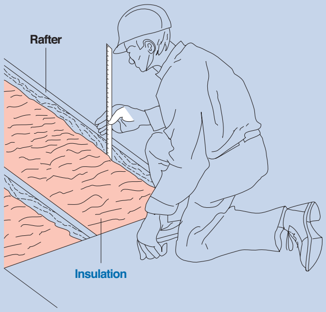
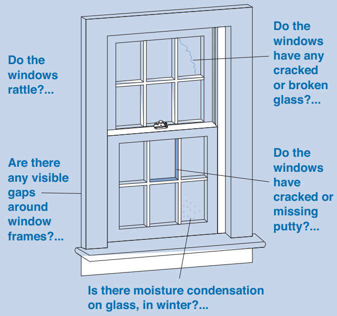
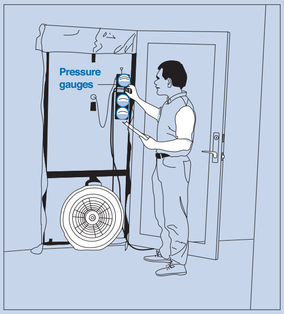
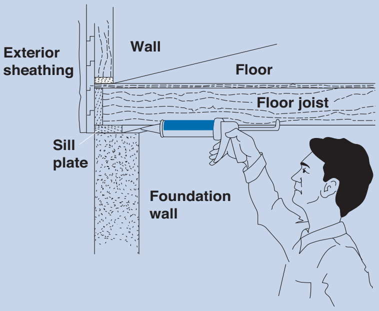


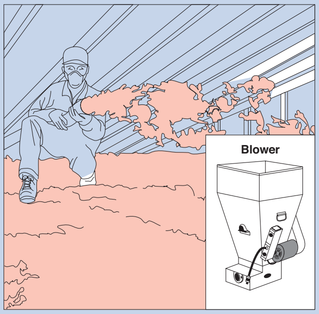


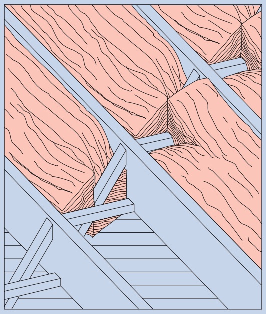
The Virginia Energy Savers Handbook

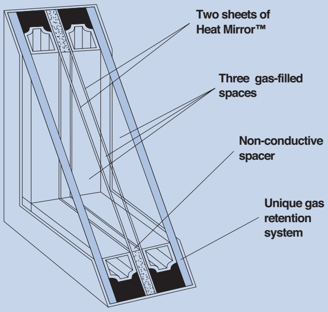
A Guide to Saving Energy, Money, and the Environment

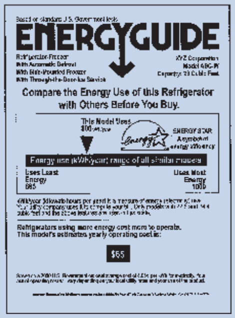


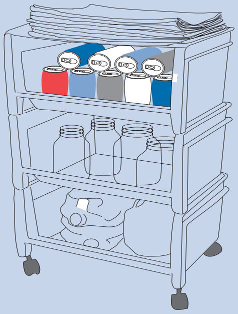


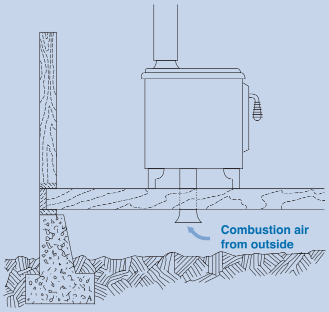












THE VIRGINIA ENERGY SAVERS HANDBOOK

A Guide to Saving Energy, Money, and the Environment

THIRD EDITION

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APPENDIX
Where to Go For More Information

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- *Small Wind Electric Systems* – A U.S. Consumers Guide
- ACEEE - *Consumer Guide to Home Energy Savings*
- Sustainable Buildings Industry Council - *Green Building Guidelines*
- National Fenestration Rating Council
- National Renewable Energy Laboratory
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- U.S. Department of Energy
- Efficient Windows Collaborative
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WHY AND HOW TO BECOME A SMART ENERGY CONSUMER

We are all energy consumers. Regardless of our types of home or car, we all require energy to conduct our daily lives. Over 90% of the energy we use today comes from the burning of fossil fuels – coal, oil, and natural gas. Fossil fuels are not renewable and their supply is limited, so common sense dictates that we use these resources efficiently. Together, Virginians consume the equivalent of over 650 million barrels of oil per year. We spend over $16 billion per year on energy, and much of that money ends up outside our state.

Energy prices are historically very unpredictable. Home heating oil, propane, and natural gas prices have risen dramatically over the past few years. We should prepare for the future by using energy efficiently and wisely. This will protect us financially against rising energy prices.

Energy efficiency not only saves each of us money by reducing utility costs, it benefits our national security and economy by cutting down our dependence on foreign oil. The United States imports more than 50% of its oil, up from 34% in 1973. With our volatile relationships with many energy-exporting countries, energy security is directly related to national security. It is therefore every consumer's responsibility to exercise personal leadership by practicing conservation and efficiency on a daily basis. It is up to each one of us.

Energy efficiency also benefits our natural environment by reducing emissions of sulfur dioxide, nitric oxide, carbon monoxide, carbon dioxide, and other air pollutants. These pollutants contribute to global warming, can cause respiratory diseases, and harm plants and wildlife. Every kilowatt-hour of electricity use (equivalent to a 100-watt light bulb burning for 10 hours) results in over two pounds of carbon dioxide being emitted into the atmosphere, with proportional amounts of other pollutants. By conserving energy, consumers can significantly improve the world in which we all live.

This *Virginia Energy Savers Handbook* is your guide to improving the efficiency with which you use energy in your day-to-day life. It will show you how to identify those areas that can be improved, how to go about improving them, and where to go for further information.

Energy saving starts at home. The *Handbook* begins (Chapter 1) with a simple home assessment or "energy audit" and proceeds to specific recommendations for improving your home's energy efficiency by controlling air leakage (Chapter 2), adding insulation (Chapter 3), upgrading your windows and doors (Chapter 4), improving your heating and cooling systems (Chapter 5), and improving your water heater (Chapter 6). It explains how to shop for and maintain energy-efficient appliances (Chapter 7) and lighting (Chapter 8). Energy efficient new construction is discussed (Chapter 10) and information is provided on alternative and renewable energy (Chapter 12).

Since all water we use must be pumped and much of it must be heated, saving water also saves energy. In recent years, Virginians have become aware that water itself is a precious resource. Water conservation is discussed in Chapter 9.

Next to your home, the largest energy consumer you own is your car. Chapter 11 includes a discussion of automobile fuel economy, some pointers on operating and maintaining your car for maximum fuel economy, and information on high efficiency alternative fuel vehicles.

As Virginia moves into a deregulated utility environment, we must carefully examine how we purchase our energy. Chapter 13 discusses Virginia Energy Choice. Chapter 14 concludes with a discussion on how the environment is impacted by energy production and use.

Each chapter in the *Handbook* ends with a summary of important energy tips and recommendations. An Appendix provides a listing of state and national resources for more information on energy and environmental issues.

It is our hope that the *Virginia Energy Savers Handbook* will serve as a valuable guide in helping all Virginians save energy, money, and the environment.

ASSESSING YOUR HOME'S ENERGY FITNESS

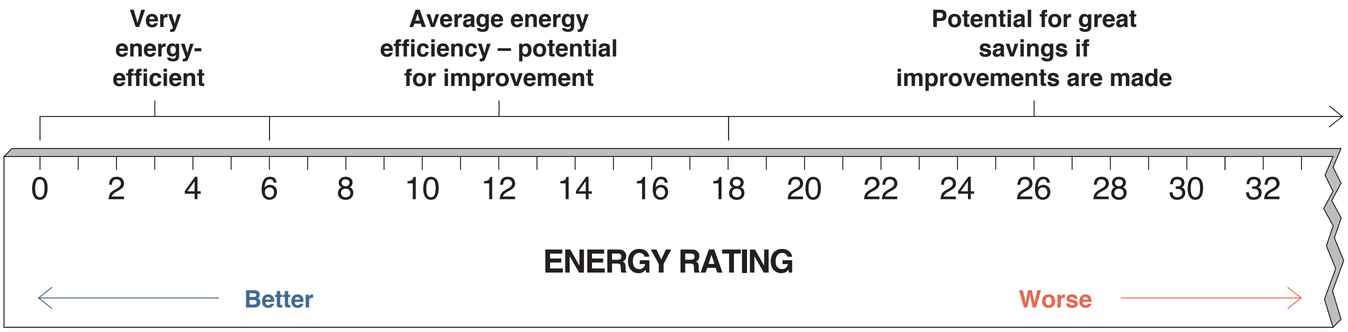

Figure 1-1 - Home Energy Rating Yardstick

Is your home as energy-efficient as it could be? If not, then how can it be improved? This chapter describes a step-by-step process to answer both these questions. It begins with a simple way to rate your home's energy efficiency using past fuel bills, followed by a home inspection procedure to identify major opportunities for reducing energy costs through improved efficiency.

You may find that you already lead an energy-efficient life and that there aren't many improvements to be made. If so, then congratulations. Nonetheless, we suggest that before relegating this book to the top shelf, you at least skim through the rest of the chapters. Chances are there are some useful and practical recommendations that can help you improve home comfort and health, and possibly further improve energy efficiency.

Your House as a System

Before you begin the process of evaluating your home's energy efficiency or have a professional energy audit performed, it is important to understand that your house operates as a system. Your house is a system comprised of many different interactive components that must work together in order for your home to perform properly. A house system has three main parts: the shell of the house, the mechanical equipment, and the people who live inside the house. The shell of the house keeps cold air out and warm air from escaping in the winter. It does the opposite in the summer - hot air out and cool air in. The mechanical equipment consists of machines that control the indoor environment (furnaces, air conditioners, fans, etc.) plus machines that perform other necessary tasks (refrigerators, stoves, computers, etc.). The people control the shell and the equipment through their behavior and activity.

Because your house is a system, you and other occupants must engage in systems thinking and understand that your actions control the movement of heat, air, and moisture. Your lifestyle and decisions, your maintenance of the shell and operation of mechanical equipment, will impact each component and effect the energy performance of the house. For instance, if you increase the level of insulation in your attic it will make your home warmer and your utility bill lower but (if you do not seal thermal bypasses) may create moisture problems in the attic. If you install low-flow showerheads but people in the home still take 20-minute showers, energy use for heating water will still be high. If you install energy efficient windows but leave the windows open when the heat is on, your heating bills will still be high. Your home is a system. Be a systems thinker, use good common sense, and operate your home with the knowledge that the components of your house are interactive and must work together to achieve real energy efficiency.

How Does Your Home Rate?

Even if you are able to obtain the services of a professional energy auditor and/or contractor it is still very important that you perform your own energy examination of the home. The best way to assess your home's overall energy efficiency is to calculate the amount of energy consumed over an average year and then compare your energy usage with similar homes. Using past fuel bills, you

Home Energy Rating Form

Column 1 Fuel Type	Column 2 Total Annual Consumption		Column 3 Conversion Factor		Column 4 Total (in million Btus)
Electricity	kWh	x	0.003413	=	
Natural gas	ccf	x	0.1	=	
Propane	gal.	x	0.096	=	
#2 Fuel oil	gal.	x	0.139	=	
Kerosene	gal.	x	0.135	=	
Wood (Hardwood)	cords	x	24	=	
Coal	tons	x	26	=	

+

Box A: Million BTU

1st Floor Area + 2nd Floor Area + Other Heated Area = Box B: Square Feet

BOX A ÷ BOX B = Box C: MBTU/Square Foot

Box C ÷ Box D (Climate Factor) x 1,000,000 = Box E: Home Energy Rating

Table 1-1-Climate Factors

	With A.C.	Without A.C.
Norfolk	4904	3446
Richmond	5296	3960
Washington – Dulles	5974	5004
Roanoke	5400	4315
Blacksburg	6092	5507
Danville	5240	3856
Average	5484	4348

can use the following simple procedure to calculate your "Home Energy Rating."

The "Home Energy Rating" is a measure of how efficiently your home operates. The lower the Home Energy Rating, the better. If your rating is less than 6, your home ranks among the best new "super-insulated" homes and there is probably little that can be done to significantly improve energy efficiency. Between 6 and 18 is an "average" rating. If your rating is in that range, there are most likely a number of energy-saving improvements that you should consider. If your Home Energy Rating is above 18, there are definitely numerous improvements that you can

Home Energy Rating Form - **SAMPLE**

Column 1 Fuel Type	Column 2 Total Annual Consumption		Column 3 Conversion Factor		Column 4 Total (in million Btus)
Electricity	**6000 kWh**	x	0.003413	=	**20.478**
Natural gas	ccf	x	0.1	=	
Propane	gal.	x	0.096	=	
#2 Fuel oil	**750 gal.**	x	0.139	=	**104.25**
Kerosene	gal.	x	0.135	=	
Wood (Hardwood)	cords	x	24	=	
Coal	tons	x	26	=	
				+ Box A	**124.728** Million BTU

1st Floor Area **960** + 2nd Floor Area [ ] + Other Heated Area [ ] = Box B **960** Square Feet

BOX A ÷ BOX B = Box C **.129925** MBTU/Square Foot

Box C **.129925** MBTU/Square Foot / Box D **5296** Climate Factor x 1,000,000 = Box E **24.5** Home Energy Rating

Table 1-1- Climate Factors

	With A.C.	Without A.C.
Norfolk	4904	3446
Richmond	5296	3960
Washington – Dulles	5974	5004
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Blacksburg	6092	5507
Danville	5240	3856
Average	5484	4348

make to achieve energy efficiency and significantly reduce your annual energy costs.

Calculating Your Home Energy Rating

To calculate your Home Energy Rating, you will need one full year of past bills for each type of fuel used in your home. The quantity purchased should be clearly marked on each bill. For electricity, it will be listed in kilowatt hours (kWh); for natural gas, it will be in ccf or therms; fuel oil, kerosene and propane will be in gallons; and wood will be listed in cords.

The following procedure converts each quantity of fuel into Btu's, the standard unit of energy, (see sidebar "Know your Btu's" on page 16 for definition), and then adjusts for house size and climate to calculate your Home Energy Rating.

Use the Home Energy Rating form to do the following calculations. A sample form is provided to help you with this process.

Step 1 - Add up the total annual quantity for each fuel type. Write down the totals in Column 2.

Step 2 - Multiply each number in Column 2 by the "conversion factors" in Column 3. Write your answers in Column 4. This step converts from common fuel units to million Btu's.

Step 3 - Add up the values in Column 4 and write your total in Box A. This is your total energy consumption, measured in "million Btu's."

Step 4 - Estimate the total floor area of your home. Include all floors, but don't include unheated basements or attics. Write the total floor area, in square feet, in Box B.

Step 5 - Divide your total annual energy use (Box A) by the total floor area of your home (Box B) and write the answer in Box C. This is your total energy use per square foot (MBtu/Square foot).

Step 6 - Find the "Climate Factor" for your geographic region in Table 1-1. If your home is air conditioned, select the climate factor in the middle column (with A/C). If you don't have air conditioning, select the climate factor in the right column (without A/C). Write your climate factor in Box D.

Step 7 - Finally divide the figure in Box C by your climate factor (Box D), multiply by 1,000,000, and write the answer in Box E. This is your "Home Energy Rating". That's it. To assess your home's energy efficiency and potential for improvement, find where your Home Energy Rating falls on the Yardstick in Figure 1-1 on page 1.

The home energy rating form only checks the amount of energy used by your home - it doesn't consider how expensive that energy is. The same amount of energy could cost very little if coming from wood, more if coming from natural gas, and still more if coming from electricity. (See "Know your Btu's" (page 16) and the fuel prices in Table 5-2 (page 72).) In some cases, you can save money not only by increasing your home's energy efficiency but by changing to a less expensive energy source.

Inspecting For Flaws

If your Home Energy Rating is above 15, there are probably improvements that can be made either to the house or the way that you are operating it. The next section describes a brief inspection process to identify the major energy conservation opportunities in your home. It consists of a series of questions that you should answer about your attic, windows, heating system, etc. If the answer to any of these questions is "yes", then you may be able to make improvements. The text outlines some specific actions you can take, and refers you to the appropriate chapters for more information. You can use the checklist provided on the following page to record your observations.

Up into the attic

The attic is often the most important part of a home energy inspection. Because it is outside of the conditioned space, any heat that leaks into the attic is lost from the house. This is created by the stack effect, which is the tendency for warm buoyant air to rise and leak out of the top of the house and be replaced by colder outside air entering from the bottom of the house. This happens because of pressure differences that occur in the house and represents a very basic and fundamental reason for heat loss and air leakage in the home.

To inspect the attic thoroughly, you should have a pair of gloves, a ruler, a flashlight, and a dust mask.

Are there any pathways where air could leak up from the living space or basement?

One of the major heat loss pathways in a house is air leakage through the attic floor. Finding and sealing attic floor air leakage is often a challenge, but it typically is one of the most cost-effective energy improvements one can make. A major source of air leakage can occur in one and a half story homes that contain knee walls that separate the attic from the living space. Be sure that the joint at the base of the knee wall - where the floor of the conditioned space meets the unconditioned area - is sealed with a rigid air barrier.

Home Inspection Checklist

	QUESTIONS	NO	YES – Refer to CHAPTER 2	3	4	5	6
ATTIC	Are there any pathways where air could leak up from the living space?		☐				
	Are there any chimney chases?		☐				
	Are exterior and/or interior walls open at the top?		☐				
	Is there enough insulation?			☐			
LIVING SPACE	Do you have drafty spots?				☐		
	Are there any single-glazed windows without storm windows?				☐		
	Do the windows have any cracked or broken glass?				☐		
	Do the windows have cracked or missing putty?				☐		
	Do the windows rattle?				☐		
	Are there any visible gaps around window frames?				☐		
	Is there moisture condensation on windows in winter?				☐		
	Are the doors leaky?				☐		
	Do the walls need insulation?			☐			
BASEMENT OR CRAWL SPACE	Are the walls insulated?			☐			
	Does the crawl space need to be insulated?			☐			
	Is there air leakage at the top of the basement wall?			☐			
	Are there any cracks or gaps in the basement walls and floor that would allow air leakage?		☐				
HEATING AND COOLING SYSTEMS	Do ducts leak air?		☐				
	Is your furnace filter dirty?					☐	
	Is your system due for maintenance or a tune-up?					☐	
	Is your chimney lined according to code requirements?					☐	
	Are your chimney and vent pipes clean and unobstructed?					☐	
	Do you use any unvented gas or oil heating appliances?					☐	
	Is the outdoor unit of your air conditioner or heat pump in direct sunlight or blocked from freely circulating air?					☐	
	Do you have UL-rated smoke and carbon monoxide detectors installed?					☐	
WATER HEATER	Does the water heater tank need to be insulated?						☐
	Is the water temperature too high?						☐
	Do your water pipes need to be insulated?						☐
	Could your plumbing fixtures be more water-efficient?						☐
	Are any faucets in the house leaking?						☐

Sometimes referred to as "bypasses" because they bypass the insulation, attic air leakage spots are often difficult to find because they are underneath the insulation (refer to Thermal Bypasses - Chapter 2). One particularly common site for air leakage is through wiring and plumbing holes at the top of interior walls. Move the insulation aside to expose the attic floor just above the interior walls. Check for gaps around any wiring or plumbing penetrations.

One trick for spotting air leakage is to look for its tracks. Look for moisture stains on wood framing. Any moisture in the attic was probably carried there by air leakage. If there are batts on the floor, check their underside for dust marks -- another sign of air leakage from below.

Action : If you find air leakage pathways, they should be sealed. See Chapter 2.

Are exterior walls open at the top?

Many older homes were built with a framing technique called "balloon framing" in which the walls are left open at the top in the attic (as opposed to modern "platform framing" in which the walls are capped with "top plates"). Thus heat from all over the house enters the walls

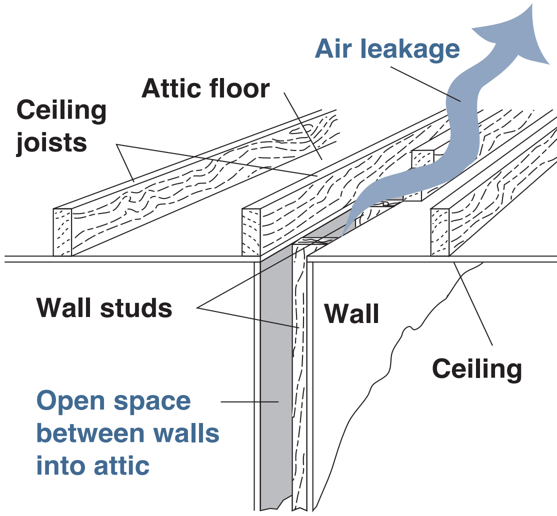


Figure 1-3 - With "balloon framing," open wall cavities allow air and heat to flow up into the attic.

and is dumped into the attic through the open tops. This is particularly problematic if the walls are hollow -- that is, un-insulated -- because the heat is able to move through the walls more easily.

Shine your flashlight down at the tops of interior and exterior walls. If you can see down into the wall, you have balloon framing.

Action: If your walls are open at the top, they should be sealed, whether or not they are insulated. See

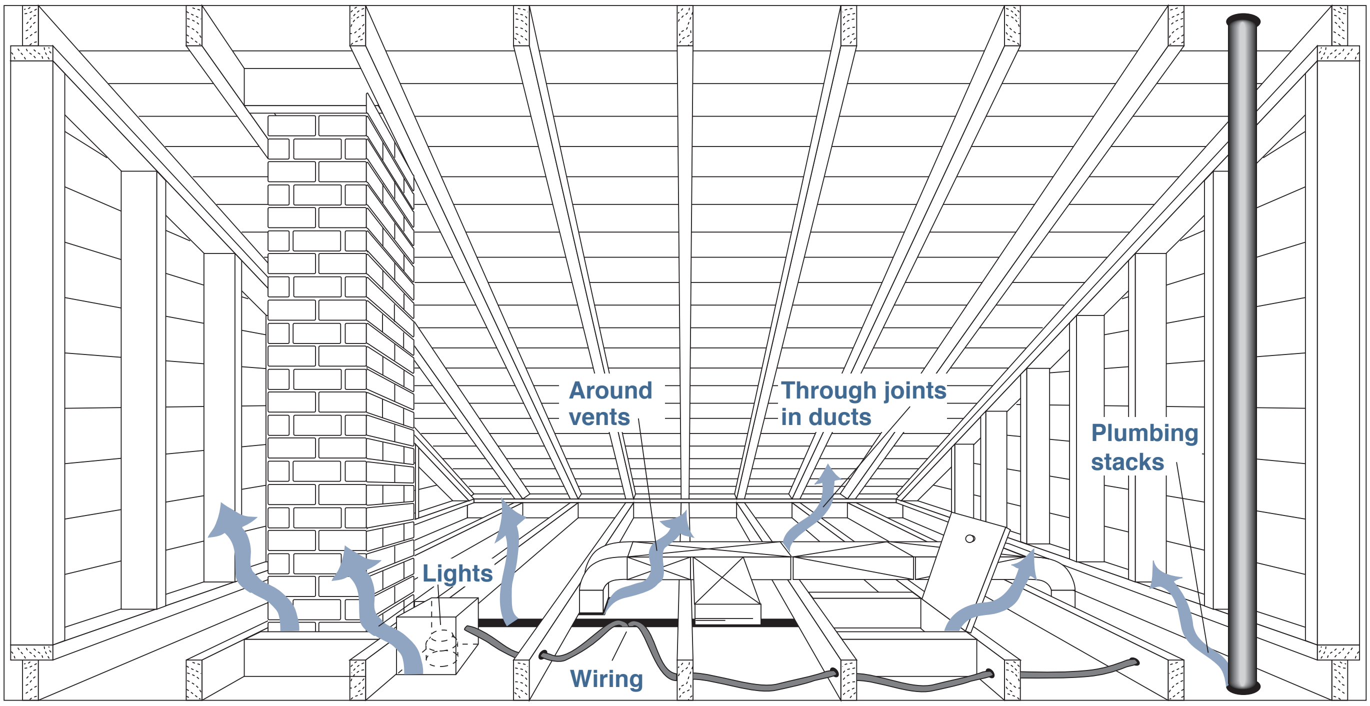


Figure 1-2- Common air leakage pathways through attic floor

Chapter 2.

Is there enough insulation?

Measure the thickness of the insulation in several places -- there should be at least 6 inches. Sometimes a higher minimum level is recommended - check with your local building inspector or insulation contractor to find recommedations for your area. Also make sure that there are no voids or un-insulated areas in the attic. If your attic has a floor installed, you may have to lift up some of the boards.

Action: If you find that the insulation is less than 6 inches thick over a large area, you should add more.

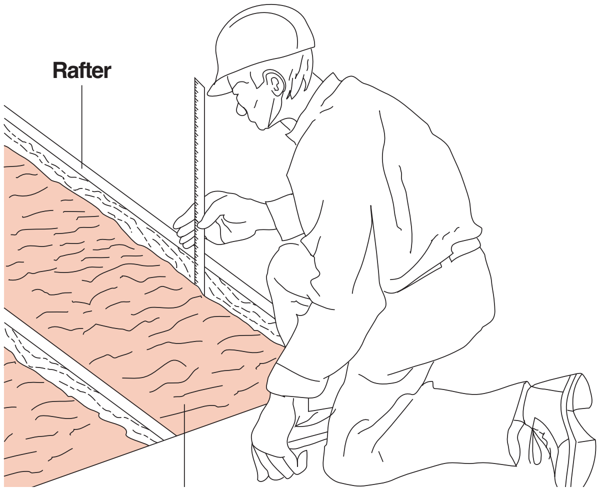


Figure 1-4 - Insulation should be at least six inches thick over entire attic floor.

See Chapter 3.

Into the main living space

The living space part of your inspection begins with an inspection of exterior walls to see whether they need insulation, followed by an evaluation of windows and doors to see if they need repair or replacement.

Do the walls need insulation?

Determining whether your exterior walls are insulated sometimes requires a bit of detective work. One good technique is to remove the cover plate on electrical outlets (turn off the power first) and poke around with a screwdriver or hooked instrument. Using a non-conductive probe, such as a plastic knitting needle, is a safe and effective method as well. Another method of finding wall insulation is to cut a small hole into a closet wall on the exterior of the house. You can then patch the hole and it will never be seen. If you find inadequate insulation it may be possible - depending on the wall construction and the type of existing insulation - to add more by blowing insulation into the walls from the outside or inside. If you are unsure, contact an insulation contractor.

Action: Un-insulated walls should be insulated by a professional contractor. See Chapter 3.

Are there any single-glazed windows without storm windows?

A single-glazed window has only a single pane of glass separating the living space from the outdoors. These windows should have storm windows for winter use. Try to purchase quality storm windows that provide air tightness when installed and insure maximum air leakage benefits. Also look for storm windows with low-e coatings on the glass to improve the energy performance.

Action: Install storm panels on single-glazed windows. See Chapter 4.

Do the windows have any cracked or broken glass?

Broken windows obviously allow a great deal of heat to escape, but even cracked panes of glass allow a significant loss.

Action: All broken or cracked glass should be replaced. See Chapter 4.

Do the windows have cracked or missing putty?

In most older windows, the panes of glass are held in place with glazing putty on the outside of the sash. From the outside of your house, inspect each window and look for missing or cracked putty.

Action: If you find only small cracks, a good coat of paint might be all you need. But if there are larger cracks or missing putty, your windows may need re-

glazing (new putty added). If the windows are in particularly bad shape, it might make more sense to replace them than to attempt repairs. See Chapter 4.

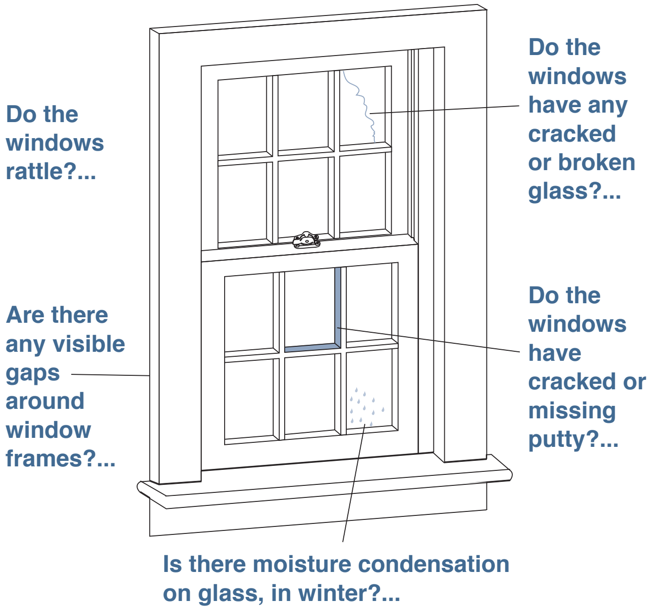


Figure 1-5 - Window flaws

Do the windows rattle?

Loose windows not only lose heat through air leakage, but are also sources of uncomfortable drafts in winter. Check to make sure the window lock is working properly. Also inspect for weatherstripping in the window side channels.

Action: Fix or replace defective lock. Install weatherstripping if necessary. See Chapter 4.

Are there any visible gaps around window frames?

Check for gaps around interior frames. There should be no visible gap between the window frame and wall surface.

Action: Gaps around interior framing should be caulked. You should also caulk exterior cracks to keep rain out of the wall. See Chapter 4.

Is there moisture condensation on windows in winter?

Condensation on the glass or frame during cold weather may simply be caused by excessive indoor humidity, but might also be caused by cold air leakage around the glass.

Action: Check these windows with particular care for the problems mentioned above and make appropriate repairs. See Chapter 4.

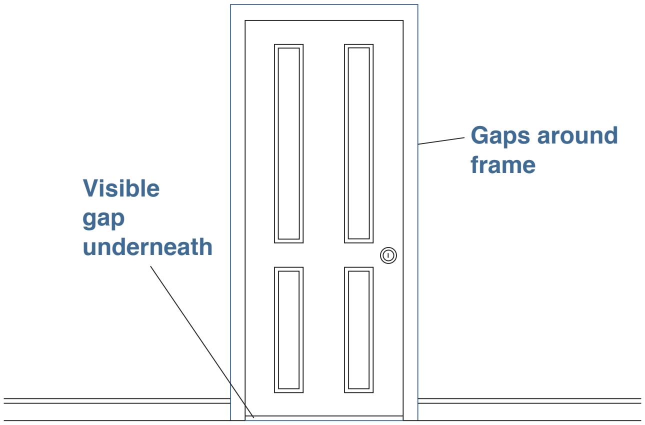


Figure 1-6 - Door checkpoints

Are the doors leaky?

Carefully inspect your exterior doors. Can you detect any air leakage around the edges? Is there a visible gap underneath? Although door air leakage is typically not a major source of heat loss, it does create uncomfortable drafts.

Action: Install door sweep or threshold, if necessary, to make the door bottoms tight. Install weatherstripping around top and sides if needed. See Chapter 4.

Do you have drafty spots?

Have you noticed drafts on windy days -- that cold feeling on the back of your neck while sitting in a reading chair? How about that cold air coming down from the attic door? Even if such drafts do not in themselves account for huge energy losses, they make you uncomfortable, and might even cause you to raise the thermostat.

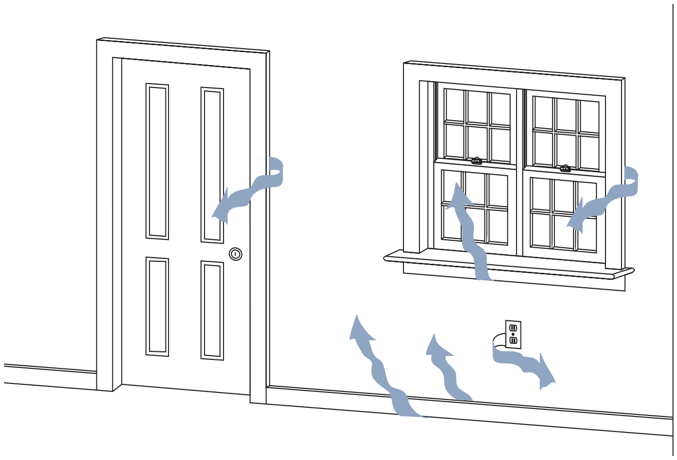


Figure 1-7 - The most common drafty spots in a home are around baseboard moldings, doors, and windows.

Check drafty spots to see if there are any obvious air leaks which could be fixed. Leaks are common around windows, electrical outlets, and in general at any place where a wall meets the floor or ceiling.

Action: Check for leaks. See Chapter 2 for how to seal them.

Down into the basement

Like the rest of your home, the basement loses heat both by conduction through the walls and by air leakage. The relative importance of this loss depends upon whether or not the basement is heated and used as living space. If it is heated, then it should be insulated, particularly if any of the walls are largely above ground. If it isn't heated, you should still check for major sources of air leakage. Insulating an unheated basement (either on the walls or the ceiling) may be worthwhile, particularly if much of the basement is above ground level. If you have a combustion- heating appliance in the basement, be careful not to tighten the basement so much that it may interfere with combustion air requirements.

Is there air leakage at the top of the basement wall?

The most important thing to check in the basement is air leakage at the point where the house sits on its foundation. Try detecting air leakage with a smoke stick or incense. If there is insulation stuffed into the cavities at the end of the floor joists, pull some out and look for dust marks, which would indicate long-term air leakage.

Action: Seal rim-joist area. See Chapter 2.

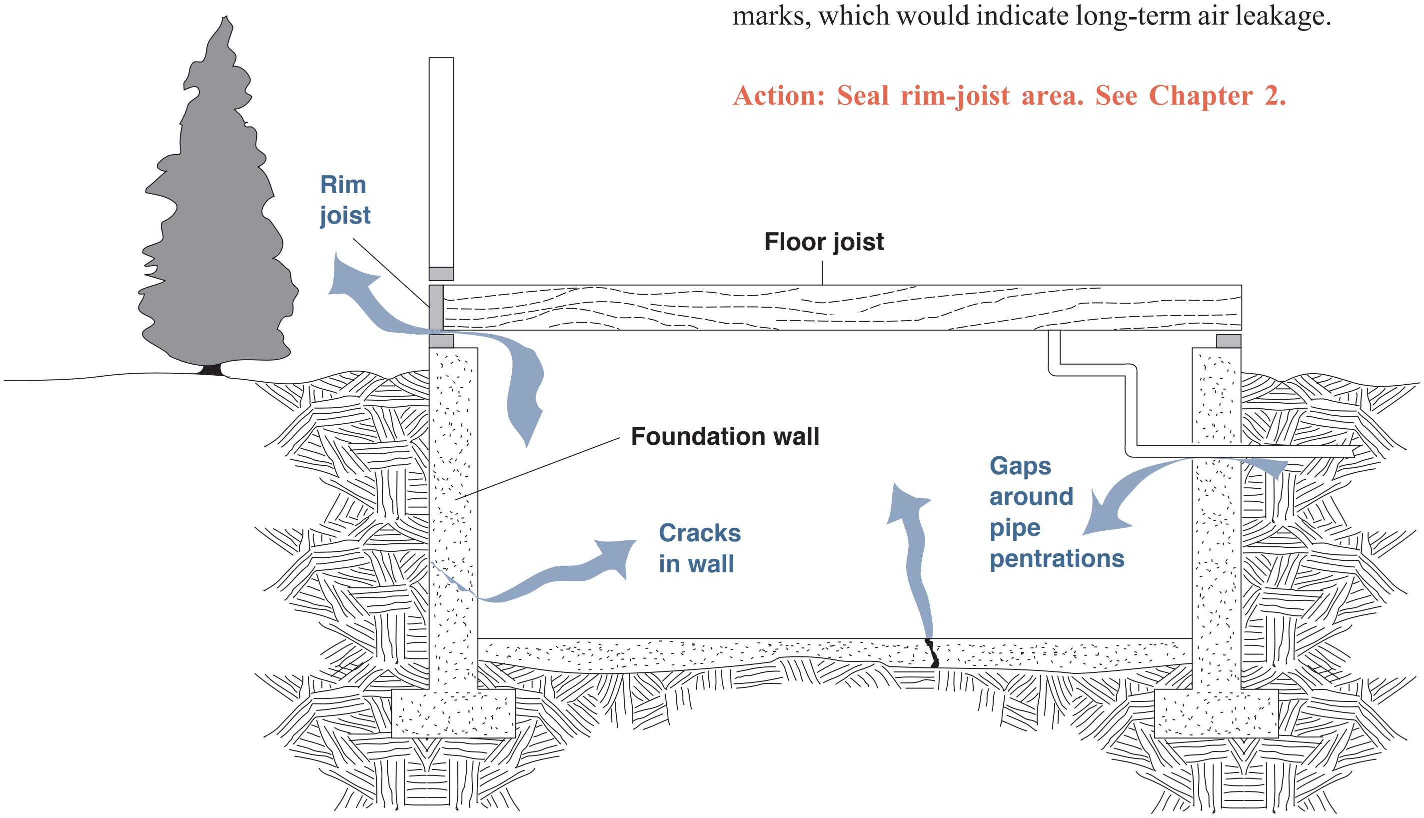


Figure 1-8 - Basement air leakage

Are there cracks or gaps in the basement walls and floor that would allow air leakage?

Cracks in the basement wall or floor or gaps around pipe penetrations can allow air or soil gas to leak into the basement and up into the house. Below ground air leakage not only wastes energy, it also can cause moisture problems and possibly feed radon into the house.

Action: Seal all cracks and gaps in basement floor. See Chapter 2.

Are the walls insulated?

In Virginia, a basement needs insulation only if it is heated. For heated basements, look for wall insulation behind any paneling in the same way that you looked upstairs. If you don't find any insulation inside, check the outside of the foundation wall. Some houses are insulated with rigid foam attached to the wall's outer surface.

Action: If the basement is heated and uninsulated, you should add insulation. If the basement is unheated and uninsulated, adding insulation may still be worthwhile. See Chapter 3.

Crawl spaces

Crawl spaces should always be insulated, particularly if they contain heating ductwork or mechanical equipment. Always install a 6-mil polyethylene ground cover to keep out moisture.

Sometimes it is difficult to inspect crawl spaces because of limited access. Use a flashlight to inspect for the presence of insulation and be prepared to get a bit dirty.

Does the crawl space need to be insulated?

Check the crawl space walls and ceiling for insulation. Also, look for uninsulated ductwork and/or heating or cooling appliances in the crawl space. Finally, see if the crawl space is vented to the outdoors and look for signs of moisture either on the floor or on wood framing.

Action: If the crawl space is uninsulated and unvented, you should install insulation on the walls.

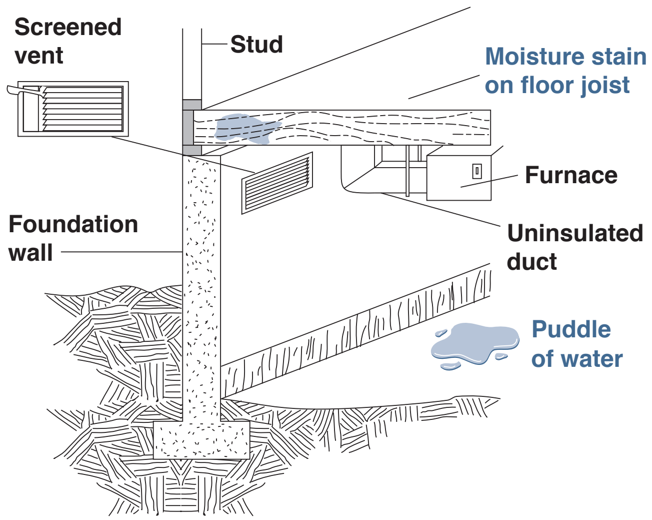


Figure 1-9 - Crawl space

Even if the crawl space is vented, you may be able to block off the vents and insulate the walls. (If this is donethe ground cover must be carefully installed, or moisture problems will result.)

If the crawl space must remain vented, then you should insulate the floor above. In that situation, any ductwork or hot water pipes that pass through the crawl space should be insulated.

If you have any doubts about moisture problems, you should consult a professional contractor. See Chapter 3.

Heating and cooling systems

Your heating and cooling system consists of more than just the furnace and air conditioner. Two other important components are the distribution equipment (air ducts, steam pipes, or hot water pipes), which are usually located in the basement, crawl space, or attic; and the venting system, which includes the chimney and vent pipes. Leaky ducts and uninsulated ducts or pipes can be a major source of energy loss in both summer and winter. Improperly lined or unlined chimneys, improper vent pipe type or installation, and dirty/obstructed chimneys and vent pipes can individually or all together cause furnaces to operate inefficiently and unsafely.

Heating system diagnosis and repair needs to be done by a skilled professional, but there are a few preliminary inspections that you can do yourself.

Is your system due for maintenance or a tune-up?

To maximize your heating and cooling system's lifespan and efficiency, you should have it inspected and serviced on an annual basis.

Action: Schedule a maintenance visit and be sure the inspector checks all chimneys and venting. See Chapter 5.

Is your furnace filter dirty?

The filter in your furnace is there to protect the blower motor and other internal components from dust. It should be inspected every few months and changed if dust visibly covers the filter's entire surface.

Action: If the filter is dirty, install a new one. See Chapter 5.

Do ducts leak air?

Ducts located in unheated attics, basements, and crawl spaces should always be insulated and tightly sealed against air leakage. Ducts in heated basements do not need to be insulated, but should be sealed. Be sure the duct leakage is tested by a professional before and after they are sealed.

Figure 1-10 - Furnace filter

Action: Leaky ducts need to be sealed, but it's a job for a pro. Insulating the ducts, on the other hand, is a good do-it-yourself job. See Chapter 5.

Is the outdoor unit of your air conditioner or heat pump in direct sunlight or blocked from freely circulating air?

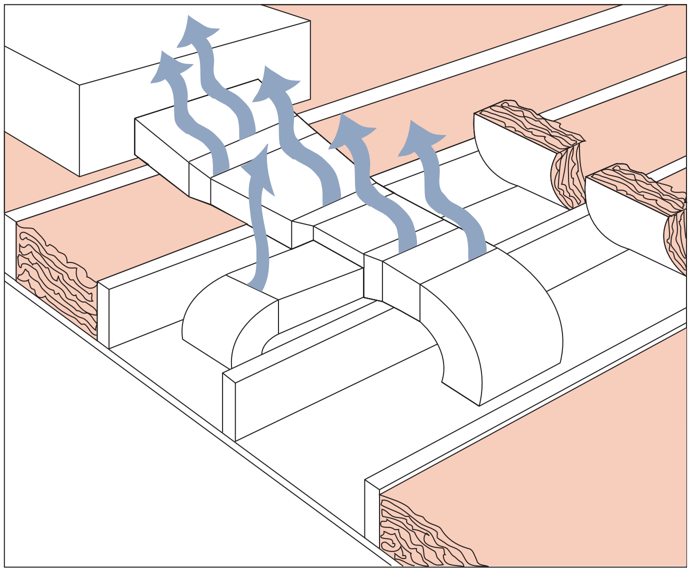


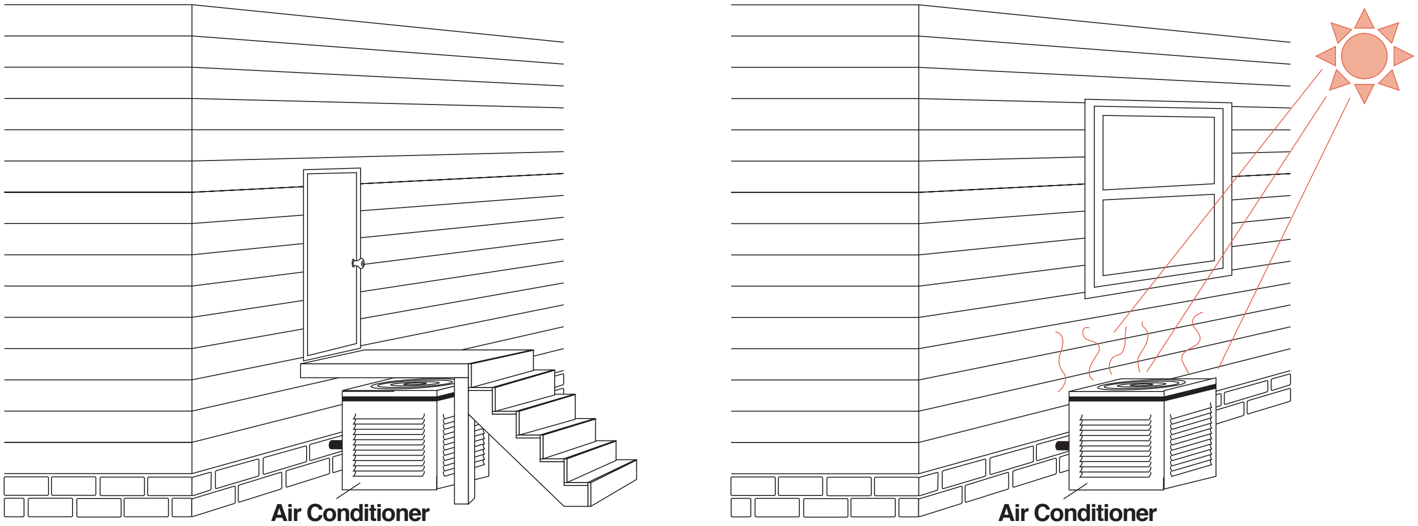
Figure 1-11 - Duct Leakage

The outdoor unit of your air conditioner or heat pump disposes of unwanted heat during the summer. To this end, it should both be shaded from direct sunlight and exposed to freely circulating air. It should not be enclosed to hide it from view. Heat pump outdoor units should be raised at least 3" above the ground (more in some areas) to keep them from becoming clogged with snow. See Figure 1-12 on page 12.

Action: Plant greenery for shade around the outdoor unit. Remove any obstructions that prevent air circulation. Raise unit to protect from snow. See Chapter 5.

The hot water heater

Your water heater is the second or third largest energy user in your home. Whether gas or electric, there may be significant potential to improve its efficiency.



Inadequate ventilation space

Exposure to summer sun

Figure 1-12 - Outdoor unit of central air contitioner

Does the water heater tank need to be insulated?

Almost all older water heaters are inadequately insulated. If your water heater is more than ten years old, it should be covered with an insulation blanket or replaced with an energy efficient model.

Action: Install an insulation blanket if necessary. See Chapter 6.

Is the water temperature too high?

The temperature of your hot water should be about 120°F -- anything more wastes energy. You can measure this temperature directly at a sink. Run the water for a while, and then fill a container and measure the temperature.

If you use a dishwasher without a booster heater, you may have to keep the water temperature at 140 degrees. Temperatures above 140°F not only waste energy, but present a hazard of scalding if someone should be exposed to unmixed hot water.

You can also check the temperature setting on the water heater itself by opening the access panel. If you have an electric water heater, turn off the power to the water heater at the circuit breaker or fuse box for safety. Depending on the particular model, the actual temperature setting may be shown, or the dial may only show relative settings: "warm" or "low" (typically 110-120°F), "medium" or "normal" (typically 140°F), and "hot" or "high" (typically 160°F).

Action: If the temperature setting is above 120°F, turn it down. See Chapter 6.

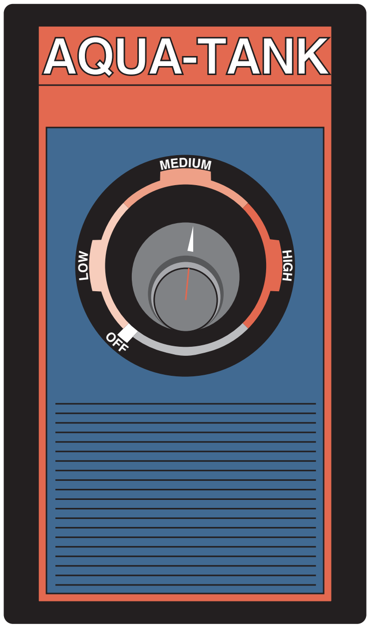


Figure 1-13 - Water heater temperature control

Do your water pipes need to be insulated?

Feel the water pipes leading from your hot water heater to determine which carry hot water and which carry cold water. All exposed hot-water pipes should be insulated. The first three or four feet of the cold-water pipes leading out of the water heater should be insulated as well.

Action: Wrap the pipes in insulation. See Chapter 6.

Could your plumbing fixtures be more water-efficient?

If you are wasting hot water, you are also wasting all of the energy that was used to heat the water. More efficient plumbing fixtures reduce this waste.

Inspect the showerheads and faucets in your bathroom(s). Look for low-flow showerheads and faucet aerators, which reduce water use. If you don't know what these look like, you can measure the actual flow of water to determine if you have them. Cut the top off a plastic gallon jug and measure how long it takes to fill with the shower or faucet on all the way.

Action: If the showerhead uses more than 3 gallons per minute, (20 seconds to fill the jug), you could save water and energy by installing a low-flow showerhead. If the faucet uses more than 1 gallon per minute, you could save by installing a faucet aerator. See Chapter 9.

Are any faucets in the house leaking?

A leaky hot water faucet dripping at a rate of one pint per hour will waste 1,092 gallons per year of water together with the energy used to heat that water.

Action: Fix leaky faucets. See Chapter 9.

Obtaining a Professional Energy Audit

Investing in a professional energy audit is money well spent. A trained energy auditor or home performance contractor uses sophisticated equipment like a blower door (Figures 1-14 and 1-15), heating and cooling efficiency testing equipment, an infrared camera, and often a computerized audit program to help identify problems. These problems may include air leakage, inadequate insulation, inefficient appliances, heating and cooling malfunctions, indoor air quality issues, and duct system inefficiencies. The auditor will identify the most cost effective measures applicable to your home's energy performance and provide you with a list of recommendations.

Obtaining a professional energy audit is certainly an appropriate place to start in determining the energy needs of your household. Some utilities provide basic energy audit services free of charge. Checking the Yellow Pages under "Home Performance Contractors", "House Doctors", "Weatherization Contractors" or "Building Science Services" may help you locate a trained energy auditor. Home Inspectors sometimes provide this service in conjunction with their more traditional home inspections.

Blower Doors and the Weatherization Program

The federally funded Weatherization Assistance Program (WAP) is the largest and oldest residential energy conservation program in America. It serves every

Figure 1-14 - Blower door for testing air leakage.

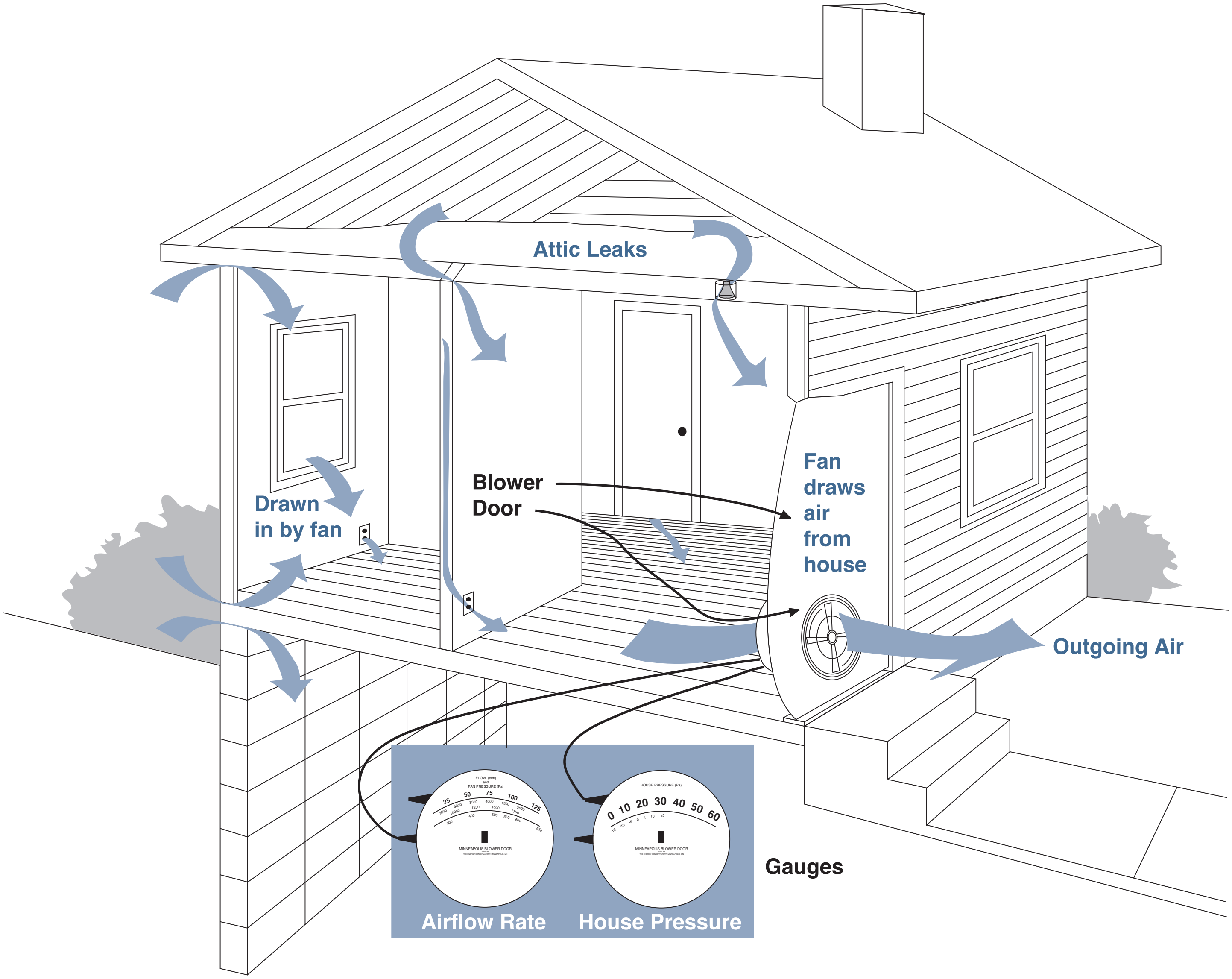


Figure 1-15 - By depressurizing the house, a blower door allows technicians to detect most leakage areas as well as measure total house air leakage.

county and city across the United States and is a program designed to provide energy conservation and efficiency services to eligible low-income families and individuals - particularly the elderly, handicapped, and families with children. Services that are provided include an energy audit, heating and cooling inspection, installation of insulation, air leakage sealing, duct diagnostics and repair, and indoor air quality testing. Weatherization professionals and contractors are trained energy auditors and building scientist who sometimes offer their services to middle and upper income households. The Virginia Weatherization Program has several programs that conduct energy audits and perform blower door tests and charge a fee that is then used to help support their program's efforts on behalf of low-income citizens. Information on how to contact a Weatherization Program in your area is provided in the Appendix.

Weatherization Programs have pioneered the use of the blower door and use it in conducting energy audits on every house that they weatherize. A blower door is a wonderful diagnostic tool that can identify air leakage areas in the home, air leakage in the duct system, help diagnose pressure problems in the house and also determine the air tightness of a home. Sometimes a house is "too tight" and the air exchange in the home is inadequate. A house that is too tight can cause significant indoor air quality problems and create negative pressure situations that may result in chimneys back-drafting.

A blower door consists of a powerful, calibrated fan that, when placed in an exterior doorway, with all the windows shut, pressurizes or depressurizes the house.

Using pressure gauges, the operator can measure exactly how much air leakage there is in your house (Figures 1-14 and 1-15). With the house depressurized, your contractor will then find and seal each major leakage point. After the work is finished, the technician should measure the leakage rate again to verify that the air sealing work was effective and also to be sure that the house has not been tightened too much (Figure 1-15).

Using a blower door not only allows the contractor to find and fix major air leakage spots, it also avoids wasting time on apparent holes that may not actually leak air. The blower door test is so effective, that it is probably the most useful technique developed for weatherization work on homes.

Energy Tips and Recommendations

1. Be a systems thinker and understand that your house is a system comprised of interactive components - the shell, the mechanical equipment, and the people who live in the house - and that all the parts of the system must work together to achieve maximum home energy performance.
2. Perform your own home energy rating by doing some simple calculations and by inspecting for flaws using a home inspection checklist.
   - Check the attic for air leakage and insulation levels.
   - Check the exterior walls of the house for existing insulation.
   - Check all windows and doors for possible air leakage, repair opportunities, and potential replacement needs.
   - Inspect basements and crawlspaces for air leakage and insulation.
   - Check the heating and cooling systems to see if they are on a regular maintenance schedule. Make sure that all chimneys and vent pipe are clean, unobstructed, and properly installed.
   - Inspect the duct system for insulation and leakage. Be sure to have a professional check and test the ducts for air leakage.
   - Examine the water heater for insulation and water temperature setting.
   - Inspect all water lines, faucets and toilets for water leaks. Check to see if showerheads are low-flow and if faucets are using aerators.
3. Make a sound investment in your home by obtaining the services of a professional energy auditor. This means that your home's energy performance will be tested using sophisticated building science equipment and technology. An energy auditor will help you prioritize and select the most cost-effective energy conserving home improvements.

Know your Btu's

In the United States, we measure energy in Btu's or "British Thermal Units." One Btu is a very small quantity of energy, typically described as the amount of energy given off by a wooden kitchen match. More precisely, it is defined as the amount of energy needed to raise the temperature of one pound of water one degree Fahrenheit.

- It takes about 80 Btu's to boil a cup of water.
- A 75 watt light bulb consumes 256 Btu's per hour.
- The average automobile (20 mpg) requires 6,250 Btu's to travel 1 mile.
- On the average, Virginians consume about 325 million Btu's per person per year.
- In 2000, the Commonwealth of Virginia used 2,304 trillion Btu's.

Your home probably consumes between 25 and 100 million Btu's per year. How much you pay for these Btu's depends on how you buy them. One million Btu's worth of electricity costs about $22.04 at today's electric rates. Natural gas costs considerably less -- about $9.64 per million Btu's. Table 1-2 lists typical current costs per million Btu's for each type of fuel.

These costs can of course change as fuel prices rise and fall. For example, Table 1-3 shows the cost per million Btu for natural gas and electricity and natural gas at different base prices.

Comparison of $/Btu for different energy sources makes it clear that all Btu's are not created equal. Some energy sources (such as coal) are more difficult to utilize, so the market drives their $/Btu price down. Others (such as natural gas) are easier to utilize, so the market drives their $/Btu price up. Electric energy is a special case because it must be generated in power plants where approximately 2/3 of the fuel energy is unavoidably lost as waste heat. This makes electric energy much more expensive, per Btu, than energy in the form of fuels. The ease and efficiency with which electric energy can be used, however, makes it the best energy source for many uses.

Table 1-2 - Cost per million Btu's for various types of residential fuels.

Fuel Type	**Cost per million Btu's at 2000 prices**
Electricity	$22.04
Natural Gas	$9.64
Fuel Oil	$9.47
LPG/Propane	$17.34
Coal	$3.12

Table 1-3 - Cost per million Btu's for natural gas and electricity at various base prices.*

Electricity at	$0.0726/kWh (1990 VA avg.)	$0.0752/kWh (2000 VA avg.)	$0.05/kWh	$0.075/kWh	$0.10/kWh
Cost per million Btu's	$21.24	$22.04	$14.65	$21.98	$29.31
Natural gas at	$0.670/ccf (1990 VA avg.)	$0.998/ccf (2000 VA avg.)	$0.50/ccf	$1.00/ccf	$1.50/ccf
Cost per million Btu's	$6.48	$9.64	$4.83	$9.66	$14.49

* Overall appliance costs are a function of end-use efficiencies and cost of fuel. See Chapter 5 for examples of typical appliance efficiencies. 1990 and 2000 average prices are from the U.S. Energy Information Administration.

CONTROLLING AIR LEAKAGE

Sealing you home against air leakage is not difficult. Reasonably handy homeowners should be able to do an effective job if they have the time and patience, and are conscientious about sealing areas that may be difficult and uncomfortable to work in. This is particularly true if the homeowners have had a blower door test done because that is the best method available to identify air leakage areas.This chapter describes the basic materials and techniques for controlling air leakage in your home.

Before You Begin: Health And Safety

Remember your home is a system of interacting components. Changing one thing often affects another. Tightening the house against air leakage is a good example of this. Before beginning any air sealing work, you should consider potential effects on the rest of the house. Two important considerations are combustion appliance safety and indoor air quality.

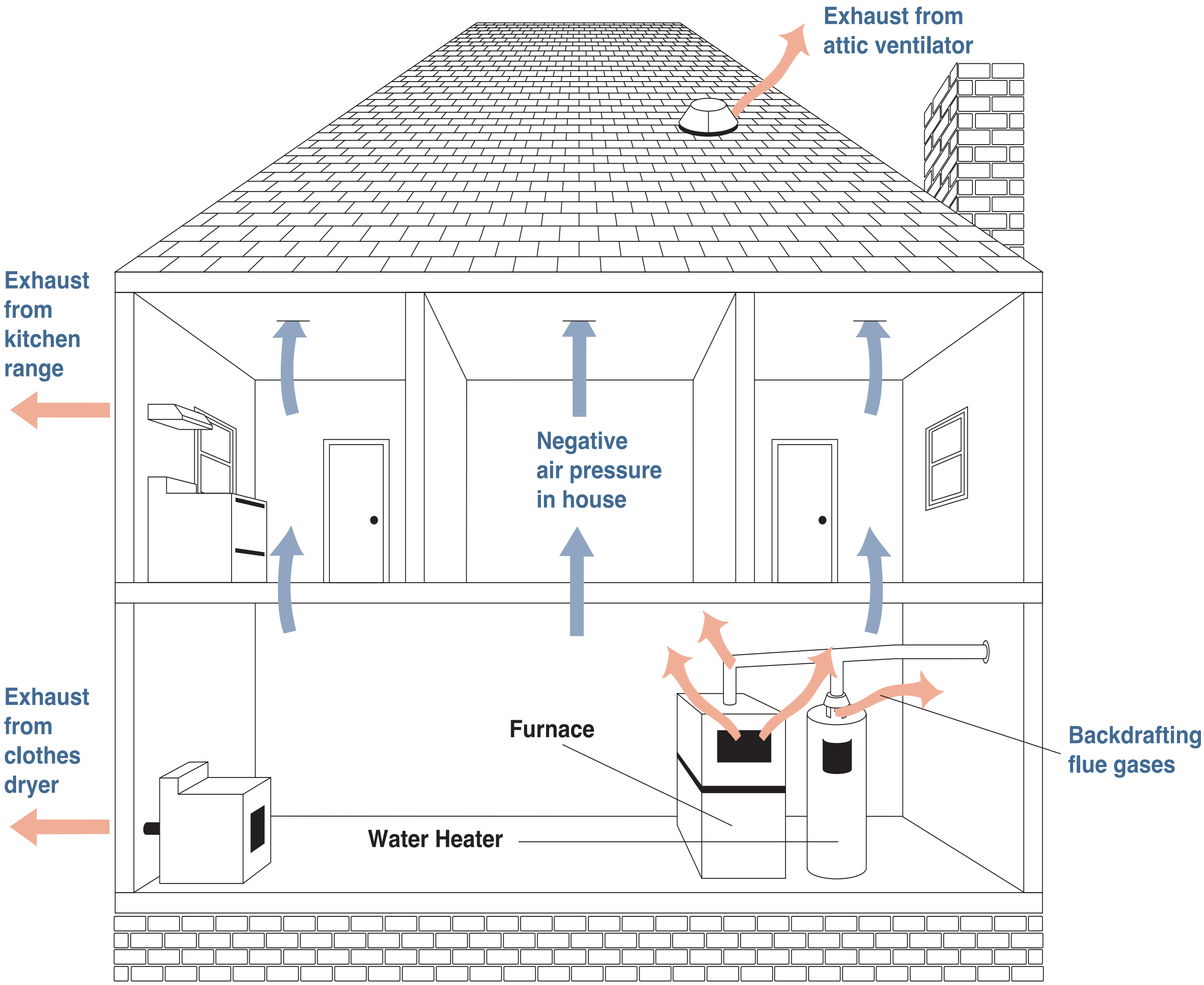


Figure 2-1 - Exhaust from other appliances can impede the proper venting of fuel-burning appliances.

Combustion Appliance Safety

If your furnace, boiler or water heater burns gas, oil, coal, or wood, you should check to make sure that tightening up the house will not interfere with proper venting of the flue gases.

Some combustion appliances depend on natural buoyancy to carry warm flue gases up the chimney and out of the house. Such appliances, called "natural draft" or "atmospheric vented", always vent into a vertical flue -- either a masonry chimney or metal flue -- and have a "draft hood" which draws in extra indoor air.

When other exhaust appliances such as clothes dryers or kitchen fans are running, they may create a negative pressure in the home which can cause flue gases from natural draft appliances to spill back into the house, creating a potential health hazard (Figure 2-1 on page 17). Tightening the house by sealing air leaks can make this situation even worse. This is why it is important to consider the value of a blower door test not only to identify air leakage but to also make sure that air sealing has not made the house too tight.

If you have natural draft appliances in your home, you must make sure that there are no potential safety hazards before embarking on an air sealing program. One simple test is to close all exterior doors and windows and turn on all exhaust appliances in the house including bath fans, clothes dryers, attic fans, central vacuum cleaners, etc. Then turn up your thermostat to activate the furnace and run hot water to activate the water heater. Using a smoke stick or incense, check whether the exhaust flue gases are flowing freely up into the chimney (Figure 2-2). If not, you have a potentially hazardous situation and should forego any air sealing work unless it can be corrected.

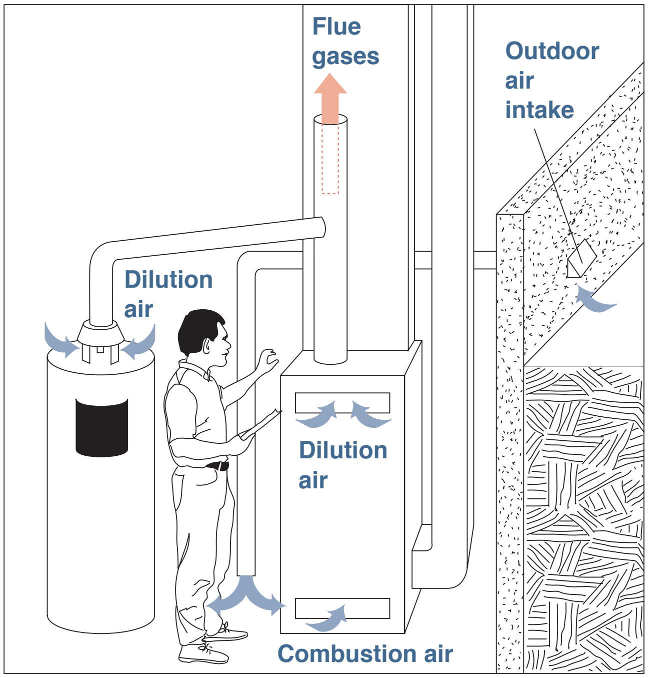


Figure 2-2 - A simple spillage/backdraft test.

The best method to check draft is to have a professional draft test performed. Most heating contractors, weatherization professionals, and home inspectors can perform this test. It is extremely important that all combustion appliances in the home be tested for proper draft and venting before any air sealing work is started. If the professional that you hire is not using any equipment to test draft or is simply using a flashlight and a cigarette lighter then the test is subject to inaccuracy and an unsafe situation may not be recognized.

It is equally important to re-test natural draft appliances after all air sealing work is completed. Once again, to ensure the safety of you and your family, it is best to have this testing done professionally. Remember, because your house is a system, tightening the shell may significantly impact how the mechanical equipment operates.

Carbon Monoxide: The Silent Killer

Carbon Monoxide (CO) is the leading cause of accidental poisoning deaths in America. It is a colorless, tasteless, odorless, toxic gas that is produced by the incomplete combustion of fuels. All fuel burning appliances - gas, oil, wood, or coal furnaces, un-vented space heaters, fireplaces, gas water heaters, etc. - have the potential to produce carbon monoxide. Early symptoms of CO poisoning are headaches, nausea, dizziness, shortness of breath, and confusion - symptoms that resemble the flu. If you feel better when you leave the home and then experience these same symptoms when you return then this is a sign that there may be dangerous levels of CO in the home. Table 2-1 on page 19 shows some of the effects of breathing low levels of carbon monoxide. Sensitivity to carbon monoxide varies from person to person; children, seniors, and people suffering from certain conditions tend to be affected more quickly and at lower CO levels.

Table 2-1 Effects of Breathing Carbon Monoxide

CO Concentration in Air	Results
12,800 parts per million (1.28%)	Headache, nausea Loss of consciousness Death within 1 to 3 minutes
1,600 parts per million (0.16%)	Headache, nausea within 20 minutes Loss of consciousness Death within 1 hour
8,000 parts per million (0.08%)	Headache, nausea Loss of consciousness Death within 2 hours
400 parts per million (0.04%)	Headache, nausea after 1-2 hours Loss of consciousness Death after 3 hours
50 parts per million (0.005%)	Maximum continuous exposure over 8-hour period (Occupational Safety and Health Administration)
9 parts per million (0.0009%)	Maximum acceptable indoor air quality (Environmental Protection Agency)
0 parts per million (0%)	Desirable level
The effects of short, low level carbon monoxide exposure are quickly reversed as soon as the victim is moved to an area with fresh air. Victims who lose consciousness, however, may sustain brain damage.	

A house that is too tight or a house that has negative pressure conditions as a result of equipment (such as dryers or exhaust fans) sucking air from the home can cause backdrafting of combustion appliances. If the chimney is blocked or dirty, if vent pipes are dirty or disconnected, and/or if the furnace is not operating correctly, carbon monoxide may be spilled into the living space. These are reasons to have a regular maintenance check of your heating system and to be sure that all combustion appliances and chimneys are drafting and venting properly. This is particularly true if air-sealing work is being done to the home.

It is absolutely imperative that any home with combustion appliances also have a UL-rated carbon monoxide detector installed. These inexpensive detectors are available in hardware and variety stores, and are installed much like smoke detectors. They sound a loud alarm if CO levels become dangerously high.

Power vented appliances

Some furnaces, boilers, and water heaters are "power vented", meaning they use a small blower to exhaust flue gases from the house. Flue gases from power vented appliances rarely spill back into the house. The newest furnaces and water heaters use completely "sealed combustion" which means they bring in outdoor air for combustion through an intake pipe and vent flue gases back out through a second pipe. Because they are completely isolated from the indoor air, these appliances are generally immune to backdrafting. If you have only power-vented equipment, you need not be as concerned with spillage or backdrafting hazards. But these systems should still be tested for proper draft because any venting system can become blocked or defective.

Indoor Air Quality

We consumers are continually bringing new products into our homes, many of which give off chemical vapor into the air. Even in a leaky house, these pollutants may build up in the air, possibly enough to become unhealthy. Tightening your house only makes it more difficult for such vapors to escape, increasing the potential health risks.

The Environmental Protection Agency ranks poor indoor air quality among the top five environmental risks to public health. Air pollution within the home can be significantly higher than levels of pollution outdoors.

Americans spend as much as 90% of their time indoors. A house that is too tight or that has improper ventilation can cause and contribute to long term health problems.

An airtight house can hold in moisture as well, another potential problem. Excessive indoor humidity can cause mold and mildew growth and even structural decay.

Aside from obvious sources of air contaminants, such as paint cans, strong cleaning solutions and other chemicals, there are a few other things to check for as listed below:

Biological pollutants

Molds, mildew, fungi, bacteria, and dust mites are some of the main biological pollutants found inside the home. These pollutants thrive in areas of excess moisture and can be easily distributed by vacuuming. Allergic reactions and asthma attacks are the most common health problems associated with biological pollutants. Identifying the causes of excessive moisture is the first thing that should be done to destroy the habitat for these pollutants. Using vacuums with high efficiency filters and being sure to keep all humidifiers, dehumidifiers, and air conditioning coils clean is very important as well. The best treatment is to insure that there is adequate ventilation within the home. Air sealing a house is still appropriate but being sure that the house is not so tight that indoor pollutants are made worse is very important. If necessary, pollutants can be controlled through mechanical ventialtion.

Asbestos

Asbestos is a very common building material that was used extensively up until the late 1970s. It can be found in some types of insulation, ceiling tiles, floor tiles, wallboard compound, asbestos siding, and duct and boiler wrap. Asbestos can cause cancer if the exposure is long term and/or excessive. The important consideration here is that if you are doing any remodeling or air sealing that may disturb asbestos related products then you are creating a health risk in your home. If there is any doubt about disturbing something that may have asbestos in it, be sure to seek professional help and have that material tested for asbestos content. Always follow prescribed and safe methods of removing and disposing of any material that may contain asbestos.

Lead Dust and Formaldehyde

Lead was used extensively in house paint until 1978. Lead dust is a problem if the paint is in poor condition or while doing remodeling or air sealing work in which the paint is disturbed. Water can also be also a problem due to the lead contained in solder, fixtures, and piping. Young children are particularly affected by lead and even a small amount ingested can cause significant health problems. Before replacing those inefficient single paned windows in a house that is over twenty years old, have the paint tested for lead.

Formaldehyde is a preservative, adhesive, and sealant that is commonly found in pressed wood products such as paneling and particle board. Formaldehyde can cause a wide range of health problems. Be sure, when doing any energy remodeling that may be disturbing products with formaldehyde, that you wear an appropriate dust mask, have an adequately ventilated work area, and do a thorough clean up when the work is done.

Volatile Organic Compounds

Volatile organic compounds (VOCs) are organic chemicals widely used as ingredients in household products. These products can include:

Paints
Solvents
Aerosol sprays
Cleansers
Disinfectants
Automotive products
Adhesives
Stored fuels

All of these products can release organic compounds while you are using them and when they are stored. These pollutants can cause a variety of health problems including cancer. To reduce exposure to VOC emissions, use the products according to manufacturers instructions, always use in well ventilated areas, store in well ventilated areas that are not in the household, close containers tightly, and do not store for long periods of time.

If you are storing these products in the household and the house is not properly ventilated or is too tight to begin with then you are maximizing the problem. Never store VOCs in any area that may be subject to a leaky return duct. A leaky return may suck these organic compounds into your duct system and distribute these pollutants throughout the home. (See Chapter 5).

Mold and Moisture

Mold is part of our natural environment and plays an important role in the natural decaying process. But molds should not be allowed to grow indoors because they produce allergens, irritants, and even potentially toxic substances. There are many types of mold which have different characteristics but the one thing that they all have in common is that none of them will grow without water or moisture. Therefore, mold can be controlled by reducing indoor moisture. If there is mold growth in the home, clean up the mold but fix the water and/or moisture problem as well, or the mold will simply return.

Air sealing a home that has a moisture problem can very easily make matters worse. A leaky house can also have moisture problems but tightening a home without first correcting the source of excessive moisture is a mistake. Things to look for that may be causing mold and moisture are:

- Fix all water leaks including plumbing leaks, faucet leaks, roof leaks, and any water entering the basement or crawl space.
- Clean and repair roof gutters regularly and be sure that gutters are directing water away from the home.
- Keep air conditioning drip pans clean and drain lines unobstructed.
- Be aware of excessive condensation on windows. This can be a sign of a moisture problem. (See Chapter 4.)
- Make sure that all vent appliances that produce moisture, such as clothes dryers, stoves and furnaces are vented properly to the outside.
- Unvented space heaters like kerosene heaters and unvented gas heaters and fireplaces produce tremendous volumes of moisture and these units should be avoided.
- Seal all thermal bypasses that can move warm air through the house and cause moisture to condense on cooler surfaces.
- Use air conditioners and dehumidifiers when needed.
- Make sure that all bathroom and kitchen exhaust fans are working properly or open windows when needed.
- Be sure that your walls and attic are insulated properly. Gaps in insulated areas can cause moisture problems.
- Have your duct system inspected for moisture and mold growth. A leaky duct system can result in moisture condensation and mold growth. The duct system will then distribute the mold and moisture throughout the house.
- Check the relative humidity in your home. Kits and meters for measuring humidity levels are sold in hardware stores and in home electronics stores. Relative humidity should be between 30 and 60% when the house is heated or air conditioned. If it is greater than this, find the source of the excessive moisture. (Be sure that you are not over-using a humidifier in the home.)
- In some summer weather, high humidity levels are unavoidable without air conditioning. In very humid summer weather you should be on the alert for mold and mildew growth.

Do you have any unvented gas or kerosene space heaters in the home?

Unvented space heaters give off carbon dioxide, water vapor and, when not working properly, carbon monoxide and other chemical pollutants. If you are using unvented fuel-burning space heaters, you should postpone house tightening until they are removed.

Do you have a gas cook stove? Gas stoves give off a lot of water vapor.

The oven gives off some carbon monoxide on startup and can give off much more carbon monoxide if the stove is not working properly. Gas stoves should be vented to the outdoors through a power-vented range hood. If your gas stove is not vented, you should forego extensive house tightening.

Do your bath fans work properly?

The best way to control indoor air quality is to remove the contaminants, including moisture, at their source. Your bath fans provide an excellent opportunity to ventilate moisture and other pollutants at minimal cost.

As part of your air sealing project, you should make sure your bath fans are working. Hold a stick of incense below the fan to see whether it pulls the smoke from the room. Try it with the bathroom doors open and closed. If the fan works only when the doors are open, you will need to undercut the doors to allow air into the bathroom.

If the fan doesn't work under any conditions, you should replace it.

Adequate Air Exchange

Air sealing or tightening a home is a good step towards making a home more energy efficient, but a house that does not have adequate air exchange or natural ventilation may cause health and safety problems. A blower door test is a recommended tool in checking for adequate air exchange. If air exchange is inadequate the best remedy is mechanical ventilation, which can control the intake and exhaust of outside air and provide the necessary air exchange even if a house is tight. A tight house is an energy efficient house and can be a healthy house if there is adequate air exchange.

This is another area where a heating contractor, energy auditor, or "house doctor" can provide expertise. If you are concerned about indoor air quality issues and how air sealing may affect this, seek professional help.

In houses sealed to very low leakage levels, homeowners and builders sometimes install "air-to-air heat exchangers." These heat exchangers draw outside air in and exhaust inside air while transferring heat from one air stream to the other. They bring fresh air into the house without wasting energy and allow very high levels of energy efficiency. In any home with fuel-burning equipment, however, their installation should be planned by a professional.

Air Sealing Materials

Different types of cracks or holes require different materials for sealing. To fix large leaks and bypasses, you'll need an assortment of rigid materials, sheet materials and expanding foam sealant. To seal smaller cracks and seams, you'll need an appropriate type of caulk. To tighten windows and doors, you'll need the appropriate weather-stripping. Finally, you may need some specialty items, such as high temperature sealant and two-part foam products for sealing around chimney flues, fireplaces and thermal bypasses.

