

# **Measure Guideline: Wall Air Sealing and Insulation Methods in Existing Homes**

## **An Overview of Opportunity and Process**

S. Roberts and R. Stephenson  
*NAHB Research Center Industry Partnership*

September 2012

This report received minimal editorial review at NREL.

#### NOTICE

This report was prepared as an account of work sponsored by an agency of the United States government. Neither the United States government nor any agency thereof, nor any of their employees, subcontractors, or affiliated partners makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States government or any agency thereof.

Available electronically at <http://www.osti.gov/bridge>

Available for a processing fee to U.S. Department of Energy  
and its contractors, in paper, from:

U.S. Department of Energy  
Office of Scientific and Technical Information  
P.O. Box 62  
Oak Ridge, TN 37831-0062  
phone: 865.576.8401  
fax: 865.576.5728  
email: <mailto:reports@adonis.osti.gov>

Available for sale to the public, in paper, from:

U.S. Department of Commerce  
National Technical Information Service  
5285 Port Royal Road  
Springfield, VA 22161  
phone: 800.553.6847  
fax: 703.605.6900  
email: [orders@ntis.fedworld.gov](mailto:orders@ntis.fedworld.gov)  
online ordering: <http://www.ntis.gov/ordering.htm>



Printed on paper containing at least 50% wastepaper, including 20% postconsumer waste

**Measure Guideline:**  
**Wall Air Sealing and Insulation Methods in Existing Homes**  
***An Overview of Opportunity and Process***

Prepared for:  
Building America  
Building Technologies Program  
Office of Energy Efficiency and Renewable Energy  
U.S. Department of Energy

Prepared by:  
The NAHB Research Center Industry Partnership  
400 Prince George's Boulevard  
Upper Marlboro, Maryland 20774

NREL Technical Monitor: Stacey Rothgeb  
Prepared Under Subcontract No. KNDJ-0-40335-00

September 2012

**[This page left blank]**

# Contents

<b>Figures .....</b>	<b>vi</b>
<b>Definitions.....</b>	<b>vii</b>
<b>Executive Summary .....</b>	<b>viii</b>
<b>1 Home and Document Inspection in Existing Homes: Whole-House Baseline and Diagnostic Inspections.....</b>	<b>1</b>
1.1 Home Energy Assessment .....	1
1.1.1 Size Things Up.....	1
1.1.2 Test In .....	1
1.2 Cost-Benefit Analysis and Estimates.....	5
1.3 Identifying Risks .....	7
<b>2 Tradeoffs: Value and Marketing .....</b>	<b>9</b>
2.1 Measure Selection Criteria, Cost, and Performance .....	9
2.2 System Interactions.....	9
<b>3 Wall Air Sealing and Insulation Methods in Existing Homes.....</b>	<b>10</b>
3.1 Existing Home Wall Air Sealing Methods .....	10
3.1.1 Materials for Air Sealing .....	10
3.1.2 Field Inspection.....	10
3.1.3 Installation Procedure .....	10
3.1.4 Verification Procedures and Tests .....	11
3.1.5 Benefits .....	11
3.1.6 Drawbacks.....	11
3.2 Existing Home Wall Insulation Methods.....	11
3.3 Exterior Insulated Sheathing.....	12
3.3.1 Materials for Insulating.....	12
3.3.2 Field Inspection.....	12
3.3.3 Installation Procedure .....	12
3.3.4 Verification Procedures and Tests .....	13
3.3.5 Benefits .....	14
3.3.6 Drawbacks.....	14
3.4 Open Framing Cavities – Cavity Insulation (Fiberglass/Cellulose) .....	14
3.4.1 Materials for Insulating.....	14
3.4.2 Field Inspection.....	15
3.4.3 Installation Procedure .....	15
3.4.4 Verification Procedures and Tests .....	16
3.4.5 Benefits .....	16
3.4.6 Drawbacks.....	16
3.5 Open Framing Cavities – Spray Foam Insulation (Open/Closed-Cell) .....	16
3.5.1 Materials for Insulating.....	16
3.5.2 Field Inspection.....	17
3.5.3 Installation Procedure .....	17
3.5.4 Verification Procedures and Tests .....	18
3.5.5 Benefits .....	18
3.5.6 Drawbacks.....	18
3.6 Closed Framing Cavities – Dense-Pack Insulation (Fiberglass/Cellulose) .....	18
3.6.1 Materials for Insulating.....	18
3.6.2 Field Inspection.....	18

3.6.3	Installation Procedure .....	19
3.6.4	Verification Procedures and Tests .....	20
3.6.5	Benefits .....	21
3.6.6	Drawbacks.....	21
3.7	Interior Insulation on Exterior Mass Walls.....	21
3.7.1	Materials for Insulating.....	21
3.7.2	Field Inspection.....	22
3.7.3	Installation Procedure .....	22
3.7.4	Verification Procedures and Tests .....	23
3.7.5	Benefits .....	23
3.7.6	Drawbacks.....	23
<b>4</b>	<b>Summary and Next Steps .....</b>	<b>24</b>
	<b>References .....</b>	<b>25</b>
	<b>Appendix A. Air Barrier and Insulation Inspection.....</b>	<b>27</b>
	<b>Appendix B. Air Sealing Key Points(Georgia DCA 2012).....</b>	<b>28</b>

## Figures

<b>Figure 1. Blower door .....</b>	<b>2</b>
<b>Figure 2. Duct pressurization test.....</b>	<b>3</b>
<b>Figure 3. Infrared image .....</b>	<b>3</b>
<b>Figure 4. Draft pressure testing using combustion analyzer .....</b>	<b>4</b>
<b>Figure 5. Air sealing installation steps .....</b>	<b>11</b>
<b>Figure 6. Exterior foam insulation installation steps .....</b>	<b>13</b>
<b>Figure 7. Open framing cavities – sprayed cavity insulation installation steps.....</b>	<b>16</b>
<b>Figure 8. Open framing cavities – spray foam insulation installation steps .....</b>	<b>17</b>
<b>Figure 9. Closed framing cavities – dense-pack insulation installation steps .....</b>	<b>20</b>
<b>Figure 10. Interior insulation on exterior walls installation steps (NAHB RC 2010) .....</b>	<b>22</b>

*Unless otherwise noted, all figures were created by the NAHB Research Center and Southface Energy Institute.*

## Definitions

ASHRAE	American Society for Heating, Refrigerating and Air-Conditioning Engineers
BPI	Building Performance Institute
CAZ	Combustion appliance zone
CFM	Cubic feet per minute
DOE	U.S. Department of Energy
EPA	U.S. Environmental Protection Agency
HVAC	Heating, ventilation, and air conditioning
IRC	International Residential Code
Pa	Pascal
RESNET	Residential Energy Services Network
VAT	Vinyl asbestos tile

## Executive Summary

Modern high performance homes feature airtight building envelopes with high levels of thermal resistance that control the flows of heat, air, and moisture into and out of the home. Homes built before current building codes may have high levels of air leakage and inadequate insulation. Both issues increase heating and cooling losses and demands on heating, ventilation, and air-conditioning systems and decrease occupant comfort and indoor air quality. Air leakage can account for a high percentage of heating and cooling bills in an especially leaky house, and homes built before 1980 often have little or no wall insulation. Given that walls can represent most of the building envelope area, ensuring that walls have proper levels of insulation is an essential part of any home energy retrofit. Energy retrofit projects should consider and address air sealing in walls and wall junctions to semi-conditioned or unconditioned adjacent spaces. This guideline provides renovators and retrofit contractors an overview of considerations when including wall air sealing and insulation in an energy retrofit project. It also outlines project risks, various materials for insulating, possible field inspections needed, installation procedures, and the benefits and drawbacks. The purpose of this guideline is to provide the outline of the overview and process of insulating and air sealing walls so that home retrofit professionals can identify approaches to air sealing and insulation measures.

This new measure guideline builds on Building America research and synthesizes information from relevant guidelines from the home energy retrofit industry, as well as weatherization education documentation and product manufacturers' literature. It also includes sidebars of "Critical Takeaways," "Important Definitions," "Contractor/ Homeowner Safety," and "References to Other Guidelines, Codes, and Standards."

Home energy retrofit professionals can share this guideline with homeowners to help them understand the retrofit methods that can be employed in their home and the benefits of wall air sealing and insulation, including lower energy bills, enhanced durability, and increased comfort.



# 1 Home and Document Inspection in Existing Homes: Whole-House Baseline and Diagnostic Inspections

The first step in planning any home energy retrofit project should include an evaluation of the conditions in the home by a qualified residential energy professional to determine options for energy upgrades and identify any installation or performance issues. For example, before wall air sealing and insulation retrofits are performed, the home energy assessment should determine the existing wall conditions and insulation and whether any major air leakage pathways are present (e.g., at foundation and attic junctions or utility or heating, ventilation, and air conditioning (HVAC) penetrations). Some homes have relatively low levels of air leakage and sufficient wall insulation; others are very leaky with no insulation. This assessment may be conducted by an independent auditor, a representative from a weatherization agency or local utility company, or an employee of the contractor that will implement any planned energy upgrades. Homeowners should look for independent auditors who have Building Performance Institute (BPI) or Residential Energy Services Network (RESNET) certification.

## 1.1 Home Energy Assessment

This section is based exhaustively on PNNL and ORNL (2010).

During a comprehensive home energy assessment, the auditor will inspect, evaluate, and analyze the home, and will query the homeowners about comfort issues and current energy bills. An audit should include the following steps:

### 1.1.1 Size Things Up

The auditor should measure the home and calculate square footage, window area, and door area and record the condition of insulation, mechanical equipment, and air leaks.

