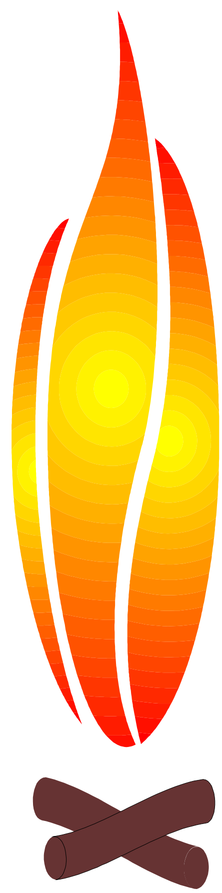
SR/EMEU/94-01

Reducing Home Heating and Cooling Costs

July 1994



Energy Information
Administration

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PREFACE

This report is in response to a request from the House Committee on Energy and Commerce that the Energy Information Administration (EIA) undertake a neutral, unbiased analysis of the cost, safety, and health and environmental effects of the three major heating fuels: heating oil, natural gas, and electricity. The Committee also asked EIA to examine the role of conservation in the choice of heating and cooling fuel.

To accommodate a wide audience, EIA decided to respond to the Committee's request in the context of a report on reducing home heating and cooling costs. Accordingly, this report discusses ways to weatherize the home, compares the features of the three major heating and cooling fuels, and comments on the types of heating and cooling systems on the market. The report also includes a worksheet and supporting tables that will help in the selection of a heating and/or cooling system.

A number of organizations have provided substantial assistance in the preparation of the report. In particular, the authors wish to acknowledge the assistance and contributions from the following organizations:

Air-Conditioning and Refrigeration Institute
American Gas Association
Appliance Manufacturers Association
Citizen Action
Dorgan Associates
Edison Electric Institute
Gas Appliance Manufacturers Association
Petroleum Marketers Association of America

In response to a Federal Register Notice requesting comments, the following organizations submitted information and comments that were used in the preparation of this report—Associated Electric Cooperative, Atlanta Gas Light Company, Brooklyn Union Gas Company, Cardinal Fiberglass Industries, Carolina Power and Light, Central and South West Corporation, Columbia Gas, Con Edison, Consumer Energy Council of America Foundation, ElectriCities of North Carolina Incorporated, Empire District Electric Company, Energy Kinetics, Walter Epp, Fiberglass Petroleum Tank & Pipe Institute, Florida Power Corporation, Henry Gluckstern Attorney and Counselor at Law, Illinois Power Company, Metropolitan Gas Marketing Group, Morgan, Lewis & Bockius Counselors at Law, Nashville Electric Service, New York State Consumer Protection Board, New York State Consumer Energy Office, North Carolina Petroleum Marketers Association, Oil Heat Task Force, Pacific Power, PacifiCorp, Petroleum Marketers Association of America, PSI Energy, South Carolina Electric & Gas Company, Southern California Edison, Southern California Gas Company, Union Electric Company, and the Wisconsin State Energy Office.

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Although the energy crisis of the late 1970's has passed, the costs of home heating and cooling are still a concern to homeowners. The homeowner's fuel bill depends on four major elements:

- The climate in which the house is located
- The amount of heat that escapes from the house in winter or the amount of heat and humidity that enters the house in the summer
- The cost of the fuel used in the central heating and cooling system
- The cost and efficiency of the central heating and cooling system.

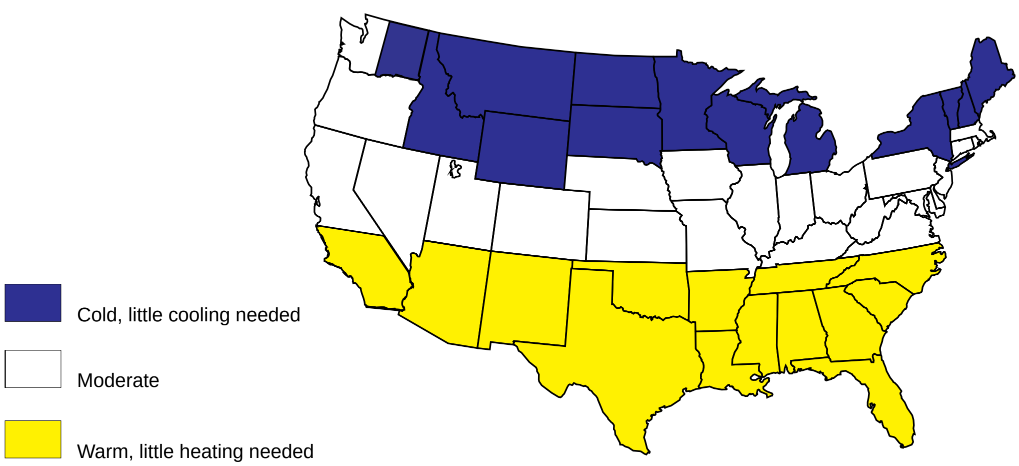
Climate is the biggest factor in determining how much heating and cooling a house will need. Although the climate and the fuel (to some extent) are out of the homeowner's control, they determine how the homeowner deals with the other two elements. This report aims to help homeowners manage those elements effectively in order to reduce their home heating and cooling costs. The report aims especially at those homeowners whose central unit is reaching the end of its useful life.