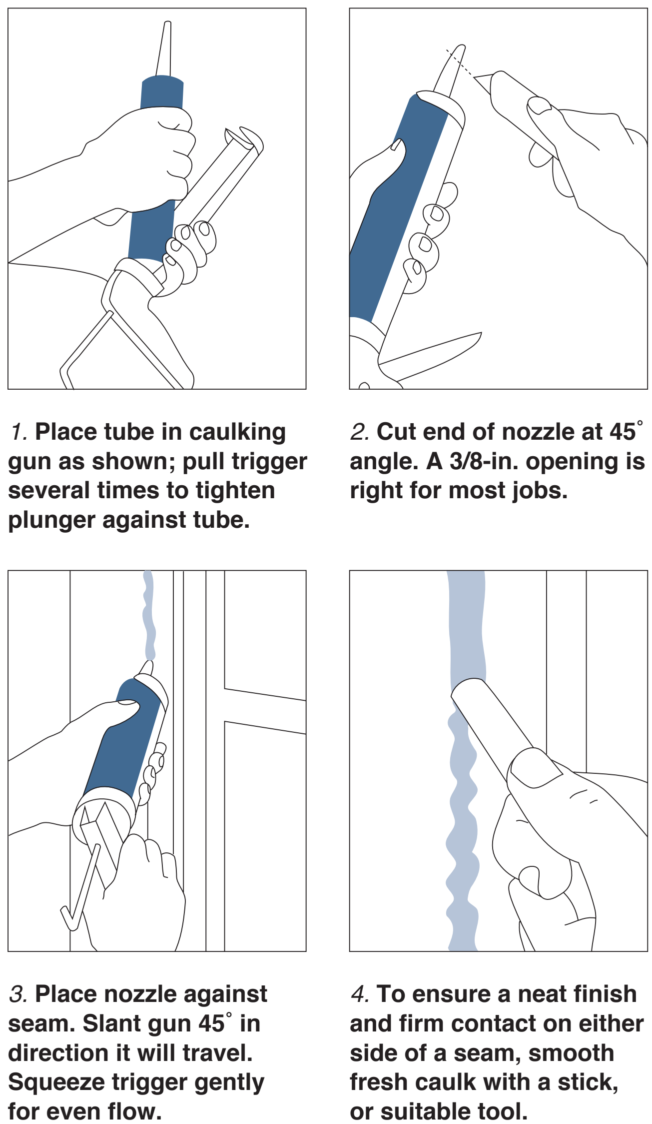


Figure 2-3 - How to Apply Caulk

Table 2-2 - Types and Properties of Caulking Compounds Suitable for Air Sealing Work.

GENERIC TYPE	COST	USEFUL LIFE	COMMENTS
Oil-base	Low	3-5 years	Poor adhesion to wet surfaces. Considerable shrinkage. Generally not recommended.
Butyl Rubber	Low to Medium	3-10 years	Good adhesion to masonry and metal; poor adhesionto wet surfaces. May be stringy during application. Long curing time before paintable.
Acrylic Latex	Low to Medium	10-20 years	One of the best all-purpose caulks. Paintable. Easy to use. Cleans up with water. Resilient and crack-resistant. Bonds well to wood and other porous substrates.
Silicone	High	20-50+ years	Excellent flexibility. Good adhesion to most materials. Effective over very wide temperature range. Easy application. Most are not paintable. May not bond well to all woods.
One-part Polyurethane	High	20-30 years	Excellent adhesion to most surfaces. Very good performance. Paintable. Clean-up may be difficult.
Ethylene Copolymer	Medium	20 years	Good adhesion to most materials. Good flexibility. Paintable. Good general-purpose caulk.
Polyurethane Foam Sealant	Medium	10-20 years	Good for filling large cracks but does not move well. Not recommended outdoors.
Solid caulking or "rope caulk"	Low	2-3 years	Clay-like material sold in coiled lengths. Used mostly as a temporary seasonal sealant at places like window sashes and unused doors.

Caulk

Not all caulks are the same. Some are paintable; some are not. Some tolerate joint movement; some don't. Different types stick to different surfaces. Some caulks, for instance, cannot be used on masonry. Finally, the life expectancy of different caulks varies considerably. When selecting the caulk for a specific task, be sure to choose one that is suitable in all of these respects. Check manufacturers' recommendations for the surfaces and temperatures on which it can be used and for any limitations.

Table 2-2 above presents a summary of general properties of the most common types of caulk.

Weather stripping

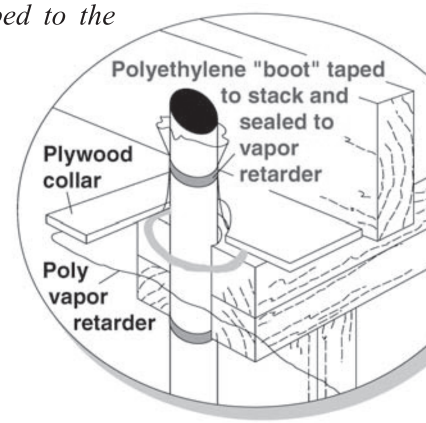
See Chapter 4 for information on weather stripping products and techniques.

Attic Work

Plumbing stacks

Figure 2-4 - Plumbing stacks expand and contract as hot water is used in the house, so the air seal must allow for some movement. Professional contractors often use a special neoprene gasket made for the problem. Ordinary polyethylene clamped or taped to the stack and stapled to the attic floor will also work

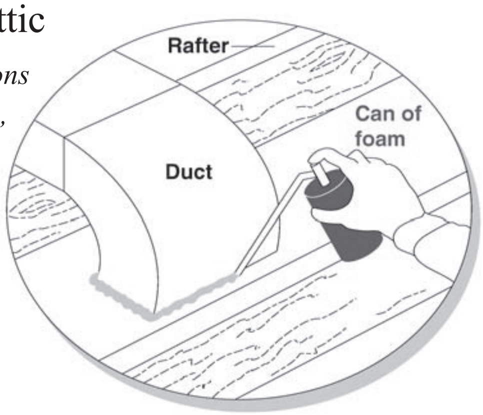
Figure 2-4

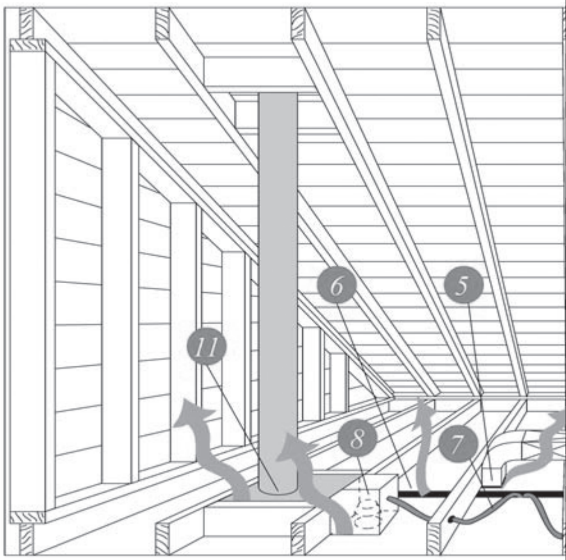


Ductwork penetrations into attic

Figure 2-5 - Seal all duct penetrations into the attic with caulk, duct mastic, or expanding foam. This includes kitchen and bath exhaust fans as well as heating and cooling distribution ducts.

Figure 2-5





Tops of balloon-framed walls

Figure 2-6 - You can either seal the tops of balloon-framed walls with heavy cardboard caulked and stapled into place, or with other rigid air barrier materials.

Figure 2-6

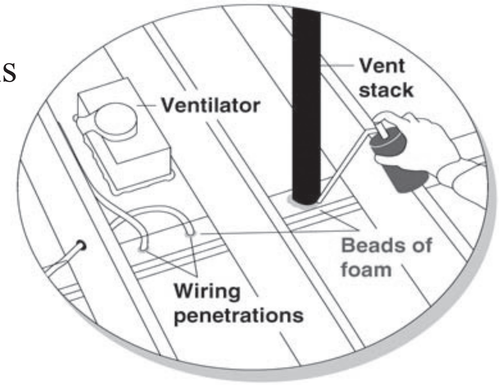
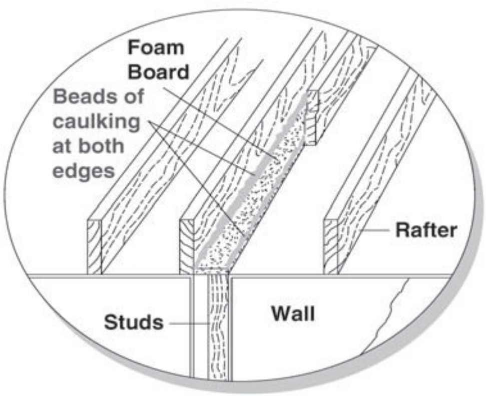


Figure 2-7



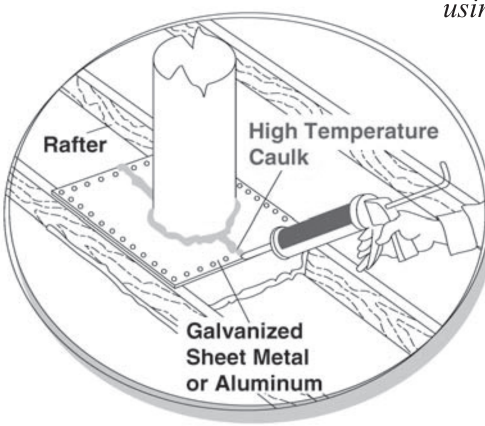
Top plates of interior partitions

Figure 2-7 - Seal all wiring and other penetrations in partition top plates with caulk or foam. Also, check the joint between the interior partition and ceiling drywall. If there is a visible crack that might allow air leakage, caulk the seam. (This is sometimes a difficult area to assess without using a blower door.)

Chimney chase

Figure 2-11 - The gap between the chimney and its framing sometimes extends all the way through the house, down to the basement. It should be sealed with a metal flashing that is nailed to the attic floor joists and caulked to the chimney using high temperature caulk.

Figure 2-11



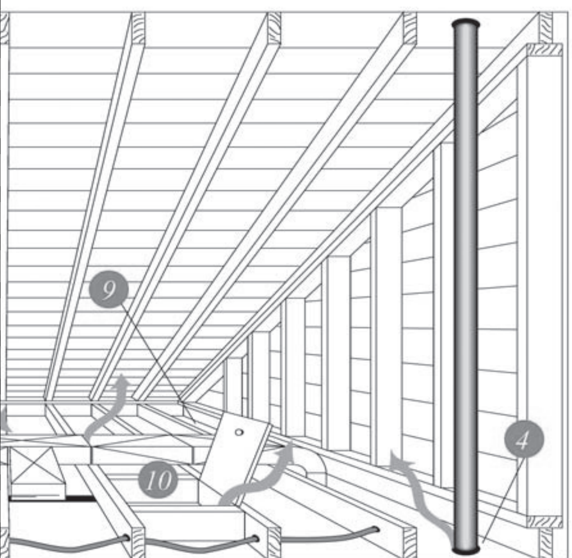
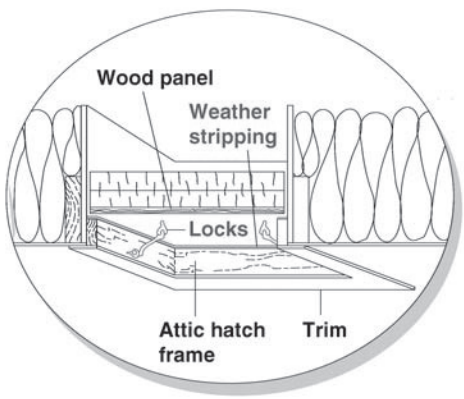


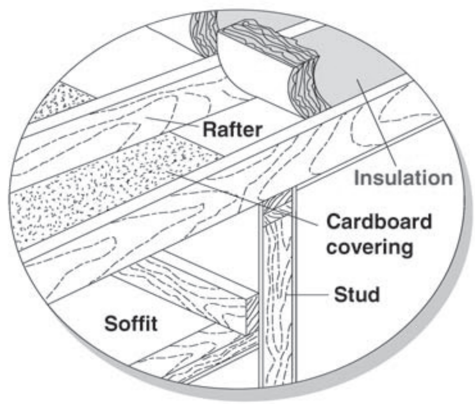
Figure 2-10



Attic hatches

Figure 2-10 - Caulk the joint between the hatch frame and the ceiling drywall, and apply foam weatherstripping around the panel edge. Also, install a latching mechanism that will hold the hatch firmly closed. The cam locks used for double hung windows work well, as does a simple hook and eye.

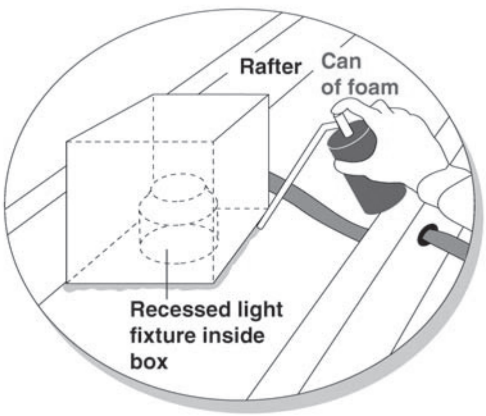
Figure 2-9



Drop soffits

Figure 2-9 - Seal drop soffits in the attic using rigid air barrier materials with caulk or foam.

Figure 2-8



Recessed lighting fixtures

Figure 2-8 - Recessed lights and electrical junction boxes are difficult air leakage spots. The best (and most expensive) treatment is to replace the fixture with an airtight fixture or retrofit the existing fixture with a new airtight trim piece. Another option is to build an airtight enclosure around the fixture. At a minimum, you should caulk the joint between the fixture and the ceiling drywall.

IMPORTANT NOTE OF CAUTION: Do not build an airtight box over a light fixture unless it is an "IC" (insulated ceiling) rated fixture, meaning that it can be covered with insulation. Also, do not attempt to caulk or tape the fixture itself to stop air leakage. You could create a fire hazard.

Thermal Bypasses

Thermal bypasses are hidden air paths, chaseways, and passageways that allow heated or conditioned air to bypass or escape through the insulation. Because warm air rises, it will continuously move up these air paths, bypass the insulation, and dump itself into the attic. This not only represents significant heat loss but can also cause indoor moisture problems. The heated air leaking into the attic can result in moisture condensing onto the cooler surfaces in the attic. This can cause ice dams, wet insulation, mold growth, and structural decay.

Common thermal bypasses are located around chimneys, in open exterior and interior walls that are often a result of balloon framing, leaky duct systems, recessed lighting, dropped ceilings and soffits, plumbing and electrical penetrations, vent pipes, and kitchen and bath exhaust fans. These bypasses must be sealed before any attic insulation is installed or added.

Techniques for sealing bypasses depend on the size of the opening. Small holes can be sealed with caulk or foam and larger openings can be sealed by a rigid air barrier - heavy cardboard, plywood, or drywall - in conjunction with a two-part foam sealant.

Places To Seal

Some holes, such as large attic bypasses, obviously allow air leakage and should certainly be sealed. In other cases it is difficult to tell without a blower door test (see Chapter 1). Minor cracks around molding, for instance, may or may not allow air to leak. If you can't get a blower door test, try feeling for drafts on a windy day.

The most significant loss of heat is usually from the living space up into the attic. Any leaks or bypasses there should be your first priority. Next, deal with any major leaks into the basement or crawl space. Leaks from the living space to the outside through walls and windows, although more conspicuous, allow less actual energy loss and should be your last priority.

Attic fans

If you have a whole house attic fan, it should be covered in winter with a tight-fitting cover. Use foam compression weather stripping to seal the cover to the attic floor. Be sure that when a whole house fan is in operation that sufficient windows are open in the home to prevent the fan from creating a negative pressure and potentially causing a combustion appliance to backdraft. These fans are used in warm weather situations so normally a heating system will not be in operation - but a gas fired water heater is operating all year. Also make sure that the attic is properly vented so that the air that the whole house fan is drawing into the attic will be quickly dispersed to the outside. This will prevent potential moisture problems.

Basement Work

Floor-foundation connection

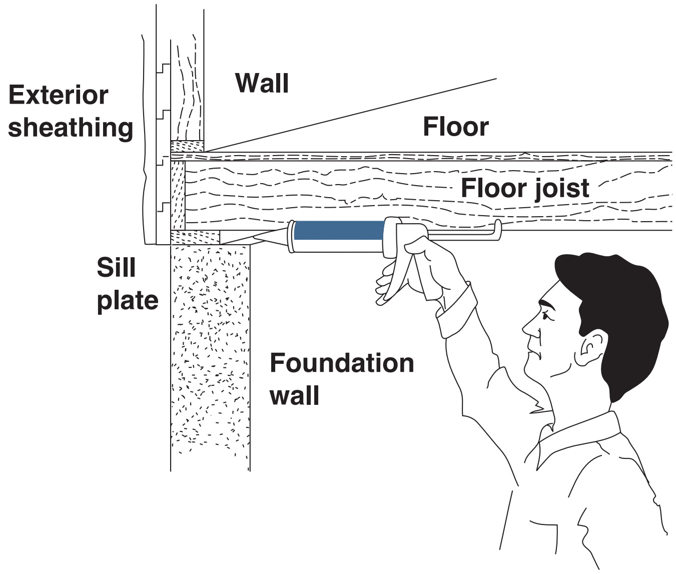


Figure 2-12 - This is one of the most important areas in the basement for air sealing. If the gaps between the sill plate and foundation are less than 1/4", caulk them with any good resilient caulk. For wider gaps, use one-part urethane foam sealant.

Holes or cracks in the foundation

Plug any holes and cracks that penetrate from the outside with caulking, two part foam, or cement.

Gaps around windows and doors

Seal around basement windows and doors in the same manner as in the upstairs part of the house.

Service entrances

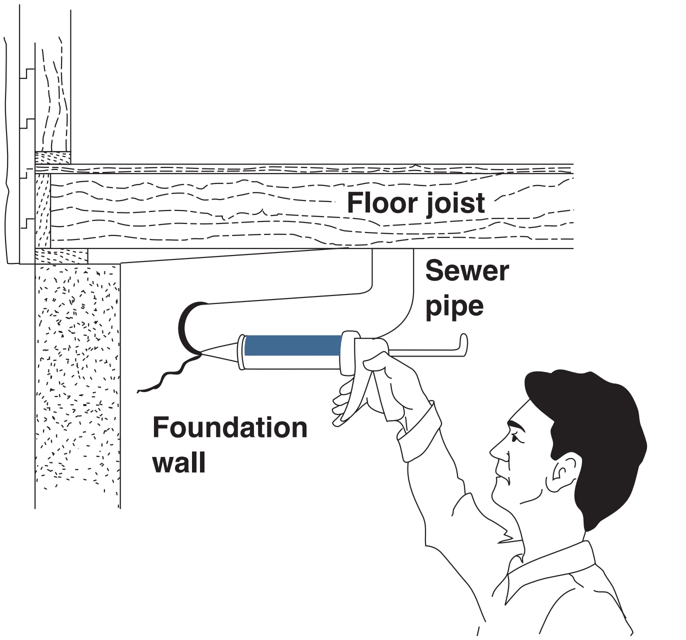


Figure 2-13 - Caulk any gaps around the openings in the basement wall through which services (electrical, plumbing, heating) enter the house.

Bathtub openings

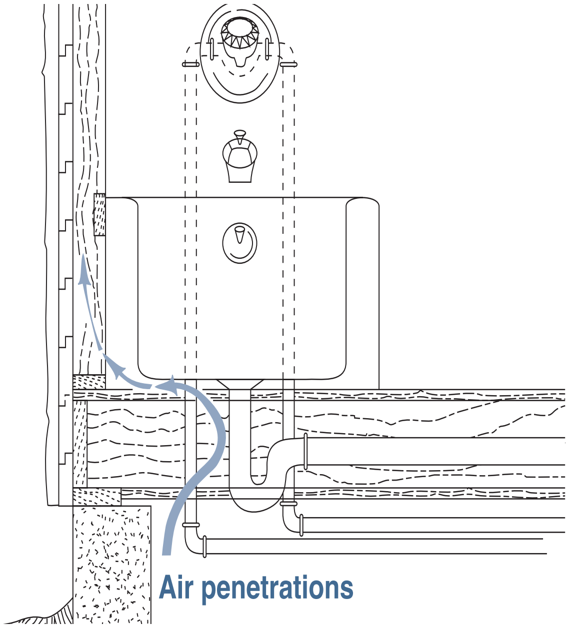


Figure 2-14 - Block air movement up into bathtub openings with stiff cardboard or gypsum board, caulked and nailed to floor members.

Bottom of balloon-framed walls

Seal the bottom of balloon-framed walls using the same technique as for the tops of open walls in attics (see Figure 2-6, page 24)-- either cardboard, caulked or foamed and stapled, or other rigid air barrier material. Balloon framing is a non-standard house framing method that was very popular many years ago. In balloon framing, the intermediate floor framing joists are face nailed directly to the studs. The studs are continuous from top to bottom of the structure with no wall plates or tops. Balloon framed buildings are very strong and durable because everything is interconnected but this style of framing also creates hidden air pathways and bypasses that reduce the energy efficiency value very significantly.

Ductwork — a special case (See Chapter 5)

All ductwork should be well-sealed with special mastic. Ordinary gray or silver-colored "duct tape" does not work and won't last (although there are special heat-activated tapes that do work). Also, disconnected or improperly connected ducts should be repaired.

Duct sealing can sometimes upset the pressure balances in a house, causing some natural draft appliances to spill flue gases into the living space. Therefore, you should consult with a professional contractor to make sure there are no potential safety hazards before sealing ducts.

Unheated Vented Crawl Space

Seal all penetrations through the floor above the crawl space using the same techniques described for the basement ceiling. If the crawl space is to remain vented, there is obviously no need to seal the perimeter walls.

Water Heater and Furnace Flue Connections

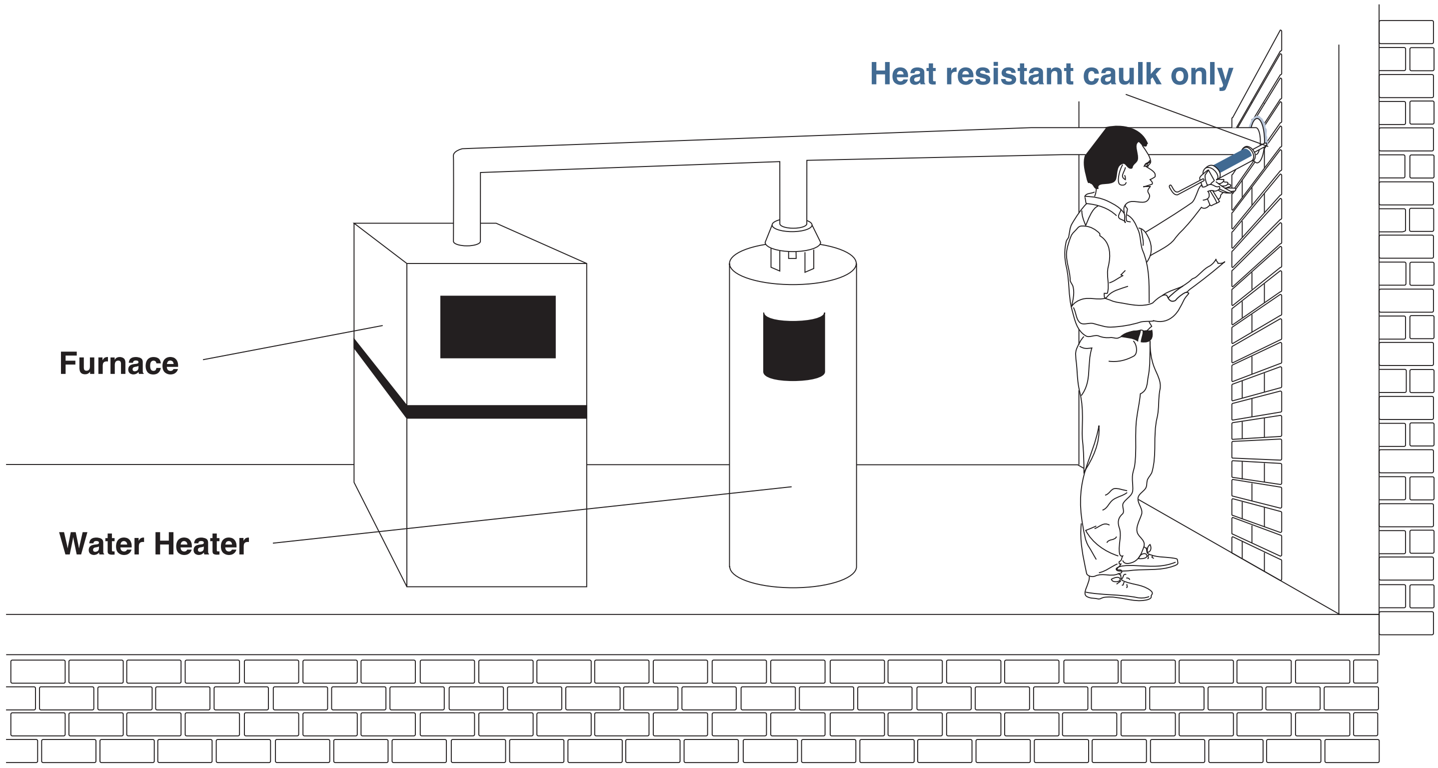


Figure 2-15 - Seal the connection of the water heater or furnace flue into a masonry chimney with high temperature caulk designed for this purpose or with furnace cement. Do not use any other material.

The Living Space

Inside versus outside - Where to caulk walls

The best place to stop air leakage in exterior walls is at the inside surface of the walls. Although many do-it-yourself manuals recommend sealing around the outside of windows and doors, we now know that air-leakage is more effectively controlled by sealing the interior surface. You may want to seal up cracks on the outside as well to prevent rain from getting into the wall.

Windows

Replace any cracked or broken glass. Weather-strip only if required. Caulk around interior trim with clear silicone caulk. For extremely leaky windows, the most effective sealing technique is to remove the interior trim and seal the opening between the window frame and rough stud frame with one-part urethane. This, however, is very time consuming. See Chapter 4 for more information on tightening windows.

Doors

Caulk the threshold if necessary with clear silicone. Also caulk around the door frame, between trim and wallboard. Add a new door sweep to the threshold if necessary.

Interior baseboard trim

If you know that there is severe air leakage around baseboard trim, the most effective remedy is to carefully remove the trim and seal the wall-floor joint with either caulk or expanding foam. If removing the trim is not practical, then caulk the trim to the wall surface and floor using clear paintable silicone or latex caulk. Air leakage around baseboard trim may be best addresses by determining where the air leakage is coming from and sealing it at the source. This is also the case for severe air leakage around electrical outlets. The best remedy is to identify the source (bypasses, gaps in the rim joist and/or sill plate) and seal these areas.

Plumbing holes

Caulk gaps around all plumbing penetrations through walls, especially under sinks and behind bathtubs. It is not necessary to seal plumbing penetrations down into the basement.

Fireplaces

If your fireplace is rarely used, consider installing an airtight plug in the flue to prevent air from escaping up the chimney. Glass doors are another option. Make sure the damper is working and that it is closed when the fireplace is not in use.

If there is a space, caulk the joint where the chimney meets the wall, removing the trim if necessary.

Radon

Radon is a radioactive gas produced by the decay of uranium, which is present to some degree in all soils. The decay process is a continuous and normal part of nature; radon gas is present at varying levels everywhere except over oceans and lakes.

Radon is invisible and has no smell or taste, even when it exists at potentially harmful levels of concentration.

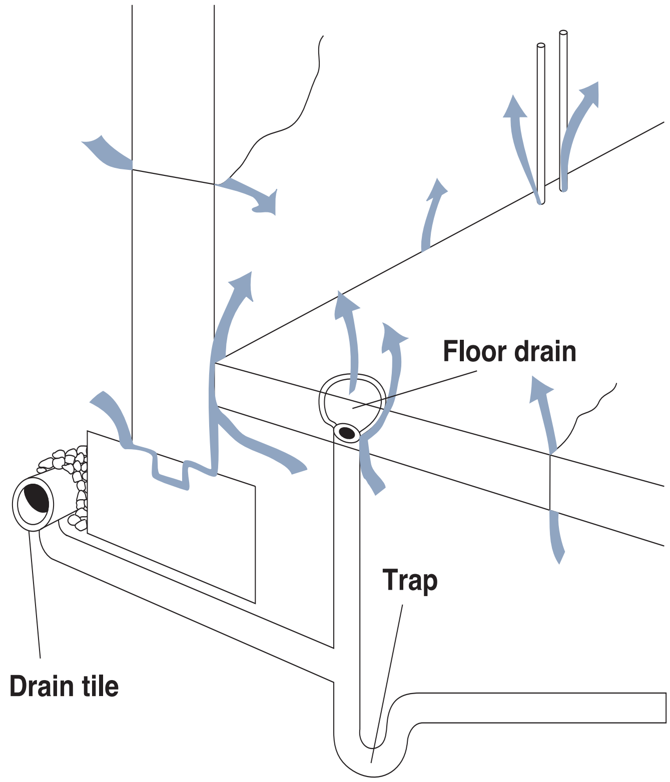


Figure 2-17 - Radon entry points

Radon is one of many "soil gases" that may be present in different soils in varying amounts. Soil gas enters houses through the areas of the building that are in contact with the ground. Typical entry points include floor drains and cracks in basement walls and floors (Figure 2-17). The amount of radon that accumulates in any particular house depends on a number of factors, including the concentration of radon in the surrounding soil, the type of soil, the way the house is constructed, the rate of soil gas entry, the rate of air exchange within the house, and even the time of day or season of year.

Radon is also present in groundwater and can be brought into a house through the plumbing system. This is sometimes a problem in rural areas with high radon concentrations in well water. Municipal water systems generally have low levels since any dissolved radon usually has enough time to decay or escape.

Building materials such as concrete, brick and stone were once thought to be a major source, but the amounts of radon released are usually insignificant.

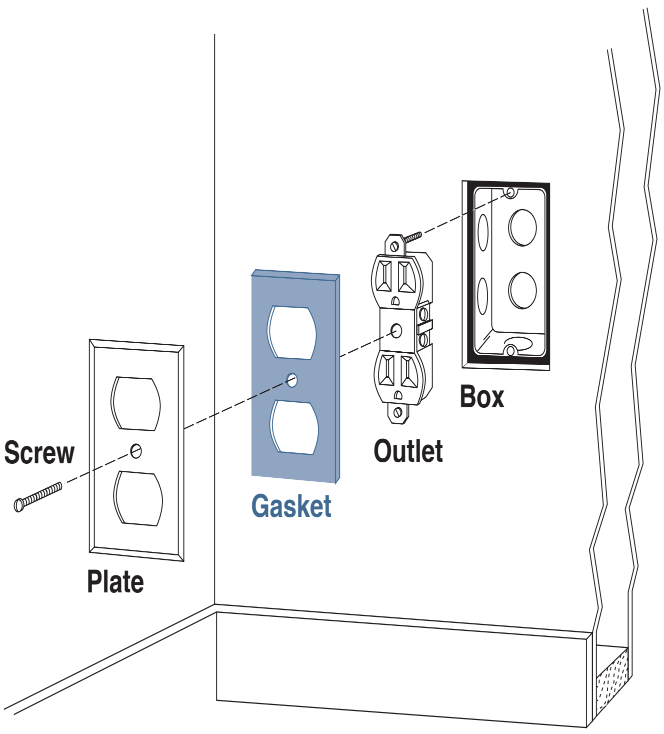


Figure 2-16 - Install gaskets behind cover plates in all electrical outlets and switches, including those on interior walls. Turn off power before installing gaskets.

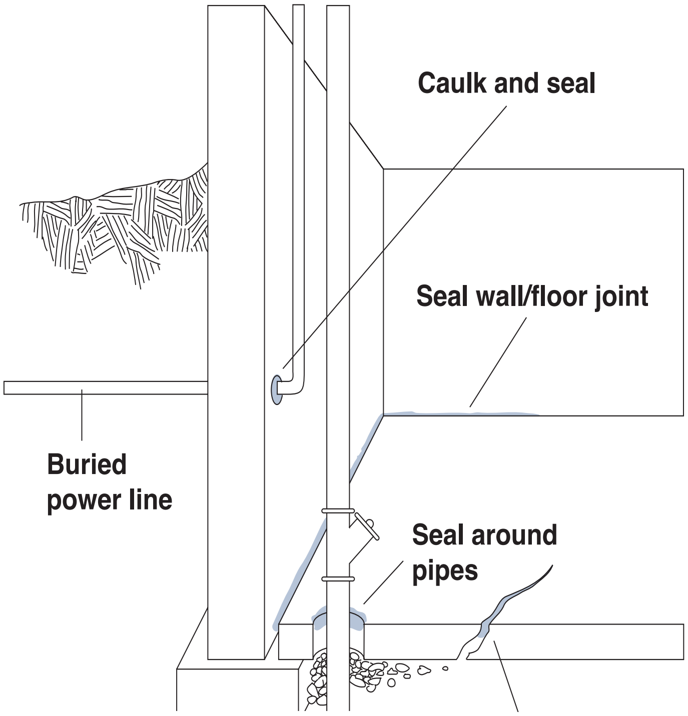


Figure 2-18 - The first step in radon control is to seal entry points in basement.

What to do about radon

Regardless of whether you perform any energy-efficiency improvements on your home, you may want to have it tested for radon. Several types of simple inexpensive tests are available from EPA (Environmental Protection Agency) certified contractors.

Typically a small detector canister is left exposed in the house for anywhere from a few days to a few weeks. After exposure, the canister is sent to a laboratory for analysis. If the measured radon levels are considered high, a more sophisticated test is performed. If the high levels are confirmed, the remedial work to reduce radon entry is called for.

Energy Tips and Recommendations

1. Before you begin any air sealing measures in your home, make sure that all combustion appliances are drafting properly and are vented correctly and safely to the outside.
2. After you have completed any air sealing work be sure that all combustion appliances are drafting properly.
3. Make sure that all combustion appliances are tested for carbon monoxide. Install a UL-rated carbon monoxide detector in the appropriate place in your home.
4. Consider any existing or potential indoor air quality problems before tightening your home. If you have any mold growth in the home, remove it and find and correct any water or moisture problems that are allowing the mold to grow.
5. Remove any unvented space heaters before any air leakage work is done.
6. Inspect all exhaust fans for proper operation and replace them if they are defective.
7. Use a blower door to identify air leakage areas and to measure the air tightness of your home after the air sealing work is done.
8. If necessary install mechanical ventilation in your home.
9. Locate and seal all thermal bypasses that may exist.
10. Have your home tested for radon.
11. Seal leakage areas in the attic, basement, crawl space, around windows and doors, all plumbing and electrical penetrations, tops and bottoms of balloon-framed walls, unused fireplaces, and existing furnace flue connections.

INSULATION MATERIALS SELECTION AND INSTALLATION

Insulation slows down the conduction of heat through walls, ceilings and floors in both winter and summer. It was first used extensively during the 1940's and 50's, not to save fuel (which was relatively inexpensive) but to increase comfort. A couple of inches of fiberglass or rockwool were sufficient.

With today's energy prices, however, we need to be considerably more conscientious. Proper insulation is among the most important tools in controlling fuel costs. Increasing existing levels of insulation or insulating areas that are uninsulated, represent one of the most cost-effective things a homeowner can do. The payback and benefits are almost immediate. This chapter describes the various types of insulation and how they are installed.

R-value – The Power Of Insulation

Insulation is rated by "R-value" which stands for "thermal resistance". R-value is a measure of a material's ability to slow down heat flow. The higher the R-value, the better. With a temperature difference of 1 degree Fahrenheit, insulation with R=1 allows 1 Btu per hour heat flow for each square foot of surface area. In general,

Heat Flow (Btu per hour per square foot) =
Temperature Difference (degree F) x R-value

The R-value of an insulation material is usually listed in terms of R per inch. For any thickness, the total R-value equals the rated R per inch multiplied by the thickness in inches. For example, cellulose attic insulation has an R-value of R-3.7 per inch. A 6-inch-thick installation will therefore have a total R-value of R-22.2 (6 inches x 3.7 per inch).

For insulation manufactured in a particular thickness, the R-value of the manufactured piece is given. For instance, one manufacturer's fiberglass blanket insulation might have an R-value of R-13. Another manufacturer's rigid foam panels might have an R-value of R-10. If more than one layer of insulation is used, the total R-value can be calculated by adding the R-values of the layers.

Throughout this chapter we will refer to representative R-values for various types of insulation. Keep in mind however, that the actual R-value for a specific type of insulation varies somewhat between manufacturers and even between different products from the same manufacturer. Manufacturers are required to label their insulation products according to strict regulations set forth by the Federal Trade Commission. The R-value is always listed prominently either on the insulation material (batts and rigid foam) or on the bag (loose-fill). When the R-value given in this book differs from the R-value used on the manufacturer's label, use the label R-value.

Five Categories Of Insulation

Residential insulation falls into five basic categories: loose-fill, batts and blankets, rigid plastic foam, spray-applied products, and reflective materials. These categories and the specific types which fall into each are described below.

Loose-fill Insulation

As the name implies, loose-fill insulation consists of granular or fluffy material that can be blown into hollow cavities or open attics. Its main advantage is that when properly installed, it completely fills the installation space without having to be cut and fitted. If an attic floor has lots of obstructions, loose-fill is probably the appropriate choice. Stores where you purchase your insulation often provide the use of a blowing machine at no cost. Other-

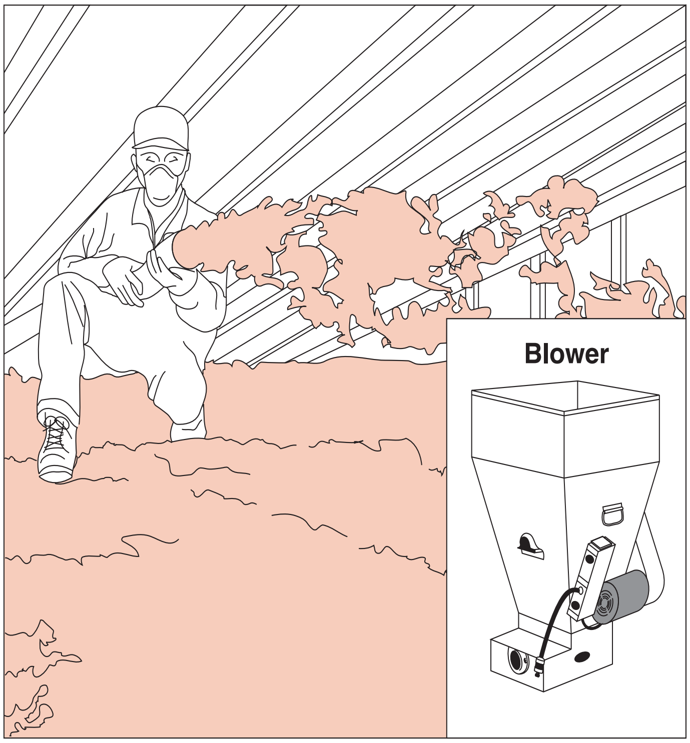


Figure 3-1 - Loose fill insulation can be blown into attics. Machine blowing produces thorough coverage.

wise a blowing machine can be rented at a minimal expense. Be sure to use all safety procedures in operating a blowing machine and always wear protective clothing, goggles, and the appropriate type of dust mask. Pouring insulation by hand is not recommended.

Cellulose fiber - R-3.7 per inch

Loose-fill cellulose fiber insulation is made from recycled paper products, such as newspapers and telephone books, which are pulverized into a fibrous material and then chemically treated for fire and pest resistance. It is suitable for both attics and exterior walls and for both new construction and retrofit work, although it is particularly effective for retrofit.

When tightly packed into walls, cellulose fiber not only adds R-value, but drastically reduces air leakage as well. Research has shown that densely packed cellulose insulation in the walls can reduce a house's overall air leakage rate by as much as 50%! Cellulose is best installed with a blowing machine. Installing cellulose without a machine gives uneven coverage and is not recommended.

Some loose-fill cellulose is intended for damp application into attics. Called "stabilized" cellulose due to its semi-rigid texture and resistance to settling, these products require special installation equipment that mixes water into the insulation as it is blown into the attic.

Fiberglass - R-2.3 to 2.8 per inch

Fiberglass is the most common type of loose-fill insulation used in homes. It is made by spinning molten glass into long thin fibers that are bound together and then cut into small tufts or cubes.

Mineral wool (Slag and Rock wool) - R-3.2 per inch

Mineral wool is made by spinning molten slag into long fibers, a process similar to that used to make fiberglass. One advantage of mineral wool is that it is totally fireproof and won't melt or burn in a house fire. (Fiberglass insulation doesn't burn, but it does melt.)

Mineral wool is fairly dense and should be installed with a blowing machine.

Vermiculite - R-2.4 per inch

Vermiculite is made by expanding mica under high temperature and pressure. Because it can withstand wetting better than any other loose-fill, it is commonly used to fill the cores of blocks in foundations. It is not commonly used in attics, partly because of its heaviness and partly because it is not as widely available as other materials.

According to the U.S. Environmental Protection Agency (EPA), all vermiculite is likely to contain small trace amounts of asbestos. A number of manufacturers produced insulation from vermiculite, but one mine in the United States produced over 70% of the world's vermiculite before the mine was closed in 1990. Vermiculite products generated from this mine were likely to have been contaminated with asbestos. If you suspect that you may have vermiculite in your attic, do not disturb it in any manner. Seek professional guidance and have the product tested for asbestos and then follow professional procedures if it must be removed or disturbed in any way.

Batts and blankets

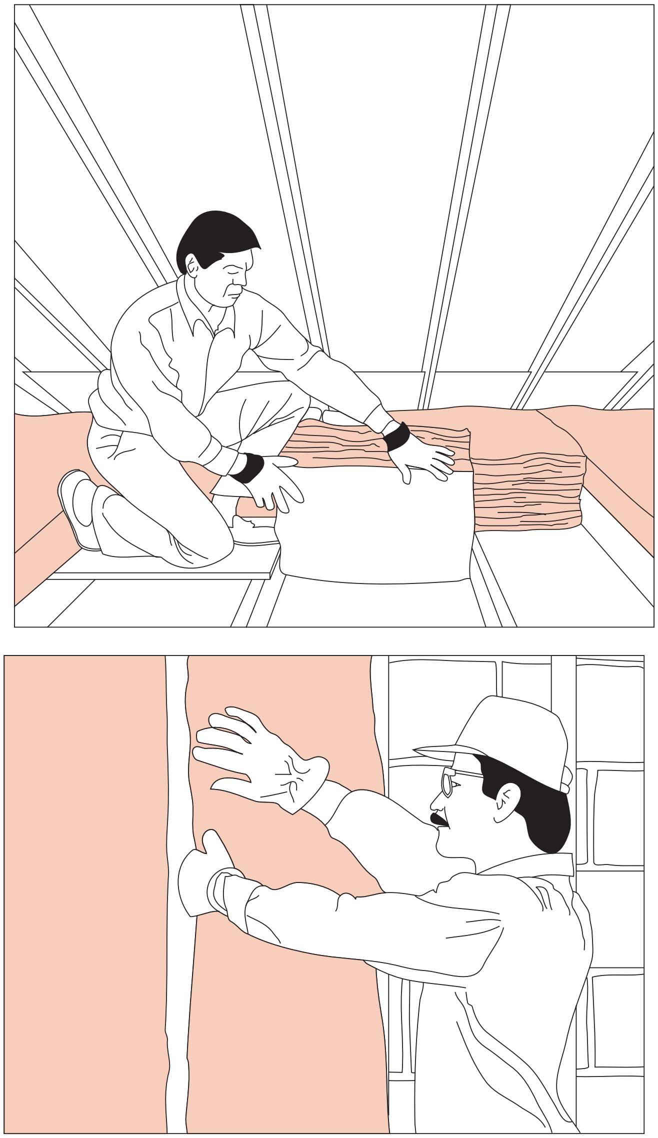


Figure 3-2 - Fiberglass batts are installed in open walls and floors. Wearing a dust mask, gloves, and goggles can help avoid irritation from fiberglass dust.

Batts and blankets are made of either fiberglass, mineral wool, or recycled cotton material that is spun into a cohesive mat. Fiberglass batts are the most common, accounting for roughly 90% of the material used to insulate walls in new homes. Mineral wool batts and blankets are relatively rare. Cotton or natural fiber insulation is fairly new to the market. An advantage to using cotton batts is that it is non-toxic and there is no itch or irritation associated with its use.

Batts and blankets can be used to insulate attics, cathedral ceilings, and basement ceilings. One advantage of batts and blankets is their ease of installation in open cavities.

The difference between batts and blankets is simply packaging. Batts are precut to roughly 4-foot or 8-foot lengths so that they will fit into a standard-height wall.

Blankets are long rolls of material that are cut to length on site, usually to be used in attic floors.

Fiberglass batts are available in the following thickness and R-values:

Thickness	R-value
3-1/2"	R-11
3-1/2"	R-13
3-1/2"	R-15
6-1/4"	R-19
5-1/2"	R-21
8-1/2"	R-30
12"	R-38

Notice that 3-1/2" batts come in three different R-values. The reason for this is that with fiberglass, as with some other insulation materials, the R-value per inch varies with density of the material. Manufacturers are able to pack more R's into a batt by increasing the density without changing the thickness.

Faced versus unfaced batts

Fiberglass batts are available with or without paper or foil facing on one side. The choice between faced versus unfaced is usually a matter of personal preference. The facers help control moisture movement into walls and floors and also have flanges for attachment to studs or joists. Unfaced batts are also suitable for any application as long as proper attention is paid to moisture control. Unfaced batts are typically made slightly wider than faced batts in order to "friction fit" into stud wall cavities without sagging. Be sure to wear protective clothing, goggles, and an appropriate dust mask whenever you work with fiberglass.

Rigid foam insulation R-4.0 to R-8.7 per inch

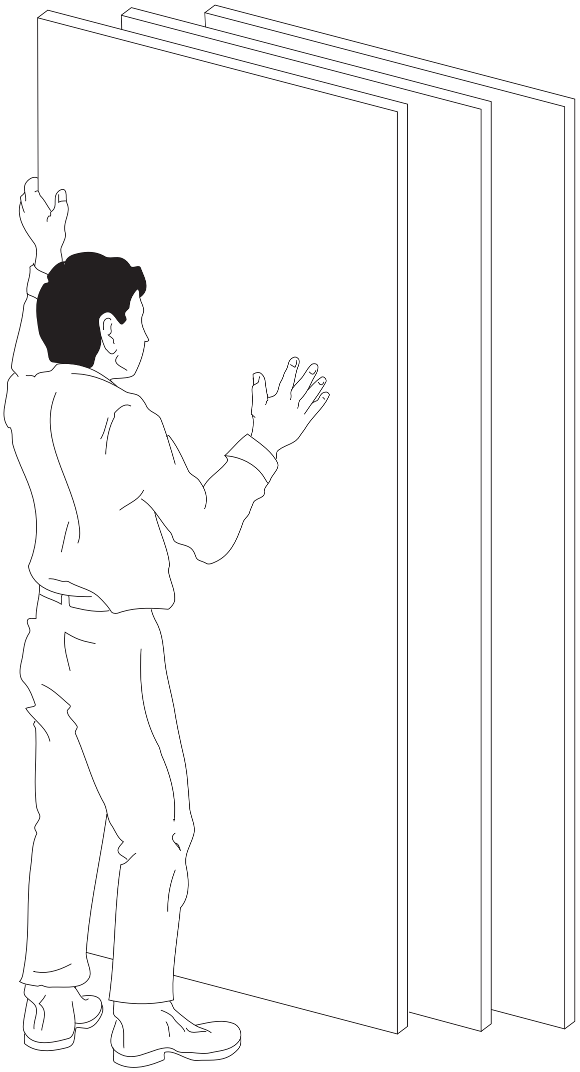


Figure 3-3 - Rigid foam insulation is made from several different types of plastic foam, each with a different R-value. The most common application for rigid foam is as exterior insulative wall sheathing. Some rigid foam insulation has the significant advantage of being resistant to water, and so is the best insulation for below grade foundation insulation.

Extruded polystyrene: R-5.0 per inch

Extruded polystyrene is made by four manufacturers in the United States, each of which uses a distinctive color: blue, pink, green and yellow. From the user's standpoint, all four are basically the same. Extruded polystyrene is very resistant to water penetration and is a good material for insulating foundations below grade.

Expanded molded bead polystyrene: R-3.5 to R-4.5 per inch

Sometimes referred to as "beadboard", expanded polystyrene insulation is very similar to the material used to make common coffee cups -- both are made of tiny beads fused together. The R-value varies with density. Expanded polystyrene is resistant to water penetration and is suitable for below grade use except in very wet sites.

Polyisocyanurate: R-7.2 to R-8.7 per inch

Most commonly sold with a shiny foil facing on one or both sides, polyisocyanurate or "iso board" has the highest R-value of any common insulation material. Though somewhat water resistant, iso board is not recommended for below-grade application.

Foam and fire - Caution!

Almost all the rigid foam insulation boards are flammable and must be protected by a fire-rated covering if installed in the living space or basement. Some building codes also require that rigid foam be covered when installed in crawl spaces.

Foam and the environment - the CFCs and HCFCs

Producing foam insulation requires use of a "blowing agent": a gas that forms the many tiny cavities in the foam and fills them after they are formed. Until recently, many of the foam products described above were made with chlorofluorocarbon blowing agents (CFCs). In fact, the CFCs helped give them their impressively high R-values.

Because scientists have discovered that CFCs are causing damage to the Earth's ozone layer, they are being phased out of production and are now banned in the US. Foam manufacturers are working to find alternative blowing agents for rigid foam insulation. Some manufacturers have already switched to hydrochlorofluorocarbons (HCFCs). HCFCs also damage the ozone layer, but they break down more quickly than CFCs in the atmosphere.

As a result, they have only 1/20 the deleterious effect on the ozone layer that CFCs have.

Because HCFCs still do some damage to the ozone layer, they are gradually being phased out of production and will be fully replaced by other blowing agents by 2030.

No foams now on the market (unless they've been in a warehouse for years) contain CFCs. Many contain HCFCs, while many others use neither CFCs nor HCFCs. Insulation labels are not required to disclose the blowing agent used in foams. Many manufacturers advertise that their foams are "CFC-free", but this is in fact a legal requirement for all foams. A few manufacturers advertise that their foams contain neither CFCs nor HCFCs, and these materials are the best for the environment. Insulating with an HCFC-containing foam, however, is much better for the environment than not insulating at all.

Spray-applied insulation

Figure 3-4 - Several types of insulation can be applied as a liquid or wet slurry. These "spray-applied" insulation materials are used mostly in new construction of walls, but some contractors use them in attics for both new construction and retrofits.

Urethane: R- 6.0 per inch

Urethane is a spray-applied foam that is chemically similar to the material used to make rigid isocyanurate. Like the iso-board, it is made using HCFCs or some other a blowing agents.

In addition to its high R-value, urethane has advantages in its air sealing properties and strength. When sprayed into a wall or attic, it forms an extremely effective air seal and adds rigidity to the structure.

One very effective use of urethane as a retrofit material is to spray a skim coat onto the attic floor, followed by loose-fill fiberglass or cellulose. The urethane will automatically seal air leakage sites and attic bypasses.

Wet-spray cellulose

Cellulose insulation can be applied wet using special equipment that mixes water into the insulation as it is blown out of a hose. Sometimes a small amount of adhesive is added. When installed in wall cavities, the wet cellulose sticks and forms a monolithic "batt". The same technique is sometimes used in attics to reduce dust during installation.

Except for attic application, wet cellulose would not be useful for retrofit situations unless the home is being rehabilitated and the interior has been gutted so the existing wall cavities are exposed.

"Blow-in-Blanket" system - R-3.9 per inch

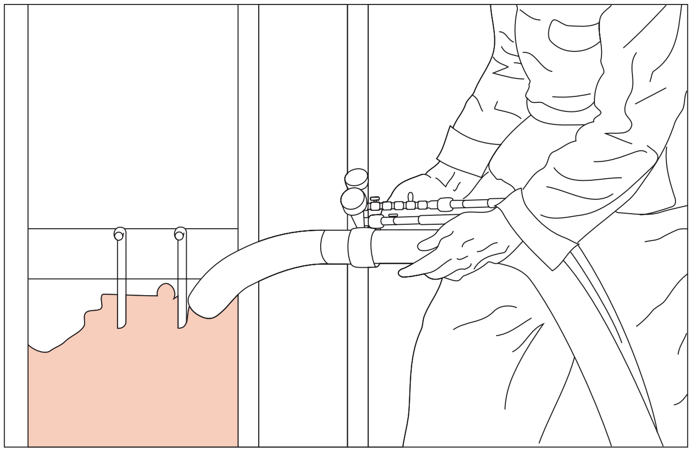


Figure 3-5 - One unique method for installing either loose-fill fiberglass or cellulose in walls is called the "blow-in-blanket" or "BIB" system.

With the BIB system, the insulation is mixed with a small amount of water and adhesive and is then pumped into wall cavities behind a nylon scrim that is stapled to the stud faces. The glue dries to form a lightweight monolithic "batt".

Reflective insulation and radiant barriers

Another type of reflective insulation, rarely used in homes, consists of multiple layers of foil, separated by spacers to create several reflective airspaces. These products are used mostly in industrial applications.

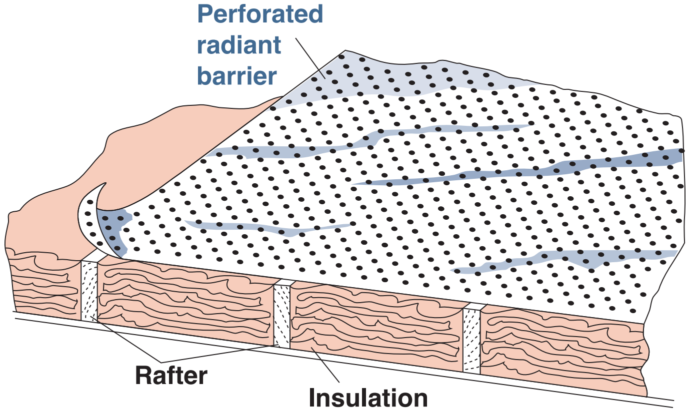


Figure 3-6 - Reflective insulation works differently from all the other types of insulation described above. When installed over attic insulation, reflective foil or metalized plastic products reflect heat away from the attic floor in summer. Referred to as "radiant barriers", these products will save up to an additional 8% on your cooling bill if installed over R-19 attic insulation. One source of moisture is water vapor in indoor air. Indoor moisture is carried into insulation primarily by air leakage into walls, ceilings, and floors. It can also diffuse through some solid surfaces such as unpainted drywall (see Figure 3-7).

Protecting Your Insulation From Moisture

Whenever you install insulation, you should protect it from all moisture sources. Wet insulation is less effective than dry insulation and can also lead to other moisture problems such as wood rot.

One source of moisture is water vapor in indoor air. Indoor moisture is carried into insulation primarily by air leakage into walls, ceilings, and floors. It can also diffuse through some solid surfaces such as unpainted drywall (see Figure 3-7).

To protect the insulation against water vapor from indoors, you should seal all air leakage pathways into walls or attic before installing the insulation. Proper air sealing should eliminate most chances of moisture problems.

The second line of defense against indoor moisture is

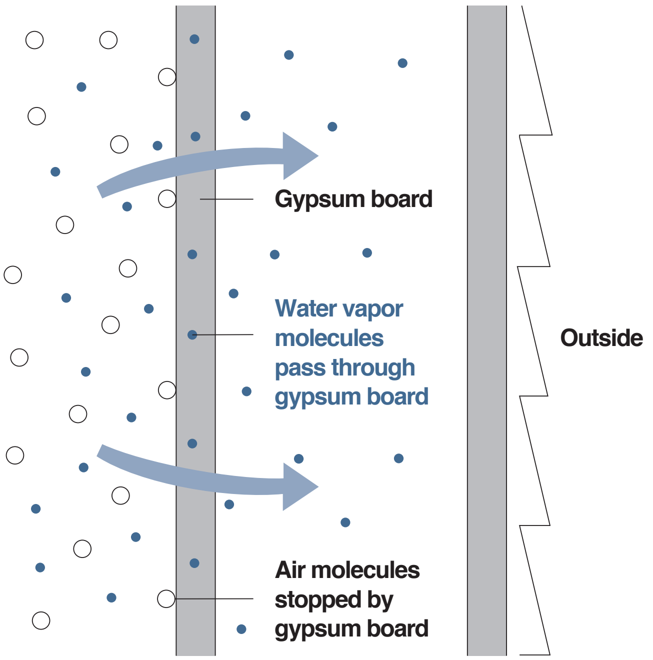
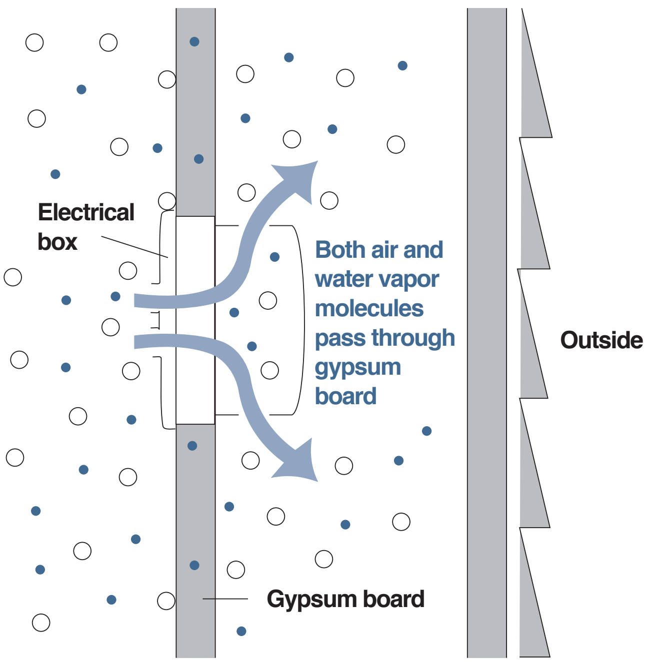


Figure 3-7a

Figure 3-7 - Moisture in indoor air can get into wall cavities either by diffusion through solid wall surfaces (Figure 7a) or by air leakage through electrical outlets and other penetrations (Figure 7b).

Figure 3-7b



to install a "vapor retarder" (sometimes called a "vapor barrier") on the warm side of the insulation to prevent vapor diffusion into the wall cavity or attic. A vapor retarder is any material that is impermeable to water vapor. Suitable vapor retarder materials include polyethylene film, kraft or foil-faced batts, and oil-based paint.

It is usually difficult to install a polyethylene vapor retarder during retrofit work. In attics, it involves removing all existing insulation to get the vapor retarder against the attic floor. It is not possible to install polyethylene in closed-in walls without removing all dry wall or plaster.

Experience has shown that installing insulation without a vapor retarder does not usually cause problems. Proper air leakage control should prevent moisture problems in your new insulation. Nonetheless, it is probably good insurance to add a vapor retarder whenever possible, especially when insulating rooms with high indoor humidity. The most practical vapor retarder for walls is one coat of oil-based paint or special "vapor retarder" paints which are available at most paint stores.

Insulation Techniques and Applications

If your attic has less than R-19 insulation, you will need to add more. The recommended minimum R-value in Virginia is R-30. If the attic is open, (no floorboards), you have a choice of either batts, blankets or loose-fill. If there are floorboards, your only alternative is blown-in loose-fill.

General considerations and precautions

Air sealing before insulation

Make sure the attic floor has been properly air sealed before installing the insulation. Keep in mind that your attic will be colder during winter after you insulate it. Any air leakage up into the cold attic will carry indoor humidity that could condense and cause moisture problems.

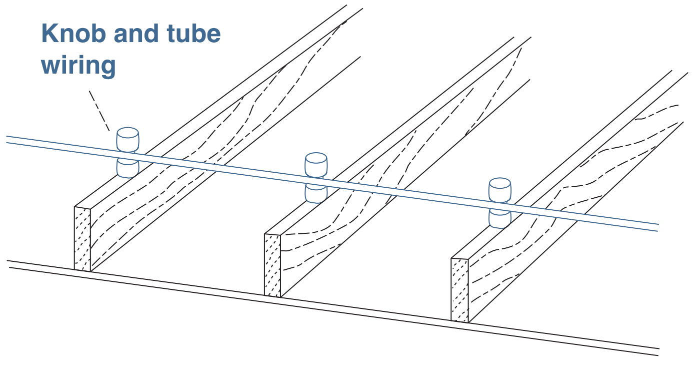


Figure 3-8 - Knob and tube wiring

See Chapter 2 for how to seal attic bypasses and other air leakage pathways into the attic.

Check for wiring hazards

Look for worn or frayed wiring that should be replaced before insulating. If you have knob and tube wiring, it must be replaced before insulating since it has exposed copper conductors.

Check for recessed light fixtures

Unless they are specifically rated for insulation contact (IC rated), you should not install insulation on top of recessed light fixtures. Non-IC-rated fixtures must be protected from contact with the insulation by a barrier on all sides and must not be covered.

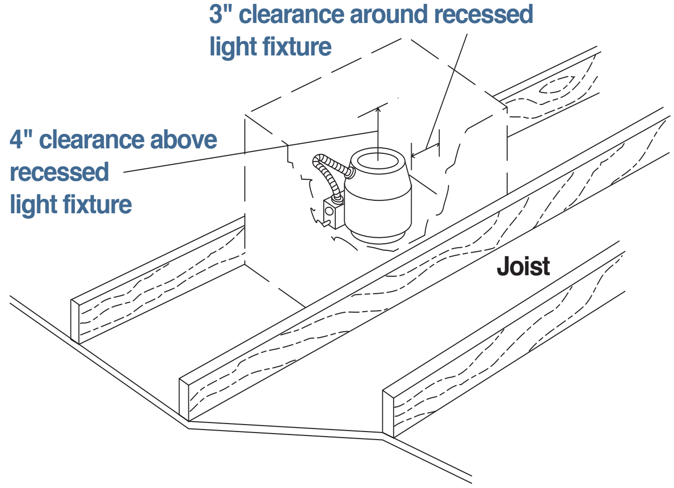


Figure 3-9 - Protected recessed light fixture

Make sure the attic is adequately ventilated

Attic ventilation serves two purposes. It removes excess heat in summer to prevent overheating, and it removes moisture in winter. Ventilation is particularly important after you add insulation because the insulation will make the attic colder in winter and thus more prone to moisture condensation. If you ventilate your attic without air sealing the attic floor, you will increase the potential for a moisture problem.

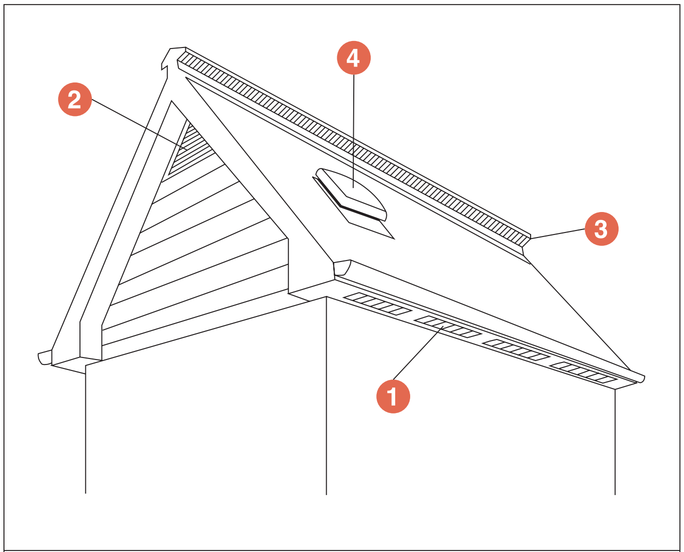
There are several types of ventilators to suit almost any attic configuration. They can be installed in the soffits, on the gable walls, or on the roof.

As a rule of thumb, you should install roughly one square foot of "net free" ventilation area per 300 square feet of attic floor area. (Net free vent area refers to the actual area of open holes in a manufactured vent. It is usually about one-half the total vent hole area.)

Repair any roof leaks

Look for signs of roof leaks and repair them before installing any new insulation. *Make sure you don't block off soffit vents with insulation*

If your attic has soffit vents, or if you install soffit vents, you should make sure not to cover the vents with insulation. If you are using loose-fill, install a baffle at the edge of the floor joists (Figure 3-11a). With batts, keep them back far enough to allow at least a two-inch airspace between the batt surface and the underside of the roof sheathing (Figure 3-11b).



Different types of ventilation: 1) soffit vents; 2) gable end vent; 3) ridge vent; 4) roof vent.

Figure 3-10 - Attic ventilators

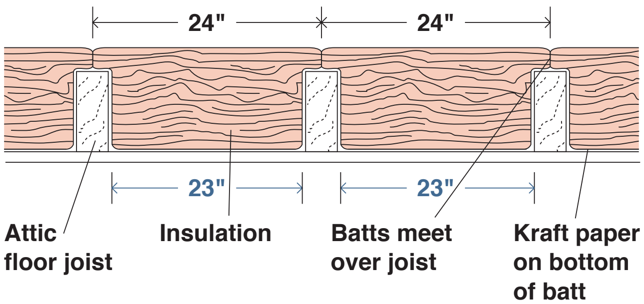
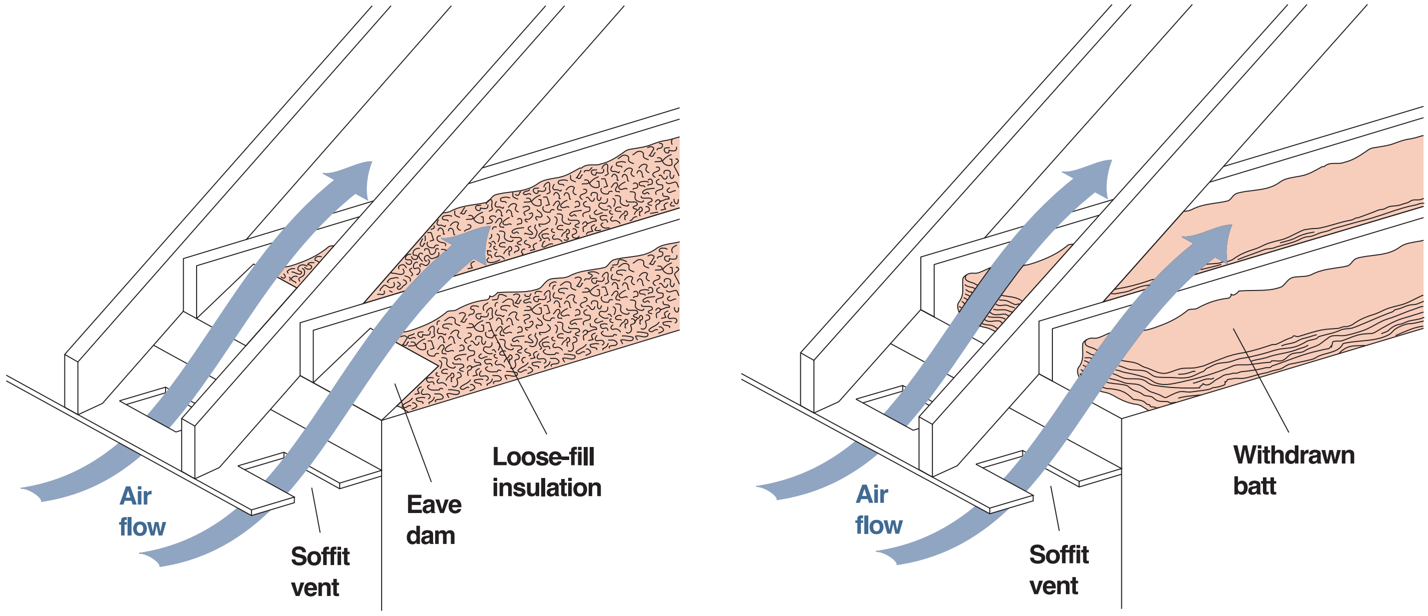


Figure 3-12 - Measure the spacing between your attic floor joists. It should be either 15" or 23". When purchasing the batts, be sure to get the proper width, made for attic application, not for walls. The proper width batts should come together above the attic floor joists. If you are installing the batts over existing insulation, buy unfaced batts. If there is no insulation in your attic, get kraft-faced batts and install them with the kraft paper facing down.



3-11a *3-11b*

Figure 3-11 - Soffit vents must be protected against blockage by attic insulation.

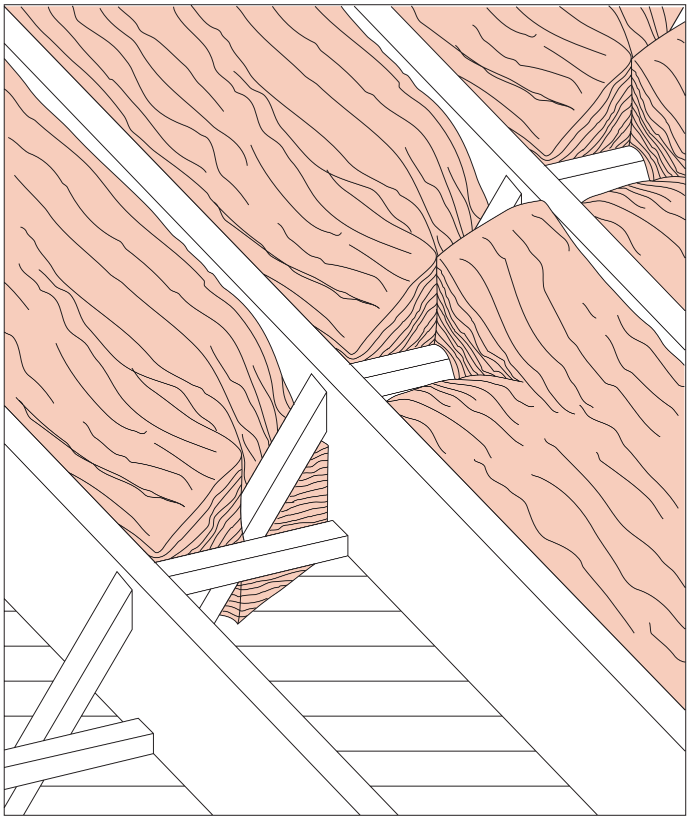


Figure 3-13 - Batts won't work well unless properly installed. It is very important that the batts are carefully fitted, as shown, to completely fill joist cavities with no gaps or voids. If even 5% of the space is left open, the R-value of the installation will be degraded by as much as 20%.

COVERAGE CHART FOR
SUPER-R
XL-100

R value @ 75° mean temperatures	Minimum inch Thickness	Bags per 1000 Sq. Ft.	Maximum Sw. Ft. Per Bag	Exposed Framing 16 in. O.C.	Minimum Wt./Sq. Ft.
50	13.2	70.18	14.25 14.90	none 2 x 6	1.75
40	10.5	56.15	17.81 18.75	none 2 x 6	1.41
32	8.4	44.90	22.27 23.89	none 2 x 6	1.12
30	7.9	42.10	23.75 25.60	none 2 x 6	1.06
24	6.3	33.68	29.69 32.64	none 2 x 6	.84
19	5.0	26.66	37.50 41.74	none 2 x 6	.67
13	3.4	18.24	54.81 61.00	none 2 x 6	.46
CAVITY FILL				Windows and Doors	
13	3.6	50	40.97 34.72	18% none	.72
21	5.6	50	26.33 22.32	18% none	1.12
28	7.6	50	19.41 16.45	18% none	1.52

Net Weight 25 lbs.

Figure 3-14 - Typical cellulose bag coverage chart.

Installing batts in attics

Avoid gaps and voids

If using batts, rather than blankets, butt the ends together. If you are installing two layers, run the top layer perpendicular to the bottom layer. Wherever there are obstructions such as cross bracing or plumbing stacks, cut the batts to fit around the obstructions.

Installing loose-fill cellulose in attics

Loose fill cellulose is installed by using an insulation blowing machine. Do-it-yourself machines are usually available from tool rental agencies or your insulation retailer. Installing loose fill cellulose by hand is not recommended. Using the "coverage chart" on the insulation bag, determine the thickness and number of bags required to obtain the desired R-value. For determining the required thickness, make sure to use the "installed thickness" listed in the coverage chart, not "settled thickness." Cellulose insulation always settles about 20% after it is installed.

When installing the cellulose, begin at the eaves and work your way back toward the center, making sure that the insulation completely fills all cavities. As you work back, spread the insulation evenly using a rake or other suitable tool.

It might take a little practice, but check your coverage as you go to make sure you are installing the proper number of bags for the area you are insulating. To obtain the desired R-value, you must install the proper thickness and the specified number of bags of insulation.

Make sure that you avoid gaps and voids due to uneven or incomplete coverage of the attic area.

Installing loose-fill fiberglass in attics

Loose-fill fiberglass should be installed by a professional with an insulation blowing machine. As with cellulose, it is necessary to install both the required number of bags, as indicated on the coverage chart, and the indicated thickness to get the desired R-value.

Insulating cathedral ceilings

The only practical way to insulate cathedral ceilings is to blow in cellulose or fiberglass. This is a professional job.

The insulation is installed by drilling holes, usually from the inside, and pumping the insulation into the rafter cavities. The job should not be done unless you are sure that there will be no air leakage up into the ceiling cavity.

A good time to do this job is when re-roofing. The insulation can then be pumped in from the top, avoiding the mess indoors.

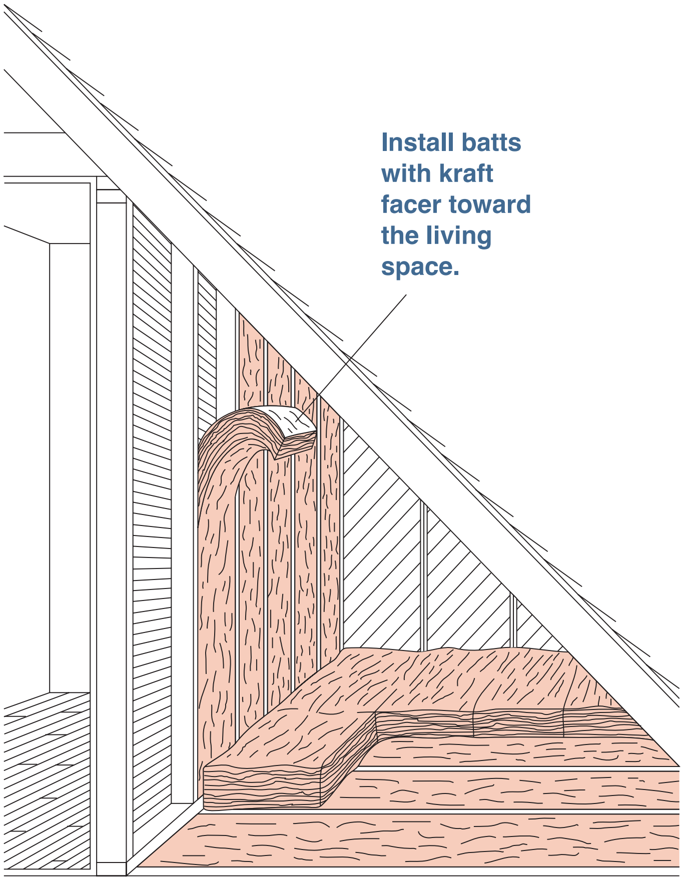


Figure 3-15 - In Cape Cod style homes, where a knee wall separates the second story from an unheated attic space, install batts in the stud cavities.

Insulating knee walls on 1-1/2 story houses

Use faced batts to create a vapor retarder and install the batts with the kraft facing inward, toward the living space. Ideally, you should also install insulation in the floor under the unheated space, but this is a tricky job. It is very important to air seal the area where the floor of the heated space interconnects with the opening to the un-heated attic space. This open area represents a very significant thermal bypass.

Installing basement insulation

If your basement is to be used as conditioned space, you should insulate the walls. For the Virginia climate, heated basements should have roughly R-10 to R-12 basement insulation. Before installing any type of basement insulation, be sure to seal any air leakage sites in the wall such as cracks or gaps around pipe penetrations. See Chapter 2.

Insulate on the outside or inside?

Your first decision is whether to insulate the walls on the inside or the outside.

Unless the inside wall surface is already finished or otherwise difficult to insulate, you are better off insulating the inside because exterior insulation requires excavation and is usually more expensive.

Framed wall insulated with batts

The most common basement wall insulation system is an insulated frame wall which can be finished to create livable space. Install a polyethylene moisture barrier against the basement wall to protect the insulation against ground moisture. The polyethylene need only extend up to grade level, but leave some excess at the bottom to run beneath the framed wall. The framed wall should be set off from the basement wall at least one inch to keep the lumber out of contact with the concrete. The bottom plate should sit on the polyethylene moisture barrier.

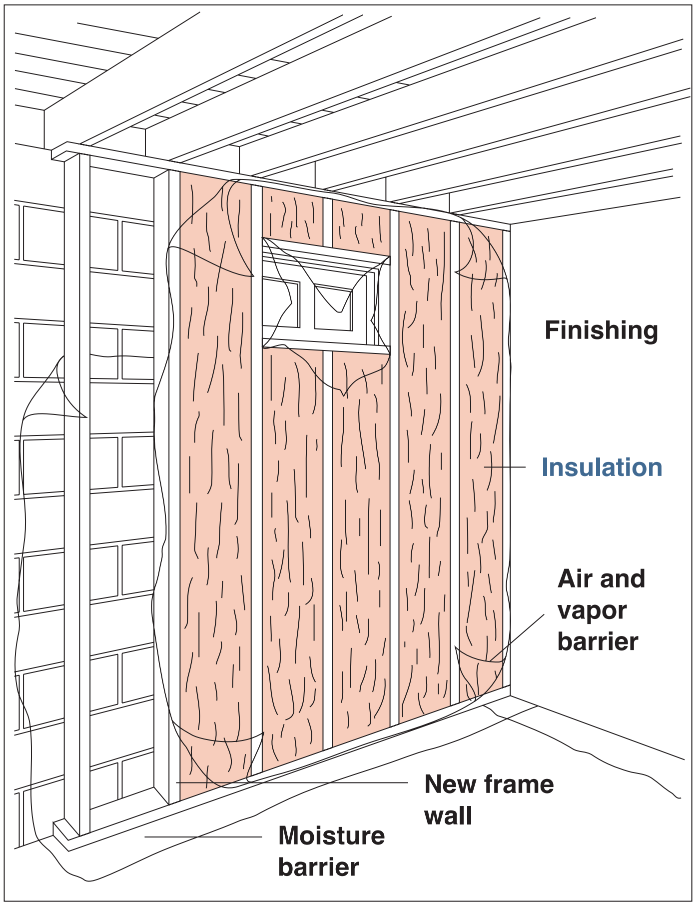


Figure 3-16 - Framed wall insulated with batts.

