Nebraska Lincoln EXTENSION

Know how. Know now.

EC479

Save Home Energy by Stopping Air Leaks

Shirley M. Niemeyer, Extension Specialist Housing and Environment
Lorene Bartos and Carroll Welte, Extension Educators

U.S. Homes are Large Energy Users

- The U.S. has about 5 percent of the world's population but uses about 26 percent of the world's energy. Energy consumption in U.S. homes accounted for about 21 percent of the total U.S. consumption in 2004.[1]

- Energy consumption from fossil fuel combustion is a main contributor to greenhouse gas emissions in the U.S. and the world. Carbon dioxide (CO_2) is a major contributor to global warming. Home energy use accounts for about 20 percent of the energy-related CO_2 emissions in the U.S. Overall, total U.S. emissions rose by 17 percent between 1990 and 2007.

- Reducing CO_2 emissions is key for slowing global climate change. Building design, construction, and maintenance have significant impacts on our environment. Home energy usage and CO_2 emissions are strongly influenced by living space features, behavior, building structures, and appliance efficiency choices.

[1] *www.climatevision.gov* July 11, 2005, and U.S. Department of Energy (DOE)

IANR

Air leakage and inadequate insulation are leading causes of energy waste in most homes; however, air leakage is often the least understood part of high energy usage. Air leakage contributes to unnecessary costs, less comfortable surroundings, and may have health risks. Reducing leakage through good air sealing may reduce utility costs by as much as 40 percent when compared to other houses of the same type and age.

When utility costs increase, managing energy use is even more important. Typically, the largest portion of a utility bill is for heating and cooling (43 percent) followed by lighting and appliances (20 percent). Water heating (12 percent), refrigeration (8 percent), and other operations (8 percent) make up the remainder. Air infiltration or leaks can account for 30 percent or more of heating and cooling costs (*Figure 1*).

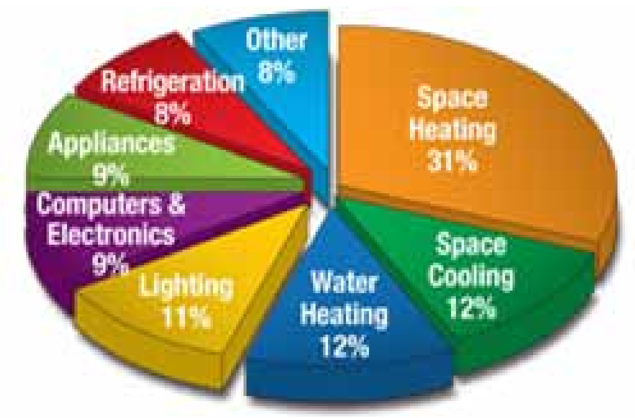

Figure 1. A breakdown showing how energy is used in homes.

Source: U.S. DOE, 2007 Buildings Energy Data Book, Table 4.2.1., 2005 energy cost data.

Home energy efficiency results in four positive outcomes:

- Helps manage increasing energy costs and may cut home utility bills
- Increases comfort
- Reduces pollution from oil, coal, and other natural resources used for electricity and fuel
- Reduces dependence on foreign oil

The information in this publication will help you:

- identify how heat, air, and moisture travel into, within, and out of a home.
- identify current home energy practices and conditions, and the changes that need to be made.
- safely implement energy efficiency strategies to manage energy use.

Primary Reasons for High Home Energy Usage and Costs

High energy usage and costs may be due to many factors. The primary reasons are:

- Excessive air leakage.
- Not enough insulation, insulation not performing as it should, or improper installation.
- Inefficient appliances and equipment that are poorly maintained and serviced, or failure to purchase more efficient models when replacing broken, worn out, or outdated appliances. (Look for ENERGY STAR® and Energy Guide labels when selecting new items.)

Where do homes leak?

