cloth-backed rubber adhesive tape) should never be used to seal ducts, even if it meets UL ratings. Do not use sealing tapes for structural purposes. Tapes have low tensile strength and should not be used to mechanically support ducts.

Underwriters Laboratories, Inc. (UL) publishes several standards that relate to duct sealants, the most important of which is UL 181. It deals with ducts

Figure 15.1. Mastic provides the most reliable duct sealing method. Ducts should be located in conditioned space.

Photo courtesy of FSEC

Photo courtesy of IBACOS

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Duct Leakage

in general, with UL 181A covering field-assembled duct-board, and UL 181B covering flex duct systems. Each standard includes test procedures for sealants. Duct tapes and packing tapes that pass UL 181B are labeled "UL 181B-FX." Mastics can pass 181A or B and are labeled "UL 181A-M" or "UL 181B-M." Foil tapes are designated with a P.

California Title 24 residential building standards requires that duct sealants meet UL 181, UL 181A, UL 181B, or UL 723 (for aerosol sealants). The California Energy Commission has approved a cloth-backed duct tape with a special butyl adhesive (CEC 2005).

Duct Location

The best practice is to locate the ducts in conditioned space, so that any leakage that does occur will send air to or draw air from conditioned space, and to make duct runs as short as possible. Conditioned air may be discharged from walls or from ceiling diffusers up to 12 feet from the window wall in most cases without compromising comfort. Such "inside throw" layouts cut ductwork runs, saving money and reducing the amount of ductwork that may run in unconditioned space. There are several options for locating the ducts in conditioned space:

- Place ducts within framing systems, e.g., open-web truss system between floors.
- Use a main duct line running through a dropped-ceiling chase in the hallway with vents to rooms off the hall. This keeps ducts in conditioned space and minimizes duct length for more even and efficient air distribution. See Figure 15.2 for help with chase design and installation.
- Locate ducts and air handlers within an insulated, non-vented, conditioned crawl space or basement.
- Locate ducts and air handlers within a "cathedralized" non-vented attic (i.e., insulated along roof line for conditioned attic space).
- Develop chase walls to accommodate duct risers.

Keeping ducts and air handlers inside conditioned space typically impacts architectural design and should be considered early in the design process. Duct chases or dropped soffits may require thinking through the sequence of how trade contractors will do the installation. For example, framers may need to install the ceiling and side wall gypsum board around the chase, then frame the chase sides and base. The gypsum board may be needed to provide a seal from the attic above and the wall cavities on the sides. Once the chase is built, and especially after the ducts are installed, these ceiling and wall surfaces may become inaccessible. After the initial gypsum board is installed and the chase is framed in, the HVAC contractor can then install the actual sealed duct work. Sheetrockers can finish off the exposed surfaces.

Building America researchers have investigated burying ducts in attic insulation above ceilings. Based on this research, California Title 24 includes provisions for this approach, including the requirement. Building America recommends that buried ducts be directly insulated to R-8, apart from the piled-on insulation. Building America does not recommend using the buried duct approach in climates where the summertime attic dew point temperature is often above 60°F, or if the Jul-Aug monthly average outdoor dew point temperature is above 60°F (refer to Table 6-3 of ASHRAE Standard 90.2-1993). The mixed-humid and hot-humid climates often exceed this dew point and so buried ducts are specifically not recommended there. In other climates, such as cold climates up through the humid river valleys, builders and designers should be cautious. All ducts should be sealed with mastic. Research on duct location and sealing techniques is ongoing.

Want to Learn More?

Sherman, M, and I. Walker. 1998. Can Duct Tape Take the Heat? *Home Energy*, Berkeley, California. http://homeenergy.org/archive/hem.dis.anl.gov/eehem/98/980710.html

California Energy Commission. 2005. *2005 Residential Compliance Manual*. Sacramento, CA www.energy.ca.gov/2005publications/CEC-400-2005-005/CEC-400-2005-005-CMF.pdf

Walker, I.; M. Sherman; M. Modera; and J. Siegel. 1998. *Leakage Diagnostics, Sealant Longevity, Sizing and Technology Transfer in Residential Thermal Distribution Systems*. Lawrence Berkeley National Laboratory, Berkeley, CA. http://ducts.lbl.gov/Publications/lbl-41118.pdf

HGTVPro.com. "How to Seal Ductwork", available at www.hgtvpro.com/hpro/bp_mechanical/article/0,,HPRO_20151_4583390,00.html

Oikos Green Building Source. "Mastic Gives Ducts the Treatment," available at www.oikos.com/library/ducts/index.html

Related Standards & Procedures

2006 International Residential Code, Section 403.2.2 and Section M1601.3.1, "Sealing," International Code Council (ICC), Falls Church, Virginia. Available for purchase at www.iccsafe.org/dyn/prod/3110S061.html

2006 International Energy Conservation Code, International Code Council (ICC), Falls Church, Virginia. Available for purchase at www.iccsafe.org/dyn/prod/3810S06.html

UL 181, "Factory-Made Air Ducts and Air Connectors," Underwriters Laboratory, http://ulstandardsinfonet.ul.com/scopes/scopes.asp?fn=0181.html

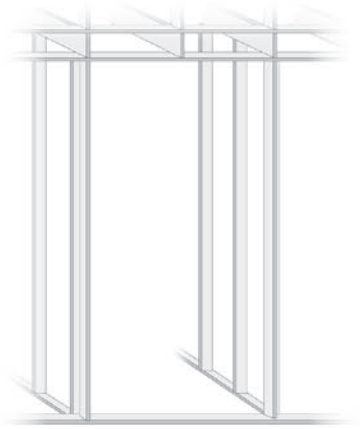
Building America Best Practices

The U.S. Department of Energy has produced a series of builders guides that provide instructions for construction "best practices" that can help builders achieve high-performance homes. These guides can be found at www.eere.energy.gov/buildings/building_america/

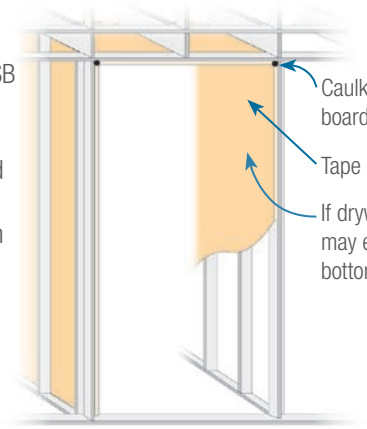
Duct Leakage

Figure 15.2. Ducts can be placed in a dropped ceiling or in open web trusses between floors to keep them in conditioned space.

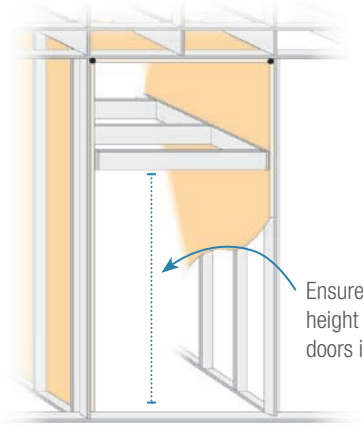
❶ Start with a framed hallway.



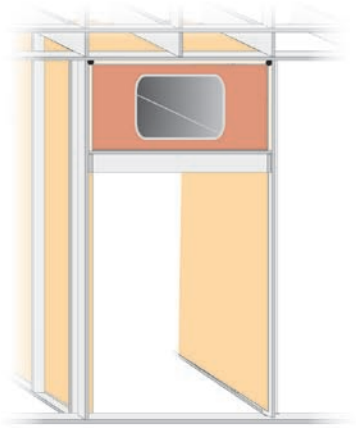
❷ Install drywall or OSB or other air barrier extending past the area to be included in chase. Framers may install gypsum board.



❸ Framers install cavity bottom framing using ladder-like structure.



❹ HVAC contractor installs sealed and insulated ducts in chase.



❺ Drywallers finish exposed surfaces with sealed, caulked, taped, and mudded drywall and seal connection of duct boot to drywall.

❻ Install register and finish.

Related Quality Criteria

See ***Criteria 6, Space Conditioning Design*** and ***Criteria 22. Air Handler Location***.

16
REQUIRED

Air Barrier and Insulation Integrity

BUILDERS CHALLENGE QUALITY CRITERIA	BUILDER DOCUMENTATION & VERIFICATION REQUIREMENTS	THIRD-PARTY VERIFICATION REQUIREMENTS
16. Air Barrier and Insulation Integrity – Required: Complete the ENERGY STAR Thermal Bypass Inspection Checklist for the home. A link to this checklist is listed on the Builders Challenge website http://www1.eere.energy.gov/buildings/challenge/	Either builder or third-party verifier may complete the checklist. Builder must keep signed copy of the checklist in builder's project records.	Either builder or third-party verifier may complete the checklist. Third-party verifier must confirm that a signed checklist has been completed.

The Thermal Bypass Checklist (Figure 16.7) is a comprehensive list of building details where thermal bypass, or the movement of heat around or through insulation, frequently occurs due to missing air barriers or gaps between the air barrier and insulation.

ENERGY STAR refers to vulnerable spots in the building envelope as thermal bypasses, areas where heat (and cold) can be transferred through the building envelope due to the lack of adequate insulation, missing air barriers, or gaps between the air barrier and the insulation. The ENERGY STAR program has prepared a thermal bypass checklist that builders can use to verify the integrity of the air barriers in the building envelope. Reducing thermal bypasses is important as they can lead to comfort and warranty issues as well as higher utility bills.

The Thermal Bypass Checklist identifies 25 points, to inspect throughout the home, covering all major components of the building envelope including exterior walls, floors, ceilings, attics, and shafts.

The garage should be completely sealed from the conditioned areas of the house. This is important from both an energy perspective, because it can be a major source of heat gain and heat loss, and from a health perspective, due to common pollutants from car exhaust and stored materials. When the garage is attached to the house, the gaps created by joists spanning both conditioned space and the garage must be blocked off and sealed.

It can become increasingly difficult to construct air barriers to close gaps between the garage and the conditioned space as the joists become more irregular at their cross section. This is particularly true for I-joists and web-trusses. A simple solution is to plan ahead and align the ends of the joists with the wall adjoining the conditioned space to allow for end blocking.

Building America researchers have worked with three building approaches that provide innovative solutions to air barriers and thermal bypasses. These approaches push the air barrier towards the exterior of the building shell, making it easier to avoid sealing around complex building features. The three approaches are

- conditioning crawlspaces and basements, or using slabs
- installing insulated exterior sheathing, with sealed seams
- conditioning attics.

Figure 16.1. In this figure, OSB and foam form the air barriers to isolate the garage from living space.

Figure 16.2. Sequence framing to install an air barrier between the porch roof cavity and conditioned space.

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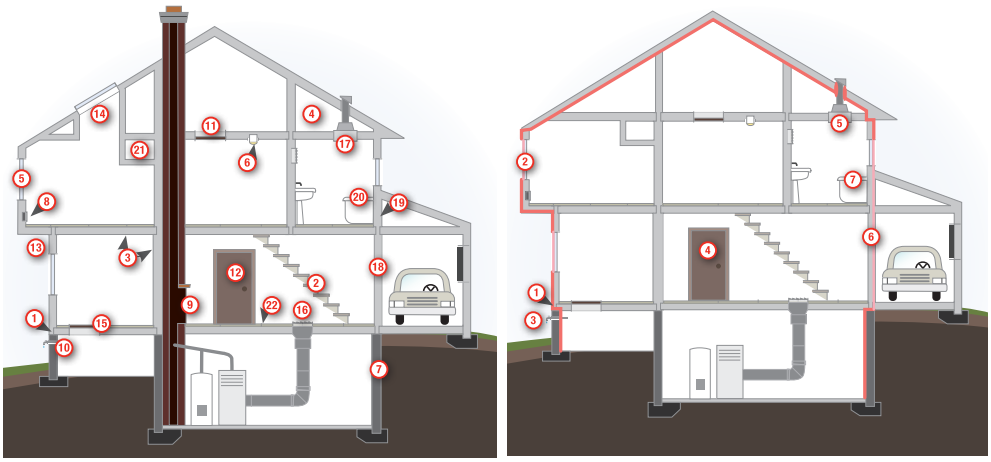
Air Barrier and Insulation Integrity

These approaches tend to move insulation and air sealing to surfaces that are not as interrupted by electrical outlets, plumbing, lights, fireplaces, and stairs. Thus the air sealing is easier because there are fewer holes to seals. The resulting increase in thermal performance tends to translate into improved scores on the Builders Challenge E-scale.

The installation of high-efficiency furnaces and water heaters can also help control air leakage. Natural gas fired condensing furnaces achieve combustion efficiency levels greater than 90%. These furnaces and water heaters are sealed combustion systems that intake and exhaust air through plastic pipes that do not require a vertical chimney. Eliminating the chimney (which is designed to move air out of the house) removes the need to seal the chimney and its chase from unwanted air and thermal leaks. A direct-vent fireplace can also eliminate the heed for a chimney entirely. Ducts located in conditioned space also eliminate penetrations through the building shell and avoid the intake of unconditioned air that occurs through duct leaks.

Figure 16.5 & 16.6. See pages 16.3-5 for diagrams showing conventional interior vs. exterior air barrier approaches.

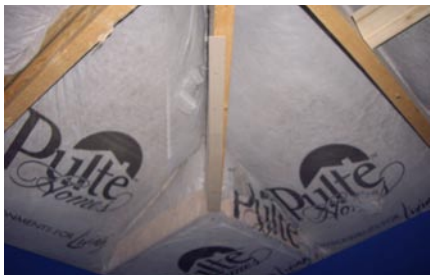


Related Quality Criteria

See ***Criteria 9. Pressurization Test; Criteria 15. Duct Leakage; Criteria 18. Combustion Safety;*** and ***Criteria 21. Garage Exhaust Ventilation***.

Figure 16.3. The intersection of walls, ceilings, and attic trusses must be sealed in non-vented attics. This example uses gaskets and canned spray foam for the seal.

Figure 16.4. Insulation in non-vented attics is applied directly under roof sheathing. (*Photo courtesy of Pulte Homes)*



Want to Learn More?

ENERGY STAR. Thermal Bypass Checklist Guide, available at www.energystar.gov/ia/partners/bldrs_lenders_raters/downloads/TBC_Guide_062507.pdf

Lstiburek, Joseph and Peter Baker. 2005. *Guide to Insulating Sheathing.* Prepared for DOE's Building America Program by the Building Science Corporation. www.buildingscience.com/documents/reports/rr-0501-guide-to-insulating-sheathing/view?searchterm=insulated%20sheathing

Straube, John. 2007. Air Flow Control in Buildings, *Building Science Digest 014.* Building Science Press. www.buildingscience.com/documents/digests/bsd-014-air-flow-control-in-buildings.

Related Standards & Procedures

2006 International Energy Conservation Code, Section 403.2.2 "Sealing," International Code Council (ICC), Falls Church, Virginia. Available at www.iccsafe.org

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Air Barrier and Insulation Integrity

Figure 16.5. Conventional Interior Air Barrier – Conventional construction (and typical retrofits) requires tracking down and sealing multiple penetrations that ultimately lead to or through the exterior shell.