One situation where this system is not advisable is in very wet basements. Although the wall can be protected against moisture, you would still be taking a chance if the basement is very wet.

Rigid foam insulation

The most common alternative to a framed wall is to apply rigid foam insulation directly to the wall and cover it with an appropriate fire-rated sheathing. Special fastening systems are available that hold the foam in place and also serve as a screw base for gypsum wallboard. Another technique is to install wood furring strips which hold the foam in place and serve as a nail base for the wallboard.

Installing exterior insulation

The only practical way to insulate a basement on the outside is with rigid foam. To avoid excavation expense, the foam can be installed only on the top portion of the foundation, extending down a foot or so into the ground, where the greatest heat loss occurs.

The foam should be covered with either parging, fiberglass or metal sheathing to protect it from sunlight and physical damage.

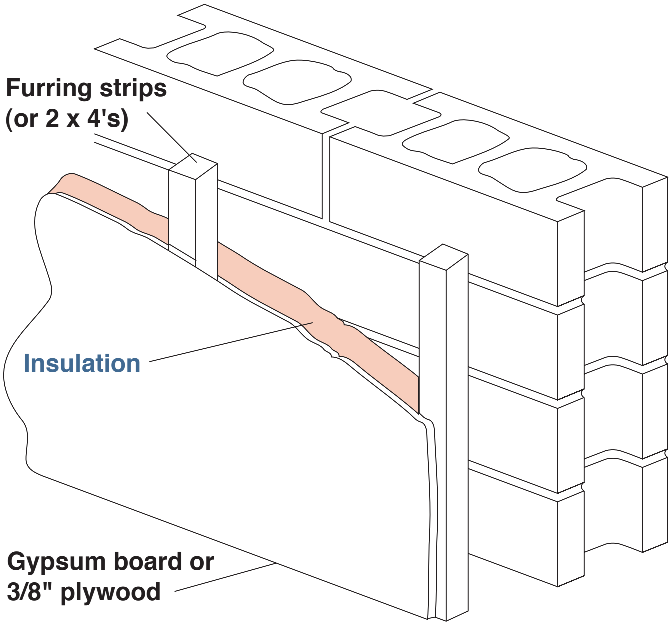


Figure 3-17 - Rigid foam interior insulation

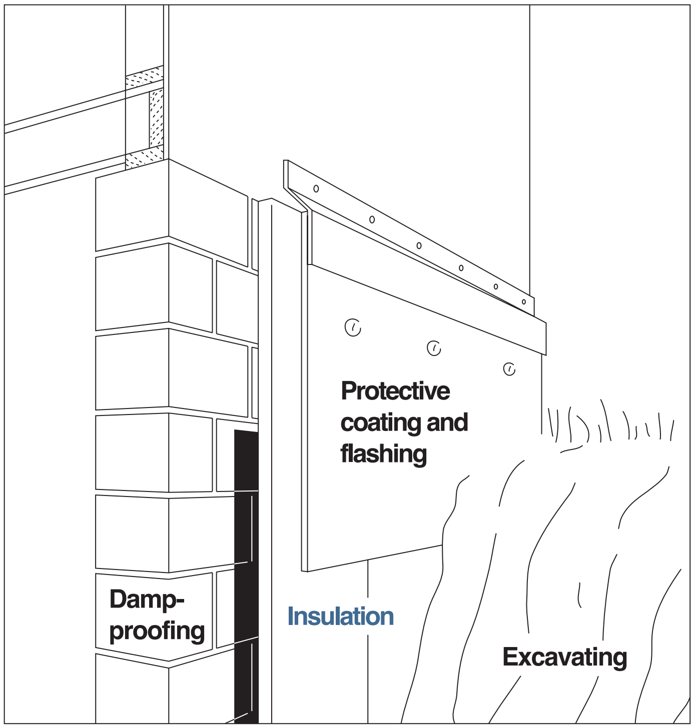


Figure 3-18 - Rigid foam exterior insulation

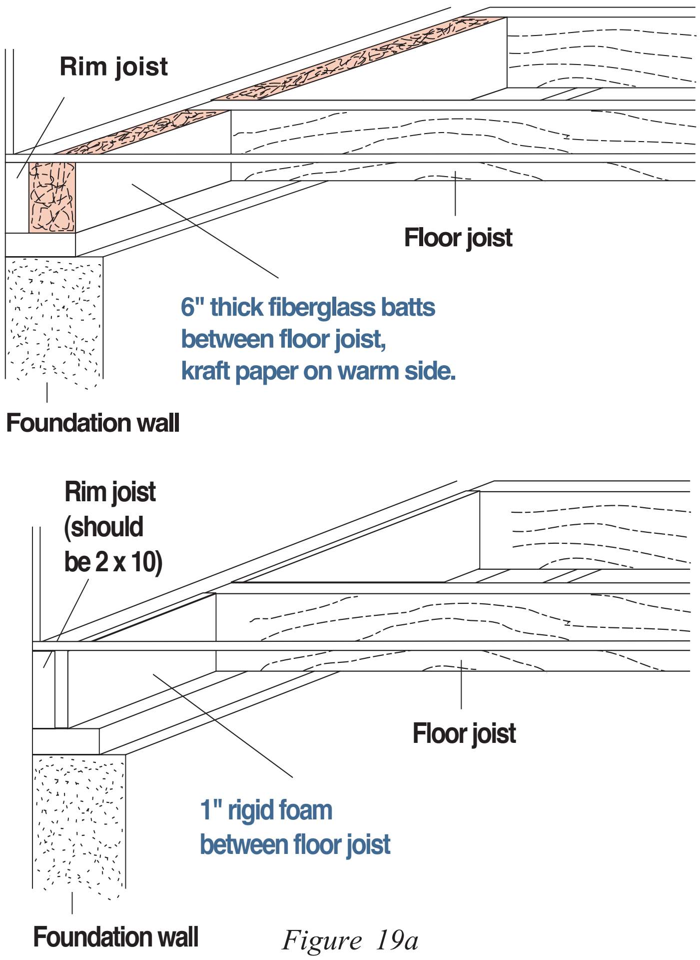


Figure 19a

Figure 3-19 - Insulating rim joist area

Don't forget the rim joist area

The final step when insulating a basement is to install insulation at the rim joist area. The most effective material for this application is rigid foam, caulked at the edges against each floor joist. This is a fairly tedious task and sometimes impractical in older homes. Alternatively, use faced batts, stapled to the floor joists.

Insulation of unconditioned basements

There is some disagreement among experts on the value of insulation in unconditioned (no heat or air conditioning) basements. In general, an unconditioned basement which is almost entirely below grade does not require insulation. If the basement has many walls above grade, however, insulation is probably worthwhile. Insulating an unconditioned basement has two benefits: it reduces energy transfer to the conditioned rooms above, and it increases winter comfort (especially in rooms with bare

Table 3-1 - Unconditioned Basement Insulation Options

	Basement Ceiling Insulation	*Basement Wall Insulation*
Advantages	• Joists are already in place for receiving batt insulation • Batt insulation on ceiling needs no protection from mechanical damage	• Basement walls easier to seal than ceiling • Protects ducts and pipes in basement • Insulated walls prepare the basement for conversion to living space
Disadvantages	• Basement ceiling may be difficult to seal because of many penetrations • Basement ceiling may be difficult to insuluate because of many obstructions • Basement ceiling area may be larger than basement wall area	• Batt wall insulation requires protection from moisture & mechanical damage • Foam wall insulation requires protection from fire, requires excavation • Required framing or furring and sheathing adds to inside insulation cost

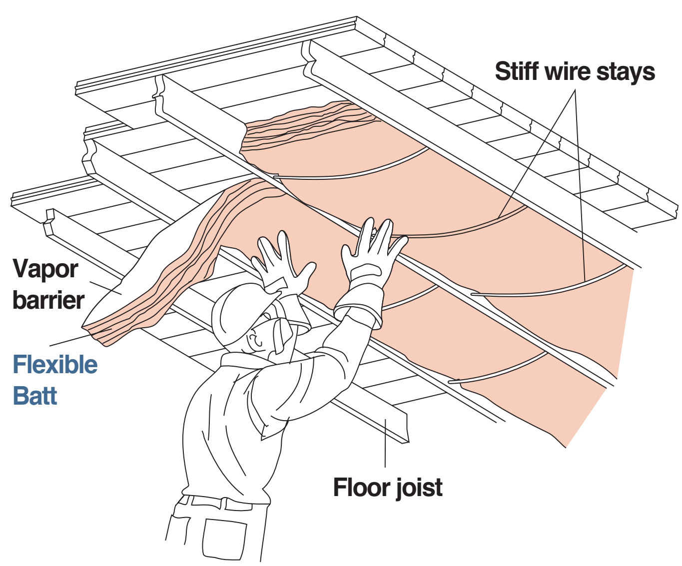


Figure 3-20 - Installing batts in basement ceiling.

floors) by making the floors above the basement warmer.

If you choose to insulate an unconditioned basement, you can either insulate the basement walls (to reduce heat transfer between the basement and the outdoors) or insulate the basement ceiling (to reduce heat transfer between the basement and the upstairs). Each approach has advantages and disadvantages, as shown in Table 3-1 on page 42.

If you insulate the ceiling, use unfaced batts rated at R-10 or R-12. Push them up snugly between the joists, against the basement ceiling, and secure them in place with wire stays. Before installing insulation, seal all air leakage points in the basement ceiling (see Chapter 2).

If you insulate the walls, use one of the techniques shown for conditioned basement spaces.

Crawl space insulation

Crawl space insulation can be installed either on the exterior walls or in the floor above. If your crawl space is not vented and appears dry, the best alternative is to insulate the walls, especially if there are ducts or other mechanical equipment located in the space. If the crawl space is vented, then the only alternative is to insulate the crawl space ceiling.

In either case, if there is obvious visible wetness in the space (e.g. wet ground or wet joists), you must cure the moisture problem before installing insulation. Install a thick (6 mil) polyethylene moisture barrier on the ground if there is not one there already. Lap the seams 12 to 18 inches, but don't bother to seal them. If this doesn't

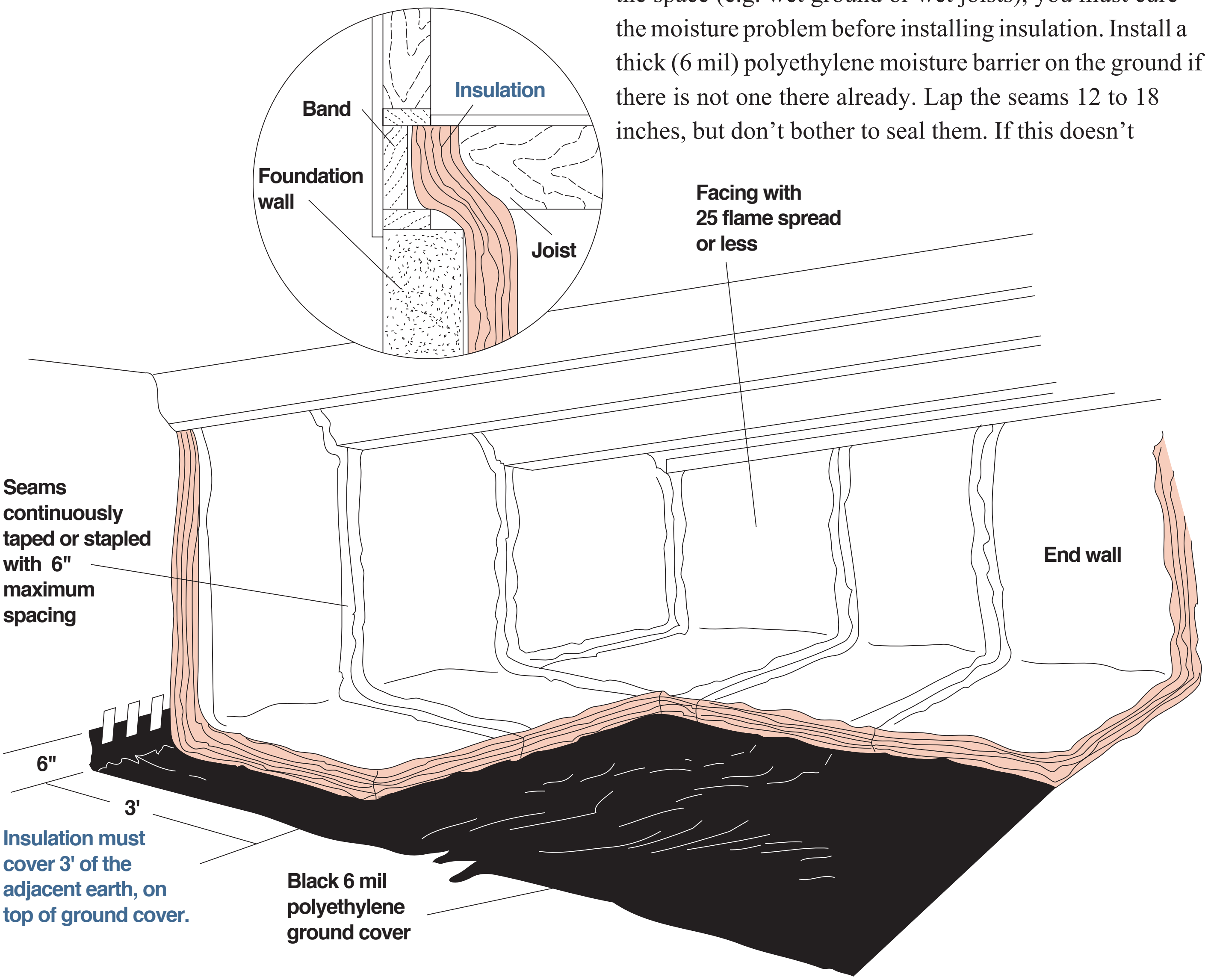


Figure 3-21 - The simplest way to insulate the inside surface of a crawl space is to staple faced batts to the rim joist and run the batts down the wall. Before installing the insulation, attach a polyethylene sheet over the wall and down onto the floor to protect the insulation from outdoor moisture.

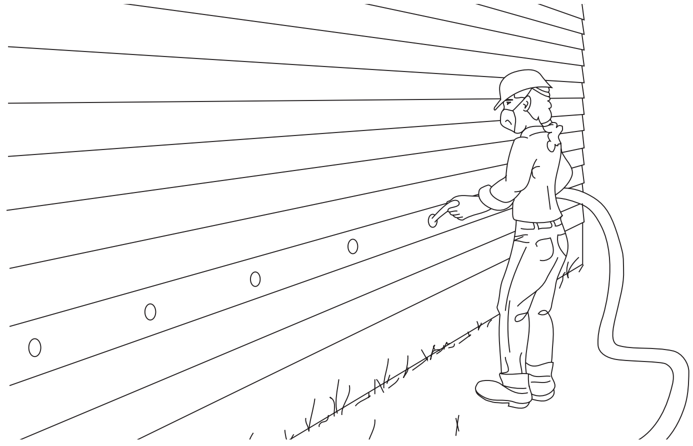


Figure 3-22 Blow-in fiberglass sidewall insulation

eliminate the visible wetness, you should consult a professional contractor before installing insulation.

The technique for insulating a crawl space ceiling is the same as for a basement ceiling (figure 3-20).

Crawl space walls, like basement walls, can be insulated either on the inside or outside. Unless access into the crawl space is difficult or impractical, insulating the inside is usually easier. Inside crawl space walls can be insulated with foam, but the foam must be covered with fire-rated sheathing (see figure 3-17). They can be insulated with fiberglass batts as shown figure 3-21, but a fairly high skill level is required to produce a neat, moisture-resistant job.

Exterior house walls

Installing insulation in the main walls of your home is a complex job that requires the skill and experience of a professional contractor. Your main decision is whether to install cellulose or fiberglass.

Dense-pack cellulose sidewall insulation

Contractors have developed a new and very effective technique for blowing cellulose into walls that not only insulates them, but drastically reduces air leakage. Called the "dense-pack" technique, it has been tried and proven in the Virginia Weatherization Assistance Program. (See Chapter One)

The "dense-pack" technique involves removing portions of the siding from the outside of the house and drilling a single hole in each stud cavity. The insulation is blown in under high pressure to about 3.5 pound per cubic foot density using a one- inch blowing hose. Exterior walls can also be blown from inside the house.

Blow-in fiberglass sidewall insulation

Blow-in fiberglass insulation is installed in the same manner as that described above for cellulose. Although fiberglass does not have the same air-sealing properties as cellulose, it still insulates quite well, adding almost R-4 per inch thickness.

Energy Tips and Recommendations

1. Insulation is one of the most important and cost-effective measures available in improving the energy performance of your home.
2. There are several different types of insulation available. Make an educated decision on what is right for your home. Consult with a professional insulation contractor if you have any questions.
3. Working with most types of insulation requires the use of protective clothing, safety goggles, and appropriate dust masks.
4. Be sure that all insulation is protected from moisture. Wet insulation is less effective and can lead to other moisture problems.
5. Be sure that the attic floor is properly air sealed before you install insulation or increase levels of existing insulation.
6. Make sure that all electrical outlets, fixtures, wiring and lighting are safe and properly covered before installing any type of insulation.
7. Loose fill insulation must be installed with a blowing machine. Make sure that there is complete and even coverage. Avoid any gaps and voids.
8. Batt insulation must be installed according to manufacturers specifications and be sure to avoid any gaps and voids.
9. Insulate your basement walls if the basement is to be used as a conditioned space.
10. Consider insulating your crawl space if it is dry. Install a 6-mil polyethylene moisture barrier on the ground.
11. Consider blowing cellulose insulation into the exterior walls of your house if there is no existing insulation. Use the dense pack method pioneered and proven to be effective by the Virginia Weatherization Program.

WINDOWS AND DOORS

Windows are a significant and important component of any home. They provide natural light, a view to the outside, ventilation, and solar heat gain in the winter. Windows also, unfortunately, can account for 10% to 30% of your heating bill and a significant portion of your cooling load. Three characteristics determine a window's energy efficiency:

• The first is U-value (U-factor) which controls heat loss in winter and, to a lesser degree, heat gain in summer. U-value is the inverse of R-value but the terms essentially describe the same thing: the heat loss and insulation value of a product. R-value is used for insulation in walls and attics, and the higher the R-value the better. U-value is used for windows. U-value is the inverse of R-value, so the lower the U-value the better. U-value is discussed in more detail in the Window Replacement section.

• The second is air leakage, which can cause significant energy waste year-round. Air leakage is especially important because drafts reduce indoor comfort in winter even if the temperature stays the same. Reducing drafts can allow energy-saving low thermostat settings without a decrease in comfort.

• The third is solar transmission, which controls unwanted solar heat gain in summer as well as useful "passive solar heating" during winter. Solar transmission is particularly important for windows exposed to many hours of direct sun.

This chapter describes how to improve all three characteristics of your existing windows to improve energy efficiency and also how to shop for energy-efficient new windows.

Exterior doors don't offer as much energy-saving opportunity as windows, mostly because of their relatively small total area. However, a very loose or badly weather-stripped door not only wastes energy, but causes uncomfortable drafts. Patio doors and single entry doors with windows can also pose significant energy performance issues. This chapter describes ways to improve your existing doors as well as how to shop for energy- efficient replacements.

Types Of Windows

Double-hung windows, with top and bottom sash that slide up and down, are by far the most common type of residential window. Single-hung windows look like double-hung, but only the bottom sash slides; the top sash is sealed in place. The sashes of some double-hung windows lift out of their tracks and tilt into the room for easy cleaning.

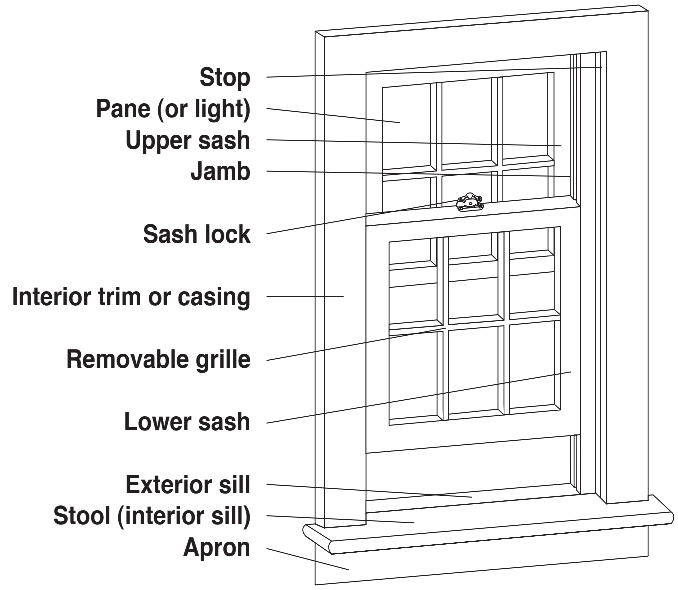


Figure 4-1 - Double-hung window

Old double-hung windows used sash weights to provide easier lifting. Those windows were typically quite leaky. New double-hung windows typically feature greatly improved weather stripping and springs that hold the sashes in place. These newer windows are nearly as airtight as the best casement windows.

Casement Windows

Casement windows hinge on the side and close with a compression seal, usually with crank controls. A few European-style casement windows have sophisticated tilt-turn hinge mechanisms which allows them to pivot either from the side or bottom.

Because of the compression seal, casement windows are typically tighter than double-hung or other sliding windows.

Figure 4-2 - Casement window

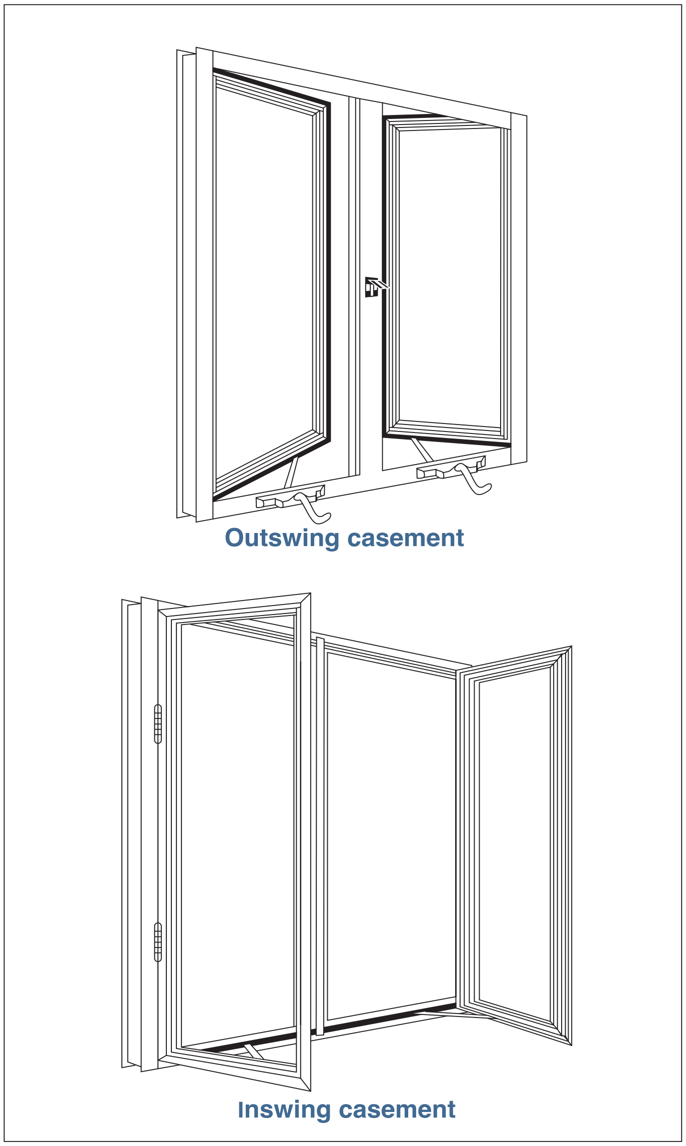
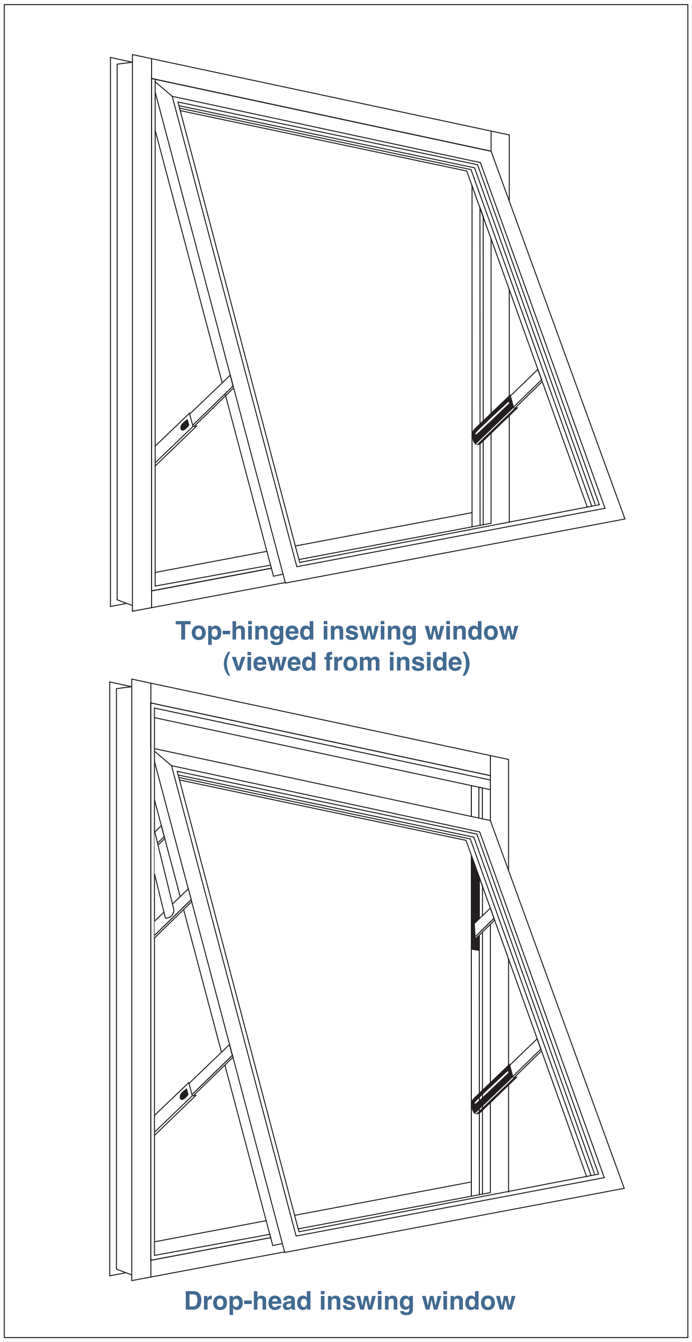


Figure 4-3 - Awning window



Awning and Hopper Windows

Awning windows hinge at the top and open outward. With some designs, the top of the window drops down to allow greater ventilation area. Like casement windows, these windows use compression weather stripping and are generally quite airtight.

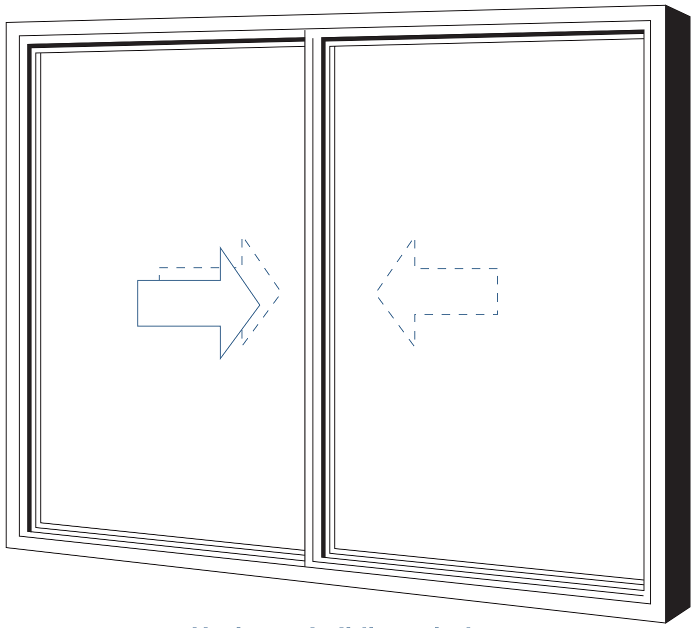
Hopper windows, operate like awning windows, but are hinged at the bottom and pivot in; these are most commonly used in basements.

One good feature of these windows is they can be left open for ventilation and still keep rain from entering the house.

Horizontal Sliding Windows

Horizontal sliders are like double-hung windows, except that they slide horizontally rather than vertically. Like double-hung windows, these tend to be somewhat leakier than casements or awnings due to the sliding-type seal.

Figure 4-4 - Horizontal sliding window



Fixed Windows

Non-operable or fixed windows are available in unlimited shapes and sizes, including custom trapezoids and circles. They are often combined with operable windows for design variety.

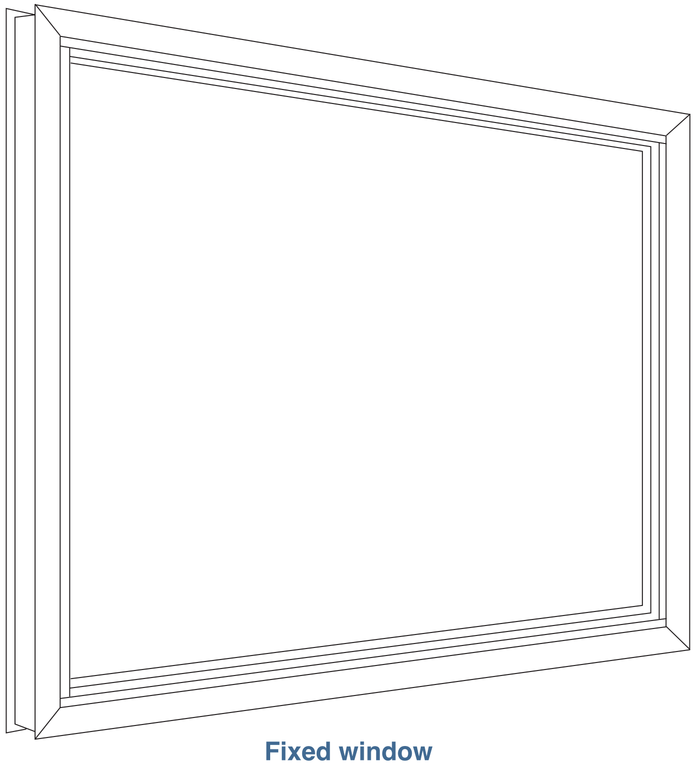


Figure 4-5- Fixed window

Technically, fixed windows are the most energy-efficient since they allow little, if any, air leakage when properly installed.

Energy Efficient Windows

"Single-glazed" windows -- just one layer of glass in a wood, metal or vinyl frame -- have a U-value of 1.25. Although many older homes still have single-glazed windows, they are unacceptable with today's high energy prices. In the colder regions of Virginia, each square foot of single-glazed window loses the equivalent of one gallon of oil during the heating season.

Over the years, manufacturers have developed a number of technologies to boost window U-values. The first was old-fashioned wooden storm windows, extra panes of glass that had to be installed each fall and removed each spring. The next was permanently-installed aluminum storm windows, in which glass and screen sections could be slid up and down as the seasons changed. The most successful was “double-glazed” insulating glass, consisting of two panes of glass with a dead air space in between. Developed during the 1950’s, double-glazed sealed insulating glass units have a U-value of 0.49.

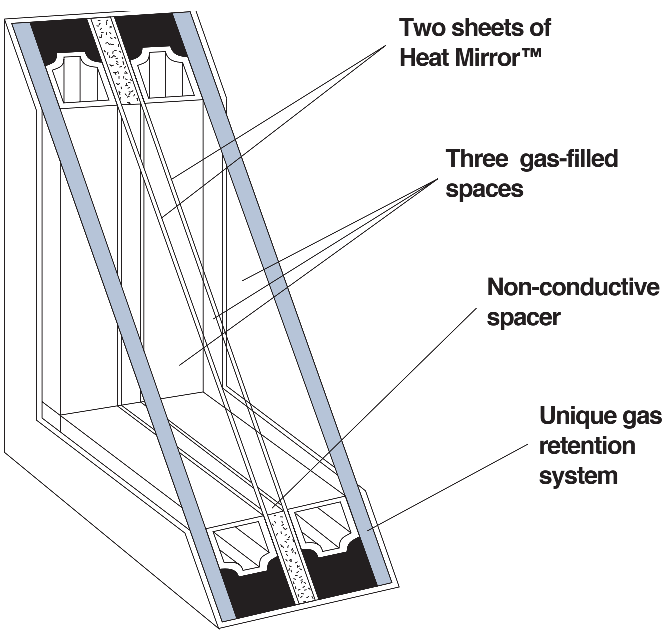


Figure 4-6 - Using a combintation of high-tech features, this glazing system for windows has a U-value of 0.22- almost as high as some insulated walls.

Further improvements have been made since the introduction of double-glazing. The most significant was the development of invisible "low-emissivity" coatings which, when applied to one glass surface, greatly reduce solar transmission while decreasing U-value slightly (to 0.48). First sold in 1980, low-emissivity or "low-E" glass is now used by every major window manufacturer and is also available in replacement glass. Additionally, most manufacturers increase the U-value of their double-glazed windows further by substituting special gases for air between the glass layers. These gases, such as argon and krypton, provide much better insulation than air. When used in a low-E window, they lower the U-value to 0.36.

During the late 1980's, manufacturers combined the technology of multiple glazing, low-E coatings and gas-filling to create "Super windows" with glass U-values as low as 0.11! Used mostly in colder northern climates, these windows can outperform a wall with R-19 insulation because of their ability to transmit useful solar heat in winter.

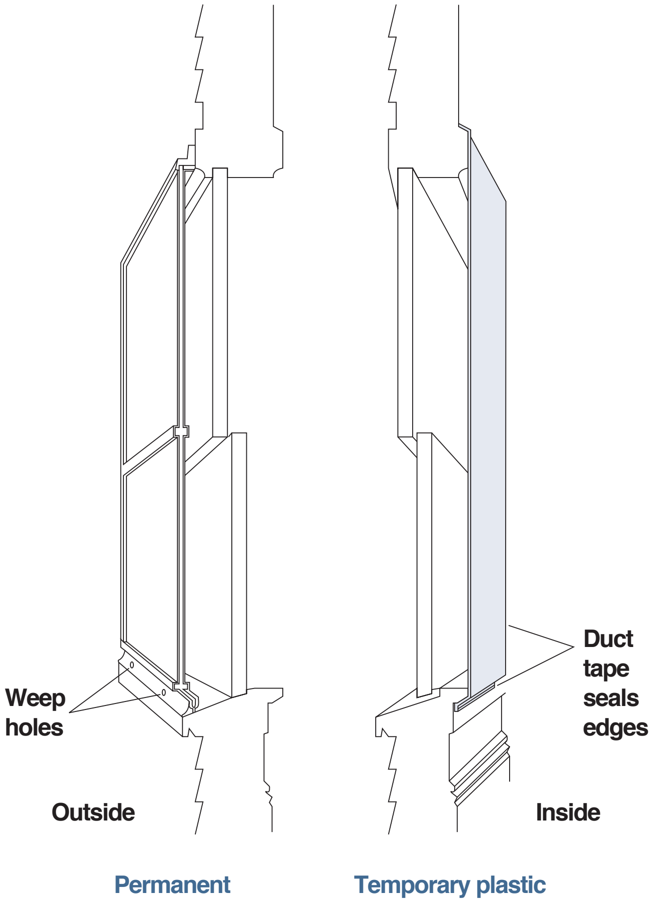


Figure 4-7- Storm windows can be an effective substitute for purchasing new windows if the existing window is still in good condition. Storm windows must be of good quality, installed properly, and have low-E glass.

Reducing your windows' U-value

If your windows are only single-glazed -- just one layer of glass -- the U-value is only about 1.0 and should be reduced. There are two general ways to reduce the U-value of existing windows: add a storm window or add moveable insulation.

Storm windows

Storm windows, if properly installed, can reduce heat loss through single-glazed windows by lowering the U-value and reducing air leakage. Storm windows can be mounted either on the inside or outside of the existing window. The choice between interior and exterior storm windows is largely one of personal preference and cost. From an energy standpoint, they perform about the same but an interior storm window, if the existing window is still an effective weather barrier, can reduce condensation more effectively than an exterior storm window.

Tight-fitting old-style wooden storm windows perform slightly better than the modern aluminum-framed combination storm/screen storm windows. This is because aluminum is a poor thermal insulator. Your house may have old-style wooden storm windows, either in use or stored away in the attic or basement. If so, they can provide important energy savings. The problem with these old-style windows (and the reason they're never used in new construction) is that putting them up every fall and taking them down every spring is a lot of work, particularly on a multi-story house.

When buying new storm windows, look for quality windows with low-E glass and good workmanship. Vinyl storm windows, with lower heat loss through the frame than aluminum, are now available. Be sure to properly install storm windows and seal them effectively where the storm window frame meets the existing window frame. Be careful not to seal the weep holes.

It is important to examine the cost-effectiveness of purchasing storm windows. Sometimes their lower cost relative to new energy efficient windows will not justify the reduced convenience, energy savings, and home improvement value.

Interior storm windows, sometimes referred to as "energy panels," are generally easier to install than exterior storm windows. They may be made of glass or various types of plastic. Shrink-to-fit plastic film for making temporary interior storm windows is available at many hardware and building supply stores. This last option is the least expensive for one-time use, but generally undesirable for homeowners. The shrink-fit windows are mainly attractive to renters, who want to reduce their energy bills without paying for permanent improvements to their landlord's property.

Always remember: your home is a system. If you do not correctly adjust and seal your storm windows when the seasons change, they might as well not be there.

Moveable insulation

Most moveable insulation is made from a quilted fabric with fiber batting and one or more layers of reflective foil. Typical R-values range from R-2 to R-4.

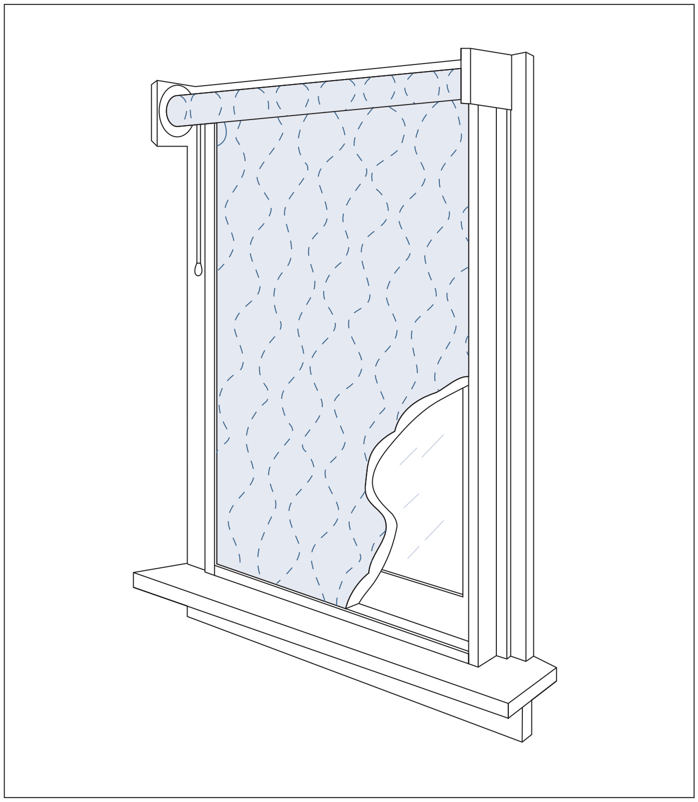


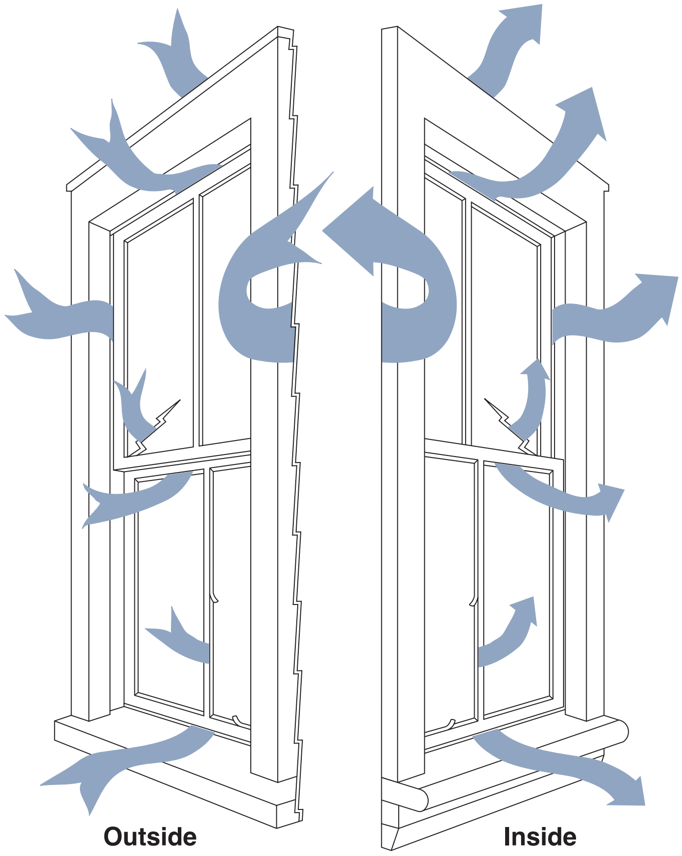
Figure 4-8- Insulated window shades can be a very effective means of reducing hear loss through sinle-pane windows- as long as the shades are used conscientiously.

If you are willing to take the time to operate moveable window insulation, it can be a very cost-effective alternative to storm windows or replacement windows. Moveable insulation not only saves energy by reducing nighttime heat loss during winter, it can also reduce summer air conditioning bills by blocking out the mid-day sun.

(Note of caution: When installed over double-glazed windows, moveable insulation may trap solar heat, causing high temperature build up that may stress the glazing and possibly even cause seal failure.)

Controlling air leakage through windows

Air leakage through windows occurs between all moving parts and around the window frame. Air leakage between the moving parts is controlled with weather stripping; air leakage around the window can be reduced by caulking.



Air leaks in windows

Figure 4-9 - Air leakage is often the primary cause of heat loss from windows and doors.

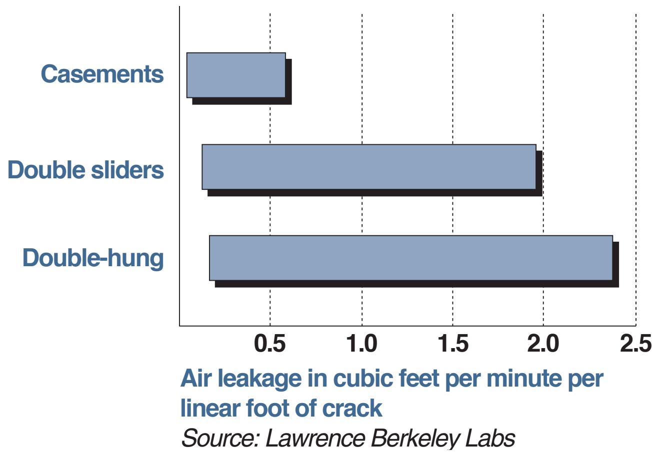


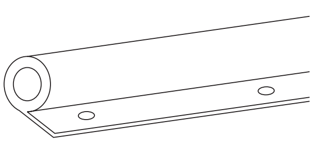
Figure 4-10 - While air leakage rates vary greatly between windows from different manufacturers (the length of each bar above represents the range), in general casement (and awning) windows are tighter than the others.

Among the most common types of windows, casement and awning windows tend to be the tightest, while double-hung windows and sliders are a lot leakier. The difference has to do with the type of weather stripping. Casement and awning windows use compression-type weather stripping-gaskets that get squeezed tight when the window is latched. Double-hung windows and horizontal sliders have a different type of weather stripping that is less effective. There are several easy and practical techniques for reducing air leakage through windows.

Install or repair window locks

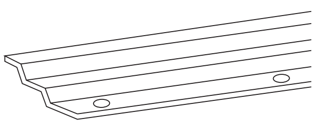
If any of your double-hung windows rattle in their frames, they may be improved by fixing or replacing the lock. This is probably the most cost-effective air leakage control strategy for older windows. Properly installed window locks should pull the sashes together tightly and should hold them firmly against the window frame. Replacement locks are available in most hardware stores.

Tubular gasket



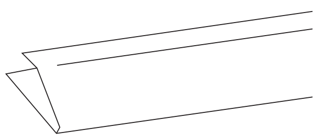
Tubular gaskets are made of vinyl or rubber, with or without a foam filling. They are durable and effective even when gaps around window or door are uneven. Applied from outside, tubular gaskets take sub-zero temperatures well.

Spring metal strip



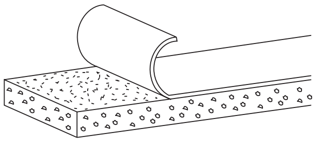
Made of bronze, stainless steel, or aluminum, these long-lasting strips fit unobtrusively in window or door channels and use tension to create a seal. They may make a tight-fitting door or window hard to open.

V-strip



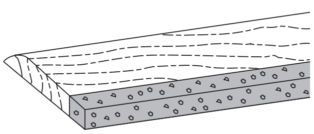
V-strips, made of metal or vinyl, also use tension to create a tight seal. They are installed in window and door channels. Vinyl strips often come with adhesive backing. However, metal V-strips, applied with nails, last longer.

Adhesive-backed foam



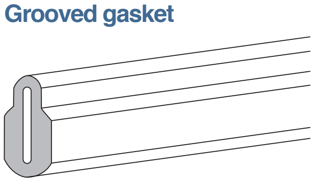
Adhesive-backed foam provides an inexpensive quick fix for a filtration problem. Very easy to apply, the foam may lose its resiliency and effectiveness during a single season.

Foam-edged wood strip



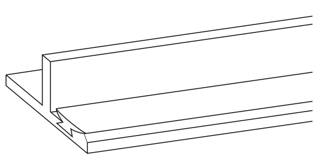
Foam-edged wood lasts longer (and costs more) than plain adhesive-backed foam. Self-sticking, it is easy to install on even surfaces but wears out in several seasons.

Grooved gasket



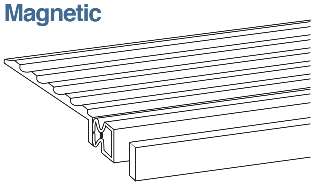
Grooved gaskets, made of various plastics, fit metal casement windows or jalousie windows. Compression makes them effective, and they last 10 years or more.

Astragal



Astragal weather stripping, vinyl or aluminum, is used on double doors (French doors). A T-shaped type consists of a single piece that attaches to the less-used door. Another design interlocks two separate strips, one for each door.

Magnetic



Magnetic seal for gliding doors works like the seal on a refrigerator door. One part, attached to door trim, holds a magnet and a gasket. Other part, attached to door, is metal. The magnet holds door against gasket in a tight seal.

Figure 4-11 - Weather stipping varies greatly in design and cost. The type chosen should be carefully matched with your needs.

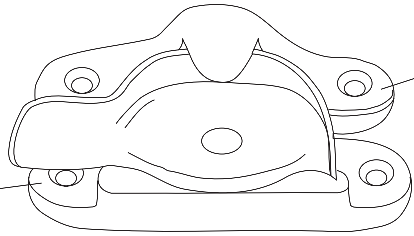
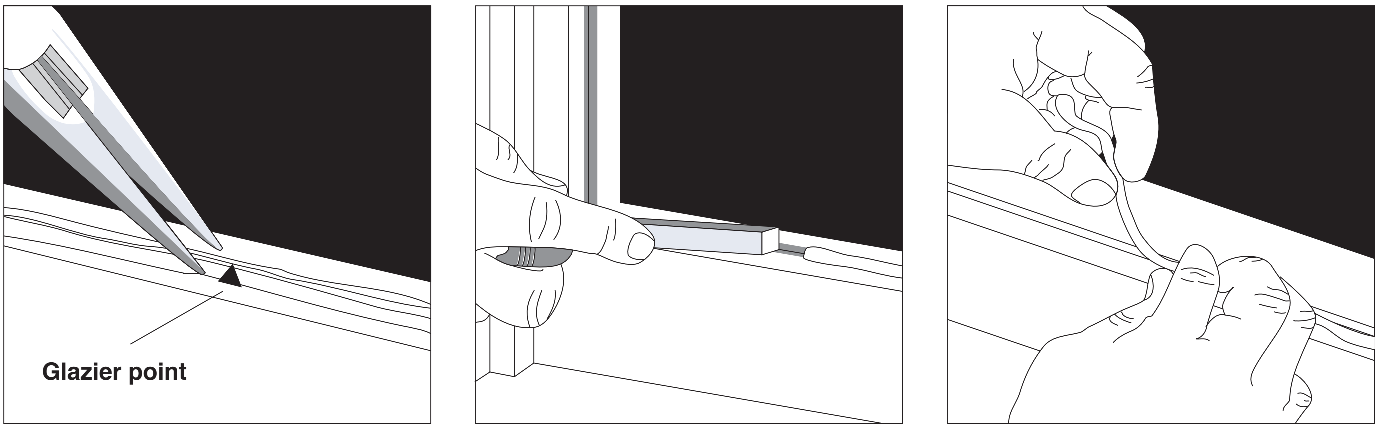


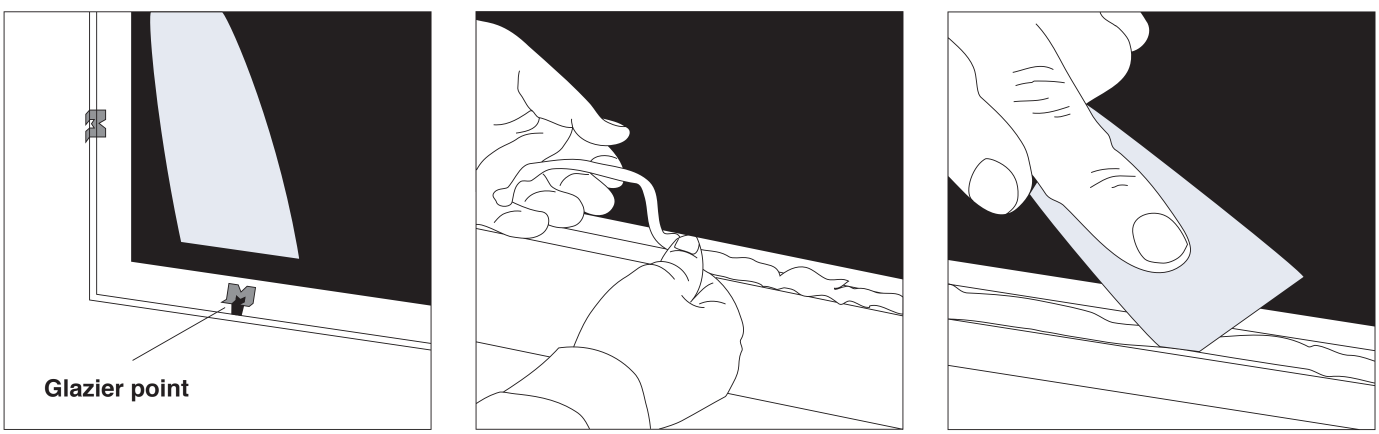
Figure 4-12 - The lock on a double-hung window is not only for security. When working properly, it holds the sashes firmly against the window frame, thus reducing air leakage.



1. Wearing heavy gloves,remove broken pane. Pull out old glazier's points with needle-nose pliers. (Glazier's points come in two styles: diamond, shown here or push type, step 4.)

2. Scrape out old compound with a chisel or putty knife. Sand the sash. Paint the raw wood with sealer or primer so that it won't absorb oil from the fresh glazing compound. Measure the opening for the pane, and deduct 1/8 in. from both dimensions. Cut the pane.

3. Rub a lump of glazing compound between your palms to make a 1/8"-in.-thick rope. Working outside, press this rope around the opening. Set the new pane against the compound, and press firmly, flattening the rope. The excess compound should squeeze out around the glass's edges.



4. Install glazier's points every 4 to 6 in. on the mutins. Be sure the points are snug against the pane. Use an old screwdriver or stiff-bladed putty knife to push them into the wood.

5. Make a slightly thicker rope (about 3/8 in.) of compound. Press this rope over the glazier's points and against the pane.

6. Hold putty knife at an angle and draw it across compound to form a smooth bead. Scrape away any excess that oozed onto the interior pane. When compound has cured (check label for curing time), paint it to match the window, overlapping the glazing about 1/16 in. to seal against moisture.

Figure 4-13 - Replacing window putty

Replace cracked or broken glass

Broken glass obviously permits a lot of air leakage, but even cracked glass can be a problem. Replace all broken or cracked panes of glass.

Weather-strip windows

If a window leaks air when firmly locked or if the original weather stripping is visibly worn or missing, you should install new weather stripping. There are a variety of weather stripping products on the market, ranging from low-cost "rope caulk" -- a putty-like material for temporarily sealing joints on the surface -- to metallic "V-strip" for double-hung windows and rubber compression strips for casement and awning windows.

Costs for weather stripping range from 50¢ to $12 per window.

Repair or replace putty

On most older windows, putty or glazing compound is used to hold the panes of glass in place. Over time this putty cracks and falls out. Old putty should be scraped out with a chisel or putty knife and new putty installed.

Install temporary or permanent storm windows

In addition to lowering the U-value of windows, storm windows also reduce air leakage. See the discussion of storm windows, above, for more on this option.

Caulk around windows

The most effective place to caulk for controlling air leakage around windows is where the window frame meets the interior wallboard. See Chapter 2 for a discussion of caulking materials and techniques.

Window Condensation

Condensation on the inside surfaces of windows is a fairly normal occurrence in most homes. But the fact that it is common does not make it a good or necessary condition. Window condensation occurs when the surface temperature of the glass, window sash, and/or frame is lower than the dew point of the humid air in the immediate living space. The moisture that is naturally present in the air in the form of vapor will change into water when in contact with these cooler surfaces. Condensation on windows can reduce the natural light, obstruct the occupant's view, and cause significant problems like peeling paint, mold, and sill rot.

Condensation can be reduced or eliminated by raising the inside temperature of the glass surface or by lowering the relative humidity of the indoor air. This is why hot air heat registers and baseboard heaters are placed under windows. But energy efficient windows represent the best solution to reducing this condensation build-up. This is done through non-conductive window sashes and frames, low-e-coatings that increase the temperature of the glass, insulating spacers that reduce heat conduction, more air-tight windows, and windows that are filled with convection reducing inert gas. But even with energy efficient windows - remember the house is a system - if the indoor humidity level is high, condensation can occur even on a high performance window. So identifying ways to reduce high humidity and moisture levels in the home is very important. (See Indoor Air Quality in Chapter 5).

Controlling solar heat gain through windows

Solar heat gain can be a blessing in winter, but an energy burden in summer when air conditioners are running.

Most summer overheating problems are caused by solar gain through windows that face east, southeast, west, or southwest. The summer sun is low enough in the early morning or late afternoon to shine directly into these windows. Each square foot of west-facing single-glazed windows can gain 235 Btu per hour at the hottest time of a clear summer day. Three 3' x 4' windows thus can add up to 8,500 Btu during the peak hour–about as much heat as a 2500-watt space heater! Heat gain through skylights is even greater.

During winter, the sun is low in the southern sky. South-facing windows thus transmit lots of useful solar heat in winter and are the basic ingredient of "passive solar design." During summer, when the sun is high in the sky, south-facing windows are easily shaded to avoid overheating.

Suggestions for controlling summer solar heat gain

Shade east and west windows

A variety of shading devices can be used to control unwanted summer sun through east- and west-facing windows. The choice typically boils down to personal preference and cost. Some examples are deciduous trees, porches, awnings, or exterior shade screens (See Landscaping in Chapter 10).

Install solar control films or screens

Special reflective films can be applied directly to windows and skylights to control summer sun. Though effective, they are sometimes aesthetically objectionable because of their shiny appearance.

Close reflective drapes or blinds

If you can't easily shade the outside of your east- and west-facing windows from the sun, your next best solution is to close sun-reflective blinds, drapes, or moveable window insulation on the inside of the windows during sunny days. To be most effective, the outer surface of these shades must be a light color.

Window Replacement

Deciding whether or not to replace old windows can be a difficult decision. Certainly new windows will be much better energy performers if high-performance, air-

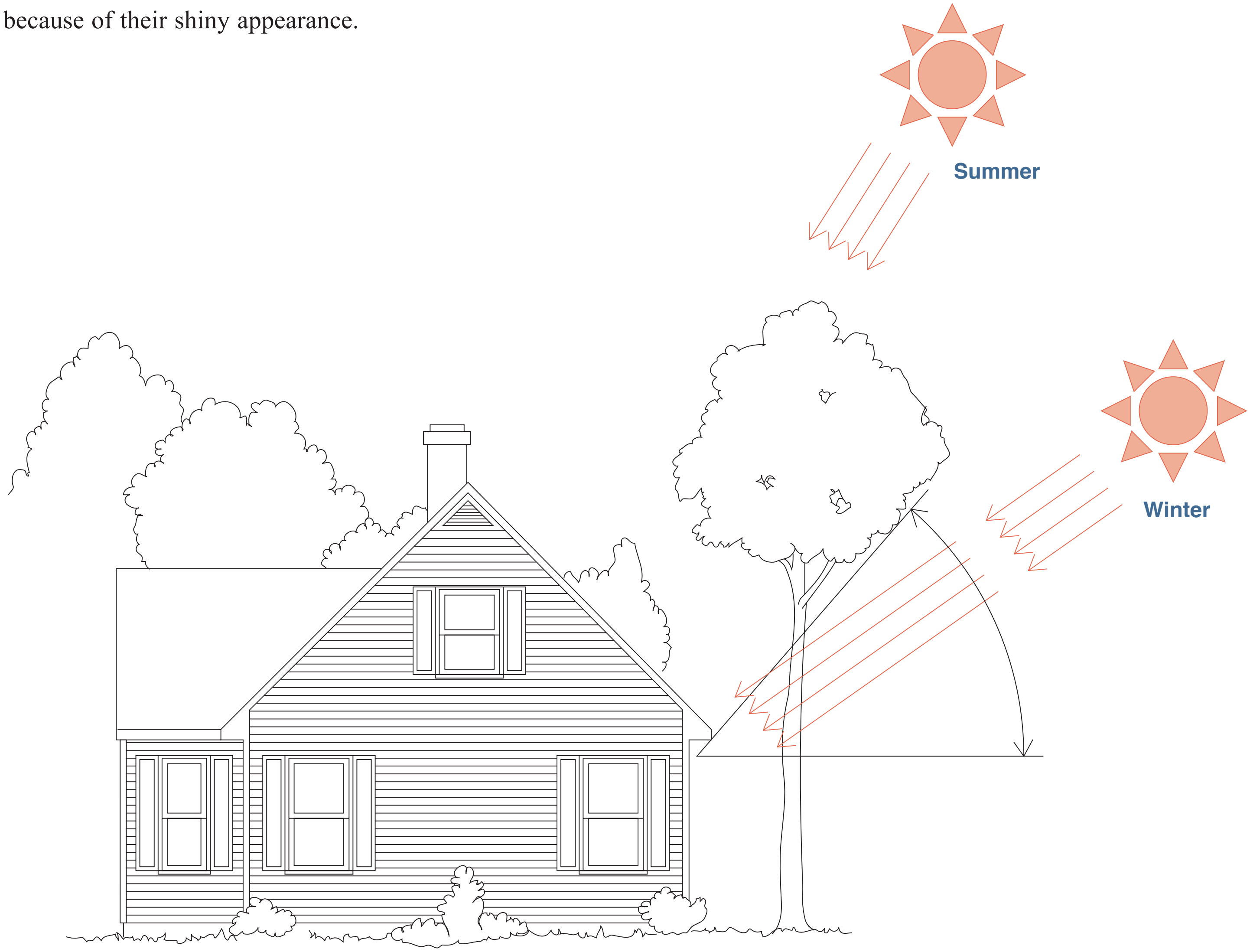


Figure 4-14 -- Trees and overhangs on the south side of a house can block the high summer sun, while allowing the low winter sun to passively heat the house.

tight models are selected. But the cost of window replacement is rarely justified by energy savings alone. Replacement usually only makes sense if your existing windows are rotted or otherwise in extremely poor shape. If your windows are in good shape or easily repairable (new glazing, replacement of broken panes, repainting, etc.), you will probably be better off keeping them and adding separate exterior storm windows or interior energy panels. A professional energy auditor or home performance contractor can help you decide whether window replacement is justified. Be wary of making the decision based on recommendations from someone (typically a distributor of storm or replacement windows) who stands to make money based on your choice.

Understanding Window Ratings

When shopping for new windows be sure to identify those that carry the Energy Star label and certification. The Department of Energy and the Environmental Protection Agency have developed an Energy Star certification for products meeting very specific energy performance criteria. (The Energy Star program is explained more fully in Chapter 7). It is also essential that you identify and study the National Fenestration Rating Council (NFRC)

Figure 4-15- Sample NFRC label

label, which appears on all window products that are part of the Energy Star program. The NFRC label is the only reliable way to determine the energy properties of a window and to compare products. The label displays pertinent information on the four major energy efficient window properties: U-value (U-factor), Solar Heat Gain Coefficient (SHGC), Visible Transmittance (VT), and Air Leakage (AL). Manufacturers are required to present U-factor, SHGC, and VT information. Presentation of AL information is optional.

U-value (U-factor)

The rate of heat loss is shown in terms of the U-value of a window assembly, which includes the sash, the frame, and the glass. The insulating value of walls is indicated by the R-value, which is the inverse of the U-value. The R-value is 1 divided by the U-value. For example, if the U-value is 0.25, the R-value is 1/0.25 or R-4.0. Figure 4-16 shows the relationship between U-value and R-value.

The lower the U-value, the greater a window's ability to resist heat flow and the better its insulating value. With a temperature difference of 1 F, insulation with U=1 allows 1 Btu per hour heat flow for each square foot of surface area. In general,

Heat Flow (Btu per hour per square foot) =
Temperature Difference (F) x U-value

Consider the U-value to be the bottom line most important factor in selecting an energy efficient window. The recommended U-value in Virginia is 0.40 or less. The larger your heating bill, the more significant a good U-value becomes. Skylights with a U-value of 0.45 are recommended.

Solar Heat Gain Coefficient (SHGC)

The ability of a window to transmit solar heat gain is measured by its SHGC. The higher the SHGC, the more sunlight admitted through the window, which is more desireable in the winter months because of the free solar heating opportunity that is provided. But for controlling summer heat gain through west and east facing windows look for a lower SHGC.

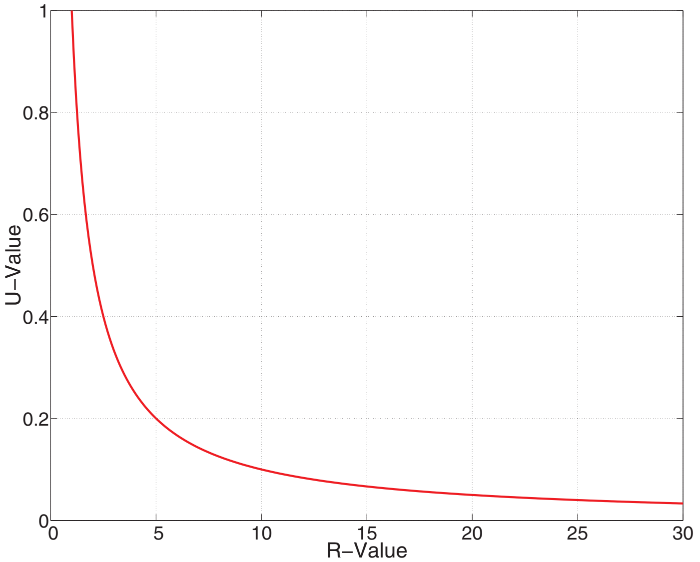


Figure 4-16- Relationship between U-value and R-value

The recommended SHGC for windows in Virginia homes that have high air conditioning bills is 0.40 or less. If your air conditioning expenses are moderate then a SHGC of 0.55 is recommended. While windows with lower SHGC values reduce summer cooling, they also reduce free winter solar heat gain. Skylights should have a SHGC value of 0.55 or less.

Visible Transmittance (VT)

The optical property that indicates the amount of natural light transmitted is called the visible transmittance (VT). The higher the VT the more light is transmitted. Most values are between 0.3 and 0.8. Windows with low solar heat gain usually have lower visual transmittance as well, but low-E windows cut out much invisible heat radiation while still allowing most visible light through.

The recommended VT in Virginia is simply the highest VT that is available for the SHGC required.

Air Leakage (AL)

Heat loss and gain occur through cracks in the window assembly. This is measured in cubic feet per minute of air passing through a square foot of window area at a standard test condition. The lower the AL, the less air will infiltrate through the window assembly.

The recommended AL in Virginia is 0.30 or less.

Window Materials and Design

Two final considerations when shopping for new windows are the frame material and the edge spacers.

Window frames are typically constructed of wood, vinyl, or aluminum. From an energy standpoint, vinyl frames are the best, especially if insulated with foam or fiber insulation, followed by wood and then aluminum. Some aluminum frames improve performance with a "thermal break", a gap filled with wood or plastic to interrupt heat flow, but even these typically don't match the performance of wood or vinyl. Without a thermal break, aluminum frames are unacceptable for the Virginia climate.

Edge spacers hold the panes of glass apart and provide the air- tight seal in a well insulated window. Pay attention to the type of material that the edge spacer is constructed of - if it is metal make sure that a thermal break exists. Silicone foam or butyl rubber are more energy efficient and will improve the energy performance by up to 10%. Choose windows that have long warranties against seal failure, which can result in window fogging and a loss of any low-conductivity gas-fill.

Doors

While there are generally only a few doors in a home, compared to a dozen or more windows, doors may often leak even more than windows.

Improving old doors

Weather strip door

Both sides and the top of a door should be weather stripped with compression-type weather stripping. Make sure the weather stripping is not so thick that it makes closing the door difficult. An alternative is V-strip weather stripping, which should interfere less with opening and closing. Follow manufacturers' recommendations on installation. Cost of weather stripping a door ranges from $8 to $15.

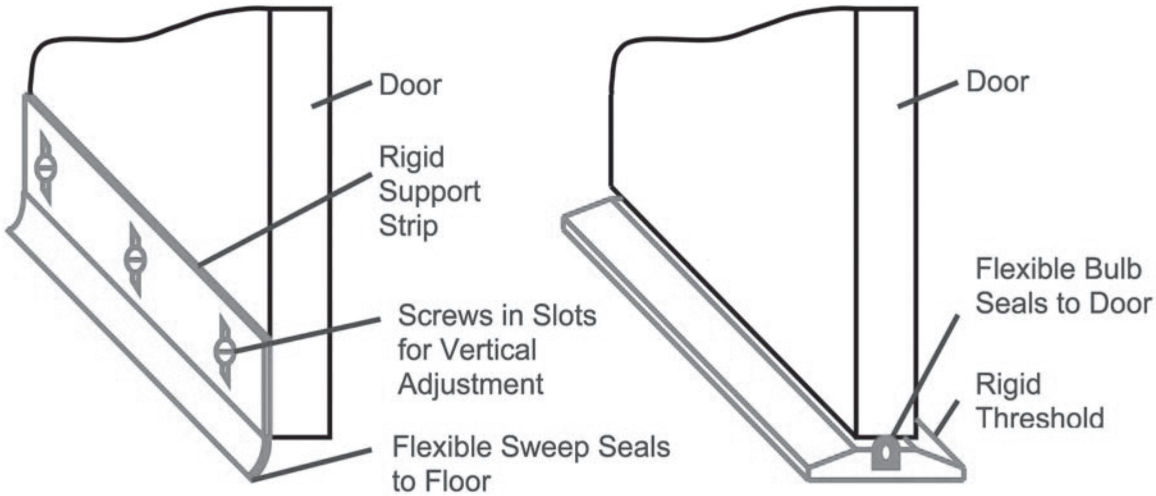


Figure 4-17 – Door Sweep and Vinyl Bulb Threshold

Install door sweep

If there is a gap at the bottom of an exterior door, you should install either a door sweep that attaches to the door, or a vinyl-bulb threshold that creates a seal under the door. A new threshold will cost $10-20, and a door sweep $2-10.

Install storm door

Storm doors are not very cost-effective energy-saving improvements in our climate. The benefits of adding a storm door are that it stops drafts when people enter the home and of course it also becomes the screen door in summer.

Repair existing doors

Both prime doors and existing storm doors may be in need of repair. With wooden doors, look for cracks in the wood that may be allowing air leakage. Also inspect for warping. Some warping can be dealt with using weather stripping, but severely warped doors should be replaced. For doors that contain windows, inspect the glass and the glazing putty and repair or replace as necessary.

Selecting a new door

Shopping for energy-efficient doors is relatively straightforward. The following guidelines should be helpful.

Shop for highest R-value

Manufacturers should list the R-value for their doors in their product specification sheets. In general, insulated steel and fiberglass doors are more energy-efficient than wooden doors. Even if a wood door is necessary for your front entryway, an insulated steel or fiberglass door may be acceptable for back and side entrances.

Check the weather stripping

Pay particular attention to the weather stripping, particularly with wood doors. There is a tremendous difference in quality– and effectiveness– of the weather stripping offered from various door manufacturers. Steel doors often have magnetic weather stripping–magnetic strips mounted in flexible neoprene rubber–that provides the best seal of all.

Check the door construction

Particularly with wood doors, the construction technique can make a huge difference in long-term durability and performance. A door made out of planks of wood glued together, for example, is likely to expand, warp, and twist a lot more than a door made out of multiple laminations of wood.

If you install a new wooden door , be sure to seal it with the appropriate weatherproof stain, paint, varnish, or sealant. This will prevent the door from warping or expanding due to moisture absorption.

Buy pre-hung doors

Doors that are factory-mounted in frames usually have far closer tolerances and better weather stripping than doors that are mounted in custom-built frames on-site.

Energy Tips and Recommendations

1. Hire a professional energy auditor to provide input, if you are in doubt, on the cost-effectiveness of purchasing new windows versus repairing and improving existing windows.
2. If you install storm windows, be sure to buy windows with low-E glass, have them properly installed and sealed, and open/close them in the spring/fall.
3. If you purchase new windows - be sure to buy Energy Star windows that have an NFRC label, which provides information on the energy properties of the window. Be sure that the Energy Star windows are suited for your climate region.
4. Make sure that you compare the U-value, Solar Heat Gain Coefficient, Air Leakage, and Visible Transmittance factors that are displayed on the NFRC label before purchasing new windows.
5. If you have high levels of condensation on the interior surface of your window glass then consider making them more energy efficient and/or reducing the relative humidity inside your home.
6. Understand the need to control summer solar heat gain through your windows and to maximize solar heat gain in the winter.
7. Purchase windows that have good warranties against seal failure, which will allow windows to fog and low-conductivity gas to leak and be lost.
8. Purchase windows that have wood and vinyl frames. Do not purchase aluminum- framed windows unless they have a thermal break.
9. Energy inefficient doors can be repaired with new weather stripping, threshold replacement and new door sweeps.
10. If you purchase a new door, buy an Energy Star certified door that will be well insulated and energy efficient.
11. It is always a good idea to have all new windows and doors installed by a professional. The installation process can directly impact the energy performance.

HEATING AND COOLING SYSTEMS

The average Virginia household uses 50% of its total energy budget for space heating and another 9% for air conditioning. Your heating system is most likely the number one energy user in your home, with water heating second and air conditioning a close third.

Heating systems, cooling systems, and the power plants that supply them with electricity emit large amounts of carbon dioxide - a major greenhouse gas - into the atmosphere, which adds to global warming. They also emit sulfur dioxide and nitrogen oxide - both major ingredients in

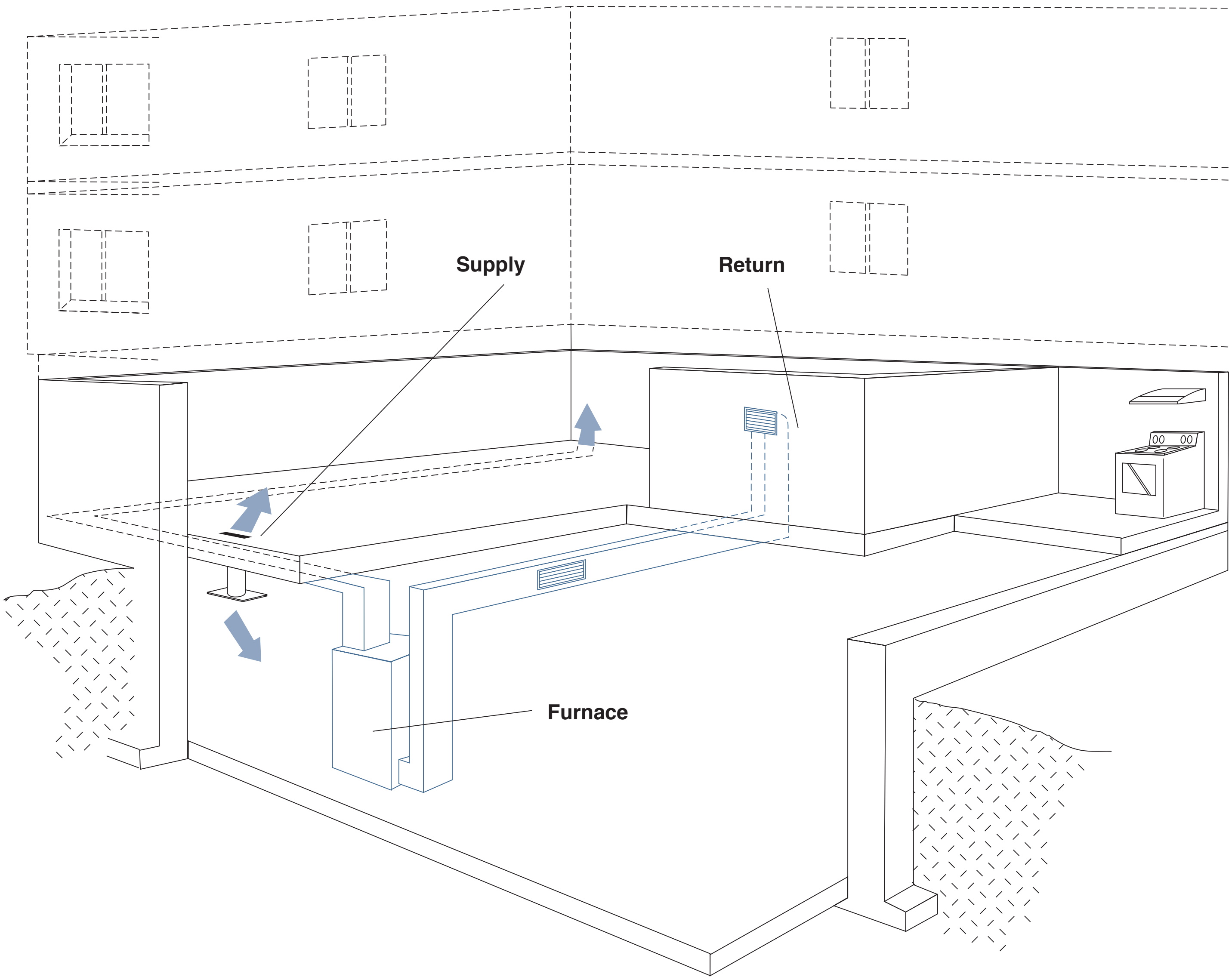


Figure 5-1 - The most common type of central heating system is a ducted forced air system with central furnace or heat pump.

acid rain. So improving the efficiency of your heating and cooling equipment will not only save you money but it will reduce pollution output and help to preserve the environment.

If your home is insulated and airtight, you've already done a lot to reduce heating and cooling energy. The next step is to further reduce energy use by improving the efficiency of the mechanical systems themselves. This can be done with better maintenance, with upgrades to a few components, and/or with total system replacement.

Remember that your house is a system and the performance of your heating and cooling equipment will depend directly on how well the shell of your home is insulated and how the occupants of the home operate and maintain the mechanical equipment inside the home.

Four Ways To Improve Your Heating And Cooling Systems' Efficiency

1. If your present heating and cooling systems are old and tired, you may be able to cut utility costs by as much as 50% by replacing the old system with a new high efficiency system.
2. Even if your furnace and air conditioner are in fairly good shape, you may be able to improve the overall efficiency of the system through adjustments, maintenance, and repair to the distribution system.
3. With the mechanical system in good shape and well maintained, you may still be able to reduce fuel costs by changing the way you operate your thermostat.
4. Be sure that all heating systems are vented properly and that all vent pipes and chimneys are installed and lined according to code requirements. Improperly lined chimneys, vent pipes that are incorrectly installed or are of the wrong material, and dirty and obstructed pipe and chimneys can impact how the systems draft. This compromises energy efficiency, indoor air quality, and fire safety.

Understanding Central Heating And Cooling Systems

Your home may be heated by individual room heaters and window air conditioners, or it may have central heating and cooling systems. Central systems typically present the greatest opportunity for savings.

A central heating system has four main elements:

• The heating and cooling plant - furnace, boiler or heat pump, and possibly air conditioner - that converts fuel or electrical energy into a temperature change.

• The distribution system - ducts for forced air or pipes for hot water or steam - that carries heat (and cool) from the central unit to each room in the house.

• The venting system - vent pipes and chimney - that are responsible for efficiently and safely removing the poisonous flue gases from your home (if the system is a combustion appliance).

• The thermostat, which controls the whole system.

The following sections focus on all four elements of your central heating system, discussing how they work and what you can do to improve their energy efficiency.

