The Homeowner's Handbook to

ENERGY EFFICIENCY

JOHN KRIGGER
CHRIS DORSI

A Guide to

BIG AND SMALL IMPROVEMENTS

Please work safely when following the procedures outlined in this book. If you cannot safely complete any of the procedures suggested in this book, hire a professional to do the job, or skip the procedure altogether. Your failure to heed this warning could result in injury, death, or damage to your home. Please perform only those tasks for which you are willing to assume responsibility.

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The Homeowner's Handbook to ENERGY EFFICIENCY

A Guide to BIG AND SMALL IMPROVEMENTS

John Krigger
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SATURN
RESOURCE MANAGEMENT

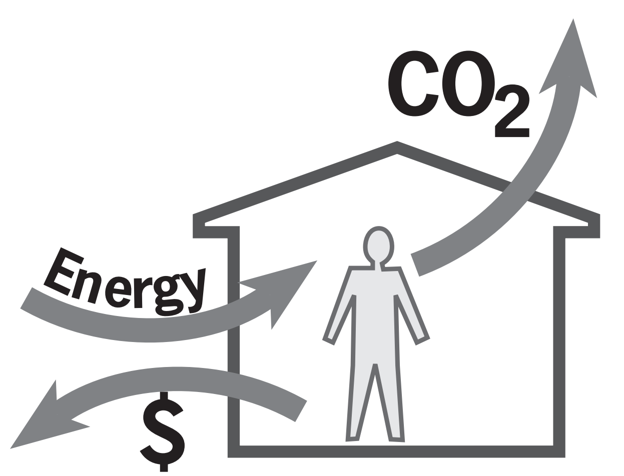
Contents

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.

DEVELOPING A PLAN

The first step in crafting a home improvement plan is to decide how to improve your home. The characteristics of efficient homes vary from one region to another, depending on climate, the type of construction, the kinds of fuel that are available, and many other factors. But the best homes share these common traits:

- They have building shells that are airtight and extremely well insulated.
- They have small heating and cooling systems.
- Their windows are oriented to collect solar heat in winter and reject it in summer.
- They have appliances and lighting that are the most energy efficient available.
- They may use solar power to generate electricity (photovoltaic systems), or to produce hot water (solar thermal systems).

Your existing home may already include some of these traits. As you work your way through this book, you'll gain an idea of how your home compares to the ideal home. But don't be discouraged by your home's shortcomings. The best time to start any investment program—whether opening a savings account or starting home efficiency projects—is right now. There are plenty of small projects in this book that you can accomplish right away.

BIG VERSUS SMALL IMPROVEMENTS

As you review the projects in this book, you'll see that they cover a large range of cost and complexity. You could probably save a hundred dollars a year, for example, by installing compact fluorescent light bulbs in your home this weekend. But you could benefit from even more impressive savings by stripping the siding off your home, applying two inches of foam insulation, and installing new siding, windows, and doors. Though this big project would require advance planning and an investment of tens of thousands of dollars, it could be an equally wise investment in your future, especially considering both the improvement to your comfort and the economic benefits. We take this view of these large projects: the current energy crunch will likely become permanent, and home improvements of this magnitude will be needed to bring our existing housing stock up to modern standards.

We suggest that you get started on some small energy improvement projects right away. At the end of this chapter we've outlined ten of the simplest ways to save energy without spending too much money. But do not neglect the big projects. We've found that these major undertakings produce the best package of overall benefits when you consider reduced utility expenses, lowered carbon emissions, improvement in comfort, and increase in home resale value. These biggest and most important projects usually include improvements to your home's shell—the walls, ceiling, floors, doors and windows. These major projects are worth the effort because most heating and cooling energy waste occurs through these areas.

Moreover, neglecting shell issues because they are too difficult will likely make other efforts less productive. It often doesn't make sense to replace your heating or cooling system, for example, without making major improvements in the building shell. That's because improvements in the shell will result in the need for far less heating and cooling capacity. Once you've made shell improvements, your new heating and cooling system can be smaller, and so will be less expensive to purchase, install, and operate. Over the lifespan of your home, reduced utility costs could easily pay for the upgrades you performed to the building shell.

HOW TO USE THIS BOOK

We recommend that you develop a written energy upgrade plan for your home. This can be as simple or complex as you'd like, but it will be worth the effort to gather your ideas on paper.

- Take time to review this book. You could read it all at once or just a chapter at a time, but you'll want to return to it occasionally when you start a specific project.
- When you read about a project that could be relevant to your home, make an entry in your written plan.

2 Lighting and Appliances

Lighting, appliances, and water heating—the types of consumption we call baseload—account for up to two-thirds of the energy consumed in North American households. If you've analyzed your utility bills as described in *Analyzing Your Utility Bill* on page 8, you've estimated how much of your utility bill goes to baseload uses and how much goes to heating and cooling. This will show you how much you can potentially save by improving the efficiency of your baseload uses.

The size of your baseload varies depending on your climate, your home, and your habits. If you live in a very hot or very cold climate, for example, your total utility costs will be relatively high, with your baseload accounting for a smaller portion of those bills. If you live where both winters and summers are mild, or if your home has an efficient building shell with good insulation and air-sealing details, your total utility costs may be low, but your baseload will account for a larger portion of your bill.

In this chapter, we'll show you some easy ways to improve the efficiency of your existing lighting and appliances. In many cases, you can make improvements that save energy right away. We'll also consider upgrades to your lighting system and replacement strategies for your appliances. We dedicate all of Chapter 3 to water heating since it is the most complicated of the baseload uses.

Let ENERGY STAR® Be Your Guide

CHANGE FOR THE BETTER WITH ENERGY STAR

The ENERGY STAR® label has emerged as one of the best ways to identify the most energy-efficient appliances available in both the U.S. and Canada.

EVALUATE YOUR LIGHTING AND APPLIANCES

How many of your light fixtures are fitted with old-fashioned incandescent light bulbs? Replacing incandescents with compact fluorescent lamps usually has a payback of less than two years. This is one of the best investments described in this book.

What is the wattage of the lamps installed in your fixtures? If you have fixtures that provide more light than you need, you can easily install smaller lamps and save energy. This is especially true of lights that are left on all night, such as nightlights and outdoor fixtures.

Do you have light fixtures installed over work areas that can be used instead of overhead fixtures? Task lighting that is installed close to your work provides illumination more efficiently than ceiling fixtures. Try using task lighting without turning on overhead fixtures to get the maximum benefit.

Do you have light fixtures that tend to be left on when they are not needed? The easiest solution is to turn the lights off when you don't need them. But lighting controls such as motion detectors and timers can also reduce this consumption.

How old is your refrigerator? Does it have an ENERGY STAR rating? Recent technological advances have made new refrigerators and freezers two to three times more efficient than older models.

Does your clothes washer have an ENERGY STAR rating? Newer front-loading washing machines use less hot water, cold water, electricity, and soap.

Do you use a clothesline or drying rack? You can reduce your drying cost to zero with this simple and effective approach.

If you have a dishwasher, does it have an ENERGY STAR rating? Dishwashers use cold water, hot water, and electricity. The best new machines allow you to trim consumption by giving you control over cycle length, water consumption, and drying cycle.

If you have groups of appliances at a desk or entertainment center, can you put them all on a control strip? Most of these appliances consume electricity even when they aren't in use. Control strips let you shut them off.

LIGHTING BASICS

The first step toward improving your lighting efficiency is to learn how to compare various types of lamps. In lighting terminology, a lamp is the tube or bulb that emits light. A fixture holds the lamps or bulbs. The output of those lamps is measured in lumens, which we perceive as brightness.

Lighting efficiency is described by the term "efficacy" (pronounced EFF-u-ke-see). Efficacy is the measure of lumens emitted per watt of electricity consumed. A higher efficacy is better.

- A 100-watt incandescent lamp that emits 1200 lumens of light has an efficacy of 12.

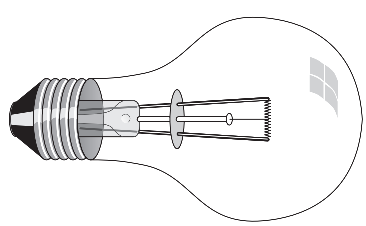
$$1200 \div 100 = 12$$

- A comparable 28-watt compact fluorescent lamp that emits 1200 lumens has an efficacy of 43.

$$1200 \div 28 = 43$$

The compact fluorescent lamp has an efficacy more than three times higher than the incandescent, and so uses less than one-third the electricity while emitting the same amount of light. When shopping for lamps, choose those with the highest efficacy possible to save energy.

Incandescent Light Bulb



Incandescent light is produced by a white-hot coil of tungsten wire that glows when heated by electrical current. Of all the electricity these lamps consume, 90 percent goes to producing heat, and only 10 percent to producing light!

TYPES OF LIGHTING

To craft a plan for improving your lighting efficiency, first inspect your light fixtures to see what sort of lamps you currently have installed. Your lighting upgrades will likely focus on lamp replacement, though replacing fixtures is also a good upgrade.

Standard Incandescent Lamps

Incandescent light bulbs are the oldest style of lamp. They are also the least efficient, and so are increasingly prohibited by both building codes and government bodies. Standard incandescent lamps have efficacies of 10 to 17 lumens per watt. Incandescent lamps have the shortest service life of the common lighting types, lasting only 750 to 2000 hours. They are the cheapest of the lamps at less than $1 for most types. But they are a poor value because of their short life and poor performance.

Halogen Lamps

Halogen lamps are a specialized type of incandescent bulb. They are filled with halogen gas that allows them to burn hotter and somewhat more efficiently. But they still run at an efficacy that is scarcely higher than standard incandescent lamps.

Halogens lamps produce a whiter light than is emitted by standard incandescents. They are always installed in dedicated fixtures, and are mounted under cabinets, as wall sconces, and as ceiling fixtures.

Halogens have an efficacy of 12 to 22 lumens per watt, and their lifespan varies from 2000 to 4000 hours.

Comparison Among Types of Lamps

Type of Lamp	Efficiency (lumens/watt)	Typical lifespan (hours)
Incandescent	10–17	750–2500
Halogen	12–22	2000–4000
Fluorescent tube lamp	30–100	7000–24,000
Compact fluorescent lamp (CFL)	50–70	8000-10,000

Fluorescent Tube Lamps

Fluorescent tube lamps are among the most efficient lamps available, with efficacies that run as high as 100 lumens per watt. They are often installed in kitchens, laundry rooms, and other utility areas. Fluorescent lamps have a service life of 7000 to 24,000 hours.

The quality of fluorescent tube lights has dramatically improved in recent years. Early fluorescent lamps cast a blue pall over a room, and were prone to flicker and hum. Modern fluorescents are quiet, and are available in models that produce natural colors of light.

Older tube fluorescents were known by the designation T-12 ($^{12}/_{8}$ or 1-$^{1}/_{2}$" in diameter). The most efficient new fluorescent lamps are slim T-8 tubes (1 inch). They fit in standard fixtures, and are 10 to 15 percent more efficient than the old T-12s.

Many new T-8 fixtures are equipped with high-efficiency electronic ballasts, which increase the fixture's efficiency by 30 to 40 percent compared with the older fixtures. These efficient T-8 fixtures provide a great replacement option for the inefficient multi-bulb fixtures found above many bathroom mirrors. Fluorescent fixtures also work well for indirect lighting when installed in a wall-mounted valance, which bounces light off the ceiling. Four-tube ceiling-mounted fixtures are a common choice in kitchens, where they produce handsome savings in this most frequently used location.

Fluorescent tube fixtures vary in price from $100 to $200. In most cases, installation will take about an hour if wiring is already in place.

Compact Fluorescent Lamps

Compact fluorescent lamps (CFLs) range in efficacy from 50 to 70 lumens per watt. They consume only one-quarter to one-third the energy of incandescent lamps. They are somewhat less efficient than fluorescent tube lamps, but can be fitted into standard light fixtures.

CFLs have a service life of up to 10,000 hours. However, some cheaper CFLs have a poor service record and may fail after only a few thousand hours. We suggest purchasing CFLs only from the major manufacturers. Good quality CFL lamps cost $2 to $5 each.

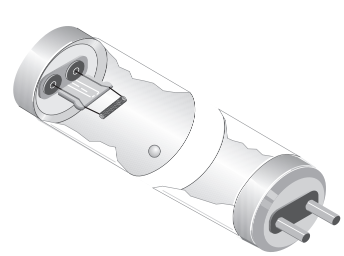
The most common CFLs have threaded bases that allow you to retrofit them to existing fixtures. Most homes have many incandescent lamps that can be easily upgraded to CFLs.

Install CFLs in light fixtures that you use the most. Start by replacing incandescent lights that are on four hours a day or more, such as those in your kitchen, bathrooms, and living room.

If you plan to replace an entire light fixture, or are choosing fixtures for a new home, select fixtures that are designed for CFLs. CFL fixtures have plug-in replaceable CFL bulbs rather than screw-in bases. They include improved reflectors that distribute light more efficiently, and they come in a wide range of designs. Many energy codes require dedicated fluorescent fixtures in high-use areas such as kitchens.