1. Sill Plate & Rim Joist
2. Stairs
3. Wall & Ceiling Drywall
4. Kneewalls
5. Windows
6. ICAT Can Light
7. Electric Circuit Box
8. Outlets & Switches
9. Fireplace
10. Plumbing Penetrations
11. Attic Access
12. Doors
13. Cantilever
14. Skylight
15. Crawlspace Access
16. Registers
17. Exhaust Fan
18. Garage Common Wall
19. Wall Adjoining Cavity
20. Tub
21. Interior Soffit
22. Plywood Floor Panels

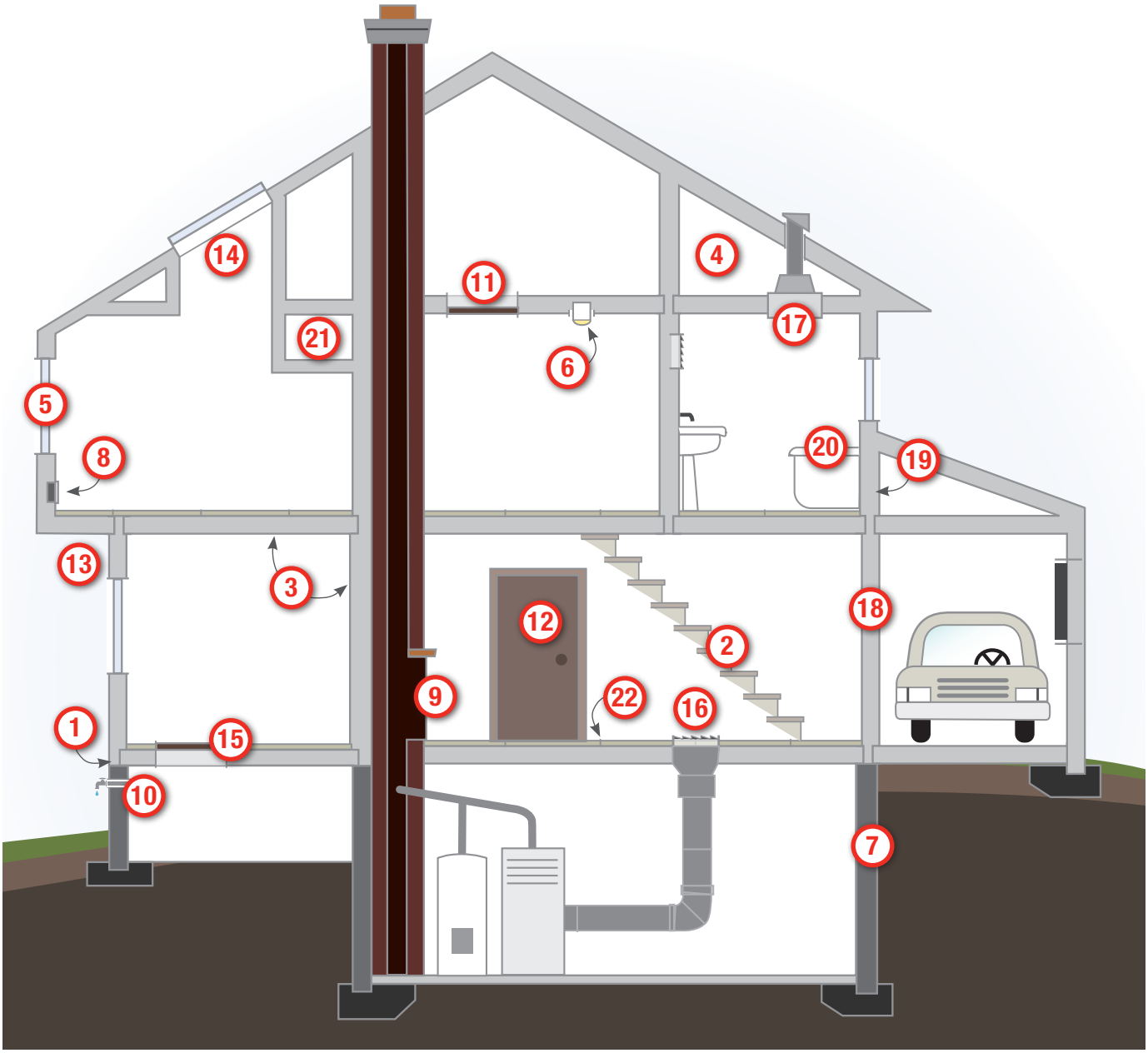
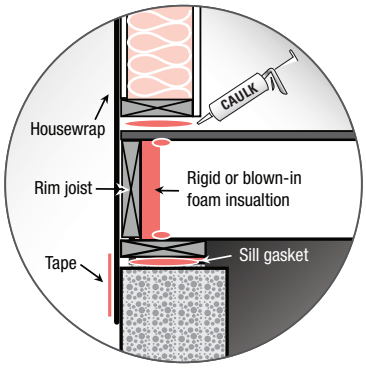
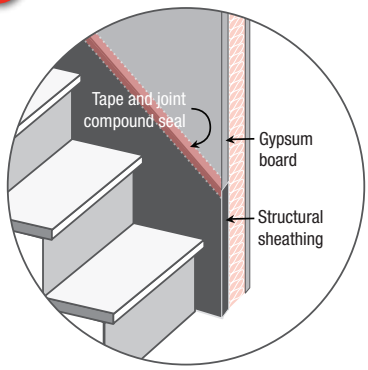


Figure 16.5. Conventional Interior Air Barrier – Details *(Continued)*

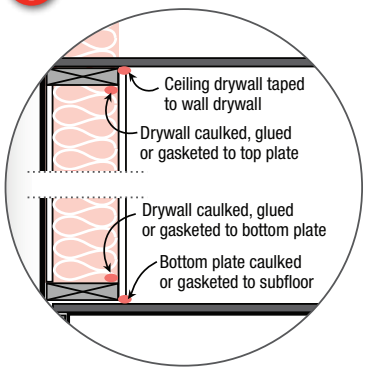
1 Sill Plate & Rim Joist



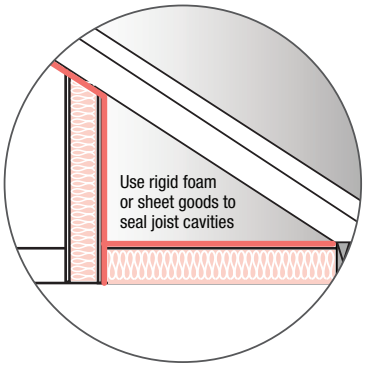
2 Stairs

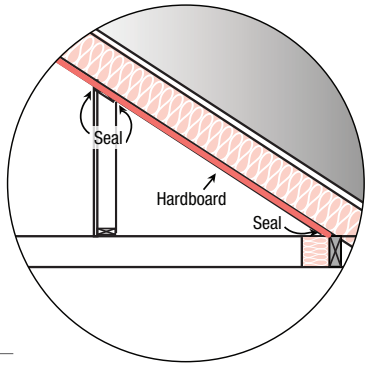


3 Wall & Ceiling Drywall

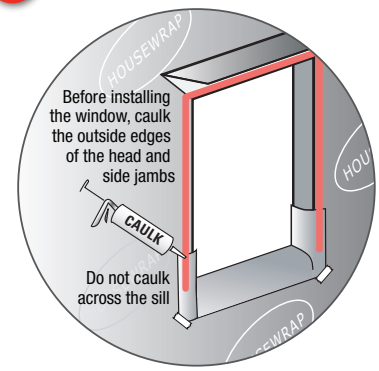


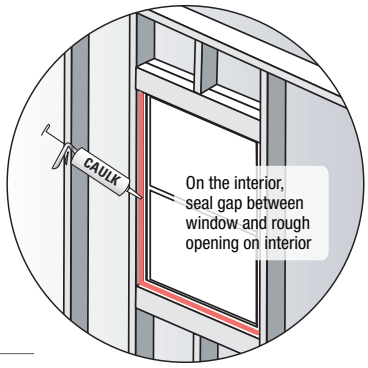
4 Kneewalls



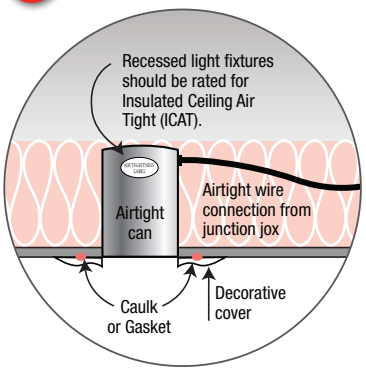


5 Windows

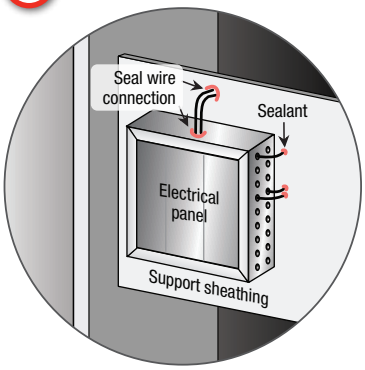




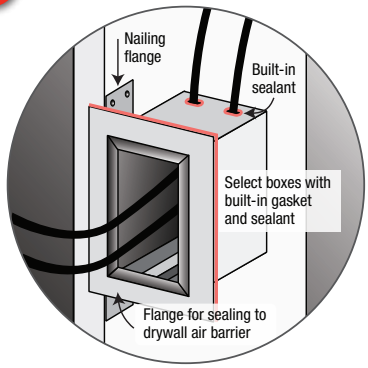
6 ICAT Can Light



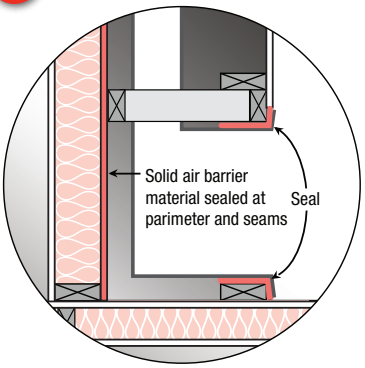
7 Electric Circuit Box



8 Outlets & Switches



9 Fireplace



Direct vent fireplace eliminates the chimney; but seal fireplace alcove

10 Plumbing Penetrations

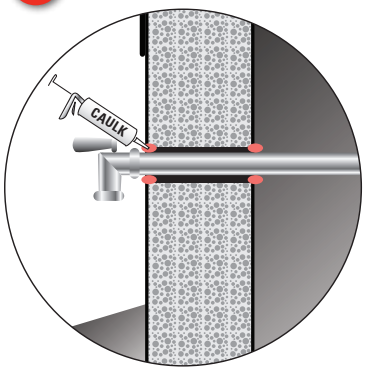
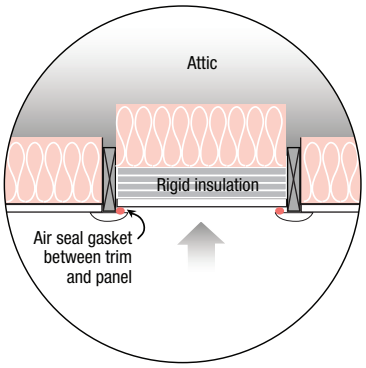
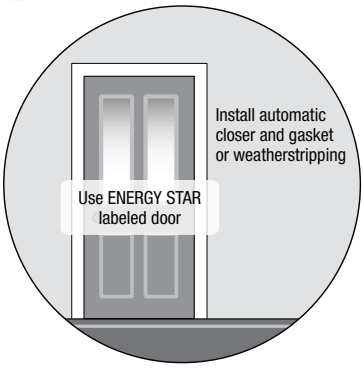