Gas furnaces

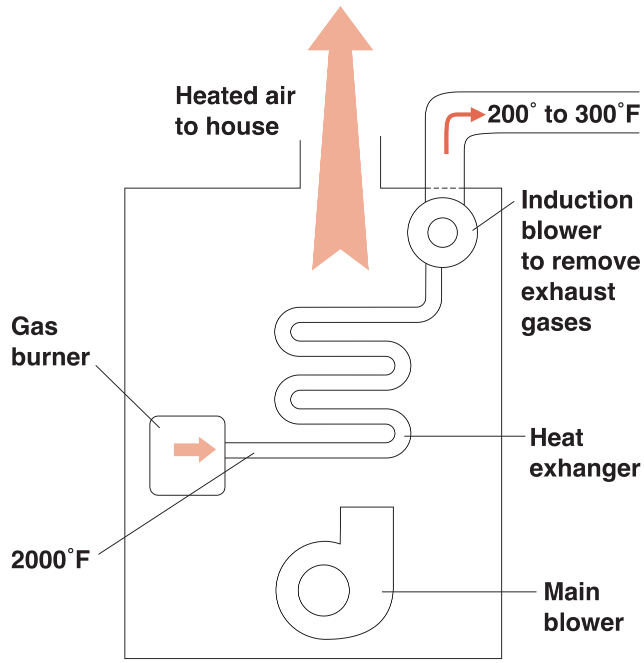


Figure 5-2 - Typical mid-efficiency gas furnace

Gas furnace technology has progressed by leaps and bounds during the past decade. Efficiencies have jumped from about 65% to as high as 95%. Efficiency of a heating system can best be defined as how effective the system converts fuel into useful heat.

Most gas furnaces have the same basic components: A gas burner where fuel is burned, an ignition device to start the fire, one or more heat exchangers where the heat from combustion gases is transferred to the house air, a circulation blower to circulate air to and from the house, and (on modern units) a small second induction blower to draw flue gases through the furnace and assist in bringing combustion air to the unit.

As the hot exhaust gases from the gas burner pass through the heat exchanger, they are cooled by the circulating house air, which carries the heat throughout the house.

The road to high efficiency

To achieve high efficiency, manufacturers designed special heat exchangers which squeeze as much heat as possible from the hot combustion gases before venting them out of the house. For example, in "mid-efficiency" furnaces (78% to 83%), the exhaust gases are cooled to about 250°F before exiting the furnace. To attain even higher efficiency, manufacturers install a second heat exchanger which further cools the exhaust gases to as low as 65°F. At that temperature, the gases are so cool that water vapor (one of the products of combustion) condenses out of the flue gases and is drained through a plastic tube to the sewer or floor drain. These ultra-high efficiency furnaces, called "condensing furnaces", have efficiencies ranging from 90% to 97%.

Condensing gas furnaces first appeared on the market in 1983 and are now available from literally every major furnace manufacturer. Because the exhaust from a condensing gas furnace is so cool, it can be vented through regular schedule #40 plastic PVC pipe (there is no need for a metal or masonry chimney).

Oil furnaces

Oil furnaces are similar to gas furnaces and share many of the same high efficiency features. The most important difference is in the firing apparatus. Oil furnaces have power burners that atomize the fuel oil, mix it with combustion air, and force it through the combustion chamber.

Condensing oil furnaces, with efficiencies above 90%, are available but are not as common as condensing gas furnaces.

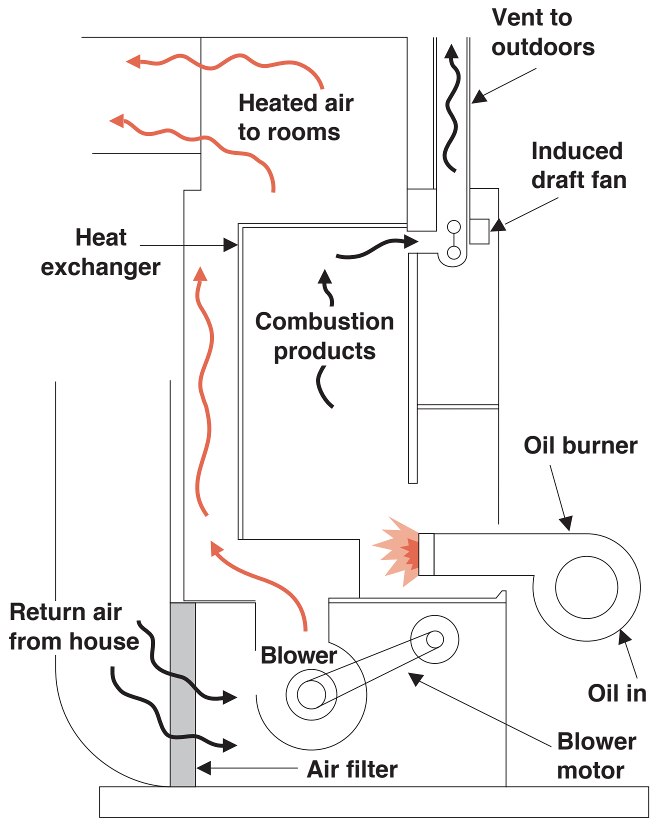


Figure 5-3- Schematic of typical oil-fired furnace

Electric furnaces

Electric furnaces contain an electric resistance heating coil that simply converts electricity directly into heat. The coil is mounted in a cabinet with a circulation blower. Except for a small amount of heat loss through the cabinet, nearly all the heat from the coil is transferred to the circulating house air. The efficiency of an electric furnace is close to 100%. Electric resistance heat, however, is generally the most expensive type of heat available and is not recommended - see "Know Your Btus" in Chapter 1.

Electric heat pumps

Heat pumps work on a completely different principle than electric furnaces. Instead of just converting electricity into heat, a heat pump uses an electric compressor that "pumps" heat from one place to another.

Heat flows naturally from hot to cold, never from cold to hot. Water flows naturally from a high level to a low level, never uphill. Just as a water pump moves water from a low level to a high level - against the direction of its natural flow -

a heat pump moves heat from a cold area to a warm area.

Refrigerators, air conditioners, and heat pumps are all basically the same. In a refrigerator, heat is pumped from the cold freezer and refrigerator compartments out into the warmer room. In an air conditioner, heat is pumped from the cool interior of the house into the hot outdoors. In a heat pump, heat is pumped from the cold outdoors to the warm interior of the house.

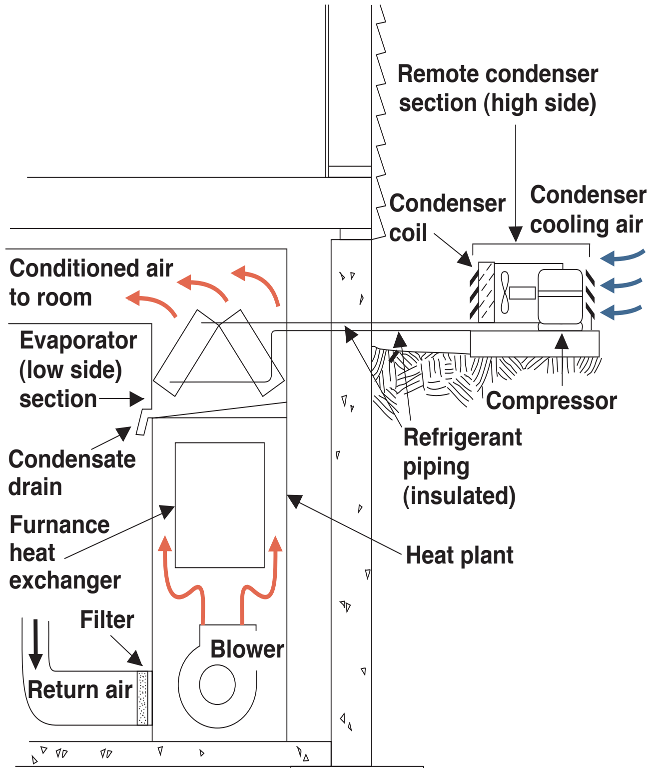


Figure 5-4 - Schematic of air-to-air heat pump

In fact, heat pump/air conditioner combinations use the same equipment for both jobs, using a flow control valve to change the direction of heat pumping from summer to winter. This ability to use the same basic equipment for heating and air conditioning is a prime advantage of heat pumps.

A heat pump makes much better use of electricity than an electric resistance furnace. For each Btu of energy that comes into the heat pump from the electric power line, it can pump one or two more Btu's from the outdoors. In this way it delivers two or three times more heat than an electric furnace for the same electric input.

All heat pumps have the same basic components: a compressor which does the actual "pumping", an indoor coil which heats or cools circulating house air, an outdoor heat source which supplies heat or cooling to the system, and copper tubing that circulates high pressure refrigerant fluid between the indoor and outdoor units.

Residential heat pumps can utilize heat sources down to 20-30°F to heat indoor air up to 80-100°F.

Heat pumps can also be used for water heating: See Chapter 6.

Air-to-Air Heat Pumps

The most common type of residential heat pump is an "air-to-air" heat pump which uses outdoor air as the heat source. Heat is extracted from the air by an outdoor unit that contains a heat exchanger and fan.

The main disadvantage of air-to-air heat pumps is that they lose efficiency and output at cold (less than 35°F) outdoor air temperature. When this happens, operating cost increases and indoor comfort decreases because the air from the heat pump is not very warm. While this is a troublesome problem in colder regions of the country, it is not a severe problem in most regions of Virginia.

Air-to-air heat pump systems are usually set up with a "two-stage" thermostat. As long as the temperature in the house remains within a few degrees of the thermostat setting, the heat pump operates normally. If the indoor temperature drops too low, the heat pumped by the compressor is supplemented by electric resistance heat and the heat pump's efficiency drops considerably. For a typical home with a heat pump, the electric resistance heat comes on during two conditions: when the outdoor temperature drops to about 15-25°F and when the heat pump is turned on suddenly when the house is cold.

When outdoor air temperatures are below about 40°F, air-to-air heat pump outdoor coil temperature may be below freezing. Moisture in the outdoor air then forms frost on the outdoor coil. If too much frost builds up, the heat transfer to the coil is restricted and heat pump output and efficiency drops. To avoid this, heat pumps have a "defrost" cycle that uses energy from the house to warm the outdoor coil and melt the frost. Frost is not a problem with air conditioners since you never cool your home to 40°F.

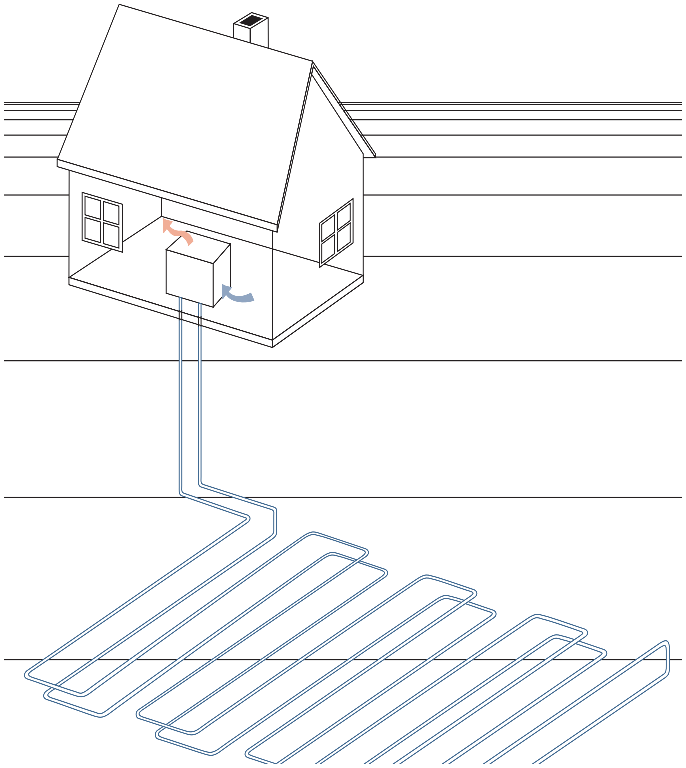


Figure 5-5 - Ground source heat pump

Geothermal Heat Pumps

"Geothermal" or "ground source" heat pumps (GHP) use the ground as the heat source. Heat is extracted from the ground by water circulating in a closed-loop pipe. This pipe is placed either in trenches or down specially drilled wells. Ground source heat pumps are generally more efficient than air-to-air heat pumps because the deep-ground temperature stays constant all year round. Just as the power required for a water pump increases as it pumps water farther uphill, the power required for a heat pump increases as it pumps heat over a greater temperature difference. Since GHPs pump heat from the relatively warm ground instead of the cold winter air, they pump heat over a smaller temperature difference. As a result, they use 25-50% less electricity than conventional heat pump systems.

GHPs can also operate as air conditioners, where they have the advantage of pumping heat into the relatively cool ground instead of into the hot summer air.

GHPs are quieter than conventional systems and they improve humidity control. GHPs tend to be more durable, require less maintenance, and have a lower environmental impact due to their increased efficiency.

GHPs have a higher installation cost, but because they are more efficient and save money in the long term, they can represent a good investment. The cost effectiveness of a GHP for a particular location depends, in part, on soil conditions and site layout since these affect the cost of the necessary excavation.

Hydronic heating systems and radiant floor heating

A hydronic heating system uses heated water to distribute heat from a central boiler to each part of the house. The distribution system may include any combination of baseboard heaters, radiators or sub-floor "radiant" heaters.

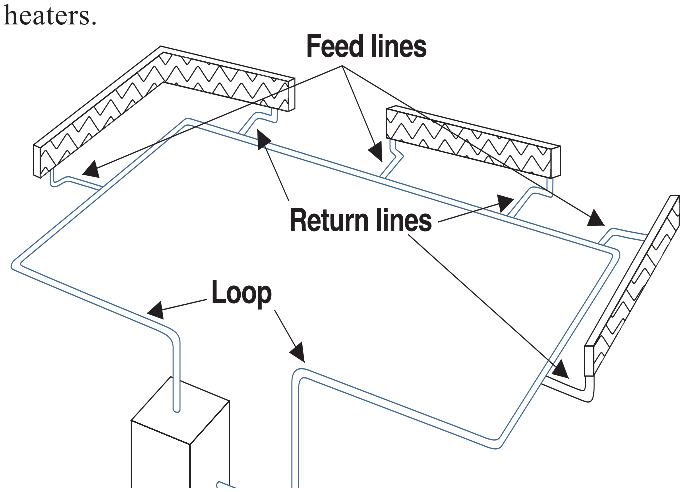


Figure 5-6 - Hydronic heating system

As with furnaces, boiler technology has advanced during the past decade although few boilers attain the impressive efficiency of condensing gas furnaces. Several gas- and oil-fired boilers are available with efficiencies up to 87% and condensing gas boilers are available with efficiency over 90%.

One very effective type of hydronic heating system is radiant floor heating. Radiant floor heating has been used for centuries and operates on the premise that people are most comfortable when their feet are warm and the air they are breathing is relatively cool. Radiant floor heat allows even heating throughout the whole floor and not just in specific areas like space heat and forced air systems. In hydronic floor heating systems, tubing is laid in a pattern underneath the floor and heated water is pumped from a boiler through the tubes. The temperature in each room is controlled by regulating the flow of water through each tubing loop through a system of zoning valves or pumps. A hydronic radiant floor system can save 20 to 40% per month on heating bills depending on the heat source, is very quiet to operate, and has virtually no air leakage as a result of there being no forced air distribution system.

Some radiant heating systems use electric resistance mats that are build into the floor. They provide the same comfort as hydronic radiant floor heating, but because they use the same basic technology as electric furnaces, they are expensive to operate.

Hydronic heating systems are not very common in Virginia. One reason is that most new homes have central air conditioning which requires a ducted distribution system. It's hard to justify a second distribution system when you could just as easily use the cooling ducts for forced air heating.

Energy Efficient Space Heaters

There are several types of energy efficient, direct vented, sealed combustion space heaters on the market. These heaters, which normally can use natural gas, kerosene, or propane as their fuel source, are direct vented through the wall - eliminating the need for a chimney.

They are sealed combustion, which means they bring in outside air for combustion. This helps to eliminate air infiltration due to an unsealed combustion system that sucks air from inside the house to provide combustion air, which in turn can force air to be drawn from outside the house. Their efficiency ratings run from 82 to 90% and they are generally equipped with programmable thermostats, which can maximize efficient operation.

The BTU output can range from 10,000 to 40,000 and they can heat one room or a 2,000 square foot house.

Many older houses have vented space heaters without sealed combustion. These units are less efficient than good sealed combustion heaters because the combustion gases leave at high temperatures and because they use indoor air for combustion. The best of these units, however, are fairly efficient. They must be vented through a metal or masonry chimney, and care must be taken to ensure they have adequate draft.

Unvented space heaters claim high efficiency, but can produce hazardous indoor pollutants. See "Unvented Heating Systems" at the end of this chapter.

Cooling Systems

There are basically three types of air conditioning systems available: room air conditioners, central air conditioners, and heat pumps.

Room air conditioners provide cooling to rooms rather than the whole house. These units can be installed in a window or mounted in a wall, but in both cases the compressor is outside. Room air conditioners generally range from 5,500 BTU per hour to 14,000 BTU per hour. They can normally be plugged into a 115- volt household circuit although larger units may need their own dedicated circuit. National appliance standards require new room air conditioners to have an Energy Efficiency Ratio (EER) of 8.5 or greater. If you replace an older unit that has an EER of 5 with one that has an EER of 10, you will reduce your energy costs by 50%.

Central air conditioners cool the entire house. They are normally a split system unit with the compressor and condenser outside and the evaporator inside. The cool air is distributed by a forced air duct system that pushes air into individual rooms through a supply system and then returns the used air back to the air conditioner through a return system. National minimum standards require a Seasonal Energy Efficiency Ratio (SEER) of 12 for central units but there are units on the market with SEERs reaching 17.

Heat pumps operate like central air conditioners except a heat pump can reverse the cycle and provide heat during the winter months. Heat pump effectiveness is expressed by using the term Heating Season Performance Factor (HSPF) and this as well as EER and SEER will be discussed later in the chapter.

Air conditioners use the same operating principles as a refrigerator. An air conditioner cools with a cold indoor coil called an evaporator. The condenser is a hot outdoor coil that releases the collected heat outside. The evaporator and condenser are copper tubing surrounded by aluminum fins and a pump called the compressor moves a heat transfer refrigerant between the evaporator and the condenser. The compressor forces the refrigerant through the circuit in the tubing and fins. The refrigerant evaporates in the indoor evaporator coil drawing heat out of the indoor air and cooling the house. The hot refrigerant gas is pumped outdoors in the condenser where it returns back to a liquid releasing its heat to the air flowing over the condensers tubing and fins.

Evaporative Coolers

Evaporative coolers are air conditioning systems that are most effective when the outside humidity is low, in dry areas of the country like the Southwest. They operate by blowing air over damp pads, so that the evaporation of water cools the air. The cooled, humidified air is then blown into the house.

Evaporative coolers are not effective in a humid climate like Virginia's. Although they reduce air temperature, they result in uncomfortably high indoor humidity.

Variable-speed systems — comfort with efficiency

One of the most noteworthy new developments in both heat pumps and air conditioners is the introduction of new "variable speed" systems. A variable speed air conditioner has the capability of varying its cooling capacity to match the needs of the house. Thus when a house needs little cooling, the system runs at a low speed, which not only saves energy, but is also extremely quiet. During very hot or humid weather, the system can switch to a higher speed to match the increased load.

Another advantage of variable speed air conditioning is enhanced humidity control. During very humid weather, some variable speed air conditioners can lower the indoor coil temperature to squeeze extra humidity out of the circulating house air.

All in all, a variable speed system gives the homeowner a combination of maximum comfort and energy efficiency.

How To Make Your Heating And Cooling Systems More Efficient

Change your filter regularly

The filter in your forced air system is intended to protect the blower and coils from dust. As dirt builds up on the filter, less air can pass through. The reduced air-flow reduces the capacity and efficiency of your heating system and increases the power draw of your air conditioner.

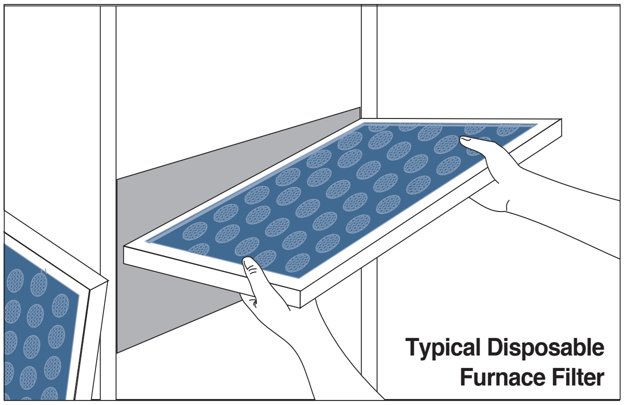


Figure 5-7 - Furnace filters should be replaced every one to three months, depending on conditions.

Depending on how dusty your home is, you should check the filter every one to three months and change it whenever visible amounts of dirt accumulate on the surface.

Eliminate duct leakage in forced air systems

One of the worst culprits in forced air heating and cooling systems is duct leakage. Duct leakage can account for 35 to 40% of heating and cooling energy loss in the home, particularly if the ducts are located in unconditioned areas like attics or crawlspaces. Since the air in your duct system is under high pressure and temperature (low temperature in summer), any leakage in the duct system results in high energy loss. Sealing leaky ducts is one of the most cost-effective improvements you can make to your forced air system.

A duct system consists of supply ducts and return ducts. A central heating or cooling system contains a fan that pushes heated or cooled air into the supply ducts that provide this air into each room of the house. The fan that is

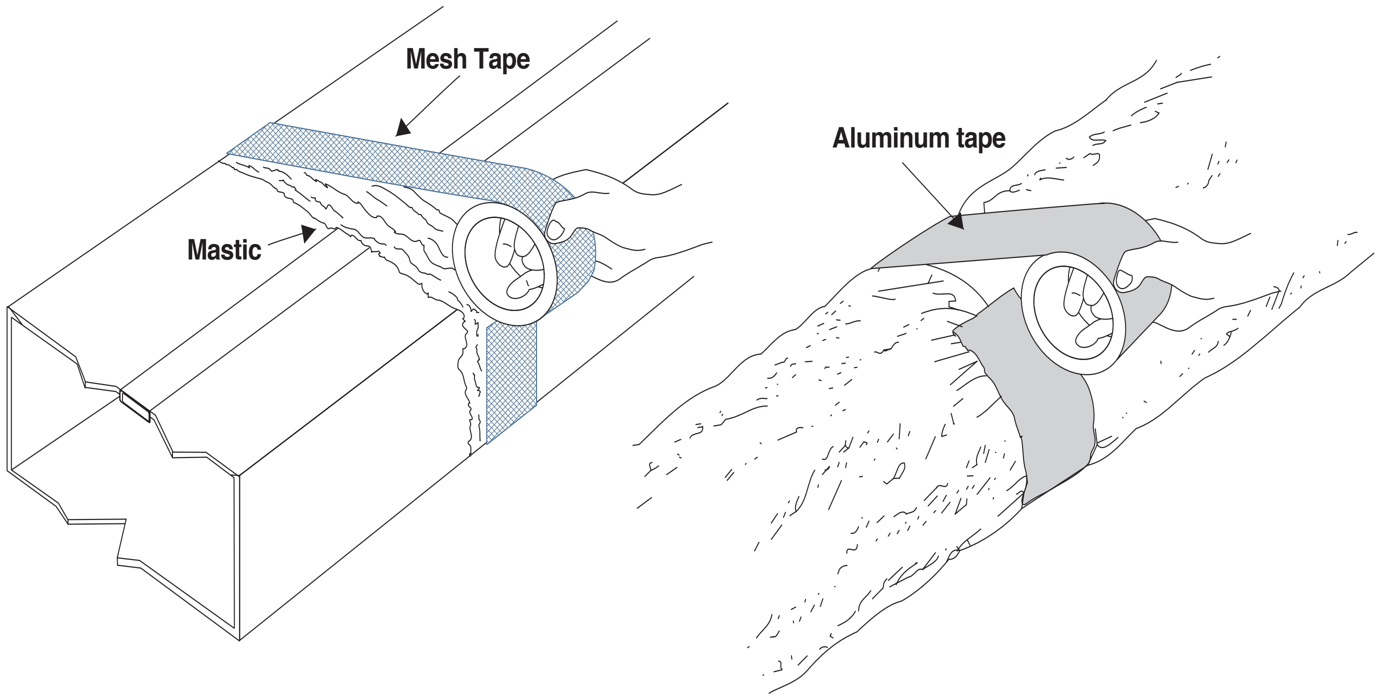


Figure 5-8 - Sealing ducts against air leakage

pushing the air gets its air supply through the return ducts that are located in the house. Ideally each room of the house should have a return register so that the system is balanced, but it is more common to have one return register for each floor of a house.

Leakge hurts duct system performance. If the supply side is leaky then two things can happen. First you will lose heated or cooled air and secondly the replacement air that is needed will be drawn in from outside due to the negative pressure that is being created by the leakage (infiltration). If the return side is leaky then unconditioned air is being pulled into the return system. This makes the furnace work harder because it must now heat or cool air that is not conditioned within a sealed return system. The positive pressures that return leakage cause within the living space will also force the conditioned air to be forced out of the house (ex-filtration). Return leakage can also create significant health hazards within the living space by pulling indoor pollutants into the system and by causing the combustion appliances to back-draft.

Sealing ducts is very important and can be relatively straightforward. But it is imperative that the system be tested by a professional - before and after sealing - to insure that repairing duct leaks has not unbalanced the system thus creating the types of problems discussed above.

Always seal ducts using duct-sealing mastic. Never use duct tape. The seal must be permanent and only mastic provides this long- term application. Duct tape does not last nor does it provide a proper seal. Make sure that your combustion appliances are drafting properly before and after any duct sealing is done.

A professional can test the duct system for leakage and also insure that your furnace is drafting properly. A blower door or air flow measurements can be used to test and diagnose duct leakage (Chapter 1) and draft testing is discussed in (Chapter 2). If you're hiring a professional to work on your duct system (affecting your energy bill, your health, and your safety), be sure he or she is well-qualified:

• Use someone with a reputation for good work. Talk to your friends and neighbors for recommendations. Check with your local Better Business Bureau or contractor licensing department for complaints. Ask for references and contact them.

• Ask questions about home energy use: How do leaky duct systems lose energy? How can leaky duct systems create health hazards? How can you test the ducts to determine that they leak? How will you fix the leaks and what material will be used to make repairs? How can the duct system cause combustion appliances to backdraft? A qualified professional should be able to answer such questions clearly and correctly.

Balance air distribution system

For optimum performance, an air distribution system should supply the proper amount of air to each room. A large bedroom, for example, requires more air flow than a small study. When the duct system is designed, duct and register sizes should be selected to provide adequate air flow to each room. System sizing, however, can only control air flow approximately. Once a system is constructed, air distribution can be fined-tuned by adjusting the flow-control dampers in each register. This fine-tuning is called "system balancing."

In large commercial buildings, the engineers who design the air distribution system specify the correct air flow to each register. Once the building is finished, specialized "Testing and Balancing" (TAB) contractors adjust the system to provide correct air flow. In residential air distribution systems, design is often approximate and the correct air flow to each register is often not specified. Nevertheless, residential systems can benefit from proper balancing.

When systems are not properly balanced, one or more rooms can be uncomfortably warm or cold. To keep these rooms comfortable, the whole house may have to be over-heated or over-cooled, making other rooms uncomfortable and wasting energy. In the worst case, the only way to keep the whole house comfortable may be to keep some windows open while the heat or air conditioning is on!

One way to balance your system is to have a qualified contractor do the work. Since you probably do not have design drawings for your house specifying correct air flows, the contractor must calculate the air flow required for each room (based on size, use, and exposure to the outdoors) and balance the system to his calculated flows. The contractor should also ask you what rooms are uncomfortable, and take your preferences into account.

You can also adjust the balance of your air distribution system yourself. If you have a room that doesn't get enough air (too cold in winter and too warm in summer):

• Check if the damper to the room is fully open. If not, open it further.

• If the damper is already fully open, slightly close all other dampers on the distribution system to force more air into the room in question.

Getting all your rooms comfortable may take some experimentation. Adjust some dampers, see how the occupants like it, and then try again if they're still not comfortable. Be careful not to close dampers off any more than necessary, since closing too many dampers hurts system efficiency and generates noise.

Remember: your house is a system, and you are part of the system. If you aren't comfortable, the system isn't working right!

Insulate ducts and hot water distribution pipes

Insulating your duct system, particularly if ducts are located in unconditioned areas (attic, crawlspace, unheated basement), is usually very cost effective and can save significant money on your heating and cooling bill. Insulation will keep the heated air inside the duct warm and the cooled air inside the duct cool. Be sure to use the appropriate type of insulation and if there is any doubt, consult a professional. Obtaining the services of a professional is always a good idea because insulating the duct system must be done correctly.

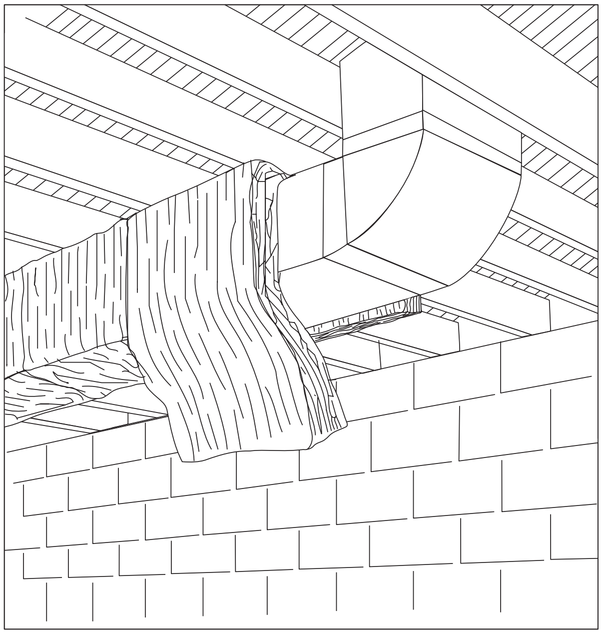


Figure 5-9 - Ducts and pipes that run through unheated spaces should be insulated. Special insulation is available for both types of systems. Keep in mind that duct insulation is not a good air seal. Have your ductwork sealed against air leakage before wrapping it with insulation.

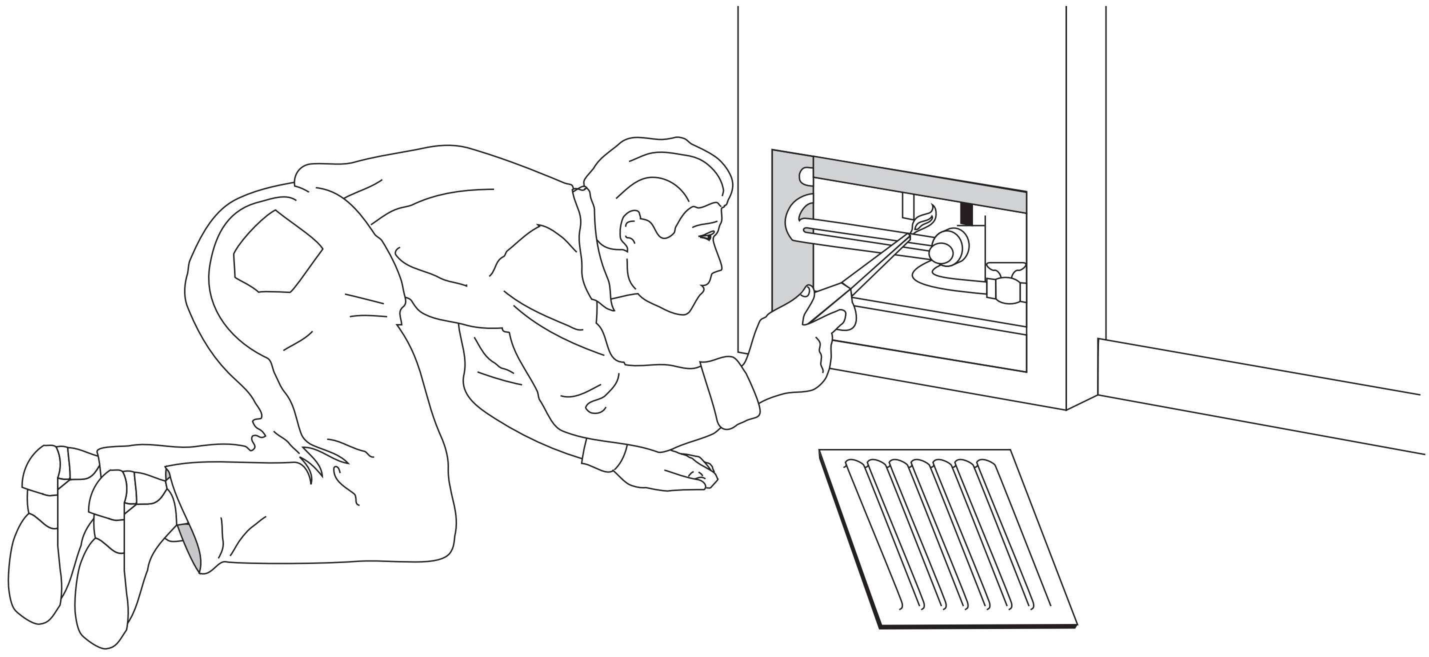


Figure 5-10 - Gas Furnace service

Make sure that all leaks have been repaired and tested before insulating the duct system.

Have your system inspected, cleaned and tuned up by a professional service contractor

Regardless of the type of system in your home, you should have your heating and cooling system inspected and maintained on an annual basis. Professional cleaning and maintenance will not only assure optimum efficiency, but will also extend the life of the appliance and insure the health and safety of the occupants.

Gas furnaces and boilers

Your service contractor should check the combustion efficiency of your gas furnace or boiler by measuring flue gas temperature, oxygen, carbon monoxide, and draft. He or she should also check the heat exchanger for dirt buildup or leaks. Dirt buildup on the heat exchanger can significantly reduce efficiency, particularly with high efficiency condensing gas furnaces, which have two heat exchangers. See Figure 10.

Oil furnaces and boilers

Oil-fired appliances are more complex than gas systems and generally require more frequent maintenance. Your service contractor should check the operation of the oil-burner and make any necessary air and fuel flow adjustments to produce the proper flame. He or she should also clean the burner nozzle and heat exchanger. After servicing the system, your contractor should perform an efficiency check by measuring stack gas temperature, oxygen reading, carbon monoxide, draft test and smoke levels. If the efficiency cannot be brought up higher than 70%, you should consider installing a new burner or even replacing the heating system itself with a higher efficiency, Energy Star unit. Modern "flame retention" burners provide much higher efficiencies than the conventional burners found in most older furnaces and boilers.

Make sure that the contractor inspects your vent pipes and chimney for dirt, obstructions, disconnects, and whether the chimney is lined properly. If your contractor is doing these tests with no testing equipment other than a cigarette lighter and a flashlight, then you are not getting the professional service that your system needs.

Your furnace should be inspected by a qualified professional every year.

Heat pumps and air conditioners

Of all residential mechanical systems, heat pumps and air conditioners can benefit most from professional maintenance and servicing. In addition to the usual problems resulting from normal wear and tear, many heat pumps function very poorly simply because they were installed incorrectly. Field studies have shown that heat pump and air conditioner efficiency can be commonly improved as much as 30% through proper tune-up and repair. At a minimum, regular inspection is recommended every two to three years but an annual check up is a good idea as well.

Make sure your outdoor unit is properly ventilated and shaded

The outdoor unit of your air conditioner should have at least two feet of clearance on all sides for proper airflow. Some installers and homeowners try to hide the outdoor unit by placing it under a deck or by surrounding it with bushes. This is not a good idea because if the air circulation to the unit is restricted, it cannot reject heat efficiently and system performance will be degraded.

The outdoor unit should also be elevated to keep the coils free of snow and other debris such as leaves. In Virginia, code requires that units be elevated at least 3” above grade, but more elevation may be desirable in areas with a lot of snow.

If possible, the outdoor unit should be shaded from direct sunlight in summer so that it may run cooler and reject heat more efficiently. Ideally, it should be located so that it is shaded in summer, but exposed to sunlight in winter to improve wintertime heating performance. Don’t place the unit directly under a roof pitch that might dump snow onto the unit in winter.

If your outdoor unit is improperly located or protected, consult with your service contractor about having it relocated.

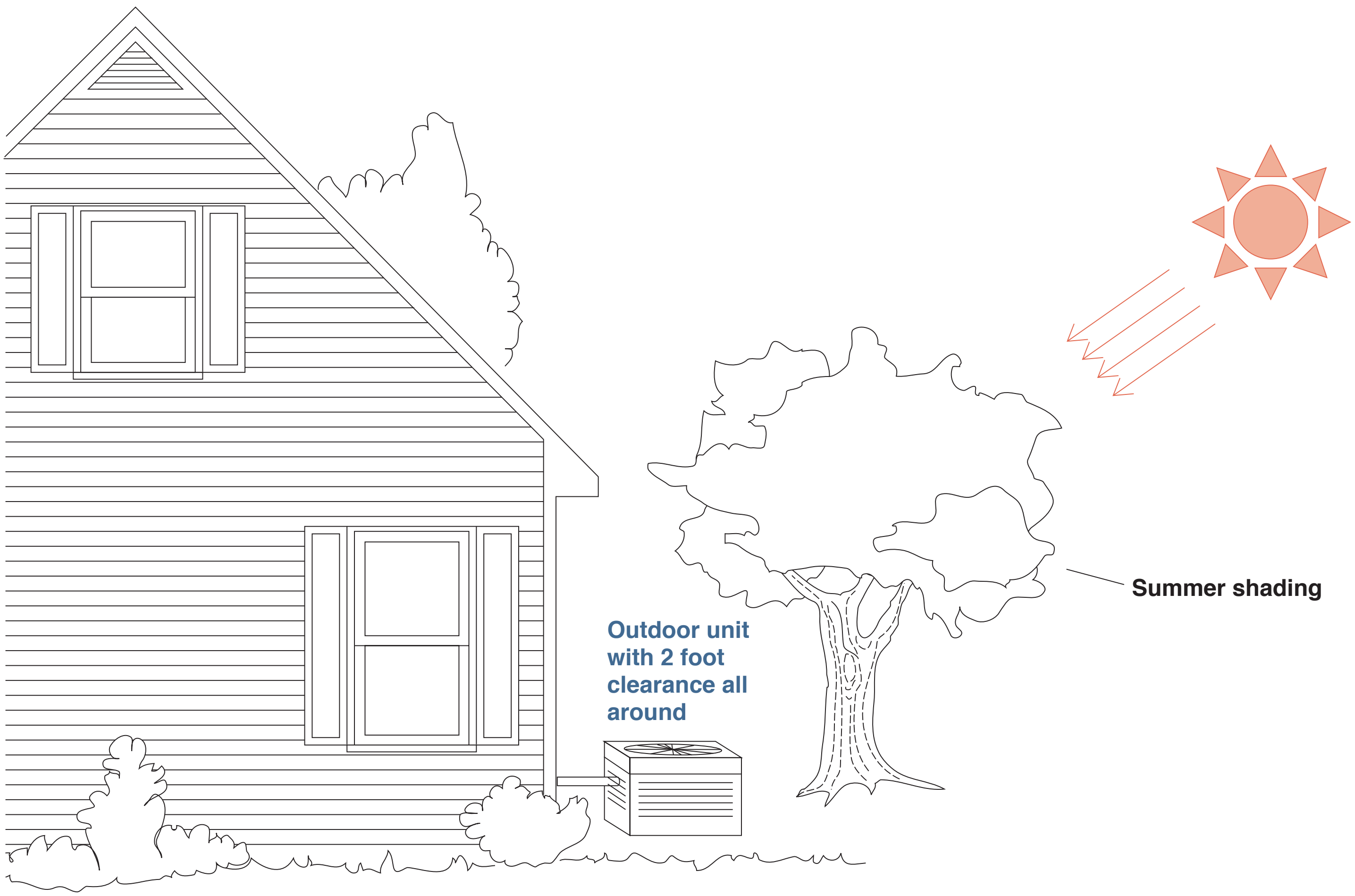


Figure 5-11 - Air conditioner unit with proper ventilation and sun protection

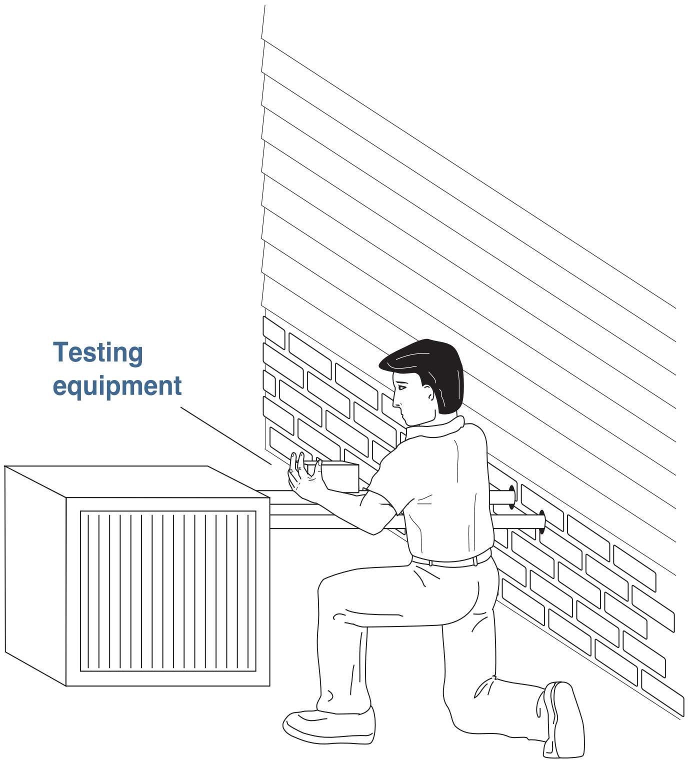


Figure 5-12- Service person should check refrigerant charge as part of routine inspection.

Call for a service inspection and maintenance

Have your service contractor perform all the following inspections and maintenance procedures.

1. Inspect and clean both indoor and outdoor coils

The indoor coil in your air conditioner acts as a magnet for dust because it is constantly wetted during the cooling season. Dirt buildup on the indoor coil is the single most common cause of poor efficiency. The outdoor coil should also be checked and cleaned if necessary.

2. Check the refrigerant charge

The circulating fluid in your heat pump or air conditioner is a special refrigerant gas that is put in when the system is installed. If the system is overcharged or undercharged with refrigerant, it will not work properly. Have your service contractor check the charge and adjust if necessary.

3. Check the airflow over the indoor coil

All residential air conditioners are designed for a specific volume of airflow across the indoor coil — typically about 400 cfm per ton of cooling (A "ton" of cooling equals 12,000 Btu/hr - the amount of heat necessary to melt one ton of ice in a day.)

Low airflow can be caused by dirty filters, dirty blowers, dirty coils, closed supply registers, or (most commonly) by improper duct sizing. Although the remedy to this problem may not be simple, it could significantly improve system performance.

Upgrading to High Efficiency Heating and Cooling Equipment

When to replace your existing system

Deciding when to replace an old system is not easy. Unless your present system is old and in very poor working condition, it may be hard to justify a new high efficiency system on energy savings alone.

The most important information comes from your service contractor. If a heating system's steady state operating efficiency is lower than 70%, you should consider a new unit. Particularly for a large home with a high heating load, the annual dollar savings from installing a new system may pay for the new system in a short time.

Ask your contractor to do a load calculation to determine the proper sizing of your system. If your system is undersized or oversized, this may be an additional reason to replace the existing system.

For heat pumps and air conditioners, the situation is not as straightforward since it is not easy to measure the efficiency. If your system loses cooling capacity or if the compressor fails completely, you may want to take the opportunity to move up to a high efficiency system rather than just replace the old compressor. Sometimes a failed compressor is just the first of many component failures that may end up costing you more in the long run.

Shopping for efficiency

Discussing efficiency of home heating and cooling appliances can sometimes turn into alphabet soup - AFUE, EER, SEER, HSPF, are all common terms for expressing how well a system uses energy to heat or cool the home. Despite the apparent complexity, the basic concepts are relatively simple. Be sure to look for Energy Star certified

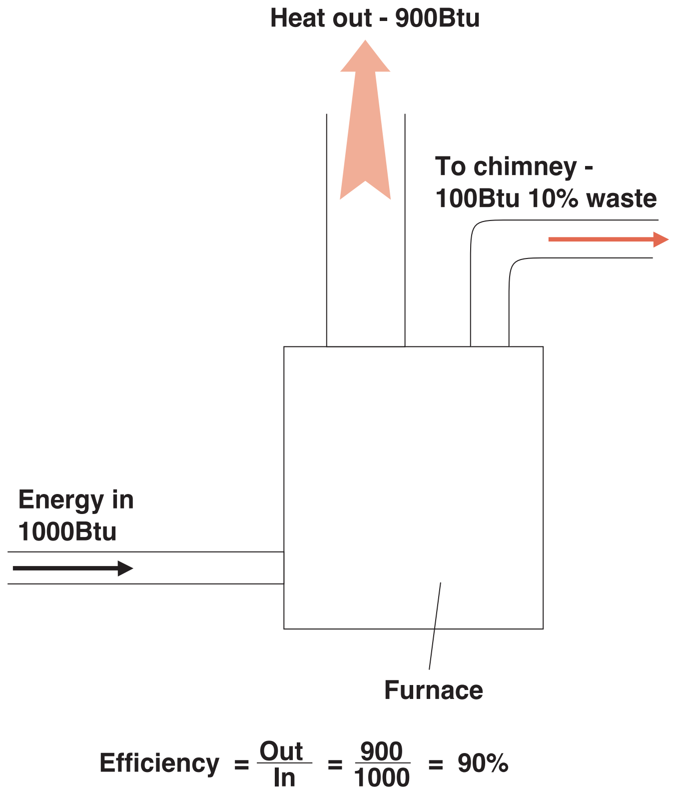


Figure 5-13 - Efficiency is defined as "heat out" divided by "energy in".

equipment. They will always rank in the highest classifications of AFUE, EER, SEER, and HSPF.

"Efficiency" is defined simply as "heat output" divided by "energy input"

Let's look at a gas furnace. It uses the chemical energy contained in natural gas (the energy input) to deliver warm air into the house (the heat output). If the furnace delivers 900 Btu of heat per cubic foot of gas (which contains 1000 Btu), then the efficiency is 90%. The other 10% is lost up the chimney.

As another example, consider an electric space heater that converts electric energy into heat energy. Because it is located in the heated space and has no flue losses, it delivers exactly 3413 Btu of heat for every kWh of electricity consumed (1 kWh = 3413 Btu). Electric space heaters are always 100% efficient. Since electricity costs much more per Btu than gas, however, this doesn't translate into low energy costs.

Many modern fuel-burning appliances have efficiencies above 90%, but old poorly maintained units are sometimes as low as 50%.

The AFUE denotes furnace and boiler efficiency over an entire heating season

Furnaces and boilers are rated according to their "Annual Fuel Utilization Efficiency" or AFUE, which is a measure of efficiency over an entire heating season. Heating equipment may have a different efficiency at part load (cool weather) than it does at full load (very cold weather). AFUE gives the average efficiency for a typical winter, using a formula developed at the U.S. Department of Energy. (USDOE)

Heat pump efficiency is measured by the HSPF

Heat pumps do more than just convert electricity into heat; they pump heat from outdoors to indoors (see description above). The heat output is almost always more than the input.

Since the performance of a heat pump depends on outdoor temperature, we use the term "Heating Season Performance Factor" (HSPF) which is the total heat output over a typical heating season, measured in thousand Btu's, divided by the total electric input in kilowatt hours. Typical HSPF for modern heat pumps ranges from 6.8 to around 10.0. Like the AFUE for furnaces and boilers, the HSPF is calculated using a formula developed by USDOE.

Since lower outdoor temperatures decrease heat pump efficiency, heat pump HSPF depends on climate. If you live in a cold area, the performance of a heat pump will be lower than the HSPF for a typical season; if you live in a warm area it will be higher.

Air conditioners are rated by EER or SEER

Air conditioner performance is expressed as the "Energy Efficiency Ratio" (EER) or "Seasonal Energy Efficiency Ratio" (SEER). The EER is the amount of heat energy removed from the house when the air conditioner is running, measured in thousand Btu's, divided by the amount of electricity used, measured in kilowatt hours. EER is always listed for window air conditioners, but is usually not listed for central air conditioners or heat pumps.

High efficiency window air conditioners have EER ratings of 10.0 or above.

SEER is the seasonal efficiency of an air conditioner, essentially the average EER over a typical summer. It is calculated as the amount of heat removed from the house over an entire cooling season, in thousand Btu's, divided by the electricity consumed, in kilowatt hours. SEER is always listed for central air conditioners and heat pumps.

High efficiency central air conditioners have SEER ranging from 10.0 to as high as 17.0.

The Federal Standards

The National Appliance Energy Conservation Act (NAECA) sets minimum efficiency standards for all home heating and cooling equipment. All new equipment for sale must meet NAECA standards. You can save money and energy, however, by buying equipment that exceeds the minimum NAECA standards.

The Federal Energy Management Program (FEMP) lists recommended efficiencies and the efficiencies of the best equipment currently available. The FEMP recommended efficiency is also the minimum efficiency allowed for Energy Star labeling.

Consider your fuel options

When replacing your existing heating or cooling system, you may want to consider switching to a different fuel. The best fuel for you may not be immediately obvious.

When selecting fuel type, you need to consider both efficiency and cost (and of course availability).

Which fuel is most expensive? That depends on both purchase price and the efficiency of your heating system. Together they determine the delivered cost of energy to heat your home.

Table 5-2 lists the purchase price per million Btu for the common residential fuels used in Virginia. Notice that electricity is more than three times as expensive as natural gas. But this doesn't mean that electricity is always the most expensive fuel to use.

Table 5-3 lists the delivered energy cost for various types of heating systems and fuel types. Notice that a high efficiency electric heat pump (9.0 HSPF) is less expensive to operate over a typical heating season than an oil or gas furnace. In colder climates heat pump HSPF decreases while furnace AFUE stays fairly constant, so the relative cost of heat pump and furnace operation may change.

Table 5-1 – Recommended and Best Available efficiencies for heating and cooling appliances according to the Federal Energy Management Program.

Equipment	Performance Units	Recommended	Best Available
Air Conditioners			
Window < 20,000 Btu/hr	EER	10.7	11.7
Window > 20,000 Btu/hr	EER	9.4	10.0
Central Split-System	EER SEER	11.0 13.0	14.6 16.5
Central Unitary	EER SEER	10.5 12.0	12.2 16.0
Heat Pumps			
Air-Source Split-System	HSPF EER SEER	8.0 11.0 13.0	9.6 14.9 17.4
Air-Source Unitary	HSPF EER SEER	7.6 10.5 12.0	8.3 12.0 15.6
Ground-Source Closed Loop	EER	14.1	25.8
Ground-Source Open Loop	EER	16.2	31.1
Furnaces			
Gas and Oil Furnaces	AFUE	90%	97%

Table 5-2 - Fuel prices in Virginia

Fuel type	Cost per million Btu purchased(2000 average prices)
Electricity	$22.04
Propane	$17.34
Natural gas	$9.64
Fuel oil	$9.47
Coal	$3.12

Table 5-3 - Delivered energy costs with various types of heating systems.

System type	Cost per million Btu delivered (1993 average prices)
100% electric space heater	$22.73
80% oil boiler	$10.25
78% natural gas furnace	$9.52
9.0 HSPF heat pump	$8.44
93% natural gas furnace	$7.99

NOTE To calculate the cost per million Btu of delivered energy at differing fuel prices, use the following equation:

Cost per million Btu ($) = (Unit fuel price) x 1,000,000 / (Btu per fuel unit)(Table 4)

Example: For electricity at $.06 per kWh:

Cost = ($.06) x 1,000,000 / 3413 Btu per kWh
= $17.58

Table 5-4 - Btu content in various fuel units

Fuel Type	Unit	Btu content
Electricity	kWh	3,413 Btu/kWh
Natural gas	ccf	100,000 Btu/ccf
Propane	gallon	96,000 Btu/gallon
Fuel oil	gallon	138,000 Btu/gallon
Coal	ton	27 million Btu/ton

For gas heating, consider a power vented or sealed combustion furnace or boiler

"Atmospheric vented" or "natural draft" furnaces and boilers, which rely on natural buoyancy to carry flue gases up the chimney, are sometimes subject to flue gas "spillage" or "backdrafting" into the house. The cause of the problem is competition between the furnace and other exhaust appliances such as clothes dryers, central vacuum cleaners, range-top stove exhaust fans, and even bathroom exhaust fans. The negative indoor pressure created by those fans can reverse the flow in the chimney, drawing the flue gases back into the house.

Power vented furnaces and boilers have a small blower that pulls combustion air to the heating system, making them much thus less prone to spillage or backdrafting. Sealed combustion furnaces are also power-vented and use outdoor air for combustion, making them completely immune to the problem.

But in all cases, make sure that your vent pipes and chimney are code and manufacturer approved and that they are clean and unobstructed. Backdrafting or spillage can result from obstructed or improper venting.

Operating Your System For Maximum Efficiency

Never turn the thermostat up high for faster heating

Your thermostat is an on-off switch that simply goes to "on" whenever the temperature in the house passes the setpoint. Simple as it is, the way you use your thermostat can significantly affect your heating and cooling energy consumption.

Unlike a gas pedal in a car, pushing the thermostat higher does not usually make the house heat or cool any faster. It just makes the system run longer. The system runs at maximum capacity as long as the thermostat calls for heating or cooling. By pushing the thermostat farther, you may cause the house to overheat or overcool, thus wasting energy.

One exception to this is with heat pumps. Pushing the thermostat higher with heat pumps may bring on the auxiliary electric resistance heater. Although you will get more heat, it will be expensive due to the high operating cost of electric resistance heat.

Reduce your thermostat setting whenever the house is unoccupied

Thermostat setback in winter and setup in summer always saves energy. As a rule of thumb, you will save about 3% for each degree of setback. Keep the thermostat set as low as you can in the winter and as high as you can in the summer. A rule of thumb setting is 78°F in the summer and 68°F in the winter but this depends on different variables. The important thing is to understand that how you set or operate your thermostat can have a very significant impact on your energy bill. Your house is a system and even if your home is well insulated with an energy efficient heating and cooling system, this can all be minimized if you operate your thermostat inefficiently.

One possible exception is with heat pumps, which may resort to supplemental resistance heat to recover from setback. In general, there is little to be gained by manually setting back a heat pump thermostat unless it can be left set back for 24 hours or more.

Programmable thermostats can save as much as 10% on your heating and cooling bill by automatically setting the thermostat when the house is not occupied or when the occupants are asleep. Using a programmable thermostat allows you to adjust the times you turn on a heating or cooling system according to a pre-set schedule. Be sure to look for the Energy Star label if shopping for a programmable thermostat.

A few special programmable thermostats are made specifically for heat pumps. These thermostats start the heat pump early – before the heat is required – and then use electric resistance heat to warm the house only if the heat pump is unable to get the job done on time.

Use the sun wisely in both summer and winter

The primary source of cooling load in summer is solar heat gain through windows. By controlling sunshine into windows with interior shades, exterior shutters or yard plantings, you will make the house more comfortable and reduce cooling energy costs.

In winter, solar gain through windows can provide useful space heating energy.

On sunny days, keep window shades open on south-, east-, and west-facing sides of the house.

For more information on passive solar heating see Chapter 10.

Wood Burning Appliances

Wood heating appliances have changed radically over the past decade. Modern wood stoves are far more efficient and clean burning than their pot-bellied predecessors. The efficiency of new wood heating appliances ranges from 65% to 78% and averages about 72%. Although this efficiency is lower than that for gas or oil-fired furnaces, wood heat may still be the most economical alternative in areas where wood is plentiful and inexpensive.

Wood heat and the environment

Although wood heat is generally regarded as "environmentally friendly" since wood is a renewable resource, wood smoke contains a plethora of combustion products, many of which are potentially hazardous air pollutants such as carbon monoxide and "polycyclic organic material" (POM). In some regions with climatic temperature inversions, such as Juneau, Alaska and Denver, Colorado, local authorities have passed ordinances limiting the use of wood stoves and/or requiring special low-emission stoves.

In 1988, the U.S. Environmental Protection Agency (EPA) passed emission standards for new wood stoves and fireplace inserts. The regulations reduce the average smoke production from about 3 pounds per day, which is typical for most older wood stoves, to less than 1/2 pound per day from stoves that meet EPA standards. All new wood stoves manufactured after July 1, 1990, or sold at retail after July 1, 1992, must now be tested and certified to meet the new EPA standards.

Although the reason behind the new standard is to control outdoor air pollution, two side benefits are increased efficiency and safety (less creosote formation and thus less fire hazard).

To comply with the standards, manufacturers have redesigned appliances and added new technologies. The most common new component is the "catalytic combustors".

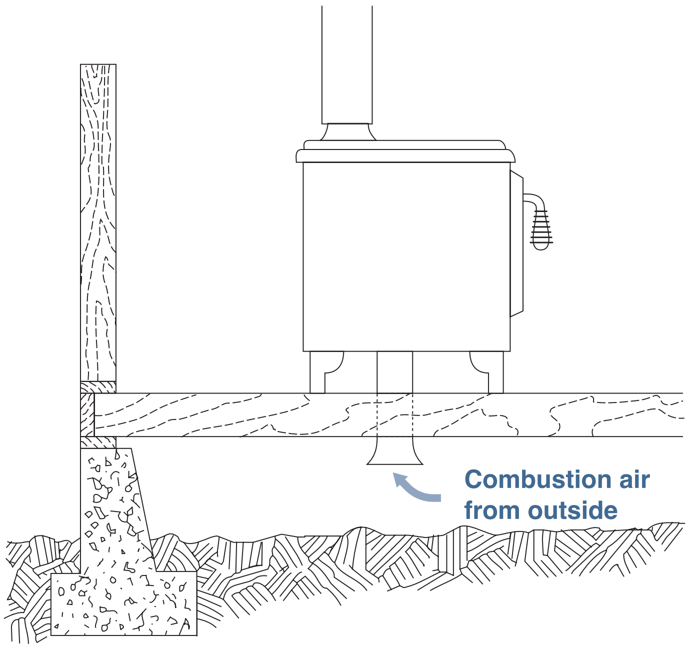


Figure 5-14 - Wood stoves should have outdoor combustion air intakes to avoid backdrafting and to reduce air leakage into the house.

A catalytic combustor is similar to the catalytic converter in a car. A metallic catalyst (usually platinum or palladium) on the combustor enhances smoke combustion at lower temperature so that more smoke is burned and less is exhausted up the chimney.

Catalytic combustors are now incorporated into many new wood stoves and can also be added to existing stoves using special retrofit devices. One possible drawback to stoves with catalytic combustors is that the catalyst has a limited lifetime that varies anywhere from 1 to 10 years. The combustors also require some special care to prevent clogging.

Not all certified wood stoves have catalytic combustors. Some manufacturers have improved their designs in other ways to meet federal emission standards without catalytic combustors. The advantage of these appliances is that they should not lose burning efficiency over time as do stoves with catalytic combustors.

Wood furnaces, wood stoves that connect to a duct system to heat the whole house, are exempt from most wood stove emissions regulations and therefore do not usually include catalytic converters. Separate catalytic converters can be bought and installed on wood furnaces, but care must be taken to ensure that the converter does not interfere with the furnace draft.

Selecting a wood stove

Wood stoves are available in a variety of styles, efficiencies, and heating capacities. The following are a few features to check when comparing models:

Sealed Combustion

Wood stoves need large volumes of air for combustion and to help induce draft. This means that large amounts of household air will be needed to make a woodstove burn and draft properly. When selecting a woodstove try to purchase a sealed combustion model or one that can be modified to provide combustion air sources from outside. This is especially important if you live in a mobile home or a house with small volume. Make sure the unit is mobile home approved and certified if you are installing it in a mobile home.

Cast iron versus steel

Some stoves are made from steel plates that are welded together; others are made from cast iron components that are bolted together. Cast iron stoves are typically heavier, take longer to heat up and hold their heat longer after the fire burns out. Neither type is inherently more efficient.

Soapstone

Soapstone wood stoves take advantage of thermal mass principles and stores heat in the soapstone brick. Then it slowly releases the heat long after the fire has gone out. These stoves are environmentally friendly because burning a hot fire for a short time is more efficient, and produces fewer emissions, than burning a low fire for a long time. Soapstone stoves, however, are very expensive.

Fireplace inserts

A fireplace insert is basically a wood stove designed to fit into a conventional open fireplace. Like conventional stoves, inserts may be made of cast iron or steel, and may come with or without glass doors. Some inserts have catalytic combustors, and there are some that burn pellets.

Inserts either fit in the opening of the fireplace or protrude onto the hearth. The latter position is more efficient because the sides, top, and bottom provide additional radiant heat. Some inserts have integral blowers that circulate room air through the heater, providing enhanced heating as well as increased efficiency. The blower may be either manually or thermostatically controlled.

In the past, most installers placed inserts in fireplaces without any chimney connections. This method, in some cases, allowed creosote to build up inside the fireplace, presenting a potential fire hazard. To prevent this, the National Fire Protection Association (# 211) now requires that inserts be installed with a connector between the appliance outlet and the first section of the flue liner. Fireplace inserts have one major drawback: they weigh over 400 pounds. This can be a problem when they need to be moved so that the chimney can be cleaned. However, the insert can stay in place if you install a full relining collar — a stainless steel pipe that connects to the insert and goes to the top of the chimney.

Fan-driven heat exchangers

Many manufacturers supply stoves with fan-driven heat exchangers either as standard or optional equipment. These heat exchangers increase heat output and energy efficiency. Their disadvantages are that they make some noise and that they won't work in case of an electric power failure.

Heat reflecting glass doors

Many stoves come with glass doors and a few manufacturers now use special heat-reflecting glass that improves combustion efficiency by keeping more heat in the stove than with conventional glass.

Convenience features

There are a variety of convenience features available including a thermostat control that automatically controls combustion air, insulated handles for easy door opening without a pot holder, and a removable ash pan for easy ash disposal.

Pellet fuel

Pellet fuel is manufactured from a variety of materials compressed to resemble animal feed. The pellets may be made from sawdust, bark, wood shavings, cardboard, peat, or agricultural wastes like corn husks and rice hulls.

Apart from the fact that they both burn solid fuel, there are few other similarities between pellet stoves and wood stoves. In a pellet stove, the pellets are poured into a hopper, from which an auger, a corkscrew-shaped device, transfers the pellets into the fire chamber as needed. A mechanical blower provides combustion air and other fans distribute the heat into the living area. The rate at which the fuel is burned and the speed of the fans may be controlled by thermostats. Some pellet-burning appliances use elaborate electronic circuitry that does everything from controlling the circulation air to sounding a buzzer to let the user know the stove is low on fuel.

A major advantage of pellet stoves is that they need to be refueled less frequently than most wood stoves; refueling varies from once a day to only twice a week. Pellet stoves pollute very little and are highly efficient, with an average efficiency of 78%. The creation of creosote and ash is reduced or eliminated, depending on the type of pellet being burned. The flue gases are relatively cool and can be exhausted through a side vent in the wall to the outdoors. The exterior surfaces of the heater are also relatively cool, reducing the risk of accidental contact burns.

However, pellet-burning appliances also have disadvantages. The internal fans, which may require around 100 kWh of electricity each month, add to the total energy bill. Also, since the fans are necessary for operation, the stove will not function during a power outage. Because using pellets is a relatively new way to burn fuel, the fuel is expensive and often difficult to find.

Chimney safety

Studies have shown that house fires related to solid fuel heating appliances often originate around the chimney or stovepipe. The main causes of fires are insufficient clearance from combustibles, creosote build-up, use of a single-walled stovepipe as a chimney, and leaks and cracks in the chimney. Chimneys require some care and attention in order to reduce fire hazards.

All chimneys that service a wood-burning appliance should be lined with a code-approved liner. Chimney liners come in three main types: Clay tile, metal, and cast-in-place. Clay tiles are the most common and if kept clean they perform fairly well. But they can deteriorate due to moisture and crack because of expansion. They are not suitable for gas appliances and if cracked or in disrepair they should be replaced. Metal chimney liners, usually stainless steel or aluminum, are commonly used for upgrading and repairing existing chimneys. These liners are very safe and durable and if properly installed keep the flue gases hot, which promotes draft and inhibits creosote build up. They generally work best with an approved high temperature insulation installed on the outside of the liner. Metal liners work well with wood, oil, and gas and the aluminum liners can be used very effectively in certain gas applications. Cast-in-place liners are made of a light-weight cement product and are excellent for restoring the structural integrity to old chimneys. They are very durable and are suitable for all fuels. But they can also be very expensive to install.

An unlined chimney can have cracks, missing bricks and mortar that has deteriorated and is non-existing. This is not only a fire hazard but allows cool winter air to infiltrate the chimney and dilute the hot flue gases. This dilution will cool the hot flue gases and cause condensation that can lead to chimney deterioration and creosote build up, and will impede draft – cooler flue gas will be heavier and exit the chimney slower – which can effect the efficiency of your furnace and make back-drafting more possible.

Stoves and chimneys should be installed according to the manufacturer's instructions, and inspected by a local fire or building inspector. The chimney or stovepipe must be as specified in the installation instructions for the appliance, and if a chimney connector is required, it must be of the correct gauge (thickness). Chimney connectors should be kept at least 18 inches from stud walls, ceilings, curtains, or any combustible materials. Achieving proper clearances from combustibles is a critical safety measure in preventing residential fires. Consult your local building inspector, a licensed heating contractor, or a local fire marshal if you are unsure about clearance requirements. Chimney cleanouts should be installed to make soot and creosote removal easy, especially for woodstoves. Where the chimney exits from the roof it should be at least three feet taller than the roof, and two feet taller than any roof surfaces within ten feet.

In using the appliance, there are several things that can be done to prevent creosote build-up. Start each fire at a high burn rate for about 30 minutes to bring all surfaces up to operating temperatures. Short, hot fires are more efficient and produce less creosote than long, slow-burning fires. Avoid overloading the stove. Try to burn only dry and seasoned wood. Green wood is full of moisture, which will produce a cooler flame and flue gas and promote creosote formation.

Finally, chimneys should be inspected and cleaned if necessary at least once a year and stovepipe should be checked every few weeks. Be sure that the chimney and stovepipe are clean and show no signs of wear or deterioration. Creosote should be removed when it accumulates to one-eighth to one-quarter of an inch. Consider using the services of a professional chimney sweep on an annual basis to clean your chimney and provide a thorough safety inspection of your entire venting system. Be sure that the chimney sweep is qualified, experienced, and has references.

It is absolutely imperative that you have UL- rated smoke alarms and carbon monoxide detectors placed in appropriate places within the home – whether you use wood as a fuel or have any combustion appliance in the home. Consult your local building inspector or fire department if you need more information. Smoke alarms and carbon monoxide detectors are mandatory safeguards that save lives on a daily basis.

Un-vented Heating Systems

Un-vented combustion space heaters, which include natural gas, propane, and kerosene fueled free standing heaters, fireplaces, unvented gas logs and wall- mounted heaters are not recommended due to significant health and safety concerns. These systems are growing in popularity even though vent-free heaters have been banned for use in homes in five different states.

Unvented combustion heaters use indoor air for combustion and vent the combustion by-products directly into the living space. These by-products include nitrogen oxide, carbon monoxide, and large amounts of water vapor that can cause mildew, condensation, mold, and potential for rotting of walls and ceilings.

Unvented heater manufacturers claim that the systems are safe because they operate with maximum combustion efficiency. But this is only possibly true if nearby windows are cracked open and the system is installed correctly, properly maintained, and operated according to manufacturers specifications. Gas heaters are also required to have oxygen depletion sensors that will cut off the gas if the oxygen in the room is depleted below acceptable levels. These systems should never be used in a room where people are sleeping or where it will be unattended and should never be used in mobile homes or air-tight houses.

With all of the potential problems that exist, it is recommended to avoid the use and purchase of unvented heating systems.

Energy Tips and Recommendations

1. Reduce your heating and cooling load by treating your house as a system and recognizing that a well insulated, air tightened house with good energy decision making occupants will be a household that is much easier to heat and cool.
2. You may significantly improve the heating and cooling systems in your home by replacing them with more efficient units, by repairing and maintaining the units and the distribution system, by operating them more efficiently, and by making sure that the venting systems are safe and in good condition.
3. Be sure to consider all options before replacing your heating or cooling system. Obtain professional advice if necessary and always check the Annual Fuel Utilization Efficiency (AFUE) rating on furnaces and boilers, the Heating System Performance Factor (HPSF) for heat pumps, the Energy Efficiency Ratio (EER) for window air conditioners, and the Seasonal Energy Efficiency Ration (SEER) for central air conditioners. Make sure any new heating or cooling system you may purchase has an Energy Star label.
4. Change your furnace and air conditioner filters every one to three months or whenever necessary.
5. Be sure to have your duct system tested for air leakage by a professional. Duct leakage can account for significant energy loss and potential health and safety issues.
6. Make sure that your duct system is properly insulated – particularly if it is in an unconditioned space.
7. Get your heating and cooling systems inspected by a professional - preferably on an annual basis. The inspection should be thorough and include the use of testing and diagnostic equipment. All systems should be checked for efficiency and safety.
8. Use your thermostat to maximize the efficiency of your heating and cooling systems. Set your thermostat for 68°F in winter / 78°F in summer, don't turn it up high for faster heating, and (except for heat pump systems) set back the temperature when the house is unoccupied.
9. Use the sun to maximize solar heat gain in the winter and find ways to control that solar heat gain in the summer.
10. Make sure that all wood burning appliances are installed correctly and have adequate clearances from any combustibles.
11. All vent pipe and chimneys should be cleaned on an annual basis or sooner if needed. Be sure that all chimneys are properly lined and free of any obstructions.
12. Avoid using any unvented heating system, including portable kerosene heaters, unvented gas logs, unvented gas fireplaces, and unvented wall mounted heaters.
13. Install UL rated smoke alarms and carbon monoxide detectors in all recommended locations within the home.

WATER HEATING

In the average American home, water heating accounts for about 20% of total household energy consumption. In Virginia, the average household spends between $200 and $500 per year for heating water. Households with natural gas water heaters spend about $250, while those with electric water heaters are likely to spend closer to $400 or $500.

If your gas or oil water heater is more than fifteen years old, it probably has an efficiency no higher than 50%. If you have an electric water heater, its efficiency is probably high, but the high cost per Btu of electricity makes it expensive to operate. One obvious way to reduce water heating energy costs would be to replace your old heater with a higher efficiency model or with one using a cheaper source of energy. However, before looking at new water heaters, you should consider several no cost/low cost measures to improve the efficiency of your current system. This chapter begins with a discussion of ways to improve your current system and then describes how to select a new high-efficiency replacement water heater for your home.

Types of Residential Water Heaters

Several different types of residential water heaters are available. Table 6-1 on page 79 gives approximate installation and operating costs for each type of heater.

Storage water heaters

The vast majority of water heaters are storage type, which consist of an insulated tank with gas burner, oil burner or electric resistance heating element. As hot water is drawn off near the top of the tank, cold water replaces it at the bottom.

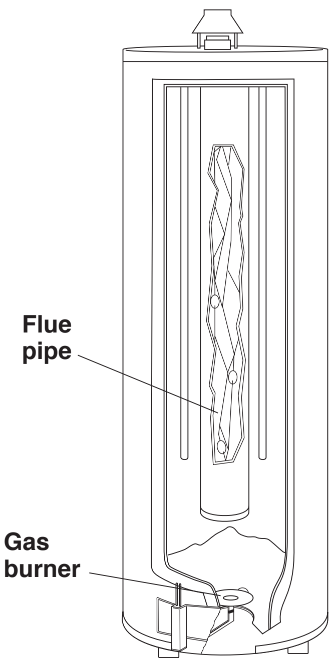


Figure 6-1a

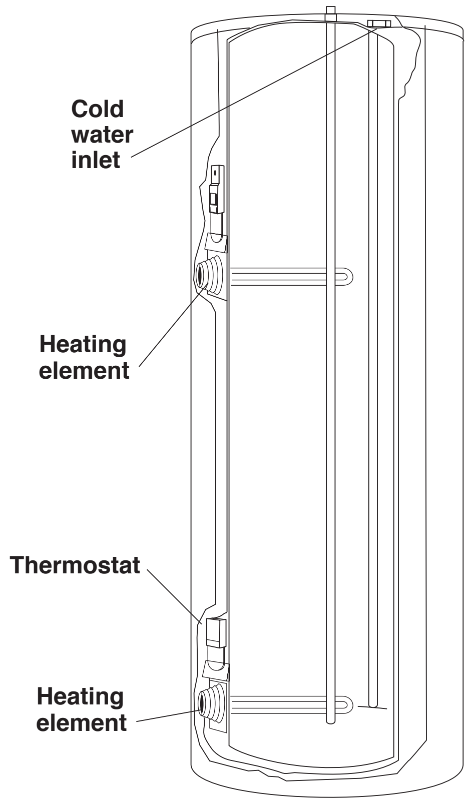


Figure 6-1b

Figure 6-1 - Storage type water heaters are by far the most common type of residential water heater. Figure 6-1a: Gas and Figure 6-1b: Electric

Table 6-1- Life-Cycle Costs for 13-year Operation of Different Types of Water Heaters

Water Heater Type	Eff.	Cost(1)	Yearly Energy Cost(2)	Life (years)	Cost over 13 years(3)
Conventional gas storage	55%	$425	$163	13	$2,544
High-eff. gas storage	62%	$500	$145	13	$2,385
Oil-fired free-standing	55%	$1,100	$228	8	$4,751
Conventional Electric Storage	90%	$425	$390	13	$5,495
High-eff. electric storage	94%	$500	$374	13	$5,362
Demand gas	70%	$650	$140	20	$2,243
Demand electric (2 units)	100%	$600	$400	20	$5,590
Electric Heat Pump	220%	$1,200	$160	13	$3,280
Indirect water heater with efficient gas or oil boiler	75%	$700	$150	30	$2,253
Solar with electric back-up	(4)	$2,500	$125	20	$3,250

Notes:
1. Approximate cost of appliance plus installation.
2. Energy costs based on hot water needs for typical family of four and energy costs of 8c./kWh for electricity; 60c./therm for gas; $1.00/gallon for oil.
3. Future operating costs are neither discounted nor adjusted for inflation. Source: American Council for an Energy-Efficient Economy, *Consumer Guide to Home Energy Saving,* 1996.
4. The efficiency value normally listed for solar water heating systems is not the same as for fuel-burning systems. It is the percent of the total solar radiation that is captured as useful heat. Since the solar energy itself is free, efficiency comparisons electric, gas, or oil heaters are not meaningful.

The most important energy related feature of storage water heaters is the amount of insulation on the tank. The best heaters have 2 to 3 inches of urethane foam, providing R-values as high as R-20. Other less expensive models have fiberglass tank insulation with R-values ranging between R-7 and R-10. (See Chapter 3 for discussion of R-value and insulation.) Storage water heaters range in size from 20 to 80 gallons.

Demand water heaters

Demand or instantaneous water heaters have no storage capacity. Water is heated as needed. When you turn on the hot water tap, the gas burner or electric element comes on and water is heated as it flows through the water heater.

One drawback of demand water heaters is limited output capacity. The largest gas-fired demand water heater can supply only 3 gallons per minute at a temperature rise of 90°F (from 50°to 140°, for example) — not enough for two simultaneous showers.

Electric models typically have even lower output. As a result, demand water heaters are better suited for low-use applications like vacation homes, rather than full-size homes with two or three baths.

It is possible to install a separate demand heater for each bath. This is energy efficient since it reduces heat losses from pipes, and saves water since it eliminates most of the wait for hot water to reach the tap. Initial costs, however, are high.

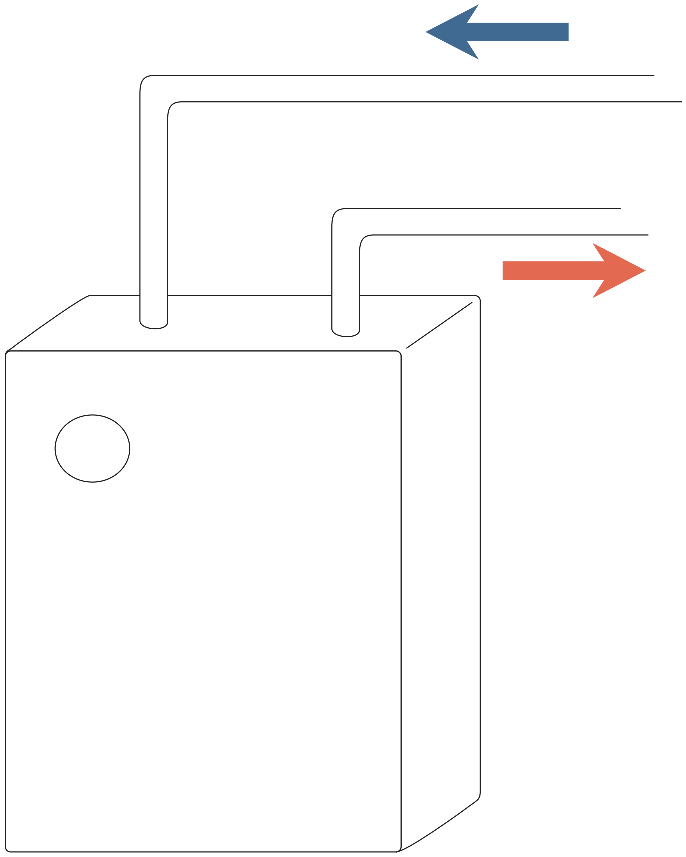


Figure 6-2 - Demand water heaters offer energy savings, but they can't heat water quickly enough to satisfy most American households.

Indirect water heaters

Indirect water heaters do not have their own heating source, but instead use the hot water from the boiler of the house heating system. The hot water from the boiler is circulated through a submerged heat exchanger in the water heater tank. When used in conjunction with a high efficiency boiler, this is one of the most efficient ways to heat water.

Heat pump water heaters

Heat pump water heaters use electricity, but work on a completely different principle than regular electric water heaters. A heat pump water heater extracts heat from the air inside the house, air outside, or spaces like the garage or basement, concentrates it to a higher temperature, and uses it to heat water in a storage tank. Just like heat pumps for home heating (see Chapter 5), they use a compressor to "pump" heat from a cooler source (air or the ground) into the hot water.

Since much of the heat required by heat pump water heaters comes from the surroundings, rather than the power line, they are very efficient.

Triple-integrated heat pumps

A few manufacturers now sell "triple integrated" heat pumps that not only heat and cool the house, but also heat water with very high efficiency. During summer, the heat pump uses waste heat from the air conditioner to heat domestic water — essentially providing free hot water. During winter, the system takes heat from outdoors to provide both space heating and water heating. The winter efficiency varies with outdoor temperature, but is always significantly better than a conventional electric resistance water heater.

Solar water heaters

Since they use free solar energy as the heat source, solar water heaters can provide the greatest savings of all. With solar water heaters, you spend most of the money up front to buy the system; operating costs are quite low. With good solar exposure, a properly designed system should be able to provide up to 80% of hot water requirements in the Virginia climate.