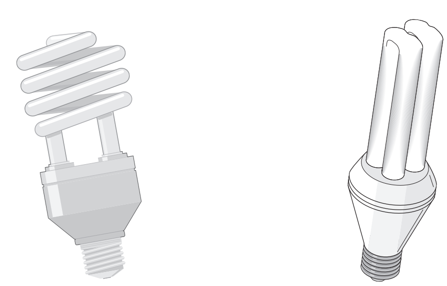
Dedicated CFL fixtures cost $50 to $125. Installation will take about an hour if wiring is already in place.

Fluorescent Lamp Operation



Fluorescent lamps emit light when the tube's phosphorescent coating is struck by ionized mercury gas. Manufacturers vary this coating to produce fluorescent lamps that emit various shades of light.

Compact Fluorescent Lamps



Replacing standard light bulbs with compact fluorescent lamps is one of the best energy-saving measures available.

3 Water Heating

Heating water is the largest baseload use in most households. In mild climates, such as California, many families spend as much or more on water heating as they do on heating or air-conditioning.

In this chapter, we describe how to reduce hot water consumption through both simple adjustments to behavior and improvements to your water-heating system. We also outline the current options for upgrading your equipment.

EVALUATE YOUR WATER-HEATING EFFICIENCY

What type of water heater do you have: a storage tank, a tankless or on-demand system, or a solar system? Traditional storage water heaters are the least efficient type of system, and so offer the best opportunities for improvement. Tankless on-demand systems are more efficient, and offer few opportunities for improvement. Solar water heating is the paradigm of efficiency.

If you have either a storage or tankless system, does it use electricity, gas, or oil? If you have electric water heat, your current high cost of water heating will improve the payback of your efficiency improvements. If you heat with gas or oil, your improvements will have a less favorable return.

What is the temperature of hot water at the taps in your home? If your water is delivered at more than 120°F, you can easily save money by adjusting your water heater thermostat downward.

What is the flow rate of the showers in your home? If your showers deliver more that 3 gallons per minute, you can save both water and the energy used to heat water by installing low-flow high-efficiency showerheads.

Are the lines between the water heater and your fixtures insulated? If your hot water lines are not insulated, you're wasting many gallons of water each day.

If you have a storage water heater, how many inches of built-in insulation does it have? If you have an older water heater with only an inch or two of insulation, you can save energy adding an external blanket.

Have you considered installing a solar water heater? Solar water heaters are not inexpensive, but in many climates they produce a good economic return.

WATER HEATING BASICS

Water heating systems present opportunities for effective conservation in three categories: demand, standby, and distribution. Trimming each category requires a different set of efficiency measures:

- **Demand** is the actual hot water used in your shower, washing machine, dishwasher, and other fixtures. You can reduce your demand by installing low-flow showerheads, upgrading appliances to models that use less hot water, or by simply adjusting your habits to use less hot water. When you conserve hot water, you save both water and the energy that would be used to heat the water.
- **Standby** loss includes the heat lost through the walls of your water heater tank. You can reduce standby loss by installing a water heater blanket, by installing a new water heater with better built-in insulation, or by insulating the water lines near your water heater tank.
- **Distribution** loss includes the heat lost through the sides of your hot water pipes when you are using hot water. You can reduce distribution loss by insulating your hot water pipes.

A vast majority of North American homes have storage water heaters that include an insulated tank and a gas burner or electric element. Recent improvements in storage water heaters include better tank insulation and improved combustion systems.

Tankless or on-demand systems include a large gas burner or electric heating element but no tank. These heat water only as you use it. They are more expensive to purchase than storage water heaters, but they use less energy since they don't incur the standby losses of storage systems.

Water can also be heated with solar systems that use no fuel for heating, though some systems consume a small amount of electricity for pumps and controls. These are the most expensive systems to install. The economic feasibility of solar water heating systems is greatest in warm climates.

ADJUSTING YOUR WATER-HEATING HABITS

The quickest way to reduce your water-heating expenses is by adjusting your habits. Some of these tips can make a surprising difference in consumption without causing much hardship.

- Use cold water whenever possible.
- Take shorter showers. Avoid running the shower for longer than necessary before you get in.

Typical Hot Water Consumption

Number of residents	Electric annual kWh	Gas annual therms	Gallons per day
1	2700	180	25
2	3500	230	40
3	4900	320	50
4	5400	350	65
5	6300	410	75
6	7000	750	85

For single-family homes in the United States. Compiled from the Energy Information Administration, Lawrence Berkeley Laboratory, and others.

- Run your washing machine with full loads. If you must do a small load of wash, adjust the machine's water level to match the load size. Don't use the hot water setting on your washing machine. Modern detergents work perfectly well in warm or cold water, and your clothes will last longer.
- Run your dishwasher with full loads. Set it to Air Dry to save additional electricity. Avoid pre-washing dishes when loading your dishwasher.

SIMPLE IMPROVEMENTS

You can also make some inexpensive improvements to your water heating system that will produce a handsome payback. Taken together with the above changes in habits, these improvements can help most households save a third or more of their water-heating costs.

Lowering Your Hot-Water Temperature

One of the most effective conservation measures for water-heating is to reduce the temperature of water in your storage tank. That's because many storage water heaters are set to keep water at 140°F or more, causing more heat to conduct through the walls of the tank than would occur at lower temperatures. High water temperatures also encourage scale and corrosion to form inside the tank, shortening its lifespan. And extremely hot water increases the risk of someone getting scalded.

We recommend that you reduce your hot water temperature to about 120°F. Avoid adjusting your thermostat lower than this, since harmful water-borne microbes can thrive at cooler temperatures.

Follow this procedure to adjust the temperature of gas water heaters:

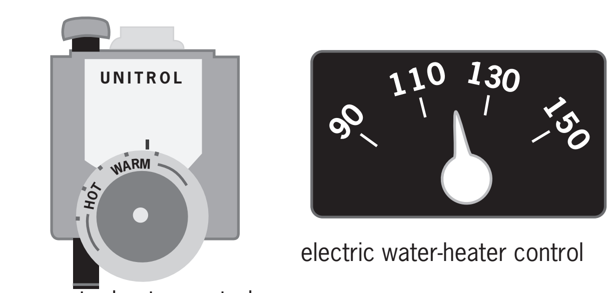
- Measure the hot water temperature at the tap that is farthest from the water heater. The goal is to get this water to approximately 120°F.
- Find the thermostat on the water heater—it is usually a round knob near the bottom of the tank.
- Turn the thermostat a small amount toward the correct temperature.
- Wait a few hours for the water in the tank to stabilize. Use your thermometer to again measure the water temperature at the faucet.

- Readjust the thermostat as needed.
- When you find the setting that corresponds to 120°F, mark that setting on the thermostat with a permanent marker.

Follow this procedure to adjust the temperature of electric water heaters:

- Measure the hot water temperature at the tap that is farthest from the water heater. The goal is to adjust this water temperature to approximately 120°F.
- Turn the power to the water heater off at your home's electrical panel.
- Use a screwdriver to open the two access panels on the front of the water heater tank. You'll find a separate thermostat under each panel.
- Use a small screwdriver to adjust both thermostats a small amount towards the correct temperatures.
- Wait a few hours for the water in the tank to stabilize. Use your thermometer to again measure the water temperature at the faucet.
- Readjust the thermostats as needed.
- When you find the setting that corresponds to 120°F, mark those settings on the thermostats with a permanent marker.

Adjusting Your Water Heater Temperature



electric water-heater control

gas water-heater control

Most gas water heaters don't state actual water temperatures on their thermostats—they show just Low and High, or similar descriptions instead. Electric water heaters sometimes show actual temperatures, but they aren't very accurate. It's best to measure water temperature with a thermometer at the faucet.

You can also collect some additional savings by turning your water heater down to a lower temperature if you'll be away from home for more than a few days. Adjust it to the "Vacation" setting if your water heater has one. Or simply turn the thermostat to a lower temperature, and when you return adjust it back to the mark you've made on the dial.

Evaluating Your Showerheads

Showering is typically the biggest hot-water use in the home, and so should be one of the first places you turn to reduce your consumption.

Modern low-flow showerheads must by law deliver less than 2.5 gallons per minute (GPM). Most can do this while still producing a satisfying shower—a design advance that includes controlling the size of the droplets and mixing air into the water. With these new showerheads, you'll never know you're saving energy and water.

The savings can be substantial. With an old shower head that uses 5 GPM, a family of four that each takes a daily six-minute shower will use about 43,000 gallons of hot water per year! Low-flow showerheads will cut that use in half, saving up to a few hundred dollars per year.

It is worth installing a new showerhead if your existing one uses more than 3 GPM. Follow this procedure to determine the flow rate of your existing showerhead:

- Find a one-gallon plastic milk jug, and cut a hole in the top so it will fit over the showerhead. Or use any vessel that can hold a gallon.
- Hold the jug over the showerhead, note the second hand on your watch, and start the shower.
- If the jug fills in less than 20 seconds, your flow rate is more than 3 GPM, and you could significantly reduce consumption by installing a new showerhead.

You'll have a lot of choices when shopping for showerheads, though most of the features don't decrease consumption. One energy-saving feature, though, is the addition of a small valve on the side of the showerhead that allows you to adjust the flow of

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.

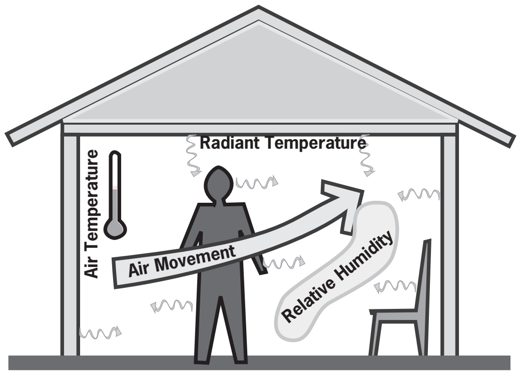
Have you had your heating and/or cooling systems serviced recently? Poor maintenance can cause substantial deterioration in the efficiency of this equipment.

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

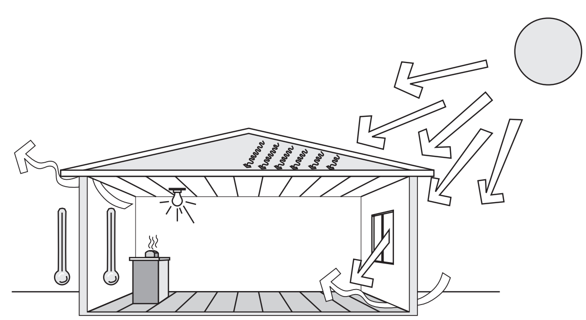
Your home's radiant temperature is almost as important as its air temperature. Radiant temperature is the temperature of all the objects in the room: the ceilings, floors, and walls are of primary importance, though the temperature of the furniture and everything else in the room does have some effect. 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



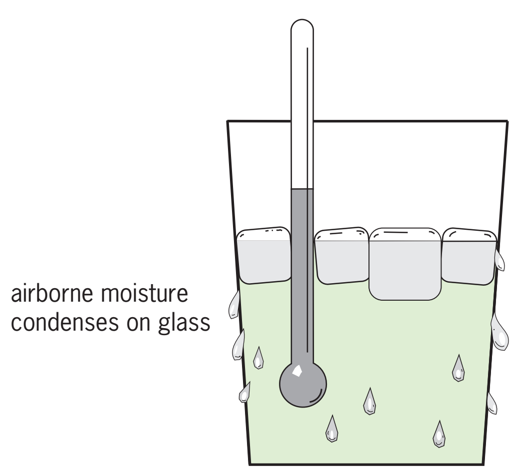
Solar energy heats your home by shining on the roof, entering through the windows, and heating outdoor air that travels into the home through air leaks. Internal gains, such as appliances and lighting, also release heat into your home.

Air Movement

In winter you perceive moving air in your home as a cold draft. If your home is drafty, you will likely raise your thermostat in response, requiring your heating system to run more often to keep you comfortable. In a drafty home, you may need to set your heating thermostat at 72°F. If you can control drafts inside your home, you may be just as comfortable at 68°F. This can make a huge difference in your heating bills.

In summer, moving air is your friend. If you seal up your home and run an air conditioner, you may not feel comfortable until the temperature is lowered to 78°F. Yet if you run a simple table fan at the same time, the cooling breeze may allow you to raise your cooling thermostat to 82°F with no notable reduction in your comfort. If you live where it is dry and not excessively hot, you could take it one step further: shut off the air conditioner, open your windows to take advantage of an outdoor breeze, and be comfortable at 86°F. It's all a matter of adjusting your environment to create acceptable comfort. Most importantly, moving air can help you save money by reducing your reliance on air conditioning.

Defining Dewpoint



Dew point is the temperature at which condensation occurs. In wet climates, the dewpoint will be at a higher temperature than in dry climates.

Relative Humidity

Relative humidity (RH) affects your comfort because it changes the rate at which moisture evaporates from your skin. Your sweat will evaporate more quickly in dry weather, and that's why 90°F is a more comfortable temperature in Tucson than it is in New Orleans. Whenever water evaporates, whether from your skin or from the surface of a lake, it absorbs heat and cools the area where the evaporation occurred. This cooling by evaporation is an important physical factor in human comfort.

Relative humidity describes the amount of moisture in the air. It is measured as a percentage: air at 100 percent relative humidity is saturated and can hold no more water vapor.