Figure 16.5. Conventional Interior Air Barrier – Details *(Continued)*

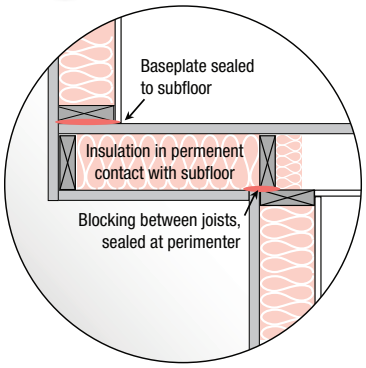
11 Attic Access



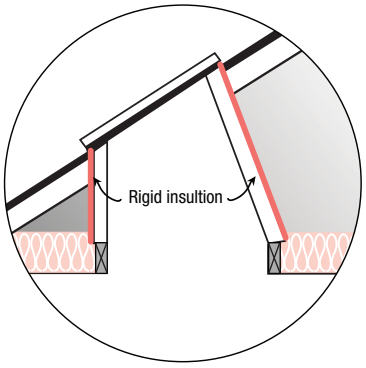
12 Doors



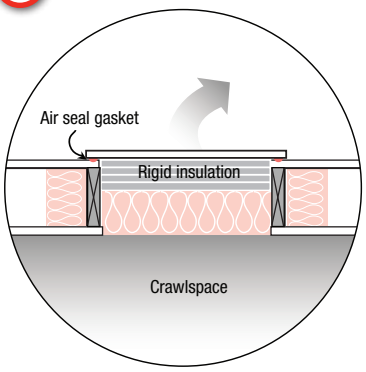
13 Cantilever



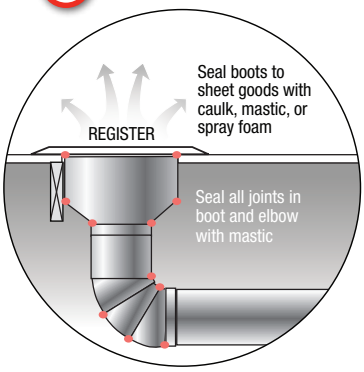
14 Skylight



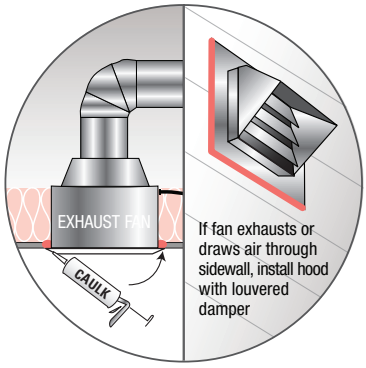
15 Crawlspace Access



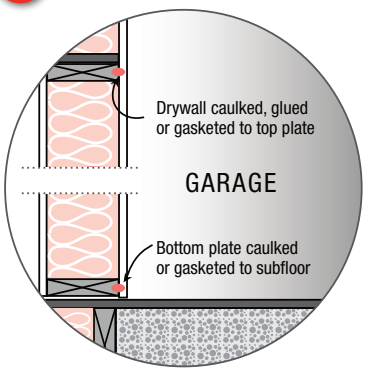
16 Registers



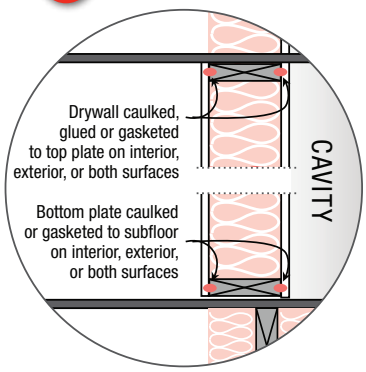
17 Exhaust Fan



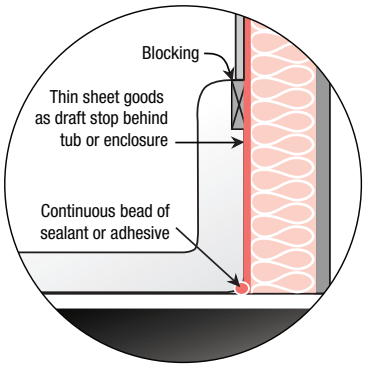
18 Garage Common Wall



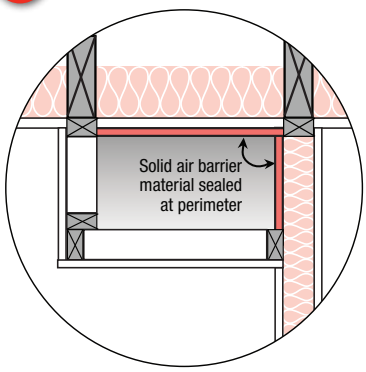
19 Wall Adjoining Cavity



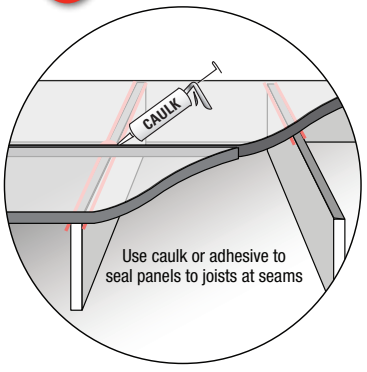
20 Tub



21 Interior Soffit



22 Plywood Floor Panels

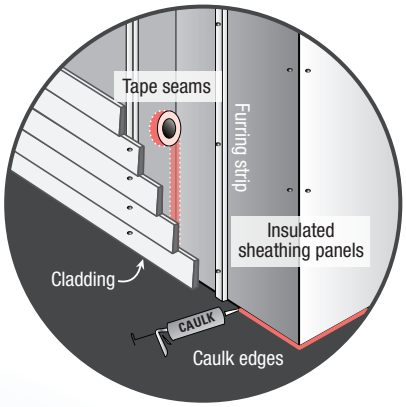


Air Barrier and Insulation Integrity

Figure 16.6. Exterior Air Barrier – This figure shows an approach to construction used in some Building America homes. Exterior insulated sheathing provides an air barrier for walls. The non-vented attic is sealed and insulated under the roof. Particular attention is paid to the intersection of foundations, walls, and the roof. Sealed combustion furnaces and water heaters do not require a vertical chimney. Insulated sheathing requires structural elements.

1. Sill Plate & Rim Joist
2. Windows
3. Plumbing Penetrations
4. Doors
5. Exhaust Fan
6. Garage Common Wall
7. Tub

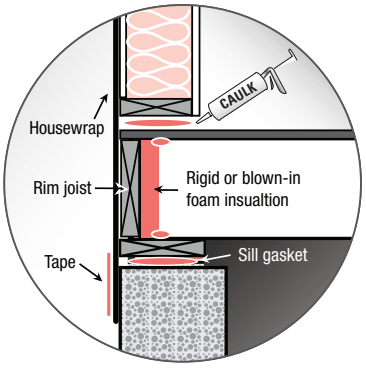
Insulated Sheathing Detail



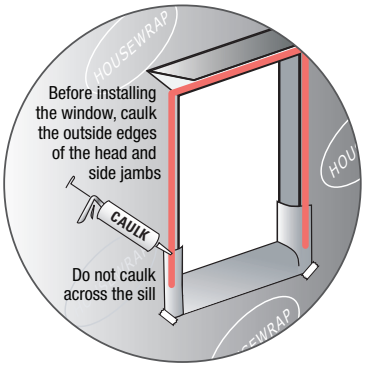
Air Barrier and Insulation Integrity

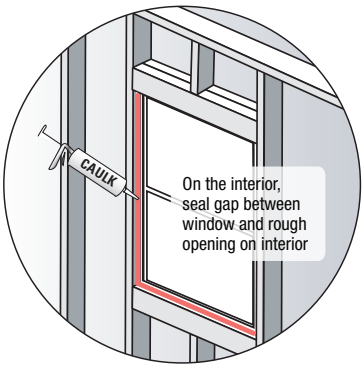
Figure 16.6. Exterior Air Barrier – Details

1 Sill Plate & Rim Joist

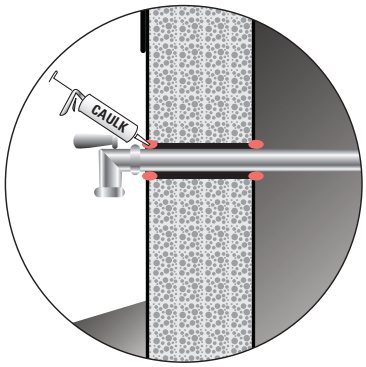


2 Windows

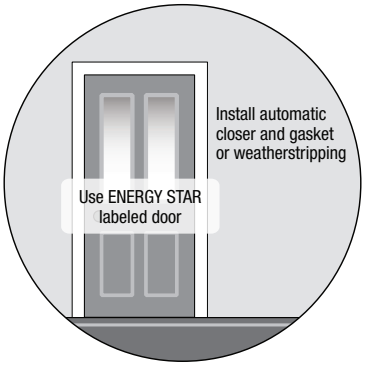




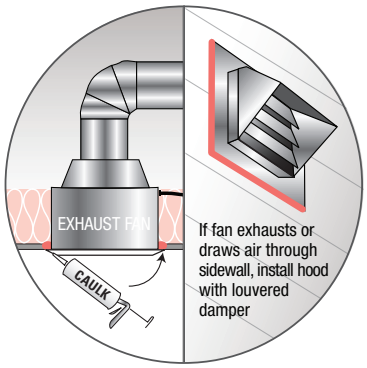
3 Plumbing Penetrations



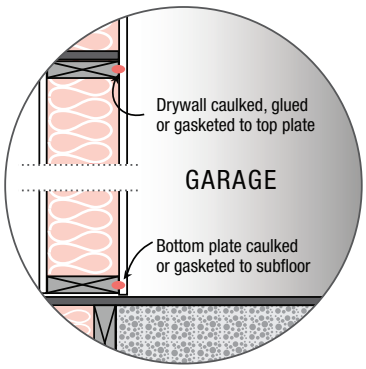
4 Doors



5 Exhaust Fan



6 Garage Common Wall



7 Tub

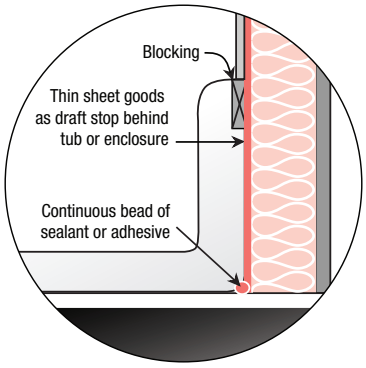


Figure 16.7. ENERGY STAR Qualified Homes Thermal Bypass Inspection Checklist

ENERGY STAR Qualified Homes Thermal Bypass Inspection Checklist

Home Address:_____ City:_____ State:_____

Thermal Bypass	Inspection Guidelines	Corrections Needed	Builder Verified	Rater Verified	N/A
1. Overall Air Barrier and Thermal Barrier Alignment	**Requirements:** Insulation shall be installed in full contact with sealed interior and exterior air barrier except for alternate to interior air barrier under item no. 2 *(Walls Adjoining Exterior Walls or Unconditioned Spaces)*				
	All Climate Zones:				
	1.1 Overall Alignment Throughout Home	☐	☐	☐	☐
	1.2 Garage Band Joist Air Barrier (at bays adjoining conditioned space)	☐	☐	☐	☐
	1.3 Attic Eave Baffles Where Vents/Leakage Exist	☐	☐	☐	☐
	Only at Climate Zones 4 and Higher:				
	1.4 Slab-edge Insulation (A maximum of 25% of the slab edge may be uninsulated in Climate Zones 4 and 5.)	☐	☐	☐	☐
	Best Practices Encouraged, Not Req'd.:				
	1.5 Air Barrier At All Band Joists (Climate Zones 4 and higher)	☐	☐	☐	☐
	1.6 Minimize Thermal Bridging (e.g., OVE framing, SIPs, ICFs)	☐	☐	☐	☐
2. Walls Adjoining Exterior Walls or Unconditioned Spaces	**Requirements:** • Fully insulated wall aligned with air barrier at both interior and exterior, **OR** • Alternate for **Climate Zones 1 thru 3**, sealed exterior air barrier aligned with RESNET Grade 1 insulation fully supported • Continuous top and bottom plates or sealed blocking				
	2.1 Wall Behind Shower/Tub	☐	☐	☐	☐
	2.2 Wall Behind Fireplace	☐	☐	☐	☐
	2.3 Insulated Attic Slopes/Walls	☐	☐	☐	☐
	2.4 Attic Knee Walls	☐	☐	☐	☐
	2.5 Skylight Shaft Walls	☐	☐	☐	☐
	2.6 Wall Adjoining Porch Roof	☐	☐	☐	☐
	2.7 Staircase Walls	☐	☐	☐	☐
	2.8 Double Walls	☐	☐	☐	☐
3. Floors between Conditioned and Exterior Spaces	**Requirements:** • Air barrier is installed at any exposed fibrous insulation edges • Insulation is installed to maintain permanent contact with sub-floor above including necessary supports (e.g., staves for blankets, netting for blown-in) • Blanket insulation is verified to have no gaps, voids or compression. • Blown-in insulation is verified to have proper density with firm packing				
	3.1 Insulated Floor Above Garage	☐	☐	☐	☐
	3.2 Cantilevered Floor	☐	☐	☐	☐
4. Shafts	**Requirements:** Openings to unconditioned space are fully sealed with solid blocking or flashing and any remaining gaps are sealed with caulk or foam (provide fire-rated collars and caulking where required)				
	4.1 Duct Shaft	☐	☐	☐	☐
	4.2 Piping Shaft/Penetrations	☐	☐	☐	☐
	4.3 Flue Shaft	☐	☐	☐	☐
5. Attic/ Ceiling Interface	**Requirements:** • All attic penetrations and dropped ceilings include a full interior air barrier aligned with insulation with any gaps fully sealed with caulk, foam or tape • Movable insulation fits snugly in opening and air barrier is fully gasketed				
	5.1 Attic Access Panel (fully gasketed and insulated)	☐	☐	☐	☐
	5.2 Attic Drop-down Stair (fully gasketed and insulated)	☐	☐	☐	☐
	5.3 Dropped Ceiling/Soffit (full air barrier aligned with insulation)	☐	☐	☐	☐
	5.4 Recessed Lighting Fixtures (ICAT labeled and sealed to drywall)	☐	☐	☐	☐
	5.5 Whole-house Fan (insulated cover gasketed to the opening)	☐	☐	☐	☐
6. Common Walls Between Dwelling Units	**Requirements:** Gap between drywall shaft wall (i.e., common wall) and the structural framing between units is fully sealed at all exterior boundary conditions				
	6.1 Common Wall Between Dwelling Units	☐	☐	☐	☐

Home Energy Rating Provider: _____ Rater Inspection Date: _____ Builder Inspection Date: _____

Home Energy Rater Company Name: _____ Builder Company Name: _____

Home Energy Rater Signature: _____ Builder Employee Signature: _____

Posted 06/02/08

17 REQUIRED

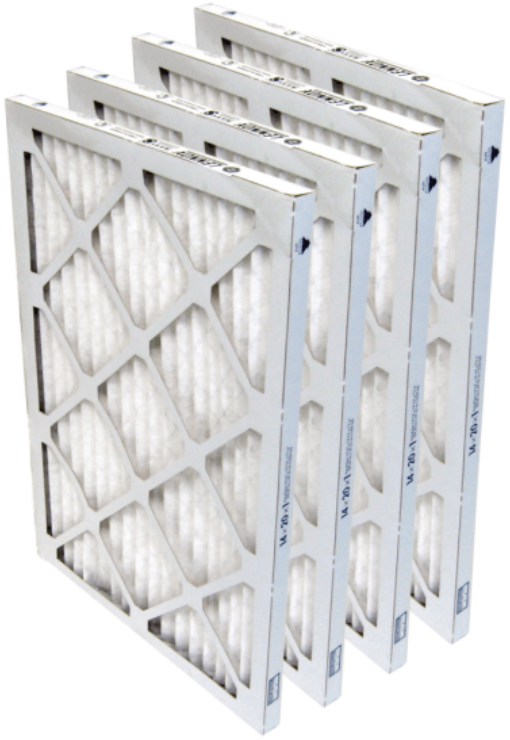
Filtration

BUILDERS CHALLENGE QUALITY CRITERIA	BUILDER DOCUMENTATION & VERIFICATION REQUIREMENTS	THIRD-PARTY VERIFICATION REQUIREMENTS
17. Filtration – Required: Equip the central air handler(s) with a MERV 8 filter or higher. Account for the associated pressure drop from the filter in the design and sizing of the duct work.		Verify the installation of a MERV 8 or higher filter.

For improved indoor air quality in forced air heating, cooling, and ventilation systems, the heating or air conditioning return air stream should be filtered with a 4-inch-thick standard filter or a new MERV 8 normal-thickness filter (MERV stands for Minimum Efficiency Reporting Values). Ventilation air should also pass through this filter, if possible. Filters should be easily accessible for cleaning or replacement and the filter slot should be designed so that there is no air bypass around the filter when the HVAC system is operating.

Provide instructions for filter maintenance to home occupants.

Figure 17.1. MERV 8 air filter



Want to Learn More?

"Understanding MERV Ratings," available online at www.furnacefiltercare.com/merv-ratings.php

"MERV-Filter Efficiency Simplified", available online at www.filterair.info/articles/article.cfm/ArticleID/7AF95A61-EAF8-4C90-BFA98EE04B0DD02B

Related Standards & Procedures

ASHRAE Standard 52.2-2007, "Method of Testing General Ventilation Air-Cleaning Devices for Removal Efficiency by Particle Size," available from ASHRAE's bookstore www.ashrae.org

Building America Best Practices

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18 REQUIRED

Combustion Safety

BUILDERS CHALLENGE QUALITY CRITERIA	BUILDER DOCUMENTATION & VERIFICATION REQUIREMENTS	THIRD-PARTY VERIFICATION REQUIREMENTS
18. Combustion Safety – Required Fossil fuel-fired furnaces or water heaters installed in conditioned spaces must be sealed combustion, direct vented, or power-vented units.		Verify that combustion-based furnaces and water heaters are direct vented or power vented, if installed in conditioned space.