There are a number of different types of solar water heaters. Most common is a flat-plate collector system in which heat transfer fluid is piped through one or more collectors on the roof where it is heated, then through a heat exchanger in a hot water tank where the sun's heat is transferred to your water. Flat plate collectors differ according to the type of piping used (usually copper, but some plastics and EPDM rubber are also used). There are various strategies used for pumping the fluid through the collectors and preventing risk of freezing in cold weather. A few flat-plate collector water heaters operate passively (without pumps), circulating water by natural convection or using a unique geyser-pumping principle. Finally, the simplest solar water heaters of all–called batch solar water heaters– just have a tank of water in an insulated glazed enclosure exposed to sunlight.

Prices for solar water heaters have dropped considerably since they first became popular in the 1970s and 80s. An

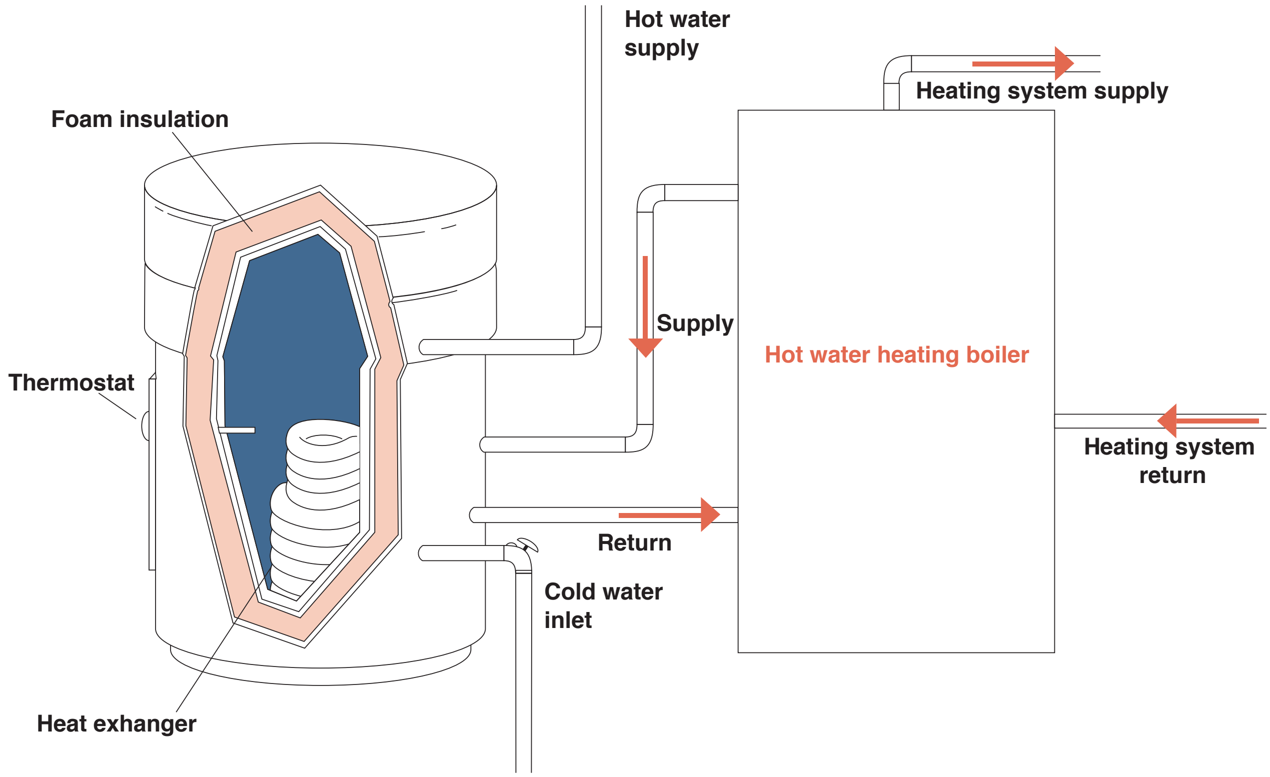


Figure 6-3 - Indirect water heaters take advantage of the higher efficiency of a heating system to provide inexpensive hot water.

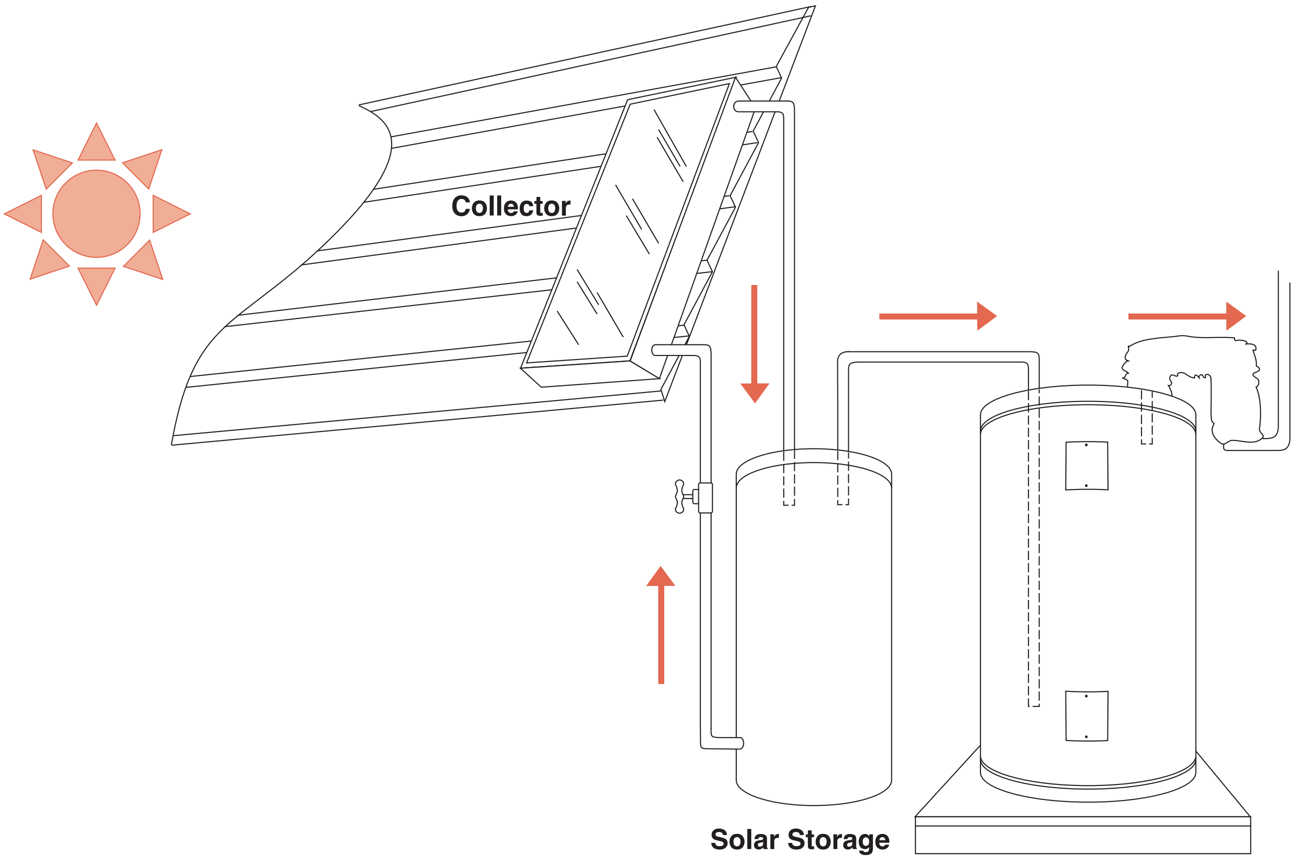


Figure 6-4 - Solar water heaters typically consist of a roof-mounted collecter and storage tank in the house.

installed system typically costs less than $3,000. Despite the high installation cost, solar water heaters can compete economically with electric when total "life-cycle cost" is taken into account. Life-cycle costing takes into account both installed cost and cost of operation over the life of the heater. Table 1 on page 79 compares the life-cycle cost of solar water heaters to conventional gas, electric and oil heaters. Notice that although it is not the least expensive heater on the list, the solar water heater costs far less to own and operate than several of the conventional water heaters.

Energy Efficient Water Heating

Turn down your water heater temperature

Each 10°F reduction in your water heater temperature will save 3-5 percent on your annual water heating bills. Lowering the water temperature will also increase the lifetime of your water heater and reduce the risk of scalding.

Most water heaters are factory set at around 140°F. For most household uses, that is higher than necessary. Usually, 120 degree water is perfectly adequate for household needs. (One exception is if you have a dishwasher without a booster heater. In this case, you may need to keep the temperature set at 140° for optimal dishwashing performance – see Chapter 7.)

Water heater temperature is controlled by one or more thermostats on the water heater (large electric models have two). With electric water heaters, first turn off power to the water heater at your electric control panel, then open the access panel to get to the controls. If the water heater has been insulated, you will have to open up the blanket to reach the access panel. Simply adjust the dial to the desired temperature level. With larger electric water heaters, be sure to adjust both the upper and lower thermostats. If your water heater only has a few relative settings ("Warm," "Normal," etc.), you can set the dial between these for an intermediate temperature. Consider turning your water heater off or significantly lowering the temperature setting if you are going on vacation or leaving the home unoccupied for more than a few days.

Insulate your water heater

Wrapping your water heater with insulation can reduce water heating energy use by 4% to 9% and pays for itself in less than one year. Some new water heaters come with high

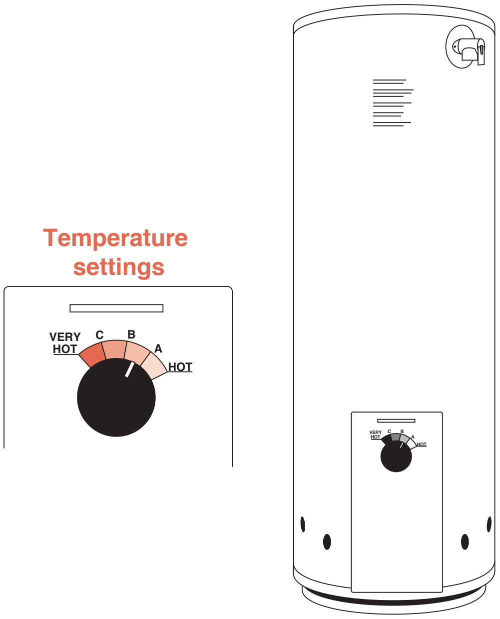


Figure 6-5 - Lowering the temperature setting on your water heater is one of the easiest ways to save on water heating costs.

levels of foam insulation and do not require blankets, but the extra insulation is cost-effective with most older models.

Water heater insulation blankets are widely available at hardware stores and come in standard sizes to fit 40, 60, and 80 gallon water heaters. Most consist of 2" or 3" fiberglass insulation with vinyl facer.

Follow the manufacturer's instructions for installing the blanket. With gas or oil fired water heaters, the insulation must not interfere with the air inlet or the exhaust hood, and the control panel should not be covered. With electric water heaters, it is okay to wrap the entire tank. To allow future temperature adjustment, position the blanket so that the seam lines up with the access panel(s). Pay attention to newer models that specifically say "Do Not Wrap" – this warning is always found on the outside of the tank.

Install water-conserving plumbing fixtures (see Chapter 9)

Reducing hot water consumption naturally reduces the amount of energy necessary for water heating. Studies have shown that low-flow showerheads and faucet aerators reduce

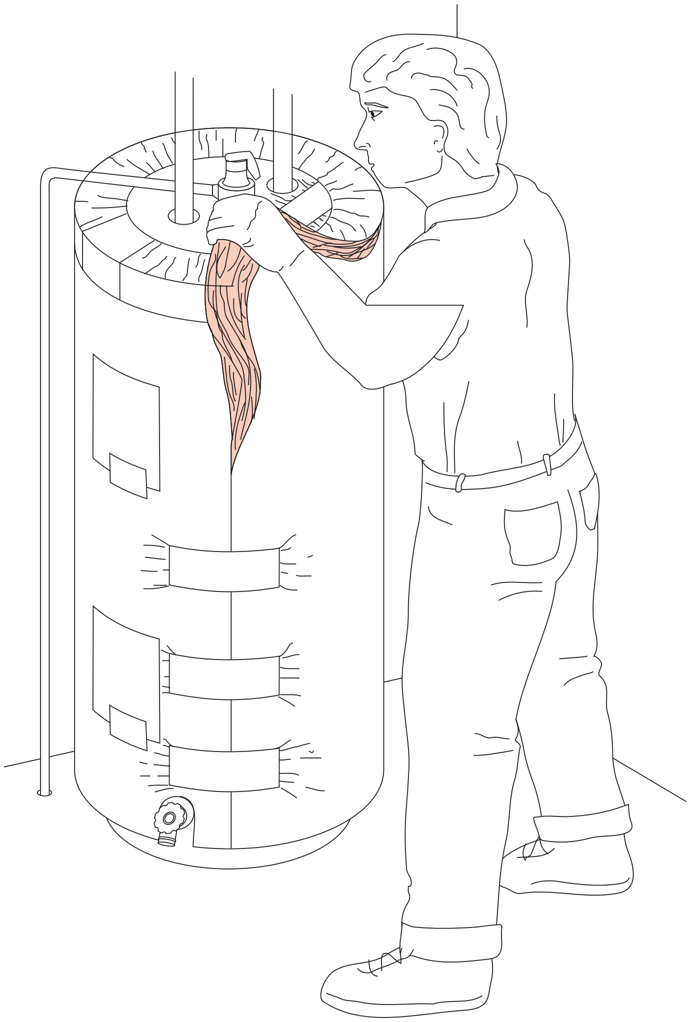


Figure 6-6 - Adding insulation to your water heater is almost always cost-effective, especially with older models.

water heating energy use by up to 50%!

A low-flow showerhead delivers between 2 and 3 gallons per minute — about half the volume of a standard shower head. And unlike some of the early "flow-restrictor" types that produced only a fine mist, high-quality low-flow showerheads now on the market provide perfectly comfortable hot showers.

A top quality low-flow showerhead costs $10-20 and will typically pay for itself in hot water savings in only a few months.

Water saving faucet aerators are another good way to reduce hot water use. Faucet aerators cost just a dollar or two and like low-flow showerheads, pay for themselves in energy savings in just a few months.

Look for aerators that deliver between 1/2 and 1 gallon of water per minute. Some faucet aerators also offer convenient shut-off levers.

Before putting water saving aerators on all your faucets, think about the specific uses. For example, in the kitchen, where you want high flow to fill cooking pots, an aerator may be annoying.

Showerheads and faucet aerators are easy to install. Removing the old one is often the most difficult part and may require pliers or a pipe wrench. Use a cloth to protect chrome pipes and fittings.

Insulate hot water pipes

Hot water pipes should be insulated wherever they are accessible. Pipe insulation not only saves energy, but also keeps water in the pipes warm. Either pre-formed foam insulation or wrap-around fiberglass insulation can be used. Costs range from about $.10 per foot for fiberglass up to about $.60 per foot for foam.

Cold water pipes should also be insulated within 3 or 4

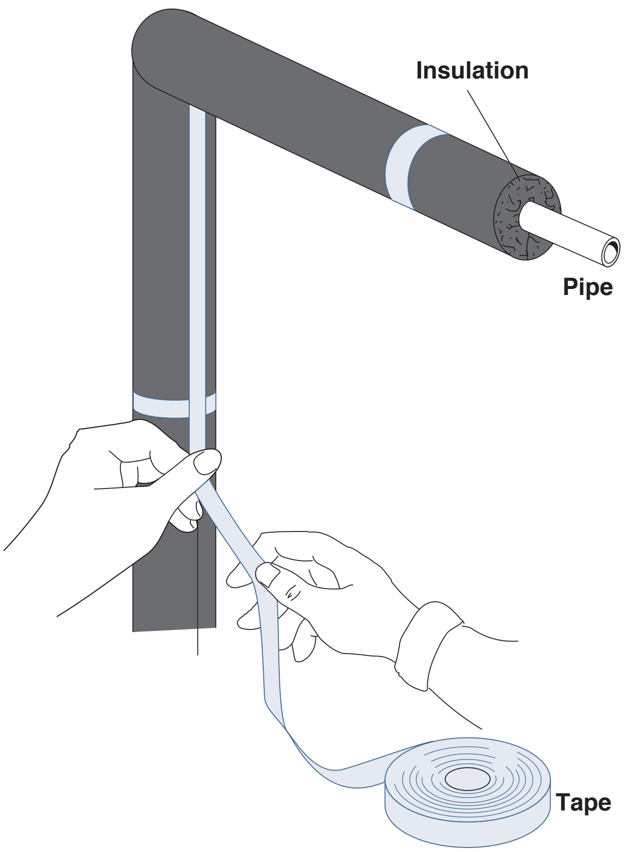


Figure 6-7 - Pipe insulation around your hot water pipes is good both for energy savings and comfort.

feet of the water heater, or between the water heater and heat traps (see heat traps below).

Install heat traps

Heat traps are valves or piping loops that are installed in the hot and cold water lines to prevent water from circulating when the heater is off. They cost around $30 plus installation.

Experts disagree as to the effectiveness of heat traps. If no other work is being done to your water heater, it will be hard to justify the cost of having a plumber make a special trip just to install heat traps (insulating the pipes is more cost-effective). If the water heater is being relocated or replaced, heat traps are probably a good idea.

Fix leaky faucets

Dripping faucets can waste significant quantities of water and energy. A leaky hot water faucet dripping at a rate of one pint per hour will waste 1,092 gallons or water per year. Dripping faucets can often be fixed simply by replacing a washer. (see Chapter 9)

Use appliances efficiently

Whenever possible, use the warm water or cold water cycles on your washing machine and the light wash cycle on your dishwasher (see Chapter 7).

Don't heat water when you don't need it

Special water heater timers are available that turn the heater off at night when you don't need hot water and on again in the morning in time for the morning showers. A simple timer costs around $30; more sophisticated multi-setting timers cost up to $100.

Another obvious energy saver is to turn your heater down or off completely when away on vacations.

Buying a New Water Heater

If you are replacing an older water heater, you have an opportunity to choose a more efficient model. Even if your existing water heater is in good working order, it makes sense to give some thought to what you might replace it with if and when it does fail. That way, when your water heater dies, you'll be less likely to replace it with just any model your

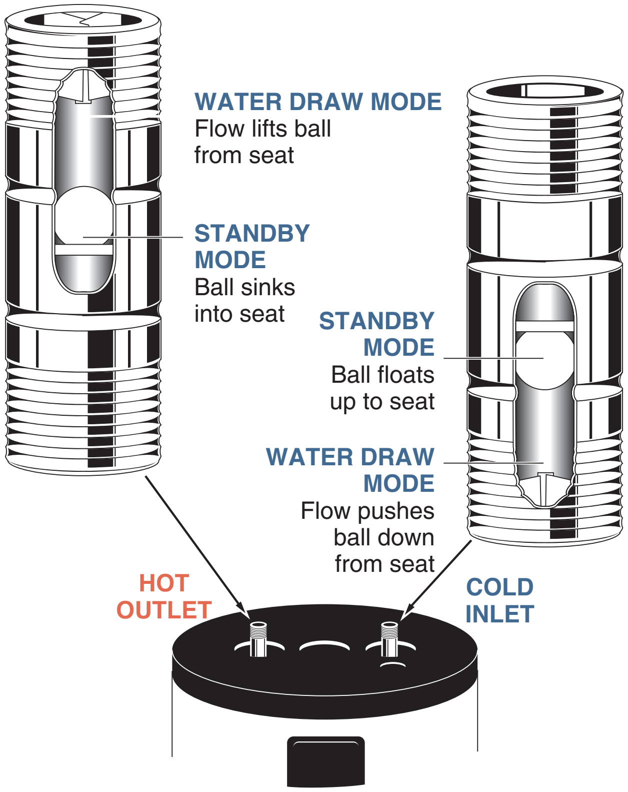


Figure 6-8 - Heat traps installed on the pipes leading to and from your water heater help to reduce stand-by losses.

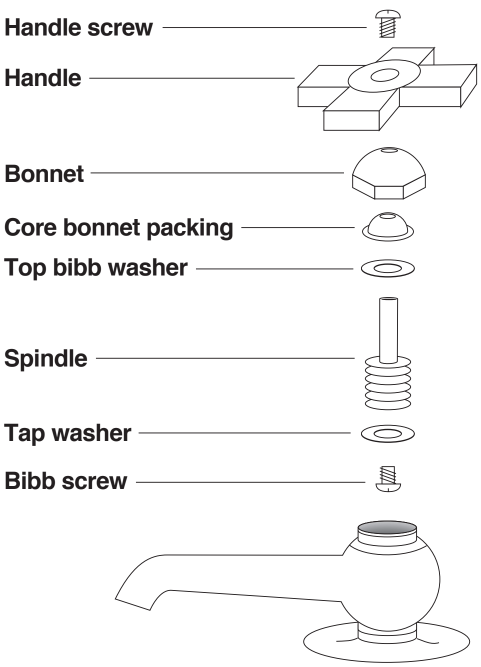


Figure 6-9 - Many costly leaks can be easily repaired by replacing the tap washer in the faucet.

plumber suggests–without thinking about energy. Estimate how much hot water you and your family may use and try to select the proper size of storage tank that is needed. Buying a water heater that is too big or too small will ultimately lead to inefficient water heating.

To make a well-informed decision on a new water heater, it makes sense to understand the options. The most common types of water heaters are described below, along with tips on the selection of new equipment.

EnergyGuide labels for water heaters

All new water heaters sold must have yellow EnergyGuide labels that provide information on energy use. The EnergyGuide label for a water heater provides one large number, at the bottom of the label, that represents the approximate annual operating cost for that model given average national energy costs. The label also provides estimates of the appliance's annual energy use and a range of ratings for similar models – from "uses least energy" to "uses most energy." For electric water heaters, the fuel costs will be in cents per kilowatt-hour; for natural gas models, fuel costs will be in cents per therm or ccf (hundred cubic feet); for propane and oil-fired models, fuel costs will be in cents per gallon. While EnergyGuide labels provide an excellent way to compare the energy efficiency of different models, they do not necessarily provide an accurate representation of how much you will actually spend for water heating. Your water use habits and the temperature setting on your water heater will also affect yearly operating cost.

Selecting a storage water heater

Select an efficient model

Storage water heaters are rated according to their Energy Factor (EF) which ranges from about .50 to 1.0. An EF of 1.0 would be equivalent to100% efficiency. The most efficient electric water heaters have EF ratings up to .98, and a few gas-fired models have EF's as high as .86, while most are in the range of .50 to .70. Larger water heaters have somewhat lower EFs than smaller water heaters because of their greater surface area.

The National Appliance Energy Conservation Act (NAECA) sets minimum efficiency standards for water heaters. All new equipment for sale must meet NAECA standards. You can save money and energy, however, by buying equipment that exceeds the minimum NAECA standards.

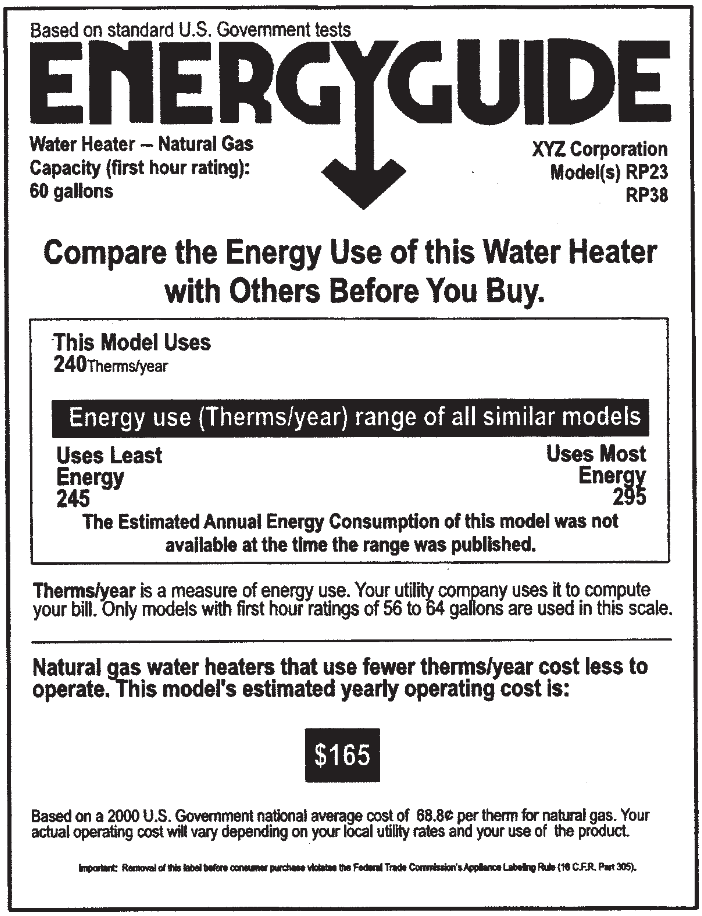


Figure 6-10 - Water heater EnergyGuide label

The Federal Energy Management Program (FEMP) lists recommended efficiencies and the efficiencies of the best equipment currently available. The FEMP recommended efficiency is also the minimum efficiency allowed for *Energy Star* labeling.

Sealed combustion and power venting

With oil or gas-fired water heaters, look for "power-vented" or "sealed combustion" models which use a small blower to exhaust flue gases up the chimney or out through a side vent. The advantage of these heaters is that they are not subject to "back-drafting" or "spillage" of exhaust gases into the house.

Table 6-2 – Recommended and Best Available efficiencies for water heaters according to the Federal Energy Management Program.

Heater Type	Measurement Units*	Recom-mended	Best Available
Electric	Energy Factor Annual Energy Use (kWh)	0.92 4773	0.95 4622
Gas	Energy Factor Annual Energy Use (therms)	0.61 246	0.72 208

* A higher energy factor indicates a more efficient heater, while a lower energy use indicates a more efficient heater

Selecting a demand water heater

Choose a model that can provide constant temperature water at varying flow rates. This feature is sometimes called "modulating temperature control." Without this feature, water temperature will vary whenever another faucet or shower is turned on or off.

If you are considering an electric demand water heater, make sure your house has adequate electric supply. Some electric demand water heaters use as much as 75 amps (18 kW at 240 volts), yet provide less than 2 gallons per minute at a 70° temperature rise.

Energy Tips and Recommendations

1. Improve the efficiency of your existing water heater by:
   - Lowering the water temperature.
   - Installing low-flow water conserving fixtures.
   - Fixing any existing water leaks.
   - Installing an insulation blanket.
   - Insulating hot water pipes.
   - Installing heat traps.

2. If your water heater is over ten years old (life expectancy of water heaters is 10-15 years) consider replacing it with a high efficiency model. Older water heaters are generally no more than 50% efficient.

3. Always consider life-cycle costs when purchasing a new water heater. The cheapest model may not be the smartest choice.

4. Use the EnergyGuide label to help compare the efficiency of water heaters. This label, which is required by law to be displayed on all new water heaters, provides important information on annual energy use and expected yearly costs with different fuel costs.

APPLIANCES

Energy Use for Appliances

Household appliances, including lighting, account for roughly 23 percent of energy consumption in the average Virginia home. Because these appliances are primarily powered by electricity, which is more expensive per unit of energy than other fuels, they comprise a larger share of the average household energy expenditure: roughly 30 percent.

There is a lot you can do to control and reduce appliance energy use. If any of your appliances need replacement, you can select more efficient models. Even if your current appliances don't need to be replaced, it might be a good idea to do a little research now so that when they do go, and you have to rush out to buy replacements, you'll know what you want (as you know, appliances usually fail over holiday weekends when the in-laws are visiting!).

If you're not planning to replace an existing appliance, there are often simple measures that can be taken to improve its energy performance. And, even if your appliances are in perfect working order, adjusting the way you use them can often reduce their energy consumption.

Shopping for New Appliances

Most new appliances tend to be considerably more energy efficient than their predecessors. Energy efficiency alone is rarely enough justification for replacing an old appliance since the energy savings are typically not great enough to justify the cost of the new appliance. However, there are many reasons people decide to replace an old appliance. It may have stopped working completely or it may simply not look right in a newly remodeled kitchen. Regardless of the reason for buying a new appliance, it almost always pays to buy an energy efficient model.

One very useful resource is the Consumer Guide to Home Energy Savings, published each year by the American Council for an Energy Efficient Economy (1001 Connecticut Avenue, N.W., Suite 801, Washington, D.C. 20036)

Energy Star

The U.S. Department of Energy (USDOE) and the Environmental Protection Agency (EPA) have formed a partnership to promote the use of a wide range of energy efficient equipment, products, appliances and even new homes – by awarding the Energy Star label (above) to those items that save energy by meeting specific energy efficiency criteria. This label helps consumers identify products that save money and energy.

Energy Star is also an educational program that provides information to consumers about the benefits of high efficiency appliances, equipment and building components. The payoff is decreased energy consumption, which lowers energy bills over time and reduces the environmental impacts of fossil fuel power generation.

Energy Star is forming partnerships with manufacturers and retailers nationwide. Companies are volunteering to place the Energy Star label on all of their products that meet or exceed the Energy Star criteria, which always surpasses the minimum national efficiency standards.

An Energy Star equipped household can reduce its home energy bill by 40 percent and prevent the release of 70,000 pounds of carbon dioxide over the lifetime of the products.

When shopping for new appliances always be sure to look for the Energy Star label so that you can purchase the most energy efficient dishwasher, refrigerator, or clothes washer that is available. The initial purchase price for an Energy Star labeled appliance may be higher than a less efficient unit but you will save money over the lifetime of the product and you will be helping to preserve the environment as well.

The EnergyGuide label

One of the most useful tools for shopping for energy efficient appliances is the EnergyGuide label. Federal law requires that EnergyGuide labels be attached to all new refrigerators, freezers, water heaters, dishwashers, clothes washers, air conditioners, heat pumps, furnaces, and boilers. These labels are bright yellow with black lettering and should be prominently displayed. The guide shows the type of appliance, the size, make and model, model's annual energy consumption or energy efficiency rating, the scale range or its annual energy consumption or efficiency rating for models similar in size and type, and the estimated yearly operating cost. The labels do not tell the consumer which appliance is best to buy but do indicate the estimated annual energy consumption and operating cost at a given rate, which allows you to compare models. The following explanation should give you a good idea of exactly what the EnergyGuide labels tell you and how it can help you make an informed decision when shopping for new energy efficient appliances.

It is important to remember that an EnergyGuide label does not mean that the appliance is an Energy Star appliance. But EnergyGuide labels often note whether the product is Energy Star qualified.

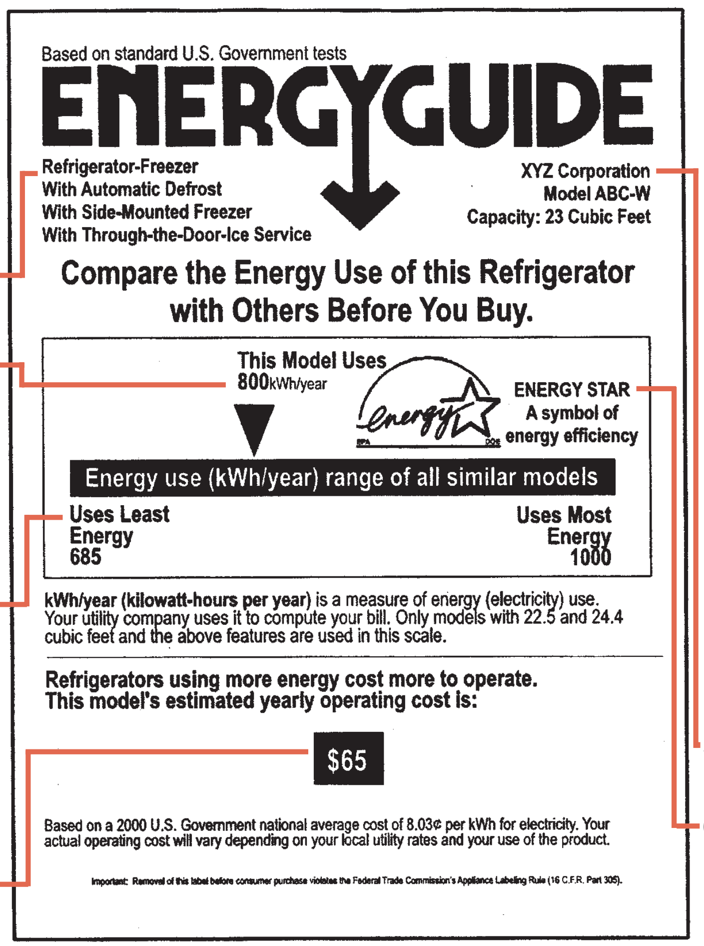
The information provided by EnergyGuide labels varies somewhat with different appliances, so we'll take a look at several different categories of appliances and provide examples of labels. EnergyGuide labels are not required on kitchen ranges, microwave ovens, clothes dryers, demand type water heaters, portable space heaters, or lights.

Refrigerators and freezers

For refrigerators (Figure 7-1), you will see a large number at the bottom of the label. This tells you the approximate yearly operating cost for that particular model, and it's the best way to quickly compare one model to another. Keep in mind that all these estimates are based on standardized tests. As with EPA auto mileage ratings, the values are very useful for comparing one model to another, but your real costs may vary.

EnergyGuide labels for freezers are the same as for refrigerators.

Figure 7-1 - EnergyGuide refrigerator label. Like all EnergyGuide labels, it is bright yellow with bold black letters and numbers.



1. Top of label: Type of appliance and features.
2. Estimates of the appliance's annual energy use or consumption. The lower the number, the more energy efficient the appliance and the less it costs to run.
3. The range of ratings for similar models, from "uses least energy" to "uses most energy." This scale shows how a particular model measures up to the competition.
6. An estimate of the annual cost to run this model or an estimated yearly operating cost. This is based on the average cost of electricity around the country, which changes from year to year. The labels on different models or even on the same models in different stores may have been printed at different times, so the numbers may be a little different. Also, because your electricity costs are probably different from the national average, this may not tell you how much the refrigerator will cost to operate in your area.
5. Size, make, and model information.
6. An Energy Star logo indicates the appliance is Energy Star qualified.

Water heaters

For water heaters, the EnergyGuide label looks just like the label for refrigerators, except that the detailed information provided for determining the actual operating cost is based either on electricity costs or gas costs, depending on the type of water heater. Electricity prices are given in cents per kilowatt-hour and gas prices in cents per therm (100,000 Btu) or cents per ccf (hundred cubic feet) of natural gas.

Water heaters designed for propane should have EnergyGuide labels with energy costs in cents per gallon, although the range may not go as high as your propane cost. If the per-gallon prices listed on the label do not go high enough, divide your actual propane cost by the highest propane cost listed, and multiply the estimated annual cost by that value. Refer to Chapter 6 for more information on water heaters.

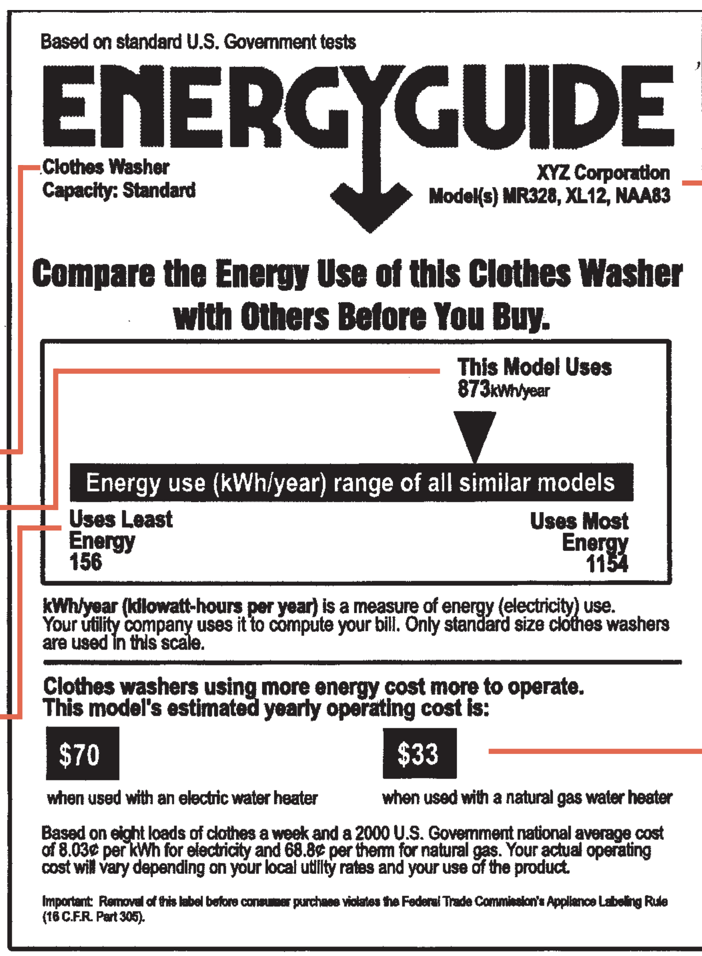
Dishwashers and clothes washers

For appliances that use hot water (dishwashers and clothes washers), the labels are a little different. Most of the energy used by these appliances is for heating the water rather than running the appliance itself. Under typical usage patterns, water heating accounts for about 80 percent of the energy use by dishwashers and 90 percent of the energy use by clothes washers. (The rest of the energy is used for pumps, motors, and an electric drying cycle in dishwashers.) So how much money you spend each year for one of these appliances depends on how you heat your water.

The EnergyGuide labels for these appliances, therefore, provide two sets of numbers– one for electric water heating and one for gas water heating (Figure 7-2).

If you have a propane water heater, you will need to calculate your annual operating cost using the natural gas table. One gallon of propane is equivalent in energy content to .93 therms (or ccf) of natural gas. Because a

Figure 7-2 - EnergyGuide clothers washer label. Clothes washers and dishwashers vary in their operating costs depending on whether you heat your water with electricity or gas. Figures for both are listed on the labels.



1. Type of appliance
2. Estimates of the appliance's annual energy use. The lower the number, the more energy efficient the appliance, and the less it costs to run.
3. The range of ratings for similar models, from "uses least energy" to "uses most energy." This scale shows how a particular model measures up to the competition.
4. Manufacturer and model number information.
5. Estimated annual operating cost. If you have an electric water heater, use the number on the left. If you have a gas water heater, use the number on the right.

gallon of propane is usually a lot more expensive than a therm of natural gas, the tables on the EnergyGuide label probably do not go high enough. Use the following method to calculate your costs if using a propane water heater:

Divide your cost of propane (per gallon) by the highest cost per therm of natural gas listed, and multiply that value by 1.08 (to account for the greater heat content in natural gas). The resulting number is the factor you should use to calculate your expected annual operating cost. Multiply that factor by the annual operating cost listed on the bottom horizontal line of the EnergyGuide label. For example, using the dishwasher EnergyGuide label in Figure 7-2, if you pay $1.28 per gallon for propane, divide $1.28 by $.60 and multiply that value by 1.08 ($1.28 ÷ $.60 x 1.08 = 2.3). If you do six loads of dishes per week, your expected annual operating cost would be $97 ($42 x 2.3 = $97).

Room air conditioners

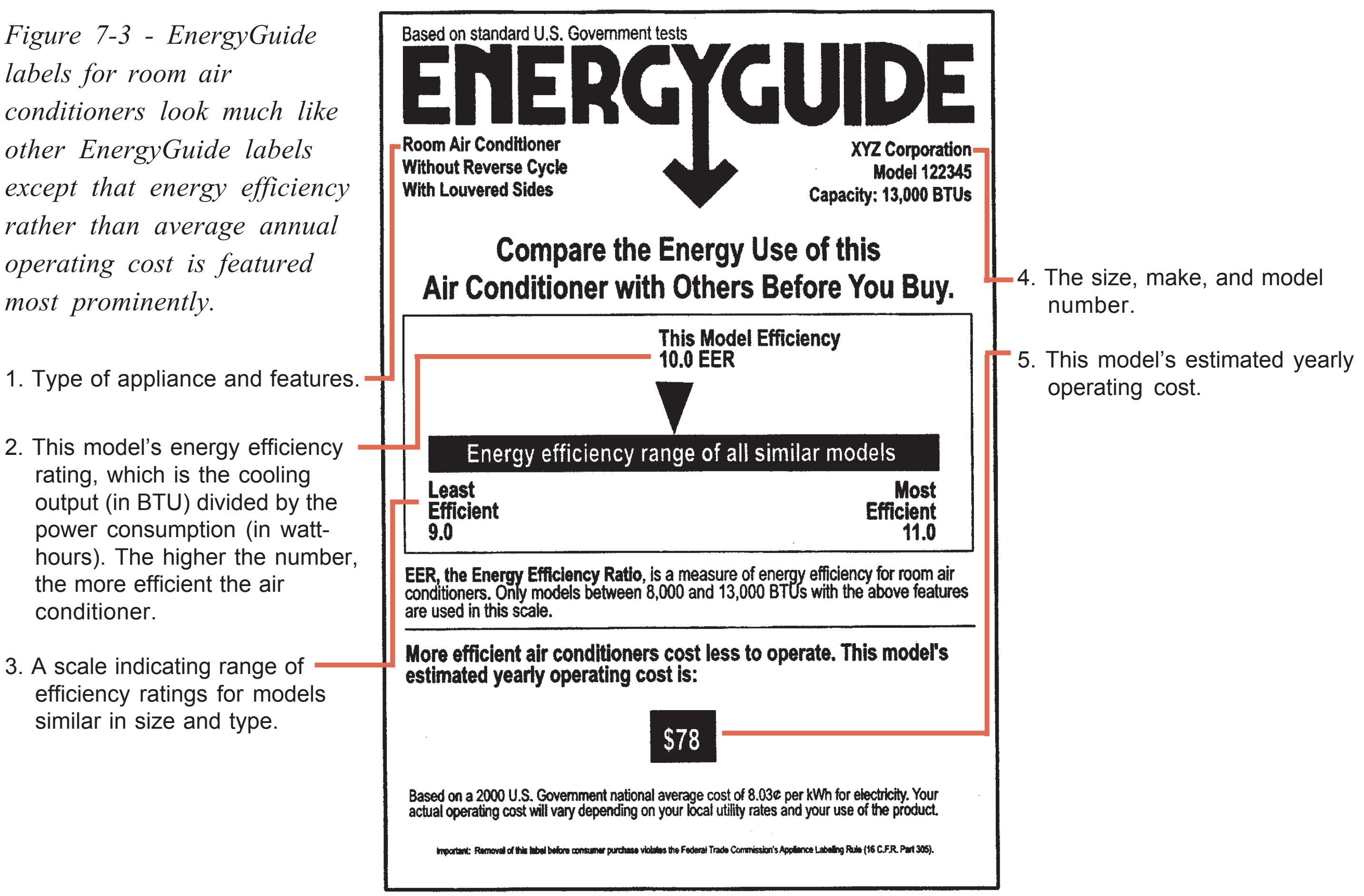
For room air conditioners (air conditioners that are installed either in a window or into an opening in the wall), the EnergyGuide label includes an energy efficiency rating (EER) instead of an annual energy cost number. The EER tells you how efficient the air conditioner is. An average model on the market has an EER between 8-1/2 and 9-1/2, while the most efficient models have EERs as high as 12.

An EnergyGuide label for room air conditioners is shown in Figure 7-3. For federal recommendations on room air conditioner EER, see Table 5-1.

Choosing And Using Appliances

On the following pages, each of the major home appliances are covered in detail, listing considerations for selection of new equipment, suggestions for improving the efficiency of older models, and tips on how to use the equipment for maximum energy performance.

Figure 7-3 - EnergyGuide labels for room air conditioners look much like other EnergyGuide labels except that energy efficiency rather than average annual operating cost is featured most prominently.



Refrigerators and freezers

If your refrigerator was purchased before 1975, it probably consumes at least twice as much electricity as an energy efficient new model. If your refrigerator is 10 years old or older, it uses as much energy as two of today's Energy Star labeled refrigerators.

The National Appliance Energy Conservation Act (NAECA) sets maxiumum energy use standards for all home refrigerators and freezers. All new equipment for sale must meet NAECA standards. You can save money and energy, however, by buying equipment that exceeds the NAECA standards.

The Federal Energy Management Program (FEMP) lists recommended annual energy use and the energy use of the best refrigerators currently available. The FEMP recommended annual use is also the maximum energy use allowed for *Energy Star* labeling.

When looking for a new refrigerator or freezer, also consider these points:

- Avoid convenience features that you don't really need. In most cases, through-the-door ice dispensers and water dispensers increase energy use.
- Most new refrigerators have heating elements built into the wall of the refrigerator that help prevent condensation from forming. This feature is often not needed and wastes energy if not turned off. Choose a model that has a power saver or energy saver switch to turn off these heating coils when not needed.
- With freezers, manual defrost models are considerably more energy efficient than frost-free models – this difference in efficiency will be reflected on the Energy-Guide labels.

Chest freezers are 10-25% more efficient than upright models because they are better insulated and they don't expel as much air when the door is opened.

Installation of refrigerators and freezers

You will achieve better energy performance from a refrigerator or freezer by observing the following recommendations:

Table 7-1 – Recommended and Best Available annual energy use for refrigerator-freezers according to the Federal Energy Management Program.

Equipment type	Annual Energy Use (kWh)	
	Recommended	Best Available
Single-Door Compact Refrigerators		
<2.4 cu. ft	270	—
2.5-4.4 cu. ft	285	—
4.5-6.4 cu. ft.	305	245
6.5-8.4 cu. ft.	325	—
>8.5 cu. ft.	345	—
Refrigerators with Bottom-Mount Freezer		
<18.4 cu. ft.	505	501
18.5-20.4 cu. ft.	510	—
>20.5 cu. ft.	515	510
Refrigerators with Top-Mount Freezer		
<10.4 cu. ft.	350	—
10.5-12.4 cu. ft.	375	—
12.5-14.4 cu. ft.	400	394
14.5-16.4 cu. ft.	420	372
16.5-18.4 cu. ft.	445	414
18.5-20.4 cu. ft.	465	417
20.5-22.4 cu. ft.	480	457
22.5-24.4 cu. ft.	500	498
>24.5 cu. ft.520	516	
Refrigerators with Side-by-Side Freezer		
<20.4 cu. ft.	590	—
20.5-22.4 cu. ft.	610	568
22.5-24.4 cu. ft.	640	605
24.5-26.4 cu. ft.	665	591
26.5-28.4 cu. ft.	685	—
>28.5 cu. ft.	710	614

- Make sure that air can freely flow across the coils. Don't close the refrigerator into a confined space unless it's a model that is specially designed to be "built in." Leave at least a 1" space on each side of the unit to allow for adequate air flow to carry heat away.
- Install refrigerators and freezers away from heat sources, such as oven and dishwashers, and out of direct sunlight.
- It often makes sense to install freezers in a cooler basement or attached garage, though manufacturers recommend against installation in locations where temperatures can drop below freezing.

Maintenance

- Keep the condenser coils clean. Dust and dirt accumulation on the heat exchanger coils on the back or bottom of a refrigerator will reduce its efficiency. They should be vacuumed off at least once a year– more often if your home is particularly dusty. Follow the manufacturers instructions for cleaning, and as a safety precaution, unplug the unit while moving and cleaning it.
- Check door seals and replace if leaky or worn. To test the seals, close a dollar bill in the door. If the dollar bill pulls out with no resistance, the seals probably should be replaced.
- Check the temperature settings and adjust as necessary. The refrigerator compartment should be between 36°F and 38°F, and the freezer compartment between 0°F and 5°F. Lower temperature settings are unnecessary and waste energy.

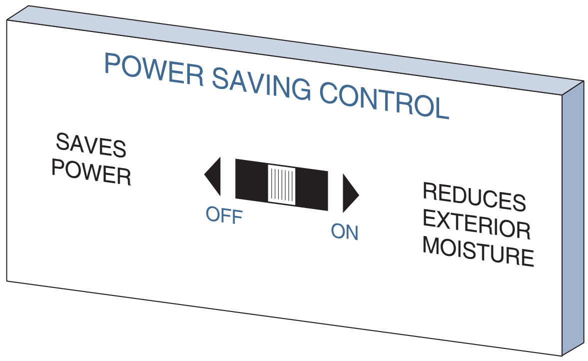


Figure 7-4 - Most new refrigerators have a "power saver" switch like this one to turn off heating elements in the walls when condensation is not a problem.

- Defrost as necessary. Ice buildup on the coils decreases heat transfer and reduces overall efficiency of refrigerators and freezers. Manual defrost and partial automatic defrost refrigerators and freezers should be defrosted whenever ice builds up more than 1/4" on the coils.

Operation

- Don't keep your freezer or refrigerator doors open any longer than necessary. Keep your refrigerator and freezer organized so that items can be found without a long search.
- Avoid putting containers of hot food in a refrigerator or freezer. Let them cool first.
- Keep your freezer fairly full– it will perform better than if it is nearly empty. You can fill plastic containers with water and freeze them to fill up extra capacity.
- Rethink that old spare refrigerator running in the basement. It may be costing you as much as $200 per year to keep a couple of six-packs of beer cold. Perhaps your spare refrigerator should be run only when you need the extra space: for holidays, parties, and family gatherings. If you decide to stop using it long-term, unplug it and remove the door for safety.

Dishwashers

Water heating accounts for about 80 percent of the energy use of dishwashers; most of the rest is for the electric drying cycle. As a result, the most important strategies to reduce energy use involve cutting hot water use and limiting usage of the electric drying cycle, as explained under "Operation" on the next page.

Buying a new dishwasher

The EnergyGuide labels on new dishwashers list annual operating cost, but it is important to note that the EnergyGuide ratings are based on very specific operating cycles, and that they do not factor in certain energy saving features.

- Look for an energy saving wash cycle option.

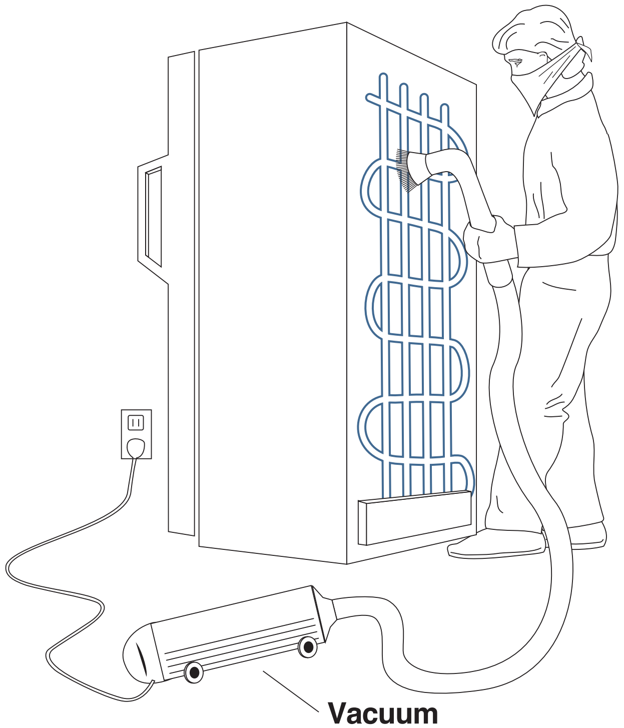


Figure 7-5 - The coils on the back or bottom of your refrigerator need to be cleaned periodically to maintain peak efficiency.

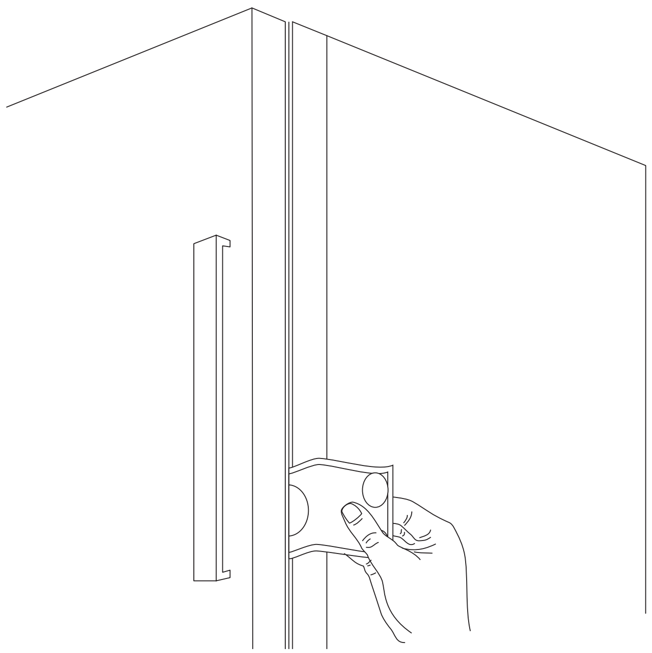


Figure 7-6 - Check the seal in your refrigerator door by closing it on a dollar bill. If the bill pulls out easily the door may not be sealing properly.

Many dishwashers offer a "light wash" cycle that uses less water and operates for a shorter period of time. This cycle will be perfectly adequate for lightly soiled dishes, and it will save energy.

- Buy a dishwasher that has a built-in booster heater. For optimum performance, dishwashers need 140-145°F water. Many dishwashers have booster heaters that can heat water from 110°F or 120°F up to the required temperature. The advantage, from an energy standpoint, is that with a booster heater, you can turn down the temperature setting on your water heater, thereby avoiding unnecessary standby losses.
- Look for dishwashers with Energy Star labels. Energy Star labeled dishwashers have been identified by the U.S. Department of Energy as the most energy efficient dishwashers available, exceeding Federal standards by at least 13%.

Installation

- Position the dishwasher as close as possible to the water heater to minimize the piping run and resulting heat loss.

Operation

- If your dishwasher has a lower water use light-wash cycle, use it whenever possible.
- Use the no heat, air dry feature on your dishwasher. If you have an older model without this feature, you can turn off the dishwasher and open the door after the final rinse cycle to let the dishes air dry. Be aware that drying will take longer, however, and some spotting is possible. Federal law requires that all new dishwashers have a no heat drying option.
- If your dishwasher has a booster heater, turn the thermostat on your water heater down to 120-130°F (check the dishwasher manufacturer's recommendations for minimum water heater setting).
- Avoid the temptation to pre-rinse dishes before putting them in the dishwasher. Most quality dishwashers today do an excellent job without pre-rinsing. Simply scrape off solids and pour out

liquids before loading dishes. If you must rinse dishes first, use cold water. Some advanced dishwashers can sense how dirty the dishes are and adjust the cycles accordingly. These dishwashers don't use more water than is needed to clean the dishes. This saves energy.

- Wash full loads. A dishwasher will use the same amount of water (and energy) whether it is washing a full load or a nearly empty load. If possible, gradually fill up the dishwasher during the day and operate it just once, at night. However, don't overfill the washer to save "even more" energy. You need to leave plenty of room for water to circulate between dishes for proper cleaning.
- If you have a dishwasher but usually wash dishes by hand, you might not be saving any energy. If you tend to leave the water running while washing dishes, you would probably reduce your water and energy use by using the dishwasher instead.
- Look for dishwashers that use the least amount of water. Ask the salesperson how many gallons of water are used during different cycles. Dishwashers that use the least amount of water will cost the least to operate as well as conserve water most effectively.

Clothes washers and dryers

The average energy cost for washing and drying one load of clothes ranges from 17¢ to $1.10 at current Virginia energy prices. As with dishwashers, most of the energy use of washing machines is for heating the water used, so it's best to use less water and cooler settings. With dryers, the primary differences in energy use among different machines relates to how they sense when the clothes are dry. Gas dryers also generally cost a lot less to operate than electric models. You can usually save the most energy (and money) by changing the way you do the laundry. In fact, a load of laundry that is washed and rinsed in cold water, and hung on a line to dry, uses only about 3¢ worth of energy. Tips on buying and operating washers and dryers for maximum energy savings are presented below.

Buying a new washing machine

- Look for Energy Star labeled clothes washers. They come in front loading and top loading models. Both use less water and energy than standard clothes washers. Front loading models typically use less water and energy.
- Compare EnergyGuide labels of the different washing machines you are considering.
- Look for a model that lets you adjust the wash and rinse temperature settings individually. With warm and cold cycles, your energy and dollar savings can be dramatic, as shown in Table 7-2.
- You will need to determine for yourself whether or not the lower temperature wash settings clean your clothes as well as hotter settings. Cold water rinses are just as effective as warm water rinses, so they should always be selected.
- Choose a model that offers different water level settings, allowing you to use less water (and energy) for smaller loads. A typical top-loading machine uses about 20 gallons per load for the smallest setting, and up to 40 gallons per load for the largest.

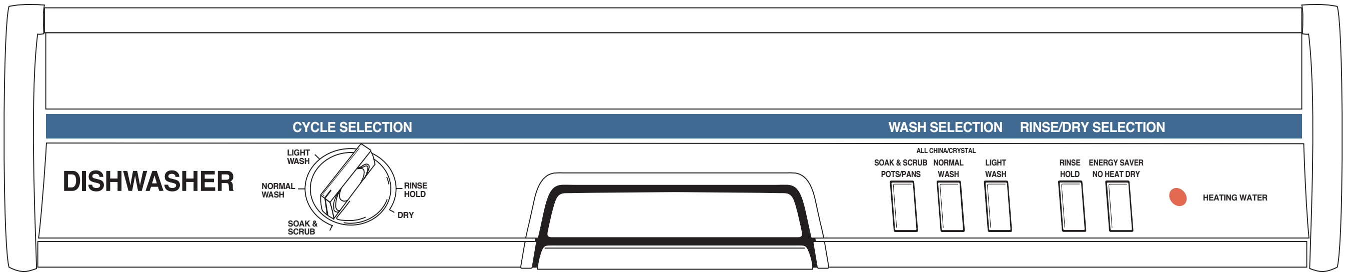


Figure 7-7 - Light/China and no-heat drying options offer substantial energy savings. This model also features an automatic booster heater, allowing you to turn your water heater down to 120-130°F.

- Consider a front loading (horizontal-axis) model instead of a standard top-loader. Front loaders use about half as much water and energy as top loaders, and some say the washing performance is actually better. Along with saving money for water heating, a front loading machine can cut your water and sewage bills (if you are on a municipal system), extend the life of a rural septic system, and save a lot of money on detergent. Energy Star top loading washers use sensor technology to control water temperature and volume, then use high pressure spray rinses to remove soap from clothes.
- Water extraction. The more water your washing machine extracts during its spin cycle, the less your dryer will have to work. Some (but not all) manufacturers list the water extraction specifications in their literature. Energy Star labeled clothes washers remove more water in the spin cycle than traditional washers.

Buying a new dryer

- Choose a dryer that shuts off automatically when the clothes become dry instead of one that can only operate on a timed cycle. If the only option is a timed cycle, you might be wasting a lot of energy by just heating clothes that are already dry– and damaging the clothes as well. The best controls have actual moisture sensors, while others sense only the temperature of the exhaust air.
- Gas dryers are usually much less expensive to operate than electric models– at least if you are

Table 7-2- Cost of washing a load of laundry

Electric Water Heaters			**Gas Water Heaters**		
Wash/Rinse Settings	kWh Used	Avg. Cost Per Load (cents)	Wash/Rinse Settings	Therms Used	Avg. Cost Per Load (cents)
120 F hot water temperature					
Hot/Hot	6.5	52	Hot/Hot	.248	19
Hot/Warm	4.9	39	Hot/Warm	.186	14
Hot/Cold	3.4	27	Hot/Cold	.124	9
Warm/Warm	3.4	27	Warm/Warm	.124	9
Warm/Cold	1.9	15	Warm/Cold	.062	5
Cold/Cold	0.4	3	Cold/Cold	-	3
140 F hot water temperature					
Hot/Hot	8.3	66	Hot/Hot	.329	20
Hot/Warm	6.3	50	Hot/Warm	.247	15
Hot/Cold	4.3	34	Hot/Cold	.164	10
Warm/Warm	4.3	34	Warm/Warm	.164	10
Warm/Cold	2.3	18	Warm/Cold	.082	5
Cold/Cold	0.4	3	Cold/Cold	---	3

Assumptions: Electricity price = $.08 per kWh; Gas price $.60 per therm.. Source: *Consumers Guide to Home Energy Savings*, ACEEE, 1996.

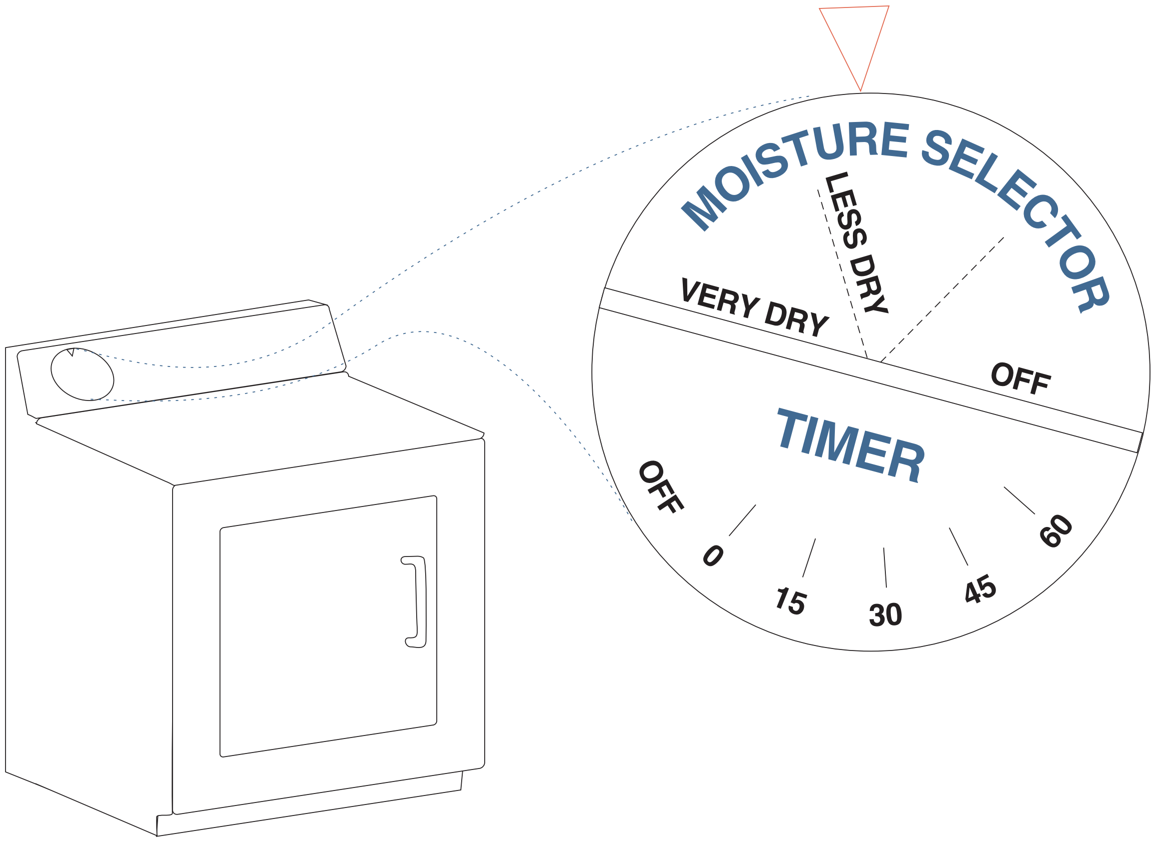


Figure 7-8 - Dryer selector dial. Setting the moisture selector to "less dry" may reduce wrinkling of laundry, thus saving energy for ironing as well as dryer operation.

able to use natural gas rather than propane. All gas dryers sold today are required to have electronic ignition instead of pilot lights. If you are considering buying a used model, be aware that the pilot light can waste a lot of energy.

Installation of washers and dryers

- Install the washing machine as close to the water heater as possible, and insulate the hot water pipes.
- Install a quality dryer vent hood that blocks return airflow. Standard metal vent hoods can result in considerable heat loss and cold air drafts. Dryers should always be vented to the outside. The best vent material is smooth metal ducting, since it does not impede airflow or collect lint. If you use flexible ducting, use the all metal type: it is resis-

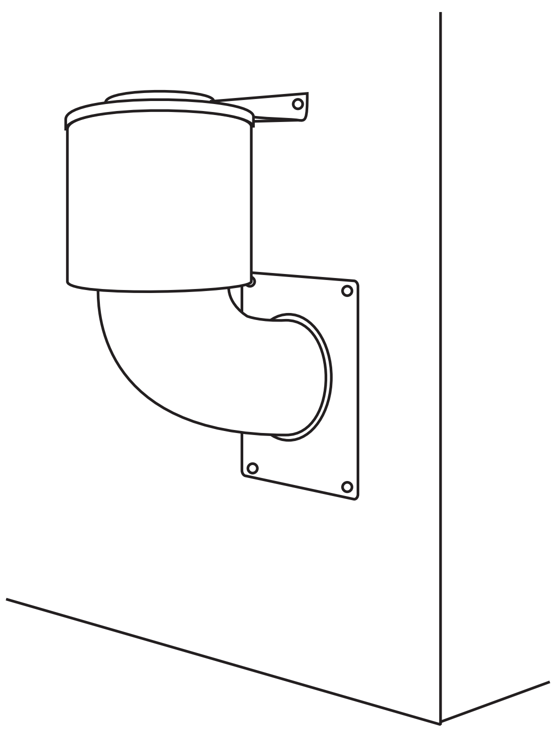


Figure 7-9 - A specially designed dryer vent hood will reduce air leakage into the house when the dryer is not running. Conventional hoods often allow significant leakage, increasing your heating or cooling bills.

tant to crushing and non-flammable. If your existing dryer is connected with flexible plastic ducting, make sure it is not crushed or compressed so as to restrict air flow.

- Never vent a dryer inside – not even an electric model. The exhaust contains chemical contaminants and lots of moisture, which can affect indoor air quality.
- Install washer and dryer in a heated space. Dryers in particular work more efficiently in heated spaces than in unheated spaces (such as garages).

Operation and maintenance

- Turn down your water heater. 120°F water will be adequate for most washing needs that require "hot" water.
- Fill the washing machine to capacity, but don't overload. Most people tend to under load washing machines, necessitating extra loads. When you don't have enough laundry to fill up the washing machine, use a lower water volume setting.
- Use the energy saving wash settings (lower temperature, water volume matched to load size). Cold water washing offers the greatest energy savings, and with detergents specially formulated for cold water, washing performance is usually satisfactory. Always use cold water rinse settings.
- Try to separate your clothes into like fabrics that will dry at a similar rate. Synthetics generally dry much faster than cottons.
- Never add wet clothes to a load of laundry that is already partially dry.
- Use the automatic drying cycle rather than timed drying. Timed drying continues to add heat after the clothes are completely dry, wasting energy.
- Be careful not to overdry clothes. Experiment with the settings on the automatic drying control, as many tend to overdry. You may find that the "less dry" is plenty dry enough. If possible, dry two or more loads in a row to benefit from the residual heat in the dryer.
- Clean the dryer lint trap after each load for improved drying efficiency and safety (follow manufacturer's instructions). Accumulated lint prevents moisture from escaping and can be a fire hazard.
- Periodically check the outside dryer exhaust hood to make sure that it isn't blocked and that the flapper or seal is in proper working order.
- In good weather, hang your laundry outside and use free solar energy to dry your clothes.

Federal Standards for Dishwashers and Clothes Washers

The National Appliance Energy Conservation Act (NAECA) sets maximum energy use standards for dishwashers and clothes washers. All new equipment for sale must meet NAECA standards. You can save money and energy, however, by buying equipment that exceeds the NAECA standards.

The Federal Energy Management Program (FEMP) lists recommended annual energy use and energy use of the best equipment currently available. The FEMP recommended annual energy use is also the maximum energy use allowed for *Energy Star* labeling.

Table 7-3 – Recommended and Best Available annual energy use for dishwashers and clothes washers according to the Federal Energy Management Program.

Equipment	Annual Energy Use (kWh)	
	Recommended	Best Available
Standard Dishwasher	555	277
Clothes Washers		
1.6 – 2.0 cu. ft.	315	239
2.1 – 2.6 cu. ft.	415	248
2.7 – 3.3 cu. ft.	520	309

Cooking appliances

Selecting cooking equipment has gotten a lot more complex in recent years. Along with the old stand-by gas or electric kitchen range with oven and top burners, we now have microwave ovens, high-tech halogen and induction cooktops, downvented ranges with popout grills, convection ovens, slow cook crockpots (insulated ceramic pot with electric heating element), single loaf bread ovens, and sophisticated countertop toaster ovens.

Just as importantly, our living and cooking habits have changed. Two career families need to consider speed and efficiency in cooking, plus the possibility of programming appliances to operate while family members are at work. There are no EnergyGuide labels for cooking equipment, because within a given model category and style there is very little difference in energy use between brands.

Cooktops

Cooktops can be part of a standard kitchen range, or a separate unit built into a counter. Different types of gas and electric cooktops are described below, with ovens discussed separately afterwards.

Gas cooktops

Many cooks prefer gas burners because they offer instant heat and greater temperature control. All new gas cooktops are required to have electronic ignition instead of

Figure 7-10 - Some of the newer technologies used in electric cooktops include solid disk elements, radiant coils or halogen bulbs under a ceramic glass top, and induction burners.

wasteful pilot lights. Some new models have sealed burners which make them easier to keep clean, but do not affect their energy use. You should always operate an exhaust fan when using a gas range to remove products of combustion as well as steam, grease, and cooking odors. Gas cooktops can produce carbon monoxide so be sure to have a UL-rated Carbon Monoxide (CO) detector in your home to determine if there are any unsafe levels of CO in your home as a result of operating a gas appliance.

Keeping the burners clean and making sure that there is no unnecessary flame impingement occurring between the flame and the pot are also good measures in preventing CO. Keep an eye on the bottoms of your pots and pans: if they get sooty from the burner flame, you may have a problem with poor combustion. Have a serviceman check, clean, and adjust the burners.

Electric cooktops

Exposed electric coils are the most common type of electric burner, and generally the least expensive. Several other types of electric cooktops are described below. Of these, only the induction elements offer significant energy savings over standard electric coils, and these elements are so expensive that the cost cannot be justified for energy savings alone.

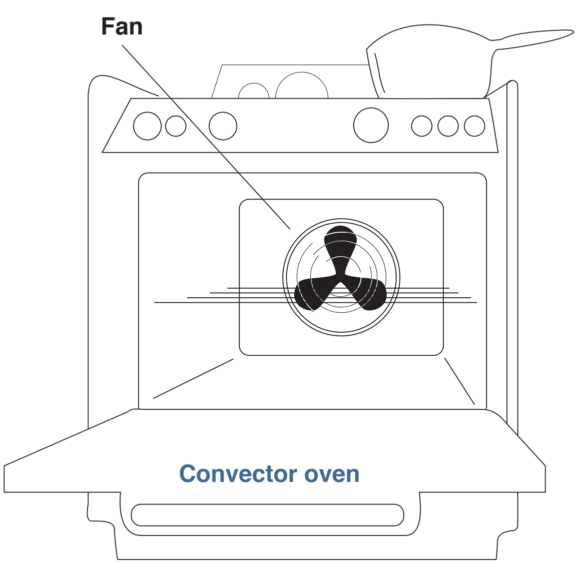


Figure 7-11 - A convection oven cooks more quickly and evenly than a standard oven, using less energy, by continuously circulating air within the oven compartment.

Solid disk elements. Solid disk elements look better and are easier to clean than electric coils, but they take longer to heat up and cool down so they tend to use more energy. The disks transfer heat to pans primarily through direct contact, so it is important to have good flat-bottomed pans for maximum contact between the disk surface and the pan.

Radiant elements under ceramic glass. Ceramic glass cooktops heat up more quickly than solid disk elements, though not as quickly as electric coils. They are more efficient than solid disks, and some are even more efficient than coil elements. Ceramic glass cooktops are quite expensive, however. As with solid disks, flat bottomed pans for good contact are important.

Halogen elements under ceramic glass. Halogen cooktops use halogen lamps under a ceramic glass surface to heat the cooking vessel. The lamps heat up very quickly, offering improved cooking control and providing slightly improved efficiency compared to standard radiant elements under ceramic glass cooktops. As with standard radiant elements, halogen elements require good contact between the pans and the surface.

Induction elements. Induction elements transfer electromagnetic energy directly to the pan containing the food. Since they don't waste any heat on the cooking surface, they are very efficient, using less than half the energy of standard electric coil ranges. Induction elements require the use of ferrous metal pans (iron or stainless steel); aluminum cookware will not work. Induction cooktops are also very expensive, making them hard to justify for energy savings alone.

Ovens

Standard gas and electric ovens are available either combined with cooktops (typical kitchen range), or as independent units. Newer convection ovens and microwave ovens can provide considerable energy savings. Smaller specialized cooking appliances that can be used in

Table 7-4 - Energy costs of various methods of cooking

Appliance	Temp.	Time	Energy	Cost(1)
Electric oven	350deg.	1 hr.	2.0 kWh	16 cents
Convection oven (electric)	325deg	.45 min.	1.4 kWh	11 cents
Gas oven	350deg.	1 hr.	.112 therm	7 cents
Frying pan	420deg.	1 hr.	0.9 kWh	7 cents
Toaster oven	425deg	.50 min.	.95 kWh	8 cents
Crockpot	200deg.	7 hrs.	0.7 kWh	6 cents
Microwave oven	"High"	15 min.	.36 kWh	3 cents

1. Assumes 8 cents/kWh for electricity and 60 cents/therm for gas. Source: *Consumer Guide to Home Energy Savings,* ACEEE, 1996.

place of full-size ovens and cooktops are also potential energy savers. These appliances include slow-cook crockpots, individual loaf bread cookers, and countertop toaster ovens.

Standard ovens

Among standard gas and electric ovens, those with a self-cleaning feature tend to be more efficient, because they have more insulation in the walls. Using this feature too often however (more than once a month) will cancel out any energy savings from the extra insulation, because so much energy is required for the self-cleaning. Ovens with no window in the door will be more energy efficient than those with one. The slight advantage may be lost, however, if the lack of a window makes the cook repeatedly open the door to check the food.

Be sure to keep gas ovens clean and all burners clean to prevent any unsafe levels of carbon monoxide. Always operate kitchen exhaust fans when gas ovens are in use.

Convection ovens

Convection ovens offer considerable energy savings because a fan circulates hot air throughout the oven compartment, allowing cooking temperatures and cooking time to be reduced. (See Table 7-4).

Microwave ovens

Introduction of the microwave oven was the most significant advance in cooking in the last fifty years. Cooking times can be reduced dramatically with many foods, and total energy consumption for cooking can be

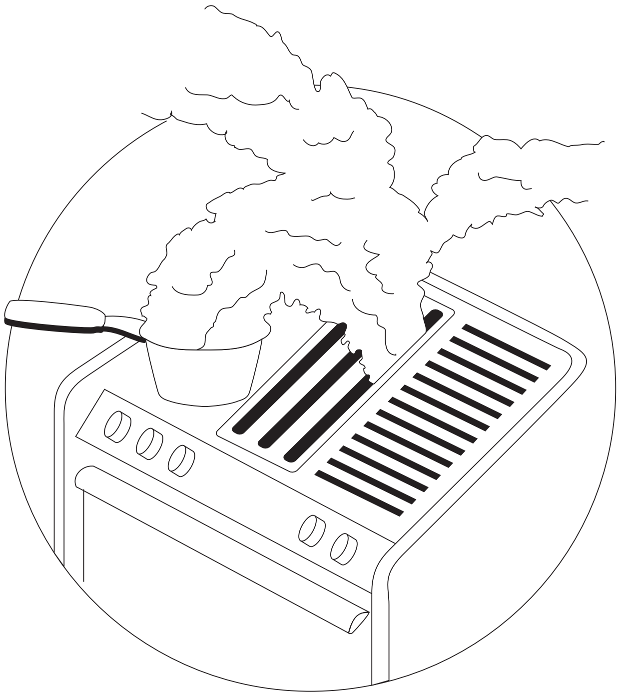


Figure 7-12 - Downdraft style kitchen exhaust fans are powerful. If a makeup air supply is not provided to replace the exhausted air, they can cause backdrafting of other combustion appliances in the house.

reduced by about two-thirds. You can save further by reducing the number of dishes to wash (you can serve food in the dishes it is cooked in), and by introducing less heat into the kitchen (you won't need to operate an air conditioner as frequently).

Ventilation

A range hood or other ventilation fan is very important for exhausting fumes and smells out of the house. When cooking with gas the fan should be running continuously. The exhaust fan must blow the air out of the house, not just recirculate it through a filter. A variable speed fan is the best option, since it allows control over how much air is exhausted.

There is a danger, however, with exhaust fans that are too powerful, particularly the popular downdrafting types, some of which are as large as 1,000 cfm (cubic feet per minute). When operating, these fans depressurize the house, drawing cold outside air in through cracks and gaps in your walls. This depressurization can also cause hazardous backdrafting of combustion appliances. If you do install a large ventilation fan, consider putting in a makeup air supply to balance the exhaust air.

Tips for energy-efficient cooking

- Instead of using your full-size oven for cooking small dishes, use a microwave oven, toaster oven, or slow-cook crockpot. A number of different ways of cooking a casserole are compared in Table 7-4.
- For stovetop cooking of rice, beans, and other foods that require a long cooking time, consider a pressure cooker, which will reduce cooking time considerably.
- For stovetop cooking, use the smallest pan necessary to do the job. With electric cooktops, try to match the pan size to the element size.
- Pans with copper or aluminum bottoms heat up more quickly than steel or cast-iron pans and can thus save energy.
- Clean the burner pans (the metal pans under burners used to catch grease) and keep them shiny so that they will reflect more heat up to your cooking vessel.
- With electric burners, including solid-disk and ceramic cooktops, make sure your pots and pans have flat bottoms to provide good heat contact between burner and pan.
- Cook with lids on your pans. Without a lid, cooking spaghetti can use three times as much energy.
- With gas burners, the flame should be blue. If you have a yellowish flame, the burner might not be operating efficiently. Have your gas company inspect it. Inefficient or dirty burners can produce dangerous levels of carbon monoxide.
- To reduce cooking time, defrost frozen foods in the refrigerator before cooking. When time constraints require quicker defrosting, use the microwave.
- Minimize oven preheat time. With many dishes, preheating the oven is not necessary.
- Avoid the temptation to open the oven door.
- To allow air circulation within an oven, don't lay foil across the grills. Try to stagger pans on the shelves to allow air circulation.
- When possible, cook several dishes at the same time in the oven. Cook double portions and freeze half for another meal. It takes a lot less energy to reheat food than to cook it.
- For oven cooking, use glass or ceramic pans instead of metal. You can usually turn the oven down 25° and not increase the cooking time.
- Avoid overcooking. Use meat thermometers and timers.
- If you have a self cleaning oven, try to use it soon after cooking a meal so that the oven will already be warm. Limit use as much as practical.
- Keep the inside surface of microwave ovens clean to improve efficiency, and cook foods right in microwaveable serving dishes (follow manufacturer's instructions on what type of cookware can be used in a microwave oven).