How does conditioned air in homes escape? Air infiltrates into and out of homes through every hole and crack. About one-third of this air infiltrates through openings in ceilings, walls, and floors (*Figure 2*).

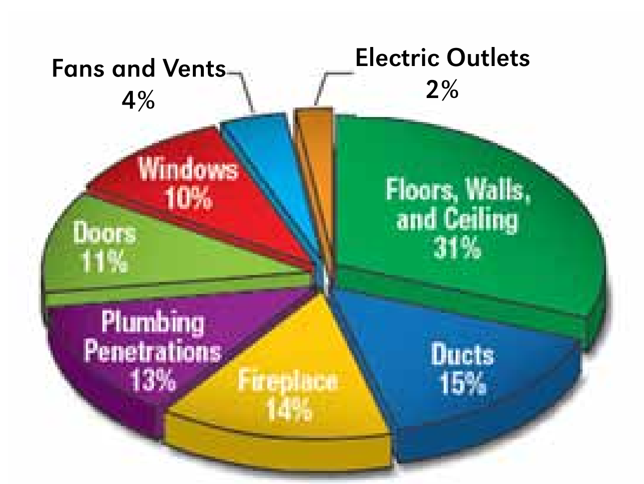

Figure 2. Common sources of air leaks in homes.

Source: U.S. DOE, Energy Savers: Tips on Saving Energy and Money

Reduce Home Energy Use and Air Leakage

The recommended strategy to improve leaky homes is to reduce air leakage as much as possible AND provide the controlled ventilation needed for combustion appliances and healthy air quality.

Start with understanding the basic house system and how air moisture and heat move in, around, and out of a home. The *building shell* or *outer envelope* is supposed to be a continuous unbroken barrier to the movement of heat, air, and moisture. Air and moisture or vapor pressure barriers include polyethylene, aluminum foils, and tar paper. Insulation is a temperature barrier.

When this envelope or shell is performing the way it should, the home will be more energy efficient. If the barrier is broken or has holes and gaps in it, heat, moisture, and air move more easily in and out of the home. This source of air is irregular and not an efficient way to provide air intake and exhaust for homes.

Why do homes leak? How does air move?

Temperature, moisture vapor, and air pressure try to equalize within homes and between the indoor and outdoor environment.

- The driving force for **heat movement,** or transfer in and out of the home, is the difference in temperature. Heat moves from warm to cold or areas of high to low temperatures. Warm air is more buoyant; it "rises."
- The driving force for **air movement** is air pressure differences. Air moves from high to low air pressure areas.
- The driving force for **moisture movement** is differences in the moisture level in the air or the relative humidity level. Moisture moves from areas of high moisture or vapor pressure levels to lower moisture or vapor pressure areas.

These forces create drafts, airflows within the home, and airflows between the inside and outside of the home. The more continuous the air barriers are to air, temperature, and moisture movement, the more efficient your energy use.

Heat moves from warm to cold in three ways.

- ***Convection.*** Convection refers to the flow of heat through a substance or space, and is caused by air currents. Warm air is less dense, more buoyant, and rises upward. Cold air "falls." This creates air movement or drafts. For example, warm air at the ceiling level and cold air at the floor.
- ***Conduction.*** Warm moves to cold through a solid material as the molecules touch and vibrate. For example, a metal spoon becomes hot in boiling water. The warm molecules vibrate faster and cause the next molecules to vibrate until the heat moves though the material. Insulation and energy efficient windows help to reduce heat conduction.
- ***Radiation.*** Heat energy moves through space in the form of light or waves and reaches an object a distance away, and moves from high to low temperatures. Radiation is the transfer of heat energy via visible and invisible light rays such as when the sun warms a home through space.

Air also flows through the *stack, exhaust* and *wind* effect. The *stack effect* exists when warm air tends to exit through higher openings (it's less dense, more buoyant) and cool air enters through lower openings in the home to equalize, creating something like a natural draft or chimney effect. The warm air moves up stairwells, pipe chases, chimneys, laundry chutes, and holes and cracks. Thus, holes in the lower part of the home (crawl space or basement) and in the ceiling or attics will leak more air than an equal sized hole near the middle or window level of the home.

