The Homeowner's Handbook to

ENERGY EFFICIENCY

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A Guide to

BIG AND SMALL IMPROVEMENTS

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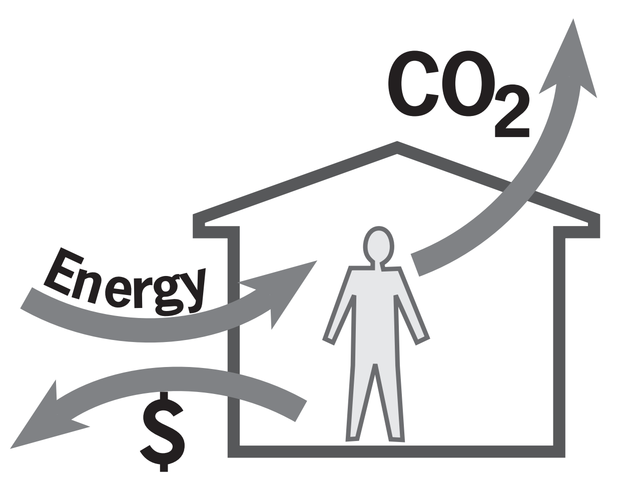
Introduction

We consume huge amounts of energy in North America. More than twenty percent of that energy flows through our homes, and if you include commercial and industrial structures, our buildings account for over forty percent of our total energy consumption. The energy we use also has an environmental impact—much of the pollution we create is emitted by the construction, maintenance, and operation of those structures.

More than ever before, the economic and environmental burdens of supporting our buildings presents a major challenge to each of us as individuals and to society at large. It is hard to imagine how any of us could have an impact on such large issues. Yet the management of our own homes does present such an opportunity, because we can each reduce our energy consumption at home through careful planning and investment. Helping you do so is the goal of this book.

Energy, Dollars, and Carbon Dioxide



The energy you consume costs money. It also results in the release of carbon dioxide (CO_2) and other "greenhouse gases" that contribute to climate change. When you improve the efficiency of your home, you save money and reduce your carbon footprint at the same time.

THE BENEFITS OF ENERGY EFFICIENCY

We have long had the technical ability to minimize the energy consumption of our buildings. But this knowledge has not always made its way into mainstream construction practice. We believe that it's now time to bring this expertise to bear on our homes.

Many of us are ready to invest in the energy-wise renovation of our homes in order to provide future energy security for our families. Efficient homes offer many benefits to their owners.

- Efficient homes are cheaper to operate. You'll save money, and you'll be less vulnerable to price fluctuations.
- Efficient homes have a smaller carbon footprint. You'll be doing your part to control climate change.
- Efficient homes are more comfortable. Your home will be less drafty and the temperature will be more even.
- Efficient homes are more valuable. You'll get top dollar at the time of sale for a well-designed home with small utility bills.

This book will help you evaluate your home and embark upon improvements that allow you to reap all these benefits.

ALL HOMES CAN BE IMPROVED

The projects in this book are targeted toward typical single-family wood-frame homes in North America. These homes are most likely heated by forced-air furnaces or by boilers. If they are located in a hot region, they may be cooled by a central air conditioner. Hot water is probably provided by a standard storage water heater.

Most of these homes are supplied with a fossil fuel such as natural gas, propane, or oil. This fossil fuel is likely used for heating, water heating, cooking, and/or clothes drying. Almost all North American homes rely upon the electrical grid to power air conditioning systems, lights, appliances, and sometimes heating systems.

There are perhaps ninety million of these single family homes in the U.S. today, and another nine million in Canada. Most of them offer an abundant crop of energy waste that can be turned into savings. Why are these homes so inefficient? Weren't they constructed according to building codes? The answers are buried in history and economics.

Energy in North America has been relatively inexpensive for several generations now, owing to the discovery of large fossil fuel reserves both at home and abroad. Government subsidies have helped keep fuel prices artificially low. During and after the oil embargoes of the mid-1970s, the U.S. and Canadian governments and private sectors launched initiatives to improve energy efficiency. From about 1976 through 1986, the energy-efficiency of homes increased. New buildings were constructed to improved efficiency standards, and owners of existing homes invested in insulation, storm windows, and improved heating systems. But with the discovery of new oil and gas reserves in the 1980s and the stabilization of foreign energy supplies, energy costs dropped and the trend toward energy efficiency stalled. For the last few decades, energy concerns have faded from public consciousness.

Meanwhile, we've built millions of inefficient homes and installed millions of inefficient heating and cooling systems. Most have been built according to the latest building codes, and a few even exceed those standards. But building codes establish the minimum legal standards for health, safety, and energy efficiency—they define what a builder must do to avoid breaking the law. Despite recent revisions, today's building codes fail to provide wise guidance on building or remodeling for energy efficiency. The end result is that most of our homes are quite inefficient, and offer ample opportunities for improvement.

HOW THIS BOOK CAN HELP

Our primary goal is to present proven methods for reducing your home's energy consumption. Many of the projects we describe will also improve your home's comfort, safety, and durability. In each case, we offer clear explanations of the possible options, we describe the necessary commitments of time and money, and we present basic methods for estimating energy savings.

Throughout this book, we also describe how your home operates. We hope that by explaining some building science principles, we can help you analyze home improvement tasks beyond the ones we're discussing. This knowledge will also help you cut through the sometimes conflicting claims made by vendors of home improvement products and services.

It's possible to make reductions of up to eighty percent in your home's energy consumption. The projects described here are a good start toward that goal. But we also recognize that the most important step for each of us is to simply get started on whatever level we can. We've included both big and small improvements here, so you can find projects that fit both your budget and your personal commitment. An investment of any size in your home's efficiency will reduce both your monthly energy expenses and your environmental footprint.

The projects you choose from this book will also depend on the characteristics and current condition of your home. Some improvements are relevant to every home, while others may apply to only a few. But we'll show you how to craft a plan that suits your home. Whatever progress you make toward improving the energy efficiency of your home will benefit us all in the long run. We thank you for your commitment.