Table7-5 - Energy Consumption of Miscellaneous Appliances in the Home

Household Product	Typical Wattage	Typical Usage	Cost Per year @ $.076/kWh
Bathroom fan	60	1 hr/day	$1.66
Black & white television	556	0.6 hrs/day	9.15
Bottled water dispenser - (hot & cold)	65	24 hrs/day- 203 kWh/hr	15.43
Ceiling fan	23	hrs/day-5 mos/yr	2.22
Clock	860	24 hrs/day	1.33
Coffee maker	200	2 times/day	10.16
Color television	200	6 hrs/day	33.29
Computer	250	2 hrs/day	11.10
Dehumidifier	200	7 hrs/day-5 mos /yr	19.95
Electric blanket	200	4 hrs/day-5 mos/yr	9.12
Electric mower	900	12 hrs/yr	0.82
Furnace fan	300	1600 hrs/yr	35.36
Garbage disposal	450	22 hrs/yr	0.75
Humidifier	170	360 hrs/yr	4.66
Instant hot water	7000	2 hrs/wk	55.33
Iron	1100	4 hrs/mo	4.01
Spa/hot tub (electric)	2000	3 hrs/day	166.44
Sump/sewage pump	500	80 hrs/yr	3.04
Toaster	1100	2 hrs/mo	2.03
Toaster oven	1500	4 hrs/mo	5.47
VCR	20	4 hrs/day	2.22
Waterbed heater	350	7 hrs/day	67.96
Well pump	750	1.5 hrs/day	31.21
Whole-house fan	375	6 hrs/day-5 mos/yr	25.65
Window fan	200	3 hrs/day-5 mos/yr	6.84

Miscellaneous appliances

There are lots of other energy users around the typical home, some of which can be very significant. A few of them are described below. Others are listed in Table 7-5.

Humidifiers

Humidifiers can make you feel more comfortable in the winter months, when your household air tends to dry out, but some models use a considerable amount of energy to operate. If your home is too dry, consider reducing the natural air leakage (see Chapter 2). By reducing the amount of air exchange between the inside and outside during the winter, you will maintain higher humidity levels indoors. House plants also help to add moisture to the indoor air.

There are three main types of humidifiers on the market today: pad, ultrasonic, and heated.

- In a pad humidifier, a porous pad is kept wet and room air is blown through it, picking up moisture.
- In an ultrasonic humidifier, high-frequency sound waves break water into tiny droplets, which then evaporate in the room air.
- In a heated humidifier, an electric heating element boils water. The steam is then mixed with the room air.

Each of these humidifier types is available both in portable models and in models that permanently install on a furnace or heat pump.

Pad and ultrasonic humidifiers use much less energy than heated humidifiers, since the energy to evaporate the water comes from the room air rather than from an electric heating element. They must be cleaned regularly, however, to avoid a hazard from molds and bacteria (such as *Legionella*) that can grow on their cold, moist surfaces. In general, the ultrasonic models are easier to clean than the pad models. Cleaning is less critical for heated humidifiers, since the high temperatures kill most molds and bacterial.

Dehumidifiers

Used most commonly to keep basements dry, dehumidifiers can use significant amounts of electricity. One way to reduce dehumidifier energy consumption is to find and eliminate some of the moisture sources. Some possible sources are stored firewood in the basement, water leaking into the basement, and inadequate kitchen and bathroom ventilation. Be sure to keep windows closed when running a dehumidifier.

Look for a dehumidifier with the Energy Star label. To qualify for this energy efficient certification, a dehumidifier with the capacity to remove 10 – 24 liters of water from the air per day must have an Energy Factor of 1.30 or greater.

Home Office Equipment

With more people working out of their homes, energy use for computers, laser printers, copiers, and other office equipment is on the increase. When selecting equipment, consider the energy use. Laser printers, for example, use far more electricity than ink-jet printers and dot-matrix printers. Similarly, laptop computers use just a fraction of the electricity of desktop models. With copiers, look for models that have a low-energy-use standby mode.

On the subject of home offices, it is worth noting that the amount of energy you save by working at home and not commuting regularly to work will almost always more than make up for the increased energy use at home.

Be sure to purchase office equipment such as computers, monitors, printers, fax machines, and copiers that carry the Energy Star label.

Computers: An Energy Star qualified computer, in sleep mode uses 70% less electricity than computers without power management capabilities. If left inactive, Energy Star computers assume a low power mode and use 15 watts or less. New chip technologies make power management features more reliable and dependable than just a few years ago.

Monitors: An Energy Star monitor, in sleep mode, uses 90% less electricity than monitors without power management features. Energy Star labeled monitors automatically enter two successive low power modes of less than or equal to 15 watts and eight watts after a period of inactivity. Spending a long time in low power mode will save energy and help the monitor run cooler and last longer.

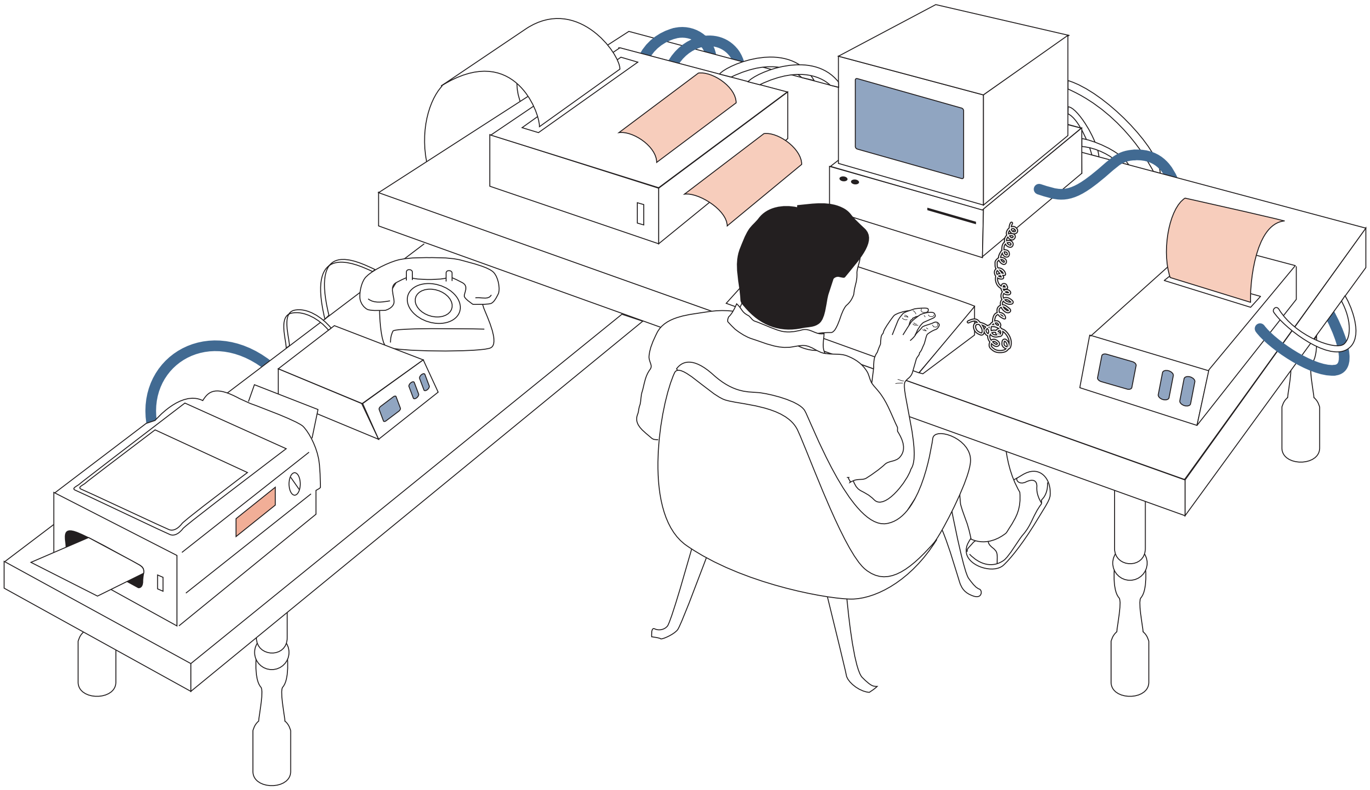


Figure 7-13 - Although home office equipment can use quite a bit of energy, it's almost always less than you would use otherwise by commuting to work.

Printers: Energy Star labeled printers can reduce the electricity usage by over 60%. Energy Star printers automatically enter a low power sleep mode after a period of inactivity and this not only saves energy but increases the longevity of the printer.

Fax Machines: An Energy Star qualified fax machine can save you about $35 in electricity bills over its lifetime. Because they power down, Energy Star labeled fax machines can reduce energy costs by 40%.

Copiers: Copiers can be the biggest energy users in the office because they sit idle for long periods of time. Energy Star copiers "sleep" or power down when not in use, and use 40% less electricity compared to standard models.

Remember that all Energy Star labeled office equipment uses power management features that save energy and reduce the use of electricity – this is good for the consumer and the environment.

Waterbed heaters

Surprisingly, a waterbed can be the single largest electricity consumer in the home, exceeding even the electricity use of a refrigerator. To reduce energy use by your waterbed, be sure to cover it with a comforter during the day, a simple measure that can cut energy use by 30 percent. Insulating the sides of the bed can save another 10 percent. You might also want to put the heater on a timer so that it isn't keeping the waterbed warm all the time. Some people don't use heaters at all, and instead insulate themselves from the waterbed with blankets or foam padding.

Well pumps

In rural areas that are not on municipal water systems, a lot of energy can be required for pumping water out of deep wells. Any measures taken to reduce water use in the home (low-flush toilets, low-flow showerheads, faucet aerators, water-saving cycles on the dishwasher and clothes washer, etc.) will reduce energy used for water pumping. If the pump seems to be coming on more than it should, there may be a leak somewhere in the system, or the pressure switch may be malfunctioning. Have the system inspected.

Spas and hot tubs

While not found in most homes, spas and hot tubs can be huge energy users. If you have one, be sure to buy and use an insulated cover. When installing a hot tub, insulate well around the sides and bottom.

Color television sets

Some color television sets have an instant-on feature to avoid the long warm-up period. While the convenience feature is nice, it wastes a lot of energy because the TV is never fully off. If you have an older television with this feature, consider installing a switch on the power cord to turn it all the way off when not in use, or unplug it.

Energy Star labeled television sets consume less energy both when they are turned off (in standby mode) and when they are on (in active mode). Energy Star labeled televisions require three watts or less of power when switched off compared to conventional televisions that use up to 12 watts. Energy Star labeled consumer electronics save energy whether you are using them or not.

Cordless phones, answering machines, VCRs and DVD players also expend the majority of their energy during standby – while not in use.

Appliances and Air Conditioning

In summer, a hidden cost of inefficient appliances is in added air conditioning cost. This is because energy wasted by most appliances is dumped into the room as heat. For typical air conditioning system efficiency, each dollar saved in appliance operating cost saves about thirty cents in air conditioning cost.

Energy Tips and Recommendations

1. Consider replacing an appliance if it is over ten years old. Newer models are considerably more energy efficient.
2. Always purchase an appliance that is Energy Star qualified. Energy Star appliances and equipment are certified by the U.S. Department of Energy and the Environmental Protection Agency according to specific energy efficiency criteria and always surpass minimum Federal efficiency standards. Energy Star appliances may cost more initially but will save money over the life of the appliance and also help preserve the environment.
3. Study the black and yellow EnergyGuide label that is required by Federal law to be displayed on most appliances. This label will help you to comparison shop and identify those models that use the least amount of energy and cost the least to operate.
4. Provide all necessary maintenance on appliances and fully utilize any energy saving features that may exist such as power saving switches on refrigerators, energy saving wash cycles on dishwashers, and power management on computers and peripherals.
5. Keeping burners and ovens clean will enhance efficiency.
6. Use kitchen exhaust fans when operating gas ovens or cooktops. Gas appliances can produce carbon monoxide and proper ventilation is very important. Make sure that you have an UL-rated carbon monoxide detector installed in your home.
7. Take full advantage of energy efficient cooking tips. (page 83)
8. Purchase Energy Star labeled office equipment such as computers, monitors, printers, copiers, and fax machines. They possess power management features that save energy when the equipment is on as well as when the equipment is off.

ENERGY USE FOR LIGHTING

Lighting accounts for about five to ten percent of total energy use, or $50 to $150 per year in the typical home. If a home has extensive outdoor lighting or if any lights are left on all night, the annual lighting cost could be considerably higher. In any case, there are several new energy-saving lighting technologies, described in this chapter, that every homeowner should consider.

How light output, energy use, and efficiency of lights are measured

To understand the energy use of lights – and the savings that can be realized by switching to more efficient lights – we have to understand how light and electricity use are measured. Because we are used to incandescent lamps, which are rated according to their wattage, most of us think of wattage as a measure of light output (a 100-watt light bulb produces much more light than a 60-watt bulb).

Wattage is not a measure of light output. Wattage is a measure of power input. Light output is measured in lumens. A standard "75 watt" bulb uses 75 watts of power to produce about 1200 lumens of light. An 18- watt compact fluorescent bulb uses only 18 watts of power to produce about the same level of brightness (1100 lumens).

The efficiency of lamps can be confusing. With most other energy users around the home (heating systems for example), there is a maximum amount of energy contained in the fuel being burned. The amount of energy we actually get out from that heating system is a measure of its *efficiency* (80%, 90%, etc.) (see Chapter 5). But with lighting, the upper limit is not so obvious. As a result, the term *efficacy* is often used instead of efficiency. Efficacy

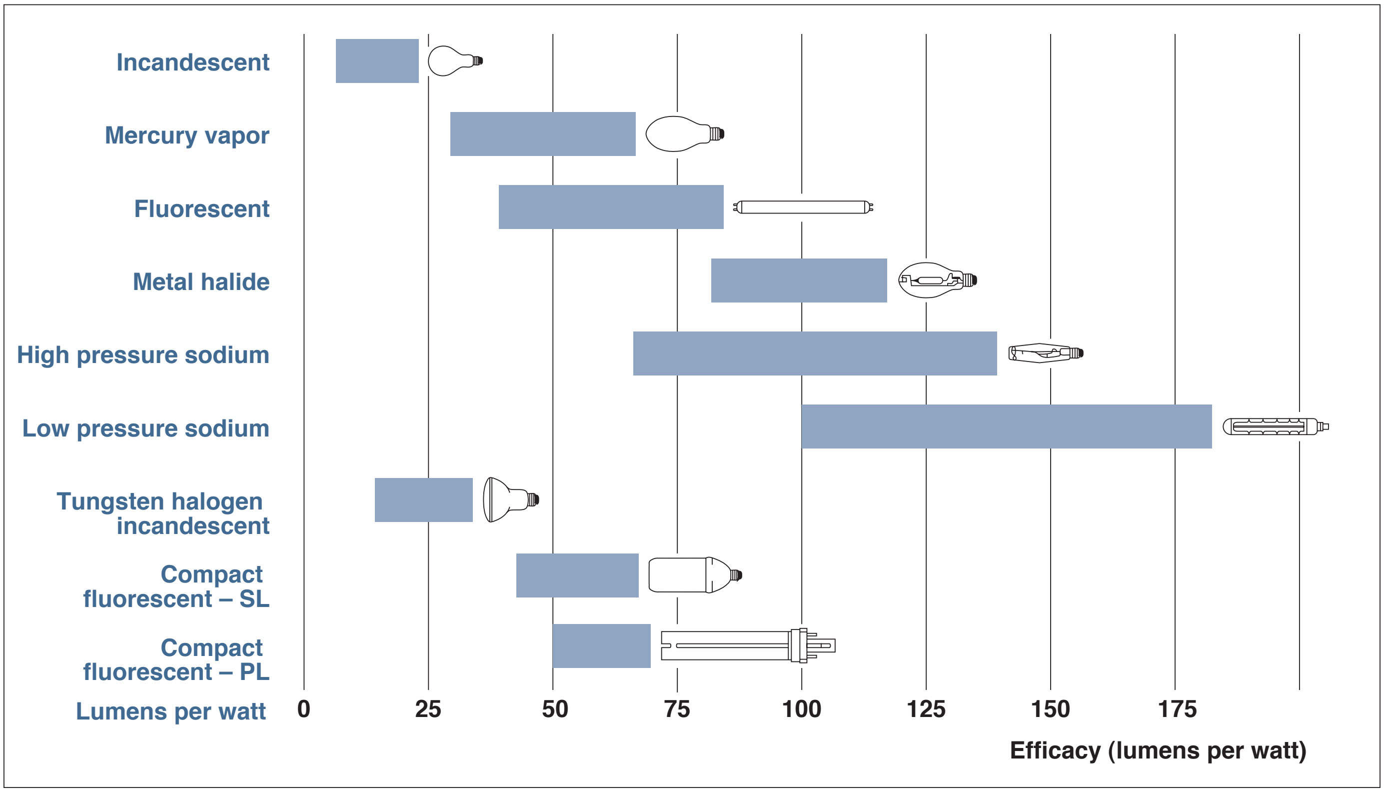


Figure 3-1 - The energy performance of lamps is expressed as efficacy which is a measure of light output, in lumens, per watt of electrical input (lumens per watt). The efficacy of a regular incandescent light bulb is only a fraction of the efficacy of a fluorescent bulb.

is the lumen output divided by the watts of power input (lumens per watt). Standard incandescent lamps produce 10 to 20 lumens per watt, while fluorescent lamps produce 50 to 90 lumens per watt, and high-pressure sodium lamps as much as 140 lumens per watt.

The Spectrum of Light

There are other factors in choosing an electric lamp besides power use, issues related to the pleasantness of the light produced. In order to understand these factors, one must know something about the spectrum of light and other electromagnetic radiation.

The color of light depends on its wavelength. Visible light has a wavelength ranging from about 380 nanometers (deep violet) to 840 nanometers (deep red). A nanometer (nm) is one-billionth of a meter. Light at wavelengths just below 380 nm is ultraviolet (the light that causes sunburn), while light at wavelengths just above 840 nm is infrared (radiant heat). Other parts of the spectrum include things such as radio waves, microwaves, and x-rays. Visible light is the only part of the spectrum that we can see, so in measuring lamp lumens only the visible part of the spectrum is considered.

Objects, when heated, become "incandescent": that is, they glow visibly. Most incandescent objects emit light with a continuous spectrum, that is, they emit light at every wavelength simultaneously. The hotter an object is, the lower the wavelength (more blue-violet) the light it emits. On Figure 8-2, the spectrum of sunlight (sun surface temperature about 8000°F) is spread from ultraviolet to infrared, with the highest levels in the visible range. The spectrum of an incandescent lamp (filament temperature about 4000°F) has its highest levels in the invisible infrared. It is no coincidence that the highest levels of sunlight are in the visible range: our eyes have evolved to use the available light!

The continuous spectrum of incandescent objects produces a very pleasant light because it has a full range of colors. The disadvantage of this light is that much of its energy is wasted in the infrared or the ultraviolet,

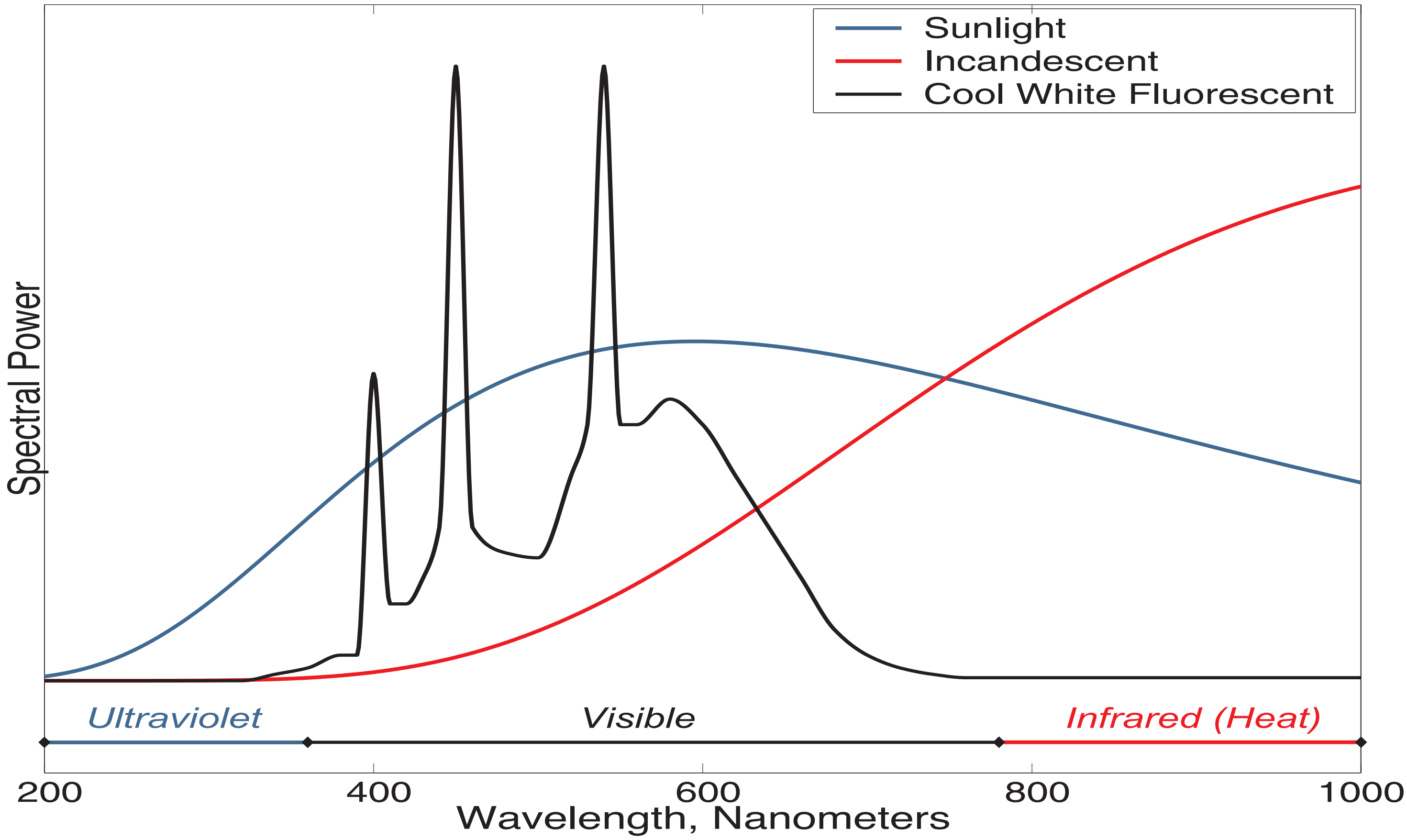


Figure 8-2 - Spectra of sunlight, incandescent light, and cool white fluorescent light.

rather than used as visible light. This is particularly true of incandescent lamps, most of whose energy goes into heat.

The light coming from the phosphor coating of a fluorescent lamp is not produced by heating the coating. The ultraviolet rays coming from the gas in the lamp strike the phosphor molecules, which then emit visible light. The difference between this light and incandescent light is that it is produced over a few narrow ranges of frequencies, as shown on Figure 8-2 for a typical "cool white" fluorescent lamp. Most of the light energy coming from the fluorescent lamp is in the visible range. This is also true for other high-efficiency lamp types such as metal-halide, sodium, and mercury vapor.

Lamps with a limited spectrum use their input energy much more effectively because they don't waste energy on invisible infrared and ultraviolet light. The disadvantage of these lamps is that within the visible region the spectrum is not smooth, but spiky, so that the light is stronger in some colors than in others. As a result, the light is less pleasant and colors appear less vivid. The worst case is with low pressure sodium lamps (sometimes used for streets and parking lots) which emit a single-color orange light. In low-pressure sodium light you don't see colors at all – just different shades of orange.

Since the invention of fluorescent lights, scientists and engineers have been working to improve the phosphors' color spectrum. The ultimate goal is to provide a spectrum that is nearly continuous in the visible region, but doesn't waste any energy in the ultraviolet or infrared. As new fluorescent phosphors are developed they come closer and closer to this goal.

Besides working for a continuous spectrum, lamp developers have learned to change the "color temperature" (the equivalent temperature for an incandescent source) of the light that phosphors produce. For professional lighting designers, manufacturers specify lamp color temperatures. For consumers, the colors are described using terms such as "Daylight" for lamps that try to simulate sunlight, "Cool White" for lamps that are slightly less blue, and "Warm White" for lamps that have a more yellowish light similar to that of incandescent bulbs.

The quality of fluorescent lamp light has reached a level where it is satisfactory for most situations in your home. For some tasks where excellent color perception is very important – sewing, applying makeup, etc. – incandescent light is still preferred.

Energy-efficient lighting options

Compact fluorescent lights

Fluorescent lamps produce light by passing an electric charge through a glass tube filled with mercury vapor. The mercury vapor is energized and gives off ultraviolet (UV) light. The UV light is absorbed by a special phosphor coating on the inside of the glass tube, which fluoresces, emitting visible light.

The most important innovation in home lighting during the past forty years is, without a doubt, the compact fluorescent light. First introduced in the United States in 1980, the compact fluorescent light is a miniaturized version of the straight-tube fluorescent. Instead of a 2-foot, 4-foot, or 8-foot fluorescent tube with separate ballast in a light fixture, manufacturers have packaged both ballast

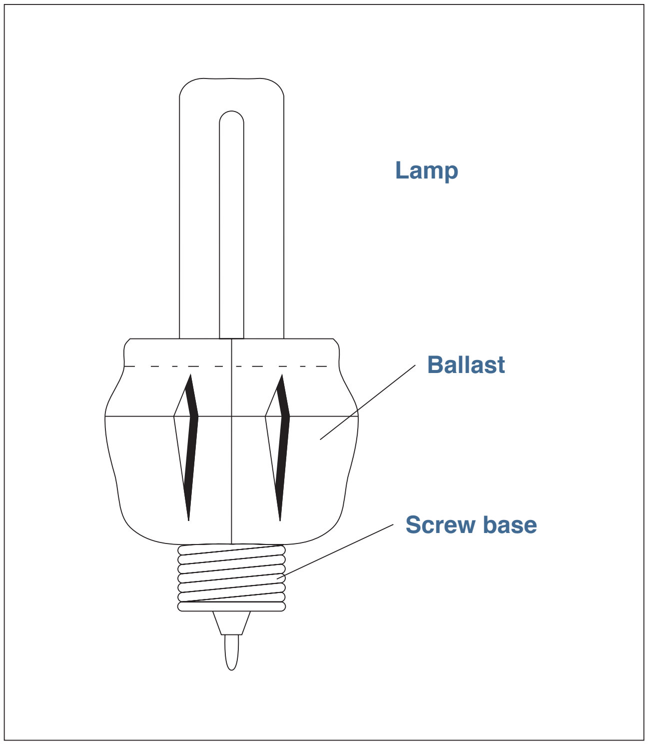


Figure 8-3 - Compact fluorescent lights offer high quality light and excellent energy efficiency in a size that can fit into many fixtures designed for incandescent bulbs.

and fluorescent tube (lamp) into a unit slightly larger than a standard light bulb.

While compact fluorescent lights are still bigger than standard light bulbs, many can fit into conventional light fixtures. Because most compact fluorescent lights use high-quality phosphors, the light quality is excellent – almost indistinguishable, in most cases, from incandescent light. Compact fluorescents light instantly, but take a minute or two to come to full brightness. Compact fluorescent lights last much longer than incandescent bulbs – generally at least ten times as long. Many are now sold with 5 and 7 year guarantees!

Ordinary compact fluorescent lamps can replace incandescent lamps in most fixtures, though they are too large for some. Special, but widely available, compact fluorescent lamps are needed for three-way fixtures and for fixtures with dimmers. Compact fluorescent lamps should not be used on fixtures with photocells unless the photocells are rated for fluorescent lamp service.The major drawback to compact fluorescent bulbs is that they are expensive to buy – anywhere from $5 to $20 per bulb, depending on the type. But, as we shall see, the high initial cost is more than offset by the savings in energy that these bulbs offer, and by the fact that one compact fluorescent will outlast ten or more regular incandescent bulbs.

Most compact fluorescent lamps are integral – that is the ballast and lamp are a single unit. Integral lamps use electronic ballasts and are less expensive and more readily available than separate magnetic ballasts. Modular compact fluorescent lamps have separate magnetic ballasts and lamps. The advantage to buying ballasts and lamps separately is that the magnetic ballasts have lifetimes 5 to 7 times longer than that of the lamp. So just replacing the lamp, when it has burned out, instead of the whole unit might be more cost effective.

The disadvantage of modular lamps is that there is no single standard mount to connect the lamp to the ballast. As a result, you must generally replace the lamp with one made by the same manufacturer.

All fluorescent lights contain small amounts of mercury. You should never dispose of burned out fluorescent lamps in the trash can. Take them to a recycling center and dispose of them with other household hazardous wastes such as batteries, solvents, and paints.

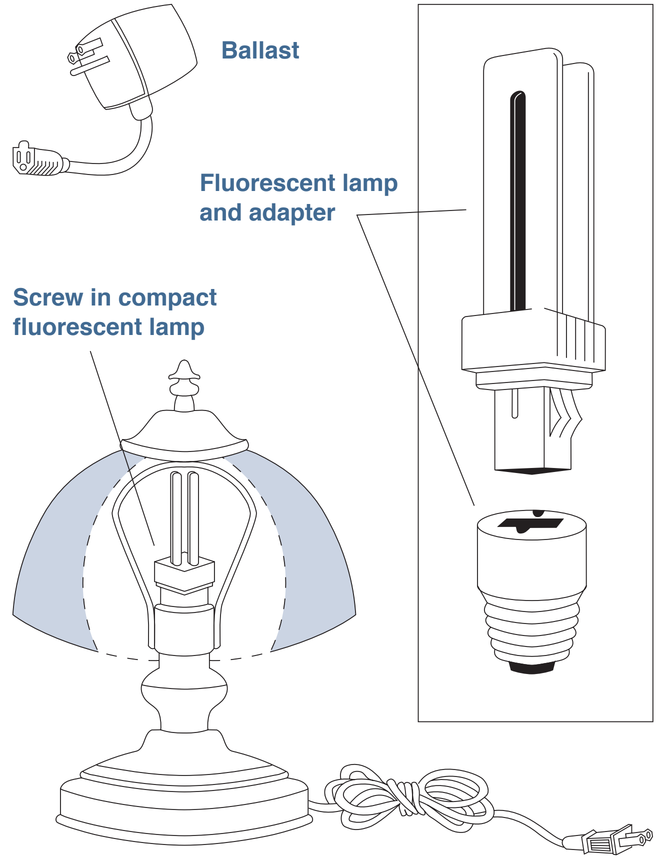


Figure 8-4 - Ballasts that plug into the wall solve the problem of compact fluorescent lights that are too big or too heavy for some fixtures.

Savings with Compact Fluorescents

A single 75 watt incandescent bulb, used an average of six hours per day, costs about $12 per year to operate. An equivalent 18 watt compact fluorescent bulb used for the same number of hours costs less than $3 per year to operate – a savings of $9 per year in electricity. If you keep lights on for longer periods of time, the yearly savings will be greater, up to about $36 if the light is on all the time.

More expensive to buy; Cheaper to own

Although it is hard to adjust to paying $15 or $20 for a light bulb, a simple example shows how compact fluorescent lights actually cost much less to buy and use than conventional incandescent bulbs.

An 18 watt compact fluorescent light replaces a 75 watt incandescent. Over its 10,000 hour lifetime, it will consume a total of 180 kWh of electricity. At 7.3¢ per

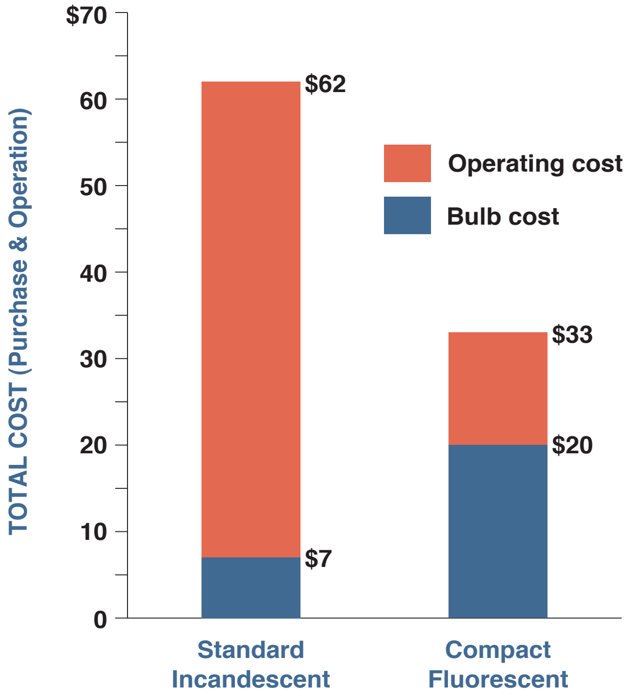


Figure 8-5 - Compact fluorescent lamps are more expensive to buy than incandescent bulbs, but they are much less expensive to own because of their much lower operating costs.

kWh, the total operating cost is about $13. Add to that the $20 cost for the bulb, and your total lighting cost for that fixture is about $33.

Over the same 10,000 hour period, a 75 watt incandescent bulb, with the same light output, would require 750 kWh of electricity at a cost of $55. Also, since incandescents only last about 750 hours, you would also need to replace the bulb 12 times at a cost of about $7, making your total cost $62, compared to $33 for the compact fluorescent (Figure 8-5). Thus, over its expected lifetime, a compact fluorescent light bulb saves about $29 and the work of changing 12 lightbulbs!.

Energy-efficient incandescent bulbs

Incandescent bulbs are the familiar "light bulbs" that are currently used for the vast majority of home lighting applications.

In an incandescent bulb, light is produced by heating up a wire filament made of tungsten until it glows white-hot, giving off visible light. In a typical incandescent lamp, 90% of the electricity is converted into heat; only 10% into light. The percent light output can be even lower with long-life bulbs. As a light bulb ages, the tungsten filament gradually burns up, depositing a black coating on the inside of the bulb, further reducing light output.

Incandescent light bulb efficacy has been improved in recent years in a number of ways. With the so-called "Watt-Miser," "Econ-o-watt," or "SuperSaver" light bulbs, efficiency is boosted roughly 10-15% through the use of different gases in the bulb that help the filament burn hotter (putting more light in the visible range) and minimize blackening of the inside of the bulb. The actual efficacy in lumens per watt depends on the strength of the bulb – high-wattage bulbs burn much more efficiently than low-wattage bulbs.

Table 8-1 - Savings Achieved by Substituting Compact Fluorescent for Incandescent Lights

Replace 75-watt Incandescent with an 18-watt Compact Fluorescent	Savings After 1st Year	Savings After 2nd Year	Savings After 3rd Year	Savings After 5th Year	Savings After 10th Year
Lights on 2 hours per day	[16.21]	[12.42]	[8.64]	[1.06]	17.88
Lights on 4 hours per day	[12.42]	[4.85]	2.73	17.88	35.75
Lights on 8 hours per day	[4.85]	10.30	25.45	35.75	90.75
Lights on 12 hours per day	2.73	25.45	28.18	52.88	125.75
Lights on 24 hours per day	25.45	50.15	75.60	125.75	272.25

More significant are the tungsten halogen incandescent lamps. These lamps have the filament in a separate capsule within the glass bulb. The capsule contains halogen elements such as bromine and iodine to reduce the blackening of the glass as tungsten burns off the filament. Some tungsten halogen lamps also have a heat reflective coating on the glass that reflects heat back in toward the filament, making it burn more efficiently.

Another way to get easily focused task lighting or accent lighting is with low-voltage systems. Low-voltage incandescent and tungsten halogen lamps are not inherently any more energy efficient than their 120 volt counterparts, but because the filament is shorter and fatter, the light source is smaller and can be focused more precisely. This can provide some savings in situations where light is needed on a very specific area. These lamps also last longer.

Using halogen bulbs in torchiere floor lamps is a mistake. It is safer and more energy efficient to use Energy Star qualified compact fluorescent light bulbs in torchiere lamp fixtures. They burn much cooler and use 60% to 80% less energy.

Despite the fact that improved standard incandescent lamps and tungsten-halogen lamps have higher efficiency than old-fashioned light bulbs, their decreased energy use is small compared to what is available from standard and compact fluorescent lamps. For maximum energy efficiency, incandescent lamps should be used only where a very compact light source is needed or where excellent color perception is required.

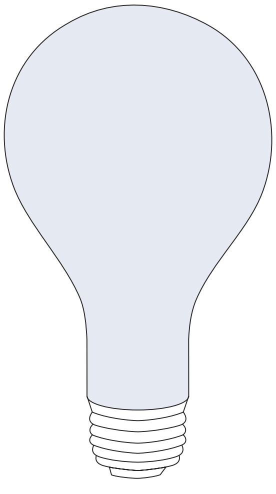


Figure 8-6 - Incandescent lamps, commonly called "light bulbs," give off 90% of their energy as heat, and only 10% as light.

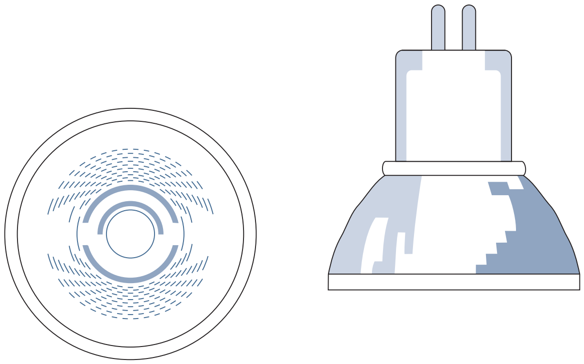


Figure 8-7 - Tungsten halogen lights are most common in reflector styles, though some are available in a more conventional light bulb style.

Improved straight-tube fluorescent lighting

While compact fluorescent lights are relatively new, straight-tube fluorescent lights have been around since the 1930s. Fluorescent lights have been used widely in commercial and industrial buildings, largely because of their dramatic energy savings over incandescent lights and the fact that they typically last ten to twenty times as long. They use just 1/4 to 1/3 as much electricity to produce a given quantity of light as incandescents. But because of problems with the light quality, fluorescent lights have not been a popular light source in homes – until recently, that is.

Improvements in fluorescent light quality have occurred on two fronts: the ballast that regulates the electric current going to the lamps, and the lamps themselves. There are three types of ballasts found in fluorescent light fixtures: standard magnetic ballasts, energy-saving magnetic ballasts, and electronic ballasts.

Magnetic ballasts are relatively inefficient and commonly produce an audible hum or buzz. Also, since they cycle on and off at 60 cycles per second, they produce a flicker that is noticeable to some people. Most ballasts sold in new fixtures are energy saving magnetic ballasts, which are 5-10% more energy efficient than older

Figure 8-8- Standard tube fluorescent lights are now available in a much wider range of color temperatures, and with much better color rendition than the typical "cool white" models.

standard ballasts, but even these can hum or buzz noticeably.

Far better from both an energy and aesthetic standpoint are the newer electronic ballasts, which are 25 to 35 percent more energy efficient than standard magnetic ballasts. Electronic ballasts are usually silent, and because they operate at 10,000 to 20,000 cycles per second, there is absolutely no discernable flicker. Even though electronic ballasts cost more than magnetic ballasts, they are a very good investment in homes, both because of the energy savings and because of user satisfaction.

The light quality of fluorescent lamps has also been significantly improved in recent years. New "rare-earth" phosphor coatings result in greater light output, whiter light that is closer to incandescent light in appearance, plus improved color rendering.

These higher-quality lamps are not as easily available as standard cool-white or warm-white lamps (you might have to order them through an electrical equipment supplier), and they will be more expensive, but they are strongly recommended for living areas.

HID lighting

High-intensity discharge (HID) lamps are similar to fluorescent lights in that an electric arc is passed through a gas. But in this case, the light produced is visible light, not UV, and no phosphor coating is required on the glass.

High-intensity discharge (HID) lighting is most commonly used along streets and highways, but it can be used for outdoor lighting where lots of light is desired but where color rendition is not crucial. The main advantage of HID lighting is its high efficacy when used for high-power floodlighting. As is the case with fluorescent lighting, HID lighting technology has advanced rapidly in recent years, with improvements in both light quality and efficiency. Although some HID lamps are significantly more efficient than fluorescent lamps, the improvement is not very great in the low wattage sizes that are most useful for homes.

Of the three HID light sources that are suitable for residential settings (mercury vapor, high-pressure sodium, and metal halide) mercury vapor is the most common, but the light quality is relatively poor and the energy efficiency the lowest (see Figure 8-1).

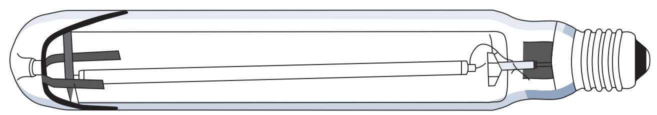


Figure 8-9 - High-intensity discharge (HID) lamps are generally used for outdoor lighting. Most HID lights are more efficient than fluorescent lights.

High-pressure sodium lights offer the greatest efficiency, but the light is yellowish in color. Metal halide is slightly less efficient than high-pressure sodium, but the light is much whiter— closer to the light from incandescent lights. All HID lamps require ballasts to operate, and most of these ballasts require relatively long warm-up periods.

The primary application for HID lighting around a home is for outdoor lighting where a lot of light is required, such as outdoor tennis courts and swimming pools.

Because of their long warm-up period, these lights are not practical for short intermittent uses, such as taking out the trash.

Energy saving lighting controls

So far we have discussed saving energy for lighting by using more efficient lamps. But there is another strategy that can be just as effective at saving energy and money: lighting controls that automatically turn lights off when they aren't needed, or turn them on only when they are needed.

Lighting control strategies are most applicable to outdoor lighting, particularly if you are in the habit of leaving lights on all night or 24 hours per day. For those who currently tend to keep lights on all the time – or who frequently forget to turn them off during the daytime – photocell controls can be used to turn the lights on at dusk and off at dawn. In buying photocell controls, one must be aware that their maximum power capacity (watts) is smaller for fluorescent lamps than for incandescent lamps.

If your primary need for outdoor lighting has to do with security, or for a few minutes of light now and then when you're putting out the trash or letting the dog in, motion detector controls might be a good investment. Motion detectors sense the motion of somebody walking up or driving within range of the detector and activate a switch to turn on the lights. Most can be set to keep the lights on for a specific period of time, such as three, five or ten minutes. The better products also include manual override features. The savings possible by installing motion detector controls depends on how long the lights would be left on unnecessarily without these devices.

Motion detectors, or slightly different occupancy sensors that sense the heat given off by occupants, are available for indoor use also. Products are available that replace a standard light switch and automatically turn lights off a few minutes after everybody leaves the room. With some occupancy sensors, you have to manually turn the lights on, while others control both the on and off. Be aware that the lower cost occupancy sensors may not prove very satisfactory– as you will quickly discover if the lights suddenly go out while you are sitting quietly reading.

Daylighting

Daylight is the ideal light source, both in terms of quality and energy use. A single skylight provides as much light as a dozen or more light bulbs, and the light quality is unsurpassed. Many people feel that exposure to natural daylight is conducive to good health. But too much natural lighting – especially glare – can be distracting, and, of course, this light source is only available during the daytime.

Skylights and windows have to be designed carefully so they don't contribute to overheating. The potential for overheating from skylights will vary, depending on the pitch of your roof and the direction it's facing. North-facing skylights on relatively steep roofs will generally not lead to overheating because the sun never shines directly down onto them. Skylights placed elsewhere may need some exterior shading placed over them in the summer. Greenhouse shading material is commonly used for this purpose.

Windows can also contribute to overheating. If not shaded, east and west facing windows can admit considerable amounts of unwanted solar heat in summer. Keep this in mind if adding windows and plan on either installing some type of summer shading device or using glass with low solar transmission.

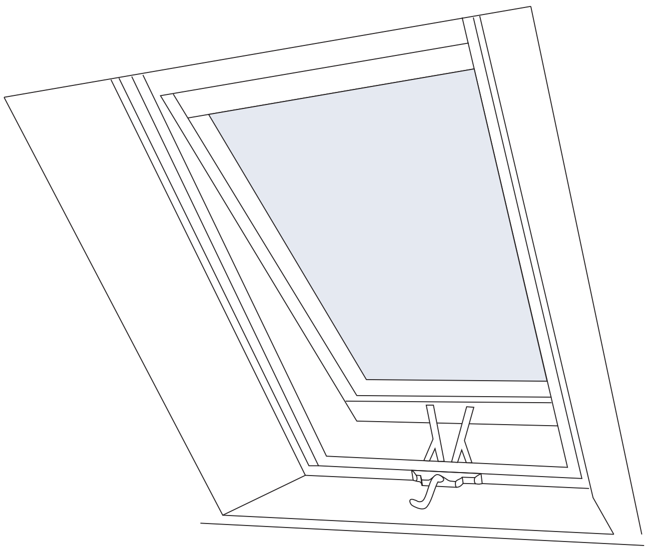


Figure 8-10 - Installing a skylight in a work or play area can significantly reduce the need for electric lights during the day.

Planning a new home to take maximum advantage of daylighting is best done during the design phase, when you or your designer can plan the layout of rooms and placement of windows and skylights to greatest advantage. There are many factors to take into account to provide optimal daylighting without causing overheating, so it's best to work with a designer experienced in this area. Glazing types, overhangs, vegetation, placement of windows, and room layout are all important factors for consideration.

A new way to add daylighting to a room is with a "skylight tube." These devices consist of a lens that is installed on the roof, an adjustable mirror-lined tube (10-20" diameter) that passes through the attic, and a light fixture that installs in the ceiling. Skylight tubes bring daylight into the house with much less disruption of roof and ceiling construction than is required for ordinary skylights.

You can also make some changes in your existing home to better utilize natural lighting. Simple things that can be done include rearranging furniture to take advantage of light from windows, and replacing dark curtains with light-colored curtains or venetian blinds. More involved changes that can make a big difference might be cutting some of the sun-blocking trees or branches from around the house, and adding a skylight or two – particularly in an upstairs study, workroom, or home office that is likely to be used a lot during the daytime.

Whenever adding new windows or skylights, it is important to consider possible solar overheating and to install appropriate shading or other solar control measures.

Modern buildings designed for daylighting typically use 40 to 60% less electricity for lighting needs than do more conventionally designed buildings.

Solar powered lighting

Another way to power lighting – particularly outdoor lights – is to use solar energy. A photovoltaic (PV) panel uses the solar energy of the sun to generate electricity, which is stored in a battery. The energy stored in the battery can be used to provide electric power to the outdoor lights. Solar powered lights work very effectively as patio and walkway lights, security lights, and to accomplish different landscape lighting effects in the garden. Solar lighting is versatile because no wiring is required and they can be moved around to achieve different effects.

Energy Star qualified Light Bulbs, Fixtures, and Ceiling fans

Look for the Energy Star label if you are purchasing compact fluorescent bulbs, light fixtures, or ceiling fans. Energy Star labeled lighting products meet strict energy efficiency criteria without sacrificing performance. The Energy Star label is awarded to both hard-wired and portable light fixtures including table lamps, torchieres, suspended fixtures, ceiling fixtures, outdoor light fixtures, recessed, and security lighting. Energy Star qualified ceiling fans and fixtures use compact fluorescent light bulbs, which reduce heat output and energy consumption as well as protecting the environment by reducing air pollution and global warming associated with energy production.

Lamp Packaging Disclosures

Effective in May of 1995, the Federal Trade Commission's Appliance Labeling Rule required light bulb manufacturers to display information on packages to help consumers choose the most energy efficient light bulbs. This rule applies to all household light bulbs except small bulbs like night- lights and chandelier bulbs. The information provided includes:

- Light Output: how much light the bulb produces, measured in lumens.
- Energy Usage: the total electrical power a bulb uses, measured in watts.
- Design Voltage: if the bulb is not 120 volts, which is what most bulbs operate on.
- Average life in Hours: how long you can expect the bulb to last.
- Number of light bulbs in the package.

Lighting strategies for your home

The floor plans in Figure 8-11 represent a typical home, showing where different energy-efficient lighting strategies might be applied. Your home will of course differ considerably from what is shown here, but the ideas may be applicable.

Energy Tips and Recommendations

1. Go through your house and make a list of which lights are on the most. The most-used lights are the best candidates for replacement with compact fluorescent lights. Compact fluorescent lights require special dimming ballasts and lamp holders in order to be used in dimming circuits.
2. Measure the light fixtures for those most used lights and then go to a lighting store or hardware store that carries a selection of compact fluorescent lights. Check the dimensions of the various types of compact fluorescents and buy one or two (don't

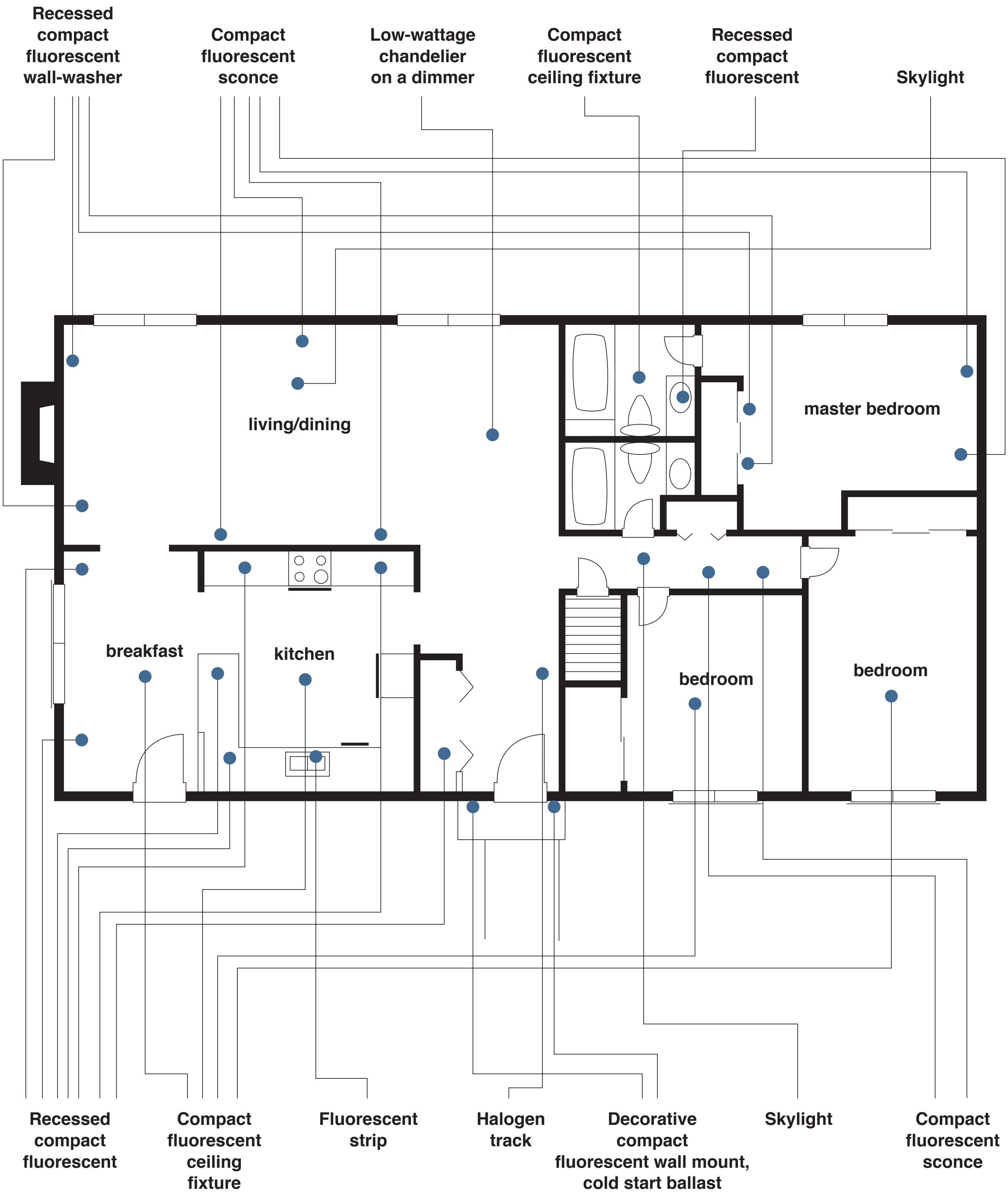


Figure 8-11 - Possible locations for energy-efficient lighting are shown in this typical floor plan.

buy a lot until you have made sure they will fit in your fixtures).

3. For situations where you need the highest quality light focused on a very specific area, consider tungsten halogen lights – either standard or low-voltage. Avoid using halogen lights in torchiere floor lamps – they can be a fire hazard.
4. Make use of natural daylighting whenever possible, especially in rooms that are used a lot during the daytime. In some situations you may need to rearrange your furniture to position your work-space by a window or under a skylight. In an upstairs room, you might want to consider putting in a skylight. (If you have an unheated attic above the ceiling, you will have to construct a light-well with insulated walls to allow the light to get down into the room.)
5. If you choose to continue using incandescent bulbs, use one high-wattage bulb in place of multiple low-wattage bulbs wherever possible. A 100-watt light bulb produces as much light as two 60-watt bulbs. Use incandescent bulbs that are energy efficient and avoid long-life bulbs.
6. If you tend to keep outdoor lights on all the time, buy and install a photo-sensor or motion-detector. Most hardware stores and building supply stores now carry these; if you can't find what you need there, try an electrical equipment dealer.
7. Utilize lighting controls and install timers, dimmers, and occupancy sensors in appropriate rooms.
8. If you need a lot of outside illumination (for a tennis court or swimming pool, for example), consider replacing incandescent lights with HID lights (either high-pressure sodium or metal halide).
9. Call your electric utility company to see whether they offer any incentives or assistance for purchasing compact fluorescent lights.
10. Use task lighting, which is focusing light on the area that you need light and avoid lighting up the entire room.
11. Turn off lights when not in use.
12. Clean fixtures, lamps, and lenses annually to remove dust and dirt that is preventing proper illumination and minimizing lighting efficiency.
13. Dispose of all fluorescent light bulbs properly.
14. Look for the Energy Star label when purchasing new lighting products.

WATER CONSERVATION

Water is essential to life. It is a primary building block in the cycle of life and an absolutely precious natural resource. We use water in our homes in a variety of ways. We use it to clean and wash, to drink and to flush; water is essential for operating appliances; we use it outdoors and in our cars, and for all types of recreational uses. As a matter of fact every American, on average, uses over 80 gallons of water every day. Water is an integral part of the household system and how we use and manage our residential water supply will impact all of the other components of that system.

In this chapter we will focus on conserving water and using it more efficiently. Using less water minimizes the demand on your spring, well, or municipal water supply and (since most of the water you use goes down the drain) reduces demand on your septic system or municipal sewer system. The American Water Works Association estimates that indoor water consumption can be reduced by 32% simply by fixing water leaks and installing efficient water fixtures and appliances. With basic water conservation practices, even more can be saved.

Drought

Drought is an unusually long period of dry weather that creates significant water shortage. Drought is a phenomenon that can devastate water supplies, agriculture and livestock, the economy, and human life over long periods of time. Drought is a natural disaster that affects more people worldwide than any other natural hazard. Rainfall is an obvious solution, but one that is not under our control. Water conservation, which is normally mandated during times of drought, is a necessary action to alleviate the dangers of drought conditions.

Drought is worse because it occurs randomly and unpredictably. During times of good rainfall, population growth and development increase our water needs. As long as water is adequate, we are not enthusiastic about spending money to conserve water or to expand our water supplies. When drought finally hits, it is often too late to take action.

Serious drought conditions in Virginia caused a State of Emergency to be declared in 2002. Under penalty of law Virginia residents were not allowed to water their lawns, wash their vehicles, or fill their swimming pools. State agencies were required to reduce water use by 15% and more serious measures were installed in other states and regions of the country.

The only good thing that comes from a drought is that water conservation becomes an important issue and the value of water as a resource becomes fully appreciated. The challenge is for every citizen to practice water conservation on a daily basis whether a drought exists or not. This kind of personal leadership will benefit everyone: money will be saved, energy will be saved, and our water quality and supply will be preserved and protected.

Water Saving Practices

In a single day, waste and inefficiency may cost you up to 100 gallons of water for each person in your house. Listed below are some simple water saving measures that can be applied in any residence.

- Fix leaky faucets, leaky toilets, and leaky pipes. Fixing water leaks may save from 15 to 100 gallons of water per day.
- Install low-flow showerheads and faucet aerators. This can reduce the water used by over 50%.
- Replace an old toilet with a water-saving model that uses 1.6 gallons of water per flush. Your old toilet (pre-1992) may be using 5 or more gallons per flush.
- If you do not use an efficient toilet then install a toilet displacement bag or kit and save ½ a gallon per flush.
- Flush toilets only when necessary. Do not use toilets for waste-baskets.
- Take short showers. Five minutes should be the maximum.
- If you take frequent baths, only fill the tub by 1/3. A full tub can use over 50 gallons of water.

- Do not run water continuously while shaving or brushing your teeth.
- Wash clothes only when you have a full load of clothes and use cold water whenever possible
- Using an Energy Star certified washing machine will reduce water use by 50%.
- Only operate dishwashers when the load is full.
- Limit the pre-rinse cycle in dishwashers by scraping dishes and dirty pans.
- Avoid using garbage disposals or use recycled water to operate a disposal.
- Do not water your lawn, plants, or trees needlessly. Excessive watering retards root growth, resulting in more need for water and more damage when drought hits and water conservation measures are imposed.
- Add mulch to trees and plants. This will trap and hold water in the ground and roots.
- Avoid fertilizing your lawn in summer because this will increase your lawn's need for water. Fertilize in fall or early spring instead.
- If you use a lawn sprinkler use it efficiently. Lawn sprinklers that are left on all day can waste thousands of gallons of water. Water the lawn in the evening or early morning, when evaporation is less.
- If you have a swimming pool, keep it covered when not in use. This will prevent evaporation and the need to fill the pool unnecessarily.
- When you wash your car use a shut-off nozzle on your hose or choose a car wash that recycles water.
- Conserving water is simply using good common sense. Examine your habits and practice conservation by making better decisions.

Low Flow Water Saving Fixtures and Appliances

The National Energy Policy Act of 1992 set the following standards for all new fixtures manufactured in the United States:

- Toilets use no more than 1.6 gallons per flush.
- Showerheads use no more than 2.5 gallons per minute.
- Kitchen and bathroom faucets not exceed 2.5 gallons per minute.

If your kitchen and bathroom fixtures were purchased after 1992 then you probably have an energy efficient low flow water device. There are showerheads and faucets that exceed the minimum standards set by law and if you are ready to replace your fixtures then be sure to check these out. If you have fixtures that are pre-1992 then you could be experiencing a faucet flow rate of almost 7 gallons per minute and a showerhead that flow rate of over 5 gallons per minute. But remember: your house is a system and the impact of low flow fixtures will be minimized if you leave the water running or take lengthy showers. Be sure to combine conservation with efficiency to maximize the energy and water saving potential in your household.

Low Flow Toilets

The toilet is the greatest consumer of water in a household and typically can account for up to 25 to 30% of indoor water use. If you have a toilet that was manufactured before 1992 then consider replacing it with a low flow toilet that will only use 1.6 gallons per flush compared to older models that will use from 3.5 to over 5 gallons per flush. It is important to research and carefully select a toilet because they will vary in quality. If you buy a low quality toilet that takes two flushes to empty the bowl, you won't be saving much water!

Waterless Urinals

A waterless urinal is a non-flushing urinal that allows the urine to pass through a lighter-weight liquid, which serves as a trap and keeps odors from escaping into the room. There are no moving parts and therefore very little maintenance. These appliances are currently used in commercial applications exclusively but a waterless toilet for residential use may be available in the future.

Composting Toilets

Composting toilets allow human waste to be converted into nutrient rich compost, which can be used for fertilizing non-food crops and plants. There is no water used in flushing a composting toilet. The composting chamber consists of organic matter like wood shavings, peat moss, and some water that will aid in the decomposition of the waste. These systems are expensive and may not be for everyone but they certainly save energy and water and reduce the costs of treating wastewater.

Low Flow Faucets

Faucets purchased after 1992 will be equipped with an aerator that uses 2.5 gallons per minute. Compared to faucets manufactured before 1992, which use 5-7 gallons per minute, this is a significant saving. An aerator adds air to the water stream, increasing the effectiveness of the flow and reducing water consumption. Aerators on the market range from 0.5 to 2.5 gallons per minute.

Low Flow Showerheads

Showers account for almost 17% of indoor water use and use almost half of all hot water that is consumed within a household. Showerheads manufactured after 1992 are required to operate at 2.5 gallons per minute. Pre-1992 showerheads may use up to 8 gallons per minute. There are low flow showerheads on the market now that use only 1.5 gallons per minute. Some showerheads come with shut off valves that allow the individual to cut off the flow of water when shampooing or soaping up and then turn it on again when needed. There are many different models to choose from so be smart, do some research and ask questions before purchasing a low flow showerhead. A low flow showerhead will save water and energy by reducing hot water use. Remember, though, that combining this efficient device with practicing conservation by taking shorter showers is the way to operate your household at maximum energy performance levels.

High Efficiency Washing Machines

An Energy Star labeled washing machine (Chapter 7), uses 30 to 40% less water than a traditional machine. They do this by not filling the entire tub with water and agitating the clothes covered with water but by rotating the clothes through a partially full tub. They also spin the clothes better, producing clothes ready for the line or the dryer that have less moisture. A typical household does nearly 400 loads of laundry a year, which accounts for over 20% of indoor water use. So consider an energy efficient washing machine for your next appliance purchase and you will significantly reduce your household water consumption.

Dishwashers

Dishwashers (Chapter 7) manufactured after 1994 use 7-10 gallons of water per cycle versus pre-1994 models that use 8-14 gallons of water per cycle. This is due to national efficiency standards. When purchasing a new dishwasher be sure to study the EnergyGuide label and look for those that are Energy Star certified to insure that they exceed the minimum efficiency standards.

Fixing Water Leaks

Household water leaks can account for over 10% of a home's water consumption and can result in an average loss of over 25 gallons per day. Thousands of gallons of water can be lost annually due to leaky faucets, toilets, and water pipes. The Environmental Protection Agency (EPA) concluded in 2002 that 14% of the water that we buy is lost to water leaks. The EPA calculated that the water lost to leaks in homes totals 1.72 billion gallons daily nationwide. That is the equivalent to the amount of water consumed daily by New York City and Chicago combined.

Prevention and consistent maintenance is the key to correcting this wasteful and costly problem. Prevention of leaks is first accomplished by using quality fixtures, plumbing hardware, pipes, fittings and valves. Always select National Sanitation Foundation (NSF) approved plumbing fixtures, piping, and fittings. Quality products will minimize the potential for water leaks.

Most water leaks are fairly obvious while some may require testing or crawling under the house to check a water line. If you have a water meter, check it when no water is being used. If the meter is showing that usage has occurred when all the water in the house is off, then you have a leak somewhere. If you are unsure whether your toilet may be leaking or not, give it the dye test. Lift the lid off the toilet tank and put several drops of dark food coloring into the tank. Wait several minutes and then check to see if there is any dye color in your toilet bowl. Your toilet is leaking if there is color in your bowl.

Table 9-1 – Water Loss from Leaks*

Pipe Leaks *(at 60 pounds of water pressure)*		**Faucet Leaks**	
Size of Hole	Gallons Wasted Monthly	Drops per Minute	Gallons Wasted Monthly
1/32"	6,300	60	192
1/16"	25,000	90	310
1/8"	100,000	120	429
3/16"	225,000		
1/4"	400,000		

**Source: California Urban Water Conservation Council*

Hiring a plumber to fix a water leak, particularly if it is a leaky pipe that might require replacement or re-soldering, is a good investment and should be considered whenever there is potential loss of water due to leaks. At the same time a homeowner can make faucet and toilet leak repairs simply by making an adjustment or by replacing a washer. This can save time and money. Follow the instructions below and you may be able to fix toilet and faucet leaks without hiring a plumber. The following illustrations and information are courtesy of the New Mexico Office of the State Engineer and is contained in their water conservation booklet "Don't Waste a Drop". Check their website at www.ose.state.nm.us .

Toilet Types

The first step in fixing a toilet leak is determing what type of mechanism your toilet has: float ball / tank ball, float cup/ flapper, or float ball/flapper.

Float Ball/Tank Ball Models

Float ball / tank ball models use a ball float to sense the water level in the toilet tank and a ball valve to control the flow from the tank to the toilet bowl. They have the following components (see Figure 9.1):

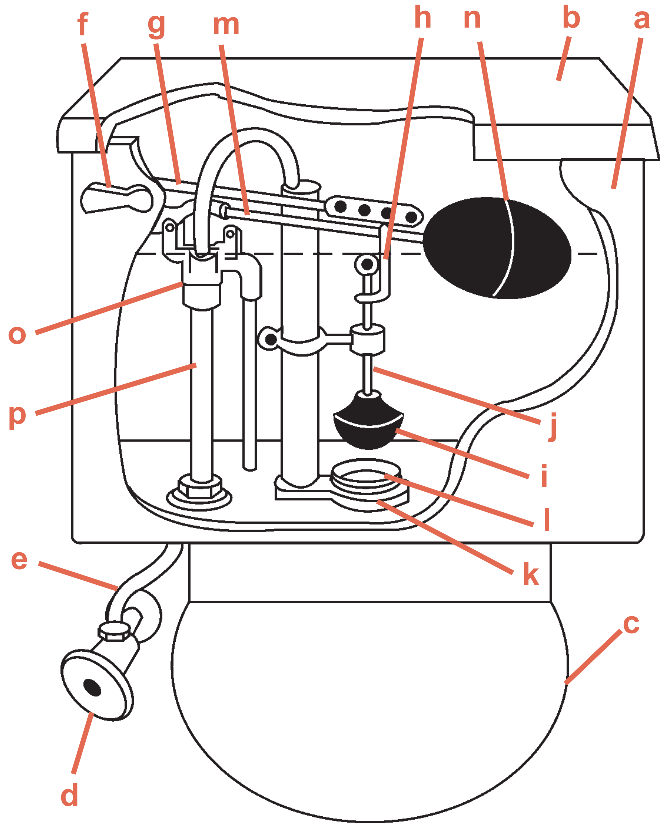


Figure 9-1 - Float ball / tank ball toilet

- **a. Tank**– The top portion that holds water waiting to be flushed. Also inside are the flush mechanisms and components.
- **b. Tank lid**– The cover that sits on the tank and conceals the flush mechanisms.
- **c. Bowl**– The lower half of the toilet that holds waste prior to flushing.
- **d. Water shutoff valve**– The valve located on the wall near the base of the toilet (typically with an oval or round handle) that controls the flow of water into the toilet tank.
- **e. Water supply line**– A hose-like line, typically made of flexible material, that connects the water shutoff valve to the bottom of the tank.
- **f. Flush handle**– The mechanism that is pushed to activate the flush.
- **g. Lift arm**– The metal or plastic rod connected to the flush handle.
- **h. Lift wire**– The connecting link between the lift arm and the tank ball.
- **i. Tank ball**– The rubber ball that sits in the flush valve (the hole in the bottom of the tank) to keep water in

the tank until the flush.

- **j. Guide arm**– A fixed piece, connected to the over-flow pipe, which ensures that the tank ball falls snugly on the flush valve.
- **k. Flush valve**– The opening through which water flows from the tank to the bowl.
- **l. Valve seat**– The rubber seal at the bottom of the tank into which the tank ball fits.
- **m. Float arm**– The metal or plastic rod connected to the ball cock at one end and the float ball at the other. The angle of the float arm is what tells the ball cock to shut off the water supply to the tank.
- **n. Float ball**– A hollow rubber ball that rises and falls with the water level in the tank.
- **o. Ball cock valve**– The tall mechanism on the left-hand side of the tank that controls the flow of water into the tank.
- **p. Overflow pipe**– The vertical pipe that drains excess water from the tank to prevent overflow.

Float Ball/Flapper Models

Float ball / flapper models use a ball float to sense the water level in the toilet tank and a flapper valve to control the flow from the tank to the toilet bowl. Besides the general components of the float ball /tank ball models, they have (see Figure 9.2):

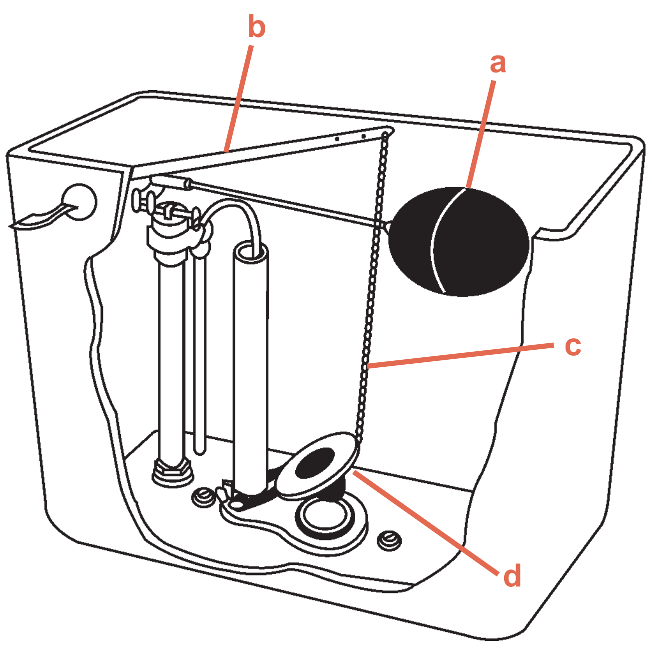


Figure 9-2 - Float ball / flapper toilet

- **a. Float ball**– A hollow rubber ball that rises and falls with the water level in the tank.
- **b. Lift arm**– The metal or plastic rod connected to the flush handle.
- **c. Lift chain**– The connecting link between the lift arm and the flapper.
- **d. Flapper**– The flush valve seat that controls the volume of water passing from the tank to the bowl during a flush.

Float Cup/Flapper Models

Float cup/ flapper ball models use a float cup (sometimes called a "vertical ballcock") to sense the water level in the toilet tank and a flapper valve to control the flow from the tank to the toilet bowl. Besides the general components of the float ball /tank ball models, they have (see Figure 9.3):

- **a. Float cup**– A variation on the float ball, a float cup performs the same basic function, rising and falling with the water level in the tank. When the float cup rises high enough along the ball cock tube, it triggers the ball cock to stop the flow of water into the tank.
- **b. Lift arm**– The metal or plastic rod connected to the flush handle.
- **c. Lift chain**– The connecting link between the lift arm and the flapper.
- **d. Flapper**– The flush valve seal that controls the volume of water passing from the tank to the bowl

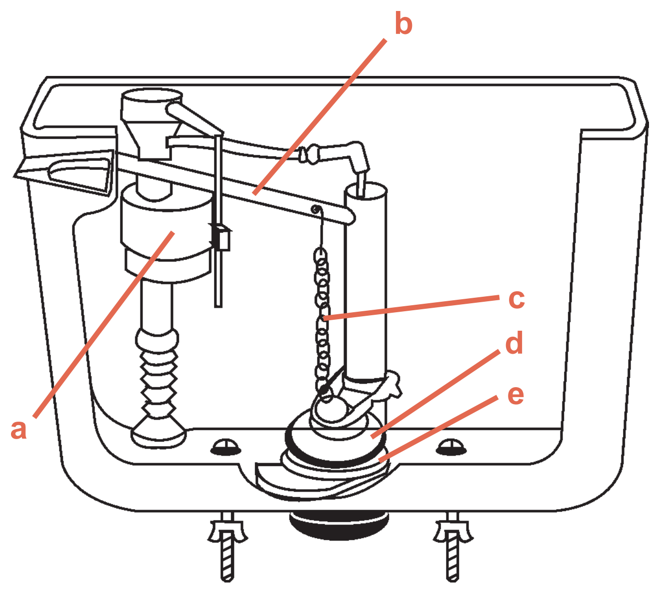


Figure 9-3 - Float cup / flapper toilet during a flush.

e. **Flush valve**– The opening through which water flows from the tank to the bowl.

Another type of toilet is the pressure-assisted toilet, which uses air pressure within a cylindrical tank inside the toilet tank to propel the water during a flush. Tuning up a pressure-assisted toilet is best left to a professional plumber.

Fixing Toilet Problems

Leaks and noises are the most common problems with tank toilets, and the two types of problems are often interrelated. (However, some leaky toilets are silent.) The good news: many common toilet leaks can be fixed by making minor adjustments. Let's go through some of the most common reasons toilets leak and the steps you'll need to follow to fix them.

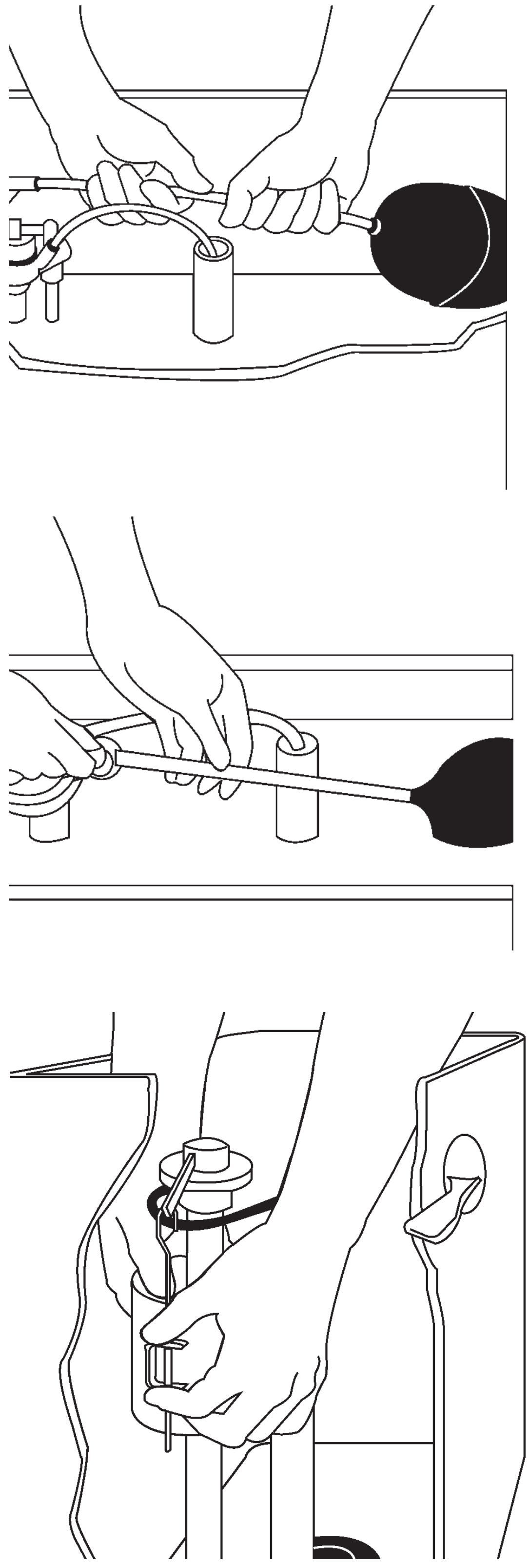
Toilet "runs" all the time, or periodically between flushings. (You hear the sound of running water.)

A running toilet can be caused by an improperly adjusted float ball that results in a water level in the tank that's so high that water is escaping into the top of the overflow pipe. A running toilet can also be caused by a cracked float ball, an improperly seated flapper or tank ball, a kinked lift chain or a bent lift wire.

If the water level in the tank is too high: Adjust the float arm.

- In older toilets with a metal float arm, you'll need to grab the float arm with both hands and gently bend the side with the float ball downward. (Figure 9-4a)
- If your toilet has a plastic float arm, there's probably an adjusting knob located where the arm meets the ball cock. Loosen the knob and move the float arm and float ball downward. (Figure 9-4b)
- If your toilet has a float cup instead of a float ball, pinch the spring clip on the side of the float cup and slide the float cup a bit lower. (Figure 9-4c)

  Some toilets have a "floatless ball cock" that controls



9-4a

9-4b

9-4c

Figure 9-4 - Adjusting tank level

the water level with a pressure sensing device. To adjust the water level on a floatless ball cock, turn the adjustment screw on top of the ball cock. Turn the screw clockwise to raise the water level and counterclockwise to lower it.

Flush the toilet and check the new water level. It should be about 1/2 inch below the top of the overflow tube (or at the line etched on the inside back of the tank).

Replace the float ball

If a simple water-level adjustment doesn't fix the problem, you might need to replace the float ball. If the float ball is cracked, it will fill up with water and never rise high enough to tell the ball cock valve to shut off the water. The float ball will be fully or partially submerged and the water level in the tank will be so high that water flows into the overflow pipe.

- Remove the float ball by unscrewing it counterclockwise.
- Coat the threads of the float arm with petroleum jelly.
- Screw a new float ball onto the float arm.

(See Figure 9-5.)

If jiggling the handle stops the toilet from running: Check the guide wire or lift chain.

- For flappers with lift chains: Make sure the chain isn't kinked or hung up on the float arm or float ball. Try adjusting the chain by hooking it into a different hole on the lift arm (which is attached to the flush handle). (See Figure 9-6.)
- For tank balls with guide wires: Check to see that the tank ball is fitting properly on the valve seat. To readjust a tank ball mechanism, loosen the thumbscrew that fastens the guide arm to the overflow pipe. Reposition the arm and the lift wire so that the tank ball is right above the flush valve.