Dew point, sometimes included in summer weather reports, is the temperature at which the relative humidity is 100 percent and condensation begins to form. On a typical summer day in New Orleans, the temperature may be 90°F and the relative humidity 75 percent, but as the temperature of the air drops, it cannot hold as much moisture. Given these conditions (90°F and 75 percent RH), the air will reach dew point, or 100 percent relative humidity, at about 81°F. At this point, moisture will begin to form on outdoor surfaces. And sweating loses some of its cooling effectiveness because it evaporates slowly off your skin. But in Tucson, air at 90°F might be at 20 percent relative humidity. Given these conditions, the dew point would not occur until the air cooled to about 43°F. Sweating is a very effective cooling mechanism in dry climates.

Most people feel comfortable at relative humidity between 40 percent and 80 percent. At less than 40 percent, the air feels dry and full of static. Above 80 percent, the air feels clammy to most people, though we all have different perceptions of comfort.

Relative humidity does not play a large part in heating strategy except in cold climates, where we try to keep humidity low enough to avoid excessive condensation on windows and other cold surfaces. But this type of moisture management is important for occupant health and building preservation, and therefore covered in *Moisture Management and Ventilation* on page 153.

5 Landscaping

Landscaping should be included in your long-term plan for reducing heating and cooling costs. If your home is presently subject to glaring summer sun or blustery winter winds, you could see substantial savings from a well-crafted landscape.

Your plantings can also improve your privacy, reduce street noise, and control dust. Add these benefits to the beauty of mature landscaping, and it's no surprise that the presence of trees and shrubs can raise a home's resale value by 10 to 20 percent.

In this chapter, we illustrate the timeless principles of good landscape design. We show you how to choose trees and bushes that will thrive in your climate, and the best ways to plant them. We also include maintenance tips to assure that your plantings will increase in value over time.

EVALUATE YOUR LANDSCAPING

Do you have trees and shrubs already growing on your property? Are they evergreen or do they shed their leaves? What are their shapes? Your landscape plan will have to incorporate the existing plantings around your home.

Does your home overheat in summer? Are some rooms hotter than others? You may be able to reduce your heating costs by planting trees or shrubs so they shade the hottest parts of your home.

Is your home located in a region where it is hot and windy in summer? You may be able plant hedges that direct cooling breezes toward your home.

Is your home located in a region where it is cold and windy in winter? You may be able to plant a windbreak to shelter your home from cold winds.

Where is the sun's daily path over your home, and how does this path vary over the seasons? You may be able to design plantings that shelter your home from hot summer sun, while still allowing the welcome sun of winter to reach your home.

Does the ground slope away from your home or toward it? You should design your landscaping to protect your home's foundation from water.

LANDSCAPING BASICS

The benefits of landscaping are substantial and well-documented. Studies by the U.S. Department of Agriculture and Department of Energy illustrate how carefully positioned trees can reduce an average household's energy consumption by 20 to 25 percent, saving $300 to $400 each year.

Landscaping also has important positive environmental effects. Plants consume carbon dioxide and water through photosynthesis. This carbon is stored, or sequestered, in the plant itself and in the surrounding soils. Since carbon dioxide is a potent greenhouse gas that contributes to climate change, improving your landscaping also reduces your carbon footprint.

Summer Benefits

The shade cast by landscaping will typically reduce your home's summer air-conditioning costs by 15 to 50 percent. The savings may be up to 75 percent for small mobile homes. The savings are the greatest in hot climates and for homes with little existing shade.

You may have noticed that parks and forests are always cooler than nearby city streets. This is because trees block sunlight before it can reach the ground, and their canopies of leaves release cooling water vapor through a process called evapotranspiration.

Several studies show that summer daytime air temperatures in neighborhoods with mature tree are 3° to 6°F lower than in newly developed areas with no trees, and that large urban parks are up to 7°F cooler than surrounding neighborhoods.

Planting trees may be ten times more cost-effective than building new electrical generating plants to meet summer cooling demands. A 1992 study by the Lawrence Berkeley Laboratory estimated that building new power plants to meet electrical peak loads (such as those caused by air conditioners running on summer afternoons) cost an average of 10 cents per kilowatt-hour. The study showed that decreasing peak-load consumption by planting trees cost only 1 cent per kilowatt-hour. The numbers may have doubled since then, but the 10-to-1 ratio is still accurate.

The effectiveness of landscaping in reducing the cost of cooling your home will depend on several factors:

- The temperature of your summer weather.
- The color and reflectivity of your roof and walls.
- The number and size of windows on the sunny sides of your home.
- The amount of insulation in your attic.

If your home is located in a hot part of the world, and has large south-facing windows and a dark-colored roof, you'll have the greatest need for summer shading. If you live in the North and you rarely need air-conditioning, the shade cast by your plantings will be less significant.

Summer Landscaping Design

Plant tall deciduous trees 5 to 15 feet away from the south-facing side of your home to block solar heat from high in the summer sky. Plant wide trees 10 to 30 feet away from the home's west side to block low-angle solar heat during hot summer afternoons.

Winter Benefits

Landscaping can also reduce your energy costs in cold weather. Landscaping that creates a windbreak can reduce your winter heating bills by up to one-third.

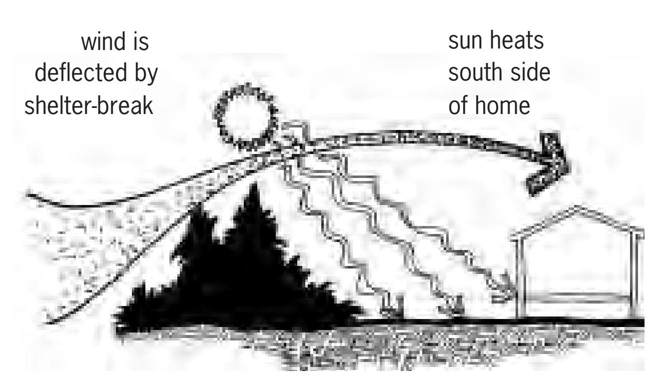
Moving air carries heat much more quickly than still air. Wind blowing on your home will cool its exterior surfaces, causing heat inside the home to conduct through the walls and other surfaces more quickly. Wind will also work its way through cracks and other openings in the home's shell, causing drafts and driving up heating costs.

Owners of rural homes have long recognized this principle when designing shelter breaks around their buildings. One study conducted in South Dakota found windbreaks to the north, west, and east of houses cut fuel consumption by an average of 40 percent. With a smaller windbreak on only the windward side, the houses still consumed 25 percent less fuel than similar unprotected homes. An Oklahoma study found that a tall evergreen hedge on the north side of a house reduced that household's fuel consumption by 10 percent during lighter winds and more than 30 percent during high winds.

The effectiveness of landscaping in reducing the cost of heating your home will depend on these factors:

- The coldness of your winter weather
- The draftiness of your home
- The windiness of your site

Winter Landscaping Design



Design your landscaping to create an energy-saving microclimate around your home. To get the full benefit of solar heating, design your landscaping to allow full access to winter sun.

If you live in a drafty home out in the open in the far north, for example, you'll receive the most wintertime benefit from landscaping. You will benefit less if your home is well-sealed, sheltered by structures or trees, and located in a warm winter climate.

In all cases, whether you landscape to improve your home's efficiency in winter or summer, your landscaping will add value to your home and reduce your carbon footprint. It's always a good idea to spend time and money improving your landscaping.

Recognizing Your Microclimate

The climate in close proximity to your home is called its microclimate. If your home is located on a sunny southern slope, for example, it may have a warm microclimate, even though you live in a cool region. If you live in a hot and humid region, your home could still be situated in a comfortable microclimate due to dense shade and cool breezes.

Certain plants may do well in your microclimate, while others languish and never thrive. This could depend on the type of soil, amount of shade, and local ground moisture. To help assess these local factors, locate a trustworthy nursery tree specialist, county extension agent, landscape architect, or landscape contractor to help you choose appropriate plants and plant care. This knowledge is invaluable when it comes to planning and maintaining landscaping, and provides a good reason to choose full-service professionals rather than discount retailers.

CLIMACTIC REGIONS

North America encompasses five climatic regions that are generally described as temperate, hot-arid, hot-humid, cool, and cold. In interpreting the effect of your general climate on your home, you should also consider the effect of your microclimate. A high-elevation north-facing site, for example, may have the climatic characteristics of a region many hundreds of miles to the north. The energy-conserving landscape strategies you employ will be different for each of these regions.

Temperate

In most of the temperate region, you need to consider both the heating and cooling seasons. Seasonal winds can be expected in any season, and periods of high humidity are common.

- Create shade during summer by planting deciduous trees that will cast deep shadows on the home during midday. Choose tall trees with open trunks that allow the low winter sun to warm your home.
- Plant windbreaks that will deflect cold winter winds. Keep them far enough from your home to allow air circulation in summer.

Hot and Arid

This region has clear skies, dry air, and long periods of hot weather. Evenings are often cool, with large daily temperature fluctuations.

- Plant drought-resistant trees to shade walls and windows. They will also cool the air by evaporation from their foliage.
- Design plantings so natural breezes reach your home. Tall shade trees with open trunks, for example, will allow ground-level circulation.

Hot and Humid

This region has high temperatures and consistent high humidity. Wind speed and direction varies.

- Allow cooling summer winds to reach your home. Don't plant dense hedges near your home that will block breezes.
- Minimize humidity around your home. Don't plant trees or shrubs against your foundation that will require watering.
- Plant tall trees that will have spreading canopies and branchless lower trunks to maximize shade without interfering with air circulation around the home.
- If you live in a hurricane zone, select trees that can survive high winds.

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

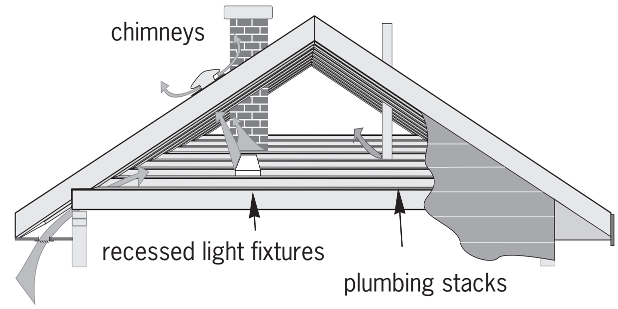
Air moves through openings in your building's shell. Air leakage is driven by pressure differences between indoors and outdoors. Ideally there should be little or no pressure difference between indoors and outdoors. Several things cause pressure differences between the indoors and outdoors.

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.

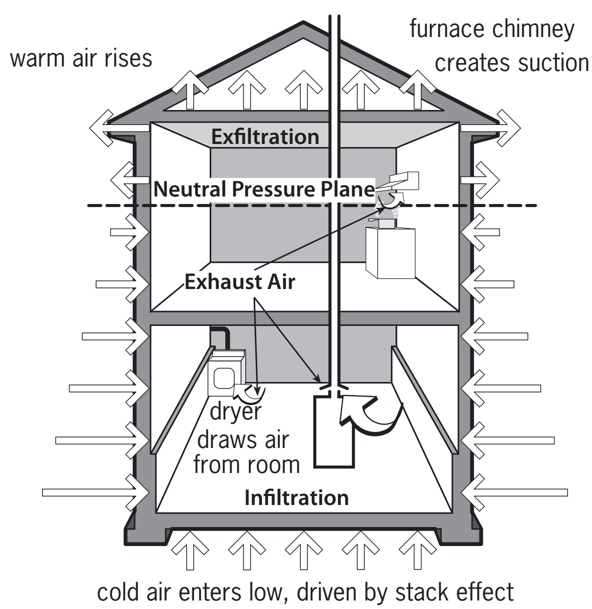
Exhaust appliances such as exhaust fans, conventional furnaces, fireplace chimneys, and clothes dryers all depressurize the home. These mechanical influences can also compete with one another. This is a potential concern when open-combustion furnaces or water heaters are installed that could be prone 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.

BLOWER DOOR TESTING

To seal up leaks in your building shell, you must first find out where they are. You may already have some ideas about where air leaks into your home. But the best way to find air leaks is by performing a blower door test. This analysis is often used by energy auditors when evaluating a home. It's also used by home performance contractors to test the airflow among house zones such as attics, crawl spaces, or garages in conjunction with energy retrofit projects. Most importantly, the results of the blower door test will help you or your contractor find air leaks that have been costing you money.

During a blower door test, the energy auditor installs a fan that temporarily blocks one of your main exterior doorways. The fan depressurizes your home, causing exaggerated air leakage that the auditor can measure and convert to natural air leakage.

The energy auditor will report your home's air leakage in either cubic feet per minute (CFM) or air changes per hour (ACH), and will compare your home's leakage to industry standards. From this measurement, you can evaluate the potential for energy savings from air-sealing your home.

A blower door test can also yield important information about the safety of combustion appliances and whether mechanical ventilation is needed to protect your home's indoor air quality.

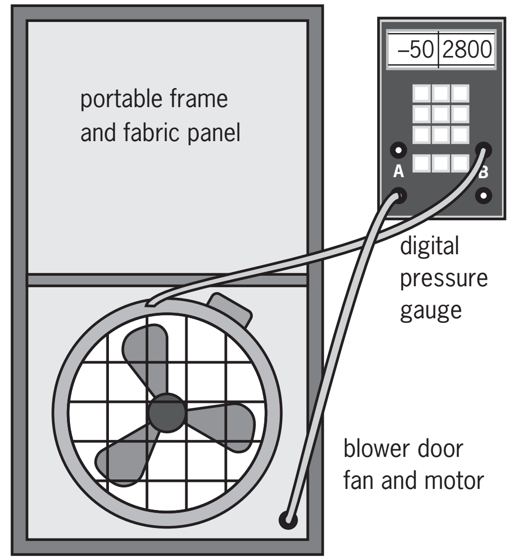
Doing a Blower Door Test

We recommend that you have an energy audit performed on your home that includes a blower door test. It's the best way to determine what level of savings are available from air-sealing projects. Because blower door testing requires specialized equipment and training, this is a job for professionals.