Do not install atmospheric (standard efficiency) gas heaters and water heaters in conditioned space including laundry rooms. These devices are recognizable by the high and low combustion air inlets in the combustion area and the "hat" or "skirt" around the bottom of the flue (where it meets the furnace or water heater). These devices depend on the stack effect to establish exhaust draft, but the stack effect can be easily overcome by dryers, exhaust fans, or supply duct leakage (which depressurizes the house), causing back drafting of exhaust gases.

Carbon monoxide is a byproduct of incomplete combustion, which becomes more common as a piece of equipment ages than at the beginning of service. In all homes with combustion appliances or attached garages, steps must be taken to prevent accidental death by carbon monoxide poisoning.

With the tight house construction of Builder Challenge homes, all combustion appliances in the conditioned space must be sealed combustion or power-vented. Any water heater inside conditioned space shall be power vented or direct vented. Designs that incorporate passive combustion air supply openings or outdoor supply air ducts not directly connected to the appliance should be avoided. Water heaters should be either 1) power vented, which forcibly discharges the products of combustion in the exhaust and draws combustion air from the house, 2) direct vented, which passively direct air to the outside through short exhaust runs, while bringing in dedicated outside air for combustion, or 3) sealed combustion units that draw combustion air from outdoors and use fans to discharge combustion gasses to the outdoors.

Related Quality Criteria

See ***Criteria 19. Carbon Monoxide*** all related to ducts, ventilation, and dehumidification and carbon monoxide detector.

Want to Learn More?

U.S. Department of Energy. 2000. "Combustion Equipment Safety," DOE Fact Sheet, May 2000. DOE/GO 10099-784. www.earthcrafthouse.com/documents/factsheets/CES-Combustion-Safety%2000-784.pdf

U.S. Department of Energy. "The House as a System: Combustion Safety." www.eere.energy.gov/buildings/building_america/pdfs/db/31046.pdf

American Lung Association. Health House Tipsheet on Backdrafting at www.healthhouse.org/tipsheets/TS_backdrafting.pdf

U.S. Environmental Protection Agency. "Indoor Air Quality Carbon Monoxide Fact Sheet" available at www.epa.gov/iaq/co.html

U.S. Environmental Protection Agency. 2009. *Indoor airPLUS Construction Specifications*, available at www.epa.gov/indoorairplus/index.html

Related Standards & Procedures

"Combustion Safety Test Procedure for Vented Appliances," Building Performance Institute, Inc., 4/07. www.bpi.org/documents/Gold_Sheet.pdf

Building America Best Practices

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19 REQUIRED

Carbon Monoxide

BUILDERS CHALLENGE QUALITY CRITERIA	BUILDER DOCUMENTATION & VERIFICATION REQUIREMENTS	THIRD-PARTY VERIFICATION REQUIREMENTS
19. Carbon Monoxide – Required For homes with combustion appliance(s) or an attached garage, install at least one carbon monoxide (CO) alarm in a central location outside of each separate sleeping area in the immediate vicinity of the bedrooms. Place them according to NFPA 720 or manufacturers' recommendations. They must be hard-wired with a battery back-up function. The alarm devices shall be certified by either CSA 6.19-01 or UL 2034.		Verify the installation of a CO alarm.

Carbon monoxide detectors (hard-wired units) shall be installed (at one per every approximate 1,000 square feet) in a central location outside of each separate sleeping area in any house containing combustion appliances and/or an attached garage.

Of course, no one intends for carbon monoxide to be introduced into the house. When it does occur, it is usually the result of an unintentional air flow pattern that draws combustion exhaust into the conditioned space. Cars should never be run with the garage door closed. Gas water heaters and standard efficiency furnaces should never be run in a space with negative air pressure; however, these conditions do sometimes occur unpredictably so the builder should provide hard-wired CO detectors to alert occupants that carbon monoxide is present. Builders should provide home owners with guidance on what to do if the CO detector alarm sounds, for example, implementing an action plan that advises occupants that a potentially life-threatening condition has occurred, to open windows and doors, turn off combustion appliances, leave the house, and go to a hospital if anyone is experiencing symptoms.

Related Quality Criteria

See guidance and references for ***Criteria 18. Combustion Safety***.

Want to Learn More?

"Carbon Monoxide Alarms," Canadian Standards Association, www.csa-international.org/consumers/consumer_tips/default.asp?language=English&load=carbon_monoxide

"UL 2034 History – CO Alarms," International Code Council, Inc., May 4, 2005. www.iccsafe.org/cs/cc/ctc/CO/CO_UL2034History.pdf

The American Lung Association's Health House tipsheet on carbon monoxide at www.healthhouse.org/tipsheets/TS_CarbonMonoxide.pdf

U.S. Environmental Protection Agency. 1996. "Protect Your Family and Yourself From Carbon Monoxide Poisoning." EPA-402-F-96-005, www.epa.gov/iaq/pubs/coftsht.html

Related Standards & Procedures

Canadian Standards Association CSA 6.19-01, Residential Carbon Monoxide Alarming Devices. www.csa-intl.org/onlinestore/GetCatalogItemDetails.asp?mat=000000000002414612

UL 2034 Standard for Single and Multiple Station Carbon Monoxide Alarms, Edition 2, October 29, 1996. http://ulstandardsinfonet.ul.com/tocs/tocs.asp?doc=s&fn=2034.toc

NFPA 720: Standard for the Installation of Carbon Monoxide (CO) Warning Equipment in Dwelling Units. www.nfpa.org/aboutthecodes/AboutTheCodes.asp?DocNum=720&Cookie%5Ftest=1

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20 RECOMMENDED

Carbon Monoxide

BUILDERS CHALLENGE QUALITY CRITERIA	BUILDER DOCUMENTATION & VERIFICATION REQUIREMENTS	THIRD-PARTY VERIFICATION REQUIREMENTS
20. Carbon Monoxide – Recommended For all homes, install at least one carbon monoxide (CO) alarm in a central location outside of each separate sleeping area in the immediate vicinity of the bedrooms. Place them according to NFPA 720. They must be hard-wired with a battery back-up function. The alarm devices shall be certified by either CSA 6.19-01 or UL 2034.		Verify the installation of a CO alarm.

This guideline recommends that all homes be equipped with a CO monitor, even those without an attached garage or combustion appliance currently installed. This is to provide protection for occupants should a combustion appliance be installed at some point in the future.

Want to Learn More?

"Carbon Monoxide Alarms," Canadian Standards Association, www.csa-international.org/consumers/consumer_tips/default.asp?language=English&load=carbon_monoxide

"UL 2034 History – CO Alarms," International Code Council, Inc., May 4, 2005. www.iccsafe.org/cs/cc/ctc/CO/CO_UL2034History.pdf

The American Lung Association's Health House tipsheet on carbon monoxide at www.healthhouse.org/tipsheets/TS_CarbonMonoxide.pdf

Related Standards & Procedures

Canadian Standards Association CSA 6.19-01, Residential Carbon Monoxide Alarming Devices. www.csa-intl.org/onlinestore/GetCatalogItemDetails.asp?mat=000000000002414612

UL 2034 Standard for Single and Multiple Station Carbon Monoxide Alarms, Edition 2, October 29, 1996. http://ulstandardsinfonet.ul.com/tocs/tocs.asp?doc=s&fn=2034.toc

NFPA 720: Standard for the Installation of Carbon Monoxide (CO) Warning Equipment in Dwelling Units. www.nfpa.org/aboutthecodes/AboutTheCodes.asp?DocNum=720&Cookie%5Ftest=1

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21
RECOMMENDED

Garage Exhaust Ventilation

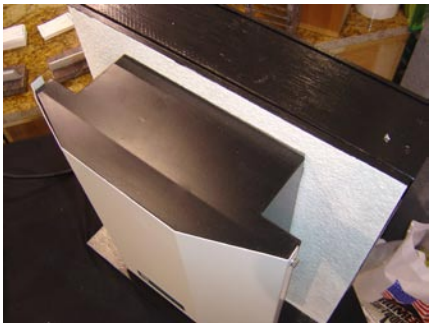
BUILDERS CHALLENGE QUALITY CRITERIA	BUILDER DOCUMENTATION & VERIFICATION REQUIREMENTS	THIRD-PARTY VERIFICATION REQUIREMENTS
21. Garage Exhaust Ventilation – Recommended: Ventilate attached garages with a 100 cfm (ducted) or 80 cfm (un-ducted) exhaust fan, venting to outdoors and designed for continuous operation. Alternatively, automatic fan controls may be installed that activate the fan whenever garage is occupied, and for at least 1 hour after garage is vacated.	Include in construction plans and contractors' work scopes	

Ventilate attached garages with a 100 cfm (ducted) or 80 cfm (un-ducted) exhaust fan, venting to outdoors and designed for continuous operation. Alternatively, automatic fan controls may be installed that activate the fan whenever the garage is occupied, and for at least 1 hour after the garage is vacated.

For occupant health and safety, pay close attention to sealing shared walls and ceilings between attached garages and living spaces.

One of the most potentially hazardous indoor air quality problems arises when return ducts run through garage spaces where the opportunity exists to draw CO from automobile exhausts or other pollutants from hazardous chemicals often stored in the garage into the duct system and redistribute it throughout the house. Locating the HVAC unit in the garage is not recommended in the 30% improved houses, but it is not always possible to relocate the air-handling unit. For air handlers that are located in the garage the recommended solution is to enclose the handler in an insulated sealed closet. Any return-air ductwork and the air handler should be thoroughly sealed with UL 181-approved mastic, with a target leakage between the duct system and the garage of 0 cfm @25Pa. This will almost completely eliminate the possibility of bringing garage air into the supply or return system.

Figure 21.1. This exhaust fan and electronic controls are designed to ventilate—and could be used to create a slightly negative pressure in—the garage. Ventilation carries pollutants to the outside, negative pressure helps to stop garage air from migrating into attached houses.



Related Quality Criteria

See ***Criteria 16. Air Barrier and Insulation Integrity***.

Want to Learn More?

"Five Steps to a Healthier Garage". http://web.extension.uiuc.edu/will/factsheets/family116.html

ENERGY STAR Thermal Bypass Checklist Guide, 2008, available at www.energystar.gov/ia/partners/bldrs_lenders_raters/downloads/TBC_Guide_062507.pdf, pg. 13

Florida Solar Energy Center. 2007. "Indoor Air Quality," available at www.fsec.ucf.edu/en/consumer/buildings/homes/airqual.htm

U.S. Environmental Protection Agency. 2007. The Inside Story: A Guide to Indoor Air Quality, EPA 402-K-93-007, available at www.epa.gov/iaq/pubs/insidest.html

U.S. Environmental Protection Agency. 2009. *Indoor airPLUS Construction Specifications*, available at www.epa.gov/indoorairplus/index.html

Related Standards & Procedures

ASHRAE Standard 62.2-2007 *Ventilation for Acceptable Indoor Air Quality in Low-Rise Residential Buildings* can be previewed from www.ashrae.org/technology/page/548

Building America Best Practices

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22
REQUIRED

Air Handler Location

BUILDERS CHALLENGE QUALITY CRITERIA	BUILDER DOCUMENTATION & VERIFICATION REQUIREMENTS	THIRD-PARTY VERIFICATION REQUIREMENTS
22. Air Handler Location – Required: Central air handler(s) is isolated from the garage by a thermal barrier and an air barrier.		Verify air handler location.

Air handlers and ducts perform best when placed within conditioned space. Keeping air handlers and ducts inside conditioned space typically impacts architectural design and should be considered early in the design process. Strategies may include the following:

- Locate air handler and ducts within an insulated, non-vented, conditioned crawl space or basement.
- Locate air handler and ducts within an insulated "cathedralized" attic.
- Design a closet inside the conditioned space for locating the air handler inside the house.
- Design a sealed mechanical closet in the garage for locating the air handler.
- Ensure the air handler closet is well air-sealed from the garage.

Related Quality Criteria

See guidance and references for ***Criteria 21. Garage Exhaust Ventilation*** and ***Criteria 16. Air Barrier and Insulation Integrity.***

Figure 22.1. This air handler closet is carved out of the garage space but is isolated with thermal and air barriers.

Figure 22.2. An alternative to a closet located in the garage is an in-house location. *(Photo courtesy of FSEC)*

Want to Learn More?

"Five Steps to a Healthier Garage". http://web.extension.uiuc.edu/will/factsheets/family116.html

ENERGY STAR Thermal Bypass Checklist Guide, 2008, available at www.energystar.gov/ia/partners/bldrs_lenders_raters/downloads/TBC_Guide_062507.pdf, pg. 13

Related Standards & Procedures

2006 International Energy Conservation Code, Section 403.2.2 "Sealing," International Code Council (ICC), Falls Church, Virginia. "All ducts, air handlers, filter boxes, and building cavities used as ducts shall be sealed." Available for purchase at www.iccsafe.org/dyn/prod/3810S06.html.

Building America Best Practices

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Building America U.S. Department of Energy Research Toward Zero Energy Homes | Builders Challenge Recognizing Energy Leadership in Homebuilding

23
REQUIRED

Building Envelope Moisture Management – Field Verification

BUILDERS CHALLENGE QUALITY CRITERIA	BUILDER DOCUMENTATION & VERIFICATION REQUIREMENTS	THIRD-PARTY VERIFICATION REQUIREMENTS
23. Building Envelope Moisture Management – Field Verification – Required: Flashing details, foundation details, vapor barrier selection, and water drainage space details noted in "Building Envelope Moisture Management" are installed per construction plans and specifications.	Builder documents that measures were implemented with a checklist or other written documentation kept in builder's project records.	Verify that builder has written documentation of implementation.

Moisture control measures are described in Quality Criteria 2. Field verification of the proper installation of these measures will require multiple inspections with each of the trade contractors involved at the various stages of construction. For example, foundation management measures are likely to be installed by the concrete trades contractor, but the wall sheathing and drainage plane systems will be installed by framers, siders, or specialized contractors. We encourage builders to develop pre-job and post-job checklists as described in Quality Criteria 1 to use with their trade contractors in verifying that all moisture management practices are properly installed.

Related Quality Criteria

See guidance and references for ***Criteria 2. Building Envelope Moisture Management – Design Phase***.

Want to Learn More?

Lstiburek, Joseph. 2003. *EEBA Water Management Guide*, available for sale on line at: www.eeba.org/bookstore.

Straube, John. 2001 "Wrapping it Up," *Canadian Architect*. May 2001. www.cdnarchitect.com

IBACOS. 2002. "Moisture Issues in Homes with Brick Veneer" article available at www.eere.energy.gov/buildings/building_america/pdfs/db/36397.pdf

Related Standards & Procedures

FMA/AAMA 100-07. "Standard Practice for the Installation of Windows with Flanges or Mounting Fins in Wood Frame Construction." Available from AAMA's online store at www.aamanetstore.org/pubstore/ProductResults.asp

ASTM E-2112-07. "Standard Practice for Installation of Exterior Windows, Doors and Skylights." Available from ASTM at www.astm.org/Standards/E2112.htm

2006 International Energy Conservation Code, International Code Council (ICC), Falls Church, Virginia. Available for purchase at www.iccsafe.org/dyn/prod/3810S06.html.