### 1.1.2 Test In

The auditor will use diagnostic equipment to measure how the house performs in ways that cannot be detected visually. These tests may include whole-house air leakage, duct leakage, infrared thermography scans, and combustion equipment safety assessments.

- **Whole-house air leakage.** A blower door test system uses a calibrated fan to measure air infiltration levels for the whole house. The blower door is mounted at an exterior door

#### **Important Definitions: Qualified Residential Energy Professional**

A qualified residential energy professional has BPI Building Analyst or Energy Auditor certification ([www.bpi.org](http://www.bpi.org)), or RESNET Home Energy Rater certification ([www.natresnet.org](http://www.natresnet.org)).

BPI and RESNET certified auditors may be independent consultants or working on-staff for a remodeling or HVAC contractor.

Additional qualified auditors include representatives from the local utility, or representatives from a city or state recognized weatherization agency.

An independent third-party auditor may be required to participate in certain programs such as Home Performance with ENERGY STAR® ([www.energystar.gov](http://www.energystar.gov)) sponsored by the U.S. Department of Energy (DOE) and U.S. Environmental Protection Agency (EPA), the National Green Building Certification ([www.nahbgreen.org](http://www.nahbgreen.org)) Green Remodel Path, or EarthCraft House.

and the fan pulls air out of the house at a specific pressure (see Figure 1). Outside air then flows into the house through all unsealed cracks and openings. The calibrated airflow through the fan is a measure of the amount of total air leakage from the home. A record of this measurement can then be compared with tests following air sealing upgrades. For measuring infiltration rates, the home should be depressurized to 50 Pa below the outside reference pressure per RESNET Chapter 8, as well as equipment manufacturers' and energy program guidelines (RESNET).



**Figure 1. Blower door**

- **HVAC duct air leakage.** Leaky, uninsulated (or minimally insulated) ducts in attics, basements, or crawlspaces can account for significant heating and cooling energy losses. Similar to a blower door, a duct pressurization test uses a calibrated fan to test the leakage rate in air ducts. To measure leakage rates, ducts are typically pressurized to 25 Pa above outside reference pressure following equipment manufacturers' and energy program guidelines. Duct leakage can be expressed in multiple ways, including the fan flow (CFM) at 25 Pa (CFM25)/ft<sup>2</sup> of conditioned area served, CFM25/100 ft<sup>2</sup>, and/or percent of system design flow. Duct air leakage tests can either be configured to test total leakage or leakage outside the building envelope (see Figure 2).



**Figure 2. Duct pressurization test**

- Infrared thermography scans.** Thermography, using an infrared camera, can be used to assess framed wall cavities for the presence and completeness of insulation (Figure 3). An infrared camera can also be used in conjunction with a blower door to locate infiltration pathways. This infiltration test should always be conducted after completing cavity insulation inspections. The American Society for Non-Destructive Testing's Level I Thermographer designation provides a minimum level of knowledge for conducting building inspections.



**Figure 3. Infrared image**

- Combustion equipment safety assessment.** To determine if vented combustion appliances can be backdrafted, a combustion appliance zone (CAZ) worst case depressurization test should be conducted following BPI standards (Figure 4). The CAZ testing indicates whether combustion equipment could leak combustion gases into the home. The auditor should also measure the level of carbon monoxide in the undiluted combustion gas and compare to acceptable ranges for the appliance.



**Figure 4. Draft pressure testing using combustion analyzer**

## **1.2 Cost-Benefit Analysis and Estimates**

The energy assessment may include use of an energy analysis simulation tool such as REM/Rate, BEopt, EnergyGauge, or other software packages to estimate the energy savings when implementing efficiency measures. The estimated savings can then be compared with estimated costs for installing the energy efficiency measures. The cost of the measures divided by the annual savings will tell you the “simple payback,” or how many years it will take to recover the initial outlay, as shown in the following example. Investments in energy efficiency can be viewed in a similar way to financial investments—an outlay of cash results in a return on the investment. Beyond monetary benefits, comfort often increases and heating and cooling are more consistent.

## **Critical Takeaways: Air Sealing and Insulation – Breakout Box for Trade Contractors and Remodelers**

### **Project: Air Seal and Insulate From the Outside**

The Smiths purchased their 1964 split-level home in the suburbs of Washington, D.C. with new carpet and newly painted walls. They had budgeted for the cost of replacing the aluminum siding in the spring, but after the move-in, realized that the house was drafty and expensive to heat and needed more than just curb appeal. Not wanting to disturb the newly furnished, pristine interior of their home, the Smiths asked the contractors that were bidding on their siding job how they could incorporate air sealing and insulation into the siding project and at what cost. The winning contractor presented the following solutions:

<i>Scope of Work:</i>	<i>Added Project Cost</i>
1. Add 4 in. of loose fill fiberglass insulation to attic (R-26 to R-40). <sup>a</sup>	\$ 864
2. Install gasket at attic access panel and insulation above it.	50
3. Remove soffit from cantilevered floors front and rear; install rigid foam air barrier as joist blocking at wall plane and install 1 in. of spray polyurethane foam at floor deck and blocking perimeter. Fill joist cavity with loose fill fiberglass (R-13–R-35). Trim with pre-finished material.	1,224
4. Install a taped and sealed weather resistant barrier over the wall sheathing and 1 in. of rigid foam, taped. (Add R-5 to walls.) <sup>b</sup>	2,120
5. Install new vinyl siding and trim. <sup>c</sup>	Included
<b>Total</b>	<b>\$ 4,258</b>

<i>Estimated Annual Utility Costs:</i>	<i>Before</i>	<i>After</i>	<i>Savings</i>
Heating	\$ 1,012	\$ 721	\$ 291
Cooling	313	313	
Water Heating	289	289	
Lights, Misc.	693	693	
<b>Total</b>	<b>\$ 2,307</b>	<b>\$ 2,016</b>	<b>\$ 291</b>

Simple Payback in Years: \$4,258/\$291 = 15 years

The Smiths' contractor and the siding manufacturer had provided a limited lifetime warranty on the siding, which the Smiths expect to last at least 30 years. By their calculations, the utility savings in years 15 through 30 would almost pay for the residing.

<sup>a</sup> The contractor proposed accessing the attic through the gable end wall before the house was resided to keep the traffic and hose applicator out of the house.

<sup>b</sup> The sealed and taped weather-resistant barrier was included in the contractor's scope of work at no additional charge to comply with the siding manufacturer's warranty. The contractor estimated that these air sealing measures employed in the residing project would result in a 25% improvement in air infiltration.

<sup>c</sup> The contractor's estimate was \$3.25 /ft<sup>2</sup> for the siding. Gable end walls were finished with the same materials as the main house walls.

<sup>d</sup> Because the Smiths had the work performed during 2010 the portion of the cost directly attributed to insulation cost was also eligible for a 30% tax credit. Accordingly, their initial cost for the energy efficiency features netted to \$3,700, and decreased the simple payback to 12 years.

<sup>e</sup> The cost of increasing the efficiency of the home may be eligible for state, federal, or other incentives, which reduce the investment cost and the payback period.

### 1.3 Identifying Risks

Although saving energy is a primary goal for significant air sealing and insulating efforts, just as important is maintaining a healthy indoor environment. Older homes may have materials, paints, and equipment that are no longer used today. As part of a home assessment, these materials and systems, along with other risks such as water leaks, should be clearly identified with provisions to satisfactorily remediate the risks.

For example, any combustion venting problems identified during CAZ testing must be addressed before air sealing begins. The energy assessment should also identify any obvious sources of excessive moisture that may lead to indoor air quality problems. Obvious damage to building components should also be addressed during the planning for the energy upgrades. The upgrades included in a home energy retrofit will also reduce air infiltration and heat loss across the envelope, reducing natural air exchange and the ability of wall assemblies to dry following bulk moisture intrusion.

Professional visual inspections and tests can identify safety and operational problems that may require attention before any other work on the house proceeds, including (EPA 2010a):

- **Combustion safety.** Combustion safety inspections should follow BPI standards (BPI 2005).
- **Ventilation.** Based on post-retrofit infiltration levels, additional controlled mechanical ventilation may be necessary and should be installed to have the capability of supplying outdoor air at levels prescribed by the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) Standard 62.2 (ASHRAE 2010).
- **Moisture.** Evaluate potential sources of moisture such as bathroom ventilation, window and door flashing, and vapor barriers, that will need to be addressed during the energy upgrades.
- **Lead.** Assume that lead paint is present when working in any home built before 1978. Renovations and retrofit activities should comply with EPA (2010b) if an area greater than 6 ft<sup>2</sup> of interior or 20 ft<sup>2</sup> of exterior painted surfaces will be disturbed.
- **Asbestos.** Asbestos can pose a hazard in homes built after 1930 and before the 1970s, and it can also be a concern in homes built or renovated prior to the 1990s. If you are unsure whether material contains asbestos, contact a qualified asbestos professional to assess the material, sample and test as needed.
- **Electricity.** If a home has live knob and tube wiring, insulation should not be added to wall cavities. Consider installing any new insulation over the exterior of sheathing, with exterior wall cladding and sidings installed over the new insulation, or insulate the walls at a time when the electrical system is being upgraded.
- **Radon.** The requirements of the local ordinance for radon mitigation should be followed. Where local ordinances do not address radon mitigation for existing buildings, the protocol for new construction can be followed with regard to establishing radon hazard levels and the need for mitigation measures. Use the EPA Map of Radon Zones (EPA 2012c) or conduct radon testing on site to establish the radon hazard level. If radon level

exceeds 4.0 pCi/L, implement mitigation measures in accordance with ASTM E2121 (ASTM 2009b).