John Krigger
Chris Dorsi

1 Developing a Plan for Your Home

We presume you're reading this book with the intention of improving the energy efficiency of your home. We hope to help you do that and more.

Improvements to your home's efficiency are among the best financial investments available. The projects described here yield returns in utility cost savings that range from five to fifty percent annually, exceeding the interest yielded by many traditional investments. These economic returns will only improve as energy prices increase.

Most of the projects described here also offer benefits beyond energy efficiency. Many will increase your home's comfort, safety, and durability. And the resale value of efficient homes continues to climb in comparison to homes with high utility costs.

The best time to start improving your home's energy efficiency is now. Your savings won't begin until you take time to analyze your energy consumption, formulate your own solutions, and upgrade your home.

ENERGY CONSUMPTION VERSUS CARBON EMISSIONS

Your consumption of energy has an effect on the planet, which varies widely depending upon the amount and type of energy you use. The primary environmental factor we evaluate in this book is the emission of carbon dioxide (CO_2), a normal byproduct of the combustion process that is released when you burn hydrocarbon fuels such as coal, oil, or natural gas. Combustion takes place within your home heating equipment, and at the central power plants that produce most of our electricity. When carbon dioxide is released, it traps heat in the atmosphere through the process called the greenhouse effect. When you improve the efficiency of your home, you produce less carbon dioxide and other pollutants, saving money *and* reducing your environmental impact.

Comparing Emissions of Various Energy Sources

It's not difficult to estimate the amount of CO_2 released by the natural gas, propane, or oil you consume in your home. Your utility bill shows you how much fuel you consume. Burning that fuel releases predictable amounts of CO_2 up the chimney of your heating system.

It's more difficult to evaluate the carbon emissions that result from your electricity consumption because electricity is produced by a variety of methods. The fuel most commonly used to generate electricity in North America is coal, though natural gas and fuel oil are also used. These are burned to produce steam that spins electric generators. The combustion of these fuels, for both heat and electricity, accounts for the majority of greenhouse gas emissions that we produce.

Hydroelectric plants use falling water to generate electricity. Hydropower emits no carbon directly, though the associated construction and maintenance of dams, generators and transmission lines do incur a large environmental cost.

Even nuclear power can be described as "carbon neutral," since nuclear reactors don't burn fossil fuels and so don't release CO_2. Yet the operation of nuclear power plants and the disposal of their waste incurs large environmental and economic costs. Carbon emissions are not the only way to measure the desirability of potential energy sources.

One of the most promising ways to generate electricity today is with photovoltaic (PV) systems. You may have seen banks of PV solar panels on the roofs of buildings, or even in large arrays operated by utility companies. PV systems convert sunlight to electricity. But even this is not a perfect technology: PV systems are still relatively expensive and their manufacturing process consumes energy and incurs other environmental costs. Wind power and other renewable energy sources are also becoming a part of the mix as we develop sustainable energy systems.

When it comes to generating electricity, there is no perfect solution. The improvement of existing buildings, to make them more efficient, still produces a better economic return than the construction of almost any type of power plant. That's why using less energy is the best way to save money and trim your carbon footprint.

EMBODIED ENERGY AND DURABILITY

Your home leaves an environmental footprint beyond its carbon emissions from daily energy consumption. Two other factors carry great weight: the embodied energy in its materials, and the durability of the structure.

Embodied energy is the sum of energy inputs a material requires over its lifetime. Several organizations have proposed indexes of embodied energy that allow comparison among building materials. Not everyone agrees on what inputs should be included in these indexes, making comparisons difficult. But most such indexes account for the energy consumed in some or all of these activities.

- Mining or harvesting the raw materials
- Shipping the raw materials to the manufacturing facility
- Processing the raw materials into building products
- Shipping the materials to the job site
- Installing the building materials
- Performing needed maintenance over the material's lifetime
- Disposing of or recycling the material when it is replaced or the building is demolished

Other considerations may affect embodied energy, making a reliable estimate difficult to calculate. For example, should embodied energy include the energy required to build the manufacturing facility? Should it include the energy required to build the vehicle used to transport the material? What about the energy used by housebuilders to commute to the job where the material is installed?

The longevity of a material must also be considered when assessing its environmental impact. For example, PVC plastic roof gutters that last for ten years or less cannot be compared pound-for-pound to PVC plastic plumbing that remains functional for fifty years or more. And if a material is recycled when the building is demolished—common for aluminum in today's market but not for concrete—then some or its embodied energy is reclaimed by recycling.

You can minimize the embodied energy in your home by following these general guidelines:

- Build small. It's best to use less of any building material. Smaller homes have less impact on the environment both during their construction and throughout their lifetimes.
- Remodel your home rather than building a new one. You'll avoid the cost and environmental impact of buying an entire houseful of new materials. Focus your efforts on improving the efficiency of an existing building instead.
- Choose long-lived high-quality building materials. Materials with a long lifespan have less environmental impact than those that wear out quickly, plus they require less maintenance.

But remember that embodied energy is only part of the picture. Your home's operational energy—the electricity, gas, and other fuels used year after year to operate and maintain your home—are still your biggest concern. This is a simple matter of scale. Most research that compares the embodied energy and operational energy of homes shows that embodied energy accounts for only ten to twenty percent of the total energy consumed by the building over the years. Operational energy consumes the other eighty to ninety percent. The goal of this book is to help you control that ongoing energy consumption.

4 Heating and Cooling First Steps

The energy used by your heating and cooling systems probably makes up the majority of your utility expense for many months of the year. Several of the big improvement projects described elsewhere in this book—improving insulation, replacing heating and cooling equipment, or upgrading doors and windows—reduce these seasonal costs.

Here we describe the small steps you can take to improve the comfort of your home without embarking on those bigger projects. In some instances, particularly if your heating and cooling system is relatively new, these steps may be all you need to substantially reduce your seasonal energy consumption.

We describe guidelines for upgrading and replacing complete systems in *Cooling Systems* on page 117, and *Heating Systems* on page 129.