Building America Best Practices

The U.S. Department of Energy has produced a series of builders guides that provide instructions for construction "best practices" that can help builders achieve high-performance homes. These guides can be found at www.eere.energy.gov/buildings/building_america/

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24 RECOMMENDED

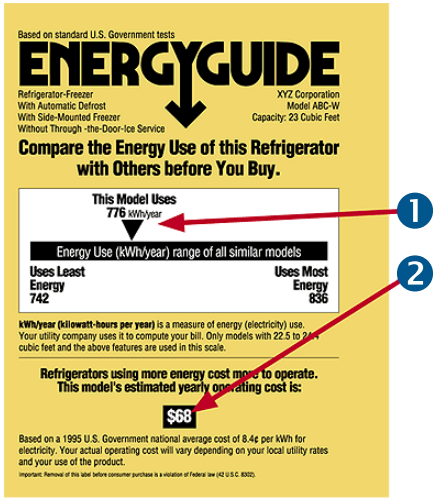
ENERGY STAR Equipment

BUILDERS CHALLENGE QUALITY CRITERIA	BUILDER DOCUMENTATION & VERIFICATION REQUIREMENTS	THIRD-PARTY VERIFICATION REQUIREMENTS
24. ENERGY STAR Equipment – Recommended: For equipment included in the sale of the home, use ENERGY STAR qualified appliances and equipment (including HVAC systems).		Verify that appliances are ENERGY STAR-qualified, if included in sale of home.

When it comes to shopping for energy-efficient appliances and home electronics, look for the ENERGY STAR label. The ENERGY STAR label identifies products that have been tested to meet energy efficiency and performance criteria. Building America recommends using best-in-class products for appliance categories that are not currently rated by ENERGY STAR.

The EnergyGuide label can also be a helpful source of information for comparing energy-using products and appliances. The Federal Trade Commission requires EnergyGuide labels on most home appliances (except for stove ranges and ovens), but not home electronics, such as computers, televisions, and home audio equipment. EnergyGuide labels provide an estimate of the product's energy consumption or energy efficiency. They also show the highest and lowest energy consumption or efficiency estimates of similar appliance models.

Figure 24.2. The EnergyGuide Label Helps Consumers Compare the Energy Efficiency of Appliances.



❶ Estimated energy consumption on a scale showing a range for similar models

❷ Estimated yearly operating cost based on the national average cost of electricity.

Figure 24.3. A Refrigerator Labeled with both the ENERGY STAR Label and the Energy Guide Label.

Figure 24.1. The ENERGY STAR Label

Want to Learn More?

ENERGY STAR
www.energystar.gov

Energy Efficient Windows
www.efficientwindows.org/energystar.cfm

SRP. "Energy Guide Labels help you compare,"
www.srpnet.com/energy/energyguide.aspx

California Energy Commission Consumer Energy Center "EnergyGuide," available at www.consumerenergycenter.org/home/appliances/energyguide.html

Related Standards & Procedures

ENERGY STAR
www.energystar.gov

Building America Best Practices

The U.S. Department of Energy has produced a series of builders guides that provide instructions for construction "best practices" that can help builders achieve high-performance homes. These guides can be found at www.eere.energy.gov/buildings/building_america/

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25 RECOMMENDED

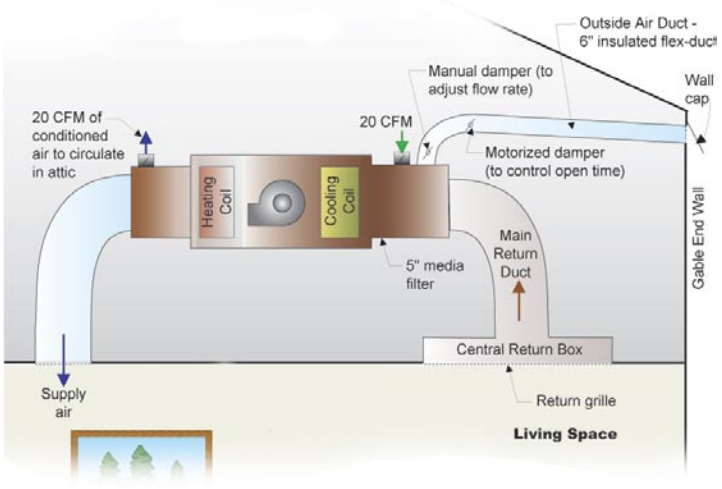
Whole Building Mechanical Ventilation II

BUILDERS CHALLENGE QUALITY CRITERIA	BUILDER DOCUMENTATION & VERIFICATION REQUIREMENTS	THIRD-PARTY VERIFICATION REQUIREMENTS
25. Whole Building Mechanical Ventilation II – Recommended: Install a whole building mechanical ventilation system complying with the requirements of ASHRAE 62.2-2007. Whole building ventilation systems may consist of an exhaust system, supply system, or balanced system, and must be capable of providing the outside air rates specified in Standard 62.2-2007. Refer to Section 6.4 of ASHRAE 62.2-2007 "Combustion and Solid-Fuel Burning Appliances" for information on providing for adequate combustion air for combustion appliances. (Also see QC Provision: Whole Building Mechanical Ventilation I – which is a required measure).	Include mechanical plans which include systems for whole building MV in project records.	

Building America recommends that all new homes be equipped with whole-house mechanical ventilation that complies with ASHRAE 62.2. Mechanical ventilation systems for indoor air quality include exhaust–only fans, systems that supply outside air, and systems that do both.

Most of the Building America teams have designed and field-tested ventilation systems that bring outside air to the home's central air handler. The systems involve exterior air intakes, ductwork running to the return air side of the HVAC system, dampers to allow control of the air intake, and electronic controls to ensure that the HVAC fan operates frequently enough to draw in adequate outside air and to time the operation of a motorized damper. Advantages to these systems are that the fresh air volume can be adjusted to meet ASHRAE 62.2 requirements, outside air is filtered, and fresh air is delivered to every space. One such system was estimated to cost $260 in 2005.

Figure 25.1. Example of a central fan-integrated supply ventilation system



Source: Building Science Consortium

Want to Learn More?

Russell, M., M. Sherman, A. Rudd. 2005. *Review of Residential Ventilation Technologies.* LBNL 57730. Ernest Orlando Lawrence Berkeley National Laboratory, Berkeley, CA.

Rudd, Armin. 2006. *Ventilation Guide.* Building Science Press Inc., Energy & Environmental Building Association, Minneapolis, MN, available for purchase at www.eeba.org/bookstore/default.asp.

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Whole Building Mechanical Ventilation II

Continuously operating an exhaust fan located in a bathroom or central area of the house provides a lower cost solution. High-quality, efficient fans are typically used for this application. Because exhaust fans draw air from leaks in the building envelope, air is not filtered and may not be evenly distributed. In 2005, costs for this type of system were estimated at $145 (cost estimates from Russell, Sherman, and Rudd 2005).

Rather than an isolated exhaust fan, another example is to tie all bathroom exhaust ducts together and route them through a single, continuously operating, high-efficacy axial fan that is vented to the exterior.

Related Quality Criteria

See guidance and references for ***Criteria 11. Whole Building Mechanical Ventilation I***.

Related Standards & Procedures

ASHRAE Standard 62.2-2007 *Ventilation for Acceptable Indoor Air Quality in Low-Rise Residential Buildings* can be previewed from www.ashrae.org/technology/page/548

Building America Best Practices

The U.S. Department of Energy has produced a series of builders guides that provide instructions for construction "best practices" that can help builders achieve high-performance homes. These guides can be found at www.eere.energy.gov/buildings/building_america/

26
RECOMMENDED

Pressure Balancing

BUILDERS CHALLENGE QUALITY CRITERIA	BUILDER DOCUMENTATION & VERIFICATION REQUIREMENTS	THIRD-PARTY VERIFICATION REQUIREMENTS
26. Pressure Balancing – Recommended: All rooms in the conditioned space of the home do not exceed +/- 3 Pascals pressure difference relative to the central (open) areas of the home, when interior doors are closed and the central air handler is operating. Powder rooms and laundry rooms are exempt. OR Return ducts or transfer grilles are installed in every room with a door to which conditioned air is supplied, except for bathrooms, closets, pantries, and laundry rooms.	Pressure testing record is kept in builder's project records (if measure is implemented)	

Testing and balancing of HVAC systems helps to ensure even air pressure throughout a building. Pressure imbalances may cause air movement through the envelope when the HVAC system is operating, wasting energy and potentially causing moisture problems. Imbalanced airflows can also cause excessive room-to-room or floor-to-floor temperature differences, leading to comfort complaints. Imbalanced airflows can draw unwanted pollutants, including humid air, into the house, causing indoor air-quality problems.

Florida code, for example, requires that the differences in static pressure between any two rooms remain below 2.5 pascals at all times.

One key factor in eliminating excessive room-to-room and indoor-to-outdoor pressure imbalances is the adequacy of the return air path to the air handler. In homes with individual-room ducted returns, this is generally

Figure 26.1. Jump ducts

Photo courtesy of IBACOS

Want to Learn More?

Building Science Consortium. *Sizing Heating, Cooling and Ventilation Ducts, Trunks, and Runouts for Energy Efficient Housing*. BSP-050. www.buildingscience.com

The Building Science Consortium has produced a number of design guides with titles such as "Designs that Work," and "Houses that Work." Each of these guides contains a section on duct design and air flow that describes the use of jump ducts and transfer grilles.

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Pressure Balancing

not a problem. Individual-room ducted return systems were common in colder climates, but are losing favor because of their costs. From a cost-effectiveness standpoint, a well-designed central return system with individual room pressure relief is considered the best approach.

A well-designed return system must incorporate adequate relief from each room where entry doors may be closed. Return air recommendations include the use of ceiling "jump ducts," or transfer grilles located in the walls. Door under-cuts are generally not considered to be acceptable because they are often too small and/or are blocked by the installation of carpeting. One important consideration in the installation of "jump ducts" or transfer grilles is to maintain sound separation between spaces. Sound transmission can be controlled by the use of flex duct, duct lining with sound-absorbent material, a slightly circuitous path, or some combination of these strategies.

Related Quality Criteria

See guidance and references for ***Criteria 15. Duct Leakage***.

Related Standards & Procedures

Associated Air Balance Council. *AABC National Standards for Total System Balance 2002.*
www.aabchq.com/resources/national.aspx

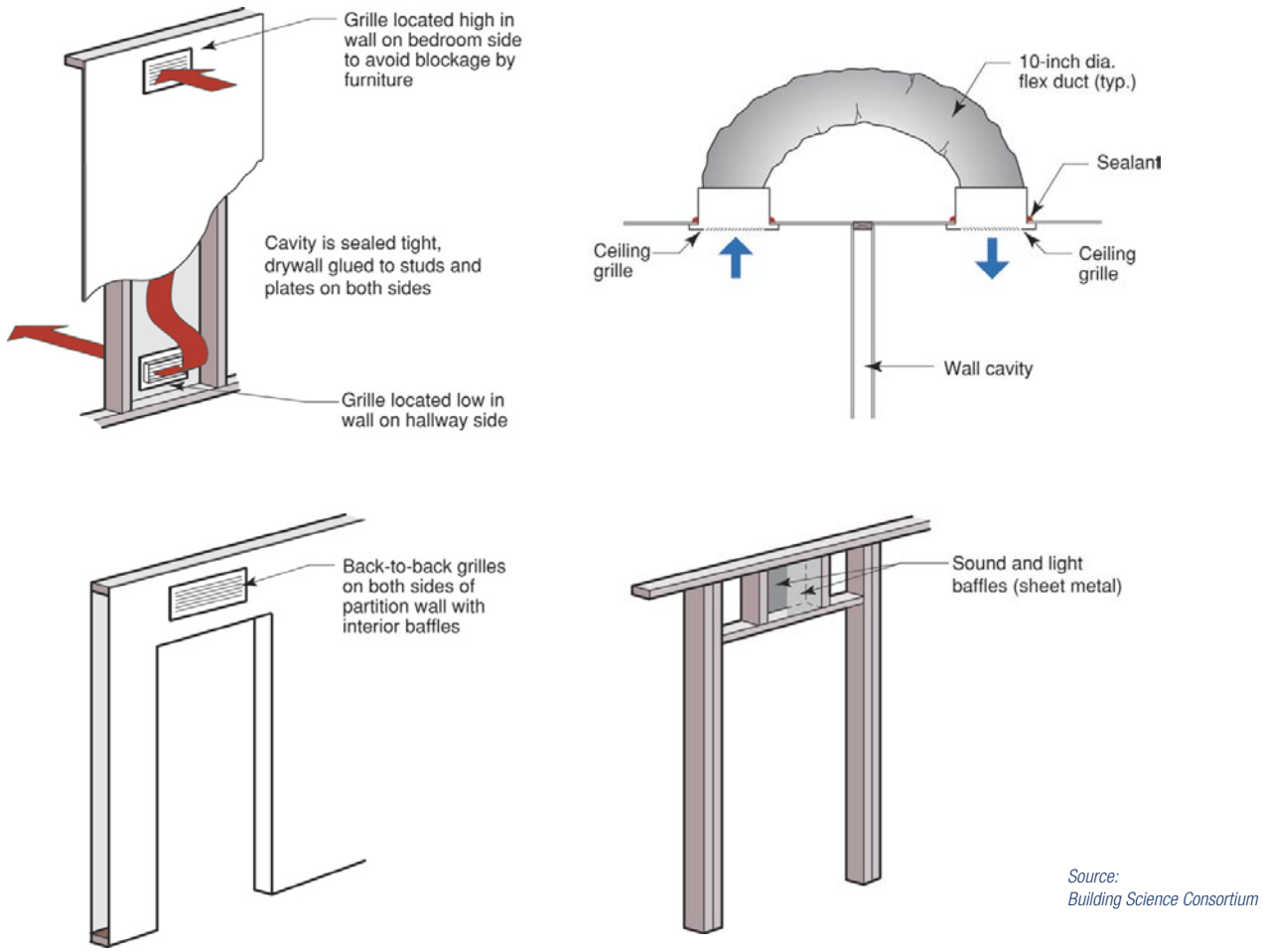
National Environmental Balancing Bureau, (NEBB)
Section 15990 - Testing, Adjusting, and Balancing.
www.nebb.org/tabspec.htm

Florida Building Code
www.floridabuilding.org

Building America Best Practices

The U.S. Department of Energy has produced a series of builders guides that provide instructions for construction "best practices" that can help builders achieve high-performance homes. These guides can be found at www.eere.energy.gov/buildings/building_america/

Figure 26.2. Jump ducts or transfer grilles provide air pressure balancing between rooms.