### **Contractor/Homeowner Safety: Safety Points**

*Professionals who combine home improvements with energy efficiency features should physically examine the house before tightening and insulating it.*

1. Professionally test all combustion appliances and remediate as required (BPI or RESNET certified inspector). Have professional discuss results and care and maintenance with the homeowners. If absent, include carbon monoxide detector(s) in the improvement's scope of work.
2. If the house was built before 1978, test each unique part that will be impacted by the upgrade work for lead paint. If results are positive, follow EPA guidelines (EPA 2012a,b) for lead-safe work practices or for lead remediation.
3. If the house has an in-ground basement, is in a high or moderate radon potential zone (EPA 2012c), or does not have a radon abatement system installed, it should be tested for radon gas. Homeowner(s) can be tasked with ordering, placing, and submitting test kits (EPA 2012d).
4. Visually inspect for asbestos (EPA 2012e). Do not break or otherwise disturb asbestos products, as the mineral fibers becoming airborne present the material's hazard. Notify homeowner of damaged surfaces and locations that require remediation and work with the homeowner to develop a plan to address these during the planned improvement. Asbestos can be left in place, encapsulated, or removed and specially disposed of. Possible areas include:
  - a. Vinyl asbestos tiles (VATs) used in basements, laundry rooms, and kitchens. Many 12- and 9-in.<sup>2</sup> tiles manufactured between 1950 and 1981 fall in the VAT category.
  - b. Some loose fill attic insulation may contain asbestos mined with the vermiculite that was used as insulation.
  - c. Exterior shingle-style siding was made from asbestos in the mid-20th century.
  - d. Some furnace and other combustion appliances have asbestos batt insulation or backer boards. As with the VAT tiles, these would have been manufactured before 1981.
5. Inspect electric service for knob and tube wiring (found in pre-1930 houses). The National Electrical Code (NEC) limits loose fill insulation in cavities containing the old wiring (K8T).
6. Inspect wet rooms—kitchen, baths, laundry—for excessive moisture and leaks. Include caulk, washers, regrouting, as required, in your Scope of Work. Discuss maintenance intervals and offer to provide future service.
7. Inspect for exterior water infiltration areas—flashing, siding and trim junctions, etc. —and discuss maintenance interval and service schedule.
8. Develop a climate-appropriate strategy for bringing in outdoor air should the upgrade warrant it. ASHRAE Standard 62.2 is a controlled ventilation standard for new and existing homes. Be familiar with its recommendations and install controlled mechanical ventilation if necessary.



## **2 Tradeoffs: Value and Marketing**

### **2.1 Measure Selection Criteria, Cost, and Performance**

In addition to the home energy assessment, a cost-benefit analysis showing the potential savings and payback period for various home energy retrofit options can be provided to the homeowner to help in the decision process to select the most beneficial and affordable energy upgrades. Compared to other more expensive energy retrofits such as HVAC system replacement, air sealing and adding or upgrading wall insulation have the potential to increase homeowner comfort, reduce energy consumption and utility bills, and provide a relatively short payback period; however, these measures should be considered along with other efficiency upgrades. Each home has unique characteristics and conditions, so the specific energy efficiency upgrades must be tailored to the situation.

### **2.2 System Interactions**

Because a home functions as a system, with no single component performing independently, it is important to consider the impacts of home energy retrofits and the effects upgrades will have on existing systems or future system selection. Two of the significant system interactions when considering wall insulation and air sealing in existing homes are ventilation to provide outdoor air and the HVAC system loads and sizing.

Air sealing a home may necessitate the installation of mechanical ventilation based on the blower door test results to ensure occupant health and indoor air quality. Mechanical ventilation is preferable to relying on infiltration to provide fresh air, as the source and pathway of ventilation air can be controlled, reducing contamination and the potential for durability problems. Alternatively, air sealing can improve the function and effectiveness of existing ventilation systems, if present.

Adding wall insulation and reducing air infiltration will also reduce loads on HVAC equipment. When energy retrofits coincide with addition projects, adding insulation and air sealing upgrades that lower heating and cooling loads can allow an existing system to serve the added living area. A smaller unit may be used to replace an oversized system, which will lower the net cost.

### **3 Wall Air Sealing and Insulation Methods in Existing Homes**

Wall air sealing and insulation for existing homes should be considered together in an energy retrofit. Together they can significantly improve energy performance. This section outlines general air sealing provisions followed by specific considerations of upgrading insulation. The goal is to provide remodelers and homeowners an overview of considerations for including wall air sealing and insulation in an energy retrofit project.

#### **3.1 Existing Home Wall Air Sealing Methods**

Various materials and methods are used to complete an air sealing job, depending on the conditions in the home and the size of the air leakage pathway. Air leaks through building walls via two primary modes:

- Bypasses, or large holes in the home's air barrier
- Seams between building materials (DOE 2007).

##### **3.1.1 Materials for Air Sealing**

Materials used to seal air leakage sites must be as close to impermeable to air movement as possible and must form a continuous, nonporous surface over the opening being sealed (DOE 2007).

- Use caulk or spray foam sealant to seal cracks or holes smaller than a pencil width in the ceiling, floor, or exterior walls. Seal holes on the inside and outside surfaces of walls.
- For larger openings, use spray foam sealant or fill the crack with backing material and caulk the surface (fibrous insulation is not an air sealing material).
- Use sheet materials, such as insulation board or plywood, to cover large holes. Seal the edges of the sheet materials with caulk or spray foam sealant. Seal openings between the attic and house, and between the crawlspace or basement and house.

##### **3.1.2 Field Inspection**

Large air leakage pathways can be identified through visual inspections. Smaller air leakage pathways can be located using a blower door in conjunction with other diagnostic tests, such as a smoke pencil or infrared thermography. The contribution from small cracks and holes can be significant, and the improvements from identifying and fixing these areas should not be discounted.

##### **3.1.3 Installation Procedure**

See Figure 5 and Appendices A and B for more information.



1. Sealing large bypasses in the air barrier may require the use of sheet goods, such as plywood or extruded foam sheathing. These rigid barriers should be attached with mechanical fasteners and sealed with caulk or expanding foam.



2. Seams between building materials and small holes or cracks can be sealed using expanding foam or caulk. Backer rod can be used for seams larger than 5/16 in. to support the air sealing product.

**Figure 5. Air sealing installation steps**

### **3.1.4 Verification Procedures and Tests**

Following air sealing and the completion of all other energy retrofit projects, the home should be tested again using a blower door to determine the post-retrofit envelope air leakage levels and to determine if mechanical ventilation will be warranted.

### **3.1.5 Benefits**

- Reduces heating and cooling costs.
- Reduces air infiltration through potentially contaminated pathways.
- Increases room comfort.
- Helps to control indoor moisture levels.

### **3.1.6 Drawbacks**

- May be difficult to locate and remediate.
- May involve removing insulation and reinstalling.
- May require access to locations used for storage.

## **3.2 Existing Home Wall Insulation Methods**

The method and type of insulation selected for a wall retrofit application depend on many factors, including the presence or lack of insulation, the type of insulation, access to framing cavities, building façade and structure, project budget, and homeowner preferences. Residential wall insulation retrofits can thus be broken down into four categories:

- **Exterior insulated sheathing.** If the homeowner is open to removing and replacing the home's façade, insulation can be added to the exterior. This can be either a rigid foam or mineral wool sheet good, which is added in single or multiple layers over the exterior sheathing (if present).

- **Open framing cavities, gut rehab.** In an extensive renovation, often referred to as a *gut rehab*, the interior finish materials in the home (or in a room) are removed so the renovation contractor has direct access to the framing cavities to install the insulation. In this situation, the insulation methods and materials available to the contractor, including blown and spray-applied products, are identical to those in new construction.
- **Closed cavities, dense-pack.** For homes with insufficient insulation and where energy retrofit work needs to be minimally invasive, insulation can be added to the wall cavities using the dense-pack method. Small holes are cut into the walls from the exterior or interior to allow access to the framing cavities for insulation application.
- **Interior insulation application on exterior walls.** For uninsulated exterior mass walls—block, brick or concrete—insulation can be added to the interior side of the wall. Installing foam sheathing directly to the wall and then installing a layer of wall board is an effective method for doing this. If the wall is built out, insulation options will be identical to those suggested for open cavities (DOE n.d.).

### 3.3 Exterior Insulated Sheathing

#### 3.3.1 *Materials for Insulating*

Selection of insulated sheathing will depend on desired performance and project budget. The thickness of the sheathing should also be considered, as it will affect the finish details required to install new siding and the integration of the new façade with the home’s trim and flashing details.

- Polyisocyanurate provides the highest insulation value; however, it is the most expensive and can absorb water, making it unsuitable for below-grade applications. It has an R-value of R-5.6–R-8/in.
- Extruded polystyrene has a slightly lower insulation value but it is more impact-resistant and does not absorb water. It has an R-value of R-3.8–R-5.0/in.
- Rigid mineral wool panels are vapor permeable, unlike rigid foam sheathing. Mineral wool has an R-value of approximately R-3.7/in.

#### 3.3.2 *Field Inspection*

Before applying new exterior insulation on existing walls, examine the walls for signs of obvious moisture problems that should be repaired before, or along with, the energy upgrades.

