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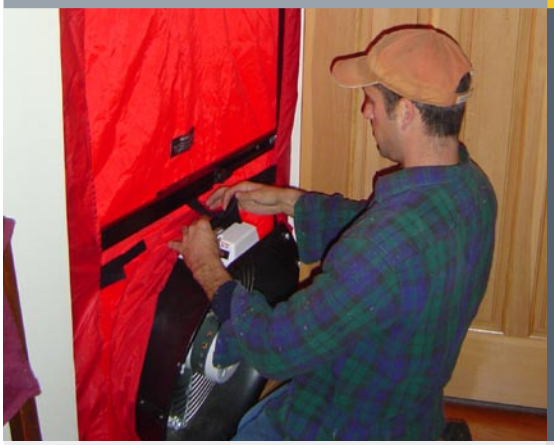

## Retrofit Techniques & Technologies:

# Air Sealing

## A Guide for Contractors to Share with Homeowners

PREPARED BY

Pacific Northwest National Laboratory
& Oak Ridge National Laboratory

April 12, 2010

Building AMERICA
U.S. Department of Energy
Research Toward Zero Energy Homes

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## Retrofit Techniques and Technologies:

# Air Sealing

## A Guide for Contractors to Share with Homeowners

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# Preface

Building AMERICA
U.S. Department of Energy
*Research Toward Zero Energy Homes*

You can learn more about Building America and download additional copies of this document, other best practices, research reports, and case studies at

**www.buildingamerica.gov**

The U.S. Department of Energy recognizes the enormous potential that exists for improving the energy efficiency, safety, and comfort of existing American homes. This series of Retrofit Techniques and Technologies describes approaches for homeowners and builders working on existing homes. This guide will help homeowners identify ways to make their homes more comfortable, more energy efficient, and healthier to live in. It also identifies the steps to take, with the help of a qualified home performance contractor, to seal unwanted air leaks while ensuring healthy levels of ventilation and avoiding sources of indoor air pollution. Contractors can use this document to explain the value of these air sealing measures to their customers. The references in this document provide further explanation of air sealing techniques and technologies.

Studies show that the measures described in this guide can typically achieve whole-house energy savings of 10% to 20% over pre-retrofit energy usage. In older homes or homes with greater levels of air leaks, savings may be much higher.

These practices are based on the results of research and demonstration projects conducted by the U.S. Department of Energy's Building America and Home Performance with ENERGY STAR sponsored by the U.S. Environmental Protection Agency and DOE. Home Performance with ENERGY STAR offers a comprehensive, whole-house approach to improving the energy efficiency and comfort of existing homes and requires a test-in/test-out to test combustion products (www.energystar.gov/homeperformance).

DOE's Building America has worked with some of the nation's leading building scientists and more than 300 production builders on over 41,000 new homes. Building America's research applies building science to the goal of achieving efficient, comfortable, healthy, and durable homes.

Please submit your comments via e-mail to:
George James (George.James@ee.doe.gov)

# Contents

## Introduction


Imagine opening a window in your house and leaving it that way 24 hours a day, all year long. On balmy spring days, the breeze wouldn't be so bad. But, in the freezing cold of winter and the sticky heat of summer, with the furnace or air conditioner on, smart homeowners would recognize they might as well be throwing buckets of quarters out the window to pay for the escaping heated or cooled air.

Air leaks in most existing homes add up to an open window in your home. Air sealing is one of the least expensive and most cost-effective measures you can take to improve your home's comfort and energy efficiency. By sealing uncontrolled air leaks, you can expect to see savings of 10% to 20% on your heating and cooling bills, and even more if you have an older or especially leaky house. But, before you grab your caulk gun, there are some things you should consider.

Many older homes lack proper ventilation, so they depend on those cracks and leaks to let in air, especially when fuel-burning appliances are operating inside the home. Without ventilation, carbon monoxide and air pollutants from cleaning chemicals, combustion appliances, and off-gassing household products can build up, creating an unhealthy and even dangerous environment in the home. Opening windows is one way to ventilate, but there are times when opening the windows is not practical (e.g., it is too cold or too hot outside). Fortunately there are other options for bringing fresh air into your home. A *certified* contractor can help you get all the energy savings and comfort possible from a well sealed home, along with the safety of proper ventilation.

Your house is a system and every component in it works together. Adding insulation and sealing air leaks can improve the energy efficiency of your home and improve your home's comfort and durability. However, every change you make to the building's envelope (walls, floors, and ceiling) and components will affect how the home works to keep out the elements and keep your family safe and comfortable. Tightening the building envelope without providing appropriate ventilation can cause pressure imbalances or negative pressure in the house. This negative pressure can set up the conditions for backdrafting of fireplaces or fuel-burning (combustion) appliances and may draw pollutants into the home. A trained contractor understands how systems work together to keep your house operating as it should.