Source: Building Science Consortium

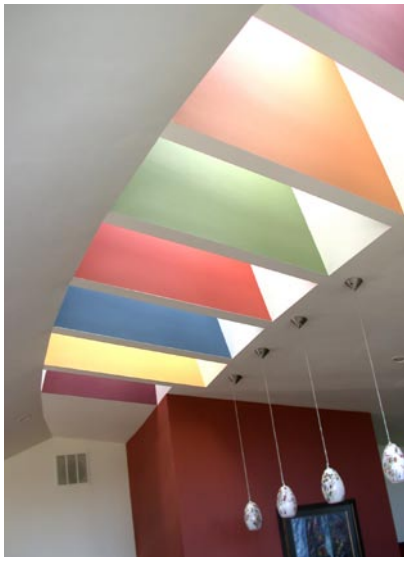
27
RECOMMENDED

Low VOC Interior Coatings

BUILDERS CHALLENGE QUALITY CRITERIA	BUILDER DOCUMENTATION & VERIFICATION REQUIREMENTS	THIRD-PARTY VERIFICATION REQUIREMENTS
27. Low VOC Interior Coatings – Recommended: Paints, coatings, and primers applied to interior walls and ceilings have VOC levels of no more than 50 g/L (flats) or 150 g/L (non-flats). *(reference LEED for Homes MR Credit 2.2)*	Keep specifications in project record	

Finishes such as paints, sealers, adhesives, fabrics, and surface-covering roll goods (i.e., vinyl wall coverings) are all potential sources of indoor air pollutants, including various volatile organic compounds (VOCs). Most of the liquid-applied materials dissipate rather rapidly as they dry. Leaving windows open as they are applied removes the high initial concentrations of the VOCs. After this initial "dry-out" period, a properly designed ventilation system will continue to bring in fresh air and remove further off-gassing of pollutants. Some organizations offer recycled paint, which may or may not be low-VOC paint.

Figure 27.1. This Building America home used low VOC paints and finishes throughout to meet local green building guidelines.



Related Quality Criteria

See *Criteria 11. Whole Building Mechanical Ventilation I*, *Criteria 25. Whole Building Mechanical Ventilation II*, *Criteria 28. Low VOC Adhesives*, and *Criteria 29. Low Emission Cabinets*.

Want to Learn More?

U.S. Green Building Council LEED for Homes website: www.usgbc.org/LEED/homes/

GREENGUARD Environmental Institute's guide to third-party certified low-VOC-emitting interior products at www.greenguard.org

The Carpet and Rug Institute's "Green Label" program at www.carpet-rug.com/drill_down_2.cfm?page=8&sub=4&requesttimeout=350

"A Word About VOCs," www.concretenetwork.com/concrete/finished_basements/a_word_about_vocs.htm

National Home Builders Association (NAHB) Green Building Program website: nahbgreen.org

Related Standards & Procedures

U.S. Green Building Council. LEED for Homes. January 2008. www.greenhomeguide.org/documents/leed_for_homes_rating_system.pdf

U.S. Environmental Protection Agency. EPA's Environmentally Preferable Purchasing Program, www.epa.gov/epp/

California Air Resource Board (CARB), "Regulation for Reducing Volatile Organic Compound Emissions from Consumer Products," available online at www.arb.ca.gov/consprod/regs/cp.pdf

Masco Home Services. Environments for Living Program Services. www.environmentsforliving.com

Building America Best Practices

The U.S. Department of Energy has produced a series of builders guides that provide instructions for construction "best practices" that can help builders achieve high-performance homes. These guides can be found at www.eere.energy.gov/buildings/building_america/

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28
RECOMMENDED

Low VOC Adhesives

BUILDERS CHALLENGE QUALITY CRITERIA	BUILDER DOCUMENTATION & VERIFICATION REQUIREMENTS	THIRD-PARTY VERIFICATION REQUIREMENTS
28. Low VOC Adhesives – Recommended: Adhesives comply with the following maximum limits for VOCs: Carpet pad adhesives: 50 g/L (excluding water); Indoor carpet adhesives: 50 g/L (excluding water); Wood flooring adhesives: 100 g/L (excluding water); Subflooring adhesives: 50 g/L (excluding water); Multi-purpose construction adhesives: 70 g/L (excluding water) *(reference LEED for Homes MR Credit 2.2)*	Keep specifications in builder's project record.	

Finishes such as paints, sealers, adhesives, fabrics, and surface-covering roll goods (i.e., vinyl wall coverings) are all potential sources of indoor air pollutants, including various volatile organic compounds (VOCs). Most of the liquid-applied materials dissipate rather rapidly as they dry. Leaving windows open as they are applied removes the high initial concentrations of VOCs. After this initial "dry-out" period, a properly designed ventilation system will continue to bring in fresh air and remove further off-gassing of pollutants.

Figure 28.1. Several low VOC adhesives are now available.

Related Quality Criteria

See ***Criteria 11. Whole Building Mechanical Ventilation I***, ***Criteria 25. Whole Building Mechanical Ventilation II***, ***Criteria 27. Low VOC Wall Coverings***, and ***Criteria 29. Low Emission Cabinets***.

Want to Learn More?

"Low- or No-VOC Paints, Finishes and Adhesives." www.toolbase.org/Home-Building-Topics/Indoor-Air-Quality/low-voc-paints

GREENGUARD Environmental Institute's guide to third-party certified low-VOC-emitting interior products at www.greenguard.org

Related Standards & Procedures

LEED for Homes. USGBC, January 2008. www.greenhomeguide.org/documents/leed_for_homes_rating_system.pdf

South Coast Air Quality Management District Rule 1168 – Adhesive and Sealant Application. www.arb.ca.gov/DRDB/SC/CURHTML/R1168.pdf

California Air Resource Board (CARB), "Regulation for Reducing Volatile Organic Compound Emissions from Consumer Products," available online at www.arb.ca.gov/consprod/regs/cp.pdf

U.S. Environmental Protection Agency. 2007. *ENERGY STAR Indoor Air Package Specifications*, version 2, April 19, 2007, available at www.energystar.gov/index.cfm?c=bldrs_lenders_raters.nh_iap

National Home Builders Association (NAHB) Green Building Program website: nahbgreen.org

U.S. Green Building Council LEED for Homes website: www.usgbc.org/LEED/homes/

Building America Best Practices

The U.S. Department of Energy has produced a series of builders guides that provide instructions for construction "best practices" that can help builders achieve high-performance homes. These guides can be found at www.eere.energy.gov/buildings/building_america/

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29
RECOMMENDED

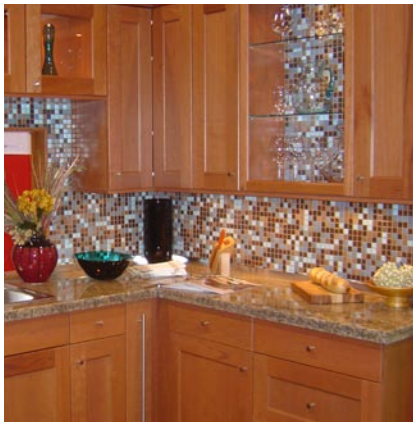
Low-Emission Cabinets

BUILDERS CHALLENGE QUALITY CRITERIA	BUILDER DOCUMENTATION & VERIFICATION REQUIREMENTS	THIRD-PARTY VERIFICATION REQUIREMENTS
29. Low Emission Cabinets – Recommended: Kitchen and bath vanity cabinets are in accordance with one of the following. (1) Installed kitchen and bath vanity cabinets comply with the Kitchen Cabinet Manufacturers Association Environmental Stewardship Program 01-06. (2) Installed kitchen and bath vanity cabinets are in accordance with the CARB standard for urea formaldehyde emissions in composite wood. (3) Installed kitchen and bath vanity cabinets contain no added urea formaldehyde or comply with GREENGUARD testing protocol and emission standards (ASTM D 6670) or equivalent. (reference National Green Building Standard 901.10).		

We recommend that builders contact local green building certification programs and organizations to find qualifying products. Leaving windows open as cabinets are installed removes the high initial concentrations of VOCs. A properly designed ventilation system will continue to bring in fresh air and remove further off-gassing of pollutants.

Environmentally friendly cabinets include FSC-certified or salvaged wood, recovered-fiber wood products, agrifiber (other names include agfiber and biofiber) panels, low-formaldehyde or formaldehyde-free wood products, and low-VOC finishes. The Forest Stewardship Council (FSC) provides third-party certification, evaluation and monitoring of sustainable forestry practices. Agrifiber is similar to particleboard but agricultural fibers, such as straw, are bonded together to form the panels rather than saw mill waste. Formaldehyde-free hardwood plywood and particleboard products are available.

Figure 29.1. Some cabinet makers are now specializing in low-VOC cabinetry to meet growing consumer demand.



Related Quality Criteria

See ***Criteria 11. Whole Building Mechanical Ventilation I***, ***Criteria 25. Whole Building Mechanical Ventilation II***, ***Criteria 27. Low VOC Wall Coverings***, and ***Criteria 28. Low VOC Adhesives***.

Want to Learn More?

GreenHomeGuide Product Directory: low-VOC cabinets www.greenhomeguide.com/index.php/product/C126

Center for ReSource Conservation. Before you buy…Cabinets. www.greenerbuilding.org/buying_advice.php?cid=4

Greenguard Environmental Institute. Product Guide: kitchen cabinets. www.greenguard.org/Default.aspx?tabid=12

U.S. Environmental Protection Agency. Wood Coating Case Studies by Company. Available at www.epa.gov/ttn/atw/wood/low/casebyco.html

National Home Builders Association (NAHB) Green Building Program website: nahbgreen.org

U.S. Green Building Council LEED for Homes website: www.usgbc.org/LEED/homes/

Related Standards & Procedures

KCMA Environmental Stewardship Program 01-06. www.greencabinetsource.org/index.cfm?fuseaction=Defining.Welcome

California Air Resource Board (CARB) "Airborne Toxic Control Measure (ATCM) to Reduce Formaldehyde Emissions from Composite Wood Products" www.arb.ca.gov/toxics/compwood/factsheet.pdf

ASTM D6670 – 01 (2007) "Standard for Full-Scale Chamber Determination of Volatile Organic Emissions from Indoor Materials/Products", www.astm.org/Standards/D6670.htm

National Green Building Standard 901.10, August 10, 2007, pg. 70.

Building America Best Practices

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Appendix I: Other Considerations and Recommendations

ENERGY STAR

Houses that display the E-Scale label (meaning they are Builders Challenge certified and meet the quality criteria) should exceed current requirements for the ENERGY STAR for New Homes Program. ENERGY STAR can be used as an additional means to gain market recognition. See www.energystar.gov for more information and marketing tools.

RECOVERY ACT BUILDING CODE REQUIREMENTS

The American Recovery and Reinvestment Act of 2009 (Pub.L. 111-5) requires State governments accepting State Energy Program (SEP) or Block grants to implement the latest IECC energy efficiency codes. The 2009 IECC would increase energy efficiency levels to about a HERS index rating of 85. For comparison, the Builders Challenge stipulates that home meet or do better than a HERS index score of 70. ENERGY STAR homes are usually at least 15% better than code. As homes are tightened up, moisture and combustion product issues can increase. Many local code jurisdictions mix and match IECC and IRC code requirements, adopting different versions of these codes. Thus, energy measures and health and safety measures may not be optimally combined. NOTE: All homes, regardless of energy level, should at least meet the provisions of the Builders Challenge Quality Criteria that affect moisture management, ventilation, and combustion product safety.

QUALITY MANAGEMENT

Builders who establish formal quality management programs are more likely to achieve consistent success in meeting the Builders Challenge Quality Criteria, as well as reducing costly defects. Quality management programs include components like written procedures and checklists, scopes of work, and inspections, as well as post-construction air leakage tests, and training of staff and subs. There are a number of formal quality programs, such as the National Housing Quality Program (www.nahbrc.org/quality) , Quality Built (www.qualitybuilt.com), and First Time Quality (firsttimequality.com). These programs are based on ISO 9001.

INDOOR AIR QUALITY

In January 2009, the U.S. Environmental Protection Agency published the Indoor airPLUS Construction Specifications. Homes meeting these specifications can earn the EPA Indoor airPLUS label. These specifications are applicable to many of the Builders Challenge Quality Criteria. See Figure A-I.2 for the EPA Indoor airPLUS Verification Checklist.

Want to Learn More?

Database of State Incentives for Renewables and Efficiency. Site managed by the North Carolina State University Solar Center. www.dsireusa.org

First Time Quality website: firsttimequality.com

ICC. 2009. 2009 International Energy Conservation Code. International Code Council, Washington DC, www.iccsafe.org

ISO 9001 2008. Quality Management Requirements, published November 15, 2008, by the International Organization for Standardization, www.iso.org

Masco Home Services. Environments for Living Program Services. www.environmentsforliving.com

National Home Builders Association (NAHB) Green Building Program website: nahbgreen.org

National Association of Home Builders Research Center, Energy Value Housing Award website. www.nahbrc.org/evha/

National Housing Quality Program website: www.nahbrc.org/quality

Quality Built website: www.qualitybuilt.com

Public Law 111-5. The American Recovery and Reinvestment Act of 2009, signed Feb 17, 2009.

U.S. Environmental Protection Agency. 2009. *Indoor airPLUS Construction Specifications*, available at www.epa.gov/indoorairplus/index.html

U.S. Environmental Protection Agency. National Menu of Stormwater Best Management Practices (updated Jan 09, 2008). http://cfpub1.epa.gov/npdes/stormwater/menuofbmps/index.cfm

U.S. Green Building Council LEED for Homes website: www.usgbc.org/LEED/homes/

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BUILDERS CHALLENGE GREEN PARTNERSHIPS

Builders can meet the performance path for Builders Challenge directly, or by working through a number of partnerships. Partnering programs include the U.S. Green Building Council (www.usgbc.org/LEED/homes/), and the National Green Building Standard (www.NAHBgreen.org). Gaining the Builders Challenge certification through a green partnership helps builders gain market recognition as a green builder.

ENERGYVALUE HOUSING AWARD

The EnergyValue Housing Award (EVHA) recognizes specifc homes in which builders integrate energy efficiency into all aspects of production. The U.S. Department of Energy, is a sponsor of the award. The EVHA program judging criteria focuses on high levels of residential energy performance through building science, new technologies and construction methods, and green building. Beginning in the 2010 award cycle, the Builders Challenge criterion will be integrated into the EVHA application (www.nahbrc.org/evha/).

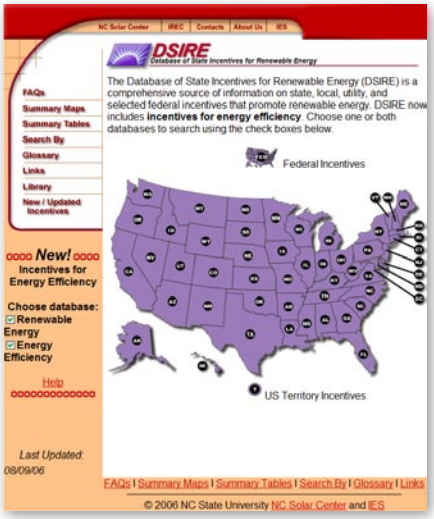
UTILITY INTERFACE ISSUES

Buildings consume about 72% of all electricity produced by utilities, with over half that consumption in residences. Because that consumption represents a substantial carbon impact, future carbon reduction programs may address building energy use. Utilities are increasingly implementing smart meters, peak load management, and demand response measures. Building design and HVAC equipment selection can substantially reduce peak load impacts.