#### 3.3.3 *Installation Procedure*

Before proceeding with installation, complete all air sealing details as previously discussed, and address and repair any moisture problems. To address air sealing, caulk or foam at penetrations, around windows and doors, and at the top and bottom plates of the wall, if accessible. If the foam will be used as a weather-resistive barrier, tape the seams using manufacturer-recommended tape. If not, install house wrap or other weather-resistive barrier directly over the rigid foam. As a matter of good practice, repair any damage uncovered during the retrofit process.

When retrofitting rigid foam insulation over the exterior of an existing home, you can install insulation directly over the siding if it is flat enough, or apply it directly to the underlying oriented strand board, plywood, or dimensional lumber sheathing. Install rigid foam sheathing

according to the manufacturer's instructions for nail type and nailing pattern. To determine the thickness of door and window jamb extensions, measure the combined thickness of the new insulation, siding, and any desired air space between the siding and underlying insulated sheathing. Also be sure to extend flashings and sills, if necessary (see Figure 6).



1. Extend door and window jambs as necessary.



2. Secure insulation using plastic cap nails.



3. Caulk and seal at penetrations, and at window and door jambs.



4. If foam sheathing will function as WRB, tape seams according to manufacturer's instructions.



5. If siding is installed in a rain screen configuration install furring strips attached directly to the underlying framing.



6. Install siding according to manufacturer's instructions.

**Figure 6. Exterior foam insulation installation steps**

### **3.3.4 Verification Procedures and Tests**

Before you install siding, visually inspect the insulated sheathing to ensure all flashing and air sealing work has been completed and, if the foam will serve as a weather-resistant barrier, that joints have been taped properly. After construction is complete, you should test the home using a blower door to determine the post-retrofit leakage levels and if a mechanical ventilation system will be warranted.

### 3.3.5 Benefits

The main advantage of applying rigid foam sheathing over the exterior of an existing home is that the insulation is continuous, reducing heat loss through uninsulated framing components of the home while increasing the insulation at the cavity areas. A layer of exterior insulation in addition to cavity insulation can be one of the more efficient wall systems available.

### 3.3.6 Drawbacks

No matter the type of foam insulation selected for exterior sheathing, installers should recognize that adding foam insulation to the exterior of a home reduces the ability of walls to dry to the outside, meaning that any wall with exterior foam sheathing should have the ability to dry to the home's interior.

## 3.4 Open Framing Cavities – Cavity Insulation (Fiberglass/Cellulose)

### 3.4.1 Materials for Insulating

The selection of cavity insulation for installation from the interior depends on desired performance and project budget. Fiberglass batts with air sealing considerations are one option. In addition, cellulose and fiberglass fibers can be installed into open wall cavities to provide full-fill insulation with increased air sealing properties.

- Fiberglass batts are frequently installed as cavity insulation.
- Cellulose, an insulation product manufactured from recycled wood fiber, and loose fiberglass fibers can be applied in open framing cavities using two approaches:
  - **The damp-spray approach.** The fibers are combined with a wet adhesive and sprayed into each individual wall cavity. The additive adheres the material to the wall cavity and keeps it stable until the finished material is installed. Following installation, excess insulation is trimmed to be even with the interior edge of the wall studs. Walls should be allowed to dry out adequately, given the added moisture in the adhesive additive.
  - **The netted approach.** This approach employs a mesh net or other similar blanket material to hold the insulation in place. It avoids the added moisture of the damp-spray approach, and finish materials can be installed immediately following insulation.

Fiberglass batts can provide insulation values of R-13–R-15 in a 2 × 4 wall cavity and R-19–R-21 in a 2 × 6 wall cavity. Depending on installation density, loose fill cellulose and fiberglass can provide insulation values of R-3.6–R-3.8/in.

#### ***References to Other Guidelines, Codes, and Standards: Vapor Barrier***

The current edition of the International Residential Code (IRC) (ICC 2012) includes details on the use of vapor barriers and is a good resource to determine when the use of interior vapor barriers is appropriate. Air sealing the wall and ensuring that there are no exterior water leaks provides the most benefit in ensuring good moisture performance in the walls.

The application of interior vapor barrier depends on climate. Three steps to successful water management are:

1. Make sure there is no bulk water leakage from the exterior.
2. Minimize air leakage into wall by sealing all penetrations.
3. Use the IRC to determine if the application of an interior vapor barrier is appropriate for the climate.

#### ***3.4.2 Field Inspection***

Before installing new insulation, inspect the walls for evidence of obvious moisture or other damage that should be repaired before, or along with the energy upgrades. If the condition of the façade, sheathing, door and window framing, or interior wall finish indicates moisture problems, do not proceed with insulation retrofit until the moisture issue has been identified and repaired.

#### ***3.4.3 Installation Procedure***

Before insulation is installed, all air sealing details should be completed and any moisture problems addressed and repaired. To address air sealing issues, caulk or foam at penetrations, around windows and doors, and at the top and bottom plates of the wall, if accessible. As a matter of good practice, repair any damage to the building uncovered during the retrofit process. All rough-in work in exterior walls should be completed before insulation is installed, and junction boxes and other open items should be masked. Insulation should be installed by qualified personnel, following the manufacturer's instructions, but as a rule insulation should fill each cavity, completely fitting around electrical wiring, plumbing and other utilities. The use of interior vapor barriers should be carefully considered with respect to the IRC (ICC 2012) and local requirements (see Figure 7).



1. Complete all air sealing and rough-in work before insulation is installed. Mask junction boxes.



2. Apply insulation to fill entire cavity, according to manufacturer's instructions.



3. Remove excess insulation if necessary.

**Figure 7. Open framing cavities – sprayed cavity insulation installation steps**

### **3.4.4 Verification Procedures and Tests**

Before drywall is installed, the insulation should be visually inspected and graded per RESNET protocols. Grade I insulation should be achieved. After construction is complete, the home should be tested with a blower door to determine the post-retrofit leakage levels and if dedicated mechanical ventilation will be warranted.

### **3.4.5 Benefits**

- Fiberglass batts are installed by most insulation contractors. They are often a low-cost solution for cavity insulation.
- Spray-applied cellulose and fiberglass provide full fill of wall cavities, fitting around utility runs and other obstructions.
- Although they are not a substitute for other air sealing measures, blown cellulose and fiberglass provide some additional air sealing benefit.

### **3.4.6 Drawbacks**

- If not installed to achieve Grade I of RESNET protocols, fiberglass batts may be compressed, lowering the effectiveness of the insulation.
- If not installed at the prescribed densities, blown fiberglass or cellulose can settle, lowering the effectiveness of the insulation by causing open areas at the top of building cavities.

## **3.5 Open Framing Cavities – Spray Foam Insulation (Open/Closed-Cell)**

### **3.5.1 Materials for Insulating**

Spray foam insulation has many advantages over other types of insulation because it can completely fill cavities and provides air sealing benefits. It comes in two varieties, which provide different insulation values and moisture permeability characteristics:



- Open-cell foam has insulation values of approximately R-3.6/in. and is permeable to moisture.
- Closed-cell foam has insulation values of up to R-6.5/in. and is not moisture permeable. It can also provide additional structural integrity to wall assemblies due to its strength.

### **3.5.2 Field Inspection**

Inspect walls for evidence of moisture or other damage. If the condition of the façade, sheathing, door and window framing, or interior wall finish indicates moisture problems, do not proceed with insulation retrofit until the issues have been identified and repaired.

### **3.5.3 Installation Procedure**

Any additional air sealing details that the spray foam will not address (e.g., around windows and doors as well as top and bottom plates, if accessible) should be completed and any moisture problems addressed and repaired. As a matter of good practice, any damage to the building uncovered during the retrofit process should be repaired.

All rough-in work in exterior walls should be completed before insulation is installed. Junction boxes and other open items should be masked. Similar to spray cellulose or fiberglass, insulation should be installed by qualified personnel, following the manufacturer's instructions. Insulation should fill each cavity, completely fitting around electrical wiring, plumbing, and other utilities. Wall cavities are not always completely filled, especially when using closed-cell foam, given its high cost and insulation value, but in a full fill application a "stud scrubber" is used to remove excess insulation material, leaving insulation flush with the face of each cavity. The use of interior vapor barriers should be carefully considered with respect to IRC (ICC 2012) and local requirements (see Figure 8). Vapor barriers are generally not recommended in walls with spray foam insulation.



**1.** Complete all air sealing and rough-in work before installing insulation. Mask junction boxes.



**2.** Apply foam to desired thickness following manufacturer's instructions



**3.** Remove excess foam if necessary

**Figure 8. Open framing cavities – spray foam insulation installation steps**

### **3.5.4 Verification Procedures and Tests**

Before drywall is installed, the insulation should be visually inspected and graded per RESNET protocols. Grade I insulation should be easily achieved for spray applied products. After construction is complete, the home should be tested with a blower door to determine the post-retrofit leakage levels and if mechanical ventilation will be warranted.

### **3.5.5 Benefits**

- Blown open- and closed-cell spray foam can provide full fill of wall cavities, fitting around utility runs and other obstructions.
- Although they are not a substitute for all air sealing measures (e.g. around windows and doors), open- and closed-cell spray foam provide air sealing for the surfaces where they are installed.
- Open-cell foam provides air sealing in addition to insulation levels similar to fiberglass batts.
- Closed-cell foam has a higher R-value for a given thickness than open cell foam.

### **3.5.6 Drawbacks**

- Spray foam insulation is typically the most expensive option for adding insulation to an existing wall.
- Special precautions are necessary when installing large areas of spray foam insulation.

