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Guidelines for Measures & Strategies – Wall Air Sealing & Insulation Methods in Existing Homes

An Overview of Opportunity & Process

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Introduction

Modern high-performance homes feature airtight building envelopes with high levels of thermal resistance that control the flow of heat, air and moisture into and out of the home. Existing homes built prior to current building codes may have high levels of air leakage and lack adequate levels of insulation, both issues which increase heating and cooling losses and demands on HVAC systems. 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 wall insulation or potentially none at all. Given that walls can represent a majority of 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 adjacent spaces which can be semi-conditioned or unconditioned.

This guide provides renovators and retrofit contractors an overview of considerations when including wall air sealing and insulation in an energy retrofit project. It also outlines the potential project risks, various materials for insulating, possible field inspections needed, installation procedures, as well as the benefits and drawbacks. The purpose of this document 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 guidelines document builds upon 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. In addition, the document 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 guide 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/or Document Inspection in Existing Homes: Baseline & Diagnostic Inspections

The first step in planning any home energy retrofit project should include an evaluation of the existing 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 going forward with wall air sealing and insulation retrofits, 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 HVAC penetrations). Some homes may have relatively low levels of air leakage and sufficient wall insulation while others will be very leaky with no insulation whatsoever. This assessment may be conducted by an independent auditor or by a representative from a weatherization agency or local utility company. Homeowners should look for independent auditors that have BPI Building Analyst or RESNET Home Energy Rater certification.

Home Energy Assessment

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

Sizing things up

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

Testing 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, thermography scans, and combustion equipment venting.

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 and the fan pulls air out of the house at a specific pressure. Outside air then flows into the house through all unsealed cracks and openings. The calibrated air flow 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 existing infiltration rates, the home should be depressurized to 50 Pascals per the ANSI/ASTM E-779 standard, as well as equipment manufacturers' and energy program guidelines.

Figure 1. Blower Door.

Important Definitions:
Qualified Residential Energy Professional

A qualified residential energy professional has Building Performance Institute (BPI) Building Analyst certification (www.bpi.org), or The Residential Energy Services Network (RESNET) Home Energy Rater certification (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 sponsored weatherization agency.

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

References to Other Guidelines, Codes, and Standards:
Thermographic Image Methodology

Thermographic images show air leakage and missing insulation more accurately when temperatures inside and outside the home differ by at least 18°F, the home has not been in direct sun for at least three hours and winds are less than 15 miles per hour.

Inspections should follow these parameters and additional guidance found in ASTM C 1060. Following the cavity insulation inspection, the home should be depressurized to 20 Pa for at least 10 minutes.

The American Society for Non-Destructive Testing's (ASNT) Level I Thermographer designation provides a minimum level of knowledge for conducting building inspections.

HVAC Duct Air Leakage: Leaky, uninsulated (or minimally insulated) ducts in attics or crawlspaces can account for a large amount of a home's heating and cooling energy losses. Similar to a blower door, a duct blaster (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 following equipment manufacturers' and energy program guidelines. Duct leakage can be expressed in multiple ways including the fan flow (CFM) at 25 Pascals (CFM25) per square foot of conditioned area served, CFM25 per 100 square feet, and/or percent of system design flow.

Figure 2. Duct Blaster.

Thermography Scans: Insulation and Air Sealing Integrity: Thermography, using an infrared camera, can be used to assess framed wall cavities and for the presence and completeness of insulation. In addition to identifying missing or insufficient insulation, 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 per the guidance from the ASTM E 1186 Standard.

Figure 3. Infrared Image.

Combustion Equipment Venting: To determine if backdrafting of vented combustion appliances is possible, a Combustion Appliance Zone (CAZ) Worst Case Depressurization test should be conducted following the BPI Home Energy Auditing Standard. The CAZ testing indicates whether the potential exists for combustion equipment to leak combustion gases into the home.

Figure 4. Draft Pressure Testing using Combustion Analyzer.

Cost-benefit Analysis and Estimates

The energy assessment may include use of an energy analysis simulation tool 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, the home environment is often noticeably improved such as comfort and more consistent heating and cooling.