EVALUATE YOUR HOME'S COMFORT

Does the temperature of your home feel consistent in winter? If you notice large temperature swings in winter, it may indicate that your home has insufficient insulation or excessive air leakage.

Does the temperature of your home feel consistent in summer? If you notice large temperature swings in summer, it may indicate that your home is subject to excess solar gain through your attic or windows.

Are there individual rooms in your home that are too cold in winter or too hot in summer? You may be able to solve these room-by-room problems by improving the delivery of heated or cooled air. In summer, rooms that tend to overheat may benefit from window-shading devices.

Do members of your household have regular schedules? If so, you may benefit from the installation of a clock thermostat.

If you use central air-conditioning, do you ever use portable room fans as well? You can often trim your cooling consumption substantially by using fans to create a cooling breeze or to flush hot air out of the home at night.

If you use central air-conditioning, do you live in a dry climate? If so, you may be able to cut your cooling costs substantially by installing an evaporative cooler.

Do you have a dark-colored roof? If so, you may be able to trim your cooling costs by installing a light-colored cool roof that absorbs less heat.

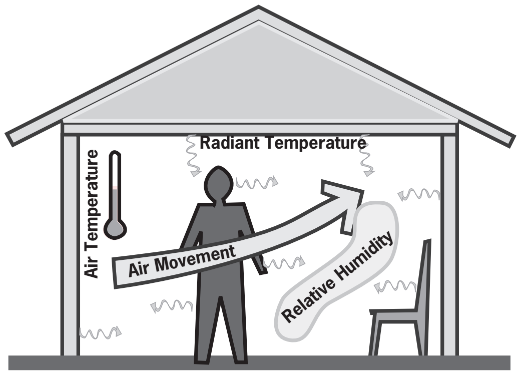
Have you had your heating and/or cooling systems serviced recently? Poor maintenance can cause substantial deterioration in the efficiency of this equipment.

BASICS OF COMFORT

Your home should be comfortable. If it's not, you will likely adjust your thermostat to a more comfortable setting, forcing your heating or cooling system to operate, and making your gas or electric meter spin faster. It's a simple cause and effect relationship that all begins with human comfort. Sometimes a small adjustment that increases comfort can allow you to cut your energy consumption substantially.

Our perception of indoor comfort is primarily based upon four things: the air temperature around us, air movement within the room, the radiant temperature of our surroundings, and the humidity of the air. Your ability to control all of these factors in your home is a key to efficient heating and cooling. If one of these factors drifts beyond what is comfortable, most people compensate by adjusting the thermostat to a setting that increases consumption. Your comfort threshold is an important determinant of your utility costs.

What Determines Comfort?



Your perception of comfort is made up of these four factors. The thermostat for your heating or cooling system only measures temperature, but the other factors also play a large role in your comfort.

Air Temperature

This most obvious factor is the one that is directly controlled by your thermostat. In winter, you spend more money to maintain the same indoor temperature because the greater temperature difference between indoors and outdoors will force more heat across the shell of your home—through your ceiling, walls, floors, doors, and windows—and force your furnace to run more. In summer, the indoor-outdoor difference increases the cost of cooling.

Radiant Temperature

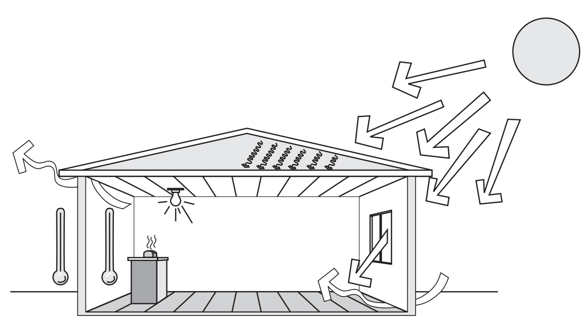
Your home's radiant temperature is almost as important as its air temperature. Radiant temperature is the temperature of all the objects in the room: the ceilings, floors, and walls are of primary importance, though the temperature of the furniture and everything else in the room does have some effect. Your body gains or loses heat directly across space to these objects. It is uncomfortable to have hot objects in the room in the summer, and equally uncomfortable to sit near cold objects in winter. The radiant temperature of these objects determines how fast your body gains or loses heat from them.

The insulation level (R-value) of a house has a big effect on its radiant temperature. In summer, for example, the sun tends to heat up your attic, often to as high as 150°F in sunny regions. That heat eventually conducts down through your attic insulation and heats the ceilings in your home. The hot ceiling radiates heat down upon you. It is distinctly uncomfortable to sit in a room with a 100°F drywall ceiling over your head, no matter how cool the thermometer on the wall says it is in the room. Attic insulation helps slow this flow of heat down into your home, so your ceilings stay cooler.

In winter, you are uncomfortable in a home with poor insulation because the walls, ceilings, and floors are so cold. Again, the thermometer on the wall may say 75°F, but you can't shake the chill caused if your warm skin radiates heat to cold surfaces in the room. Insulation improves your comfort because it helps the interior surfaces of the walls, ceiling, and floor stay closer to the room temperature rather than sinking towards the outdoor temperature. But unlike summer, when attic insulation is most important, winter calls for good insulation in the entire building shell. That's because in winter your attic is close to the same temperature as outdoors. If you have a crawl space under your floors, it may be cold, too, though it will be somewhat tempered by the ground.

Shading affects radiant temperature in summer. Good shading keeps radiant temperatures low, promoting good comfort and low air-conditioning costs. Taken together, shading and insulation allow for a higher comfortable summer thermostat setting. In winter, insulation is most important.

How the Sun Heats Your Home



Solar energy heats your home by shining on the roof, entering through the windows, and heating outdoor air that travels into the home through air leaks. Internal gains, such as appliances and lighting, also release heat into your home.

6 Finding and Sealing Air Leaks

Air leaks in the walls, ceilings, and floors of your home can waste up to 30 percent of the energy consumed by your heating and cooling equipment. Holes and gaps in your home's shell also allow moisture, insects, dust, and pollutants to enter your home. Sealing air leaks reduces this energy loss and helps keep these environmental contaminants under control. A properly sealed home is also more comfortable.