## **3.6 Closed Framing Cavities – Dense-Pack Insulation (Fiberglass/Cellulose)**

### **3.6.1 Materials for Insulating**

- Cellulose and fiberglass fibers can be dense-packed into closed wall cavities to provide full fill insulation with additional air sealing properties.
- Cellulose should be installed at the recommended density of 3.25-4.0 lb/ft<sup>3</sup>.
- Fiberglass fibers should be installed at the recommended density of 1.6 lb/ft<sup>3</sup>.

### **3.6.2 Field Inspection**

Inspect walls for evidence of moisture or other damage. If the condition of the building façade, sheathing, door and window framing, or interior wall finish indicates moisture problems, do not proceed with insulation retrofit until the issues have been identified and repaired. Cracks and other evidence of weakness in wall finish materials should also be addressed, as dense-packing insulation compresses the insulation in a confined space and further damage can occur at these weak points. Repair areas that might be compromised during installation.

Pathways where insulation can escape from wall cavities should also be identified and addressed using the air sealing methods discussed previously. These pathways may include electrical outlets and switches on exterior walls, utility chases and penetrations, junctions to adjacent spaces such as attics and foundations, and open floor cavities. Wall cavities may also be open to return air ducts or plenums. Inspect the HVAC system to determine if this is the case, and seal and separate wall cavities from ducts and plenums if necessary. Blocking in each wall cavity should be located and if found necessitate multiple fill locations in the cavity.

### **3.6.3 Installation Procedure**

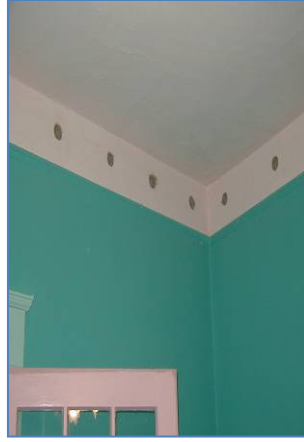
Before installation is installed, all air sealing details should be completed, and any existing problems addressed and repaired. To address air sealing issues, caulk or foam at penetrations, around windows and doors, and at the top and bottom plates of the wall, if accessible. As a matter of good practice, any damage to the building uncovered during the retrofit process should be repaired.

The dense-pack method for retrofitting both fiberglass and cellulose insulation in the closed wall cavities of an existing home is quite similar. Whatever the insulation material, it must be installed to the required density throughout the entire cavity to reduce the risks of convective looping, settling and air leakage. The steps below outline the one-hole dense-packing method, the best practice for closed-cavity insulation retrofit (see Figure 9).

1. Determine whether insulation will be installed from the exterior or interior of the home.
2. Exterior installation is preferred for occupied homes as it does not disrupt the residents.
3. Exterior installation is preferred for homes with wood, fiber cement, or vinyl siding, and asbestos shingles that are not blind nailed.
4. Interior installation is preferred for brick, stucco, or stone façades, and will be easier and more cost effective.
5. Cellulose calls for a density of  $3\frac{1}{4}$ –4 lb/ft<sup>3</sup>.
6. Blown fiberglass calls for a density of 1.6 lb/ft<sup>3</sup>.



1. Access holes are drilled for each cavity, in this case through the siding and exterior sheathing



2. Interior installation is identical to that of an exterior application, but holes are drilled directly through interior finish material



3. Hole locations are chosen based on ease of access to minimize the number of access holes necessary. Additional holes may be needed for framing cavity areas blocked by obstructions.



4. Insulation installation should begin with full-height walls without obstructions to accurately gauge insulation density. Best practice is to fill the top of the cavity completely and then to reinsert the tube to fill the bottom of the cavity. The fill tube is slowly removed as the cavity fills.



5. After the insulation is installed, retrofit access holes are sealed using tapered wooden plugs. For exterior applications siding is reinstalled. Interior plugs should be spackled and prepped for paint finish.

**Figure 9. Closed framing cavities – dense-pack insulation installation steps**

### **3.6.4 Verification Procedures and Tests**

Given adequate temperature difference across the wall assembly, thermographic scans can be used to confirm that insulation has been installed into the entire wall assembly. After construction is complete, the home should be tested with a blower door to determine the post-retrofit leakage levels and if mechanical ventilation will be warranted.

### **3.6.5 Benefits**

- Except in the case of very large obstructions, blown cellulose and fiberglass provide full fill of wall cavities, fitting around utility runs and other obstructions.
- Although they are not a substitute for other air sealing measures, blown cellulose and fiberglass provide some additional air sealing benefit.
- When installed at higher densities of 1.8 lb/ft<sup>3</sup> spray fiberglass can achieve an R-value of R-15 in a 2 × 4 cavity and R-21 in a 2 × 6 wall cavity.

### **3.6.6 Drawbacks**

- Significant wall repair is necessary after the installation.
- Each cavity must be evaluated for the location of blocking.
- Open areas of framing, for example at the location of a tub on an exterior wall, may not have any covering to stop the flow of the blown insulation onto the ceiling below.
- Some frame cavities are open to the basement and must be blocked before installing insulation.

## **3.7 Interior Insulation on Exterior Mass Walls**

Homes built with mass walls—made of concrete, brick, or block—often have no insulation. In this case, a worthwhile insulation retrofit would include adding insulation to the interior side of the exterior walls.

### **3.7.1 Materials for Insulating**

- Insulation on the interior of the exterior concrete or brick walls can be retrofitted using various methods, or a combination of methods. Foam sheathing can be applied to the block directly or with furring strips. Alternatively, a frame wall may be constructed in front of the block or brick wall. Still a third option (see Figure 10), a combination of foam sheathing and framing may be used.
- Foam insulation may be either polyisocyanurate (approximate R 6.5/in.) or extruded polystyrene (approximate R-5.0/in.). Both can be applied using compatible adhesives or special fasteners. Caulks and/or spray foam can be used to seal wall-floor and wall-ceiling joints.
- Wood framing can be installed in any configuration as it will not serve as the structural support when used for building out the wall in front of the main structural wall.
- If framing is used, fiberglass batts or blown insulation may be used to fill the cavities.



1. Remove drywall.



2. Install rigid foam and air seal.



3. Construct 2 × 4 wall.



4. Insulate 2 × 4 wall.



5. Finish interior walls.

**Figure 10. Interior insulation on exterior walls installation steps (NAHB RC 2010)**

### **3.7.2 Field Inspection**

Inspect walls for evidence of moisture or other damage. If the condition of the façade, sheathing, door and window framing, or interior wall finish indicates moisture problems, do not proceed with insulation retrofit until the issues have been identified and repaired.

Adding insulation to a mass wall will reduce heat transfer across that wall and correspondingly reduce drying potential, resulting in more moisture retention in the masonry wall structure. Especially in colder climates, this will increase the risk of freeze-thaw damage. Wood beams may also be exposed to increased moisture and begin to rot. These risks should be fully understood and investigated before interior insulation is installed on mass walls.

### **3.7.3 Installation Procedure**

Before insulation is installed, all air sealing details should be completed, and any moisture problems addressed and repaired. To address air sealing issues, caulk or foam at penetrations, around windows and doors, and at the top and bottom plates of the wall, if accessible. As a matter of good practice, any damage to the building uncovered during the retrofit process should be repaired.

Rigid foam insulation should be retrofitted directly over the interior of a mass wall with mechanical fasteners according to the manufacturer's instructions. Once foam is in place, furring strips should be installed to allow for drywall installation. Alternatively, interior walls could be built out allowing for the installation of additional cavity insulation. Window and door openings must be framed to accommodate the new interior insulation and/or framing. Careful air sealing and window flashing detail are needed to avoid future moisture problems.

#### **3.7.4 Verification Procedures and Tests**

When construction is complete, the home should be tested with a blower door to determine the post-retrofit leakage levels and if mechanical ventilation will be warranted.

#### **3.7.5 Benefits**

- Rigid foam sheathing installed over the interior of a mass wall significantly increases the wall thermal performance and provides an opportunity for air sealing and moisture protection.
- Interior insulation installed using framing members can provide an opportunity to upgrade and locate electrical and duct systems out of the mass wall and insulated behind these systems.

#### ***Critical Takeaways: Insulation and Air Sealing Overview***

This guide provides renovators and retrofit contractors an overview of considerations when including wall air sealing and insulation in an energy retrofit project.

Before proceeding with any insulation installation, all air sealing details should be completed. Then, based on costs and energy performance the goal is to select the wall insulation method and material for the retrofit.

The benefits, drawbacks, field inspection, installation procedure, and verification procedures and tests for various materials are detailed, including:

- Exterior foam
- Open framing cavity fiberglass and cellulose insulation
- Closed cavity dense pack fiberglass and cellulose
- Interior insulation application on mass exterior walls.

#### **3.7.6 Drawbacks**

- Installing insulation over existing interior finish surfaces may necessitate the relocation of utilities, junction boxes, and other items not needing upgrades.
- Window and door openings will require new jamb extensions and new framed openings.
- Reduced drying potential from added insulation may lead to freeze-thaw damage, rot of embedded wood beams, and other durability issues.