The *exhaust effect* happens when exhaust fans and chimneys create a slight vacuum or lower air pressure indoors because they exhaust air out of the building (*Figure 3*). Incoming air is needed for replacement for quality and for combustion air, and to equalize the pressure. If a lot of air is exhausted, such as by running the dryer and/or stove vented to the outside, the home may be depressurized. Sufficient depressurization can pull air and combustion products back down a chimney or any flue, such as from a gas water heater or furnace, into the house. This becomes a dangerous situation. Thus, managed air exchanges are important and mechanical ventilation is needed.

SAFETY FIRST

Use precautions when conducting energy inspections. Observe safe practices when using ladders, examining attics, and working around any electrical item. When in doubt, have a professional do the task. Professionals should service combustion and electrical equipment and appliances. Provide adequate ventilation for combustion equipment and use carbon monoxide alarms. Many energy and health professionals do not recommend weatherizing a home if unvented space heaters or unvented fireplaces are present.

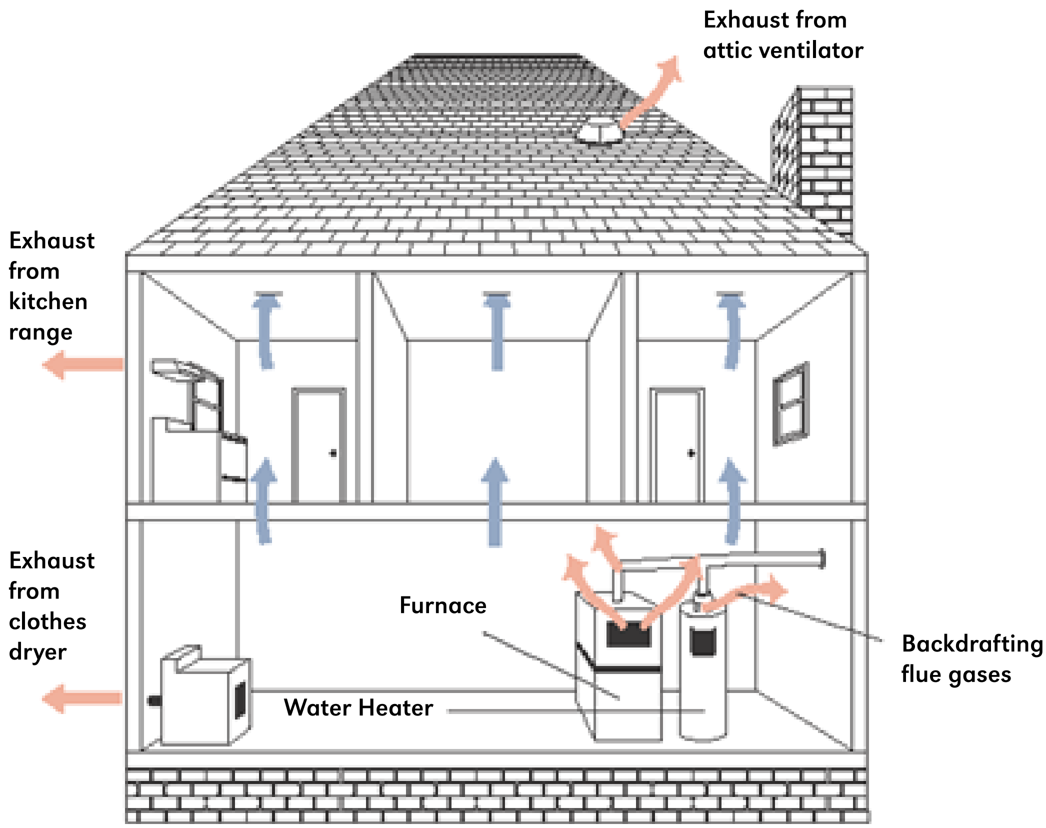

Figure 3. Exhaust effect and fans can lower air pressure indoors, resulting in gas appliances backdrafting. Provide for adequate air exchanges.