In this chapter we'll show you how to evaluate the air leakage between your home and the outdoors. We'll describe some simple projects so you can get started on reducing you home's air leakage right away, and we'll identify some big projects that are best left to professionals. Taken together, these air-sealing tasks can reduce your utility consumption by several hundred dollars a year. The improved comfort and cleanliness of your home will be an added benefit.

EVALUATE YOUR HOME'S AIR LEAKAGE

Do you notice drafts in your home? Drafts indicate that air is moving through your home's shell. This air leakage is expensive. It carries heated air out of your home in winter, and carries cool air out in summer.

If you live in a cold dry climate, do you notice a lot of static electricity in the winter? Excess air leakage in these climates tends to dry out your home and encourage the production of static electricity.

Do you hear a lot of outdoor noise when inside your home? Cracks and holes in your home's shell allow both outdoor air and sound to pass into your home. Well-sealed homes are quieter.

AIR LEAKAGE BASICS

Every home has some drafts. It's just the nature of building construction that gaps and holes will be left in the walls, ceilings, floors, doors, and windows where outdoor air can make its way into the home and indoor air can escape to outdoors. During mild weather, air leakage through these openings is harmless—on any day when you might open a door or window for ventilation, air leakage through the building shell incurs no energy penalty. But air leakage is costly and uncomfortable when you are running your heating or cooling system. During these times, any air leaking through your home's shell is carrying valuable energy with it. Air-sealing controls this expensive loss.

Your home will ideally be surrounded by a continuous layer of insulation that has a continuous air barrier installed immediately adjacent to it. This air barrier may be the drywall, exterior sheathing such as plywood, or building paper that is properly sealed at its seams. In retrofit work you will probably need to seal air leaks at some combination of these locations. For example, you might seal the drywall by caulking around recessed light fixtures, and seal the sheathing and building paper when installing new windows or doors.

In some climates, infiltrating air also carries unwanted moisture. In hot and humid climates, your air conditioner works hard to remove moisture from your home. When moist outdoor air gets into your home, your cooling system must work overtime, at extra expense, to remove this moisture. In cold climates, moist outdoor air can condense in your walls and attic in winter and cause moisture damage. Air-sealing allows you to control where the heat and moisture go in your home.

You may notice air leaks in the form of wintertime drafts. A drafty home is never comfortable, because moving air always feels cool. With proper air-sealing, you can set your thermostat lower and save on your heating bills without sacrificing comfort.

A well-sealed home is quieter inside. This side effect of air-sealing often surprises homeowners after they finish performing major air-sealing work. In areas near airports where residents tire of the sound of aircraft, noise abatement programs always include home air-sealing.

The Driving Forces of Air Leakage

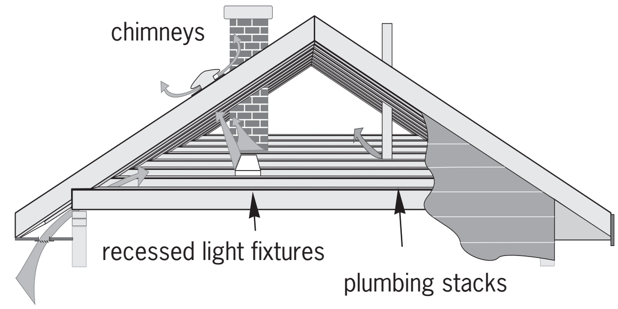
Air moves through openings in your building's shell. Air leakage is driven by pressure differences between indoors and outdoors. Ideally there should be little or no pressure difference between indoors and outdoors. Several things cause pressure differences between the indoors and outdoors.

Wind creates pressure and suction on different sides of the home. You perceive this as drafts on a windy day.

Stack effect takes place when warm air rises toward your ceilings and dense cold air sinks to the floors. This drives air leakage during cold weather more than it does when it's warm outside. When leaks are driven by the stack effect, you tend to notice them low on the ground floor. You don't usually notice air leaks higher in your home, where warm air exits, unless you go up into your attic and feel warm air emerging from around recessed light fixtures and through cracks in the ceiling. But these high leaks in the shell are important because they drive air leakage elsewhere in your home. A draft coming under your front door is driven, in part, by airflow up into your attic.

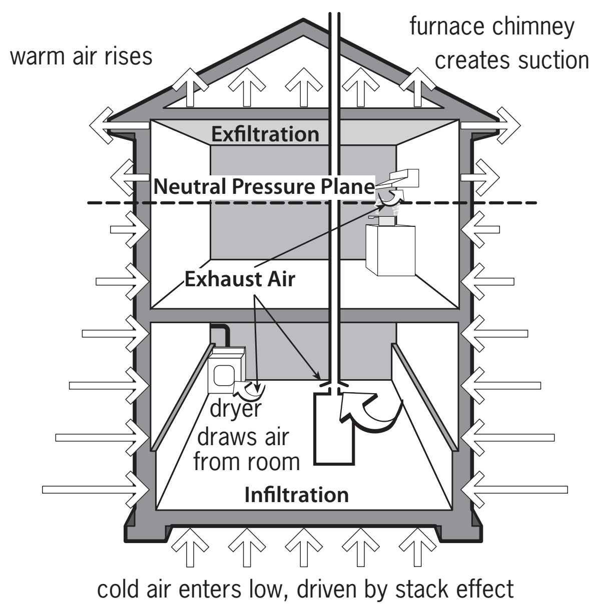
Exhaust appliances such as exhaust fans, conventional furnaces, fireplace chimneys, and clothes dryers all depressurize the home. These mechanical influences can also compete with one another. This is a potential concern when open-combustion furnaces or water heaters are installed that could be prone to backdrafting, since this can spill carbon monoxide and other gases into your home. To learn more about the potential hazards of backdrafting, see *Combustion Safety on page 130*.

Sealing Air Leaks in Your Attic



Attics contain a variety of air leaks that draw conditioned air out of your home. These leaks should be sealed to reduce heat loss and prevent moisture damage.

What Drives Air Movement



Air is driven through your home by several sources of pressure. The goal of air-sealing is to reduce air movement through the shell, while allowing your appliances and heating equipment the airflow they require.