## **4 Summary and Next Steps**

This guideline provides renovators and retrofit contractors an overview of considerations when including wall air sealing and insulation in an energy retrofit project. The purpose is to provide the necessary information and guidance to home retrofit professionals to assess energy upgrade opportunities in the walls of an existing home and identify approaches to air sealing and insulation measures. All air sealing details should be completed before any insulation is installed. Then, based on costs and energy performance the goal is to select the wall insulation method and material for the retrofit. The overview outlines the benefits, drawbacks, field inspection, installation procedure, and verification procedures and tests of exterior foam, open framing cavity fiberglass and cellulose insulation, closed cavity dense pack fiberglass and cellulose, and interior insulation application on mass exterior walls. The next step is to produce detailed installation guides for each type of insulation in the overview and the specific air sealing considerations for each.



## References

ASHRAE. (2010). *ASHRAE Standard 62.2-2010 Ventilation and Acceptable Indoor Air Quality in Low-Rise Residential Buildings*. Atlanta, GA: American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc.

ASTM. (2003). *ASTM C1060 - 90(2003) Standard Practice for Thermographic Inspection of Insulation Installations in Envelope Cavities of Frame Buildings*. West Conshohocken, PA: American Society for Testing and Materials.

ASTM. (2009a). *ASTM E1186 -03(2009) Standard Practices for Air Leakage Site Detection in Building Envelopes and Air Barrier Systems*. West Conshohocken, PA: American Society for Testing and Materials.

ASTM. (2009b). *ASTM E2121 - 09 Standard Practice for Installing Radon Mitigation Systems in Existing Low-Rise Residential Buildings*. West Conshohocken, PA: American Society for Testing and Materials.

BPI. (2005). *Building Performance Institute Technical Standards for the Building Analyst Professional*. Malta, NY: Building Performance Institute.

DOE. (2007). *Midwest Weatherization Best Practices Field Guide*. Chicago, IL: U.S. Department of Energy Midwest Regional Office.

DOE. (n.d.) *Insulation and Air Sealing*.  
[www.energysavers.gov/your\\_home/insulation\\_airsealing/index.cfm/mytopic=11220](http://www.energysavers.gov/your_home/insulation_airsealing/index.cfm/mytopic=11220)

EPA. (2010a). *Healthy Indoor Environment Protocols for Home Energy Upgrades*. Washington, D.C.: U.S. Environmental Protection Agency.

EPA. (2010). *The Lead-Safe CerTified Guide To Renovate Right*. Washington, D.C.: U.S. Environmental Protection Agency.

EPA. (2012a). *Testing Your Home for Lead in Paint, Dust, and Soil*. Washington, D.C.: U.S. Environmental Protection Agency. [www.epa.gov/lead/pubs/leadtest.pdf](http://www.epa.gov/lead/pubs/leadtest.pdf).

EPA. (2012b). *Lead Abatement Professionals*. Washington, D.C.: U.S. Environmental Protection Agency. [www.epa.gov/lead/pubs/traincert.htm](http://www.epa.gov/lead/pubs/traincert.htm).

EPA. (2012c). *Map of Radon Zones*. Washington, D.C.: U.S. Environmental Protection Agency. [www.epa.gov/radon/zonemap.htm](http://www.epa.gov/radon/zonemap.htm).

EPA. (2012d). *Home Buyer's and Seller's Guide to Radon*. Washington, D.C.: U.S. Environmental Protection Agency. [www.epa.gov/radon/pubs/hmbyguid.html](http://www.epa.gov/radon/pubs/hmbyguid.html).

EPA. (2012e). *Asbestos in Your Home*. Washington, D.C.: U.S. Environmental Protection Agency. [www.epa.gov/asbestos/pubs/ashome.html](http://www.epa.gov/asbestos/pubs/ashome.html).

Georgia DCA. (2011). Georgia State Supplements and Amendments to the International Energy Conservation Code (2009 Edition). Atlanta, GA: U.S. Georgia Department of Community Affairs.

ICC. (2012). International Residential Code. Washington, D.C.: International Code Council. [www.iccsafe.org](http://www.iccsafe.org).

ICC. (2009). International Energy Conservation Code. Washington, D.C.: International Code Council. [www.iccsafe.org](http://www.iccsafe.org).

Krigger, J., & Dorsi, C. (2004). *Residential Energy Cost Savings and Comfort for Existing Buildings*. Helena, MT: Saturn Resource Management, Inc.

NAHB Research Center. (2010). *ENERGY PERFORMANCE REMODELING Case Study: Habitat for Humanity Montgomery County (HFH-MC) Montgomery County, MD*. Upper Marlboro, MD: NAHB Research Center.

PNNL and ORNL. (2010). *Retrofit Techniques & Technologies: Air Sealing A Guide for Contractors to Share with Homeowners*. Richland, WA: Pacific Northwest National Laboratory and Oak Ridge, TN: Oak Ridge National Laboratory.

RESNET. (2006). *Mortgage Industry National Home Energy Rating Systems Standards*. Oceanside, CA: Residential Energy Services Network.

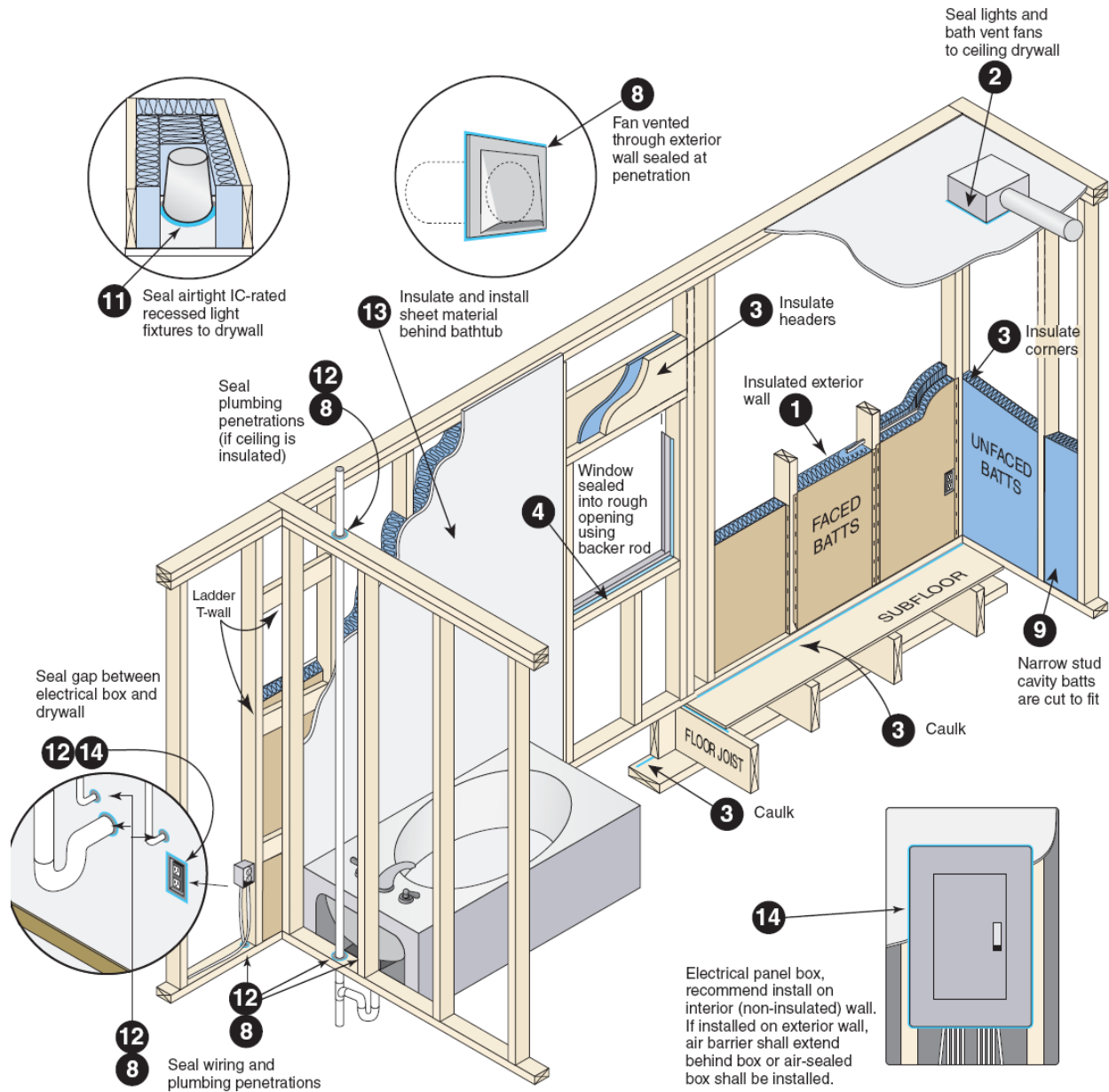
## Appendix A. Air Barrier and Insulation Inspection

2009 International Energy Conservation Code, Table 402.4.2 (ICC 2009)

Number	Component	Criteria
1	Air Barrier and Thermal Barrier	Exterior thermal envelope insulation for framed walls is installed in substantial contact and continuous with building envelope air barrier.
		Breaks or joints in the air barrier are filled or repaired.
		Air-permeable insulation is not used as a sealing material.
2	Ceiling/attic	Air barrier in any dropped ceiling/soffit is substantially aligned with insulation and any gaps are sealed
		Attic access (except unvented attic), knee wall door, or drop down stair is sealed.
3	Walls	Corners and headers are insulated. Junction of foundation and sill plate is sealed.
4	Windows and doors	Space between window/door jambs and framing is sealed.
5	Rim joists	Rim joists are insulated and include an air barrier.
6	Floors (including above garage and cantilevered floors)	Insulation is installed to maintain permanent contact with underside of subfloor decking. Air barrier is installed at any exposed edge of floor.
7	Crawlspace walls	Insulation is permanently attached to walls. Exposed earth in unvented crawlspaces is covered with Class I vapor retarder with overlapping joints taped.
8	Shafts, penetrations	Duct shafts, utility penetrations, knee walls and flue shafts opening to exterior or unconditioned space are sealed.
9	Narrow cavities	Batts in narrow cavities are cut to fit, or narrow cavities are filled by sprayed/blown insulation.
10	Garage separation	Air sealing is provided between the garage and conditioned spaces.
11	Recessed lighting	Recessed light fixtures are airtight, IC rated and sealed to drywall.
		Exception—fixtures in conditioned space.
12	Plumbing and wiring	Insulation is placed between pipes and exterior. Batt insulation is cut to fit around wiring and plumbing, or sprayed/blown insulation extends behind piping and wiring.
13	Shower/tub on exterior wall	Showers and tubs on exterior walls have insulation and an air barrier separating them from the exterior wall.
14	Electrical/phone box on exterior wall	Air barrier extends behind boxes or air sealed type boxes are installed.
15	Common wall	Air barrier is installed in common wall between dwelling units.
16	HVAC register boots	HVAC register boots that penetrate building envelope are sealed to subfloor or drywall.
17	Fireplace	Fireplace walls include an air barrier.