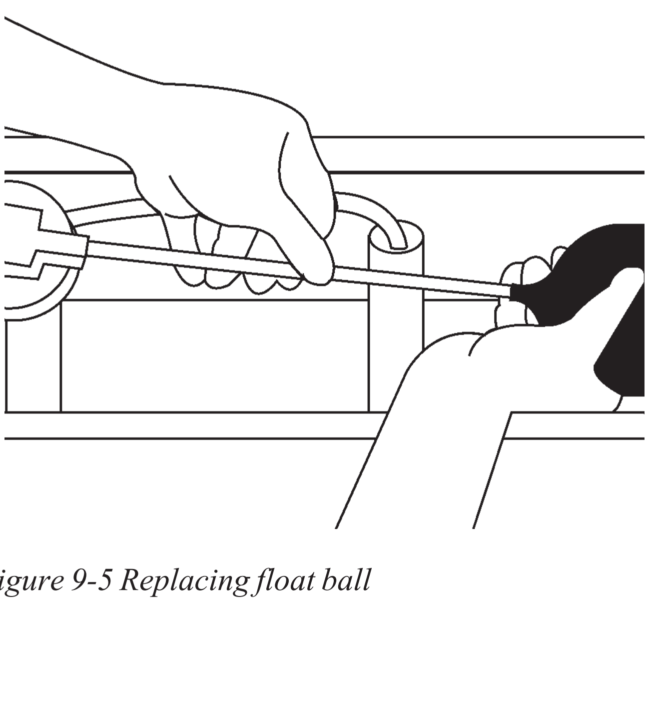


Figure 9-5 Replacing float ball

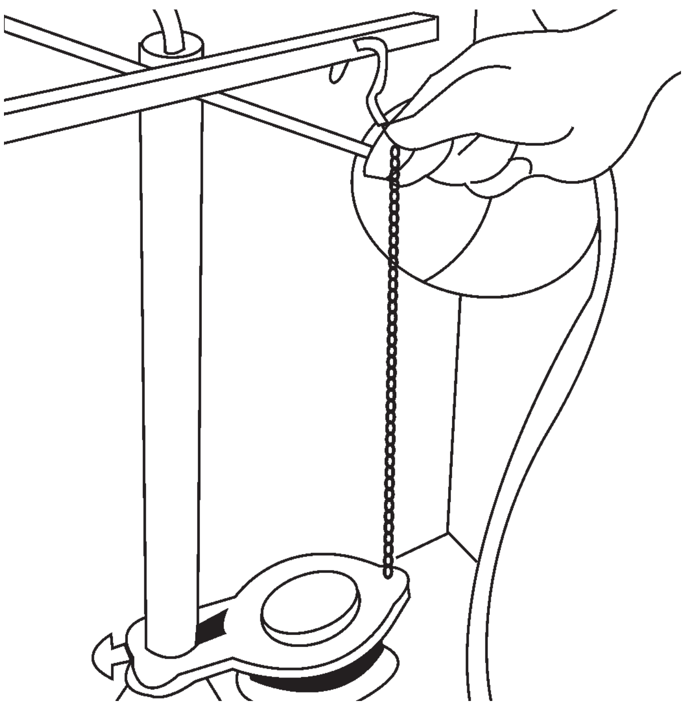


Figure 9-6 - Check the lift chain

If the toilet STILL leaks, replace the ballcock

If none of the above procedures has fixed the leak, or the toilet is making a high whine or whistle when the tank is filling up, consider replacing the ball cock, the mechanism that controls the flow of water into the toilet tank. Replacement ball cocks are sold at plumbing, hardware and home improvement stores.

Although it is possible to replace an older ball cock with a new one, consider replacing it with a new float cup valve, which many plumbers prefer because it is less prone to leaking.

- Turn off the water shutoff valve and flush the toilet to drain the tank.
- Disconnect the water supply tube from the bottom of the tank.

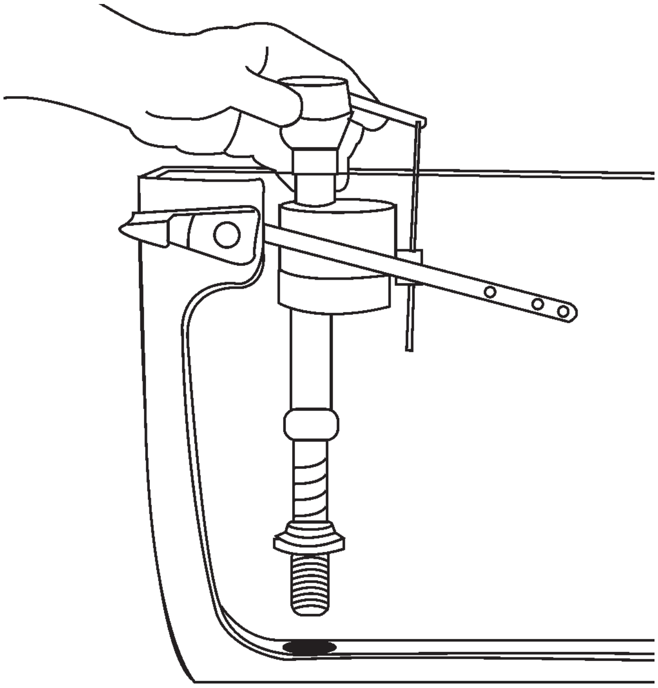


Figure 9-7 - Replacing the ballcock

- Remove the float arm from the ball cock.
- Remove the refill tube from the top of the ball cock.
- Loosen the nut under the tank that holds the ball cock into place. If the ball cock turns when you try to loosen the nut, hold the ball cock with one hand while loosening the nut under the tank with your other hand. Once the nut is removed, lift the ball cock out of the tank.
- Install a new float cup valve into the tank and tighten the nut on the underside of the tank.
- Attach the refill tube to the float cup and to the overflow tube.
- Reconnect the water supply tube and turn on the water supply.
- Adjust the float cup until the water level is about 1/2 inch below the top of the overflow tube. To adjust the water level, simply pinch the spring clip on the side of the cup and move the cup higher (to raise the water level) or lower (to lower the water level.)

(See Figure 9-7.)

Faucet Types

The first step in fixing a leaking faucet is determing whether it is a compression faucet or a washerless faucet.

Compression faucets

Compression faucets, sometimes called stem faucets, have one handle for cold water and one for hot water. When the handle is turned on, the stem rotates. The threads cause the stem to rise, moving a rubber washer away from the faucet seat and allowing water to flow. When turning the faucet off, you can sometimes feel the rubber washer being squeezed against the faucet seat to stop the flow of water.

A typical compression faucet is shown in Figure 9-8.

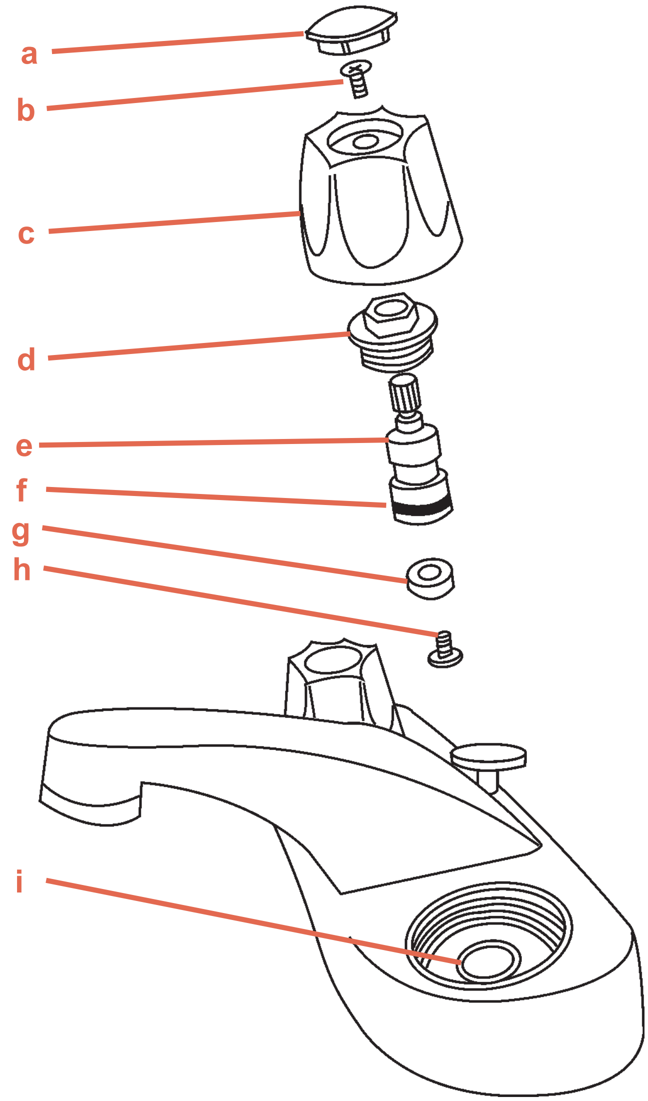
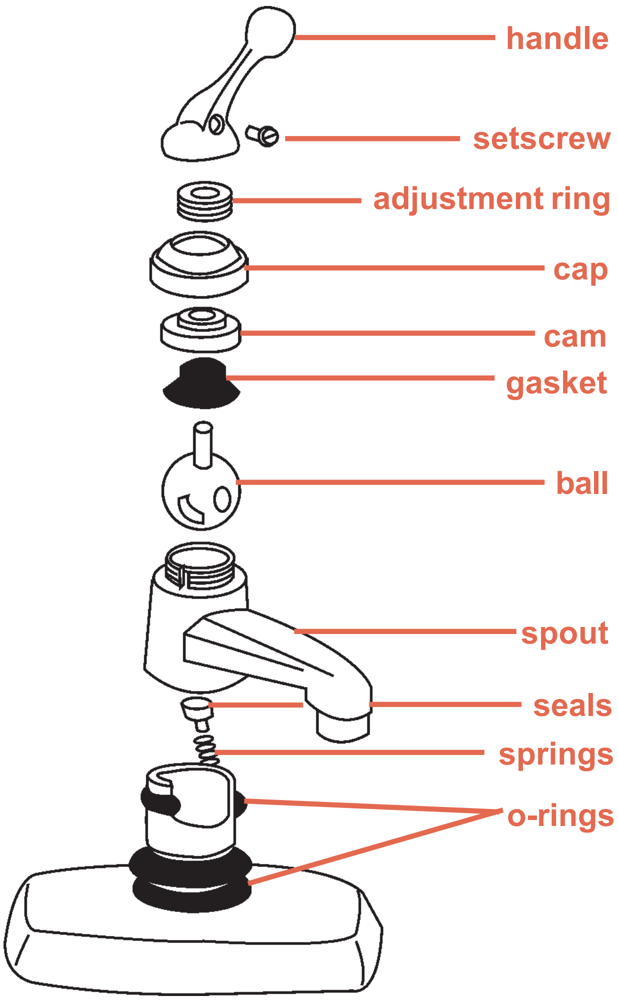
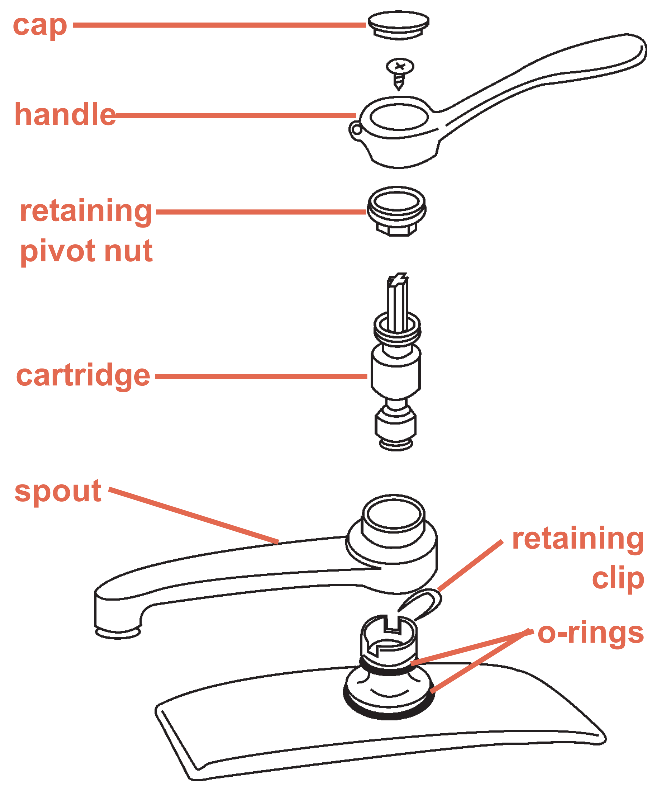


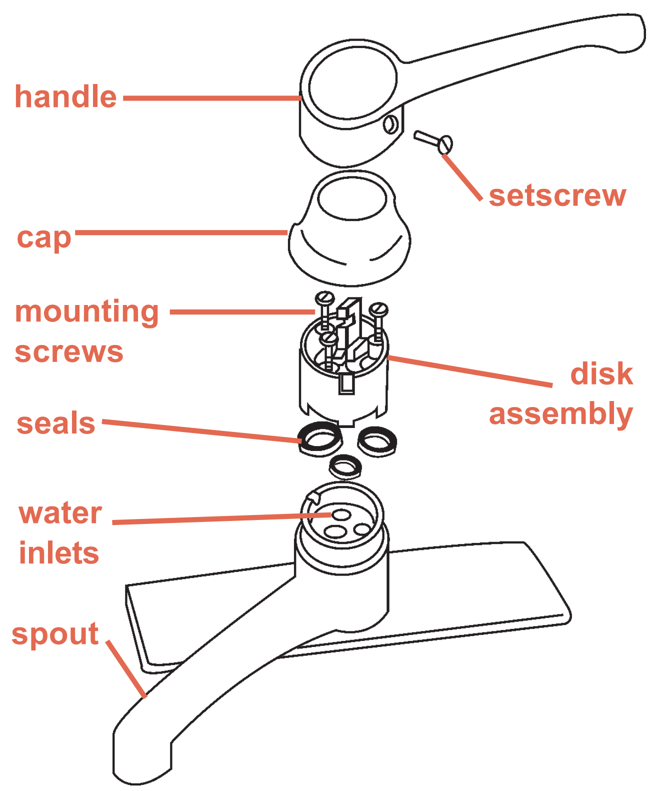
Figure 9-8 - Compression faucet:
a. decorative cap *b. handle screw*
c. handle *d. retaining (packing) nut*
e. stem *f. packing washer or o-ring*
g. seat washer *h. seat screw*
i. valve seat



9-9a - *Ball faucet*



9-9b - *Cartridge faucet*



9-9c - *Disk faucet*

Figure 9-9 - Washerless Faucets

Washerless faucets

Washerless faucets typically have just one handle that controls both the hot and the cold water. Washerless faucets are known for providing years of trouble-free service because their design minimizes friction and wear. There are three primary types of washerless faucets:

- A **ball faucet** has a single handle over a dome-shaped cap.
- A **cartridge faucet** has a narrow plastic or metal cartridge inside the faucet body. Most cartridge faucets are single-handle models, but some two-handled faucets use cartridge designs.
- A **disk faucet** has a single handle and a wide cylinder inside the faucet body.

Washerless faucets are shown in Figure 9-9.

Fixing Faucet Leaks

Most leaky faucets can be repaired by installing a few inexpensive parts.

Helpful Tips

- Turn off the water before you start any faucet repair. The shutoff valves for indoor faucets are underneath the sink. Turn the left knob clockwise to shut off the hot water; turn the right knob clockwise to shut off the cold water.
- Before disassembling a faucet, cover the sink with a towel to protect it from dropped tools and to prevent small parts from going down the drain.
- When dismantling parts, line them up in the order and orientation in which they were removed to make it easier to properly reassemble the pieces.
- When using metal tools on a polished surface, protect the polished surface with a rag or several layers of masking tape.
- Take the old parts with you when you go to a plumbing or hardware store to buy replacement parts. This will help ensure that you get the right parts for the job.
- Most faucet repair kits come with good instructions. Follow them!

Fixing a compression faucet

To fix a leaking compression faucet, first determine whether it's a hot water leak or a cold water leak. If you can't tell from the temperature of the dripping water, turn off the hot water supply valve under the sink. If the drip stops, it's the hot water stem that's leaking. If the drip continues, the culprit is the cold water faucet.

- Remove the handle screw. (It may be hidden under a decorative cap or behind the handle.) Remove the handle.
- Unscrew the retaining (packing) nut.
- Remove the stem by either jiggling it from the valve seat or unscrewing it counterclockwise with a wrench.
- To replace the washer on a standard stem, remove the seat screw at the bottom of the stem and pry out the old washer with a screwdriver. Install a new washer.

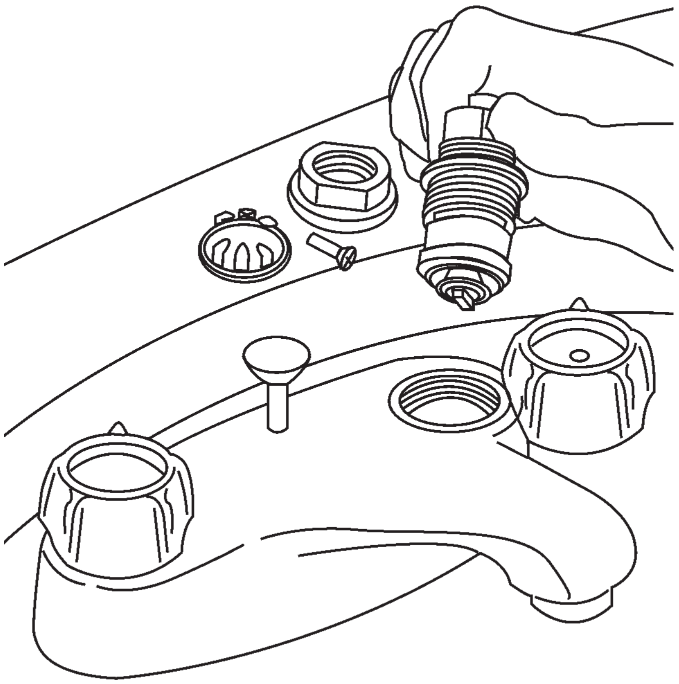


Figure 9-10 - Compression faucet repair.

- For some compression faucets, you'll also need to replace the packing washer or packing string, which prevents water from leaking at the faucet handle.
- Check the valve seat (the metal that the washer seals on) for damage by running your finger along the rim of the seat. If it's pitted and not completely smooth, remove the valveseat using a seat wrench. Install a new valve seat.
- Reassemble the parts.

Compression faucet repair is shown in Figure 9-10

Fixing a ball faucet

- With an allen wrench (hex key), loosen the setscrew at the base of the handle. Remove the handle.
- Underneath the handle you'll find a protective cap with an adjusting ring. Sometimes a dripping ball faucet can be fixed by tightening this ring. Turn it clockwise gently.
- If tightening the ring doesn't stop the leak, close both shutoff valves beneath the sink.

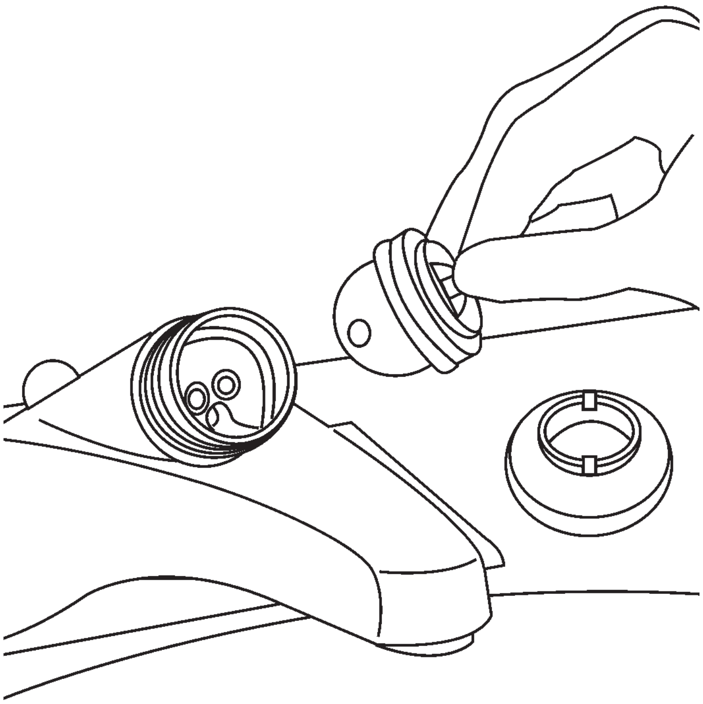


Figure 9-11- Ball faucet repair.

- Unscrew and lift off the cap, plastic cam, cam gasket and rotating ball.
- Rubber faucet seats are held against the bottom of the ball by small springs. Using the point of a screw-driver or a pair of needle-nose pliers, gently remove the two seats and springs. Remove any loose debris.
- Install new seats and springs from a repair kit.(Follow the instructions provided in the repair kit.) Also, lift the spout and replace the two O-rings. (Apply a light coating of petroleum jelly or valve grease to the new O-rings before installing them.)
- Reassemble the faucet and tighten the adjusting ring enough to prevent leaks without making the handle difficult to operate.

Ball faucet repair is shown in Figure 9-11.

Fixing a cartridge faucet

- Shut off both water supply valves underneath the sink.
- Remove the decorative cap (if any) and remove the handle screw. Remove the handle.
- Unscrew the retainer nut.
- Some models have a U-shaped clip that holds in the cartridge. Use needle-nose pliers or the tip of a screwdriver to remove the clip.
- The cartridge fits tightly in the faucet body. Remove the cartridge by pulling up on it firmly with a pair of pliers.
- Replace damaged O-rings and lubricate the new ones with petroleum jelly or valve grease. If the cartridge is worn or damaged, replace it with an identical part. (Cartridge repair kits typically contain a new car-tridge, new O-rings and grease.)
- Install the new cartridge, making sure that the notch in the stem faces the sink.
- Reattach the U-clip, retainer nut, handle, handle screw and decorative cap.

Cartridge faucet repair is shown in Figure 9-12.

Fixing a disk faucet

- Shut off both water supply valves underneath the sink.
- Remove the setscrew from the handle. Lift off the handle and remove the body cover (escutcheon cap).

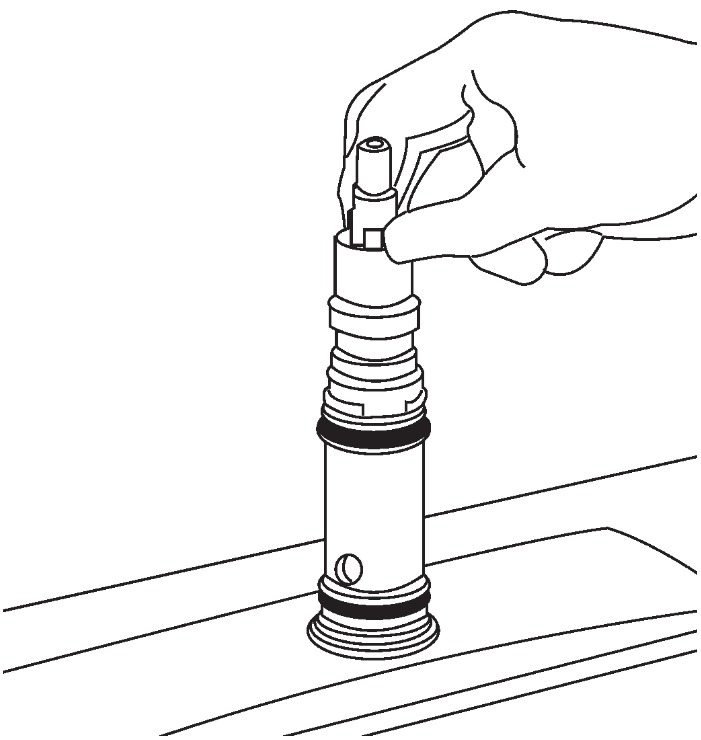


Figure 9-12- Cartridge faucet repair.

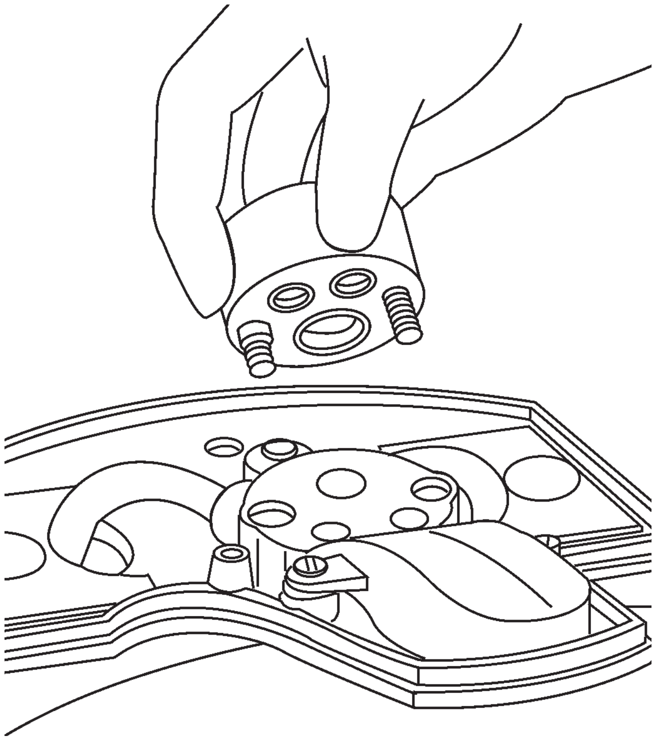


Figure 9-13 - Disk faucet repair.

- Remove the disk assembly as a unit by unscrewing the mounting screws. Pull the disk out.
- Turn the disk over and remove any dirt lodged between the ceramic disks.
- Remove the rubber seals from the cylinder openings. Clean the cylinder openings and flush out any debris.
- Install new rubber seals and reassemble the faucet.
- If the faucet still leaks, replace the entire disk assembly with a new one.

Disk faucet repair is shown in Figure 9-13.

Stormwater Management

Stormwater is rainfall that does not soak into the ground or evaporate. Instead it flows along the surface of the ground and becomes runoff. Stormwater runoff can cause major problems in cities and towns because of flooding and the pollutants that are picked up and then dumped into our waterways. This is a very serious and significant issue in developed areas because of all the roadways, paved parking lots, sidewalks, and stormwater management systems that channel and direct the water rather than allowing it to permeate the ground and become part of the groundwater system. The pollutants that are collected into this runoff come from road salt, animal waste, and vehicle fluids that are commonly found on the impervious materials that make up much of our developed environment. Water conservation includes properly managing rainfall to maximize its ability to enter the ground rather than obstructing that reentry with improperly placed impervious materials. The earth is a sponge and when we cover that sponge with obstructions that cause runoff, we are not allowing mother nature to replenish the ground with water. This does not represent good water conservation practice.

Residential stormwater management is an excellent way to conserve water and can be accomplished by following some simple recommendations:

- Separate impervious surfaces such as driveways, walkways, and patios with vegetation to reduce run-off.
- Use porous or pervious materials for driveways and patios.
- Avoid installing curbs or obstructions that allow water to be channeled into runoff.
- Preserve the natural topography on your property as much as possible.
- Reduce or eliminate any pollutants – like fertilizers and pesticides - that you may use on your lawn and garden that may become part of any runoff that occurs.
- Do not allow pollutants like gas or oil to collect on any impervious material such as a driveway and then become part of any stormwater runoff.
- Set up your roof downspouts so that the water is distributed in a manner that will maximize ground absorption.
- Set up a simple rainwater collection system that catches and stores rainfall so that it can be used for selective irrigation and even household potable water needs.

Rainwater Harvesting

People all over the world have been using some type of rainwater collection system for centuries. This was before drilled wells, pumping systems, and municipal water plants. It was a combination of good common sense and survival to collect water as it fell from the sky, store it in some type of cistern or tank, and then use it for household, agricultural, and landscaping purposes. In many parts of the world rainwater collection or harvesting still provides the majority of water that is used. Survival and common sense still make rainwater collection a practical measure even in modern society. Rainwater harvesting can save a homeowner money, energy, and is a great way to practice water conservation on a daily basis.

Most rainwater collection systems are designed to collect water from roofs of buildings. The water is then carried through gutter or other piping into a storage tank. A normal rainwater collection system consists of the following components:

- A collection area
- A system or method of transferring the water
- A filtering device or system
- A storage tank or cistern
- A distribution system

If the harvested water is to be used for non-drinking use then any material can be used in the collection system. If the rainwater will be used for household potable water needs then it is very important that the collection and distribution systems be free of any harmful materials or impurities. There are many types of tanks, filters, and distribution systems available for rainwater collection and the prices will vary accordingly.

It is estimated for every inch of rainfall, an average of 1,200 gallons of rainwater can be harvested from the roof of a 2,000 square foot home. Utilizing this time-honored method is a natural way to practice conservation and save money at the same time.

Water Saving Tips and Recommendations

1. Conserving water and using it more efficiently will help to save and preserve this valuable natural resource. Water conservation will also help to reduce home energy consumption and lower water and energy bills.
2. Mandating water conservation measures during time of drought is necessary but the practice of conserving water should be a daily activity whether drought conditions exist or not.
3. The following basic water saving tips can be applied to just about any residence:
   - Fix water leaks. Water leaks in faucets, toilets, and piping can account for 100 gallons of water being lost daily.
   - Install low-flow showerheads and faucets. This can cut water use by 50%.
   - If your toilet was manufactured before 1992, consider replacing it with a low flush toilet that will use over 50% less water per flush.
   - Combine conservation with efficiency – take short showers using a low flow showerhead and don't leave your low flow faucet running unnecessarily.
   - Consider purchasing an Energy Star washing machine. You will use 50% less water per load.
   - Use cold water when washing clothes and wash clothes only when you have a full load.
   - Operate dishwashers only when the load is full.
   - Use lawn sprinklers and outdoor hoses efficiently.
   - Avoid overwatering your lawn, plants, and shrubs. Use mulch to trap moisture and reduce the need to water plants and trees.
4. Before you call a plumber, try to fix simple water leaks in your faucets and toilets yourself. Sometimes this can be accomplished by making an adjustment or replacing a washer.
5. Apply good stormwater management practices at your home and save water and minimize pollution by reducing strormwater run-off.
6. Consider harvesting rainwater by installing a simple rainwater collection system at your home. You will save water and save money at the same time.

ENERGY-EFFICIENT NEW CONSTRUCTION

For new homes, there is no single best design or technique for achieving optimal energy efficiency. Builders now have at their disposal a vast array of materials, components, appliances and techniques. Quality work and good materials have always been hallmarks of a well built home but an understanding of how a house operates as a system is essential in building an energy efficient home. Knowing how to properly integrate all of the building components and understanding that they all interact is necessary in order to produce a high performance home. This chapter describes how to identify those features in a new home and presents a few representative examples of each – many of which have already been discussed in previous chapters. The chapter also briefly discusses green building concepts in a special section located at the end of the chapter preceding Energy Tips and Recommendations. Green building emphasizes the importance of environmentally friendly building techniques, which obviously includes energy efficient construction. Green building is essentially an umbrella that encompasses any energy efficient building method or practice and everything discussed in this chapter is a component of the green building approach.

Energy Star Homes

Purchasing or building an Energy Star labeled home means that you will live in a house that is certified to be energy efficient. An Energy Star home will have tight ducts, good ventilation, maximum insulation levels, high performance windows, air tight construction, and energy efficient heating and cooling equipment. This combination of construction gives reduced utility bills, healthy indoor air, and low maintenance. They are site inspected and diagnostic tested by accredited Home Energy Raters.

For more information please visit the Energy Star Web site at www.energystar.gov/homes

High Levels Of Insulation

Insulation (Chapter 3) is one of the most important and most cost-effective ways to improve the energy performance of your home.

High Performance Windows With Proper Solar Control

The windows in an energy-efficient house in Virginia should have overall U-values of at least 0.40 or less. Most commonly they will be double-glazed, low-E windows with wood or vinyl frames. Super insulated windows have a U-vale of 0.22. (See Chapter 4 for a description of how high performance windows work.)

To help control cooling loads, your builder may incorporate solar control glass, which reduces solar heat gain into the house, particularly into south and west facing rooms that have large glass area.

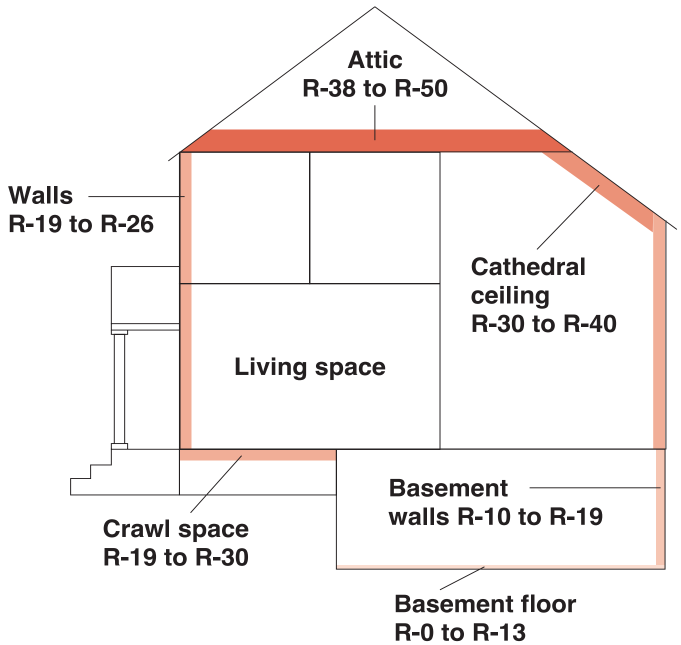


Figure 10-1 - To control heat loss through walls, ceilings and floors, an energy efficient new home has high R-values around the entire thermal envelope. (See Chapter 3 for an explanation of R-values.)

Low Air Leakage Rate

Airtight construction and controlling air leakage is the primary key to the performance of an energy efficient house. It is also one of the most elusive features to identify. As discussed in (Chapter 1), it is an excellent investment to have a professional blower door test done to identify air leakage areas and to determine how tight your house is. All builders should be interested in including blower door testing into their house-as-a-system testing procedures (Chapter 1).

Building for air-tightness entails a variety of materials, techniques, proper testing, and an appropriate design. Air leakage is discussed thoroughly in Chapter 2. In general, all joints, seams and penetrations should be sealed with either caulk, two part foam, gaskets or polyethylene

Figure 10-2a

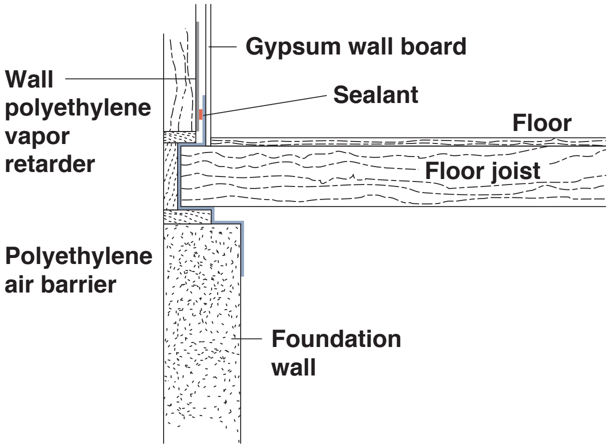


Figure 10-2b

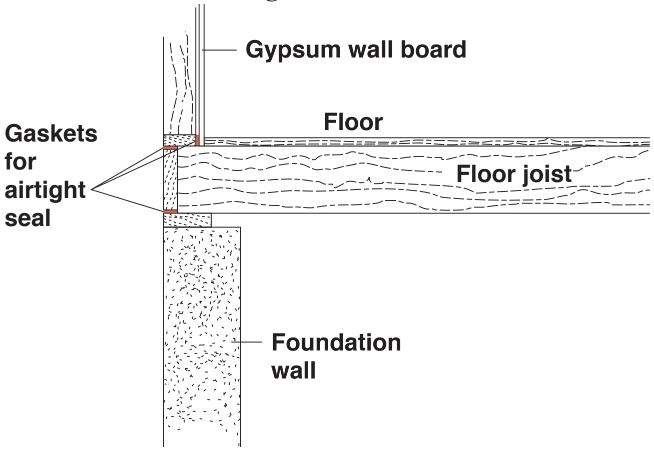


Figure 10-2 - The area around floors is the single most important area to seal for air leakage control. One common approach for controlling air leakage around floors is to wrap a plastic sheet around the edge of the floor system and seal it to the wall above and foundation below (a). Another common approach is to place gaskets between the various framing members (b). Both methods have been tested and proven effective.

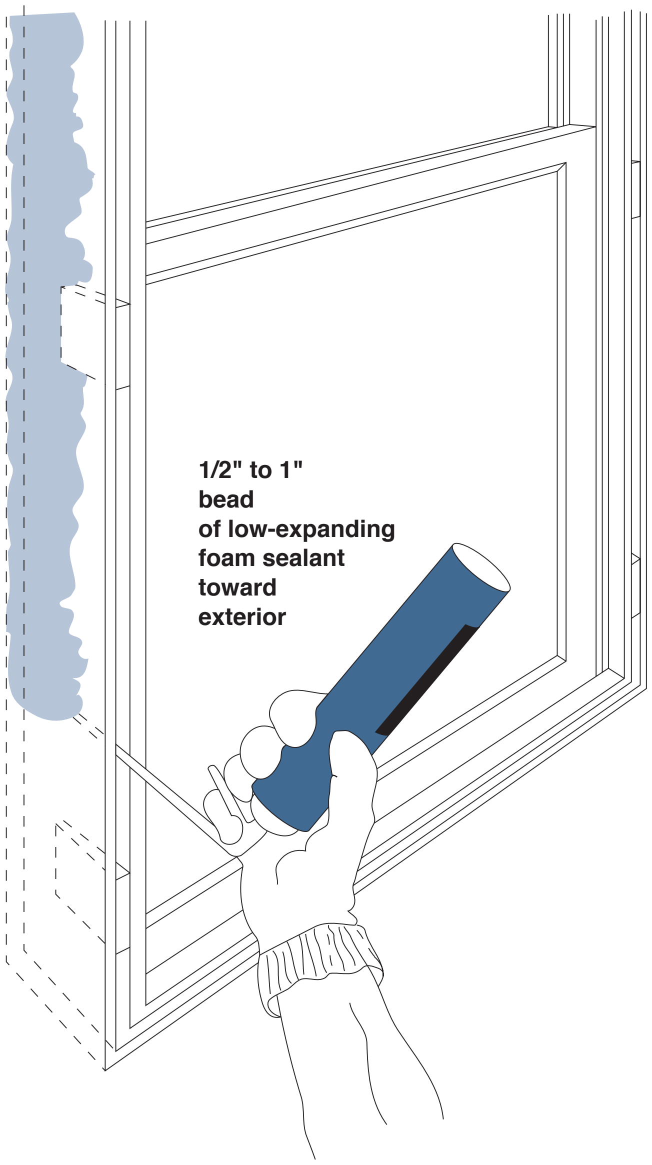


Figure 10-3 - Although most modern windows are very airtight, the gap between the installed window and the rough framing into which it is installed can be a major air leakage pathway if not properly sealed. One common and simple technique is to fill the gap with expanding foam sealant.

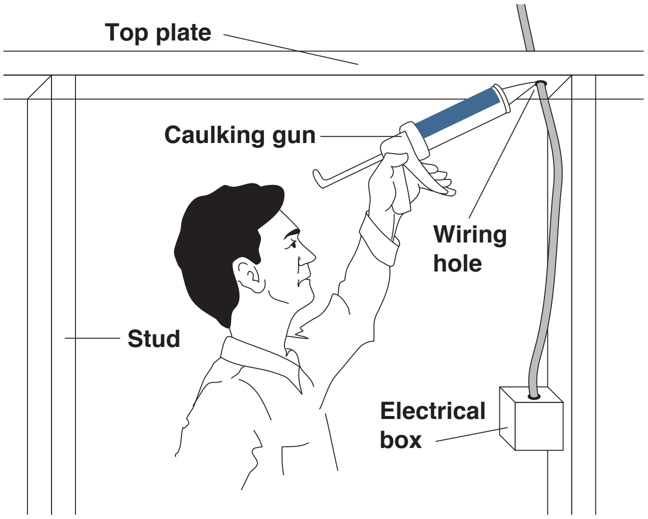


Figure 10-4 - All wiring holes in the top plate of interior partitions are caulked to prevent air leakage up into the attic.

film with special attention being made to avoiding the creation of any thermal bypasses when constructing the home. The result is a continuous "air barrier" that surrounds the entire conditioned space of the house.

Fresh Air Ventilation For Indoor Air Quality Control

Energy efficiency goes hand in hand with indoor comfort and health and a key component for providing all three is a mechanical ventilation system that exhausts stale air and brings in fresh outdoor air in a controlled fashion. Adequate air exchange is essential in a tight house in order to create a healthy indoor air quality environment (Chapter 2). Some contractors go further by installing a fully ducted system. In a ducted system, a central ventilator exhausts stale air from bathrooms and kitchen while distributing fresh air to each part of the house. The most sophisticated residential ventilation systems include a "heat recovery ventilator" which extracts waste heat from the exhaust air and uses it to preheat the incoming fresh air (reverse in summer) (Figure 6). Typical installed costs for these systems are listed in Table 1.

A typical "exhaust only" ventilation system (see Figure 10-5) includes a fan that extracts stale air from bathrooms and kitchens and exhausts it to the outdoors. The fan creates a slight negative pressure in the house, which causes fresh outdoor air to be drawn in through a "passive" inlet duct that is connected to the return plenum of the forced air distribution system or through window or wall ventilators. Many varieties of timers and controls are available and most fans now operate very quietly. Keep in mind that ventilation fans can cause combustion appliances to back draft because they do create a negative pressure within the house.

Table 10-1 - Typical ventilation system installed costs.

Central exhaust fan with passive outdoor air inlets	$300 to $600
Balanced ventilation system with heat recovery ventilator	
Rotary wheel	$400 to $800
Flat plate core	$600 to $2000

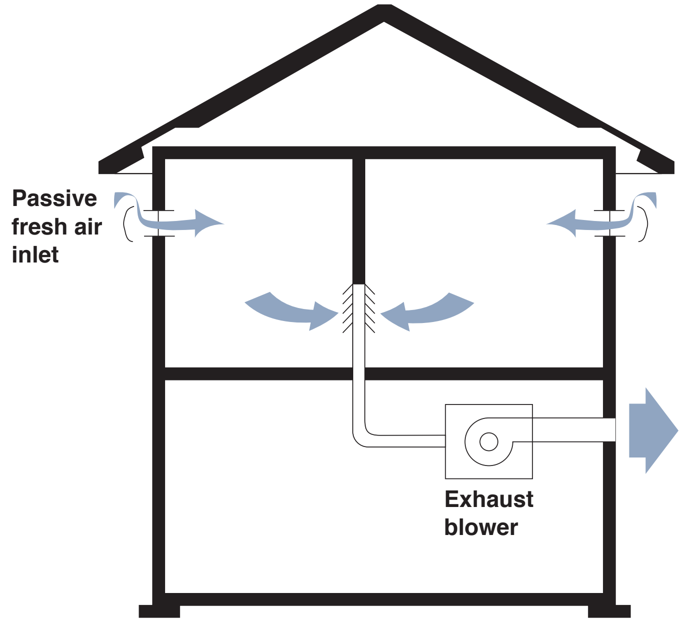


Figure 10-5 - A typical "exhaust-only" ventilation system.

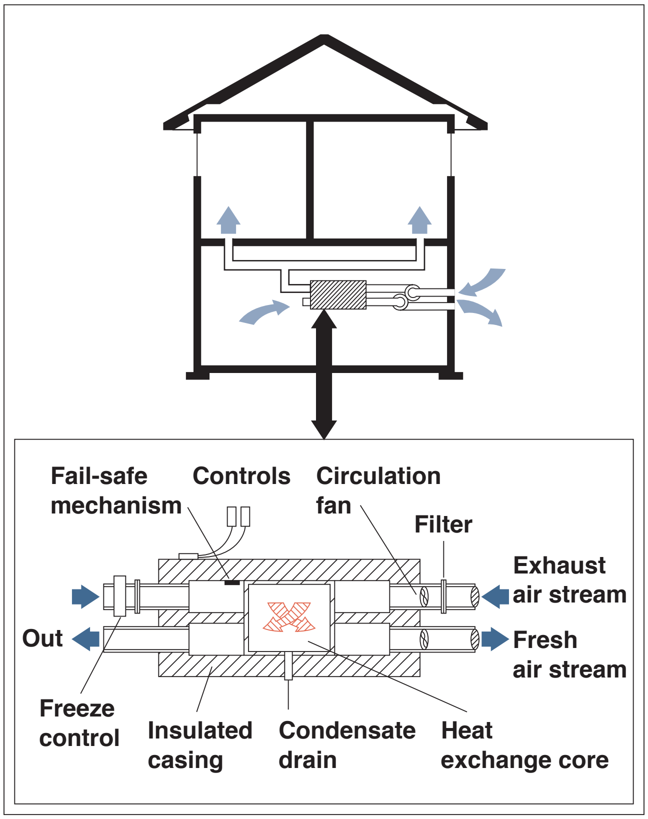


Figure 10-6 - The most sophisticated type of residential ventilation system includes a central heat recovery ventilator that has two separate blowers -- one for exhausting stale air and a second for bringing in fresh outdoor air. A system of ducts carries both airstreams to and from the ventilator.

The core of the heat recovery ventilator extracts heat (in winter) or coolness (in summer) from the exhaust air stream before expelling it from the house.

High Performance Mechanical Systems

In a tightly built, well insulated home, the efficiency of the heating and cooling systems is not as important as in a less energy efficient home but it is still an important investment. The reason is because the heating and cooling loads will be so much lower that a 5% or 10% improvement in efficiency may translate into only a small decrease in energy costs. (10% savings of an already small load is only a small savings.) Nonetheless, energy efficient homes should have appliances with reasonably efficient heating and cooling equipment. More efficient combustion appliance equipment will also burn cleaner and produce less harmful pollutants that are released into the atmosphere.

For fuel-burning heating appliances, look for an Annual Fuel Utilization Efficiency (AFUE) of 90% or better. For central air conditioners, look for a Seasonal Energy Efficiency Ratio (SEER) of at least 12.0. For heat pumps look for cooling SEER between 11 and 12 and Heating Seasonal Performance Factor (HSPF) of 8.0 or better. (See Chapter 5 for explanation of heating and cooling system efficiencies.) Remember to study the Energy Guide labels and look for the most efficient models available and always try to purchase Energy Star certified equipment, which represent those products that exceed the minimum government efficiency standards (Chapter 7).

Perhaps the most important appliance to check for efficiency is the water heater (Chapter 6). Since the water heating energy consumption is unaffected by how energy efficient the house is, water heating is sometimes the biggest energy load in an energy efficient house. In a gas-fired water heater, look for an Energy Factor (EF) of 0.61 or more. In an electric water heater, look for an EF of 0.92 or more.

Power-vented or sealed combustion appliances

In a tightly sealed house, there are few leaks to bring in air for combustion appliances. To prevent any chance of flue gases spilling into the house, all fuel-burning appliances should be either power vented or have completely sealed combustion. This includes gas and oil-fired furnaces, boilers and water heaters as well as kerosene and gas space heaters. (See Chapter 2 for discussion of combustion safety.)

Duct Systems

New construction is the perfect opportunity to properly install, size, and seal duct systems. Leaky and improperly installed duct systems can account for significant heating and cooling loss, increased energy bills, and serious health and safety problems within a household. Duct systems should be tested for leaks by a professional contractor and properly sealed using mastic. Ducts are discussed in Chapter 5.

Advantageous Use Of Available Solar Energy

A properly designed and built energy efficient home requires so little space heating energy, that it rarely can benefit from extensive solar heating systems. That is not to say, however, that it cannot benefit at all from solar heating. On the contrary, because the heat load is so small, it is easy to provide a good portion of your heating needs using simple “passive solar” principles. In most cases, this will mean concentrating a higher percentage of your window area on south-facing or east-facing walls to maximize winter sun.

Conversely, to control excessive summer cooling loads, an energy efficient house, should, if possible, minimize west-facing windows. It may also have solar control glass for year-round solar heat gain control (see Chapter 4).

Other Features For Energy Efficiency And Comfort

Solar water heater

Solar water heaters are discussed in Chapter 6. Though expensive to install, solar water heaters may produce hot water at a lower cost than fuel fired water heaters when analyzed on a life cycle cost basis (see analysis in Chapter 6).

Zoned heating and cooling

A zoned heating and cooling system allows you to control various “zones” of your house independently. There are two advantages to zoning. From a comfort perspective, it allows you to control the indoor environment according to the needs of the people and/or functions of a particular space. A workshop, for example, can be kept cooler than the living room. A bedroom for an elderly person can be kept warmer than one for a child.

From an energy standpoint, zoning allows you to turn down the heating or air conditioning for spaces that are not in use. Bedroom temperatures can be set back during the day, for example. Field studies have shown that when properly operated, zoning systems can save up to 25% of total utility bills in moderate climates like ours. (Ironically, if not properly operated, zoning can actually increase energy use by maintaining full temperature in all parts of the house.)

Thermal storage heating and cooling

Some electric utility companies offer special low “off-peak” electric rates during nights and weekends. To take advantage of those rates, manufacturers now sell special “thermal storage” heaters that store heat during off peak periods for use the following day while rates are high.

The use of a heat pump requires a different approach to thermal storage. Since outdoor temperatures are lower at night, heat pump performance drops. The decreased heat pump performance may waste more money than the off-peak electric rate saves. For heat pump systems in areas without off-peak rates it can sometimes be worthwhile to store heat during the day (when outdoor temperatures are high) for use during the night.

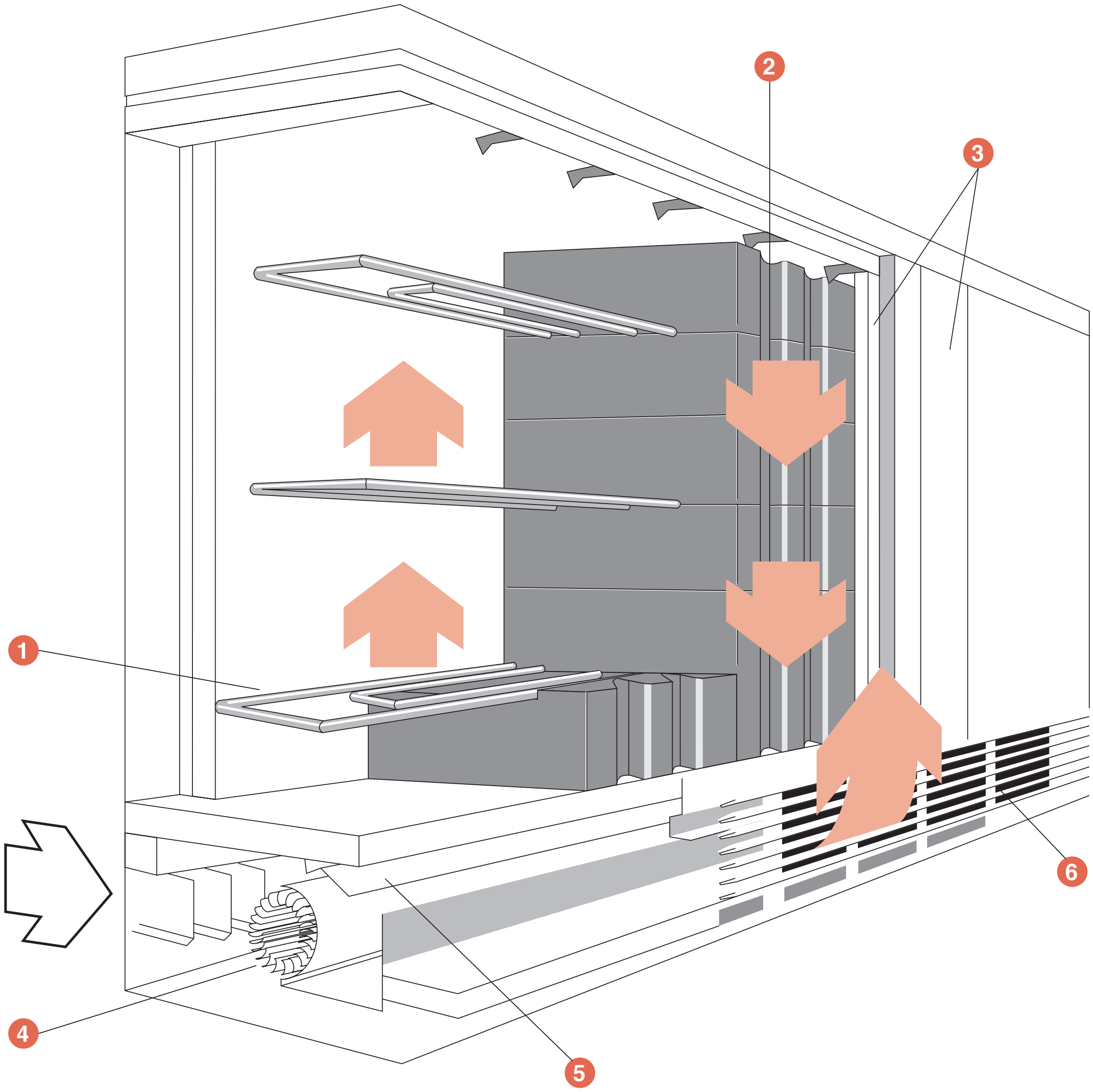
Various wood-fueled heaters (such as soapstone stoves) also incorporate thermal storage, allowing them to run more efficiently and heat the house for a long time on a single load of wood.

Another new technology is “cool storage”, which uses the same principle to store coolness either as ice, as chilled liquid, or as chilled solid material. Cool storage allows the air conditioner to build up coolness at night, when electric rates may be lower and outside air is cooler, for use the next day. It is now widely used in commercial applications, while residential applications are small but growing.

The cost-effective use of thermal storage heating and cooling depends in part on the willingness of your electric service provider to sell energy at lower cost during off-peal periods. Utility restructuring (see Chapter 13) may increase consumer access to different rate structures.

Geothermal Heat Pumps

Geothermal heat pumps (also referred to as ground source heat pumps and discussed in Chapter 5) use the constant temperature of the earth to heat and cool your home. They are typically more efficient than the more



1 Special alloy heating elements use off-peak electricity to heat...

2 ...magnesite bricks which efficiently store the heat until it is needed.

3 Glass fiber and microtherm insulation keep the heat inside of the unit.

4 A quiet, low velocity fan is activated when the room thermostat calls for heat. Room temperature air is drawn into the unit and heated as it is circulated around the hot bricks.

5 A bimetallic damper mixes additional room air with the hot air inside to provide an even, comfortable flow of warm air into the room through...

6 ...the air discharge grille at the bottom of the unit.

Figure 10-7 - This thermal storage space heater contains high density bricks that are heated at night electrically and store the heat until the following day.

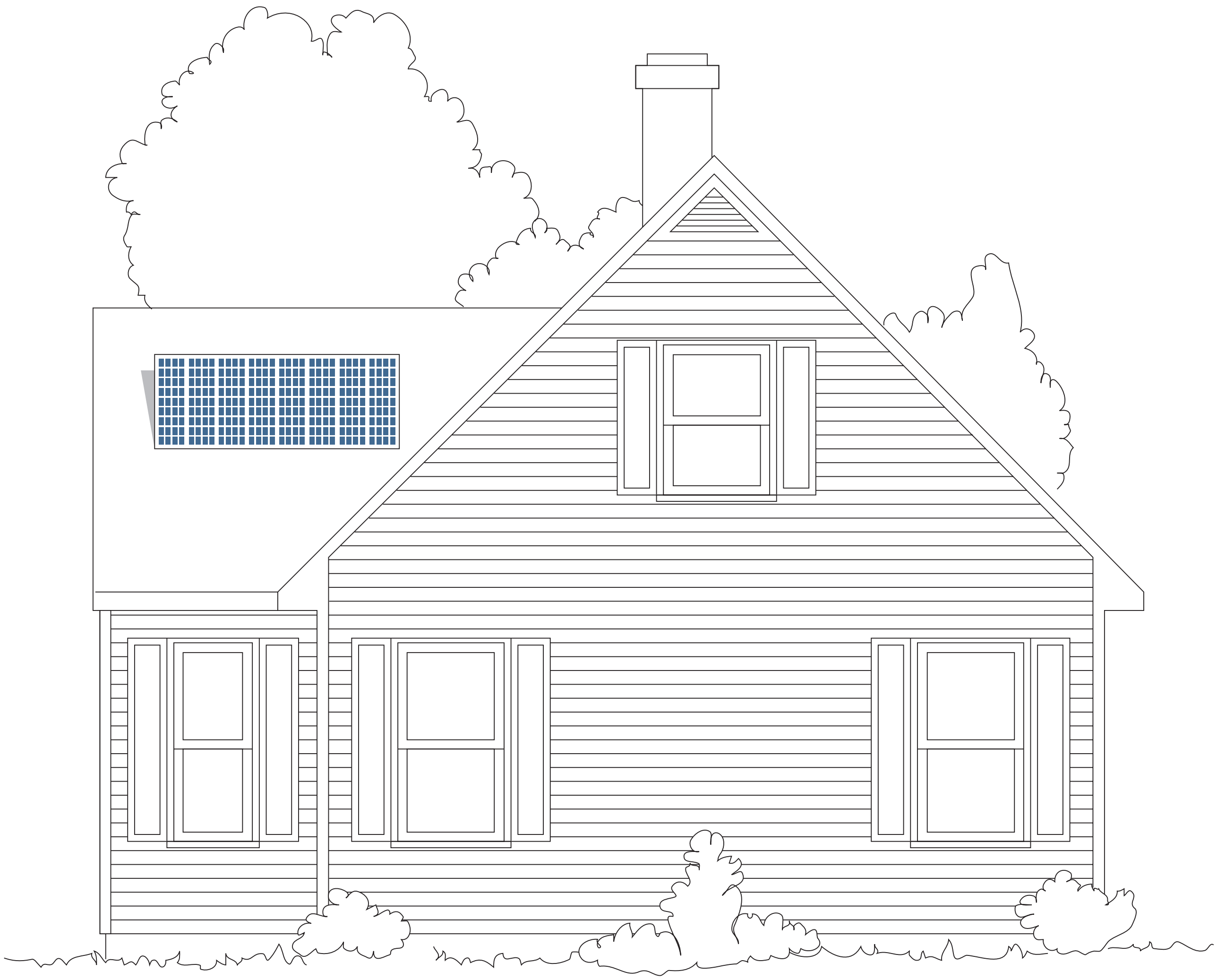


Figure 10-8 - Photovoltaic panels, mounted on the roof of a home, produce 12-volt electricity for use by specially equipped appliances.

common air-source heat pumps, they tend to last longer, and they can provide hot water more efficiently than standard electric water heaters.

Radiant Floor Heating

Hydronic radiant floor heating systems (Chapter 5) represent a quiet and efficient heat source. They use water filled tubing that is situated under the floor and delivered by a boiler that provides a very even distribution of heat.

Gas heat pumps and air conditioners

Air conditioners and heat pumps that use natural gas instead of electricity have been available for years and are constantly being improved. The newest generation of gas heat pumps and air conditioners use a natural gas-fired internal combustion engine to drive the compressor. As the efficiency of these systems improves, they could provide an economical alternative to electric air conditioning.

Energy Efficient Lighting

New construction is an ideal time to effectively design lighting strategies for your home. Utilizing energy efficient lighting sources such as compact fluorescent lamps (Chapter 8) can save money by using less electricity while also reducing harmful emissions from power plant generation.

Daylighting

Daylighting (discussed in Chapter 8) is using natural light in appropriate ways to minimize the need for turning on electric lights. Daylighting should always be considered when designing an energy efficient home.

Energy Star Appliances

The house is a system of interactive parts and an energy efficient home that is well insulated, air tight with proper ventilation, and installed with high performance windows should also include energy efficient appliances and equipment. Always study the black and yellow Energy Guide that is displayed on most appliances and be sure to look for those appliances that are Energy Star qualified (Chapter 7). Appliances can account for up to 20% of your household energy consumption

Photovoltaics

Electricity from sunlight contains the promise of reduced utility costs and independence from the power grid. Although photovoltaic electricity is still quite a bit more expensive than utility electricity, the technology is constantly being improved with respect to efficiency, reliability and cost. And even with today's hardware, photovoltaic electricity may be a practical option in remote locations where utility hookup is very expensive or otherwise impractical.

For many users, the high purchase and installation costs of photovoltaic systems is easily balanced by the reduced environmental cost. Electricity produced by photovoltaic systems is clean and produces no harmful emissions. This in itself is a reason to explore the potential of including solar powered equipment in any new home design.

Low Flow Water Fixtures

Install low flow water appliances, faucet aerators and low flow showerheads (Chapter 9 in combination with an energy efficient water heater (Chapter 6) and you will save significant money and energy as well as conserving a very valuable natural resource – water.

Cogeneration

Another technology just on the horizon is residential "cogeneration." Cogeneration is based on using both the shaft power output of an engine and the "waste heat" from the radiator or cooling fins and from the hot exhaust. A natural gas-fueled engine drives a generator that produces electricity, while the engine waste heat is used for space and water heating. The electricity is used for household appliances. Any excess electricity is fed back into the utility power grid and credited to the homeowner by the utility company.

Cogeneration technology is available today although its practicality is limited by cost. Further improvements in effectiveness may make it an attractive option, particularly in remote areas.

Another new technology, similar to cogeneration, is the engine-driven heat pump. A natural gas-fueled engine drives a heat pump compressor. The compressor pumps heat from the outdoors into the house, while the engine waste heat is also used. Gas engine-driven heat pumps can perform like gas-fueled furnaces with efficiency higher than 100%!

Energy Efficient Landscaping

Taking advantage of "nature's heating and cooling system" through the effective use of landscaping is an important way to cut energy costs by as much as 10-25%. Landscaping is a natural and beautiful way to block the sun and provide protection from winter winds. A well-placed tree, bush, or vine can deliver effective shade and add to the aesthetic value of your property.

The main idea behind landscaping is to plant trees and shrubs so they shade your home in hot weather and block the chilling winds of winter. When designing your landscaping, first take a good look at your home and yard. It is important to make the landscape work for you, and you must know how your house is oriented (north, south, east, west) so you can minimize heat gain in the summer and maximize it in the winter. Strategically planted or preserved trees around your home can reduce solar heat gains during the summer by 40-80% depending on the density of the trees. It is important to use plants native to your area that survive with minimal care and (once they are established) without watering. Evergreens can greatly

Green Building Technology

Green Building technology is an alternative to current building methods that strives to:

- Minimize the environmental impact of living in your house by saving energy, saving water, and reducing pollution emissions.
- Minimize the environmental impact of building your house by using building materials and construction practices that do not damage the environment.

Green building technology uses a systems approach to the overall environmental impact of a home. For instance, a green home design would avoid a building material, which saves energy once it is installed but which results in pollution during its manufacturing process.

Listed below are some basic green building principles that should be considered when building an energy efficient home:

- Use durable products and materials that require low maintenance.
- Choose low-embodied energy materials (Chapter 14).
- Use locally produced materials to minimize unnecessary transportation costs.
- Consider using recycled building products and salvaged materials if possible.
- Try not to use materials that offgas pollutants (Chapter 2).
- Reduce waste generated on site by inefficient construction practices.
- Incorporate all of the energy efficient technology that is discussed throughout this handbook.
- Utilize renewable energy (Chapter 12).
- Don't overbuild. Design and build a house that meets your needs but uses space and building materials efficiently.
- Utilize energy efficient landscaping.
- Consider responsible water management principles when designing your house. Absorb storm water rather than allowing it to run off. Collect rainwater (Chapter 9) and use it for household needs and irrigation.
- Protect the environment when you build. Protect trees, existing vegetation, and sensitive natural areas. Let the natural area guide the house design.
- Select a home location that allows you and your family to work, shop, attend school, etc. without excessive driving. Ideally, many trips should be possible by walking or using public transportation.

Green Building Materials

Green building materials are materials that are produced using environmentally friendly processes and can include salvaged products, recycled materials, certified wood products, products from renewable materials, materials that don't release harmful pollutants, and especially durable building materials.

The best available resource for identifying and locating green building materials is the GreenSpec Directory and GreenSpec Binder both of which are published by the Environmental Building News (EBN) – a leading newsletter on environmentally responsible design and construction. Over 1,200 green building products are selected by the editors of EBN who provide descriptions, environmental considerations, and manufacturer contact information. For more information, go to EBN's website at www.BuildingGreen.com.

Green Site Selection and Planning

Proper site selection and planning is essential in order to make optimum use of existing situations and to create new opportunities for an energy efficient dwelling. Considering how the house will be situated allows the home-builder to take advantage of:

- Solar access
- Natural areas
- Prevailing wind
- Water resources
- Existing landscaping

Studying site development procedures and determining the lowest environmental impact will enable the home-owner to:

- Minimize the potential impact of improper excavation
- Protect existing trees
- Provide efficient storm water drainage and management
- Avoid contamination of the soil through disposal of construction waste
- Take advantage of summer shading and winter wind protection

Incorporating green building technology, materials and site planning will produce homes that don't create problems, but rather help to solve environmental, energy and economic issues that confront a community.

An aspect of green building that is often overlooked is the selection of a location with access to schools, shopping, and work. Living in a green design, energy efficient house where you must drive 75 miles to work probably doesn't help the environment. In selecting sites, many homebuilders fail to consider future development. They build homes out in the country with a commute that is long in distance, but short in time over rural roads with little traffic. Five or ten years later, they are inundated with development and have a long commute through heavy stop-and-go traffic.

slow cold winter winds, which for the most part come from the west, north, and northwest. Large deciduous trees can provide shade and summer cooling and then allow the sun's warm rays to enter the house during winter months. Deciduous trees are most effective on the east, west, and south sides of the house.

A well planned landscape can reduce an un-shaded home's air conditioning costs in summer by 15-50%. In the winter, a house with windbreaks on the windward side can average 25% less fuel consumption.

Trees not only help conserve energy but also help the environment in other ways. They absorb carbon dioxide, release oxygen, moderate storm water runoff and soil erosion, provide wildlife food and shelter, lessen local temperature extremes, buffer against noise and dust, and mitigate the glare of urban and suburban lighting.

Xeriscaping

Xeriscaping landscape designs focus on water conservation by using native plants and avoiding exotic plants that may not be as well suited to the local climate. This means that native grasses, plants, and trees when used will require less maintenance and less water to survive.

Energy Tips and Recommendations

1. Energy efficient new construction must include quality materials and workmanship as well as a whole house or house as a system approach. Proper integration of all building components is necessary for a high energy performing home.
2. An energy efficient house must include maximum levels of insulation, high performance windows, low air leakage rates and adequate ventilation, tight ducts, energy efficient heating and cooling equipment as well as Energy Star appliances.
3. Utilize renewable energy opportunities in constructing an energy efficient home such as solar water heaters, passive solar applications, and photovoltaic panels to produce clean electricity.
4. Consider building an Energy Star labeled home. Over 100,000 homes in 2003 qualified for the Energy Star

certification.

5. Use green building technology, green building materials, and green site planning to produce a sustainable home that will solve economic, environmental, and energy problems rather than creating them.
6. When constructing an energy efficient home, make use of the energy efficient technology that has been discussed in the Handbook.

REDUCING YOUR TRANSPORTATION ENERGY USE

Transportation accounts for 31 percent of the energy used in Virginia – more than the residential, commercial, or industrial sectors – and a whopping 76 percent of total petroleum use. Sixty-four percent of the energy used for transportation is gasoline for cars and light trucks, at a total cost of nearly $7 billion in 2000. Both highway use and average annual expenditure for transportation in Virginia have been increasing rapidly in recent years.

While the statewide trend is up-up-up in terms of energy use and cost for transportation, it's not hard to buck the trend. With practice and common sense, you can achieve 10 percent fuel savings just by improving your driving habits and keeping your car properly maintained. Far greater savings can be realized by changing your habits and driving less – by using public transportation, carpooling or riding a bicycle. And when it comes time to buy a new car, savings can also be achieved by selecting a fuel efficient vehicle.

This section presents a series of practical suggestions and tips for saving energy and money with transportation.

Driving Tips

Minimize Idling

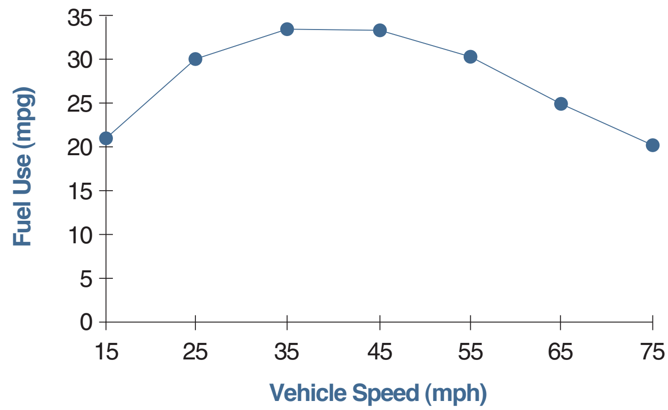
A cold engine should be warmed up by idling for about 30 seconds. Longer idling time during warmup is generally not warranted. In other situations, be aware that idling wastes energy. When you stop the car to run an errand for longer than a minute or two, turn the car off. If there is a line at the drive-up bank or fast-food window, park and walk in rather than sitting in line with the car idling. When idling, you are getting 0 miles per gallon.

Avoid quick acceleration

Accelerating from a stop requires a lot more energy than steady cruising. When you accelerate too quickly, more fuel is delivered to your engine than can be burned, wasting energy. For the most energy-efficient driving, accelerate through the gears at a moderately brisk pace, then maintain steady speeds.

Observe speed limits

Most vehicles achieve their highest fuel economy at speeds of 35 to 50 mph. At speeds above this range, fuel economy is significantly reduced because of wind resistance. According to the U.S. Department of Energy, for every one mile per hour above 55 mph, fuel economy of the average vehicle drops two percent. A car that averages 30 mpg at 55 mph, for example, will only get about 27 mpg at 60 mph, and only 21 mpg at 70 mph.



Average of fifteen American and imported cars, model years 1981-1984.
Source: US Dept. of Energy

Figure 11-1 - This chart of fuel use and vehicle speed shows how rapidly gas mileage drops as your speed increases over 50 mph.

Anticipate traffic

You can save a lot of energy by paying attention to the road and traffic ahead of you. If you see a stop sign coming up, for example, take your foot off the accelerator and coast as you approach it. By coasting as you approach a red light, it may turn green before you come to a full stop, saving energy on the acceleration.

Use Cruise Control

When highway traffic is light enough, use cruise control. Cruise control gives a steady application of the gas pedal that results in better mileage. For safety reasons, do not use cruise control in heavy traffic, on curvy roads, or in slippery conditions.

Use Air Conditioning Wisely

When starting off in a car that has been parked in the sun with the windows closed, drive with the windows open for the first couple of minutes before closing the windows and turning on the air conditioning. This allows the very hot air to be blown out the windows, making the car cool off more quickly and saving energy.

At low speeds in moderate weather, riding with the windows open gives you better gas mileage than closing the windows and running the air conditioning. At highway speeds, however, riding with the windows open increases the car's air resistance. The increased engine power to overcome that resistance is about equal to the power required to run the air conditioner, so using the air conditioner has little effect on gas mileage.

Avoid Drive-in Window Lines

Banking, dropping off laundry, or buying food at a drive-in window makes sense when you can drive to the window, quickly complete your transaction, and drive off. When you must wait in a line with other idling vehicles, however, using a drive-in is a waste of fuel and a source of pollution. Besides, a long wait using the drive-in doesn't save much time.

Automobile Maintenance

Keep your car tuned up

A tune-up can save a lot of fuel, as much as 10 percent or more, depending upon the operating condition of your vehicle. You will know it's time for a tune-up when:

- Your mileage drops for no apparent reason.
- Your vehicle fails an exhaust emission or other diagnostic test.
- The engine skips, sputters, stalls, or smoke comes out of the exhaust.

Keeping a simple mileage log will help you identify when you need a tune-up or when some other problem is reducing your fuel economy (under-inflated tires, etc.). All you need is a card or sheet of paper for writing down your odometer reading and how much gas you put into the tank each time you fill up. If you notice a drop in the mileage, for the last three fill-ups, then something might be wrong, and you should have it checked out. Keep in mind that stop-and-go driving conditions, under-inflated tires, cold weather, and other factors may also affect your mileage.

Maintain proper tire pressure

Underinflated tires reduce fuel economy by about 1% for every 2 pounds of underinflation, because of increased rolling resistance.

Inflate your tires to the pressure shown on the information plate on the frame of the driver's door. Do not inflate tires to the pressure shown on the tire sidewall. Though the sidewall pressure gives maximum tire load capacity and best gas mileage, the pressure shown on the

MILEAGE LOG

Date	End Miles	Miles Driven	Gallons to refill	Miles per gallon	City/ highway
Example	45,700	200	10	20	city

information plate also considers your car's stability, traction, and handling. Inflating tires to a pressure different from that shown on the information plate may reduce vehicle safety.

Recommended tire pressures are "cold inflation" pressures, so you should check your tire air pressure when the tires have not been heated by driving. If you must drive over a mile for air, use a tire pressure gage to check pressure before you leave home and when you get to the service station. Then reduce your inflation pressure by the pressure increase caused by heating. In any case, it is best to use your own tire pressure gage to check your inflation pressure: the gages on service station air pumps are often inaccurate.

Keep your car's front end properly aligned

Misalignment of wheels increases tire wear and can reduce your mileage.

Buy tires wisely

Each tire you buy has a size marked on its sidewall such as "P215/65R15" or ""LT235/85B16". The beginning letters are "P" for passenger or "LT" for light truck, while the letters near the end are "R" for radial or "B" for bias ply. The remaining numbers give the tire size. When replacing your tires you should always use the same size as the original equipment unless the change has been approved by the car's manufacturer. If you have an older car with bias ply (B) tires, however, you should switch to radial (R) tires. Radial tires give better handling and increased gas mileage. One caution: when changing from bias ply to radial tires, you should replace all the tires on the car simultaneously or you may have handling problems.

Following the size marking is a speed-load rating such as "89S" or "75H". The numbers give the load rating of the tire: the higher the number, the higher the load-carrying ability. The letter gives the speed rating of the tire: speed rating increases according to the sequence S-T-U-H-V-W-Y, with letters later in the sequence having a higher speed rating. When replacing your tires you should always buy at least the speed and load rating of the original equipment.

Also on the tire sidewall you will find ratings for treadwear (a number, the higher the better), traction (a letter in the sequence AA-A-B-C, with AA being the best), and temperature (a letter from A to C, with A being the best). When replacing your tires you should always buy at least as good a traction and temperature rating as the original equipment.

There are certain tradeoffs in tire design. A harder, more rigid rubber will generally give higher gas mileage and longer life. A softer rubber will generally give better traction and performance. If you buy "high performance" tires you may find that your mileage goes down. If you buy "high mileage" tires you may find that your handling and traction suffer. For saving energy and maintaining safety, buy high mileage tires that still have at least as good a traction rating as the car's original equipment.

Don't buy higher-octane gasoline than is recommended for your car

Most cars today are designed to work well with regular unleaded gasoline (87 octane). Higher octane fuel doesn't contain any more energy than regular gas – its only function is to reduce knock. If your car doesn't knock with regular gasoline, use regular. If the owner's manual recommends regular gasoline but you have a knocking problem when using regular, have your car checked by a mechanic.

Besides costing you money, some of the octane-increasing additives used in premium gasoline are worse for the environment than the constituents of regular gasoline.

Change your oil regularly and use high-quality oil

Both the engine oil and oil filter should be changed at least as often as recommended in the owner's manual. When the motor oil is used for too long it deteriorates, increasing friction, increasing wear, and reducing fuel economy.

The lubricating quality for oil used in gasoline engines is classified by the letter "S" followed by one of the letters "A" through "J" (for example, "SH"). The later in the alphabet the second letter is, the better the oil will lubricate. In general, use the highest quality (later letter) oil available. Your car owner's manual gives the oil rating for which the engine was designed, so never use oil with a lower quality (earlier letter) rating.

Your owner's manual also recommends an oil "weight" for your car, which indicates the oil's viscosity: the higher the number the more viscous ("heavier") the oil is. Single-weight oils (SAE 30, for example) can be of high quality, but their viscosity changes a lot as the temperature changes. A single-weight oil that gives adequate lubrication in a warmed-up engine may be so thick on a cold morning that the engine will not start. Multiple-weight oils (SAE 10-30, for example) perform like low-weight oils at low temperatures and like high-weight oils at high temperatures. In general, you should use the oil weight recommended in your owner's manual. Lower weight oil may not adequately protect your engine from wear, and higher weight oil will increase engine friction, wasting energy and making cold starts more difficult.

If you change the oil in your car yourself, take the old oil to a collection center so it can be recycled. This is important for three reasons: First, oil disposed of any other way can easily find its way into the ground and water supply, where a small amount of oil can contaminate a large reservoir. Second, used oil can be recycled into new motor oil using only 1/4 the energy needed to refine crude oil. Third, dumping waste oil is illegal and punishable by a fine.

Even though it is illegal in Virginia to dump used oil on any water, land or into the storm drain system, an estimated 6,000,000 gallons are disposed of improperly in the Commonwealth each year. If reprocessed, that amount of oil could heat more than 10,000 homes for an entire year. Many service stations, auto parts stores, and recycling centers display a "Return Used Oil Here" sign, indicating an oil recycling collection center. Please do your part by disposing of your oil properly.