Source: The Virginia Energy Savers Handbook. Virginia Department of Mines, Minerals and Energy.

Finding Air Leakage to Save Home Energy

How are homes tested for leaks?

You can conduct your own air leakage test by using thread, lightweight tissue, or your hand to check your home when there are high winds and a large difference between indoor and outdoor temperatures. You also can use a flashlight at night from the inside or outside to check for leaks around doors and other openings in the home.

Persons trained in weatherization and the use of heating, ventilation, and air conditioning (HVAC) equipment sometimes perform air leakage tests using a blower door test (*Figure 4*). They can determine the approximate amount of leakage or "how tight the home is" and help to identify where the leaks may be. A blower duct test can be used to determine leakage in the duct system. A hand or smoke stick or generator (chemical smoke) also can be used to sense some leaks.

Figure 4. A blower door test can determine how airtight a home is.

(Photo by Shirley Niemeyer.)

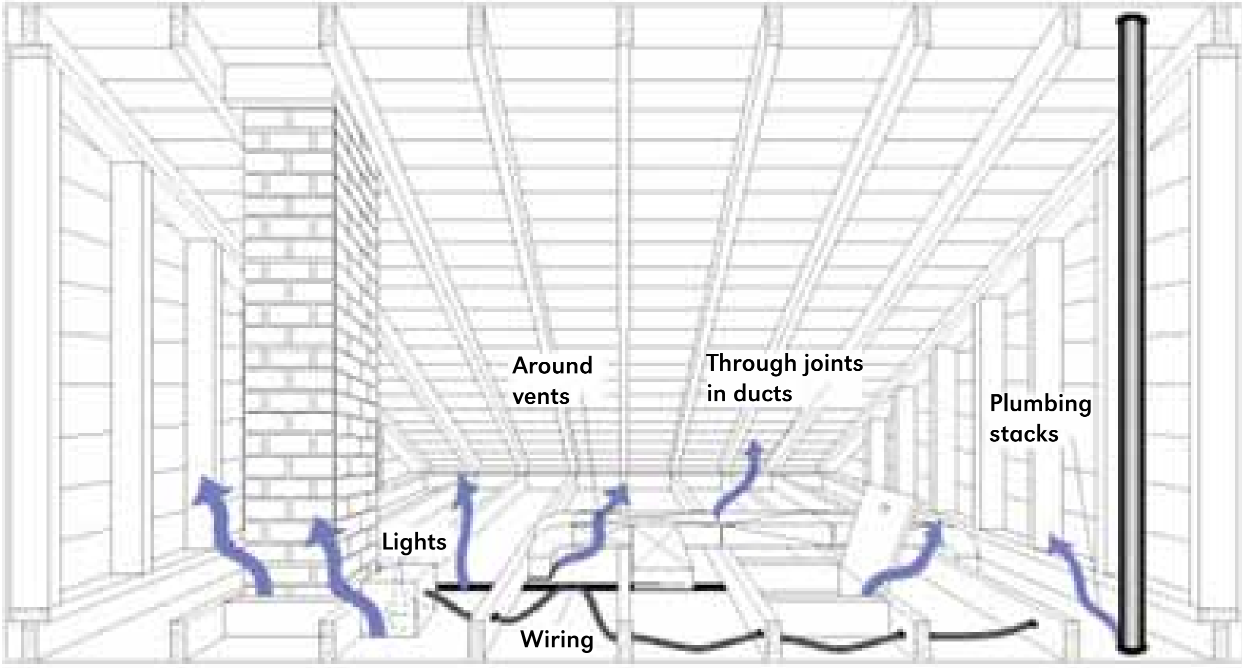

Figure 5. Common air leakage pathways through attic floor.