Critical Takeaways:
Air Sealing and Insulation - Breakout Box for Trade Contractors and Remodelers

Project: Air Seal and Insulate from the Outside

The Smith's 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 Smith's 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 contractor awarded the contract, presented the following solutions:

Action List:

1. Add 6" of loose fill fiberglass insulation to attic (R-26 to R-40).[A]
2. Install gasket at attic access panel and insulation above it.
3. Remove soffit from cantilevered floors front and rear; install rigid foam air barrier as joist blocking at wall plane and install 1" of spray polyurethane foam at floor deck and blocking perimeter. Fill joist cavity with loose fill fiberglass (R-13 to R-35). Trim with pre-finished material.
4. Install a taped and sealed weather resistant barrier over the wall sheathing and 1" of rigid foam, taped. (Add R-5 to walls.)[B]
5. Install new vinyl siding and trim.[C]

Added Project Cost

1.	$ 864
2.	50
3.	1,224
4.	2,120
5.	Included
	$ 4,248[D, E]

Estimated Annual Utility Cost Savings

	Before	After	Savings
Heating	1,012	721	29%
Cooling	313	313	
Water Heat	289	289	
Lights, Misc.	693	693	
Total	2,323	2,016	$308

Simple Payback in Years: $4,248/$308 = 14 years

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

[A] *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.*

[B] *The sealed and taped WRB 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.*

[C] *The contractor's estimate was $3.25 per sf for the siding. Gable end walls were finished with the same materials as the main house walls.*

[D] *Because the Smiths had the work performed during 2010 the portion o f the cost directly attributed to insulation cost was eligible for a 30% tax credit, as well. Accordingly, their out-of -pocket cost for the energy efficiency features netted to $3,700, and decreased the simple payback to 12 years.*

[E] *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*

Identifying Potential Risks

While energy savings 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 potential risks such as water leaks, should be clearly identified with provisions to address the risk with satisfactory remediation.

For example, any combustion venting problems arising from the CAZ testing (described above) 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. Professional visual inspections and tests can identify safety and operational problems that may require attention before any other work on the house proceeds including the following.

Combustion Safety – Combustion safety inspections should follow the BPI Home Energy Auditing Standard.

Ventilation – Based on post retrofit infiltration levels, additional mechanical ventilation may be necessary and should be installed to have the capability of supplying fresh air at levels outlined in ASHRAE Standard 62.2.

Moisture – Evaluate potential sources of moisture that will need to be addressed during the energy upgrades such as bathroom ventilation, window and door flashing, and vapor barriers.

Lead – Assume that lead paint is present when working in any home built before 1978. Renovations and retrofit activities should comply with EPA's Lead-Safe Renovation, Repair and Painting Rules if disturbing an area greater than 6 square feet of interior or 20 square feet of exterior painted surfaces.

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 unsure whether material contains asbestos, contact a qualified asbestos professional to assess the material, sample and test as needed.

Electricity – If a home has 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 siding 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. Where local ordinances do not address radon, use the EPA Map of Radon Zones (www.epa.gov) 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 2121 'Standard Practice for Installing Radon Mitigation Systems in Existing Low-Rise Residential Buildings'.

Contractor/Homeowner Safety:
Safety Points

For the remodelers whose niche marries home improvements with energy efficiency features – provide a physical exam of the house before the exercise of tightening up and insulating it.

1. Professional test of all combustion appliances and remediation as required. (BPI or RESnet certified inspector.) Have professional discuss results and care and maintenance with the homeowner(s). If absent, include carbon monoxide detector(s) in the improvement's Scope of Work.
2. If the house was built before 1978, ask the homeowner whether the home has been lead paint tested. If results were positive, retest area(s) that will be disturbed by new project and follow EPA guidelines.[A]
3. If the house has an in-ground basement, is in a high or moderate radon potential zone[B], and does not have a radon abatement system installed, the house should be tested for radon gas. Homeowner(s) can be tasked with ordering, placing, and submitting test kits.[C]
4. Visually inspect for asbestos.[D] Do not break or otherwise disturb asbestos products, as the mineral fibers becoming air borne presents 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 (VAT) used in basements, laundry rooms, and/or kitchens. Many twelve and nine inch square 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. ASHRAE Standard 62.2 concerns a ventilation standard for fresh indoor air in tightly-sealed houses. Be familiar with its recommendations and plan for mechanical ventilation should the upgrade warrant it.