## Appendix B. Air Sealing Key Points (Georgia DCA 2012)

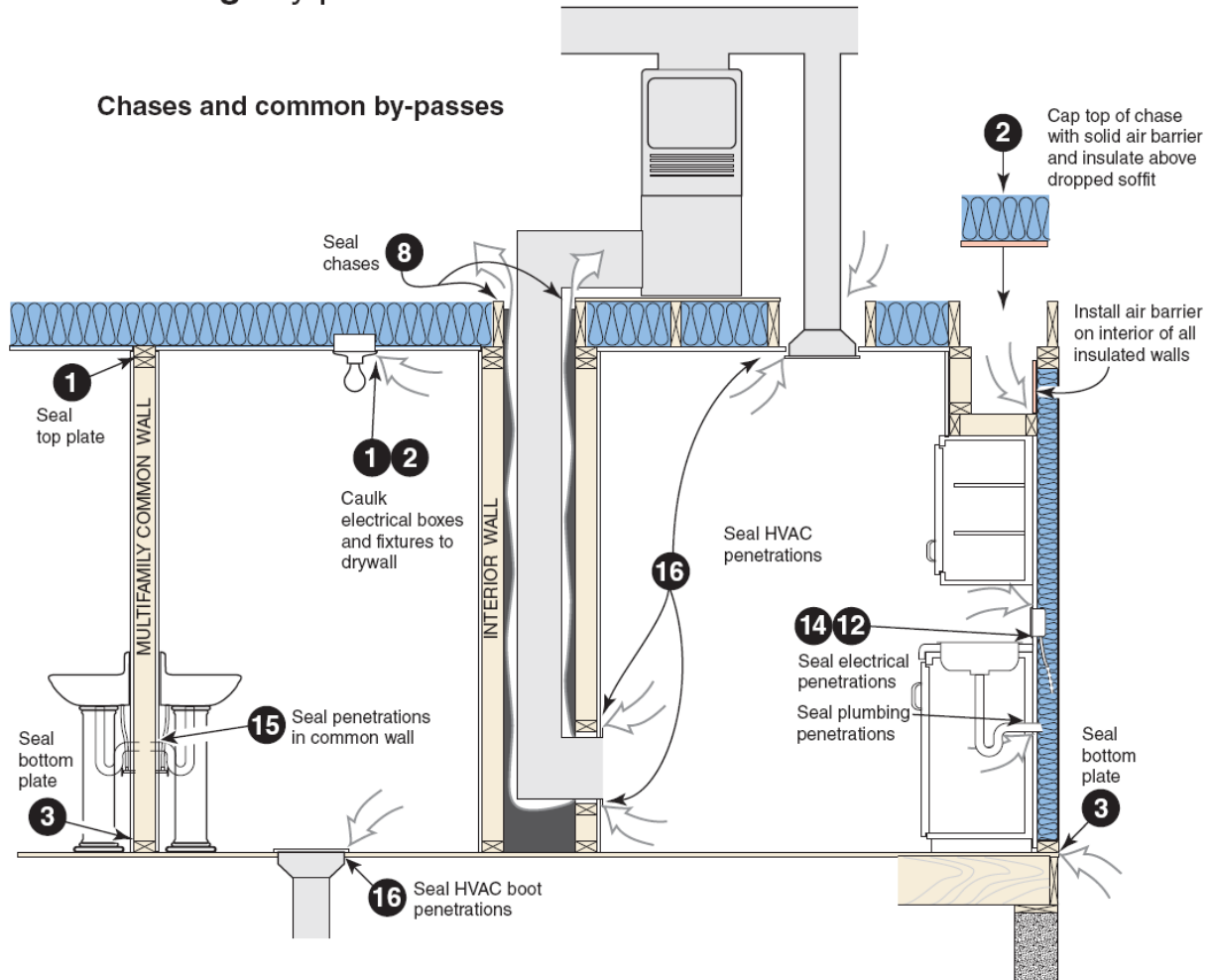
### Air sealing key points



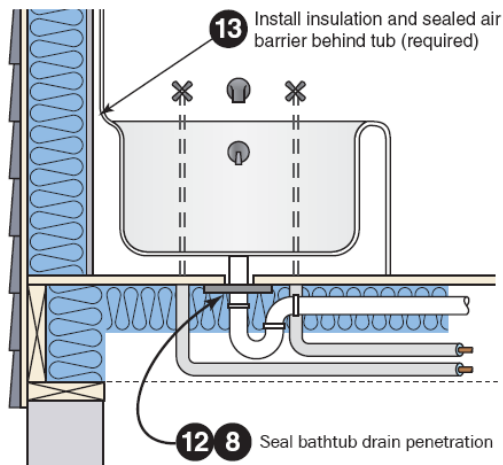
**Disclaimer:**  
This document is intended solely to help graphically demonstrate the air leakage provisions of section 402.4 of the 2009 IECC. It does not cover all airsealing locations or techniques. Other code provisions may be applicable as well.

## Air sealing key points *continued*

### Chases and common by-passes

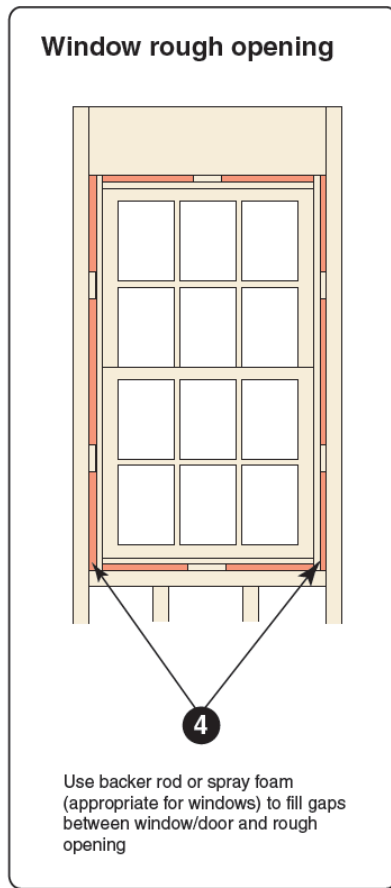


### Shower/tub drain rough opening

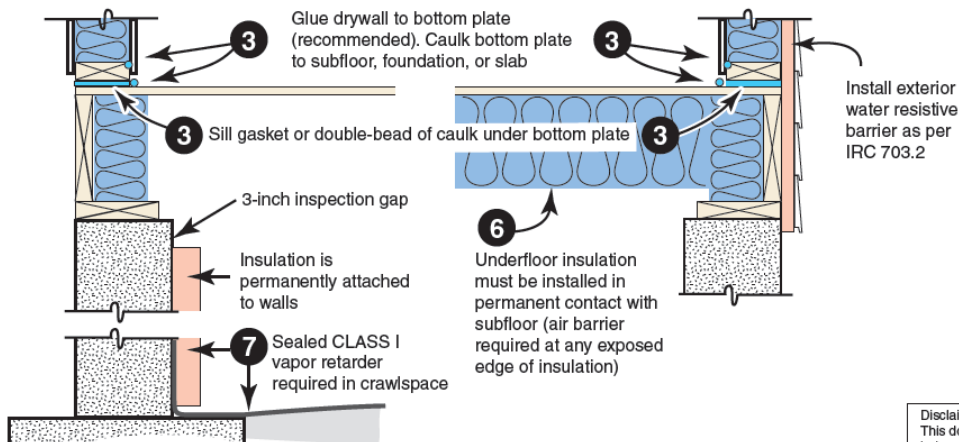
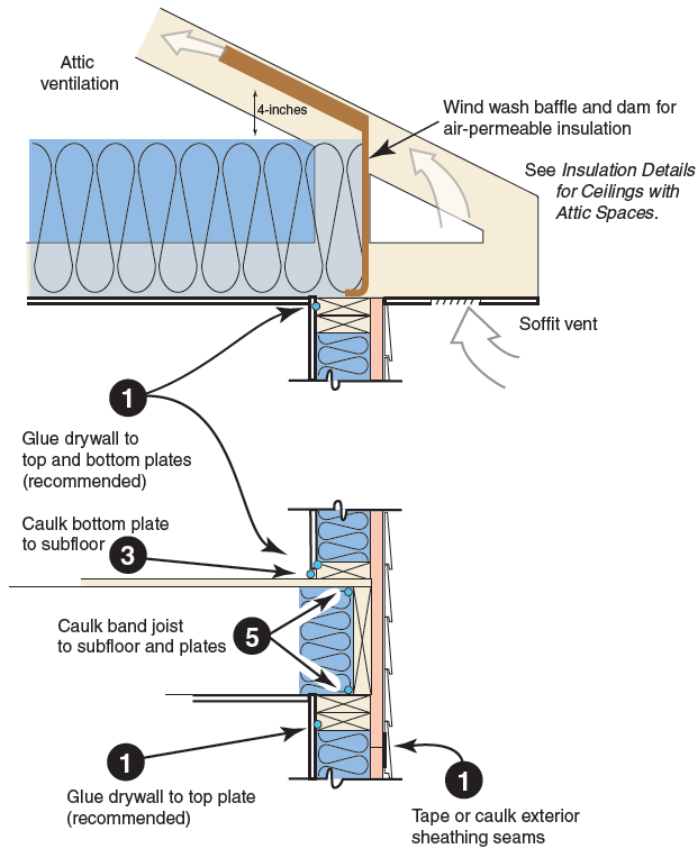


**Disclaimer:**  
This document is intended solely to help graphically demonstrate the air leakage provisions of section 402.4 of the 2009 IECC. It does not cover all airsealing locations or techniques. Other code provisions may be applicable as well.