When used motor oil is burned, the combustion

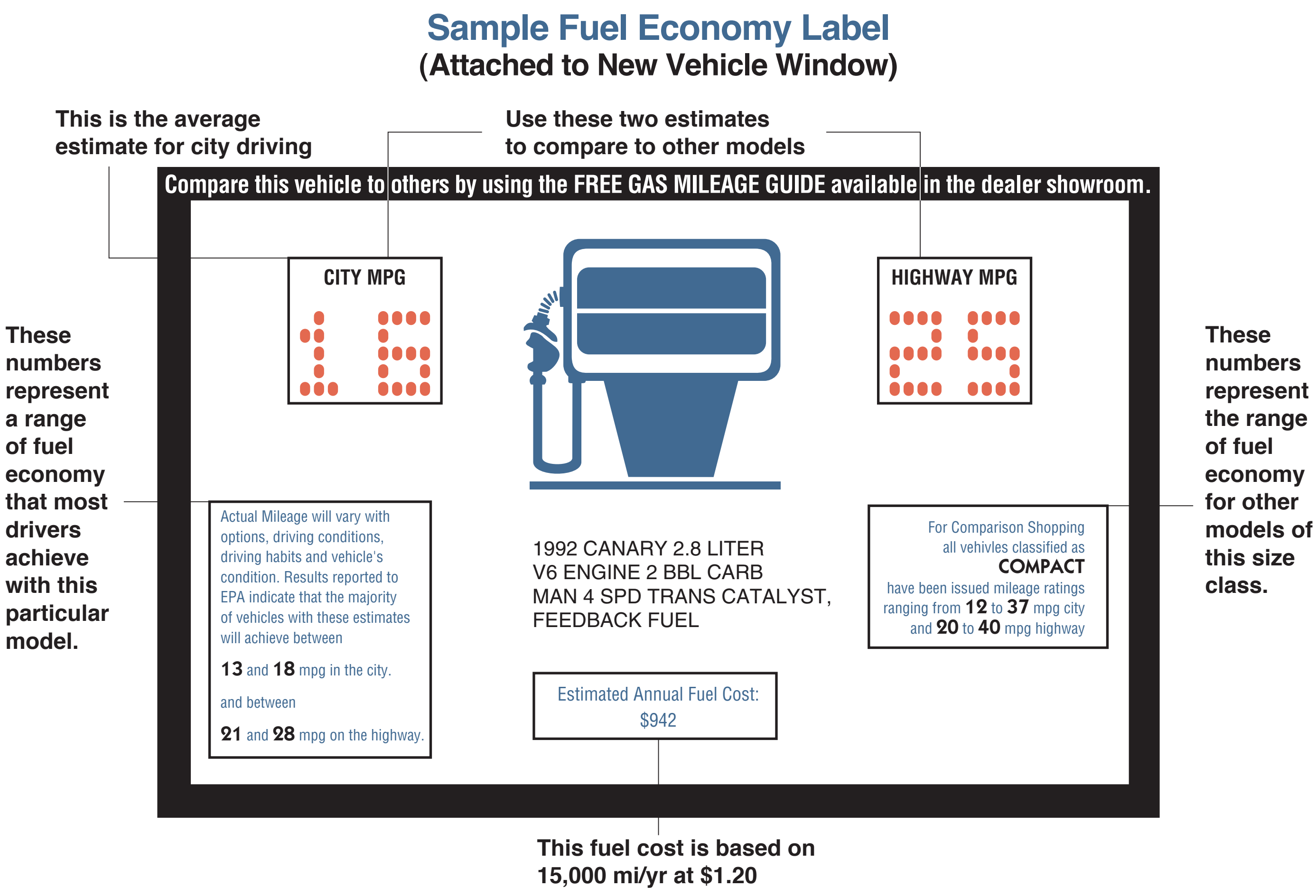


Figure 11-2 - The fuel economy label offers an easy way to compare the gas mileage of different vehicles.

products contain harmful pollutants from the oil additives and engine wear products. Used oil should not be burned in oil stoves or furnaces unless they are equipped with special pollution control equipment.

For information on how to recycle used motor oil in Virginia, check with your local recyling coordinator.

Take extra weight out of the car

An extra 100 pounds in your trunk can reduce mileage by a half mile per gallon. So if you've been carrying around your golf clubs, or still have a bag of sand in the car for winter traction even though it's now summer, take them out and boost your mileage – and performance.

Buying A New Vehicle

Choose a fuel-efficient vehicle

If you're thinking of buying a new car or truck, you're in an ideal position to make a big difference in your fuel use. Automobiles within any size class vary tremendously in their fuel economy. By choosing a car that gets just one mile per gallon more than another, you will save approximately $400 over the life of the car, assuming fuel prices stay about the same and your driving habits are average.

When selecting a car, be practical and realistic about your needs:

- Remember that you're buying transportation, not a toy. If you do demand a "fun to drive" car, you will find that many small, high mileage cars have excellent performance and handling.
- Size doesn't equate to safety. While heavy pickups and SUV's may be safer in a crash with a small vehicle, their size is no help in a crash with a tractor-trailer or a bridge abutment. Also, their poorer handling makes a crash or rollover more likely.
- Don't buy a car based on an infrequent need. If you drive off-road once or twice a year, do you really need an SUV? If you haul a load of mulch each spring, do you really need a pickup? Usually it is more economical to rent a vehicle, use a trailer, or pay for delivery instead of buying a vehicle based on an occasional use.

Study the Fuel Economy Label on the vehicles you are considering

All new cars must display a mileage performance label that lists both the estimated city and highway mpg. Compare the fuel economy of the vehicle you are interested in with that of other similar-sized vehicles. To help you with this comparison, you can get the Fuel Economy

Table 11-1 - U.S. Department of Energy (DOE) recommendations for appropriate fuel-efficient vehicle selection.

Transportation Characteristic	Preferred Vehicle Characteristic
Predominantly highway driving	Automatic transmission cruise control
Predominantly city driving	Manual transmission
Predominantly driver-only (little driving with multi-passengers)	Smaller, lighter vehicle/engine Consider renting for infrequent trips
Minimum cargo capacity needs	Smaller, lighter vehicle/engine Consider renting for infrequent cargo carrying capacity needs
Predominantly warm climate operation	Light exterior and interior colors to reduce heat buildup and air conditioning needs
Predominantly cold climate operation	Flow through ventilation rather than air conditioning

Guide (EPA Gas Mileage Guide) by writing Fuel Economy Guide, 1617 Cole Blvd., MS 1633, Golden, CO 80401 or access the website at www.fueleconomy.gov .

Consider options carefully

When considering a new vehicle, assess your transportation needs carefully. Table 10-1, from the U.S. Department of Energy, lists a number of transportation characteristics and corresponding energy considerations.

Fuel Efficiency Standards (CAFÉ)

In 1975 the Energy Policy and Conservation Act established corporate average fuel economy (CAFÉ) standards for new vehicles. These new standards were the result of the Arab oil embargo of 1973-1974 and the tripling in the price of crude oil, which brought the fuel inefficiency of U.S. automobiles into sharp focus. The current standard is 27.5 mpg for passenger automobiles and 20.7 mpg for light trucks, which includes sport utility vehicles (SUV).

Increased fuel efficiency standards will save consumers money at the gas pump, cut harmful vehicle emissions, and reduce our dependence on foreign oil.

Alternative Transportation

Take public transportation

A transit bus with as few as seven passengers is more energy-efficient than the average commuter car, on a passenger-miles per gallon basis. Fully loaded, a transit bus is six times as energy efficient. A fully loaded rail transit car is 15 times as energy efficient as the average commuter vehicle.

Carpool to work

Commuting to and from work accounts for one-third of all private auto mileage. According to the book, *50 Simple Things You Can Do to Save the Planet*, carpooling just eight miles each way will save about 2,500 auto miles per person every year.

Table 11-2 includes a list of currently operating Rideshare programs in Virginia. For more information on ridesharing, call the Virginia Department of Transportation at 1-800-693-RIDE.

Walk or bicycle instead of driving

Walking or bicycling is the ultimate energy saver, and it offers the added benefit of keeping you in shape.

Alternative Fuels and Vehicles

Alternative fuels

Transportation is responsible for more than 67% of the oil that we use in the United States. Data from the U.S. Federal Highway Administration indicates that the average car or truck emits more than 600 pounds of air pollution each year and this includes carbon monoxide, methane, nitrous oxide, and particulate matter – all of which contribute to smog and a wide variety of significant

Table 11-2 - Rideshare programs in Virginia

Program	Service Area	Telephone Number
Ridefinders	Richmond area	(804)643-RIDE 1-800-693-RIDE
Commuter Connections	Washington Metro	1-800-745-RIDE
Traffix	Tidewater area	1-800-700-RIDE
Ride Solutions	Roanoke, Salem, Vinton	(540)342-9393 1-866-260-2153

health problems. Vehicles also emit greenhouse gases due to their combustion of fossil fuels. These gases such as carbon dioxide, methane, hydrocarbons, and nitrogen dioxide contribute to global warming. According to the Environmental Protection Agency (EPA), 82% of U.S. greenhouse gas emissions consist of carbon dioxide that is caused by the combustion of fossil fuels. So common sense dictates that reducing vehicle emissions and developing and using alternative fuels is a prudent and necessary course that will reduce air pollution, global warming, and health problems.

Alternative fuels burn cleaner, produce lower emissions, and most often are renewable fuels that are replenished naturally. Alternative fuels that are in use today include ethanol, biodiesel, methanol, natural gas, propane, electricity, and hydrogen.

Ethanol: Ethanol is an alcohol usually made from corn and is the most widely used alternative fuel in America. Ethanol powered vehicles have lower carbon monoxide and carbon dioxide emissions than gas powered vehicles. Ethanol is also good for performance – pure ethanol is 98 octane! The main disadvantage of ethanol is that it has less energy per gallon than gasoline. Ethanol is blended with gasoline normally in a 90:10 mixture – 90% gasoline and 10% ethanol. Many production cars (see your owner's manual) can use this "gasohol" mixture. Using pure ethanol requires modification to the engine and fuel system.

Biodiesel: Biodiesel is a fuel that is primarily made from several types of oil – recycled cooking oils, soybean oil, and animal fats. This fuel is normally used as a blended fuel consisting of 20% biodiesel and 80% petroleum diesel. Over 30 million gallons are produced in the U.S. annually but it is currently not available to the general public. Federal, state, and transit fleets and some tourist boats are the primary users of this fuel.

Methanol: This is another alcohol fuel that is produced from natural gas and biomass (plants, wood, etc.) and is blended with about 15% gasoline to make a fuel called "M85". Methanol powered vehicles emit smaller amounts of hydrocarbons, particulate matter, and nitrogen oxides than gas powered vehicles. Like ethanol, methanol gives good performance (100 octane), has less energy/gallon than gasoline, and requires engine modifications to use as M85. There are some bus fleets currently in operation that are fueled entirely with methanol – and Indianapolis racers use methanol!

Natural Gas: Natural gas is a clean burning fuel, domestically produced, that emits significantly cleaner emissions than other comparative fossil fuel vehicles. It is used as compressed natural gas (CNG) or liquefied natural gas (LNG). There are over 100,000 natural gas powered buses in America and almost 20% of new buses are built to use natural gas as a fuel.

Propane: Propane is actually liquefied petroleum gas (LPG) and is a byproduct of natural gas and oil processing. Propane emissions are significantly cleaner than gasoline and it is a readily available fuel. There are fueling stations in all states and almost 300,000 propane powered vehicles in the U.S.

Electricity: Electric vehicles use batteries to store the electricity that powers the vehicle and need to be recharged periodically. Emissions from an electric vehicle are essentially zero, but producing the electricity necessary to power the vehicles may come from fossil fuel powered generation. There are over 7,000 electric vehicles on the road today in the U.S. If the electricity to power electric vehicles is coming from a renewable energy source – wind, solar – then the electric car is clean in every way.

Hydrogen: Hydrogen is an element that is found in organic matter, mainly in hydrocarbons that make up many of our other fuels – gasoline, methanol, and propane. Hydrogen, like electricity, must be manufactured. This can be done by using heat to separate hydrogen from the hydrocarbons or by using electricity to separate the hydrogen in water. Most hydrogen is manufactured from natural gas. The only combustion product of hydrogen is water, so hydrogen as a fuel source produces practically no harmful air pollutants. Hydrogen is currently being used as the fuel source for fuel cell powered vehicles.

Alternative Fuel Vehicles

Many auto manufacturers produce and sell alternative fuel vehicles – cars, light and heavy duty trucks, buses, and even boats. Many of these are sold as fleet vehicles but some are also part of the mainstream automobile market.

There are at least two alternative fuel vehicles that should be of particular interest to any consumer.

Hybrid Vehicles: In 2000, Honda and Toyota began selling hybrid cars – the Toyota Prius and the Honda Insight. Honda has come out with a hybrid version of their very popular Civic and the Ford Motor Company will deliver the first hybrid SUV in 2004. Hybrid vehicles combine an internal combustion engine with an electric motor and can achieve about twice the fuel economy of conventional vehicles. They are not zero emission vehicles but they emit about a third to one-half the amount of greenhouse gases emitted by conventional gas powered vehicles.

Hybrid vehicles are powered by both an engine and an electric motor, and include a battery storage system that is large enough to continue providing power to the electric motor under most driving conditions. Because the batteries are charged by the engine and by the regenerative braking - generating electricity while braking the car - hybrids do not need to be recharged at a recharging station. Hybrids are very efficient because they use a small engine for cruising – when a lot of power is not needed – and they boost power with the electric motor during acceleration. This technique also gives good performance. The future of hybrids may lie in replacing gasoline as the combustion fuel source with renewable energy sources like ethanol or methanol – thus providing a clean, efficient, car powered by renewable fuels.

The hybrid vehicles now on the market are not truly alternative fuel vehicles in that they still use gasoline. They do, however, use much less of it.

Fuel Cell Vehicles: The fuel cell is a device that converts the chemical energy of a fuel into usable electricity without combustion. Any hydrogen rich material – natural gas, methanol, ethanol, hydrogen – can serve as a source of hydrogen for fuel cells. Fuel cells have similarity with batteries in that they produce a direct current by means of an electrochemical process but unlike batteries they store their reactants externally and operate continuously as long as they are supplied with fuel. Because they produce only water vapors as emissions, fuel cells are perfect power sources for transportation.

Many major automakers have manufactured direct hydrogen fuel cell systems that have significant potential to compete with internal combustion engines by as early as 2010. No fuel-cell powered vehicles are on the market today.

Energy Tips and Recommendations

1. Pay attention to how you operate your vehicle – smart driving can save money and minimize unnecessary exhaust emissions. Observe speed limits, minimize idling to warm up your car, avoid quick acceleration, anticipate traffic, and use cruise control in light highway traffic.
2. Proper maintenance of a vehicle can save over 10% in fuel use. A well maintained car would operate more efficiently. Keep your car tuned up, maintain proper tire pressure, keep your vehicles front end aligned, use radial tires, change your oil regularly, and don't carry extra weight.
3. When buying a new vehicle, choose a fuel-efficient one. Study the Fuel Economy Label on any vehicle you are considering for purchase.
4. Avoid driving all the time. Take advantage of public transportation, carpooling, Rideshare programs in your area, and walk or bicycle when possible.
5. Consider the use of alternative fuels in your vehicle. They burn cleaner and produce less pollution than gasoline.
6. Check out Hybrid vehicles. They get great gas mileage and their emissions are as much as 50% cleaner than conventional automobiles.

RENEWABLE ENERGY AND OTHER ALTERNATIVE ENERGY SOURCES

Over the last 200 years, people have become more and more dependent on energy that they dig out of the ground.

In the 1700's, almost all our energy came from wind, water, firewood, or muscle power. The wind powered our windmills and sailing ships. Water powered our water wheels. Firewood did our cooking and heated our homes. Muscle power (human or animal) did just about everything else. All these energy sources came from the sun, since solar energy drove wind and rain, grew trees, and grew crops to nourish our animals and ourselves. All these energy sources were also renewable, since wind kept blowing, rivers kept flowing, and trees and crops kept growing.

About 1800, we began to get much of our energy from coal dug out of the ground. About 1900 we began to drill for oil and natural gas. By 1950 these "fossil fuels" had mainly displaced the older energy sources except for water power. Fossil fuels come from the decayed remains of prehistoric plants and animals, so their energy also comes, originally, from the sun. In some parts of the world new fossil fuels are being formed even today. But we are using fossil fuels at a far greater rate than they are being created, using up energy stored over hundreds of millions of years in a few hundred years.

After 1950, we began to use atomic energy from uranium dug from the ground. Uranium is not a fossil fuel, and its energy does not originate from the sun. But uranium, like fossil fuels, is non-renewable: once it's used up, it's gone forever.

Over the past 25 years, use of older renewable energy sources has increased and we have begun to use new renewable energy sources as well. We have realized that our fossil and atomic fuels will not last forever, and that their use contributes to environmental pollution. Renewable energy – which basically comes from the sun in one way or another – provides opportunities for an unlimited, sustainable energy supply with low environmental impact. And renewable energy is not just something for the future, but something we can use in our homes today.

What are Renewable and Alternative Energy Sources?

True renewable energy sources are energy supplies that are refilled by natural processes at least as fast as we use them. All renewable energy comes, ultimately, from the sun. We can use the sun directly (as in solar heating systems) or indirectly (as in hydroelectric power, wind power, and power from biomass fuels). Renewable energy supplies can become exhausted if we use them faster than they become replenished: most of England's forests were cut down for fuel before the English started using coal. If used wisely, however, renewable energy supplies can last forever.

There are other alternatives to our typical energy sources that are not renewable. Although these are "alternative energy" rather than "renewable energy", they use the energy we have more efficiently than older technologies. In doing this, they help us make our existing energy supplies last longer and give us more time before we run out of stored fossil and atomic fuels.

The use of renewable and alternative energy sources can save us money, assure that our grandchildren and great grandchildren will have enough energy, and free us from the uncertainties of depending on energy supplies outside the United States.

Types of Renewable and Alternative Energy

There are several renewable energy sources that are in use today. Listed below are brief descriptions of these resources; later we will discuss how some of these can be used in residential applications.

Hydropower:

Hydropower represents one of the oldest and largest renewable power sources and accounts for close to 10% of our nation's electricity. Existing hydropower capacity is about 80,000 megawatts (MW – one million watts or one thousand kilowatts). Hydropower plants convert the energy of flowing water into electricity. This is primarily done by damming rivers to create large reservoirs and then releasing water through turbines to produce electricity. Hydropower results in no emissions into the atmosphere but the process of damming a river can create significant ecological problems for water quality and for fish and wildlife habitat.

Biomass

Biomass is second to hydropower as a leader in renewable energy production. Biomass has an existing capacity of over 7,000 MW. Biomass as a fuel consists of organic matter such as industrial waste, agricultural waste, wood, and bark. Biomass can be burned directly in specially designed power plants, or used to replace up to15% of coal as a fuel in ordinary power plants. Biomass burns cleaner than coal because it has less sulfur, which means less sulfur dioxide will be emitted into the atmosphere. Biomass can also be used indirectly, since it produces methane gas as it decays or through a modern process called gasification. Methane can produce power by burning in a boiler to create steam to drive steam turbines or through internal combustion in gas turbines and reciprocating engines.

The largest use of biomass energy in Virginia is the forest products industry. Furniture plants, sawmills, and paper mills usually burn their wood waste to produce heat and electricity. Many homeowners use firewood or pellets for winter heat.

Geothermal

Geothermal electric capacity in the United States is over 3,000 MW. Geothermal power plants use high temperatures deep underground to produce steam, which then powers turbines that produce electricity. Geothermal power plants can draw from underground reservoirs of hot water or can heat water by pumping it into hot, dry rock. High underground high temperatures are accessed by drilling wells, sometimes more than a mile deep. In one sense, this geothermal energy is not renewable, since sometime in the future the core of the earth will cool. That time is so far off (hundreds of millions of years) that that we think of it as renewable. Most geothermal power plants are located in the western United States, but some costal regions of Virginia (near Wallops Island) have geothermal power potential.

Geothermal heat pumps use compressors to pump heat out of the earth (for winter heating) or into the earth (when running as air conditioners in summer). The energy they pump into and out of the earth is renewable, since it is replaced by the cycle of the seasons. The energy that runs the compressor can either be renewable or conventional.

Solar Energy

Solar energy comes directly from the power of the sun and is used to produce electricity, to produce heat, and for light. Solar represents a small share of the electric market in the United States – about ½ of one percent of electrical capacity. Solar's contribution to heating and lighting is much larger.

Solar-electric power can be produced either by power plants using the sun's heat or by photovoltaic (PV) technology, which converts sunlight directly to electricity using solar cells. PV technology is more practical for residential use.

Systems to use the heat of the sun directly can be either active or passive. In active systems, air or liquid circulate through solar collectors and bring heat to where it is used. In passive systems, buildings are built with windows and heat-absorbing surfaces set up to maximize solar heating in winter. Either technology is suitable for residential use.

Systems to directly use the light of the sun are most common. The most usual device for using sunlight is the window, but skylights and skylight tubes are also used.

Wind Power

Wind energy represents 4,700 megawatts (MW) of installed electric capacity in the United States. Wind has

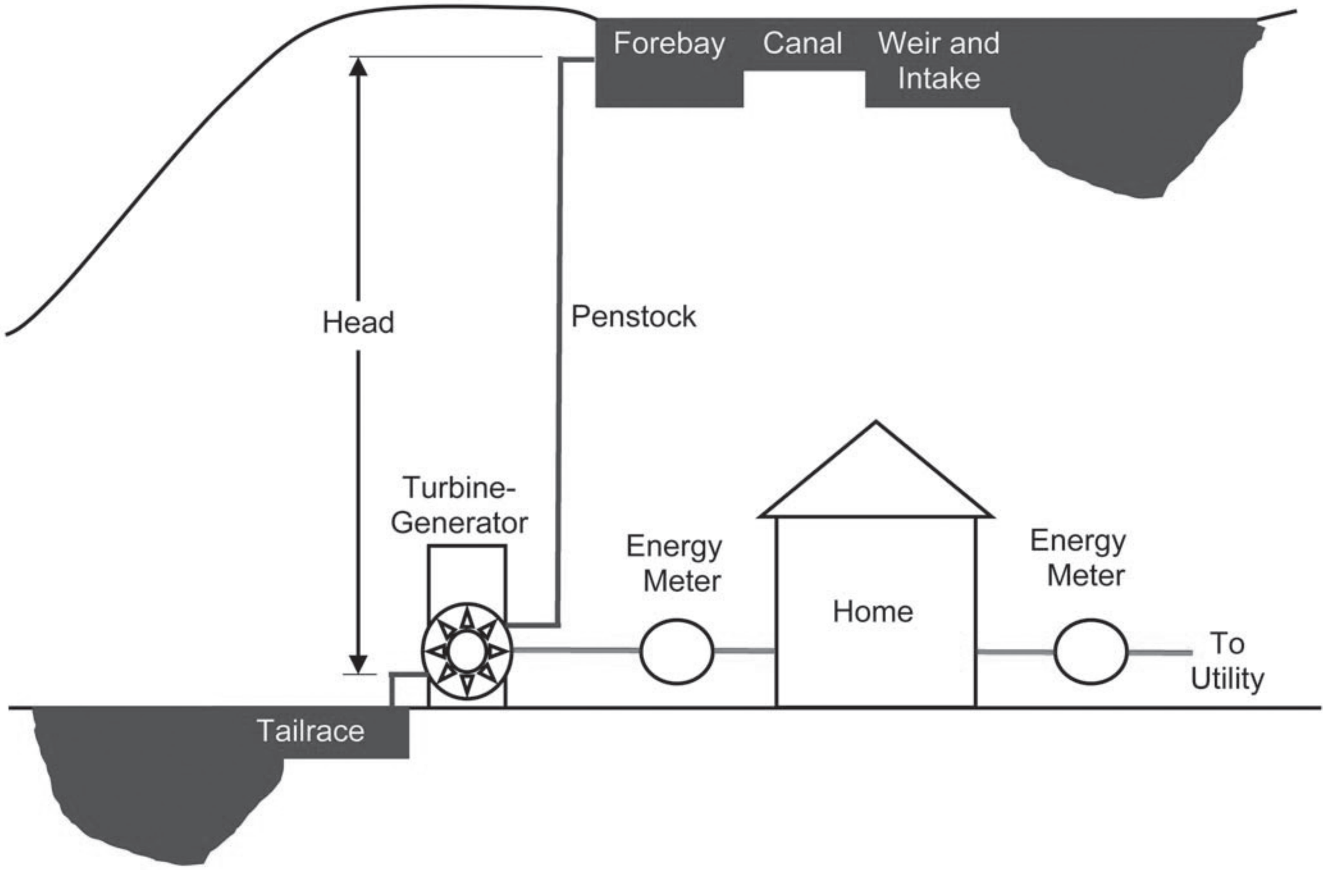


Figure 12-1 - Grid-connected residential microhydropower system. Meter between generator and home is optional.

been the fastest growing energy source in the U.S. over the last decade mainly due to very significant improvements in wind energy technology. The American Wind Energy Association predicts that 6,000 MW of windpower will be installed by the end of 2004. This is enough to power 1.5 million homes. Wind power is produced by the energy of the wind turning aerodynamic blades mounted to a hub. The hub is connected to a shaft that turns a generator. Large utility-scale wind turbines range in size from 50 kilowatts to over four megawatts. Smaller wind towers (under 50 kW) are suitable for residential and agricultural use.

Fuel Cells

A fuel cell is an alternative energy device, but it is not necessarily a renewable energy device. It is only renewable if the source of the fuel used is renewable. A fuel cell is an electrochemical device, like a battery in that it converts the energy from a chemical reaction directly into electricity and heat. But unlike a battery, which is limited to the stored chemicals within, a fuel cell has the capability of generating energy as long as fuel is supplied. Currently produced fuel cells combine hydrogen and oxygen without combustion to produce electricity. The oxygen comes from the air, while the hydrogen can either be produced from water (using electricity) or extracted from fossil fuels. New fuel cells are being developed that can use fossil fuels directly. Fuel cell technology has been around for over 150 years and it shows great promise in powering vehicles and in providing energy for residential applications.

Residential Renewable and Alternative Energy Systems

There are many opportunities to generate your own electricity and heat using renewable resources. But first you need to realize that you are making an investment, which can be substantial, and this requires the appropriate research, site considerations, need assessment, and cost effectiveness study. Generating your own electricity and heat may not always make you money or save you money but it can create independence from the utility grid and allow you to generate your own clean and green power. Keep in mind that reducing energy use through conservation and increased efficiency is almost always a cheaper alternative than installing a renewable energy system.

Here are some specific residential renewable energy systems that use the renewable resources that we have discussed above.

Microhydropower Systems

If you have a stream or creek on your property then you might be able to generate electricity using hydropower. Microhydropower systems, if resources and conditions are appropriate, are capable of powering a normal size residence. These systems operate on the same principle as a large hydropower system – moving water turns a turbine, which then drives a generator to produce electricity. Microhydropower does not need to dam the water source to operate but without a dam the power will fluctuate with the normal rise and fall of the creek or stream.

The key components of a successful microhydropower system are the head and flow of the available water resource. The head is the vertical distance that the water falls and flow is the volume of the water. Producing electricity is a combination of proper head and flow and using efficient and properly installed equipment. Utilizing the services of a trained professional to do a complete hydrological study is highly recommended but may be expensive. You can learn to perform your own feasibility study by going to http://www.eere.energy.gov/consumerinfo/refbriefs/ab2.html.

Costs will vary on microhydropower systems depending on size of generator, length of pipe needed, whether a dam is needed, and other variables.

Residential Biomass Applications

Biomass is generally used in space heating and cooking as well as an alternative fuel source for vehicles. Wood products are renewable and can be an inexpensive fuel source for heating and cooking – particularly in areas where wood is plentiful. But the combustion by-products of burning wood still contain potentially harmful pollutants (Chapter 5).

In 1988 the Environmental Protection Agency (EPA) passed emission standards for new wood stoves and after July, 1992 all new wood stoves had to pass these EPA emission standards. This means that new wood stoves burn cleaner and more efficiently than pre-1992 stoves.

Pellet stoves use a variety of biomass ingredients – sawdust, bark, cornhusks, and cardboard – which are compressed together in the form of pellets. Pellet fuel burns much more efficiently than wood, can be fed automatically, and emits fewer pollutants.

EPA rated wood and pellet stoves range from $800 to $2,500 dollars.

Biomass sources are also used to produce alternative fuels that burn cleaner than gasoline and emit fewer harmful pollutants into the atmosphere (Chapter 11).

Geothermal Heat Pumps

Using the heat from the earth is a very efficient and renewable method of heating and cooling your home. Geothermal heat pumps (Chapter 5) use the stable temperature of the ground around your home as a source of heat in the winter and cooling in the summer. These systems move heat between the home and ground instead of creating heat by burning fuel and consequently they operate very cleanly and are usually at least three times more efficient than other systems on the market – including those that are energy efficient themselves. A complete geothermal system can also have the ability to provide hot water through a “desuperheater”. A geothermal heat pump system including installation, duct system and hot water delivery can range in cost from $14,000 to $20,000 but will save significant money over the long term due to increased efficiency. To identify Geothermal Heat Pump contractors call the Geothermal Heat Pump Consortium at 1-888-333-4472. For more information check out http://geothermal.geol.vt.edu and www.geo4va.vt.edu/.

Solar Electric or Photovoltaic (PV) Systems

Photovoltaic (PV) systems differ from solar water heating systems in that they do not use the sun’s energy to produce heat but instead produce electricity directly from the interaction of sunlight and semiconductor materials. PV products are typically manufactured as individual solar panels that can be added to a structure or mounted on the ground. PV manufacturers, however, are starting to incorporate PV into building materials such as roofing shingles, metal roofing, and window glass. The cost of these products is partially offset by the cost of the building material they replace, and are architecturally very appealing.

There are numerous PV technologies, but most can be grouped into one of two major categories: "crystalline silicon" and "thin film slicon." Crystalline silicon solar cells are cut from crystals of silicon, and their size is limited by the size of crystals that can be produced. Individual cells are electricly connected together to form a PV module. One or more PV modules can be connected together on your roof to produce the desired amount of electricity. Thin film silicon cells differ in that thin layers of semiconductor materials are deposited directly onto a glass or thin metal substrate. The size of the silicon thin films can be much larger than that of silicon crystals, so individual cells can be made much larger and fewer are needed. Crystalline cells have more output for a given cell area, but thin films will cover a larger area for lower cost.

There are three things to consider before purchasing and installing a PV system: amount of southern exposure, obstructions that might shade or inhibit sun from reaching the modules, and proper space and terrain for installation of the system, including the type of roof that you have.

There are three ways that a PV system can be set up for residential use:

- Grid-connected PV systems interface directly with your electric utility connection and allow for excess solar generation to be put back on the grid. When the PV system is not meeting the consumption demand then the consumer will receive electricity from the grid. In Virginia net metering allows customers to receive credit for excess electricity generated from their PV systems, but the total amount of PV power connected to the grid is limited by law.
- Grid-connected systems with battery storage work like ordinary grid-connected systems, but the battery storage allows you back up capability in case of a power outage.
- Independent or off-the-grid systems operate independently. They are stand-alone systems appropriate in situations where there is no electric service to begin with. Independent systems require battery storage to

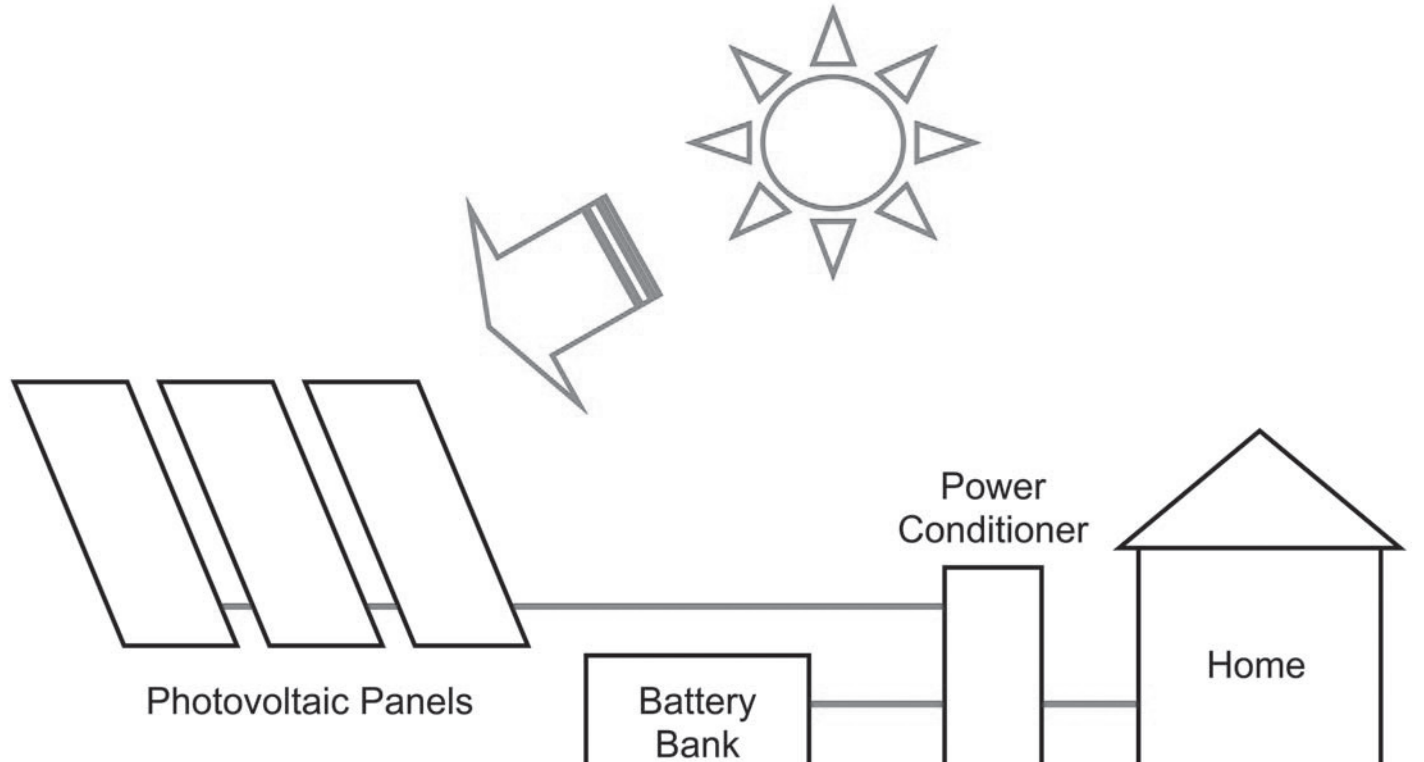


Figure 12-2 - Off-grid residential photovoltaic system.

provide power at night and in cloudy weather.

Determining the size of your system is an important consideration because this will determine your capacity as well as your initial cost. Working with a professional PV installer is a good first step in determining your electrical output needs and cost options.

There are loan programs available that might help to offset the initial costs for a PV system; they will be discussed later. PV systems are expensive, but a PV system is quiet, is non-polluting, and requires no fuel. Since solar energy is a growing technology, the price of equipment and installation will decrease over time. The price of fossil fuels and electricity, by contrast, will probably continue to increase.

Solar technology that is installed at the time of home construction can be more cost effective if integrated in such a way as to offset the cost of traditional building materials. Solar costs can be rolled into an energy efficient mortgage package.

To identify solar equipment manufacturers and solar installers contact the American Solar Energy Society at www.ases.org and the Maryland – DC – Virginia Solar Energy Industries Association at www.mdv-seia.org .

Wind Energy Systems

A small residential wind energy system can provide significant electrical power if certain conditions exist:

- Do you have enough wind where you live? Is the annual average mile-per-hour wind speed sufficient?
- Do zoning or land use requirements disallow tall towers in your neighborhood?
- Is there enough space for installation and operation?
- Is it economically feasible?

Wind energy is clean, non-polluting, and capable of providing enough electricity to power your home.

The size of your system depends on how you plan to use the power that is generated. Small wind turbines can range in size from 20 watts to 100 kilowatts (kW) with a 20-500 watt system being used to charge batteries and a 5 to 15 kW system being used to power a home using 700 to 800 kWh per month.

Residential wind systems consist of a rotor or blades, a generator mounted on a frame, a tower, the necessary wiring and the "balance of system" components: controllers, inverters, and possibly batteries. Through the spinning blades, the rotor traps the kinetic energy of the wind and converts it into rotary motion to drive the generator, which produces electricity. The diameter of the rotor and the maximum wind speed determine the amount of power that can be produced. Higher towers give more power both by allowing larger rotors and by reaching heights where wind speeds are greater. A 60 to 120 foot tower (5 to 10 stories) is common for small wind energy systems. Wind energy systems can be stand-alone or connected to the electric utility grid allowing the consumer to take advantage of net metering in the same manner as solar systems (discussed above).

A rule of thumb for estimating cost is $3,000 to $6,000 per kilowatt. A typical 10kW system costs about $47,000 installed and produces 900 kWh at an annual average wind speed of 12 mph, which is fairly common in Virginia when using a 120 foot tower. As is the case with most renewable energy systems and energy efficient products, the initial cost is high but the savings realized over the long term may be significant.

For further information and to locate and identify equipment manufacturers and installers check out the American Wind Energy Association www.awea.org , the U.S. Department of Energy Wind Energy Program www.eren.doe.gov/wind/ , and the Virginia Wind Energy Collaborative http://web.jmu.edu/vwec .

Residential Fuel Cells

Residential fuel cells represent a clean, efficient, non-polluting source of electrical power. Fuel cells are a renewable energy technology only if their fuel comes from renewable sources, but even if they use fossil-based fuels they use them cleanly and very efficiently.

In a typical fuel cell (see Figure 12-4, page 156) hydrogen molecules are broken down into negatively-charged electrons and positively-charged hydrogen ions at the anode. The electrons flow through the load (delivering power), while the hydrogen ions flow through the electrolyte. At the anode the hydrogen ions and electrons combine with oxygen molecules to form water. Since a single fuel cell has an output of only about one volt, many

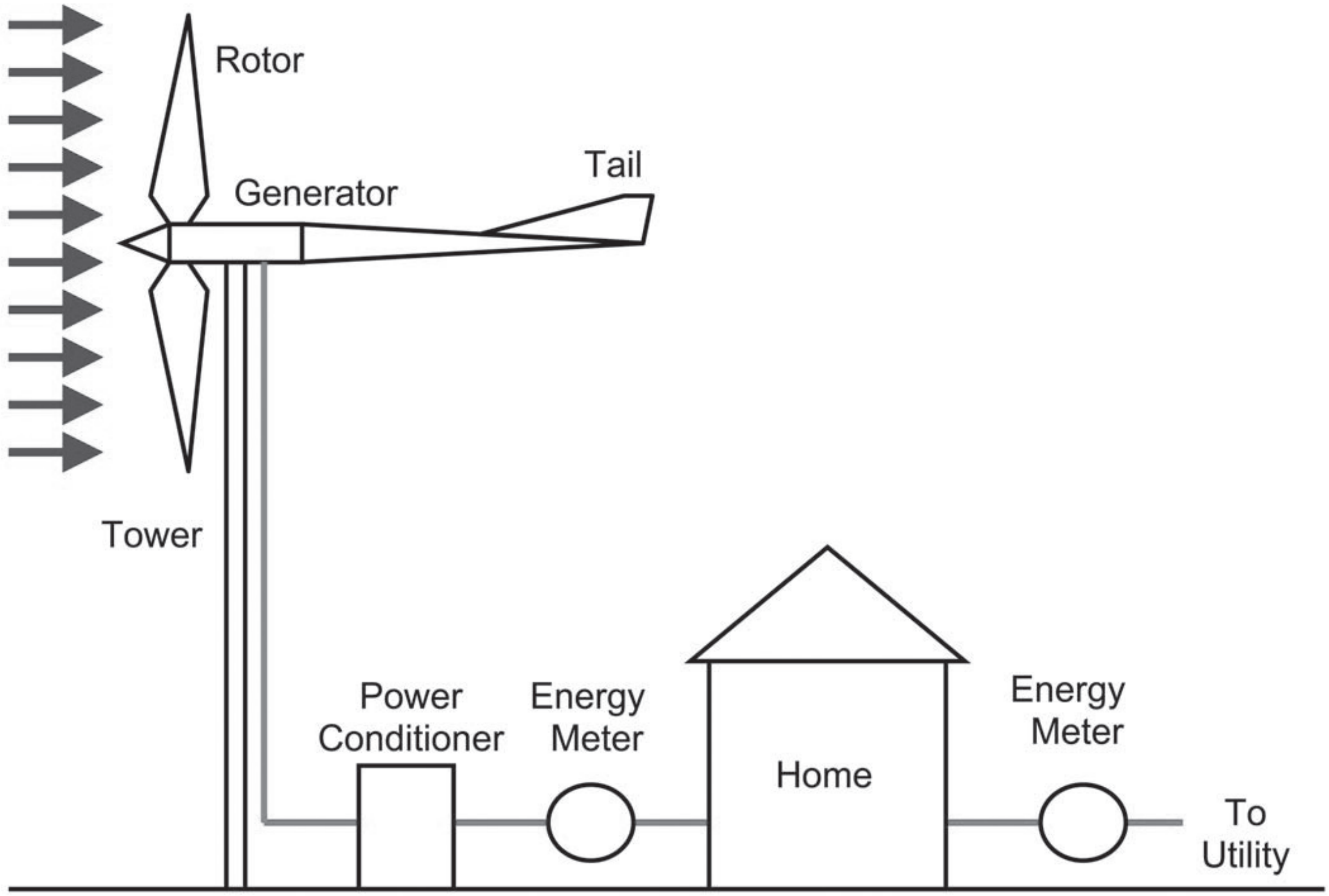


Figure 12-3 - Grid-connected residential wind energy system. Meter between power conditioner and home is optional.

are combined to form a residential power package.

The benefits of residential fuel cells are numerous:

- Fuel cells are very efficient because they convert chemical energy directly into electrical energy without combustion.
- They can operate independent of the utility grid or in conjunction with the grid.
- Unlike other renewable systems, fuel cells can provide power on demand. Independent systems thus do not require battery storage.
- Fuel cell emissions are clean: if they are using hydrogen fuel their combustion product is simply water vapor. Fuel cells that require a reformer to convert fuels to hydrogen emit both water vapor and carbon dioxide.
- Fuel cells are completely compatible with other renewable systems like PV and wind and make very successful hybrid systems.
- Fuel cells are fuel flexible and can use just about any fossil fuel: propane, natural gas, methanol, ethanol, oil, or gasoline. They can also use renewably-generated hydrogen.
- Fuel cells run continuously and are easily maintained although maintenance can vary depending on the technology of the fuel cell.

Some disadvantages to fuel cells are:

- Residential fuel cell technology is very new and still being tested
- The cost of a residential fuel cell is still high - $6,000 to $10,000 for a 5kW system that could power a standard size home.

A residential fuel cell system consists of a fuel processor that converts fuel into hydrogen, a fuel cell stack that converts the hydrogen into direct current electricity, batteries for storing power, and an inverter to produce alternating current. For further information on fuel cells check out www.fuelcells.org .

Virginia Programs that promote Renewable Energy

Virginia offers a low-interest loan program, net metering, property tax exemptions in some localities, and service programs that promote and encourage the use of renewable energy.

Renewable Energy and Energy Efficiency Loan Program

The Virginia Housing and Redevelopment Authority (VHDA) administers a low-interest loan program for low and moderate income homeowners. This program, created in 1978, provides loans for home repairs that reduce energy consumption or reduce dependence on conventional energy sources. All renewable energy technologies are eligible and this includes passive solar space heat, active solar water heat, active solar space heat, solar thermal electricity, photovoltaic systems, wind energy systems, biomass, hydropower, geothermal, and waste. The interest rate is 6.75% and loan amounts range from $1,000 to $25,000 for terms from 6 months to 20 years. Contact VHDA for more information at 804-343-5751 or www.vhda.com .

Local Option Property Tax Exemption

This Virginia statute, section 58.1-3661 from the Code of Virginia allows any county, city, or town to exempt solar-energy equipment or recycling equipment from local property taxes. Residential, commercial, or industrial property is eligible. The statute defines solar-energy equipment as any "application that would otherwise require a conventional source of energy". This includes

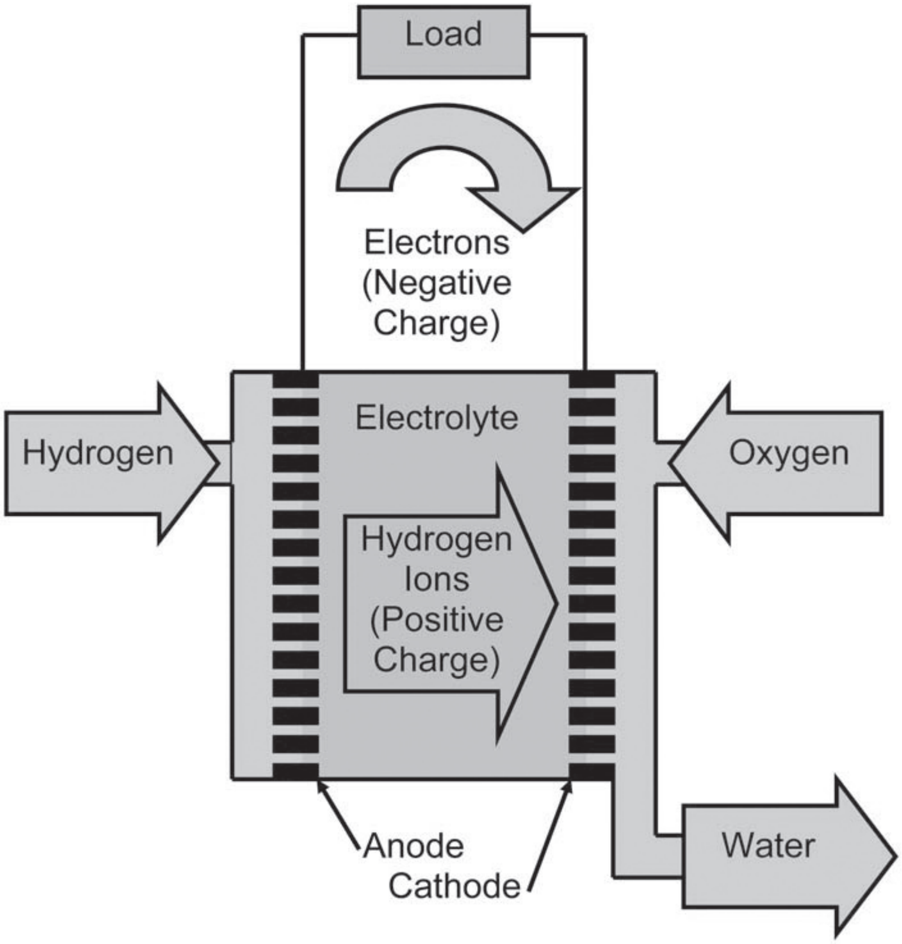


Figure 12-4 - Schematic of basic hydrogen-oxygen fuel cell operation.

solar space heat, solar water heat, solar thermal electricity, and photovoltaic systems. Contact your local Commissioner of Revenue to see if your county offers the exemption and for further information.

Net Metering

"Net metering" allows customers to receive the full retail value of any excess electricity they generate from their solar, wind, or hydroelectric system. When you use power from the grid you pay for it, but when you supply excess renewably-generated power to the grid your electric meter essentially spins backward and subtracts kilowatt hours from your bill. The law requires all utilities under the jurisdiction of the State Corporation Commission to offer net metering to residential systems of 10 kW or less and to non-residential systems of 500 kW or less. The law limits the amount of net metered generation in any particular utility distribution territory to 0.1% of the previous year's peak electricity demand. Rate payers can apply the credit for electricity generated from their system to the following month; however, at the end of the year, any excess generation is granted to the utility. Contact your local utility provider or the Virginia Department of Mines, Minerals and Energy for more information.

Program to Promote the use of Wind in Virginia

Several groups in Virginia have come together to form the Virginia Wind Energy Collaborative (VWEC) to address issues related to wind power development in the state. Information about VWEC's activities is available on their website at www.jmu.edu/vwec.

One of the key participants, James Madison University manages the Virginia State-Based Anemometer loan program (SBALP), which loans landowners a 20 meter tall wind measuring device that measures the wind speed and direction. This wind data can then be used to determine whether a wind turbine is appropriate for their location. For more information call 540-568-2560, contact the Integrated Science and Technology Department at JMU, or visit http://www.jmu.edu/sbalp/ .

Energy Tips and Recommendations

1. Consider the use of renewable energy systems that produce clean and non-polluting energy. The initial cost or investment may be high but over the long term the savings can be significant. You will also be making an important commitment to saving our natural resources and preserving the environment.
2. If you have a stream on your property, you may be able to develop a small microhydropower system that can produce enough electricity to power your home.
3. Space heating is a low-cost way in which to incorporate biomass into a residential renewable application.
4. Geothermal heat pumps, which use the heat of the earth, to provide heating and cooling for the home are three times more efficient than conventional energy efficient furnaces.
5. Solar electric systems (PV systems) use the power of the sun to produce electricity. Solar panels mounted on your roof or near your home can provide clean, non-polluting, and renewable energy to power your home.
6. Small residential wind energy systems provide a clean, non-polluting source of electricity. You must have a sufficient average annual wind speed and enough installation space for wind energy to be effective.
7. Consider using hybrid power systems, which combine different renewable energy sources to produce electricity.
8. Fuel cells combine hydrogen and oxygen without combustion to produce electricity. They are efficient, and when fueled with pure hydrogen their only emission product is water vapor. They represent an exciting new technology that is still a few years away but may represent the residential power source of the future.
9. Take advantage of existing programs to help offset the cost of renewable energy systems and to receive services and expertise.
10. Keep in mind that reducing energy use through conservation and increased efficiency is almost always a cheaper alternative than installing a renewable energy system.

YOUR HOME AND THE ENVIRONMENT

Though few of us stop to think about it, our homes, automobiles, and lifestyles affect more than just ourselves; they affect the environment as well. Whenever we make decisions to use less energy or to produce less waste, for example, we are helping everyone around us. This addresses the decisions we face from an environmental perspective. Very often, simple changes in our plans or daily actions are all it takes to lead more environmentally friendly lives.

Saving Energy Is Good For The Environment

Reducing energy consumption benefits the environment in several ways. Most of the energy we use comes from burning fossil fuels – oil, coal, and natural gas – all of which have significant environmental costs. The most obvious effect is air pollution. Whether these fuels are burned in our cars, in furnaces at home, or in power plants for electricity production, they release many different pollutants into the air, contributing to smog and acid rain. The primary combustion product of fossil fuels – carbon dioxide – was not even considered a pollutant until recently. Although climatologists and other researchers are not in full agreement, the evidence is clear that elevated CO_2 levels in the atmosphere are likely to cause gradual global warming and that human activity does indeed affect the climate.

The environmental impact of fossil fuel use goes beyond the actual burning of the fuels. As reserves of locally available fuels dwindle, we turn to increasingly remote and fragile wilderness areas – from the Amazon Rainforest of Ecuador to the North Slope of Alaska – to quench our thirst for energy. The Valdez oil spill damaged a large area of Alaska's coastline and received a great deal of media attention. But in fact, as many as seven Valdez oil tankers-worth of oil make their way into the groundwater each year just from homeowners dumping waste oil from their cars! (Virginia now has a used oil recycling program. See Chapter 11 for details.)

Nuclear power accounts for 13 percent of Virginia's total energy use and over 60 percent of its electricity. While nuclear energy is for the most part free from air pollution, the mining and disposal of uranium takes a heavy environmental toll in the western United States. Nuclear waste remains dangerous for at least several hundred thousand years.

Even some renewable energy sources have environmental problems. Wood energy in Virginia accounts for close to 100 trillion Btu's annually, nearly five percent of total energy production. Like fossil fuels, wood combustion releases various air pollutants, including CO_2 (though the CO_2 emissions from burning wood is somewhat offset by the CO_2 absorption by growing trees).

Hydropower is clean in that it results in no pollution, but damming rivers can have significant environmental impact.

The point of all this is that our energy use has substantial environmental costs associated with it, and using less energy is one of the best and most accessible ways to help the environment. By practicing energy conservation in their homes and/or businesses and by using resources more efficiently, consumers can seize the power and exercise their own brand of personal leadership. The cumulative impact of this effort would:

- Conserve our natural resources
- Lower prices by reducing demand
- Preserve the environment by reducing the negative impacts of energy production

Homeowners would also enjoy safer, healthier, more comfortable, and more affordable homes.

Global Warming

The climate has gradually changed over most of human history. These changes have been a result of natural causes that have occurred over a long period of time – tens of thousands of years. But over the last fifty years human activity has had a profound impact on climate. The increase in our burning of fossil fuels (coal,

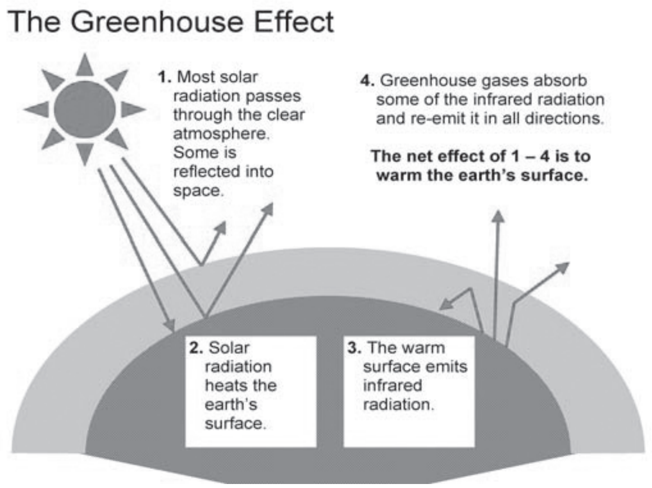


Figure 13-1 - The greenhouse effect can cause global warming

natural gas, and oil) which emit carbon dioxide into the atmosphere and the release of methane from our landfills has intensified a natural phenomenon called the "green-house effect".

As the energy of the sun heats the earth's surface much of this energy is radiated back into space. Atmospheric greenhouse gases such as carbon dioxide and methane let sunlight in, but trap thermal radiation and keep it from going back out into space. This process is similar to greenhouse panels that keep heat inside a greenhouse after the warm sun has penetrated the glass. This natural "greenhouse effect" keeps our planet warm, greenhouse gases acting like an insulation blanket. Some level of greenhouse gases are required to maintain the temperatures we're used to, but an increase in greenhouse gas levels results in a long- term rise in average temperatures. This is called "global warming."

The Intergovernmental Panel on Climate Change (IPCC), a United Nations group comprised of 2,500 scientists worldwide, the National Academy of Science, and the World Meteorological Organization have all concluded that due to this rapid increase in greenhouse gas, which is caused by human activity, the Earth will witness the fastest rate of warming to occur in the last 10,000 years. The impact of global warming could be widespread and potentially devastating.

The ten warmest years of the 20th century occurred after 1980. A warmer climate means that moisture evaporates faster creating severe droughts in some areas and heavy rainfall in others. This can cause the increased spread of disease, a dramatic rise in sea levels, increased coastal flooding, increased intensity of severe weather events, melting of the ice caps and glaciers, and drastic habitat shifts for plants and animals. Sea levels have risen from 4 to 10 inches over the past century and more than 5,400 square miles of the Antarctic ice shelves have broken off and melted in the past ten years.

What are the solutions and how do we curb the threat of global warming? Simply put, we must reduce the amount of greenhouse gas that is being emitted into the atmosphere. This is difficult to do, because almost all our current energy sources – renewable energy and atomic energy being the exceptions – produce the main greenhouse gas, carbon dioxide. Since the changeover to renewable energy will take time, and atomic energy presents other pollution hazards, the best thing to do right now is to use energy as efficiently as possible.

Every kilowatt-hour (kWh) of electricity that is not used can save from one to over two pounds of carbon dioxide from being emitted into the atmosphere, depending on the fuel type that was used by your utility company to generate electricity. Table 13-1 shows the effect on CO_2 emissions of various energy-saving measures.

Here are some other examples of how reducing energy consumption can minimize carbon dioxide emissions:

- Lowering your thermostat two degrees in winter can save 400 pounds of carbon dioxide (CO_2) per year in a typical home.
- Not using heat in the drying cycle of your dishwasher can save 200 pounds of CO_2 per year.
- Using cold water to wash clothes can save 500 pounds of CO_2 per year with an electric water heater and 150 pounds per year with gas.
- Keeping your furnace and air conditioner filters clean can save 175 pounds of CO_2 per year.
- Installing low flow showerheads can save 300 pounds of CO_2 per year with an electric water heater and 220 pounds with gas.
- Walking, biking, carpooling, or using mass transit reduces CO_2 emissions. Every gallon of gasoline you save avoids 22 pounds of CO_2 emissions.

Table 13-1 - Energy Conservation and CO_2 Savings In the Home*

Energy Conservation Measure	CO_2 Savings (tons/yr) with different energy sources Gas	Oil	Electric[1]
Installing 10 13-watt compact fluorescent light bulbs in place of 60-watt incandescent bulbs[2]	--	--	1.1
Replacing typical 1973 refrigerator with energy-efficient 1998 model[3]	--	--	1.3
Replacing a 65 percent efficient furnace or boiler with one that is 90 percent efficient[4]	2.0	3.0	--
Substituting gas or oil heat for electric resistance heat[1,4]	23.0	19.0	--
Replacing single-glazed windows with low-E, argon-fill double-glazed windows[4]	2.4	3.9	9.8
Planting shade trees around house and painting house a lighter color[5]	--	--	0.9-2.4
Installing solar water heating system[6]	0.8	1.4	4.9
Boosting energy efficiency of house when it is being built from standard insulation levels to super-insulated levels[7]	5.5	8.8	23.0

1. Assumes electricity generated using coal.
2. Assumes lights on 2,000 hours per year (5.5 hours per day).
3. Average 1978 model uses 1,600 kWh per year; energy-efficient 1998 model uses 550 kWh/year.
4. Assumes 1,850 square-foot house of average (good) energy efficiency (heating load of 6.95 Btu/ft²/°F-day) in a northern climate (6,300 heating degree-days).
5. Data from Lawrence Berkeley Laboratory, Berkeley, Calif. Based on computer simulations for various locations around the country.
6. Assumes two-panel system providing 14.25 million Btu/year (75% of demand).
7. Assumes 1,850 square-foot house in northern climate (6,300 degree-days). Boosting energy efficiency from 6.95 Btu/ft²/°F-day to 1.37 Btu/ft²/°F-day (going from R-19 walls, R-30 ceilings, double-glazed windows, and relatively loose construction to R-31 walls, R-38 ceilings, tight construction, and low-E windows).

*Source: *Consumer Guide to Home Energy Savings*, ACEEE, 1999.

- Wrapping your water heater in an insulating jacket can save 1100 pounds of CO_2 per year for electric water heaters and 220 pounds for gas.
- Insulating your walls and ceiling can save from 1000 to 2000 pounds of CO_2 per year depending on the type of heating and cooling system that is operating.

Using the energy saving techniques discussed throughout this handbook will minimize CO_2 emissions and global warming.

Houses and the Environment

If you are considering building a new home or making changes to an existing home, there are a number of important environmental issues to consider. Clearly, making your new or remodeled house highly energy efficient is a good idea. But there are other issues to consider as well. The site you choose, the materials you use for construction, the design of your home — these will all have impact on the environment. A few of the issues to consider are listed below.

In making your home more environmentally friendly, don't forget to pay attention to the indoor environment

Many materials used in construction, or even in our day-to-day lives, give off toxic fumes that can accumulate in a house without adequate ventilation. Avoiding these materials when possible and equipping your house with a controlled ventilation system are good steps towards improving indoor air quality (Chapters 2, 10).

Siting a new house

When choosing the site for a new house (Chapter 10), there are several environmental issues to keep in mind. As undeveloped open space disappears in Virginia, we should consider leaving the undisturbed land alone. In development projects, the practice of cluster housing should be followed where possible – grouping houses on a plot of land, while leaving shared common areas free of structures. In addition to preserving habitats for wildlife, this choice saves energy and resources by shortening roads and utility hook-ups. Renovating a dilapidated old house or tearing it down and rebuilding on the same site are great ways to improve a neighborhood instead of impinging on a natural area.

Consider the environmental impact of materials

Materials used in construction all have some environmental impact Chapter 10). Each product or building material you use came from somewhere, went through some type of manufacturing process, and will be disposed of in some way once it no longer serves its purpose. Each nail used in your house, for example, began as raw iron-ore, which had to be mined out of the earth. It was then transported to a mill, processed into steel, molded or stamped into a nail, packaged, and transported to your building site. Each of these steps has an environmental impact. Although our understanding of the environmental impact of building materials is still rudimentary, we already know enough to begin factoring this sort of analysis into our decision making.

Choose materials with low "embodied" energy

All building materials require energy to produce and transport to the building site (Chapter 10). We call this "embodied energy." The embodied energy in the materials used to build a house may actually be greater than the energy used to operate the house over its lifetime.

Table 13-2 - "Embodied energy" in several common building materials (excluding transportation energy).

Material	Energy for production (Thousand Btu per pound)
Lumber	1 (640 kWh/ton to harvest and process)
Brick	4
Cement	5
Plastic	6
Glass	14
Steel	24
Aluminum	126

Source: *The Natural House*

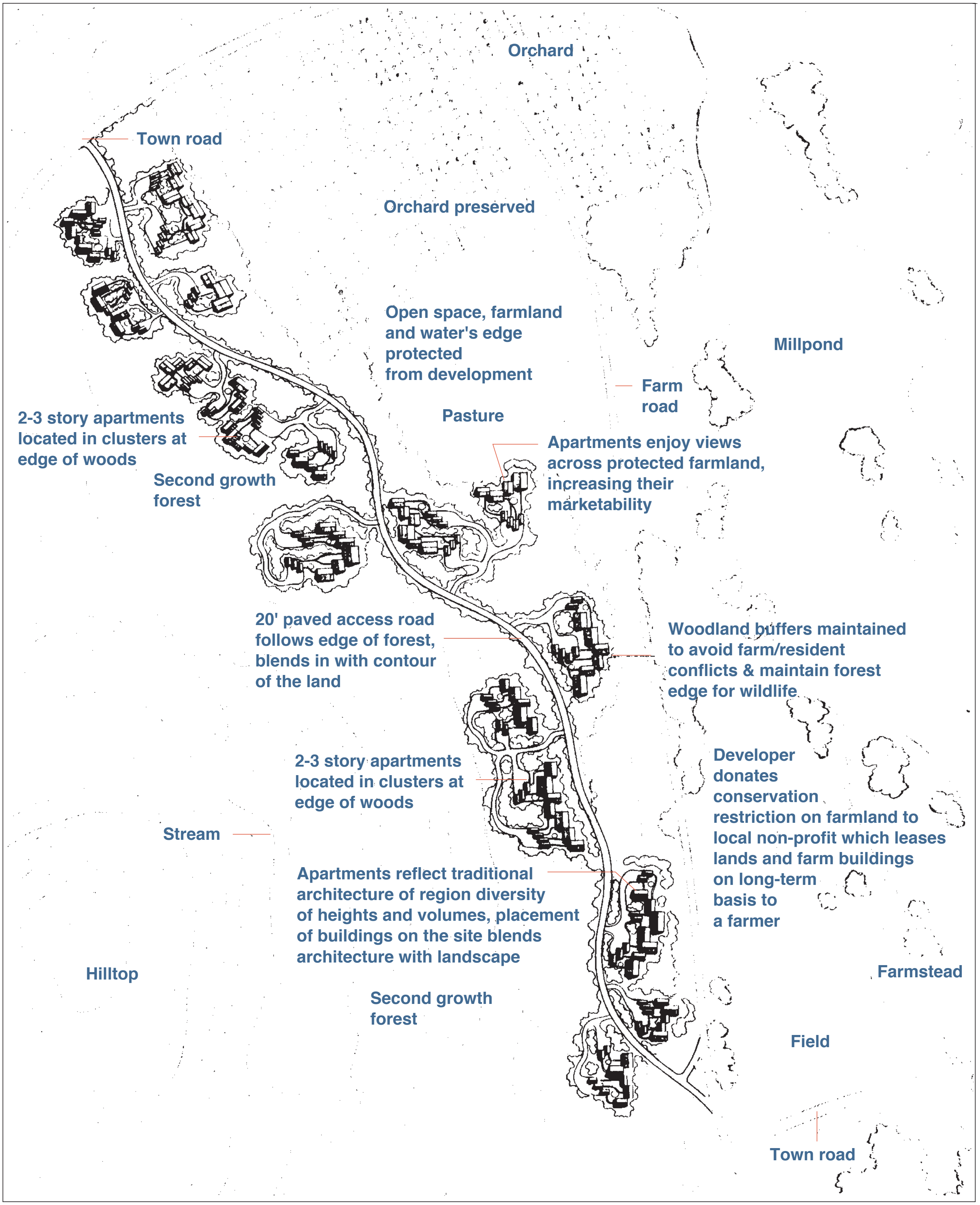


Figure 13-2 - A carefully designed group of homes can offer a sense of "neighborhood," while still preserving the privacy of individual homes and, more importantly, leaving large expanses of surrounding land undeveloped for recreation, agriculture, and habitats of wild plants and animals.

"HCFCs" (hydrochlorofluorocarbons)

Chlorofluorocarbons (CFCs, Chapter 3) are known to destroy the earth's protective ozone layer, and they are potent "greenhouse" gases, contributing to the projected global warming. CFC's have now been banned from use in building materials.

In many cases, however CFCs have been replaced with hydrochlorofluorocarbons (HCFCs). While HCFCs are not as damaging to the ozone layer as CFCs, they still have a bad effect. Because of their detrimental effect on the environment, HCFCs are scheduled for gradual phase-out between now and 2040.

CFCs were used in foam insulating materials, and most of the same materials now use HCFCs. You can get a jump on the 2040 deadline for reducing the HCFC hazard by switching to non-foam insulation or to foams not containing HCFCs.

Choose locally produced materials when possible

Locally cut and milled softwoods and hardwoods use far less transportation energy than wood products brought in from a great distance, such as plywood shipped from the Pacific Northwest. Use of locally produced materials also helps boost your local economy.

Avoid materials made from disappearing timber resources

Restrict the use of clear western red cedar, redwood, and cypress to areas where decay resistance is of highest importance. The old-growth forests of these species are quickly disappearing. If siding is to be painted, for example, pine or spruce should be adequate as long as the house or addition is properly constructed (no moisture problems in walls, no splashing on siding, etc.).

Avoid construction materials with too much packaging

Tell your building products supplier why you are selecting bulk nails, for example, rather than nails in small plastic display containers.

Use products made from recycled materials

Creating markets for recycled materials is the biggest challenge we face in coming to grips with our solid waste problem. You can help out by selecting building products made, at least in part, from recycled materials.

Some building products made from recycled materials have been around for years, such as fiberboard sheathing and cellulose insulation. Other recycled products are just coming onto the market. Examples include wood-plastic composites used in some windows and doors, ceramic tiles made from crushed glass, plastic lumber products for decks and other outdoor exposure wood applications, masonry block and brick made from fly ash, drywall products with high recycled material content, and exterior siding and roofing materials made from recycled fibers and cementitious material. Look for products that advertise the use of recycled materials.

Use durable products and materials

Manufacturing of almost any material is very energy intensive. A durable product, lasting twice as long as one less durable, will probably not take twice as much energy to produce, so there is a considerable net energy savings (Chapter 10).

Minimize your use of organic solvent based floor finishes, paints, stains and adhesives

These products release volatile organic compounds (VOCs) into the atmosphere, contributing to smog formation and ground-level ozone pollution (Chapter 2).

Avoid the use of pesticides and other chemicals that may leach into the groundwater

When backfilling a foundation or grading around a new addition, do not bury cans of solvent, adhesive, paint, or other potentially toxic chemicals (Chapter 10).

Install water conserving plumbing fixtures

Low-flush toilets, high-quality low-flow showerheads, and faucet aerators not only reduce your water use, but they reduce demand on your septic system or your town's water treatment plant. By saving hot water, low-flow showerheads and faucet aerators also save energy. (For more information on water conserving fixtures, see (Chapter 9).

Recycling Strategies For Your Home

To facilitate recycling in your home, build collection and sorting containers for recyclable materials. Typically it is the kitchen that produces most of the solid waste that comes out of a household, so provide for storage of recyclable materials in or near your kitchen. Instead of leaving the space under the kitchen sink open, for example, you could build bins for bimetal cans, aluminum cans, glass, and general refuse. Consider adding a wall-mounted can crusher so that the area devoted to recycling will not need to be as large.

In your garage, plan a longer term storage area for different colors of glass, different types of plastic (PET, HDPE, etc.), bimetal and aluminum cans, newspaper, glossy magazines, and recyclable high grade paper.

Figure 13-3 - Recycling bins make it easy to sort and store various recyclable materials for delivery to a collection center or curbside pick-up.

Check with your local recycling coordinator to find out what products can be recycled locally– and exactly what the requirements are (whether labels and bottle caps have to be removed, how newspaper should be bundled, etc.). Some materials may not yet be recyclable in all parts of Virginia.

If facilities allow, composting of organic waste is another excellent form of inhouse recycling. A small container with a cover near the sink is ideal for collecting organic matter; it should be emptied daily into a composting bin where decomposition can occur. Receptacles are available that mount inside the door below the kitchen sink and lift out for easy transport to your compost bin.

In planning for the future, flexibility is essential, because products and procedures are likely to change as recycling programs mature. With proper planning, it is not difficult to reduce dramatically the amount of waste produced by your household.

Recycling conserves energy and saves on our natural resources. One ton of aluminum from ore requires 16,000-kilowatt hours (kWh) of electricity to process while one ton of aluminum from recycled metal only requires 187 kWh. One ton of recycled paper saves 17 trees. Manufacturing recycled material causes significantly less water and air pollution than producing the same products from raw materials.

Education is the Key

America is entering the 21st century with an unhealthy reliance on 19th century fossil fuel technology, which is inefficient, polluting, and a direct contributor to global warming. Home heating oil, propane, and natural gas prices are rising dramatically, and rising fuel prices are in turn causing electricity prices to rise. Emissions from power plants, automobiles and homes are causing dramatic health problems around the country – particularly in the young and the elderly. Our national leadership often focuses on economic costs and the needs of big business while ignoring the environmental costs associated with our current energy situation. Most people don't consider energy and the environment when making decisions about how they live.

If saving energy saves money, the environment, and saves on our natural resources – then why is conservation not a national daily practice? There is only one answer: lack of education. Effective education on energy and the environment is the key to changing the way people make their energy choices. Once people understand the problem, they naturally make choices that save them money, conserve our energy supplies, and preserve the environment.

Education can eliminate the energy myths that are still so prevalent. Some of these are shown in Table 13-3.

People who believe energy myths like the ones in Table 13-3 hurt not only themselves, but everyone in the community. We can help educate them about sensible energy use by encouraging schools, state and local governments, and public utilities to provide more opportunities for energy and environmental education. We should all take advantage of the educational opportunities (such as this Handbook) that already exist.

Energy Tips and Recommendations

1. Saving energy is good for the environment because energy production generates pollutants. The less energy we use, the fewer pollutants enter the environment.
2. Saving energy conserves our natural resources for future generations.
3. Homeowners can help to curb global warming by practicing conservation in their homes and by using energy resources more efficiently.
4. Consider the environmental impact of your house by siting a new house properly, by using building materials with low-embodied energy, by using environmentally friendly building materials, and by using products that are durable and long lasting.
5. Develop and implement successful recycling habits and practices in your home.
6. Take the responsibility to learn why it is important to save energy and become educated in how this can be accomplished.

Table 13-3 – Typical Energy Myths and Facts

Myth	Fact
Energy conservation is too much of a personal sacrifice. I work hard and make a good living. I have the right to be comfortable.	Wise energy conservation saves energy and saves money without discomfort or inconvenience.
Energy efficient lamps, appliances, and equipment are too expensive. How can I save money if I have to purchase products that are the most expensive on the market?	The day-after-day savings on energy efficient devices can make them an investment that pays back their initial cost many times over.
So what if I can reduce my overall energy bill by 40%! I can easily afford to pay the bill as it stands.	Energy prices are constantly increasing – that wasted energy will cost you more and more as time goes on.
Recycling is a hassle. Landfills are free.	Everyone pays for the cost of landfills through local taxes, and these costs go up as available land decreases.
I want a car with size and power and nobody can tell me I have to drive some little, slow, uncomfortable economy car if I don't want to.	Many fuel-efficient cars are roomy, comfortable, and fun to drive.

WHERE TO GO FOR MORE INFORMATION

If you have a specific question about your present or future home, or if you just want to learn more about energy conservation in and around the home, there are a variety of information sources available to you.

With the advent of the Internet, the fastest and most convenient way to get information is electronically. This Appendix presents a list of Web sites on energy conservation topics.

The sites listed here are mainly from government, non-profit, and trade organizations. The information presented on them is generally reliable. Any Internet information, particularly from a commercial site, should be examined for possible biased or exaggerated presentation.

General Information

Virginia:

Virginia Department of Mines, Minerals and Energy, Division of Energy
http://www.dmme.virginia.gov/de

Virginia Cooperative Extension Service
http://www.ext.vt.edu

Virginia State University
http://www.vsu.edu

Virginia Tech
http://www.vt.edu/

Virginia Department of Environmental Quality
http://www.deq.virginia.gov

The Virginia Sustainable Building Network (VSBN)
www.vsbn.org

Virginia Weatherization Assistance Program
The Department of Housing and Community Development
www.dhcd.virginia.gov

Nationwide:

The Alliance to Save Energy
www.ase.org

American Council for an Energy Efficient Economy (ACEEE)
www.aceee.org

American Lung Association (ALA)
www.lungusa.org

The Association of Energy Conservation Professionals (AECP)
www.aecp.org

Environmental Building News
www.BuildingGreen.com

National Association of Home Builders (NAHB)
www.nahb.org

Sustainable Buildings Industry Council (SBIC)
www.SBICouncil.org

U.S. Department of Energy's Office of Energy Efficiency and Renewable Energy (EERE)
www.eere.energy.gov

U.S. Environmental Protection Agency (EPA)
www.epa.gov

U.S. Green Building Council
www.usgbc.org

Building Envelope

Cellulose Insulation Manufacturers Association (CIMA)
www.cellulose.org

National Insulation Association
www.insulation.org

Efficient Windows Collaborative
www.efficientwindows.org

Appliances

Association of Home Appliance Manufacturers
www.aham.org

Energy Star
www.energystar.gov

Federal Trade Commission
www.ftc.gov

Wood Heat

Hearth, Patio, and Barbecue Association
http://hpba.org/

The Wood Heat Organization
http://www.woodheat.org/

Alternative Energy

American Solar Energy Society (ASES)
www.ases.org

American Wind Energy Association (AWEA)
www.awea.org

Center for Energy and Enviromental Sustainability at James Madison University
http://www.jmu.edu/cisat

National Renewable energy Laboratory (NREL)
www.nrel.gov

Solar Energy Industries Association (SEIA)
www.seia.org

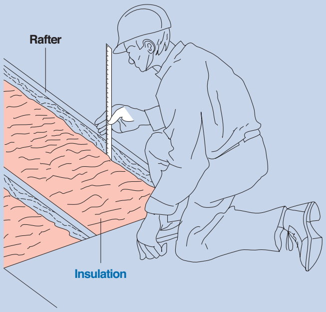
Solar Electric Power Association
http://www.solarelectricpower.org/

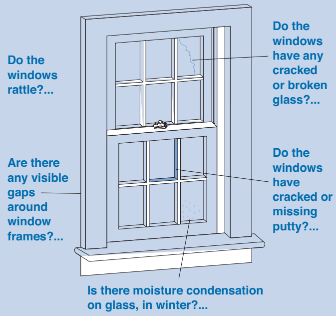
Water Conservation

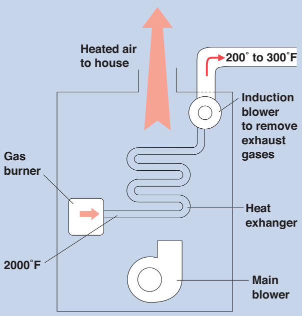
The American Water Works Association - Water Wiser
www.awwa.org/waterwiser/

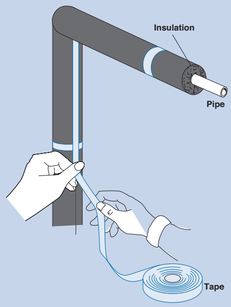
Tree Planting and Preservation

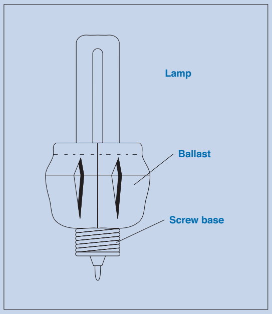
National Arbor Day Foundation (NADF)
www.arborday.org

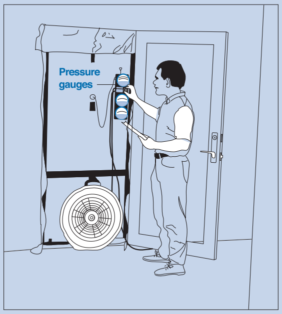

Rafter
Insulation

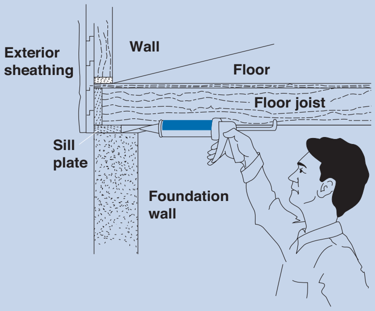

Do the windows rattle?...
Are there any visible gaps around window frames?...
Do the windows have any cracked or broken glass?...
Do the windows have cracked or missing putty?...
Is there moisture condensation on glass, in winter?...

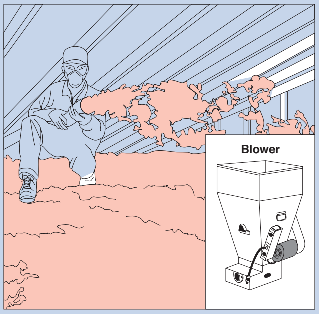

Heated air to house
200˚ to 300˚F
Induction blower to remove exhaust gases
Gas burner
Heat exhanger
2000˚F
Main blower

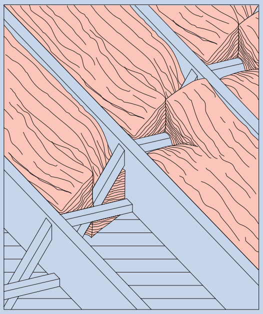

Insulation
Pipe
Tape

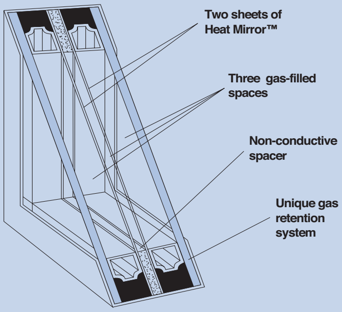

Lamp
Ballast
Screw base

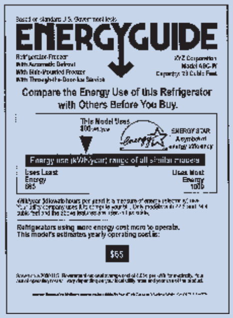

Pressure gauges

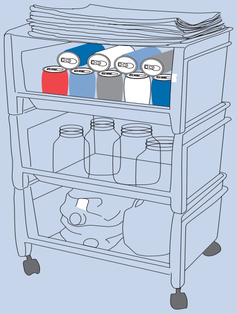

Exterior sheathing
Wall
Floor
Floor joist
Sill plate
Foundation wall

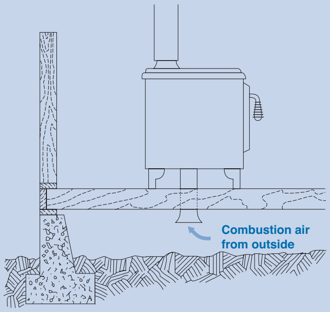

Blower




Two sheets of Heat Mirror™
Three gas-filled spaces
Non-conductive spacer
Unique gas retention system


ENERGYGUIDE
Compare the Energy Use of this Refrigerator with Others Before You Buy.




Combustion air from outside