[A] *For the homeowner, http://www.epa.gov/lead/pubs/leadtest.pdf*
For the contractor, http://www.epa.gov/lead/pubs/traincert.htm
[B] *http://www.epa.gov/radon/zonemap.html*
[C] *http://www.epa.gov/radon/pubs/hmbyguid.html*
[D] *http://www.epa.gov/asbestos/pubs/ashome.html*

2 Trade-offs: Value and Marketing

Measure Selection Criteria, Cost, & Performance

In addition to the home energy assessment, a cost-benefit analysis showing the potential savings and payback period for different 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. When 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 existing conditions, indicating that the specific energy efficiency upgrades will be somewhat unique.

System Interaction

Since homes function as a system, with no single component performing independently, it is important to consider the impact of home energy retrofits and the effect 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 fresh air and the HVAC system loads and sizing as outlined below.

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 existing 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. If replacing an existing system, a smaller unit may be used, resulting in a lower net cost.

3 Wall Air Sealing and Insulation Methods in Existing Homes

Wall air sealing and insulation considerations for existing homes should be considered together in an energy retrofit. Both of these working together can significantly improve the energy performance of an existing home. This section outlines general air sealing provisions first followed by specific considerations of upgrading insulation. The goal is to provide remodelers and/or 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

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

1. Bypasses, or large holes in the home's air barrier
2. Seams between building materials

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.

- 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 both 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 (fiberglass 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. In addition, be sure to seal openings between the attic and house, and between the crawl space or basement and house.

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.

Installation Procedure

See Appendices: Air Sealing Key Points and Air Barrier and Insulation Inspection 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" to support the air sealing product.

Figure 5. Air sealing installation steps.

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 leakage levels for the home, and if mechanical ventilation will be warranted to be capable of providing ventilation rates outlined in ASHRAE 62.2.

Benefits

- Reduces heating and cooling costs,
- Increases room comfort, and
- Helps to control indoor moisture levels in winter.

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 depends on many factors, including the presence or lack of existing insulation, the type of existing insulation, access to framing cavities, existing building façade and structure, project budget and homeowner preferences. Keeping these factors in mind, residential wall insulation retrofits can be broken down into four categories:

Exterior Foam – If the homeowner is open to removing and replacing the home's existing façade, additional insulation can be added to the exterior of the home. This added insulation is typically foam sheathing, which is added in single or multiple layers over the existing exterior sheathing.

Open Framing Cavities, Gut Rehab – In an extensive renovation, often referred to as a "gut rehab," the interior finish materials in the home (or a room) are removed so that the renovation contractor has direct access to the framing cavities for the installation of insulation. In this situation, the insulation methods and materials available to the contractor, including blown products and spray- applied foams, are identical to those in new construction.

Closed Cavities, Dense-pack – For homes with insufficient levels of 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 – When dealing with 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.

3.3 Exterior Foam

Materials for Insulating

Selection of foam sheathing will depend on desired performance and project budget. The thickness of the foam 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 existing 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-6.5 per inch.
- 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-5 per inch.

Field Inspection

Before application of new insulation the exterior of the existing walls, the walls should be examined for signs of obvious moisture problems that should be repaired prior to, or along with the energy upgrades.

Installation Procedure

Before proceeding with insulation installation, all air sealing details should be completed as previously discussed, and any existing moisture problems addressed and repaired. To address air sealing, caulk or foam at penetrations, around windows and doors, and at the top and bottom plate of the wall, if accessible. If the foam will be used as a water-resistive barrier, tape the seams using manufacturer-recommended tape. If not, install house wrap or other water-resistive barrier directly over the rigid foam. Of course, any damage to the building uncovered during the retrofit process should be repaired.

When retrofitting rigid foam insulation over the exterior of an existing home, insulation can be installed directly over the existing siding if it is flat enough, or if it is necessary to remove the existing siding, it can be applied directly to the underlying OSB, plywood, or dimensional lumber sheathing. Install rigid foam sheathing according to the manufacturer's instructions for nail type and nailing pattern. Typically, plastic-cap nails are used. To determine the thickness of door and window jamb extensions, measure the combined thickness of the new insulation, siding, and if siding is being installed in a rain screen configuration, desired air space between the siding and underlying sheathing. Also be sure to extend flashings and sills, if necessary.