This guide gives homeowners tips on where to find a good contractor, how to get your home tested for airtightness, where the biggest air leaks usually are and how to fix them, what the potential health and durability concerns are, and how your contractor can handle these concerns—in short, what you need to know to proceed with confidence to a more comfortable, energy-efficient, and healthy home for your family.

If you are a contractor, share this guide with your customers so that they can understand the process you will follow to make their home more comfortable, durable, and energy efficient. See the references in this guide for detailed explanations of air sealing techniques.

## Air Sealing versus Insulation:

### Why do I need to air seal? I thought all I needed to do was add more insulation.

Insulation is like a fuzzy wool sweater on a winter day. It will certainly keep you warm if the air is calm. But, if the wind picks up, you are going to need a windbreaker to keep the breeze from carrying away the heat. Air sealing is like adding the windbreaker. It keeps the conditioned air where it belongs.

## Keys to indoor air quality:

- Remove pollutant sources, if possible.
- Avoid combustion (fuel-burning) appliances that do not directly vent to the outdoors.
- Never use non-vented combustion (e.g., kerosene) heaters inside the house.
- Fix water leaks and moisture management problems.
- Test for radon and carbon monoxide levels.
- Provide adequate ventilation.

ICC Docket No. 13-0550
CUB-City Exhibit 1.2

Certified contractors are trained in building science principles to know the safest and most effective ways to improve your home's energy efficiency.

## Finding a Contractor

There are two nationally recognized energy certifications for home energy auditors and contractors: the Building Performance Institute (BPI) Building Analyst certification and the Residential Energy Services Network (RESNET) HERS Rater certification. Historically, BPI certification has focused on understanding the building science of retrofitting *existing* homes and RESNET has focused on building science in *new* home construction.

BPI is a nonprofit organization that accredits auditors, contractors, and other building professionals. Auditors or building analysts specialize in evaluating building systems and potential energy savings in homes. The certified BPI Building Analyst energy auditor has passed both written and field exams, and must recertify every three years. Contractors learn about building systems and are trained to install energy-efficiency measures. For more information see www.BPI.org

A certified RESNET energy auditor is called a HERS Rater. HERS (the Home Energy Rating System) provides a miles-per-gallon type rating for expected energy consumption in homes based on computer models. Each home receives a score that can be compared with other new or existing homes—the lower the score, the more efficient the home. More information about HERS can be found at www.natresnet.org.

An easy way to find a certified contractor is through a national or regional retrofit program. One such program is Home Performance with ENERGY STAR, a national program from the U.S. Environmental Protection Agency and the U.S. Department of Energy that promotes a comprehensive, whole-house approach to energy-efficiency improvements. To find a Home Performance with ENERGY STAR contractor for your area, go to www.energystar.gov and click on the link for Home Performance with ENERGY STAR. Next, click on the "locations" link for certified contractors in your state. For cities and states without Home Performance with ENERGY STAR contractors, you can find lists of contractors in your area who understand the building science whole-house approach through the BPI and RESNET websites: www.bpi.org or www.natresnet.org

Many local, state, and federal entities offer grants and tax credits for energy-efficient home improvements. Check with your local utility or city, or check the DOE-sponsored Database of State Incentives for Renewables and Efficiency (DSIRE) at www.dsireusa.org. This site is frequently updated and is a wealth of information, organized by state, on state, local, utility, and federal incentives, tax credits, and policies that promote renewable energy and energy efficiency.

# Test-In/Test-Out

If you are participating in a home performance or weatherization program, one of the first steps may be an energy audit. Depending on the program, this audit may be conducted by an independent auditor or by a weatherization contractor. Details will vary by location and program, but here is what you can typically expect.

## Step 1 - The Audit

First, the contractor or auditor should inspect, evaluate, and analyze your home. This step is commonly called an audit, but that term has been around for a long time and can mean many things. Perhaps the most important part of the audit is the conversation between the occupants and the auditor. Be prepared to talk about comfort issues and energy bills.