Energy auditors work generally within three distinct fields.

Utility company auditors who provide services for rate-payers. Some utility energy audits include blower door tests. Many utilities offer these audits for no cost or low cost. Contact the utility company that provides your heating fuel.

Blower-Door Principle



The blower door is installed in a doorway. A powerful fan draws air out of your home, and helps the energy auditor find places where air can leak through cracks and holes in the building shell. A pressure gauge is used to estimate the size of those leaks.

Blower-Door Testing

An energy auditor uses a blower door to measure air leakage through a home's shell. Home performance contractors and insulators use this information to guide air-sealing efforts.

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.

Typical R-Values Versus Recommended R-Values

Type of home	Attic	Walls	Floor	Bsmt. walls
Typical existing older home	15	9	2	0
Recommended in cold climate	50	30	30	20
Recommended in moderate climate	50	21	30	12
Recommended in warm climate	50	21	19	12
The ideal home with super-insulated details	60	40	40	40

R-values represent the whole-wall R-value, and account for the thermal resistance of the entire building assembly, including framing.

Thermal Bridging

The R-value of the insulation itself doesn't describe the overall thermal resistance of an assembly such as a wall or ceiling. The R-value for a wall accounts for both the insulated areas and the areas occupied by framing lumber. Since lumber has a relatively poor R-value per inch, the overall R-value of the assembly is lower than the R-value of the insulation itself. This overall measurement is known as the whole-wall R-value.

The whole-wall R-value of a building assembly can be considerably lower than the R-value of the insulation itself. In typical frame walls, for example, lumber occupies 15 to 25 percent of the surface area. Because wood has an insulating value of only about R-1 per inch, these framed areas create thermal bridges in the insulated wall. The interior wall areas over the framing are cold in winter and hot in summer because heat conducts through wood more rapidly than through the insulated space between the framing. If metal framing is used, the reduction in whole-wall-R-value is even greater.

For a wall with a common two-by-four wood frame and R-11 3½ -inch fiberglass insulation, the whole-wall R-value will be R-9 to R-10. For a similar two-by-six wall with 5½ -inch fiberglass insulation, the whole-wall R-value will be R-11 to R-13.

How Much Insulation Is Enough?

Most of our homes have too little insulation. This has happened because energy prices have been low for many years, allowing our building codes to neglect energy conservation. Some of our homes have adequate attic insulation, because it is fairly inexpensive to install. But our walls, floors, and foundations are often the weakest energy detail in our homes.

We recommend that you make a substantial investment in improving your home's insulation. Your attic should be insulated to at least R-50. Your wall cavities should be completely filled—which isn't always the case in homes more than a few decades old—and consider adding two to four inches of foam insulation to the outside of your exterior walls. In cold climates, your foundation or floor should be insulated to at least R-30. The total cost of these projects will range from $2000 to $10,000, and the payback will range from 5 to 15 years. Fortunately, you needn't commit to a complete insulation retrofit—every project you complete will improve your home's efficiency. You can learn more about all these procedures later in this chapter.

The table shown here lists the R-values that we recommend for existing homes.

HOW TO MEASURE YOUR INSULATION

To complete this inspection, you'll need a flashlight, a screwdriver, a tape measure, and pencil and paper. You may need a ladder.

Start by walking around your home and identifying all the parts of the building that could have different insulation details. New additions, for example, often have a framing structure that allows more insulation than in the original building. Your home will have, at minimum, different insulation details at the walls, ceiling, and floor, and it could have several different details for each. Create a list to keep track of your findings.

Inspecting Open Attics

If your home has a pitched roof and an open attic, you'll need to find the hatch. It may be outdoors, in a hallway, or in a closet. If it is in a closet, you may find it troublesome to clear things out of the way to gain access, but this inspection is well worth your time:

- If necessary, find a ladder, set it up securely, climb up and open the hatch. You may be able to inspect the attic from the ladder, or you may need to climb all the way in. Bring a flashlight and tape measure. Wear a respirator. Step only on the framing so you don't damage the ceiling or hurt yourself. *Stop now if you're not comfortable with the risk involved.*
- Inspect the insulation, and identify the type. Fiberglass batts are pink or yellow and come in rolls. Loose-fill fiberglass is white, pink, or yellow, and looks like chopped-up batts. Cellulose looks like, and is in fact made from, chopped-up newspapers. If you don't recognize the type of insulation, take a sample to your local home improvement store and ask an experienced employee.
- If you're evaluating batt insulation that came in rolls, it is probably marked with an R-value printed either on a paper or foil face, or on the batt itself. Note the R-value.
- If you're evaluating loose-fill insulation, measure the thickness all the way down to the top of the ceiling surface. If it varies in depth, take an average of thicknesses. Calculate and record the R-value according to the procedure shown here.

How To Calculate R-Value of Insulation

Once you know the type and thickness of your insulation, you can calculate its R-value:

- **Identify** the type of insulation. Determine the R-value per inch from the table *R-Value of Common Building Materials* on page 85. Use the average R-value from the table.
- **Measure** the thickness in inches.
- **Multiply** the R-value per inch times the number of inches.

Examples of R-Value Calculations

$3\frac{1}{2}$ inches fiberglass loose-fill in attic

Average R-value of 2.3 per inch

3.5 x 2.3 = R-8

$3\frac{1}{2}$ inches cellulose loose-fill in attic

Average R-value of 3.4 per inch

3.5 x 3.4 = R-12

24 inches fiberglass loose-fill in attic

Average R-value of 2.3 per inch

4 x 2.3 = R-55

$3\frac{1}{2}$ inches fiberglass dense-pack in wall

Average R-value of 4.0 per inch

3.5 x 4.0 = R-14

Inspecting Closed Cavities

The most common closed cavities are within standard vertical walls. In North American frame homes, the typical wall is assembled from wooden two-by-fours ($3\frac{1}{2}$ inches in actual thickness), or two-by-sixes ($5\frac{1}{2}$ inches in actual thickness).

Vaulted or cathedral ceilings have closed cavities above their ceilings instead of attics. These roof cavities vary in depth depending on the roof framing, but are usually 8 to 14 inches thick. Some homes are built with a combination of open and closed attic cavities.

Oftentimes the re-insulation of a poorly insulated ceiling vault can solve comfort problems and produce annual savings on the order of three to seven cents per square foot of ceiling.

Closed cavities are also sometimes constructed over garages or above unheated basements. These floor vaults vary in thickness depending on the framing, but are usually 6 to 12 inches thick.

The trick to inspecting vaults is in finding access to look inside. You may be tempted to skip this inspection on the assumption that the cavity was completely and correctly filled during construction. Our experience has shown this is rarely the case.

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:

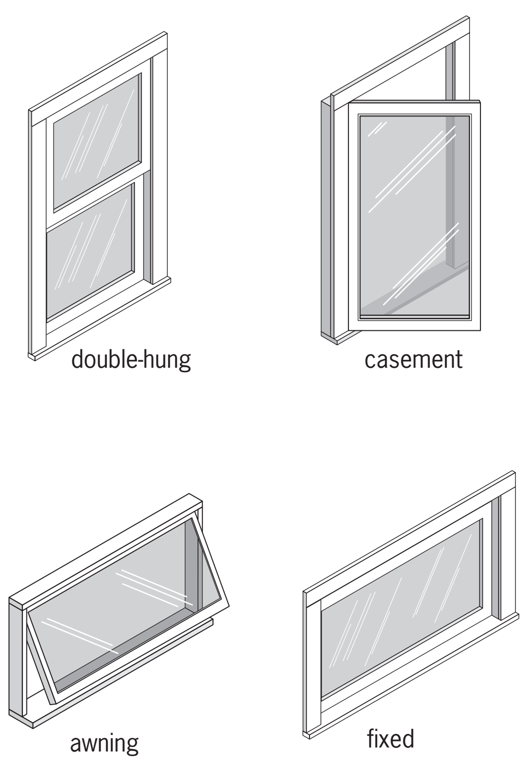
- Glass assembly—One or more glass panes with spacers and/or gaskets.
- Sash—Frames the glass assembly. Sashes are often openable for ventilation and fire escape. Sashes can also be fixed so they don't open.
- Frame—Surrounds the sash and attaches to the building.
- Rough opening—Structural framing of 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.

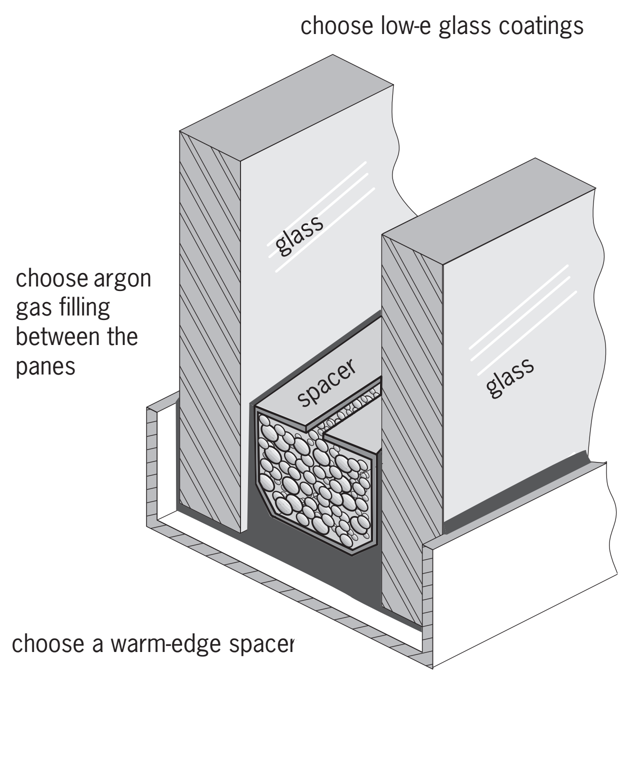
Fixed windows don't open. Though you wouldn't want them throughout your home, they do have the advantage of lower cost (no mechanism needed) and low infiltration rates (they are permanently sealed).

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.

UNDERSTANDING WINDOW RATINGS

If you're purchasing new windows, pay close attention to the ratings published by the National Fenestration Rating Council (NFRC). Most windows carry labels with the NFRC ratings on them. Don't buy windows unless they display this label.

Thermal Transmittance (U-Factor)

A window U-factor measures heat loss and is the most important information for window comparisons in cold climates. The lower the U-factor, the better the window will reduce heat loss and minimize moisture condensation on the glass during cold weather. The U-factor is the reciprocal or inverse of the R-value (U=1÷R).

Single-pane glass has a U-factor of 1.10 (about R-1). A simple insulated glass unit with no coatings or gas fill will have a U-factor of approximately 0.50 (R-2). A U-factor of 0.35 (about R-3) is the minimum acceptable rating for modern energy-efficient homes.

Achieving a U-factor of less than 0.30 requires advanced details, including some or all of these features:

- Double-pane or triple-pane glass: more panes of glass help slow heat *transmission* through the window. Some manufacturers use plastic films as interior panes for these multi-pane windows.
- Low-e coating on one or more of the panes: low emissivity (low-e) coatings reduce heat flow by slowing the rate at which heat is *emitted* from the glass. A low-e coating is made up of a transparent layer of metal just a few molecules thick that is applied to one of the inside layers of double- or triple-pane glass.
- Argon gas filling: argon gas is installed between the panes of insulated glass units. It is a slightly better insulator than air.
- Warm edge spacers: these reduce thermal bridging at the edge of the insulated glass unit.
- Insulated frames: these slow heat flow through the edges of the sash.

Window Rating Labels

Be sure to compare the rating labels when shopping for windows. The most energy-efficient windows will display the ENERGY STAR logo.

Solar Heat-Gain Coefficient (SHGC)

Solar heat gain through windows can account for up to 40 percent of the total heat removed by an air conditioner. SHGC is the fraction of solar heat passing through the glass compared to solar heat falling on the glass. Single-pane glass has an SHGC of 0.87.

A recent glass innovation is a special low-e coating that blocks solar heat while admitting visible light (a low SHGC and a high Visible Transmittance, in technical terminology). This innovation, called spectral selectivity, is widely chosen by window buyers in the South, where air-conditioning is a major expense. The heat-blocking low-e glass is sold under brand names such as Sungate 2 and Low-e^2. Ask about this feature if you spend more money on air conditioning than you do on heating.

Visible Transmittance (VT)

Visible transmittance is the measure of how much visible light is admitted by window glass. Visible transmittance is important because one of a window's main functions is to admit visible light. On the north side of a home, we want as much visible transmittance as pos-

9 Cooling Systems

The cost of running an air conditioner can be exorbitant, accounting for the largest electrical expense for many households in hot regions. The U.S. Environmental Protection Agency estimates that one-seventh of all electricity generated in the U.S. is used to air-condition buildings. It's a huge burden on all of us.

The good news is that you can reduce or eliminate your use of air-conditioning by implementing the alternate low-energy cooling methods described here. And you can do so with little reduction in your comfort.