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.

Verification Procedures and Tests

Before installation of siding, the sheathing should be visually inspected to ensure all flashing and air sealing work has been completed and, if the foam will serve as a WRB, that joints have been taped properly. Following completion of construction, it is recommended to test the home using a blower door to determine the post-retrofit leakage levels for the home and if a mechanical ventilation system will be warranted.

Benefits

- The main advantage of applying rigid foam sheathing over the exterior of an existing home is that the insulation is continuous, reducing the heat loss through the 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 common in new homes.

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)

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, both cellulose and fiberglass fibers can be sprayed into open wall cavities to provide full-fill insulation with increased air sealing properties.

- Fiberglass batts are frequently installed as cavity insulation.
- Cellulose is typically applied with a wet adhesive additive that adheres the material to the wall cavity and keeps it stable until the finished material is installed. The recommended installed density is 3.25-4.0 lb/ft^3 for cellulose.
- Spray-applied fiberglass is typically installed in a dry application at a minimum installed density of 1.6 lb/ft^3.

Field Inspection

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

Installation Procedure

Before proceeding with insulation installation, all air sealing details should be completed as previously discussed, and any existing moisture problems addressed and repaired. To address air sealing, caulk or foam at penetrations, around windows and doors, and at the top and bottom plate of the wall, if accessible. Of course, 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 installation, and junction boxes and other open items should be masked. Installation should be conducted by qualified personnel, following the insulation manufacturer's instructions, but as a general rule insulation should fill each cavity, completely fitting around electrical wiring, plumbing and other utilities. The use of interior vapor barriers should be carefully

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

The current editions of the International Residential Code (IRC) include detail on the use of vapor barriers and are good resources when considering the use of interior vapor barriers. 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 include:

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.

considered with respect to the recent editions of the International Residential Code and local requirements.

1) Complete all air sealing and rough-in work prior to insulation installation and 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 - Blown Cavity Insulation (Fiberglass/Cellulose) Installation Steps

Verification procedures and Tests

Before installation of drywall, the insulation should be visually inspected and graded per RESNET protocols. Grade I insulation should be achieved. Following completion of construction, it is recommended to test the home using a blower door to determine the post-retrofit leakage levels for the home and if dedicated mechanical ventilation will be warranted.

Benefits

- Fiberglass batts are installed by most insulation contractors. In addition, they are often a low-cost solution for cavity insulation.
- Both 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.

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)

Materials for Insulating

Spray foam insulation provides many advantages over other types of insulation with its abilities to completely fill cavities while providing 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 per inch and is permeable to moisture.
- Closed-cell foam has insulation values of up to R-6.5 per inch and is not moisture permeable. It can also provide additional structural integrity to wall assemblies due to its high density.

Field Inspection

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

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 as previously discussed, and any existing moisture problems addressed and repaired. Of course, 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 installation. Junction boxes and other open items should be masked. Similar to spray cellulose or fiberglass, installation should be conducted 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 the recent editions of the International Residential Code and local requirements. Vapor barriers are generally not recommended in walls with spray foam insulation.

1) Complete all air sealing and rough-in work prior to installing insulation and 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.

Verification Procedures and Tests

Before installation of drywall, the insulation should be visually inspected and graded per RESNET protocols. Grade I insulation should be easily achieved for spray applied products. Following completion of construction, it is recommended to test the home using a blower door to determine the post-retrofit leakage levels for the home and if mechanical ventilation will be warranted.

Benefits

- Both 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.

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)

Materials for Insulating

Both 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/ft3.
- Fiberglass fibers should be installed at the recommended density of 1.6 lb/ft3.

Field Inspection

Inspect walls for evidence of moisture or other existing damage. If the condition of the building façade, sheathing, door and window framing or interior wall finish indicates existing moisture problems, do not proceed with insulation retrofit until the moisture issue has been identified and repaired. Cracks and other evidence of weakness in existing 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 existing 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.

Installation Procedure

Before proceeding with insulation installation, all air sealing details should be completed as previously discussed, and any existing moisture problems addressed and repaired. To address air sealing, caulk or foam at penetrations, around windows and doors, and at the top and bottom plate of the wall, if accessible. Of course, 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.