Here is what your audit should include:

- **SIZING THINGS UP –** The auditor may measure your house 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 your house performs in ways that cannot be seen by eyes alone. These tests may include a blower door test, duct pressurization testing, infrared cameras and smoke sticks, combustion safety testing, and carbon monoxide sampling. A heating and cooling contractor may evaluate your furnace and air conditioning system supply and return air balance. More information on these tests is included in the next section.
- **COST-BENEFIT ANALYSIS AND ESTIMATES –** The auditor will estimate the costs of installing the measures and use a computer program to estimate the expected energy savings. The cost of the measures divided by the annual savings will tell you the "simple pay back" or how many years the measures will take to pay for themselves. Often investments in energy efficiency provide a better return than stocks, bonds, or savings accounts, while improving comfort.
- **GETTING THE GREEN LIGHT –** Expert visual inspections and tests can identify safety and operational problems that may require attention before any other work on the house proceeds. Combustion safety issues must be addressed before air sealing begins. Auditors should also point out any obvious sources of indoor air pollution. Dry rot and moisture problems must be repaired.

Your contractor may test duct leakage as part of the home's energy audit.

### Test-In/Test-Out Steps

1. Audit
2. Installing Air Sealing Measures
3. Testing Out

### Do not proceed with retrofit work if

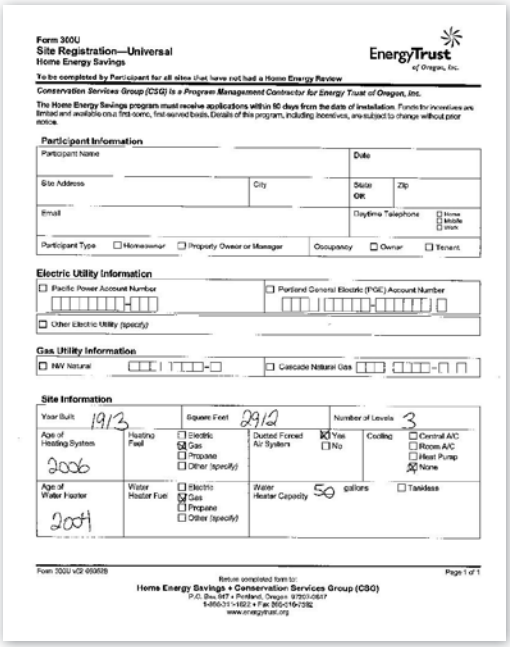
- **The house has active knob and tube wiring** - Rewire the house first.
- **The house has vermiculite insulation** - Vermiculite insulation may contain asbestos. Contact your state department of health.
- **Bathroom fans are vented into the attic** - Vent fans to outside.
- **The house has a leaking roof** - Repair the roof leak before air sealing and insulating.

(Lstiburek 2010)


*(left)* Auditors will check for dry rot and moisture problems as well as air leakage.

*(middle)* Your contractor will visually inspect the home and test for safety concerns before air sealing begins.

*(right)* Once safety and health issues have been addressed, your contractor will proceed with air sealing measures.



Form 360U
Site Registration—Universal
Home Energy Savings

EnergyTrust of Oregon, Inc.

To be completed by Participant for all sites that have not had a Home Energy Review

*Conservation Services Group (CSG) is a Program Management Contractor for Energy Trust of Oregon, Inc.*

The Home Energy Savings program must receive applications within 90 days from the date of installation. Funds for incentives are limited and available on a first-come, first-served basis. Details of this program, including incentives, are subject to change without prior notice.

**Participant Information**

Participant Name | Date
Site Address | City | State: OR | Zip
Email | Daytime Telephone (Home / Mobile / Work)
Participant Type: ☐ Homeowner ☐ Property Owner or Manager | Occupancy: ☐ Owner ☐ Tenant

**Electric Utility Information**

☐ Pacific Power Account Number
☐ Portland General Electric (PGE) Account Number
☐ Other Electric Utility (specify)

**Gas Utility Information**

☐ NW Natural
☐ Cascade Natural Gas

**Site Information**

| | | | | | |
|---|---|---|---|---|---|
| Year Built: 1913 | | Square Feet: 2912 | | Number of Levels: 3 | |
| Age of Heating System: 2006 | Heating Fuel: ☐ Electric ☒ Gas ☐ Propane ☐ Other (specify) | Ducted Forced Air System: ☒ Yes ☐ No | | Cooling: ☐ Central A/C ☐ Room A/C ☐ Heat Pump ☒ None | |
| Age of Water Heater: 2004 | Water Heater Fuel: ☐ Electric ☒ Gas ☐ Propane ☐ Other (specify) | Water Heater Capacity: 50 gallons | | ☐ Tankless | |

Return completed form to:
**Home Energy Savings • Conservation Services Group (CSG)**
P.O. Box 647 • Portland, Oregon 97207-0647
1-866-311-1822 • Fax 866-216-7582
www.energytrust.org

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Auditors use forms like this one from Energy Trust of Oregon for test-in and test-out.