If you don't already use air-conditioning, the low-energy cooling methods we describe can keep you comfortable without having to resort to using an air conditioner. Low-energy cooling is particularly important if you live in an area that is experiencing increasingly hot summer weather.

If you do use air-conditioning, the low-energy cooling methods we describe are still relevant. If you improve your home's efficiency, your air-conditioner will run less in summer, and you may be able to shorten your air-conditioning season by a few weeks in spring and fall.

We also show you how to perform maintenance on your air-conditioning equipment that will improve its performance, and we describe the most important guidelines for installing new air conditioners.

EVALUATE YOUR COOLING EFFICIENCY

If you use a central air conditioner, has it been professionally serviced in the last year? No home energy system is more prone to poor efficiency than air conditioners that go without professional maintenance.

If you use a central air conditioner, have you cleaned the filters in the last year? You can reduce the frequency of professional service visits by performing this simple do-it-yourself maintenance task.

Is your home a consistent temperature when your air conditioner is running? If the temperature in your home swings widely when your cooling system is running, it may indicate that the system is oversized, or has other problems that can be solved with a service call.

If you have a room air conditioner, do you ever use it in place of central air conditioning? Room air conditioners are considerably cheaper to operate than central systems because they cool only selected areas of your home. If you can run a room air conditioner or two, rather than your central system, you'll reap big savings.

If you live in a hot and dry region, do you use an evaporative cooler? Evaporative coolers (swamp coolers) provide sufficient summer comfort where summer humidity is low. They are a very effective substitute for air-conditioning at about one-third the electrical cost.

COOLING SYSTEM BASICS

Cooling is the most variable type of energy consumption. Two similar homes in the same neighborhood can vary widely in cooling costs, with an inefficient air-conditioned home consuming $500 worth of electricity in a hot month, while a neighbor in a well-designed home might spend only $20 per month to operate room fans and an evaporative cooler.

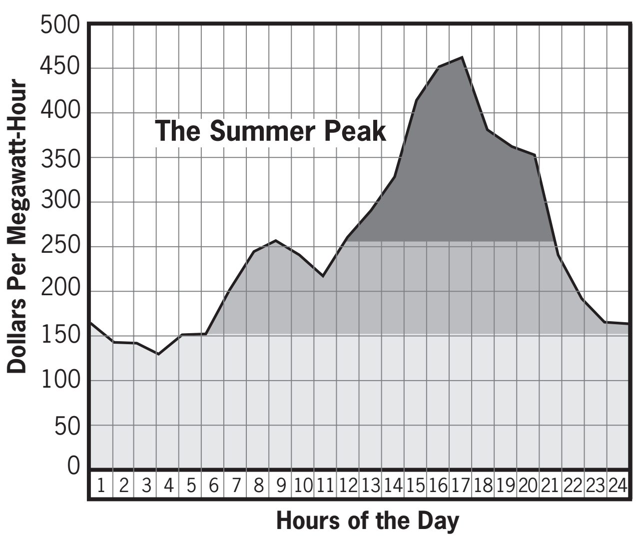
Air-conditioning systems are expensive and environmentally destructive to operate. The environmental problem is that everyone who has an air conditioner needs it at precisely the same time, creating a summer peak load for utilities. This peak is the driving force for the construction of new power plants.

Fortunately, we have proven low-cost cooling strategies that can trim home cooling costs substantially:

- Install and use window shading when possible to minimize solar heat gain. See *Shading Windows for Summer Comfort* on page 48.
- Install the maximum amount of attic insulation. See *Attic and Roof Insulation* on page 88.
- Install a reflective cool roof, or cool-roof coating. See *Improving Roof Reflectivity* on page 51.
- Run indoor fans in occupied rooms to create a wind chill. See *Circulating Air for Summer Comfort* on page 44.
- Run ventilation fans at night to remove accumulated solar heat (if the air isn't too humid). See *Ventilating with Outdoor Air* on page 45.
- Install an evaporative cooler if you live in a dry climate. See *Evaporative Coolers* on page 125.

Many of the measures described in this book will reduce your reliance on air conditioning. But if you do need to use your air conditioner, you'll save money by assuring that it is properly installed and maintained.

Air-Conditioning Creates an Electric Peak Load



The summer electric peak load is driven primarily by air-conditioning systems that run on hot afternoons. Note how the cost of electricity rises with daily demand. Providing this most expensive electricity incurs great economic and environmental burdens.

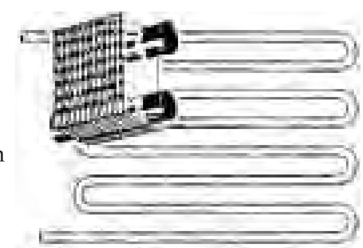
How Air Conditioners Work

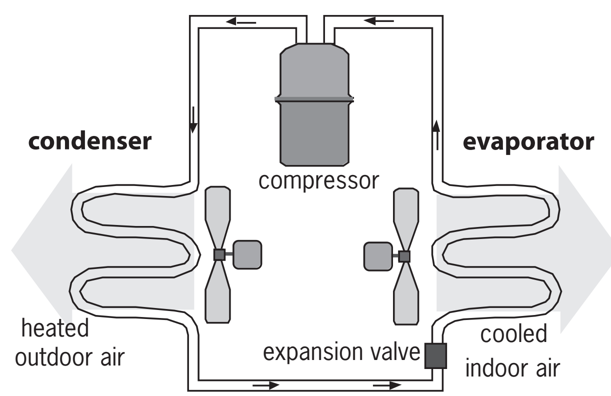
Air conditioners employ the same principles as your home refrigerator. An air conditioner cools your home with a cold indoor coil, called the evaporator. A hot outdoor coil, called the condenser, releases the collected heat outdoors. The evaporator and condenser coils are actually serpentine copper pipes surrounded by aluminum fins, similar to a car radiator. Fans move air through these coils.

A fluid, called the refrigerant, collects heat at the evaporator coil and releases it at the condenser coil. The compressor forces the refrigerant through the circuit of coils and pipes.

Air Conditioner Operating Principles

The evaporator and condenser coils of your air conditioner are made of serpentine copper tubing surrounded by aluminum fins that exchange heat with the air passing through them.



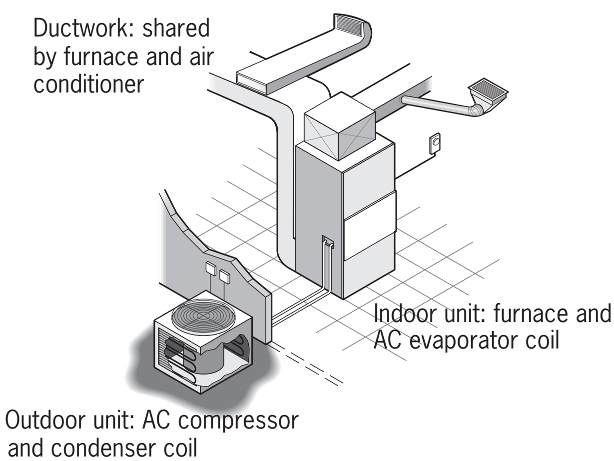


Refrigerant evaporates in the evaporator, absorbing heat from the metal tubes, fins, and passing air. The compressor compresses the refrigerant, preparing it to condense within the condenser, where the refrigerant's latent heat is transferred to the condenser's tubes and fins and then to the outdoor air passing through.

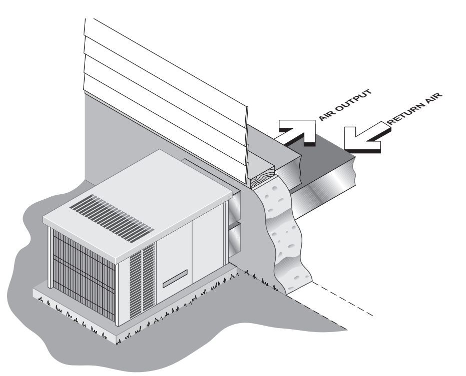
The refrigerant absorbs heat from indoor air as it changes from a liquid to a gas in the evaporator. You've felt this evaporator effect if your index finger has ever felt numbed with cold while using aerosol spray. When the liquid evaporates at the spray nozzle, it absorbs heat from the surrounding air and cools your finger. Using this same effect, the air conditioner's refrigerant evaporates inside the evaporator coil and removes heat from the house air moving through the evaporator's fins.

Heat pumps and air conditioners are almost identical in operation except that heat pumps are reversible for winter heating.

Types of Air Conditioners



Split-system air conditioners are often installed in conjunction with furnaces, sharing the air handler and ductwork.



Packaged air conditioners are less common than split-system air conditioners. They are installed on the ground or on the roof. Packaged air conditioners include all their components in a single cabinet.

Types of Central Air-Conditioning

Central air conditioners are designed in two basic configurations: split-system units and packaged units. The difference between these is the location of the air handler. Split systems have indoor air handlers and the less common packaged units have outdoor air handlers.

The air handler is a steel cabinet containing the blower and the evaporator coil. It is connected to supply and return ducts. The supply ducts carry air from the air handler to the living spaces. The return ducts bring air from the house back to the air handler. For a more thorough discussion about duct systems, see *Inadequate Ducted Airflow* on page 133.

Split-system air conditioners are often installed in conjunction with a gas or oil furnace, and share the ductwork and air handler. The evaporator coil is located indoors in the air handler. The condenser, condenser fan, and compressor are located outdoors in a separate cabinet.

Packaged air-conditioners (also called unitary air conditioners) have the compressor, condenser, evaporator, and two fans all contained in a single cabinet located outdoors. Packaged air-conditioning systems may also contain a gas furnace or some electric resistance heating coils. Packaged air conditioners are usually horizontal-flow units, mounted on the roof or on a concrete slab outdoors.

Controlling Your Air Conditioner

One of the best ways to reduce air-conditioning costs is to manage your thermostat carefully. Move the temperature setting up a degree at a time until your family's temperature limit is reached. For every degree that your cooling thermostat setting is raised, your air conditioning costs will be reduced about 3 percent.

Your cooling system will use less energy if you turn it down while you are gone. When you leave, turn the thermostat up 5 to 10°F. Your air conditioner will run very little or not at all while you are gone, then will run longer than usual when you return. But the net effect will be lower energy consumption. You can also use a programmable thermostat to do the same thing. Try programming your thermostat with a higher energy-saving temperature during most of the day,

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

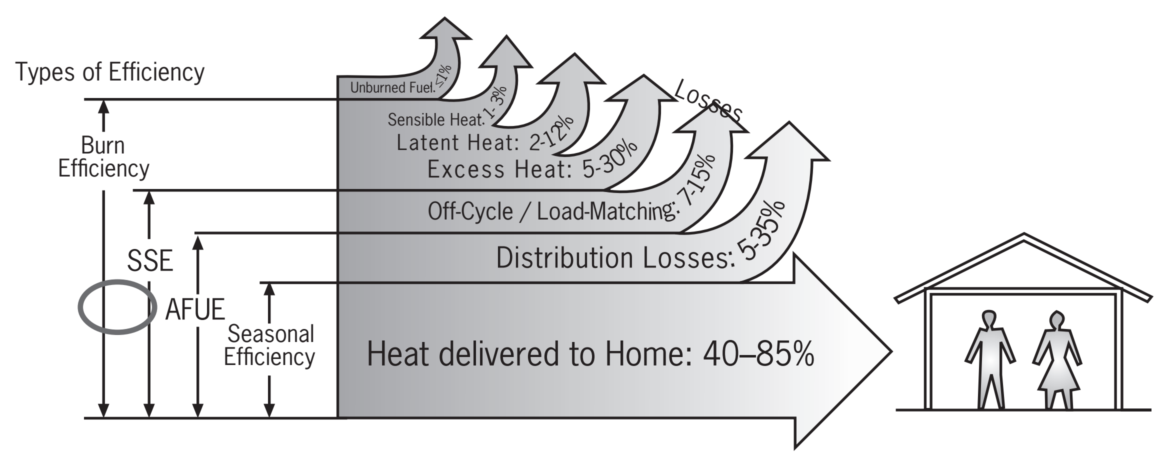
Combustion fuels are primarily hydrocarbons—molecules composed of hydrogen and carbon. The process of combustion, or burning, is simply rapid oxidation: oxygen combines with the carbon and hydrogen, splitting the hydrocarbon molecule. Carbon dioxide (CO_2) and water vapor are the main products of this 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

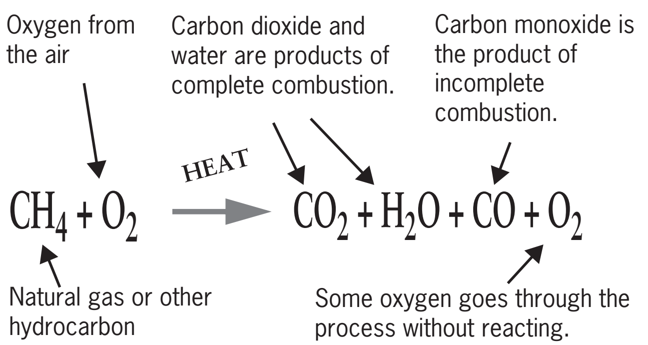


Some of the heat contained in the fuel you purchase never reaches your living space as useful heat. The annual fuel utilization efficiency (AFUE) listed on the yellow Energy Guide label accounts for combustion efficiency, cycling losses, and jacket losses. Distribution losses, which are not included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

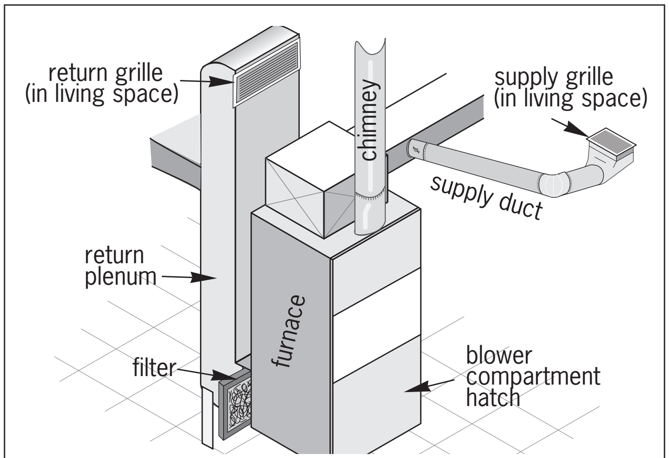
Finally, one of the best defenses against carbon monoxide and other combustion by-products is to install a carbon monoxide detector ($30 or less) on each level of your home. Be sure to replace the batteries periodically.