- Determine whether insulation will be installed from the exterior or interior of the home.
    - Exterior installation is preferred for occupied homes as it does not disrupt the home's residents
    - Exterior installation is preferred for homes with wood, fiber cement or vinyl siding, and asbestos shingles that are not blind nailed
    - Interior installation is preferred for brick, stucco or stone façades, and will be easier and more cost-effective
- Cellulose calls for a density of 3.25 to 4.0 pounds per cubic foot,
- Blown fiberglass calls for a density of 1.6 pounds per cubic foot.

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 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) Following the insulation, 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.

Verification Procedures and Tests

Thermography scans can be used to confirm that insulation has been installed into the entire wall assembly. Following completion of construction, it is recommended to test the home using a blower door to determine the post-retrofit leakage levels for the home and if mechanical ventilation will be warranted.

Benefits

- Both 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/ft3 spray fiberglass can achieve an R-value of R-15 in a 2x4 wall cavity.

Drawbacks

- Significant wall repair is necessary following the installation adding to the installation cost.
- 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.

Materials for Insulating

Retrofit of insulation on the interior of the exterior concrete or brick walls can be performed 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 existing block or brick wall. Still a third option (as shown in the photos below) a combination of foam sheathing and framing may be used.

- Foam insulation may be either polyisocyanurate (approximate R 6.5 per inch) or extruded polystyrene (approximate R-5.0 per inch). 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 as described above.

Field Inspection

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

Critical Takeaways:
Insulation & 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, and
- Interior insulation application on mass exterior walls.

Installation Procedure

Before proceeding with insulation installation, all air sealing details should be completed as previously discussed, and any existing moisture problems addressed and repaired. To address air sealing, caulk or foam at penetrations, around windows and doors, and at the top and bottom plate of the wall, if accessible. Of course, any damage to the building uncovered during the retrofit process should be repaired.

When retrofitting rigid foam insulation over the interior of an existing mass wall, the insulation can be installed directly to the wall using mechanical fasteners. Install rigid foam sheathing following manufacturer's instructions. Once foam is installed 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 as shown in the figures below. Window and door openings must be framed to accommodate the new interior insulation and/or framing. Careful air-sealing and window flashing detail is needed to avoid future moisture problems.

1) Remove drywall.

2) Install rigid foam and air seal.

3) Construct 2x4 wall.

4) Insulate 2x4 wall.

5) Finish interior walls.

Figure 10. Interior Insulation on Exterior Walls installation steps.

Verification Procedures and Tests

Following completion of construction, it is recommended to test the home using a blower door to determine the post-retrofit leakage levels for the home and if mechanical ventilation will be warranted.

Benefits

- Rigid foam sheathing installed over the interior of an existing mass wall home significantly increases the wall thermal performance as well as 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.

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

4 Summary & Next Steps

This guide provides renovators and retrofit contractors an overview of considerations when including wall air sealing and insulation in an energy retrofit project. The purpose of this document 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. 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 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 of this process would be detailed installation guides for each type of insulation in the overview and the specific air sealing considerations for each.