## Step 2. Installing Air Sealing Measures

Within a week or so, your home performance contractor should analyze the test results and provide you with a detailed proposal including a prioritized list of energy-efficiency measures, packaged options, and cost estimates. Critical safety or health issues should be dealt with before work proceeds on the agreed-upon energy-efficiency improvements. Your contractor understands state and local building codes and will work with code officials when necessary to ensure that the improvements meet building code requirements. Your contractor may bring in specialized subcontractors if needed.

## Step 3. Testing Out

Testing out means repeating some of the tests used at the beginning of the audit process now that the installation is complete. Final testing verifies that renovations have improved the home's performance and that safety standards have been met. Some contractors offer a guaranteed level of energy savings on their retrofit projects. Homeowners receive a report summarizing the improvements completed, test results, and estimated energy savings. In addition to testing out, in Home Performance with ENERGY STAR, at least 1 in 20 homes is spot-checked by independent third-party building professionals to ensure program compliance.

# Diagnostic Tools for Test-In and Test-Out

A trained contractor may run these and other diagnostic tests on your home as part of the test-in and test-out process.

## Combustion Safety

High-efficiency combustion appliances are usually sealed combustion, meaning that they draw in oxygen from outside the home through a dedicated vent and send exhaust fumes outside through a separate, dedicated vent pipe. These exhaust flues are sealed to prevent backdrafting, where exhaust fumes come back down the flue into the living space.

Older and less efficient combustion appliances are sometimes atmospheric vented, meaning they draw combustion air from the room in which they are located, often through an opening at the base of the exhaust pipe. Auditors or contractors will check combustion appliances such as stoves, furnaces, water heaters, and fireplaces for carbon monoxide levels, backdrafting, and other safety hazards, such as gas leaks and cracked heat exchangers. If problems are identified, no air sealing occurs until the problem is fixed. These may be serious safety problems; in rare instances, occupants may need to leave the house until problems are repaired.

## Blower Door

A blower door uses a calibrated fan to measure how much air a home leaks. The blower door mounts into an exterior door frame. The fan pulls air out of the house, lowering the air pressure inside. Outside air then flows into the house through all unsealed cracks and openings. The amount of fan pressure required by the fan to maintain the test pressure tells the auditor how much leakage the house has. Some contractors will seal simple air leaks as they are identified while the blower door is operating.

## Infrared Camera

An infrared camera produces images called thermographs that show variations in temperature not visible to the human eye. Infrared cameras can be used during blower door tests to capture images of temperature differences that can indicate air leakage or other conditions such as gaps in insulation and overheating circuits.

## Duct Blaster

Leaky ducts in attics or crawlspaces can account for 20% or more of a home's heating and cooling energy losses. A Duct Blaster (duct pressurization test) uses a calibrated fan to test the air leakage rate in air ducts. Another approach uses a blower door and a shallow pan (a pressure pan) to cover each register and grill to measure and prioritize duct leaks.

*(top)* Your contractor can use a blower door to measure overall house air leakage.

*(bottom)* The infrared cameras can show air leaks not visible to the naked eye.

*If initial testing or inspections identify any health or safety problems, no air sealing occurs until the problem is fixed.*

ICC Docket No. 13-0550
CUB-City Exhibit 1.2

*(top)* Studies show homes and garages may contain over 150 household products that may be harmful to humans.

*(bottom)* Lack of ventilation, poor moisture management, installation issues, and pressure imbalances combine leading to mold problems inside walls.

## Safety and Health Issues

Inspection and testing can identify health and safety issues that should be fixed before any air sealing or other efficiency improvements are made. Taking care of these issues is important to your family's health, and these issues should be fixed before doing any home improvements. If the problems are severe, fix them before returning home. Here are some problems to watch for.

- **BACKDRAFTING –** Air pressure imbalances between the outside and inside or between rooms of the house can cause fireplaces, furnaces, and other appliances that burn fuel (such as wood and natural gas) to pull exhaust gases back into the house instead of letting them vent up the flue. This situation is known as backdrafting. Carbon monoxide (CO), a toxic gas without odor and color, can backdraft into homes causing illness and death.

- **ROLL-OUT –** Combustion appliances may have a pilot light flame. Backdrafting, air pressure imbalances, and mechanical problems can cause the pilot to blow out, or worse, the flame can "roll out" of the appliance, causing a house fire.

- **MOISTURE PROBLEMS –** If the home is not properly ventilated, water vapor from showering, cooking, breathing, and burning fuels can concentrate in the home increasing humidity levels. This can lead to mold and mildew, dust mites, wood rot, material damage, and subsequent health and structural problems.