7 Insulation

The comfort and energy efficiency of your home are more dependent on insulation than any other component. Without sufficient insulation, many tasks we recommend for trimming heating and cooling loads are less effective. When you install more insulation, your heating and cooling equipment runs less and your utility bills are lower.

In this chapter, we show you why properly installed insulation is the best way to reduce heating and cooling costs. We also describe how to install insulation so it is effective and long-lived, and which types of insulation work best for each application.

EVALUATE YOUR HOME'S INSULATION

How thick is the insulation in your attic? Your attic insulation should be your first line of defense against energy waste whether you live in a hot or cold climate. Thicker insulation is better.

How thick is the insulation in your walls? Whatever the thickness of your walls, they should be full of insulation in every climate.

Do you have insulation under your floors or around your foundation? Floor and foundation insulation is mandatory for efficient homes in cold climates, and a worthwhile addition to super-efficient homes in warm climates.

INSULATION BASICS

Attic and wall insulation are the best energy investments for many homes. In hot climates, attic insulation gains importance because of the high temperatures attics reach in summer. The greater the temperature difference between outdoors and indoors, the more you need effective insulation. If you live in a climate with hot summers, your attic may be 150°F in summer, or 70°F hotter than your home's living space. It's worth installing lots of attic insulation to slow the flow of heat into your home. Wall insulation is important during hot summers, too, but it's not as critical since the temperature difference between the two sides of the wall on a hot day may be only 30°F.

In cold climates, wall insulation is just as valuable as attic insulation. This benefit is again driven by temperature difference. When the outdoor temperature is 0°F, the temperature difference across your home's walls is 70°F. You want all the wall insulation you can get. Floor and foundation insulation are more cost-effective in cold climates, too.

But these comparisons must be taken in perspective. So we make one simple recommendation with complete certainty. *Install the maximum amount of insulation possible in your home's walls, ceilings, and floors.*

The Meaning of R-Value

Insulation is rated by R-value, which is a measure of thermal resistance, or resistance to heat flow. Each type of insulation has a particular R-value for an inch of thickness. Hence a 6-inch fiberglass blanket may be valued at R-19, or about R-3 per inch, while a 6-inch sheet of polystyrene foam board has a value of R-30, or about R-5 per inch. Foam board is a better insulator than fiberglass, inch for inch. But that doesn't mean that foam board is always a preferable material.

We often use fiberglass and cellulose loose-fill insulation in attics, for example, because we have enough room there to install 16 to 24 inches of insulation. The lower R-value of these materials is not an issue when there is plenty of space. Fiberglass and cellulose are inexpensive, relatively nontoxic, and easy to install. When choosing insulation, we consider the R-value per inch, the overall cost, the ease of installation, and other factors.

8 Windows and Doors

We all want to have ample windows in our homes. Windows provide light, ventilation, fire escape, and a view. Yet they create a weak link in your home's thermal boundary, because they can't be insulated as well as the walls in which they are installed. Windows also allow some air leakage into your home.

Fortunately, you can have plenty of windows and still have an efficient home. You just need to choose the right types and install them properly. And your existing windows may be better than you think. Window replacement is not the only answer to window inefficiency.

In this chapter, we show you how to evaluate the energy performance of your existing windows and decide whether to improve them or replace them. If you choose to replace them, we show how to decide which windows are best for your home. We also include important installation details to assure that your new windows perform as well as possible.

At the end of the chapter we show how to weatherstrip doors to slow air leakage, and how to choose doors for replacement.

EVALUATE YOUR WINDOWS AND DOORS

Do you have at least two panes of glass on all your windows? Windows are always the weakest point in your home's thermal boundary. If you have single-pane windows, you can cut your window energy loss in half by installing either storm windows or insulated double-pane glass.

Are your windows watertight at the exterior? The cost of window replacement is often difficult to justify based solely upon energy savings. But if they are in such poor condition that water leaks into your home, replacement or repair should be a top priority in order to protect your home from water damage.

Do have you heavy blinds or drapes that can be drawn in cold weather? Insulated window coverings can cut the heat loss through your windows by half or more. Light curtains, mini-blinds, and roller shades are less effective.

Do you have some way to keep the sun off your windows in summer? If your home overheats during hot weather, you can trim the cost of air-conditioning substantially by shading your windows with curtains, roller shades, awnings, or trees.

Do your doors allow drafts into your home? You may be able to slow air leakage by simply installing high-quality weatherstripping. If you choose to replace an existing door, you should upgrade to an insulated unit. If you have a sliding glass door, consider replacing it with a hinged unit that has insulated glass.

Do you plan to replace the siding on your home in the near future? The cost of installing windows will be less if you are already replacing the siding on your home. You'll also have the opportunity to perform an integrated super-insulation retrofit that includes additional insulation under your siding.

WINDOW BASICS

The average home has twenty to thirty windows, totaling some 12 to 25 percent of the wall area. Since even the most advanced windows have an R-value of between R-3 and R-6, windows are by far the weakest link in your home's thermal boundary. It is for this reason that window improvement is so worthwhile.

During winter, windows probably account for 15 to 40 percent of the heat loss from your home. In summer, windows allow the sun to overheat your home, and can be responsible for up to 75 percent of the heat gain on hot days. Efficient windows can slow this heat flow and reduce your heating and cooling costs.