Source: The Virginia Energy Savers Handbook. Virginia Department of Mines, Minerals and Energy.

If a blower door test is done, building tightening limits vary from 1,000 to 3,000 CMF50 (cubic foot per minute).

Homes with around 6,000 CMF50 (leakier homes) will take more time and resources to reduce energy use. Homes with less than 1,500 CMF50 (tighter homes) are more difficult to improve and should not be tightened without adding controlled ventilation to ensure adequate air for combustion and health.

Contact the public utility company to find out if they conduct blower door tests. Also check with local community action weatherization program professionals, home energy raters, or heating and cooling professionals.

Where to Look for Air Leakage

Every time a corner or a change in levels is created, a hole is made into the outer shell, or other breaks occur in the structural barrier, a potential air leak can occur. Homes with multicorners, varying floor levels, gables, and multiroof levels have a greater chance of leaking if each joint, corner, seam, or crack is not completely sealed.

Check the following areas for potential air leaks (and for inadequate insulation).

- Openings directly above dropped ceilings may lead directly into the attic or unconditioned space.
- Areas above the soffits may open directly into unheated attics.
- Recessed light fixtures connect the conditioned space to attics or roof cavities. The result is air exchanged between conditioned and unconditioned spaces. It also allows warm, moist indoor air to reach cold roof decking, causing condensation.
- Seal and insulate floor and wall junctions, and cantilever floor areas (overhanging floors that extend over its last support point).
- Attic knee walls (short walls under the roof slope).
- Hole areas around plumbing, vents, electrical, sewer pipes, and recessed light fixtures.
- Attic and basement stairways, and attic openings often lack weatherstripping and insulation.
- Laundry chutes that continue into an unheated attic create stack effects and convection currents.
- Seal around whole-house fans and louvers into attics.
- Spaces and cracks around dormers and bay windows.
- Air ducts coming from and returning to the heating and cooling system. For high efficiency and comfort, the duct air flow should go where it is

Figure 6. Use mastic or foil-based tape to seal air handling ducts.

Source: NREL

intended. Leaking ducts can be a major source of energy waste, both by leaking conditioned air and by creating pressures that increase air leakage through the building shell.

- About 20 percent of the conditioned air moving through the duct system is lost due to leaks and poorly sealed connections or seams. The conditioned air doesn't get to where it is supposed to go. It is lost to unconditioned spaces such as basements, attics, crawlspaces and sometimes within the wall cavities. Use mastic, a material like a thick paste, or UL 181 foil-backed tape to seal air duct edges and seams after they have been thoroughly cleaned. Avoid using traditional duct tape which is fabric-based tape with rubber adhesive.

How is a continuous air barrier created?

If the air barrier and insulation are next to each other, they form a thermal shell or boundary to surround the conditioned space creating the building shell or outer barrier. Barriers include an *air retarder* (e.g., house wrap) used to reduce airflow into and out of a house's envelope and a *vapor retarder* used to reduce the movement of water vapor. Systems that control air and water vapor movement in homes rely on nearly airtight installation of sheet materials on the interior and exterior as the main barrier. One such method is the Simple Caulk and Seal that uses the drywall already installed along with caulking all seams and ends to create a continuous air barrier on the interior.

To create a continuous air barrier from ceiling to foundation and around the house:

- Replace broken window panes and reputty damaged areas.