Combustion: The Chemical Reaction



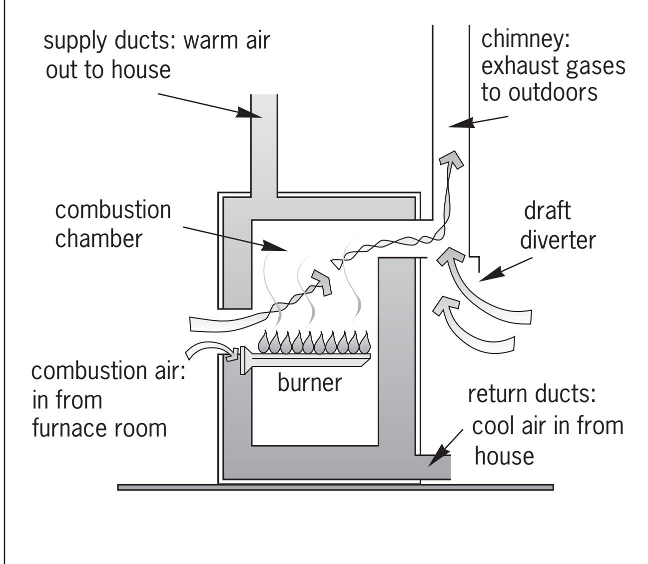
Combustion is a chemical reaction that utilizes a hydrocarbon and oxygen to produce heat. It releases carbon dioxide (a potent greenhouse gas), water, and other by-products. A properly cleaned and tuned combustion appliance will produce very little or no carbon monoxide.

Components of Conventional Furnaces



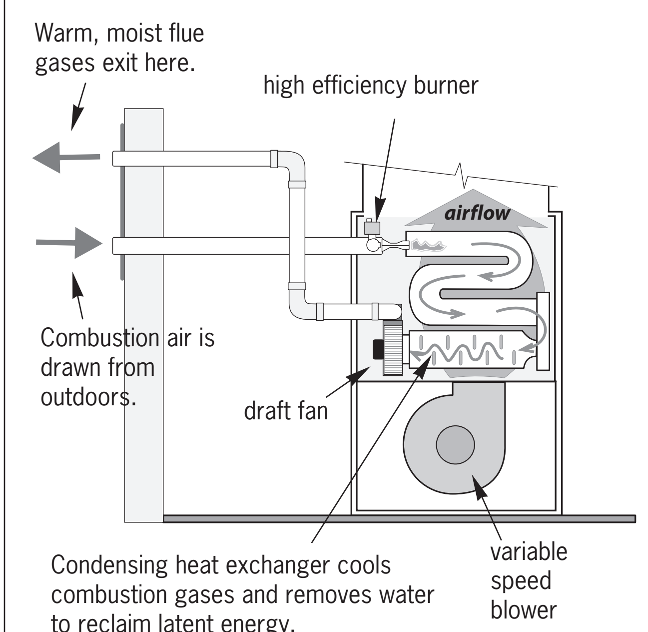
This type of conventional open-combustion furnace is found in many older homes. If it is replaced with high-efficiency equipment, the original ductwork can often be retained if it's properly sized and in good condition.

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.

11 Photovoltaic Systems

Photovoltaic systems produce electricity from sunlight. This electricity can be used to operate the lights, appliances, and electronics in your home that normally consume electricity from the power grid. Photovoltaic (PV) systems have been used in homes and business for years, but are enjoying a resurgence in popularity due to technical advances in equipment, financial incentives, and increasing utility costs.

Photovoltaic systems embody two important characteristics: distributed generation and renewable energy. Distributed generation systems are located closer to the end user, and so incur fewer transmission losses than centralized power plants. Distributed systems are also less subject to system-wide outages than central systems. Renewable energy sources such as photovoltaic power utilize unlimited sources of energy rather than finite fuels such as coal, oil, and gas. Renewable energy sources are less subject to price fluctuations than non-renewables, and they also have a smaller environmental impact.

In this chapter we show how to evaluate your site for solar power, an analysis that will apply to both PV and solar hot water systems. We also explain how photovoltaic systems work and analyze the economics of installing PV systems.

EVALUATE YOUR HOME'S PV POTENTIAL

Have you improved the insulation in your home to the maximum possible extent? Your best conservation investment is to improve the thermal efficiency of your home. Invest in insulation and other shell improvements that have a short payback before making a long-term investment in photovoltaics.

Do you have a heating system that is powered by combustion fuels such as gas or oil rather then electricity? Electrically heated homes require more electrical energy than can be provided by economically sized photovoltaic systems. If you have an electrically heated home, a better investment would be in switching your heat source from electricity to natural gas or solar thermal heat.

Does your combustion heating system operate at 90 percent efficiency or higher? If your home is heated by an older low-efficiency furnace or boiler, you should invest in its upgrade before installing a photovoltaic system.

Have you trimmed your annual electrical consumption to 2500 kilowatt-hours per person or less? Your investment in baseload conservation measures that reduce your electrical consumption will pay off by allowing you to install a smaller photovoltaic system.

Does your homesite receive sunlight for most of the day? Not every homesite is appropriate for the installation of a photovoltaic system. To get the best production from photovoltaics, you should have mostly un-obstructed access to the sun from 9 a.m. to 3 p.m.

Does your utility company or local government offer incentives for installing photovoltaic systems? Financial incentives that total up to half the cost of typical photovoltaic systems are available in many areas. These make the economics of photovoltaic power very attractive.

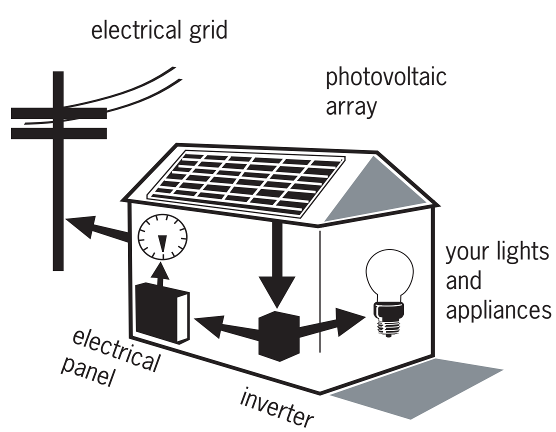
A PERSPECTIVE ON PV SYSTEMS

Since photovoltaic systems are relatively expensive and have a long payback of ten to thirty years, you should always spend your first home improvement dollars on simple conservation measures. These might include installing compact fluorescent lamps, upgrading the insulation in your attic, sealing air leaks, or replacing older inefficient appliances. These measures will reduce your electric load at a lower cost than installing a PV system, and some of them will also improve the comfort of your home. Once you've reduced your electrical load as much as possible with these basic improvements, it makes sense to consider a long-term investment in a PV system.

For families or business owners who want to reduce their environmental impact, PV power can be an important component of a personal energy plan. The average family in the U.S. today consumes about 11,000 kilowatt-hours (kWh) of electricity per year, though many get by comfortably on less than 5000 kWh. A modestly sized PV system can produce 2000 to 3000 kilowatt-hours of electricity per year, eliminating carbon dioxide emissions equal to driving about 10,000 miles in a typical automobile. Every PV system we install brings us closer to a sustainable energy future by reducing our dependence on both domestic and foreign nonrenewable sources of energy.

Some homeowners install photovoltaic (PV) systems because their buildings are located in remote areas beyond the reach of power lines. In these off-grid applications, the PV system may include batteries or a generator to provide electricity when the sun isn't shining. One advantage of these off-grid PV systems is that they allow property owners to avoid the cost of extending electric lines to their site.

Photovoltaic System Components



Most photovoltaic systems include these basic components. This system is tied into the local electrical grid.

But many consumers who are located within the service territory of an electric utility still invest in PV power. In these cases, the PV system is often connected to the electric grid. These grid-tied systems feed excess PV power into the grid when the system's production is greater than occupants' consumption, as during sunny weather. They draw power from the grid when the system's production is less than the consumption, such as at night and during cloudy weather.

Grid-tied systems are usually net-metered, with electric meters that record electricity going both into and out of the home. Many utility companies offer net metering agreements that compensate owners of qualified PV systems for power that is fed back into the electric grid.

PHOTOVOLTAIC ECONOMICS

Photovoltaic systems require a substantial economic investment, with the typical systems costing $15,000 to $30,000 before any incentives are applied. Over the life of the system, you'll pay about 25 cents per kilowatt-hour of electricity produced, compared to about 10 to 20 cents per kilowatt-hour for electricity currently purchased from North American utility companies. But as the cost of retail electricity increases, the financial return on photovoltaic systems will improve.

Fortunately, there are some incentives available for the installation of PV systems. Several utility companies offer grants to cover up to 50 percent of the cost of residential and/or commercial renewable energy systems. The Internal Revenue Service provides income tax credits for some PV installations, and many state governments and utility companies offer similar inducements. These incentives help bring the cost of PV systems within the reach of many building owners. And the financial viability of your PV system will improve in the future as electric costs inevitably increase.

PHOTOVOLTAIC POWER COMPONENTS

Solar cells are the smallest building blocks of photovoltaic systems. These silicon-based semiconductors utilize the reaction of sunlight within the cell to create an electrical current. Each cell produces a few watts of direct current (DC) electricity.

Photovoltaic modules include groups of solar cells that are electrically interconnected and mounted in lightweight frames. Modules are usually covered with glass and backed with a polymer or glass sheet that protects the cells from the elements. These modules are the basic PV components sold by most manufacturers. Typical modules produced for residential and light commercial installations produce 50 to 200 watts of power.

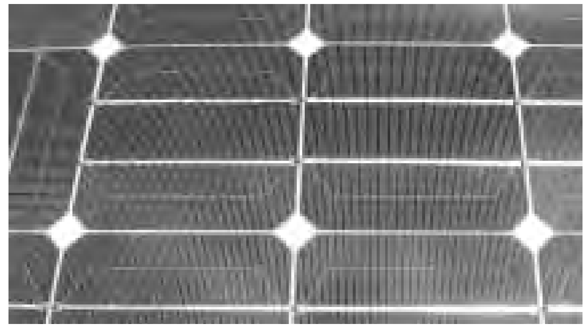
Solar arrays are the groups of these modules you see installed on the roofs of buildings or on ground-mounted racks. The electrical output of an array, usually measured in watts, is determined by how many modules it contains and the wattage of the individual modules.

Types of Solar Cells

The most common type of solar cells used in today's PV systems are crystalline solar cells. They are sliced into thin wafers several thousandths of an inch thick and a few inches long. You'll see these individual cells if you look closely at most solar panels. Among the various types of solar cells, crystalline cells convert sunlight to electricity the most efficiently, reducing the area needed for a given output. But their manufacturing cost is also the highest, requiring designers to balance the advantages of smaller area with cost.

Solar cells are also manufactured as thin-film materials, made by depositing a thin layer of PV material onto glass, plastic, or metal foil. The film is usually less than one ten-thousandth of an inch thick. Thin film materials can be integrated into building materials such as roof shingles. Thin film cells are less expensive per square foot than crystalline cells, though they require more area to achieve the same output.

Crystalline Solar Cells



This most common type of solar cell is sliced into wafers that are interconnected and assembled into modules.

Integrated Inverter and Controller

This inverter/controller converts direct current to alternating current, controls the charging of a bank of batteries, and manages a net metering connection with the electrical grid.

Inverters

Solar cells produce direct current, which can be used immediately for some applications. Solar-powered calculators and battery chargers, for example, consume direct current (DC) power, and several manufacturers make DC refrigerators and other equipment for off-grid DC systems. But almost all the lights, appliances, and equipment in modern homes use the alternating current (AC) that is supplied by the electrical grid.

Inverters are electronic devices that convert DC power into AC power. If you intend to use your PV electricity to power your home's existing equipment, your system will require an inverter. An inverter is also necessary if you plan to connect your PV system to the utility grid. The majority of PV systems installed today utilize an inverter.

12 Moisture Management and Ventilation

Your home should be a healthy and safe place to live. Over the course of a lifetime, most of us spend more time in our homes than anywhere else. Your well-being will depend in part on how you manage your home environment.