STATE, LOCAL GOVERNMENT, AND UTILITY INCENTIVES

Builders are encouraged to work with their states, local governments, and utilities to determine what local incentives, technical assistance, and marketing help might be available for installing energy-efficient appliances and lighting, and energy-efficient construction measures. Many utilities or public benefits programs offer ENERGY STAR programs and/or training and incentives. One place to start your search for local incentives is the Database of State Incentives for Renewable Energy, on line at www.dsireusa.org.

Figure A-I.1. Visit the Database of State Incentives for Renewable Energy – DSIRE



Building America Best Practices

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Figure A-I.2. ENERGY STAR Indoor airPLUS Verification Checklist – Page 1

EPA United States Environmental Protection Agency

Indoor airPLUS Verification Checklist

EPA Indoor airPLUS Qualified Home

Address or Div/Lot#:					
City/State/Zip:		Date:		Verified by	
Section		Requirements (see Indoor airPLUS Construction Specifications for details)	N/A	Builder	Rater
Moisture Control		**Water-Managed Site and Foundation**			
	1.1	Site & foundation drainage: sloped grade, protected drain tile, & foundation floor drains		☐	☐
	1.2	Capillary break below concrete slabs & in crawlspaces (Exception - see specification)	☐	☐	☐
	1.3	Foundation wall damp-proofed or water-proofed (Except for homes without below-grade walls)	☐	☐	☐
	1.4	Basements/crawlspaces insulated & conditioned (Exceptions - see specification)	☐	☐	☐
		Water-Managed Wall Assemblies			
	1.5	Continuous drainage plane behind exterior cladding, properly flashed to foundation		☐	☐
	1.6	Window & door openings fully flashed		☐	☐
		Water-Managed Roof Assemblies			
	1.7	Gutters/downspouts direct water a minimum of 5' from foundation (Except in dry climates)	☐	☐	☐
	1.8	Fully flashed roof/wall intersections (step & kick-out flashing) & roof penetrations		☐	☐
	1.9	Bituminous membrane installed at valleys & penetrations (Except in dry climates)	☐	☐	☐
	1.10	Ice flashing installed at eaves (Except in Climate Zones 1 - 4)	☐	☐	☐
		Interior Water Management			
	1.11	Moisture-resistant materials/protective systems installed (i.e., flooring, tub/shower backing, & piping)			☐
	1.12	No vapor barriers installed on interior side of exterior walls with high condensation potential		☐	☐
	1.13	No wet or water-damaged materials enclosed in building assemblies		☐	☐
Radon	2.1	Approved radon-resistant features installed (Exception - see specification)	☐	☐	☐
	2.2	Two radon test kits & instructions/guidance for follow-up actions provided for buyer (Advisory-see specification)	☐	☐	☐
Pests	3.1	Foundation joints & penetrations sealed, including air-tight sump covers			☐
	3.2	Corrosion-proof rodent/bird screens installed at all openings that cannot be fully sealed (e.g., attic vents)		☐	☐
HVAC	4.1	HVAC room loads calculated, documented; system design documented; coils matched			☐
	4.2	Duct system design documented & properly installed OR duct system tested (check box if tested) ☐	☐		☐
	4.3	No air handling equipment or ductwork installed in garage; continuous air barrier required in adjacent assemblies			☐
	4.4	Rooms pressure balanced (using transfer grills or jump ducts) as required OR tested (check box if tested) ☐	☐		☐
	4.5	Whole house ventilation system installed to meet ASHRAE 62.2 requirements			☐
	4.6	Local exhaust ventilation to outdoors installed for baths, kitchen, clothes dryers, central vacuum system, etc.			☐
	4.7	Central forced-air HVAC system(s) have minimum MERV 8 filter, no filter bypass, & no ozone generators			☐
	4.8	Additional dehumidification system(s) or central HVAC dehumidification controls installed (In warm-humid climates only)	☐		☐
Combustion Pollutants		**Combustion Source Controls**			
	5.1	Gas heat direct vented; oil heat & water heaters power vented or direct vented (Exceptions - see specifications)	☐		☐
	5.2	Fireplaces/heating stoves vented outdoors & meet emissions/efficiency standards/restrictions	☐		☐
	5.3	Certified CO alarms installed in each sleeping zone (e.g., common hallway) according to NFPA 720			☐
	5.4	Smoking prohibited in common areas; outside smoking at least 25' from building openings (Multi-family homes only)	☐	☐	☐
		Attached Garage Isolation			
	5.5	Common walls/ceilings (house & garage) air-sealed before insulation installed; house doors gasketed & closer installed	☐		☐
	5.6	Exhaust fan (minimum 70 cfm, rated for continuous use) installed in garage & vented to outdoors (controls optional)	☐		☐
Materials	6.1	Certified low-formaldehyde pressed wood materials used (i.e., plywood, OSB, MDF, cabinetry)		☐	☐
	6.2	Certified low-VOC or no-VOC interior paints & finishes used		☐	☐
	6.3	Carpet, adhesives, & cushion qualify for CRI Green Label Plus or Green Label testing program	☐	☐	☐
Final	7.1	HVAC system & ductwork verified dry, clean, & properly installed			☐
	7.2	Home ventilated before occupancy OR initial ventilation instructions provided for buyer		☐	☐
	7.3	Completed checklist & other required documentation provided for buyer		☐	☐

Rater/Provider:	Builder:
Company:	Company:
Signature:	Signature:

Figure A-I.2. ENERGY STAR Indoor airPLUS Verification Checklist – Page 2

Guidance for Completing the Indoor airPLUS Verification Checklist:

1. Only ENERGY STAR qualified homes verified to comply with these specifications can earn the Indoor airPLUS label. See Indoor airPLUS Construction Specifications for full descriptions of the requirements, terms, exceptions, abbreviations, references, and climate map used in this checklist. Verification is not complete until this checklist is completed in full and signed.
2. Check one box per line. Check "N/A" for specifications that do not apply for specific conditions (e.g., climate) according to the Exceptions described in the Indoor airPLUS Construction Specifications. Check either "Builder" or "Rater" for all other items to indicate who verified each item. Items may be verified visually on site during construction, by reviewing photographs taken during construction, by checking documentation, or through equivalent methods as appropriate. If using a performance testing alternative to meet requirement 4.2 or 4.4, the box marked "Tested" must be checked and testing documentation must be provided in the Home Energy Rating System/Builder Option Package (HERS/BOP) file.
3. The rater who conducted the verification, or a responsible party from the rater's company, must sign the completed verification checklist. The builder must sign the checklist if any items in the "Builder" column are checked, and by so doing accepts full responsibility for verifying that those items meet Indoor airPLUS requirements.
4. The builder provides one copy of the completed and signed checklist for the buyer. The HERS/BOP provider or rater files a copy with HERS/BOP and ENERGY STAR documentation (e.g., Thermal Bypass Checklist) for the home.
5. The checklist may be completed for a batch of homes using a RESNET-approved sampling protocol when qualifying homes as ENERGY STAR. For example, if the approved sampling protocol requires rating one in seven homes, then the checklist will be completed for the one home that was rated.

Note: The Indoor airPLUS Construction Specifications are designed to help improve indoor air quality (IAQ) in new homes compared with homes built to minimum code. These measures alone cannot prevent all IAQ problems; occupant behavior is also important. For example, smoking indoors would negatively impact a home's IAQ and the performance of the specified Indoor airPLUS measures.

Notes:

For further information on the Indoor airPLUS program, visit epa.gov/indoorairplus.

Qualified homes earn the Indoor airPLUS label. Place it next to the ENERGY STAR label.

All Indoor airPLUS qualified homes meet strict guidelines for energy efficiency set by ENERGY STAR, the nationally-recognized symbol for energy efficiency.

Appendix II: Builders Challenge Quality Criteria

See the following pages for a complete listing of the Builders Challenge Quality Criteria.

Building America Best Practices

The U.S. Department of Energy has produced a series of builders guides that provide instructions for construction "best practices" that can help builders achieve high-performance homes. These guides can be found at www.eere.energy.gov/buildings/building_america/

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Recognizing Energy Leadership in Homebuilding

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Builders Challenge Quality Criteria Guide – Version 1.3

The Builders Challenge Quality Criteria are designed to promote continuous improvement while ensuring construction quality and efficiency so builders and homeowners alike benefit from reduced callbacks and enhanced comfort, indoor environmental quality, and durability. To qualify for the Builders Challenge all homes, regardless of compliance pathway, must comply with the Quality Criteria and the Energy Performance threshold, as well as meet all applicable codes.

This version of the Quality Criteria is subject to revision. Registered builders will be notified of revisions and all projects built after a revision must comply with the updated criteria. Items which are not currently listed as "Required" are still Recommended. Technical resources on constructing high performance homes are available on the Builders Challenge website (www.buildingamerica.gov/challenge).

Relationship to Codes & Manufacturer Requirements

The Quality Criteria are not intended to supplant safety, health, or environmental requirements contained in other applicable codes or ordinances, and all locally applicable codes apply. In cases where a locally applicable code requirement is more stringent or is in conflict with a quality criterion, the local provision shall apply. Many of the provisions noted below are basic code requirements in the most current energy codes. By including these items as Quality Criteria, the Builders Challenge is focusing attention on their proper implementation.

Additionally, where a quality provision is in conflict with the manufacturer's requirements for a product – the manufacturer's requirements shall apply.

Roles and Responsibilities

The Quality Criteria require different parties to conduct, confirm, and/or verify good building practices for Builders Challenge homes.

Builders must establish the expectations for quality practices, oversee their implementation, and keep records to confirm what was done. These responsibilities are noted below.

Third-party verifiers must verify the implementation of the Quality Criteria (QC) either directly, by means of an actual measurement or inspection, or by confirming that the builder implemented the QC. RESNET-certified HERS raters and DOE Building Consortia team members qualify as third-party verifiers for the Builders Challenge. DOE will work with the NAHB Research Center to establish a process by which NAHB third-party verifiers can qualify to conduct QC inspections for homes qualifying for the Builders Challenge. Other professionals may be eligible to serve as verifiers, such as licensed engineers and architects or employees or authorized representatives of a utility or local building regulatory authority, if they have been trained by RESNET (or an equivalent organization) to use building performance testing methods and tools. Such professionals will be approved by DOE.

Trade contractors must implement quality practices in accordance with their scope of work. More information on quality training is available on the Builders Challenge website.

Resources

A technical resource guide with background on each of the QC provisions below, based on the Building America Best Practice Guides, is currently under development. Links to the Building America Best Practice Guides, as well as other technical resources, are posted on the Builders Challenge website.

Quality Criteria

The Quality Criteria are listed in three phases:

The Design Phase requires design, planning and documentation before construction.
The Construction Phase frequently requires the builder/superintendent to visually inspect and document proper installation by the trade contractors.
The Verification Phase requires a third-party verifier to review and measure criteria after construction.

Builders Challenge Quality Criteria	Builder Documentation & Verification Requirements	Third-Party Verification Requirements
1. Project Documentation – *Required* Construction/design documentation (e.g., plans, details, specifications, job ready and job complete checklists, and trade scopes of work and/or agreements) will include energy and quality provisions needed to meet the Builders Challenge criteria.	Develop and store construction/design and energy rating documentation in project records. The builder (or builder's representative) shall review the adequacy of the construction/design documentation for implementing the energy and quality provisions, and shall sign the completed checklists.	The third-party rater shall review the construction documentation and signed checklists.
2. Building Envelope Moisture Management – Design Phase - *Required* In the design phase, include details for integrating the weather barrier system with flashing components in the construction plans. Specify window and door flashing based	Develop construction plans with flashing details, foundation details, vapor retarder	Verify that construction plans contain specifications

Builders Challenge Quality Criteria	Builder Documentation & Verification Requirements	Third-Party Verification Requirements
on the Building America Best Practices (Trades section), or such references as the Water Management Guide (EEBA), the latest version of ASTM E-2112, the AAMA Installation Standard, or manufacturer's recommendations. Provide details to provide adequate site and below-grade drainage, and to prevent moisture from entering the building from below grade by capillary flow. Typically, this would require the builder to specify a foundation drainage system with capillary breaks below the slab, between the footer and foundation, and between the foundation wall and sill plate. Specify climate appropriate vapor retarder or barrier per locally applicable IECC. (Reference IECC Section 402.5) When using water absorptive cladding, including brick, stone (real or manufactured), stucco, and fiber cement, provide a pathway for bulk water that enters the wall assembly from the exterior to drain to the exterior. Typically this involves specifying a drainage space or pathway provided by furring strips, an air gap, contoured house wrap, or other products that create a vertical drainage channel behind the cladding and exit the wall horizontally. Cladding installation per manufacturer's recommendations is also permitted.	specification, and drainage space specification (if applicable) Include requirements for flashing, foundation details, and wall system details in contractor's construction/design documentation.	
3. Material Efficient Framing – *Recommended* Design building dimensions and layouts to minimize material cuts and waste for wall, floor, and roof system structural components and sheathing. Size all headers for actual structural loads, and insulate to the fullest extent possible. To the extent possible use building systems which minimize on-site waste, such as panelized walls, pre-cut framing packages, and engineered wood products. Incorporate these measures in the framing	Develop framing layout plan and keep in project records.	

Builders Challenge Quality Criteria	Builder Documentation & Verification Requirements	Third-Party Verification Requirements
layout plan.		
4. Construction Waste Management – *Recommended* Develop, post at the jobsite and implement a Construction Waste Management Plan. The plan should document the diversion pathways for major waste stream components including cardboard, lumber, land-clearing debris, and drywall. The plan should also document efforts to request minimized packaging from suppliers. Goals for waste diversion should be at least 25% (by weight) for construction and land-clearing waste.	Develop Construction Waste Management Plan and keep in project records.	
5. Space Conditioning Design – *Required* Right-size space conditioning system for heating/cooling loads based on ACCA Manual J Version 8 or comparable load sizing analysis (reference 2006 IRC M1401.3, 2006 IECC Section 403.6). The maximum over-sizing limit for cooling equipment is 15%, with the exception of heat pumps in Climate Zones 5 - 8 where the maximum over-sizing limit is 25%. Outdoor temperatures shall be the 99.0% design temperatures as published in the ASHRAE Handbook of Fundamentals for the home's location or most representative city for which design temperature data are available. Note that a higher outdoor air design temperature may be used if it represents prevailing local practice by the HVAC industry and reflects extreme climate conditions that can be documented with recorded weather data; Indoor temperatures shall be 75 F for cooling; Infiltration rate shall be selected as "tight", or the equivalent term. In specifying equipment, the next available size may be used. In addition, indoor and outdoor coils shall be matched in accordance with ARI standards. Identify the whole building ventilation strategy and equipment in the mechanical system design (see the 2 other Quality Criteria: Whole Building Ventilation I and II for requirements). 6. Space Conditioning Design – *Recommended*	Analyze load-sizing and duct-sizing and keep in project records.	Review the load-sizing and duct-sizing analyses to ensure that sizing criteria stated in the requirements were used for the home.