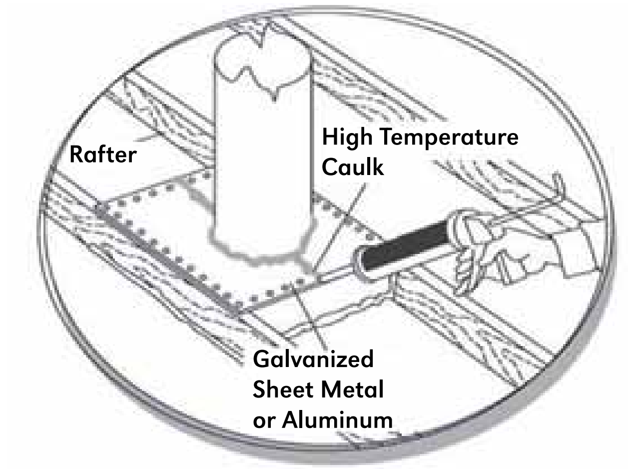

Figure 7. Seal air leaks in attic penetrations.

Source: The Virginia Energy Savers Handbook. Virginia Department of Mines, Minerals and Energy.

- Fill spaces, cracks, and holes with space fillers such as foams, caulks, and tape and mastic.
- Use gaskets, weatherstripping, and caulking around vent openings, utility entrances, doors, and windows (*Figure 7*). Start with the attic and basement first (especially around plumbing and electrical penetrations). In new construction, gaskets can be used where the foundation, sill plate, floor joist header, and subfloor meet.
- Seal areas above soffits with fire-retardant drywall or other air barriers from the attic side. Avoid creating a fire hazard if soffit lighting is present. Contact a professional electrician for assistance.
- Due to the bulb heat, ventilation, and safety issues, ask a qualified electrician to seal above recessed light fixtures. Do not cover recessed light fixtures unless they are IC rated for direct contact with insulation. Look for airtight IC fixtures. Caulk floor and wall junctions.
- Seal and insulate cantilever floor areas where accessible.
- If a laundry chute opens into the attic, seal off the top, caulk seams, and insulate.
- Seal around whole-house fans and cover and insulate when not in use.
- Insulate and weatherstrip the attic door or hatch.
- Use mastic or quality foil-backed tape to seal supply and return air duct seams and holes. Ask a professional to seal those not easily accessed.

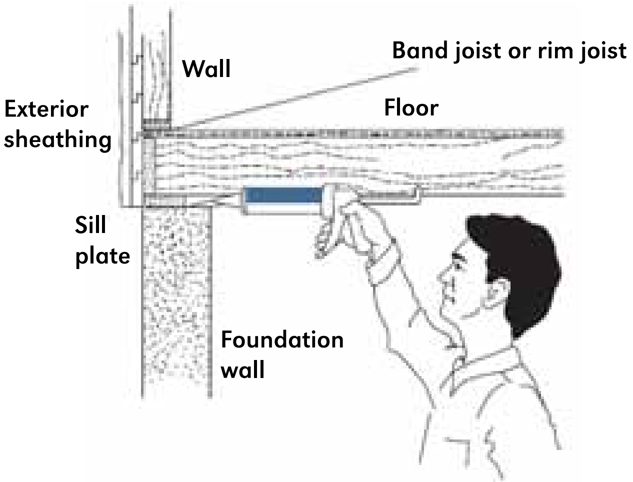

Figure 8. Seal at the band joist (rim joist) and foundation area.

Source: The Virginia Energy Savers Handbook. Virginia Department of Mines, Minerals and Energy.

Figure 9. Heat recovery ventilators are seen in some new tightly constructed homes and added to existing tight homes.

(Photo by Shirley Niemeyer)

- Seal and insulate around the band joist area where the framing rests on the foundation (*Figure 8*). The band joist forms the perimeter of a floor system in which the floor joists tie in. It rests on top of the sill plate. It is also called the rim joist or header.

How are air quality and quantity managed?

Rather than rely on irregular air flows and holes in the barrier or house shell that are too big or work only at certain times, it is more efficient to use planned ventilation sources and to manage the fresh air intake and exhaust. Use mechanical systems to manage the air exchanges.