When excess moisture accumulates in your home, it can cause health problems, deteriorate building materials, and increase your energy consumption. The management techniques we describe in the first part of this chapter can help you keep moisture under control.

Most homes are ventilated by air leakage, with help from kitchen and bath exhaust fans. But air leakage isn't a reliable or efficient way to control moisture in your home since it provides excessive ventilation during severe weather and inadequate ventilation during mild weather. The best way to maintain good indoor air quality is with a whole-house ventilation system that provides fresh air when and where it's needed. We describe ventilation systems in the second part of this chapter.

EVALUATE YOUR HOME'S MOISTURE MANAGEMENT AND VENTILATION

Do you have problems with mold or mildew in your home? You can often control these problems by managing moisture in and around your home.

Do you have exhaust fans installed in your kitchen and bathrooms? Exhaust fans are an important first line of defense against moisture and odors in the home. They become even more important as you improve the efficiency and airtightness of your home.

Does your home have a dirt-floored crawl space or basement? The ground under your home is often the largest source of moisture in your home.

Does runoff from rain or snowmelt ever puddle against your home's foundation? This water can seep into your home and cause moisture problems.

Does your home have any plumbing or roof leaks? These sources of moisture are easy to control. Give roof and plumbing repair your highest priority.

Does your home have odors and high relative humidity? Your home may be fairly airtight and may need a whole-house ventilation system to provide good indoor air quality.

MOISTURE BASICS

Excess moisture is a problem in many modern homes. Airborne water vapor isn't a problem by itself. But when the water vapor condenses to liquid water, this condensation can cause a number of problems.

- Wet homes are not healthy. Excess moisture encourages the growth of mold, mildew, fungus, and other biological contaminants. These "biocontaminants" thrive in warm, dark, moist environments such as building cavities. Biocontaminants are responsible for a range of human health problems such as allergies and asthma. Many people have strong responses to these organisms, with effects ranging from annoying sniffles to dangerous asthmatic attacks.
- Wet homes are not durable. Wet building materials may support termites, carpenter ants, and other insects. Water rusts metal building components, leaches cement out of masonry walls, and damages building materials if it freezes in cold weather. Your home will last longer if it is dry.
- Excess moisture increases energy consumption. When moisture condenses in your home's insulation, heat can travel through the insulation more easily. And both heating systems and cooling systems use extra energy when they must dry out your home. During the heating season, the air that is warmed by your furnace causes excess

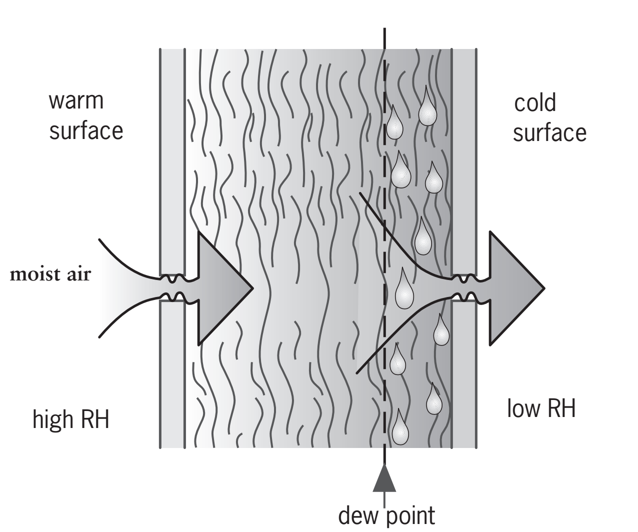
moisture in your home to evaporate, cooling the air and requiring more heating. During the cooling season, the cold evaporator coil in your air conditioner causes water to condense out of the indoor air that circulates through it. This process of condensation releases heat, which causes your cooling system to run longer. Your heating and cooling systems use more energy when they must dry out your home.

Measuring Moisture

Airborne moisture is measured in percent relative humidity (RH). Air at 0 percent relative humidity contains no water vapor. Air at 100 percent relative humidity is totally saturated with water vapor. Saturated air causes condensation when it flows near cool surfaces.

The tiny water droplets that coat the walls and ceiling of a bathroom after you shower are the result of the room air reaching 100 percent relative humidity. The bathroom's cool walls and ceiling provide condensing surfaces where water vapor becomes liquid water.

Vapor Migration in Building Cavities



Vapor is driven through flaws in the building shell by air movement and vapor pressure. Condensation occurs when moisture reaches the dewpoint.

All homes contain condensing surfaces that are hidden within the walls, in the attic and crawl space, and around carpet, wallpaper, and furnishings. Water vapor travels to these hidden areas driven by differences in air pressure or humidity. Your home's relative humidity is an important determinant of how much moisture condenses.

Most authorities agree that an indoor relative humidity of 45 to 65 percent is best. Relative humidity lower than this range is normal in drier regions. Low relative humidity can cause uncomfortably dry skin in some people. High relative humidity encourages moisture condensation. If you're curious about the relative humidity in your home, we recommend that you purchase a simple hygrometer, or moisture meter, to monitor your home's relative humidity. If the relative humidity is too high, you can take steps to counteract it as outlined here.

How Moisture Travels in Your Home

Moisture moves through your home in four distinct. ways:

- Liquid water flows downwards through openings in the building. Rain may fall on your roof, for example, and leak into your home around a poorly sealed chimney.
- Liquid water wicks through solid materials in all directions by the process known as capillary action. Water can travel up through the ground, then wick through your concrete foundation, and into the wooden structure of your home. Water seeps horizontally too—through the wood siding on your home, for example—when the siding becomes saturated after a rainstorm.
- Water vapor is carried by moving air. Humid air from indoors or outdoors can migrate into building cavities where the water vapor may encounter a cold surface and condense. In summer, the humid air moves from outdoors and the condensing surface is the back side of the drywall. In winter, the humid air comes from indoors and the condensing surface is the back side of the exterior sheathing. In either case, moisture will accumulate inside the wall.

- Water vapor moves through porous materials such as drywall, concrete, and wood by the process called vapor diffusion. It can then condense on hidden cold surfaces.

When water moves through your home by any of these mechanisms, it can accumulate and cause problems. A good moisture management plan keeps moisture in check.

HOW TO CONTROL OUTDOOR MOISTURE

Don't let water leak into your home. Rainwater or snowmelt that leaks through your roof, flows in around doors and windows, or seeps through your siding can damage your home. Fixing these leaks should be your first defense against moisture problems.

If you have standing water in your basement or crawl space, you should take immediate action to dry it out. If you have gutters and downspouts, be sure they direct water away from your home. You might also limit irrigation around your foundation. If all else fails, consider installing a sump pump to move water away from the foundation.

Moisture that enters the home through foundations and crawl spaces contributes to indoor humidity even when no wet areas are apparent. Moisture moves easily through the home, by air movement and by seeping through permeable wood and concrete. Radon and other soil gases may also migrate into dirt crawl spaces.

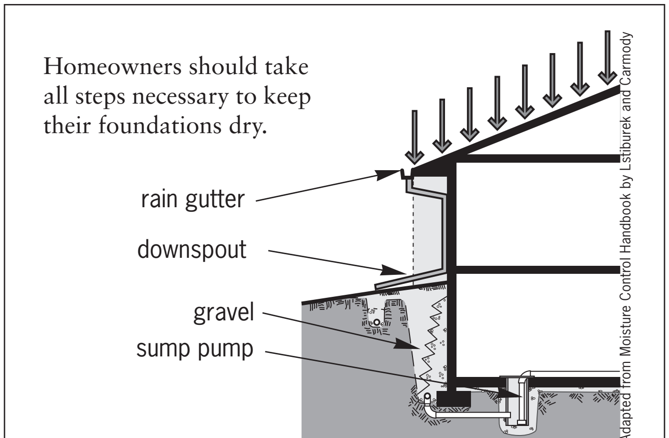
We recommend that you cover the ground in all dirt-floored crawl spaces and basements with a ground-moisture barrier. This plastic sheeting should be sealed at the seams and foundation walls. Standard polyethylene plastic, either clear or black, is acceptable, but reinforced high-density polyethylene is better. This tough moisture barrier won't tear if a tradesperson needs to crawl around on it.

A ground moisture barrier also helps to control radon, methane, and other soil gases. Seal the edges to the foundation with polyurethane or butyl sealant. Seal the seams with sealant or acrylic builder's tape (not duct tape).

Sources of Moisture in the Home

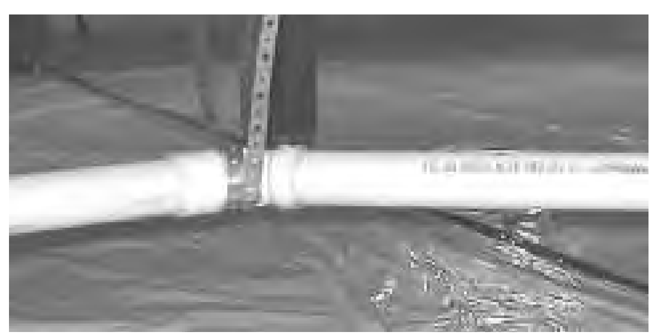
Moisture source	Typical amount, in pints
Ground moisture, basement or crawl space	0–105 per day
Respiration and perspiration, 4 people	10-12 per day
Dryer vented indoors	4–6 per load
Cooking, 4 people	2–4 per day
Showering, 4 people	2 per day
Dishwashing	1–2 per day

Exterior Moisture Control



Protect your foundation from water damage. Be sure that your gutters and downspouts direct water away from the foundation. Grade the soil around your home so water runs away from the foundation. Avoid watering plants that are against the foundation.

Well-Sealed Crawl Space



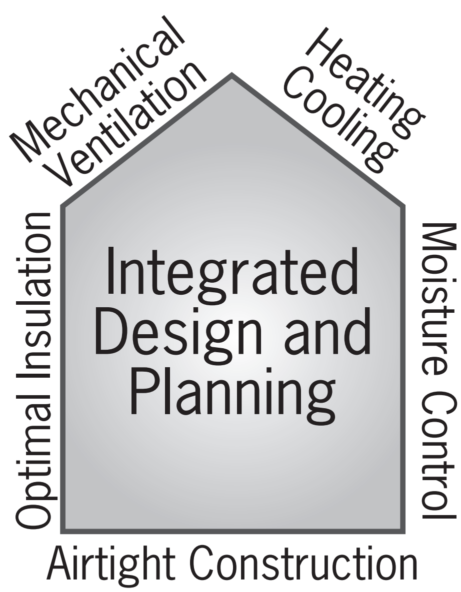
A ground moisture barrier slows the flow of moisture and other soil gases into your home. The seams should be sealed with builder's tape, and the edges fastened to the foundation wall with polyurethane caulk.

13 Building a New Home

If you build a new home, you'll have the opportunity to create a house that is exceedingly comfortable, efficient, and durable. It will take foresight and commitment to do so, because the homebuilding process is littered with pitfalls that can derail your attempts to build an energy-efficient home. Your knowledge can help assure that you get the best house possible.

Much of the information in this chapter has been addressed to some degree elsewhere in the book. But here we show how the best construction practices can be implemented when not constrained by the impediments of remodel work. We also describe some materials and methods that are used only in new construction. Finally, we identify specific energy-efficiency details that are specified in building codes.

Building an Efficient and Sustainable Home



The most efficient homes are crafted by homebuilders who understand how to facilitate communication between the owner, the designers, and the trade specialists.

NEW HOME BASICS

The efficiency of conventional frame dwellings built in North America hasn't changed much in the last fifty years. We have added many incremental improvements such as insulated glass, high-efficiency heating systems, and improved refrigerator technology. But one thing that has changed little is the design of the thermal boundary: the critical assembly of insulation and air barrier that is your primary defense against temperature extremes.

The best homebuilders now have ready-to-go designs for homes that will use 50 to 80 percent less energy than the average. These are comfortable homes that look no different than others in the same neighborhood. They vary in size and style, but they all include a common set of traits:

- A simple building shell
- Very high insulation levels
- Airtight construction
- Energy-efficient windows and doors
- A whole-house ventilation system
- A small heating system
- Little or no air-conditioning
- Efficient lighting and appliances
- Energy-efficient landscaping

The most efficient homes are small—the best predictor of energy consumption is size. We cannot emphasize this principle enough. *No matter how well you engineer a huge house, it will consume large amounts of energy.*

The largest barriers to building low-energy homes are consumer tastes and contractor habit. For years, many of us have purchased large homes with complex construction details and luxury options that maximize energy use. Most homebuyers have not been interested in high insulation levels and other low-visibility efficiency measures. We have asked for fashion, not efficiency.

The solution is simple. If you plan to build a new home, we recommend that you educate yourself on the process of efficient construction. You may have talented designers and builders working on your behalf, but your knowledge will assure that you get the energy efficiency you expect and are paying for. You should also work hard to find a builder who already builds energy-efficient homes. You will be spending your hard-earned money on this project, and you should not have to pay for the education of your homebuilder.

INSULATION FOR NEW HOMES

Insulation is the key to energy efficiency in most American climates. In cold and hot climates, insulation is essential to providing comfort. In mild climates such as the American Southwest, superior insulation can eliminate the need for heating and cooling altogether.