Builders Challenge Quality Criteria	Builder Documentation & Verification Requirements	Third-Party Verification Requirements
Design and install duct system(s) using ACCA Manual D or equivalent. Integrate HVAC duct layout with construction documentation. Select heating/cooling equipment using ACCA Manual S or equivalent.		
7. Dehumidification – *Recommended* Install equipment with sufficient latent capacity to maintain indoor relative humidity at or below 60% in Climate Zones 1A, 2A, 3A and 4A, as defined by the 2006 IECC Figure 301.1. This requirement can be met with an additional dehumidification system or a central HVAC system equipped with additional controls to operate in dehumidification mode.	Include mechanical specifications for dehumidification in construction documents and keep in project records.	
8. Space-Conditioning System Installation - *Recommended* Space-conditioning system installation meets ACCA Quality Installation Specification.		
9. Building Envelope Pressurization Testing – *Recommended* Test envelope leakage to ≤ 0.35 cfm per square foot of building envelope area at a pressure differential of 50 Pascals between the house interior and outdoors. (See QC provision: Air Barrier and Insulation Integrity).		Test envelope leakage to be below specified limit, using a RESNET-approved testing protocol.
10. Windows – *Required* Specify ENERGY STAR qualified windows or better.	Include in specification and keep in project records.	Verify installation of ENERGY STAR qualified windows.
11. Whole Building Mechanical Ventilation I - *Required* Design and install a mechanical system(s) to provide outside air to the indoor environment through either exhaust, supply, or balanced ventilation. Equip outside air intakes for ventilation with filters and shutoff dampers. (Also see QC Provision: Whole Building Mechanical Ventilation II – which is a recommended measure).	Include in mechanical plans and keep in project records.	Verify the installation of a whole building MV system.
12. Kitchen Ventilation – *Required* Provide mechanical kitchen ventilation with an exhaust fan(s) that can provide at least 100 cfm intermittent (reference 2006 IRC M1507.3) or airflow equivalent to 5 air changes per hour based on the kitchen volume (continuous use). Fans are vented to exhaust	Include kitchen ventilation requirements in construction documents.	Verify the installation of kitchen ventilation system which exhausts air to outdoors

Builders Challenge Quality Criteria	Builder Documentation & Verification Requirements	Third-Party Verification Requirements
kitchen air to outdoors. Refer to Section 6.4 of ASHRAE 62.2-2007 "Combustion and Solid-Fuel Burning Appliances" for information on providing for adequate combustion air for combustion appliances.		
13. Bathroom Ventilation – *Required* Include mechanical ventilation for all bathrooms with a bathtub, shower, spa, or similar source of moisture with an exhaust fan(s) that can provide at least 50 cfm (intermittent use) or 20 cfm (continuous use). For bathrooms without a bathtub, shower, spa, or similar source of moisture, exhaust ventilation is provided at these same rates, or the room has a window with an openable area of at least 4% of the floor area and no smaller than 1.5 square feet. All bathroom fans are vented to outdoors.	Include in construction documents.	Verify the installation of bathroom ventilation equipment which exhausts air to outdoors
14. Clothes Dryer Venting – *Required* Clothes dryer vented directly to the outdoors. (reference 2006 IRC M1502.1) Condensing dryers are exempt.	Provide for ducting to the outdoors for clothes dryers.	Verify the installation of a clothes dryer exhaust port to outdoors.
15. Duct Leakage – *Required* Comply with 15A or 15B, and 15C. 15A. Duct leakage to outdoors is less than 5% of conditioned floor area when measured at 25 Pascal using duct pressurization methods. OR 15B. All duct work is located within the conditioned envelope (meaning the air barrier and thermal barrier) of the house. AND 15C. Total duct leakage is less than 10% of conditioned floor area when measured at 25 Pascals using duct pressurization methods.		Test duct leakage to outdoors to be below specified leakage limits, using a RESNET-approved testing protocol. Verify that ducts are located within the thermal envelope of the house, if Option 15B is selected.
16. Air Barrier and Insulation Integrity - *Required* Complete the ENERGY STAR Thermal Bypass Inspection Checklist for the home. A link to	Either builder or third-party verifier may complete the checklist.	Either builder or third-party verifier may complete the checklist.

Builders Challenge Quality Criteria	Builder Documentation & Verification Requirements	Third-Party Verification Requirements
this checklist is listed on the Builders Challenge website www.buildingamerica.gov/builderschallenge	Builder must keep signed copy of the checklist in builder's project records	Third-party verifier must confirm that a signed checklist has been completed.
17. Filtration - *Required* Equip the central air handler(s) with a MERV 8 filter or higher. Account for the associated pressure drop from the filter in the design and sizing of the duct work.		Verify the installation of a MERV 8 or higher filter.
18. Combustion Safety - *Required* Fossil fuel-fired furnaces or water heaters installed in conditioned spaces must be sealed combustion, direct vented, or power-vented units.		Verify that combustion-based furnaces and water heaters are direct vented or power vented, if installed in conditioned space.
19. Carbon Monoxide - *Required* For homes with combustion appliance(s) or an attached garage, install at least one carbon monoxide (CO) alarm in a central location outside of each separate sleeping area in the immediate vicinity of the bedrooms. Place them according to NFPA 720 or manufacturers recommendations. They must be hard-wired with a battery back-up function. The alarm devices shall be certified by either CSA 6.19-01 or UL 2034. 20. Carbon Monoxide - *Recommended* For all homes, install at least one carbon monoxide (CO) alarm in a central location outside of each separate sleeping area in the immediate vicinity of the bedrooms. Place them according to NFPA 720. They must be hard-wired with a battery back-up function. The alarm devices shall be certified by either CSA 6.19-01 or UL 2034.		Verify the installation of a CO alarm.
21. Garage Exhaust Ventilation – *Recommended* Ventilate attached garages with a 100 cfm (ducted) or 80 cfm (un-ducted) exhaust fan, venting to outdoors and designed for continuous operation. Alternatively, automatic fan	Include in construction plans and contractors' work scopes	

Builders Challenge Quality Criteria	Builder Documentation & Verification Requirements	Third-Party Verification Requirements
controls may be installed that activate the fan whenever garage is occupied, and for at least 1 hour after garage is vacated.		
22. Air Handler Location - *Required* Central air handler(s) is isolated from the garage by a thermal barrier and an air barrier.		Verify air handler location.
23. Building Envelope Moisture Management – Field Verification - *Required* Flashing details, foundation details, vapor barrier selection, and water drainage space details noted in "Building Envelope Moisture Management" are installed per construction plans and specifications.	Builder documents that measures were implemented with a checklist or other written documentation kept in builder's project records	Verify that builder has written documentation of implementation
24. Energy Star Equipment - *Recommended* For equipment included in the sale of the home, use ENERGY STAR qualified appliances and equipment (including HVAC systems).		Verify that appliances are ENERGY STAR qualified, if included in sale of home
25. Whole Building Mechanical Ventilation II - *Recommended* Install a whole building mechanical ventilation system complying with the requirements of ASHRAE 62.2-2007. Whole building ventilation systems may consist of an exhaust system, supply system, or balanced system, and must be capable of providing the outside air rates specified in Standard 62.2-2007. Refer to Section 6.4 of ASHRAE 62.2-2007 "Combustion and Solid-Fuel Burning Appliances" for information on providing for adequate combustion air for combustion appliances. (Also see QC Provision: Whole Building Mechanical Ventilation I – which is a required measure).	Include mechanical plans which include systems for whole building MV in project records	
26. Pressure Balancing - *Recommended* All rooms in the conditioned space of the home do not exceed +/- 3 Pascals pressure difference relative to the central (open) areas of the home, when interior doors are closed and the central air handler is operating. Powder rooms and laundry rooms are exempt. OR Return ducts or transfer grilles are installed in every room with a door to which	Pressure testing record is kept in builder's project records (if measure is implemented)	

Builders Challenge Quality Criteria	Builder Documentation & Verification Requirements	Third-Party Verification Requirements
conditioned air is supplied, except for bathrooms, closets, pantries, and laundry rooms.		
27. Low VOC Interior Coatings - *Recommended* Paints, coatings, and primers applied to interior walls and ceilings have VOC levels of no more than 50 g/L (flats) or 150 g/L (non-flats). (reference LEED for Homes MR Credit 2.2)	Keep specifications in project record	
28. Low VOC Adhesives - *Recommended* Adhesives comply with the following maximum limits for VOCs: Carpet pad adhesives: 50 g/L (excluding water) Indoor carpet adhesives: 50 g/L (excluding water) Wood flooring adhesives: 100 g/L (excluding water) Subflooring adhesives: 50 g/L (excluding water) Multi-purpose construction adhesives: 70 g/L (excluding water) (reference LEED for Homes MR Credit 2.2)	Keep specifications in builder's project record.	
29. Low Emission Cabinets - *Recommended* Kitchen and bath vanity cabinets are in accordance with one of the following. (1) Installed kitchen and bath vanity cabinets comply with the Kitchen Cabinet Manufacturers Association Environmental Stewardship Program 01-06 (2) Installed kitchen and bath vanity cabinets are in accordance with the CARB standard for urea formaldehyde emissions in composite wood (3) Installed kitchen and bath vanity cabinets contain no added urea formaldehyde or comply with GREENGUARD testing protocol and emission standards (ASTM D 6670) or equivalent. (reference National Green Building Standard 901.10)		

Appendix III: List of Revisions

Revisions made November 12, 2009

p 2.1, 2nd bullet:
Slope driveways, garage slabs, patios, stoops, and walkways a minimum of ¼ inch per foot away from the structure.

P 2.2, 2nd bullet:
Specify and show in details that 6-ml polyethylene sheeting is to be placed directly beneath concrete slabs. The sheeting should continuously wrap the slab as well as footings up to grade. Seams in the sheathing should be overlapped 6 to 12 inches.

p 3.2 last bullet:
Use 2x3s for partitions. Interior, non-load-bearing partition walls can be framed with 2x3 (51mm x 76mm) studs at 24-inch on center or 2x4 "flat studs" at 16-inch on center (2009 IRC, section R602.5).

P 3.2 Sidebar "Related Standards... 2nd ref added:
2009 International Residential Code, section R602.5, "Interior non-bearing walls." International Code Council (ICC), Falls Church, Virginia. Available for purchase at www.iccsafe.org/e/prodshow.html?prodid=3100L09

P 5.1 In Quality Criteria box, 1st column, 1st paragraph, last line:
AHRI

P 11.2, 2nd paragraph:
Central fan-integrated supply ventilation can be an easy and inexpensive way to provide outside air to the HVAC unit. This system provides fresh, filtered, outside air in a controlled amount using the existing HVAC delivery unit for even distribution and mixing. The system involves exterior air intakes, ductwork running to the return air side of the HVAC air handler, dampers to allow control of the air intake, and electronic controls to ensure that the HVAC fans operate frequently enough to draw in adequate fresh air. These outdoor air inlets should be located at least 10 feet from any contamination sources. In humid climates care should be taken in drawing in outside air. Dehumidification may be needed to control relative humidity levels. See Criteria 7 for information on controlling humidity. Variable speed motors can be a significant source of energy savings.

P 11.2 Sidebar "Want to Learn More," last reference changed from EPA 2007 EStar Indoor Air Package Specs to:
U.S. Environmental Protection Agency. 2009. *Indoor airPLUS Construction Specifications*, available at www.epa.gov/indoorairplus/index.html

P 16.5 detail #12, Add words:
Install automatic closer and gasket or weather stripping.

P 16.7 detail #4, Add words:
Install automatic closer and gasket or weather stripping.

P 18.1 Sidebar "Want to Learn More," last reference changed from EPA 2007 EStar Indoor Air Package Specs to:
U.S. Environmental Protection Agency. 2009. *Indoor airPLUS Construction Specifications*, available at www.epa.gov/indoorairplus/index.html

P 21.1 Sidebar "Want to Learn More," last reference changed from EPA 2007 EStar Indoor Air Package Specs to:
U.S. Environmental Protection Agency. 2009. *Indoor airPLUS Construction Specifications*, available at www.epa.gov/indoorairplus/index.html

Building America Best Practices

The U.S. Department of Energy has produced a series of builders guides that provide instructions for construction "best practices" that can help builders achieve high-performance homes. These guides can be found at www.eere.energy.gov/buildings/building_america/

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On Appendix I, page A.1, change the last paragraph as follows:

Replace this paragraph:

Indoor Air Quality

The U.S. EPA has published an Indoor Air Package, dated April 19, 2007. Homes meeting these specifications can earn the ENERGY STAR Indoor Air Package label. These specifications are applicable to many of the Builders Challenge Quality Criteria. See Figure A-I.2 for the ENERGY STAR Verification Checklist, which can serve as a handy checklist for air quality- Related Quality Criteria. The ENERGY STAR website also includes the Indoor Air Package Specifications.

With this paragraph:

Indoor Air Quality

In January 2009, the U.S. Environmental Protection Agency published the Indoor airPLUS Construction Specifications. Homes meeting these specifications can earn the EPA Indoor airPLUS label. These specifications are applicable to many of the Builders Challenge Quality Criteria. See Figure A-I.2 for the EPA Indoor airPLUS Verification Checklist.

P A.1 In Sidebar "Want to Learn More," delete 11th and 12th refs (EPA 2007 Indoor Air Package Specs and verification…) insert the following reference:
U.S. Environmental Protection Agency. 2009. *Indoor airPLUS Construction Specifications*, available at www.epa.gov/indoorairplus/index.html

On page A-1.3 and A-1.4:
Replace ENERGY STAR Indoor Air Package Verification Checklist with the EPA Indoor airPLUS Verification Checklist.

A Strong Energy Portfolio for a Strong America

Energy efficiency and clean, renewable energy will mean a stronger economy, a cleaner environment, and greater energy independence for America. Working with a wide array of state, community, industry, and university partners, the U.S. Department of Energy's Office of Energy Efficiency and Renewable Energy invests in a diverse portfolio of energy technologies.

Research and Development of Buildings

Our nation's buildings consume more energy than any other sector of the U.S. economy, including transportation and industry. Fortunately, the opportunities to reduce building energy use—and the associated environmental impacts—are significant.

DOE's Building Technologies Program works to improve the energy efficiency of our nation's buildings through innovative new technologies and better building practices. The program focuses on two key areas:

- **Emerging Technologies**
  Research and development of the next generation of energy-efficient components, materials, and equipment

- **Technology Integration**
  Integration of new technologies with innovative building methods to optimize building performance and savings

For more information contact:
EERE Information Center
1-877-EERE-INF (1-877-337-3463)
www.eere.energy.gov

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Energy Efficiency & Renewable Energy

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ENERGY STAR

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