Window Terminology

You'll find it helpful to understand the terminology as you do research and make decisions about your home's windows:

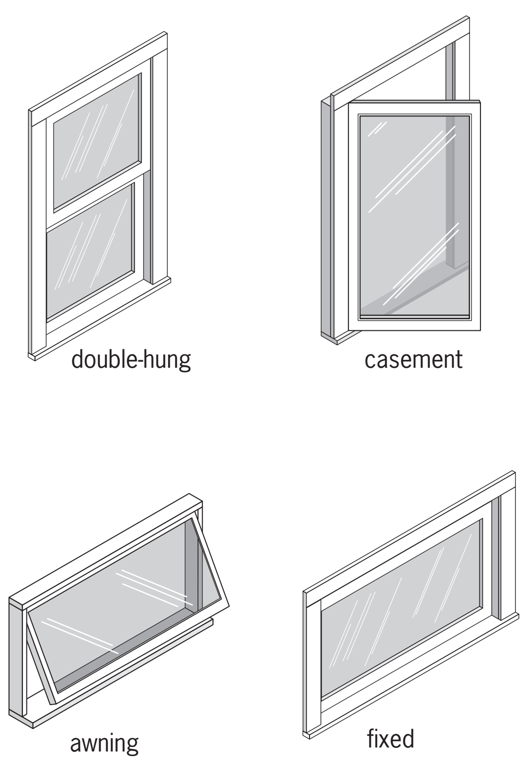
- Glass assembly—One or more glass panes with spacers and/or gaskets.
- Sash—Frames the glass assembly. Sashes are often openable for ventilation and fire escape. Sashes can also be fixed so they don't open.
- Frame—Surrounds the sash and attaches to the building.
- Rough opening—Structural framing of the building to which the window frame is attached.
- Sill—Lowermost horizontal surface at the base of the window.
- Jamb—Trim that wraps the sides and top of the window.

Types of Window Operation

Double-hung windows are the oldest window design still in use. They include two sashes that slide vertically past one another. Single-hung windows are similar, with a fixed sash at the top. Horizontal sliders usually include one sliding sash and one fixed sash. Hinged windows include casements, which are hinged on the side, and awning windows which are hinged on the top. Casement windows tend to have the lowest infiltration rates of all opening windows because their hinged swing compresses the weatherstrip most effectively when closed. They also have an advantage in hot climates because they tend to direct breezes into the home when open.

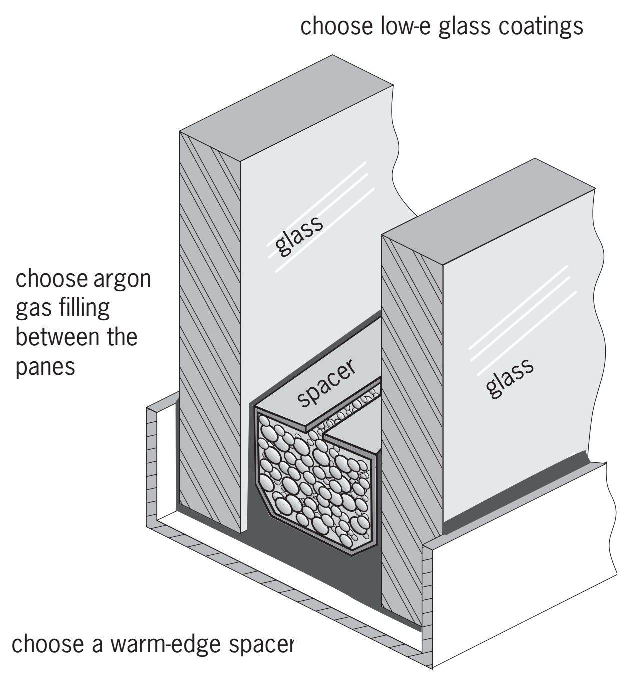
Fixed windows don't open. Though you wouldn't want them throughout your home, they do have the advantage of lower cost (no mechanism needed) and low infiltration rates (they are permanently sealed).

Types of Window Operation



The operation of windows varies by having either fixed or moveable sashes, and by the location of hinges.

Insulated Glass Unit



Insulated glass units create a dead-air space between the panes. The efficiency of insulated glass units varies widely depending on the features included.

10 Heating Systems

The cost of heating is the biggest single utility expense for many families. Heating your home has a large environmental impact, too. If you heat with natural gas, propane, or oil, your chimney probably emits 10,000 to 20,000 pounds of carbon dioxide, in addition to other pollutants, each year. Most homeowners can trim this by 10 to 50 percent through a combination of maintenance, repairs, and upgrades.

If you heat with electricity, your emissions are probably two to three times greater than they would be with gas or oil. Even though electric heat releases no emissions at the point of use, the electricity you use is most likely linked to the operation of a very inefficient power plant in a distant location.

Most single-family homes in North America are heated by central combustion heating systems that burn natural gas, propane, or oil. Most of these central systems are furnaces that distribute heat through ductwork that connects to rooms within the home. Combustion space heaters, on the other hand, are installed directly in the room and have no ductwork. Boilers that distribute heat by way of circulating water and other fluids are common in some regions. A few homes are heated by electric resistance heaters, including both furnaces and room heaters, which are also covered here.

The remaining common heating system is the electric heat pump. See "Cooling System Basics" on page 117 for information on heat pumps, since a heat pump is essentially a reversible air conditioner.

You can trim your use of energy for heating in two principle ways. The first is to improve the shell of your home so it loses less heat during cold weather. You can do this by performing air-sealing tasks or by improving your home's insulation. See "Air Leakage Basics" on page 71, and *Insulation Basics* on page 81. The second way to trim heating consumption is by upgrading the efficiency of your heating equipment itself, or by improving the delivery system, such as the ducts. Both equipment and ducts are covered in this chapter. We also describe the basic principles and common designs of heating equipment here, as well as the most important details for new installations.

EVALUATE YOUR HEATING SYSTEM

Have you had your heating system serviced recently? You should have a professional heating technician perform periodic maintenance on your heating system to assure that it operates safely and at peak efficiency. You may also want to learn how to perform the simplest maintenance tasks yourself.

Do you ever notice peculiar odors near your water heater or heating system? If so, you should investigate this right away since these systems can sometimes spill dangerous combustion gases into the home.

If you have a furnace, what is the condition of its ductwork? Energy loss in your ductwork may account for up to 40 percent of your heating expense, especially if it runs through an attic or crawl space. This can be reduced by sealing and insulating your duct system.

Do you have plans to do any major remodel work on your home? If so, you'll have an opportunity to improve the shell of your home. If you first install more insulation, seal air leaks, and improve your doors and windows, you'll be able to install a smaller and more efficient heating system.