A heat recovery ventilator is an energy efficient method of obtaining the recommended air exchange. In the winter, for example, the fresh colder outside air is brought in and passes by, but is not mixed with, the warmer exhaust air. This preconditions the colder incoming air in the winter and the hot incoming air in the summer. In the summer, the ventilator pre-cools the incoming hotter air. A heat recovery ventilator or energy recovery ventilator can salvage about 70 percent of the energy from the stale exhaust air and transfer that energy to the fresh air entering by way of a heat exchanger inside the device. A ventilator can be attached to the central forced air system or may have its own duct systems.

Environmental pollution, unvented space heaters, and heavy smoking require high ventilation rates to ensure safe, healthy indoor air. Proper maintenance and venting of combustion equipment and appliances are essential to prevent carbon monoxide poisoning and other air quality issues.

Furnaces, water heaters, clothes dryers, and bathroom and kitchen exhaust fans expel air from the house, making it easier to depressurize an airtight house. Exhaust fans may backdraft natural-draft combustion appliances and lead to a buildup of toxic gases in the house. Use sealed combustion furnaces and water heaters, and sealed combustion gas appliances that have a dedicated fresh air intake and a separate exhaust to the outside. Another option is to use combustion appliances with powered combustion systems rather than natural air ventilation. Have working carbon monoxide alarms on every level of the home. Install according to manufacturers' directions.

Air leakage can contribute to unnecessary costs due to wasted energy, less comfortable surroundings, and may pose health risks. Understanding how air moves, being able to identify potential leaks areas and knowing how to control leaks is an important first step in stopping air leaks while managing adequate air quality and quantity.

Can a house be too tight?

Getting a home "too tight" is unusual but could happen. Homes may have air quality problems caused by combustion equipment problems, smoking, moisture problems, and environmental pollutants. It is not recommended to reduce air leakage without *first* reducing indoor pollution and moisture, and installing a whole-home ventilation system or ensuring adequate mechanical ventilation.

Homes must have either sufficient air leakage or a mechanical ventilation system to remove moisture and pollutants and to provide combustion air. *Natural ventilation* through leakage, cracks, and holes may not be a reliable source of fresh air, depending on air temperatures, pressure, moisture levels, and wind. The more pollutants, the bigger the natural air leaks need to be.

Tightly sealed air and vapor retarders reduce the likelihood of air and moisture seeping through the walls. Since an energy-efficient house is tightly sealed, it needs to be ventilated in a controlled manner to ensure adequate and healthy air and prevent air being pulled from an attached garage or other unsafe source. Often, dehumidification is needed to prevent excess moisture and mold growth. *Controlled, mechanical ventilation* prevents health risks from indoor air pollution and promotes a safer, more comfortable atmosphere. It also reduces air moisture infiltration, thus reducing the likelihood of mold and structural damage.

A minimum ventilation rate of 15 CFM for each person in the room is recommended and should be continuous when occupied. The minimum recommended air exchange per hour is 0.35 (ASHRAE). A tight home may have about .25 to .50 air exchanges per hour. One air exchange per hour means that the total volume of air in the home completely exchanges, or turns over, with the same volume of outside fresh air in one hour. For example, to obtain an air change of 0.35 per hour in a 1,200 square foot home with 8-foot walls, an air change of 3,360 cubic feet of air per hour is needed. A leaky or drafty home may have 1.25 or more exchanges per hour.

Energy Audit for Your Home

Have you checked your home for energy efficiency and looked for ways to make your home a high performance home? Use this checklist to audit your home. When items need to be done, indicate when they will be completed. If some items don't apply, put NA for Not Applicable.