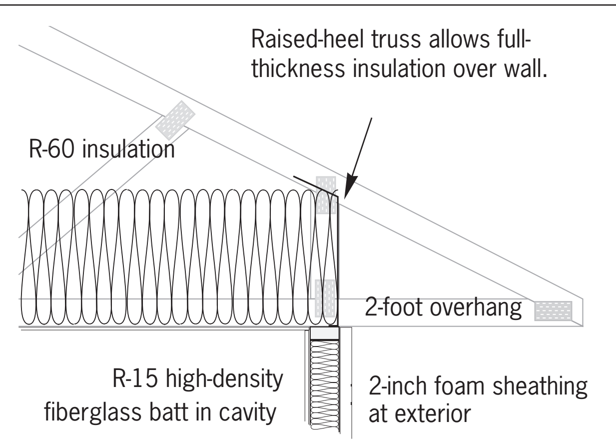
Attic Insulation

Plan to insulate your attic to between R-40 and R-60. Standard roof trusses limit the amount of insulation that can be placed directly over the perimeter of the exterior walls. A raised-heel or "energy" truss allows 8 to 16 inches of insulation or more to be placed over the outer wall.

Another way to improve the thermal integrity of this hard-to-insulate area is to blow foam insulation against the bottom of the roof sheathing above the exterior walls. Since foam insulation has almost double the R-value of fiberglass or cellulose, it makes it possible to maintain a high R-value in this area without installing a raised-heel truss.

Make sure the air leakage sites into the attic are sealed before installing attic insulation.

Efficient Roof Edge Details



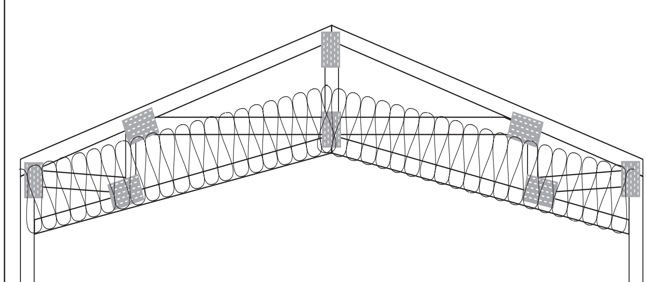
Raised-heel trusses allow eight inches or more of insulation to cover the area directly over the outside wall.

Cathedral Ceilings

No building component has generated so much trouble and controversy in recent years as cathedral ceilings. They are too shallow to insulate well. Conventional builders and building inspectors insist that they must be ventilated. Building scientists argue that the narrow ventilation space can't dry the cavity effectively, and that the only hope of keeping moisture out of the cavity is to seal it up. Electricians are forced to wreck the effectiveness of the insulation by installing recessed light fixtures. Retrofitters complain that cathedral ceilings represent a severe weakness in the home's thermal boundary, costing thousands of dollars to fix.

We recommend that you build a home with flat ceilings so you can take advantage of the myriad benefits of an open attic. But if you do choose to build a cathedral ceiling, you can avoid expensive repairs by choosing one of the following options.

Scissor Truss Cathedral Ceilings



Scissor trusses allow a thick blanket of blown fibrous insulation with adequate space for ventilation.

- Install scissor trusses. Insulate the section of the roof over the exterior wall with spray foam or buy trusses that have room for a full-depth blanket of insulation over the exterior wall.
- Install structural insulated panels. This sandwich of wood sheeting and polystyrene foam forms both structure and seamless insulation.
- Build a ventilated roof cavity. Make it absolutely airtight and install foam board between the drywall and rafters for a thermal break, and to create a high R-value over the entire roof assembly.

Above-Ground Walls

Most energy codes require a minimum wall insulation of R-13 to R-21. The best homes utilize a much higher insulation level.

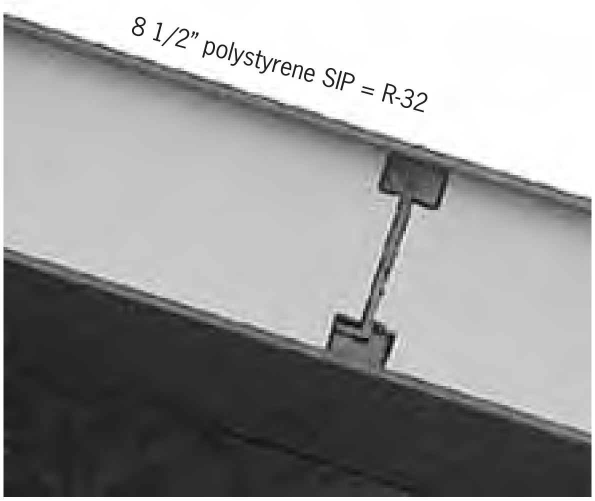
Most North American homes have wood-framed walls. The insulation should fill the wall cavity from top to bottom, side to side, and front to back. Here are a few common ways to increase the thermal resistance (R-value) of exterior walls.

- Always use wood frame two-by-six walls, filled with high density R-21 fiberglass batts.
- Install at least 2 inches of insulated foam sheathing underneath the siding to reduce heat flow through the walls and prevent condensation in the wall cavities. When installed over a two-by-six wall, this assembly will deliver R-30.
- Frame wood walls with 24-inch spacing, rather than 16-inch spacing.
- Frame exterior-wall corners, and intersections with interior walls, with as much insulation and as little wood as possible.
- Build insulated headers above doors and windows.

New Methods of Wall Construction

In the past twenty years, structural insulated panels (SIPs) and insulated concrete forms (ICFs) have become common in some parts of the United States. Both construction methods provide exceptional thermal performance.

Structural Insulated Panels for Cathedral Ceilings



Structural insulated panels (SIPs) are used here to form an engineered cathedral ceiling. The inner core of expanded polystyrene is protected by an outer skin of oriented stand board (OSB), a composite wood product similar to plywood.

Structural Insulated Panel Walls

Homes made with structural insulated panels (SIPs) are among the most airtight and well-insulated buildings in North America. SIPs provide both structure and insulation, eliminating the standard wood frame wall.

Resources

SATURN ONLINE

Saturn Online offers follow-up resources for readers of this book. Free tip sheets provide additional information about the procedures described here, and online seminars guide homeowners through the process of crafting an efficient home. The courses stress specific solutions for making deep reductions in energy consumption and carbon emission. An online forum allows participants to discuss home energy solutions with industry experts. Saturn Online also offers courses that cater to professionals and advanced do-it-yourselfers.

For more information, visit *www.saturnonline.biz*

ORGANIZATION CONTACTS

American Council for an Energy-Efficient Economy (ACEEE) - 1001 Connecticut Ave. NW, Suite 801, Washington, DC 20036. 202-429-8873. *www.aceee.org* ACEEE collaborates with other groups on research into the benefits of energy efficiency, and publishes many reports. Publishes the excellent book *Consumer Guide to Home Energy Savings*.

American Solar Energy Society, Inc. (ASES) - 2400 Central Ave. G-1, Boulder, CO 80301. 303-443-3130. *www.ases.org* ASES is a nonprofit educational organization that encourages the use of solar energy technologies. ASES publishes the magazine *Solar Today.*

Building Performance Institute - 107 Hermes Road Suite 110, Malta, NY 12020. 518-899-2727. *www.bpi.org* Certifies energy auditors and related professionals working in the weatherization and home performance fields. Provides accreditation for home performance contractors. Manages both written and field testing of technicians. Maintains a list of accredited home performance contractors.

California Energy Commission (CEC) - 1516 Ninth Street, P.O. Box 944295, Sacramento, CA 94244-2950. 916-654-4287. *www.energy.ca.gov* The CEC publishes extensive written and web-based resources on building technology and energy efficiency.

Centers for Disease Control and Prevention (CDC) - 1600 Clifton Rd, Atlanta, GA 30333. 800-311-3435. *www.cdc.gov* Provides written and web-based information on home health hazards such as asbestos, radon, carbon monoxide, and household chemicals.

Department of Housing and Urban Development (HUD) - 451 7th Street S.W., Washington, DC 20410 (202) 708-1112. *www.hud.gov* HUD manages a vast information network on homeownership in general, with topics that include buying and selling homes, identifying the most favorable mortgages, and improving home efficiency.

ENERGY STAR® - The ENERGY STAR website is one of the best online resources for information on building efficiency. *www.energystar.gov*

The Energy & Environmental Building Association (EEBA) - 6520 Edenvale Boulevard, Suite 112, Eden Prairie, MN 55346 952-881-1098. *www.eeba.org* EEBA's goal is to provide education and resources to transform the residential design and construction industry to profitably deliver energy efficient and environmentally responsible buildings and communities.

Florida Solar Energy Center (FSEC) - 1679 Clearlake Rd., Cocoa, FL 32922. 321-638-1015. *www.fsec.ucf.edu* FSEC is an important resource for anyone who owns a home in a hot, humid climate. They offer publications on topics such as passive cooling, radiant barriers, moisture control in hot climates, shading techniques, air leakage, air-conditioner performance, and more.

Home Energy - PMB 95, 2124 Kittredge St., Berkeley, CA 94704. 510-524-5405. *www.homeenergy.org* Publishers of *Home Energy Magazine*, the premier U.S. publication on home energy efficiency.

Journal of Light Construction - 186 Allen Brook Lane, Williston, VT. 802-879-3335. *www.jlconline.com* JLC publishes an excellent professional journal for the construction trades.

National Renewable Energy Laboratory (NREL) - 1617 Cole Blvd., Golden, CO 80401-3393. 303-275-3000. *www.nrel.gov* The DOE's solar and renewable energy laboratory. Performs many kinds of building energy research. Produces publications for both professionals and consumers.

North American Technical Excellence (NATE) - 4100 North Fairfax Drive #210, Arlington, VA 2220 3(703) 276-7247. *www.natex.org* NATE provides a national certification for the most skilled heating and cooling technicians. They maintain an online database of certified technicians.

Passive House Institute U.S. - 110 S. Race St. Ste 202, Urbana, IL 61801. *www.passivehouse.us* The Passive House Institute works to establish European super-efficient construction standards in the U.S. They provide technical assistance, offer training, and certify homes that are built to Passive House standards.

PVwatts, National Renewable Energy Lab - *www.rredc.nrel.gov/solar/calculators/PVWATTS* The online PVWatts calculator allows you to estimate the output of solar electric systems. The website also includes other solar design tools and research materials.

Residential Energy Services Network (RESNET) - P.O. Box 4561, Oceanside, CA92052. 760-806-3448. *www.resnet.us* National organization of home energy raters (HERS Raters) and rating organizations. Their mission is to develop a national market for home energy rating systems and energy efficient mortgages. Maintains a list of certified HERS Raters.

Solar Energy International (SEI) - P.O. Box 715, Carbondale, CO 81623 970-963-8855. *www.solarenergy.org* SEI offers the industry's best hands-on workshops and online courses on renewable energy and sustainable construction.

Southface Energy Institute - 241 Pine St. NE, Atlanta, GA 30308. 404-872-3549. *www.southface.org* Nonprofit educational institute focuses on energy-efficient building for the southern states. Website has a good question-and-answer section.

U.S. Green Building Council (USGBC) - 1800 Massachusetts Ave. NW Suite 300, Washington, DC 20036. 202-828-7422. *www.usgbc.org* USGBC administers the LEED program (Leadership in Energy and Environmental Design), an educational and rating system for green buildings.

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

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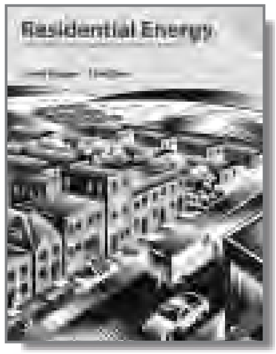
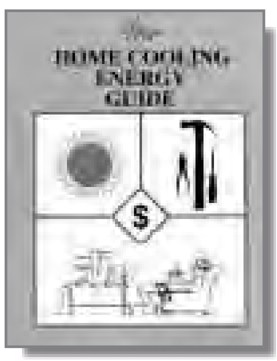
Saturn Bookstore

Residential Energy: Cost Savings and Comfort for Existing Buildings



Discusses the principles of residential energy conservation in greater detail than *The Homeowner's Handbook to Energy Efficiency.* This is the standard textbook used to train energy auditors and building performance contractors. Includes checklists, tables, a glossary, dozens of useful appendices, and illustrations on almost every page. 320 pages.

Your Home Cooling Energy Guide



Explores all the options for reducing the cost of air conditioning. Illustrates solutions that include shading, ventilation, evaporative cooling, awnings, sun screens, window films, radiant barriers, insulation, reflective coatings, and shade trees. 80 pages.

Your Mobile Home: Energy and Repair Guide for Manufactured Housing

Summarizes the collective experience of many experts who work with manufactured housing. Describes the construction process, outlines common repair tasks, and identifies the best weatherization measures to reduce utility costs. Includes many illustrated step-by-step procedures. A must-have book for all mobile home owners. 256 pages.

Residential Ventilation Systems

Outlines step-by-step procedures for properly choosing, designing and installing ventilation systems. Provides critical information for homeowners who want to control mold, mildew, and moisture problems in their homes. 26 pages.

Hydronic Heating Systems

Includes solid technical advice on installing, maintaining, and troubleshooting hydronic home heating systems. Covers both modern hot-water heating systems and legacy steam systems. Includes an analysis of installation options for new homes. 40 pages.

Visit our website to learn more about these publications or to place an order.

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www.homeownershandbook.biz

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