How old is your heating system? What is its efficiency? Older furnaces and boilers operate at 60 to 70 percent efficiency, with the remaining 30 to 40 percent of the energy you purchase going up the chimney. If your home is heated by one of these systems, you can reduce your consumption substantially by upgrading to a system that operates at 90 percent efficiency or higher.

HEATING SYSTEM BASICS

In both gas and oil heaters, burners mix and burn fuel in combustion chambers. The heat exchanger surrounds the combustion chamber, and transfers heat from the flame and combustion gases to a heating fluid such as air, water, or steam. Combustion gases leave the combustion chamber and enter a chimney. Chimneys are made of metal, masonry, or other noncombustible material.

The efficiency of a combustion heater depends on the losses of heat up the chimney, losses at the beginning and end of each burn cycle, and losses through the cabinet of the heater itself. The sum of these losses is reflected in the annual fuel utilization efficiency (AFUE), a description of the percentage of available heat actually delivered to the distribution system. The AFUE is always included on the yellow Energy Guide label which is included by law on all new heating equipment.

When comparing the AFUE ratings of heating equipment, higher is better. Older open-combustion heating equipment has an AFUE of 55 to 75 percent. The best modern sealed-combustion heating equipment, which we recommend for all replacements, can achieve an AFUE of 90 to 95 percent. If you replace an older AFUE 60 furnace with a new AFUE 90 furnace, it will reduce your fuel consumption by one-third.

Combustion Safety

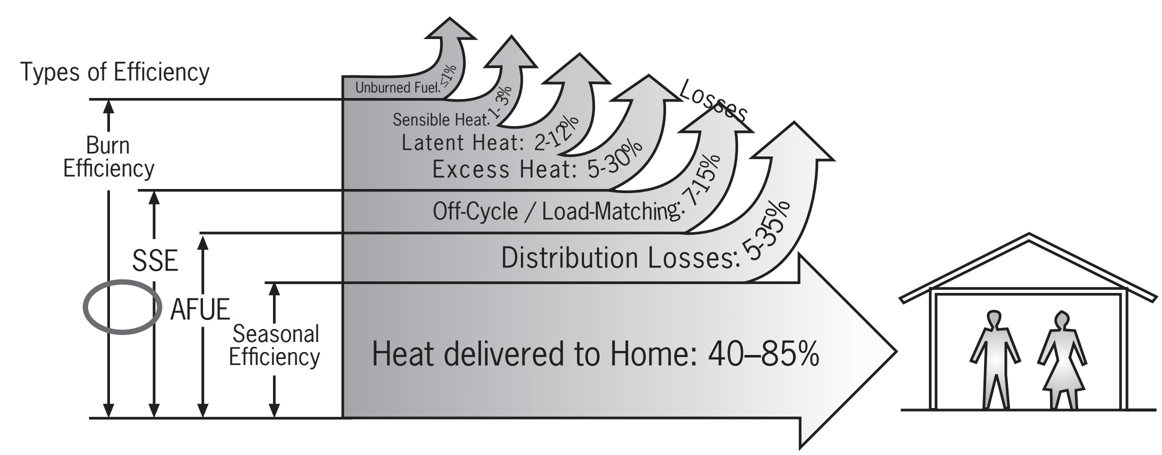
Combustion fuels are primarily hydrocarbons—molecules composed of hydrogen and carbon. The process of combustion, or burning, is simply rapid oxidation: oxygen combines with the carbon and hydrogen, splitting the hydrocarbon molecule. Carbon dioxide (CO_2) and water vapor are the main products of this heat-liberating chemical reaction. Carbon monoxide (CO), a poisonous gas produced by incomplete combustion, can also be produced if the equipment isn't operating properly.

If your home has combustion heating equipment such as a furnace, boiler, or water heater, you'll want to know that the chimney system operates effectively to carry these flue gases out of your home. When you next have a technician perform service of your heating equipment, ask them to confirm that the chimney systems for all your combustion appliances are functioning properly.

You should also perform an occasional personal inspection of your heating equipment. There should be no signs of soot or scorching, and you shouldn't notice any odd odors. Call your service technician or power company if you have any concerns.

Gas kitchen stoves present a unique air quality problem since they don't usually have chimneys, and so release all their combustion by-products into the kitchen. The best solution to this low-level pollution is

What's Included in AFUE and Other Types of Efficiency

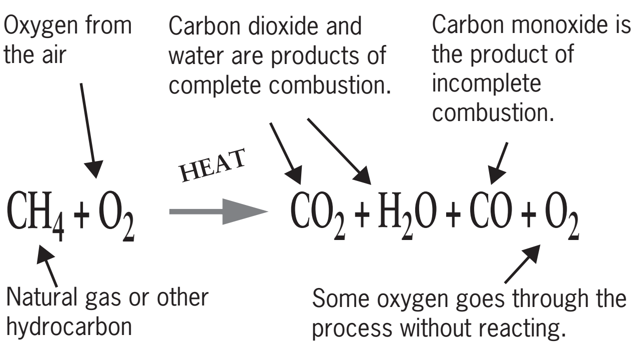


Some of the heat contained in the fuel you purchase never reaches your living space as useful heat. The annual fuel utilization efficiency (AFUE) listed on the yellow Energy Guide label accounts for combustion efficiency, cycling losses, and jacket losses. Distribution losses, which are not included on the Energy Guide, include duct leakage.

to always operate a kitchen fan when using a gas stove. In this case, it's critically important that the kitchen fan is ducted to the outdoors. Many range hoods only filter kitchen air to remove grease, and then return it to the room. This doesn't do anything to control carbon monoxide or other gaseous pollutants.