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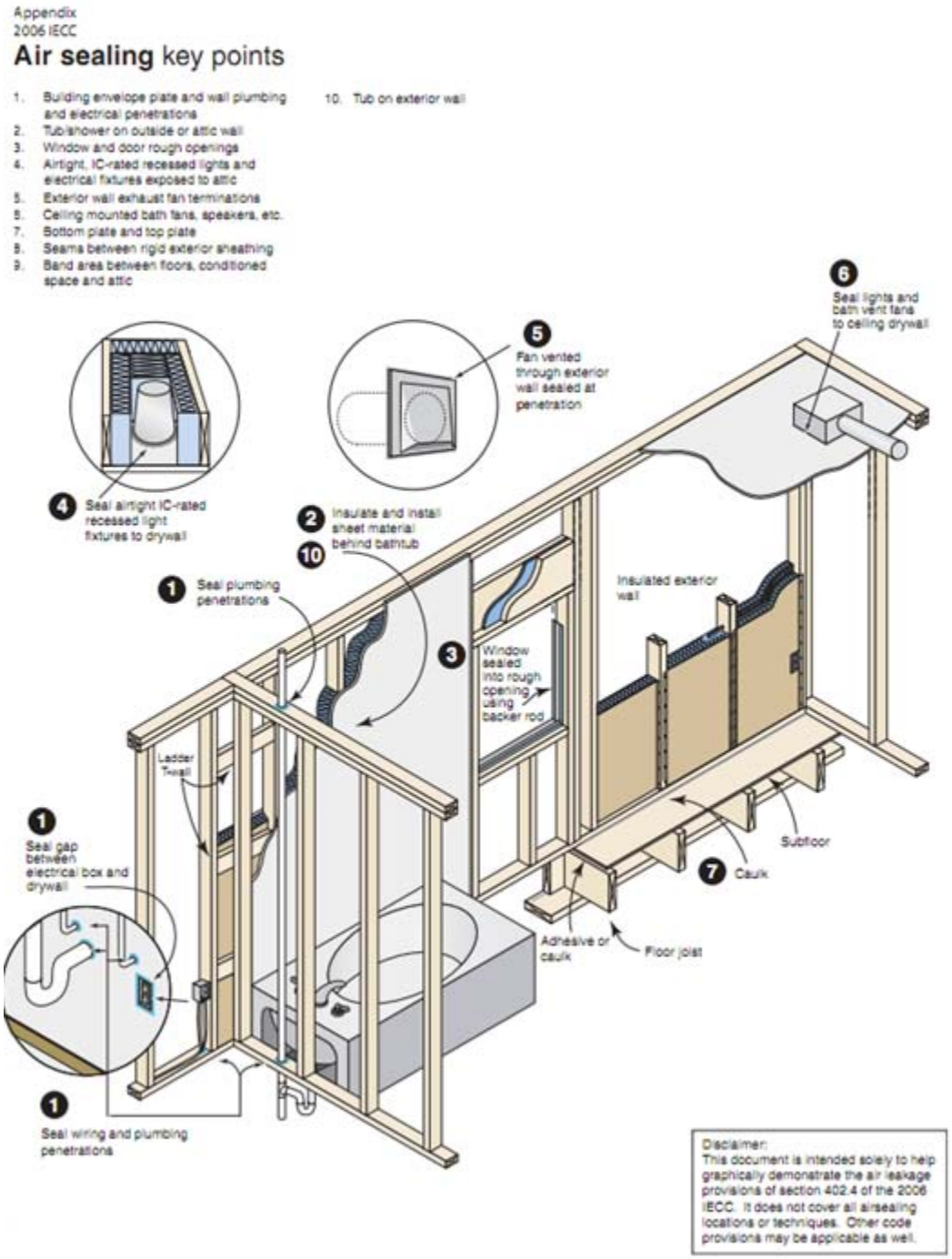
Appendix A: Air Sealing Key Points



Appendix B: Air Barrier and Insulation Inspection

2009 International Residential Code, Table N1002.4.2

Component	Criteria
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.
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.
Walls	Corners and headers are insulated. Junction of foundation and sill plate is sealed.
Windows and doors	Space between window/door jambs and framing is sealed.
Rim joists	Rim joists are insulated and include an air barrier.
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.
Crawlspace walls	Insulation is permanently attached to walls. Exposed earth in unvented crawlspaces is covered with Class I vapor retarder with overlapping joints taped.
Shafts, penetrations	Duct shafts, utility penetrations, knee walls and flue shafts opening to exterior or unconditioned space are sealed.
Narrow cavities	Batts in narrow cavities are cut to fit, or narrow cavities are filled by sprayed/blown insulation.
Garage separation	Air sealing is provided between the garage and conditioned spaces.
Recessed lighting	Recessed light fixtures are airtight, IC rated and sealed to drywall.
	Exception—fixtures in conditioned space.
Plumbing and wiring	Insulation is placed between outside and pipes. Batt insulation is cut to fit around wiring and plumbing, or sprayed/blown insulation extends behind piping and wiring.
Shower/tub on exterior wall	Showers and tubs on exterior walls have insulation and an air barrier separating them from the exterior wall.
Electrical/phone box on exterior wall	Air barrier extends behind boxes or air sealed type boxes are installed.
Common wall	Air barrier is installed in common wall between dwelling units.
HVAC register boots	HVAC register boots that penetrate building envelope are sealed to subfloor or drywall.
Fireplace	Fireplace walls include an air barrier.

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