- **AIR POLLUTANTS –** Many homes contain hazardous substances (such as cigarette smoke, volatile organic compounds and other offgases from carpets, paints, finishes, and home electronics; cleaning chemicals; and pesticides) as well as allergens (such as pet dander and dust mites). It is important to avoid or exhaust pollutants at their source. Also, air pressure imbalances between the outside and inside of the house can draw in pollutants from outside. These can include solvents and car exhausts from attached garages or radon emanating from the soil.

- **RADON –** Radon is a naturally occurring radioactive gas. Radon gas is colorless, odorless, and tasteless and cannot be detected by human senses. In some geographic areas with high concentrations of radon in the soil, it can accumulate in the home and may adversely affect human health.

### Be Safe:

All combustion appliances should be tested for backdrafting. Replace natural draft combustion appliances with sealed combustion, induced draft, or power-vented appliances, if possible. Homes with combustion appliances should have carbon monoxide detectors that meet UL 2034.

ICC Docket No. 13-0550
CUB-City Exhibit 1.2

# Ventilate it Right

Studies show the average American spends up to 90% of their time indoors. About 23 million people including 6.8 million children in the United States now suffer from asthma. Some see a correlation and point to indoor air pollutants—chemicals, gases, mold, dust, etc.—as a culprit. To provide fresh air in your older home, your contractor may recommend adding mechanical ventilation.

An old adage for building scientists is "build tight, ventilate right." When air leaks in the home are sealed up, mechanical ventilation may need to be added.

There are several options for mechanical ventilation systems. Spot ventilation, using exhaust-only fans in the kitchen and bathroom, removes water vapor and pollutants from specific locations in the home, but does not distribute fresh air. Balanced ventilation systems, like air-to-air exchangers, heat-recovery ventilators, and energy-recovery ventilators, both supply and exhaust air. Your contractor can help you determine which one is most appropriate for your specific climate, house design, and budget.

### Pros and Cons of Various Mechanical Ventilation Systems

| Ventilation Type | Pros | Cons |
|---|---|---|
| **Exhaust Only** (air is exhausted from the house with a fan) | • Easy to install<br>• Simple method for spot ventilation<br>• Inexpensive | • Negative pressure may cause backdrafting<br>• Makeup air is from random sources<br>• Removes heated or cooled air |
| **Supply Only** (air is supplied into the house with a fan) | • Does not interfere with combustion appliances<br>• Positive pressures inhibit pollutants from entering<br>• Delivers to important locations | • Does not remove indoor air pollutants at their source<br>• Brings in hot or cold air or moisture from outside<br>• Air circulation can feel drafty<br>• Furnace fan runs more often unless fan has an ECM (variable-speed motor) |
| **Balanced Air Exchange System** (heat and energy recovery ventilators) | • No combustion impact<br>• No induced infiltration/exfiltration<br>• Can be regulated to optimize performance<br>• Provides equal supply and exhaust air<br>• Recovers up to 80% of the energy in air exchanged | • More complicated design considerations<br>• Over ventilation unless the building is tight<br>• Cost |

## Heat and Energy Recovery Ventilation Systems

Heat-recovery ventilators (HRVs) and energy-recovery (or enthalpy-recovery) ventilators (ERVs) both provide a controlled way of ventilating a home while minimizing energy loss by using conditioned exhaust air to warm or cool fresh incoming air. There are some small wall- or window-mounted models, but the majority are central, whole-house ventilation systems that share the furnace duct system or have their own duct system.

The main difference between an HRV and an ERV is the way the heat exchanger works. With an ERV, the heat exchanger transfers water vapor along with heat energy, while an HRV only transfers heat. The ERV helps keep indoor humidity more constant. However, in very humid conditions, the ERV should be turned off when the air conditioner is not running. Air-to-air heat exchangers or heat recovery ventilators (HRV's) are recommended for cold climates and dry climates. Energy recovery ventilators (ERV's) are recommended for humid climates.

Most energy recovery ventilation systems can recover about 70%–80% of the energy in the exiting air. They are most cost effective in climates with extreme winters or summers, and where fuel costs are high. Energy recovery ventilation systems operated in cold climates must have devices to help prevent freezing and frost formation.

## Ventilation – too little, too much, just right

Too little ventilation can lead to indoor air quality problems, too much can waste energy and cause comfort issues. Your contractor will use ASHRAE Standard 62.2 and other industry guidelines to determine how much passive and mechanical ventilation is right for your home.