## Air sealing key points *continued*



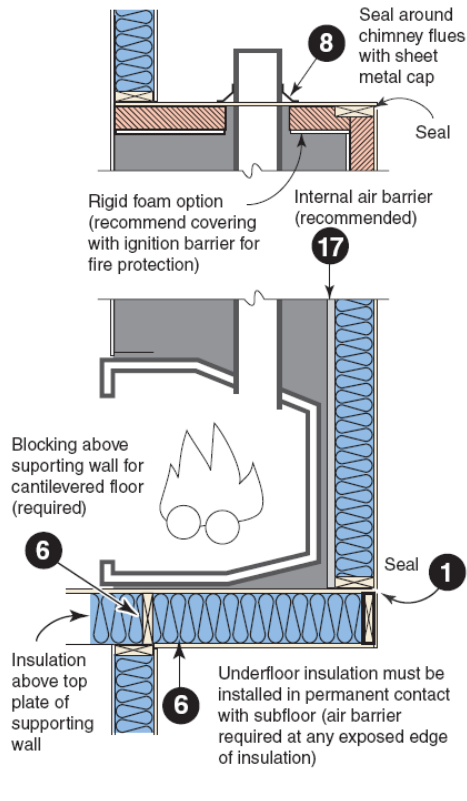
## Wall cross-section



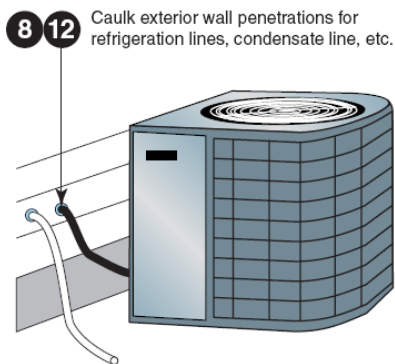
**Disclaimer:**  
This document is intended solely to help graphically demonstrate the air leakage provisions of section 402.4 of the 2009 IECC. It does not cover all airsealing locations or techniques. Other code provisions may be applicable as well.

## Air sealing key points *continued*

### Combustion chase penetrations

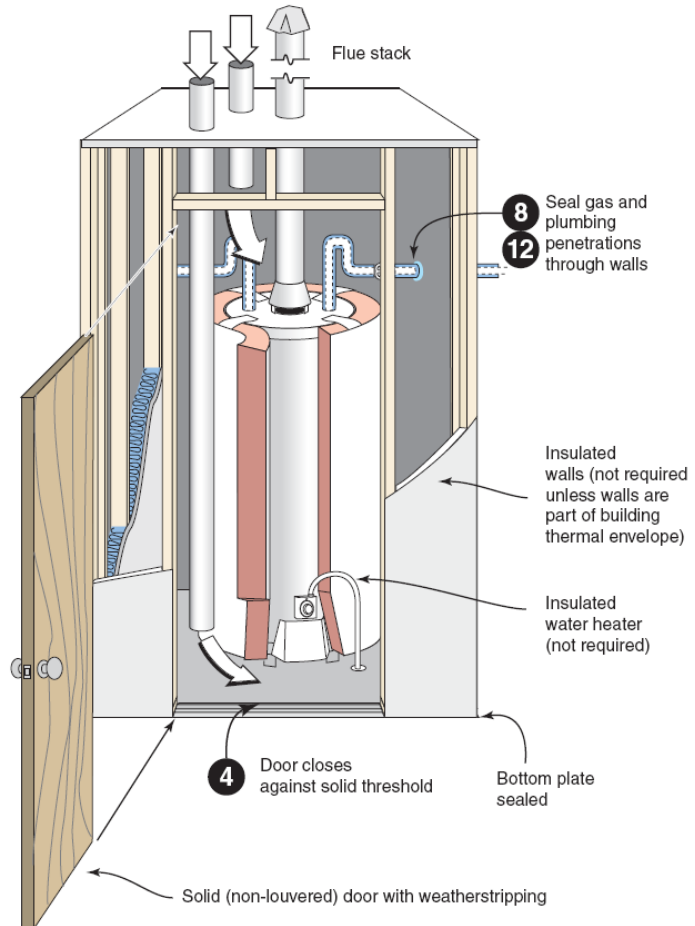


### Exterior penetrations



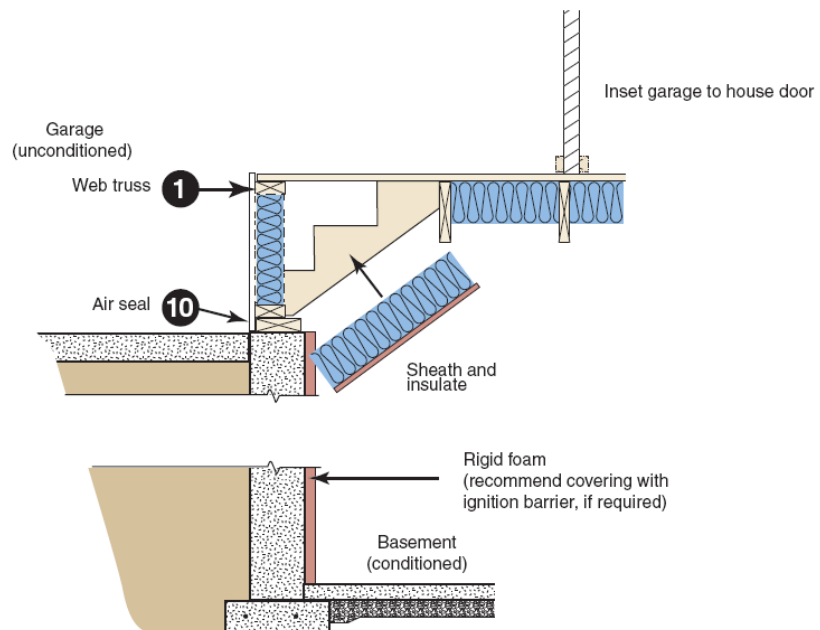
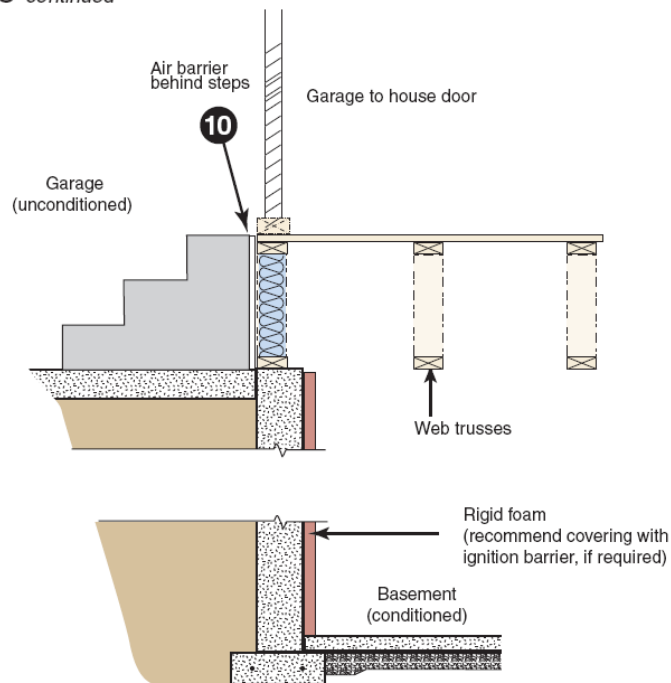
### Combustion closet

Combustion air inlets  
as per mechanical and/or fuel gas code



Disclaimer:  
This document is intended solely to help graphically demonstrate the air leakage provisions of section 402.4 of the 2009 IECC. It does not cover all airsealing locations or techniques. Other code provisions may be applicable as well.

## Air sealing key points *continued*



Disclaimer:  
This document is intended solely to help graphically demonstrate the air leakage provisions of section 402.4 of the 2009 IECC. It does not cover all airsealing locations or techniques. Other code provisions may be applicable as well.



*buildingamerica.gov*

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

DOE/GO-102012-3682 • September 2012

Printed with a renewable-source ink on paper containing at least 50% wastepaper, including 10% post-consumer waste.