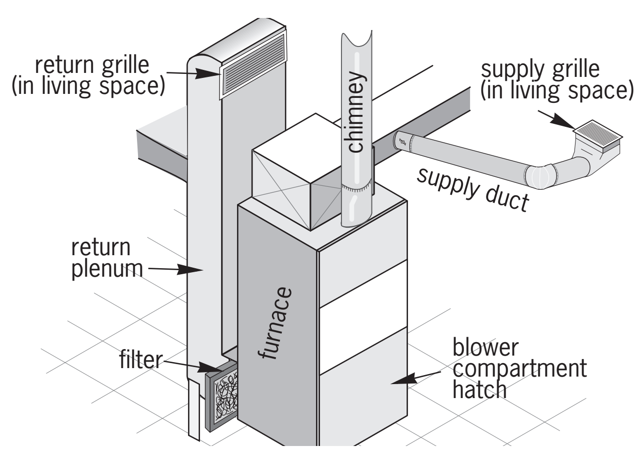
Finally, one of the best defenses against carbon monoxide and other combustion by-products is to install a carbon monoxide detector ($30 or less) on each level of your home. Be sure to replace the batteries periodically.

Combustion: The Chemical Reaction



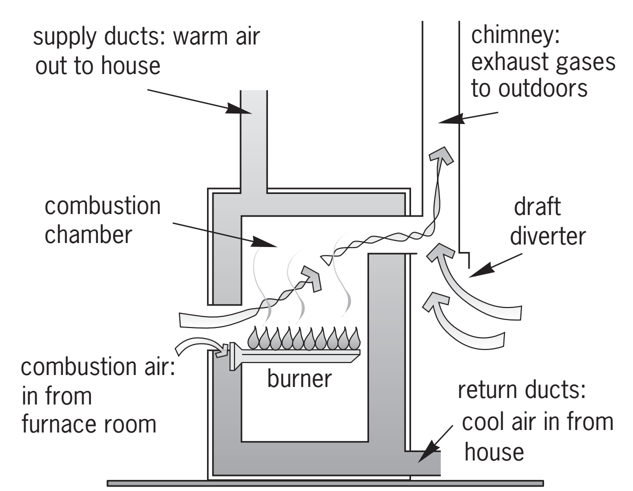
Combustion is a chemical reaction that utilizes a hydrocarbon and oxygen to produce heat. It releases carbon dioxide (a potent greenhouse gas), water, and other by-products. A properly cleaned and tuned combustion appliance will produce very little or no carbon monoxide.

Components of Conventional Furnaces



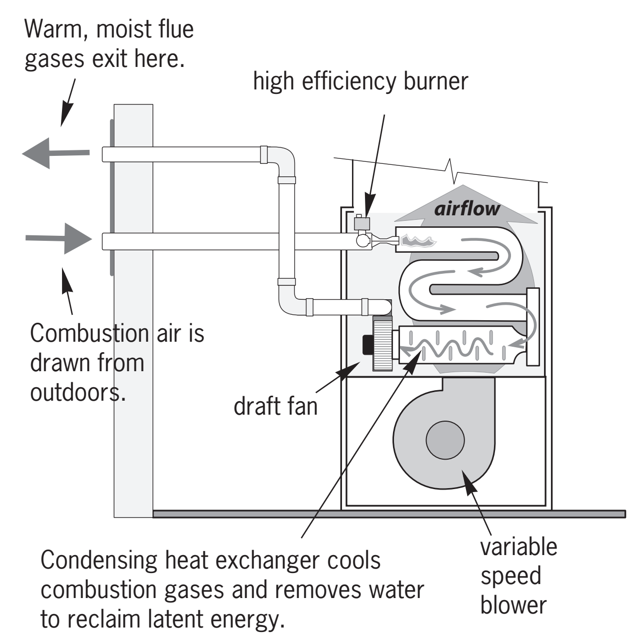
This type of conventional open-combustion furnace is found in many older homes. If it is replaced with high-efficiency equipment, the original ductwork can often be retained if it's properly sized and in good condition.

Open-Combustion Furnace (< 75 AFUE)



Most older open-combustion appliances rely on the buoyancy of the combustion gases and the flame's heat to exhaust combustion by-products from the home.

Sealed Combustion Furnace (90%+ AFUE)



Sealed combustion furnaces use electric draft fans to move combustion gases safely out of the home. The combination of features shown here raises the efficiency of modern furnaces and improves their safety.

INTERNET KEYWORD SEARCHES

The Internet offers an unlimited amount of information on the topics covered in this book. We've included some keywords here to help you find what you're looking for a quickly as possible.

For tips on conducting effective Internet searches, visit *www.google.com/help/basics.html*

Chapter 1: - Developing a Plan for Your Home
- Home Performance with Energy Star
- home performance contractor
- online energy audit
- home energy rater
- energy auditor

Chapter 2: - Lighting and Appliances
- efficient lighting
- energy star lighting
- energy star appliance
- energy star refrigerator

Chapter 3: - Water Heating
- energy star water heating
- energy factor
- on-demand water heater
- solar water heating
- solar energy international

Chapter 4: - Heating and Cooling: First Steps
- cool roof coatings
- whole-house fan
- programmable thermostat
- high efficiency furnace
- high efficiency air conditioner

Chapter 5: - Landscaping
- arborist
- energy star landscaping
- landscaping water conservation
- shade trees
- xeriscaping

Chapter 6: - Finding and Sealing Air Leaks
- energy star air sealing
- blower door test
- air sealing
- one-part foam insulation
- spray foam kit

Chapter 7: - Insulation
- where to insulate
- attic insulation
- energy star insulation
- heat loss calculation
- wall insulation

Chapter 8: - Windows and Doors
- energy star windows
- energy star doors
- sliding glass door hardware
- installation masters

Chapter 9: - Cooling Systems
- energy star cooling
- evaporative cooler
- evaporative cooler parts
- air conditioning efficiency

Chapter 10: - Heating Systems
- energy star heating
- high-efficiency heating equipment
- hydronic heating
- NATE service technician

Chapter 11: - Photovoltaic Systems
- solar energy international
- pvwatts calculator
- solar panels
- grid tied pv systems
- net metering

Chapter 12: - Moisture Management and Ventilation
- energy star ventilation
- ground moisture barrier
- polyethylene vapor barrier
- exhaust ventilation
- heat recovery ventilator

Chapter 13: - Building a New Home
- energy star new homes
- home energy rating
- energy efficient building
- green building materials
- sustainable building