Energy Check List for Reducing Air Leakage and Saving Energy

Have you. . .	Yes	No	Plan to? When?
Had a home energy audit, blower door test, or blower duct test conducted?			
Contacted the utility company about their educational services, even-payment plans, energy assistance, or energy audit services?			
Caulked and weatherstripped gaps, cracks, holes, seams where any material meets another, around pipes and outlets where wires enter the home, vent stacks, etc., and rechecked yearly to make repairs?			
Had leaky supply and return heating, ventilation, and air conditioning air ducts professionally sealed with a high quality foil-backed tape or mastic?			
Maintained adequate air intake for combustion and people by using mechanical air handling systems?			
Installed air-to-air heat exchanger or heat recovery units to manage air quantity, quality, moisture, and temperature?			
Sealed air leaks, holes, and cracks penetrating into the attic?			
Insulated the attic and walls?			
Checked the performance of existing insulation for settling, moisture damage, and blowing? Have you corrected or added insulation if needed?			
Checked attic knee walls, soffit areas, and cantilevered floor areas for air leaks and adequate insulation, and remedied if needed?			
Insulated, air sealed, and weatherstripped the attic entrance cover or door?			
Covered, sealed and insulated around the window air conditioner or removed the unit in winter?			
Sealed and insulated over whole-house fans when not in use, and removed covering when in use?			
Had the heating and cooling system professionally maintained and serviced yearly?			
Cleaned and/or changed HVAC filters as recommended (usually monthly or as needed or recommended)?			
Purchased sealed combustion equipment when replacing equipment?			
Moved objects that block air flow at vents and registers?			
Checked the attic for moisture damage and air vent obstructions?			
Replaced cracked and missing window glass, repaired putty, and sealed leaks?			
Installed double glazed windows or storms on all windows?			
Reduced humidity to 30 to 45percent to prevent moisture condensation as home is air sealed or tightened?			
Checked carbon monoxide alarms and changed batteries or added alarms.			
Closed fireplace damper unless the fireplace is in use?			
Used landscaping, windbreaks, and shade trees to create an energy efficient landscape. Blocking warm and cold wind from conditioned homes can save energy.			

Summary

Understanding how air moves, being able to identify potential leak areas, and knowing how to control leaks is important in stopping air leaks in the home, while also managing to ensure adequate air quality and quantity. Begin by making a plan. Indicate short-term and long-term plans.

Manage Your Energy Use — Formulate a Plan

1. Locate where your home is losing energy. In addition to checking for air leakage, examine losses through ineffective management of the house and equipment and through wasteful habits.
2. Prioritize the sources of energy losses.
3. Develop a whole house energy plan. Think of your house as a system. How can you make this system operate more efficiently? Use the checklist to begin your evaluation. Work with professional HVAC service, utility company or weatherization personnel for more detailed information and inspections.

Resources

Amann, J. , Wilson, A., & Ackerly, K. (2007). Consumer Guide to Home Energy Savings, 9th Edition. Washington, D.C.: American Council for Energy-Efficient Economy.

American Council for an Energy-Efficient Economy. Residential Sector: Homes and Appliances — *http://www.aceee.org/sector/residential*

American Council for an Energy-Efficient Economy. Consumer Resources — *http://www.aceee.org/consumer*

Krigger, J. (2009). Residential energy: Cost savings and comfort for existing buildings. Helena, MT: Saturn Resource Management.

Oak Ridge National Lab Building Technologies and Research Integration Center — *http://www.ornl.gov/sci/ees/etsd/btric/*

Rocky Mountain Institute — *http://www.rmi.org/rmi/*

U.S. Dept. of Energy (DOE) Energy Efficiency and Renewable Energy (EERE) — *http://www.eere.energy.gov/*

U.S. DOE Energy Savers: Tips on Saving Energy and Money at Home — *http://www.energysavers.gov/tips/*

U.S. DOE Energy Star® — *http://www.energystar.gov/*

Acknowledgement

The authors thank Diane Vigna, UNL extension specialist; Lynn Chamberlin and Jerry Loos, Nebraska Energy Office; Katherine Allen, extension educator, University of Florida; and Sharon Skipton, UNL extension educator who assisted with the original version of this publication, Energy is Not All You Save! Stop the Leaks.

This publication has been peer reviewed.

UNL Extension publications are available online at *http://extension.unl.edu/publications*.