The United States can be divided into three major climate zones based on a standard unit of measure called a heating degree-day (Figure 1). A heating degree-day (HDD) occurs when a day's outdoor temperature averages 64 degrees Fahrenheit, just 1 degree below 65 degrees Fahrenheit; a 10 HDD occurs when a day's temperature averages 55 degrees Fahrenheit. The northern climate zone has more than 7,000 HDD; the middle climate zone has between 4,000 and 7,000 HDD; and the southern climate zone has fewer than 4,000 HDD.

Older and larger homes lose more heat in winter and thus have higher heating bills.

The home's first line of defense against the climate—the attic, basement, walls, windows, and doors—should receive a periodic conservation checkup. Through weatherization—

Figure 1. U.S. Map Showing the Three Major Climate Zones



Source: Energy Information Administration, *Household Energy Consumption and Expenditures 1990*, DOE/EIA-0321(90), February 1993, p. 327.

The zones are representative of the average climate. In each climate zone, there are cooler and warmer areas that result in higher or lower heating bills.

HOME HEATING AND COOLING COSTS: AN OVERVIEW

reducing air leakage and insulating the house —homeowners can reduce their fuel bills significantly.

The second most effective measure for reducing fuel bills is to use the least expensive fuel in the particular area in which the homeowners live. Contrary to what many fuel advertisers would have the public believe, no one fuel is universally the least expensive. In some areas, heating oil is the least expensive, whereas in other areas, natural gas or electricity is the least expensive.

Fuel prices often vary by county, and no one fuel is universally the least expensive.

Also contrary to the advertisements, a homeowner's primary consideration in selecting a fuel should be its cost. None of the three fuels has any significant advantage over the others in terms of safety or health and environmental impact; all three are safe, presenting relatively few dangers to human health or the environment.

Finally, a new, high-efficiency central heating and cooling system will greatly reduce monthly fuel bills. However, these systems are expensive, and most homeowners will wait until the poor performance and high repair bills for the old system necessitate a replacement. When they do reach that point, they will have many choices—oil or gas furnaces or boilers, or electric heat pumps. Most homeowners will simplify this process by choosing the same type of unit as the one they are replacing. However, some may find it desirable to switch fuels or to switch the type of heating unit. For example, in some homes, the original heating unit may have been fueled with oil simply because natural gas was unavailable at the time. Since the deregulation of natural gas in 1985, natural gas heating units have become strong competitors with oil heating units. In other areas, rebates offered by local utilities may make a new type of system desirable.

The most efficient heating or cooling system will result in the lowest bills.

Having chosen the type of system, the homeowner must then consider its efficiency. Because of improved technology and strict Federal standards, new heating and cooling systems on the market are much more efficient than older units. Generally, homeowners can save the most over the life of the unit by buying the most efficient system they can afford. To determine their best option, homeowners should contact their local appliance dealers and utilities to determine the initial and operating costs of the various units available. With these figures in hand, they are ready to make an informed choice as to the best system for their home.

Having weatherized their homes, selected the least expensive fuel in their area, and selected the most efficient heating system, homeowners can realize much lower fuel bills. This report attempts to provide some general guidance on each of these measures, but few choices apply in every region in the country. In the end, all decisions about the relative merits of specific types of weatherization, fuels, and equipment are local ones.

WEATHERIZING THE HOME

Before rushing out to buy a more efficient heating system in hopes of reducing their heating and cooling bills, homeowners should first make sure that their home is adequately weatherized. Home heating bills will be high—no matter what fuel is used or how efficient the heating-cooling system—if the house has leaking windows, door frames, or heating ducts, and poorly insulated walls, attics, and crawlspaces.

Weatherizing the home can lower energy consumption, which means lower monthly bills. Based on a 1990 evaluation of the Department of Energy Weatherization Program, homeowners can expect weatherization to lower their space heating consumption around 18 percent, at a *contracted* cost of about $1,710 in 1993 dollars. [2, p. 10.18] If the homeowners want to do much of the work themselves, the cost of weatherization can be even less.

To find out how energy efficient their home is, homeowners may want to have a local utility or an independent architect or engineer perform an energy audit (Figure 2). Although the independent audit will cost a great deal more than a utility audit (which may even be free), the homeowner may prefer the objectivity of an independent person.

In addition to checking the efficiency of the heating and cooling equipment (to be discussed in the next chapter), the auditor will check for drafts and faulty insulation. When the auditor has finished an inspection, a written report will usually be presented that recommends what should be done and advises as to the likely benefits and the estimated cost. This chapter gives an overview of the recommended actions that energy auditors often make, many of which homeowners can implement themselves. [26]

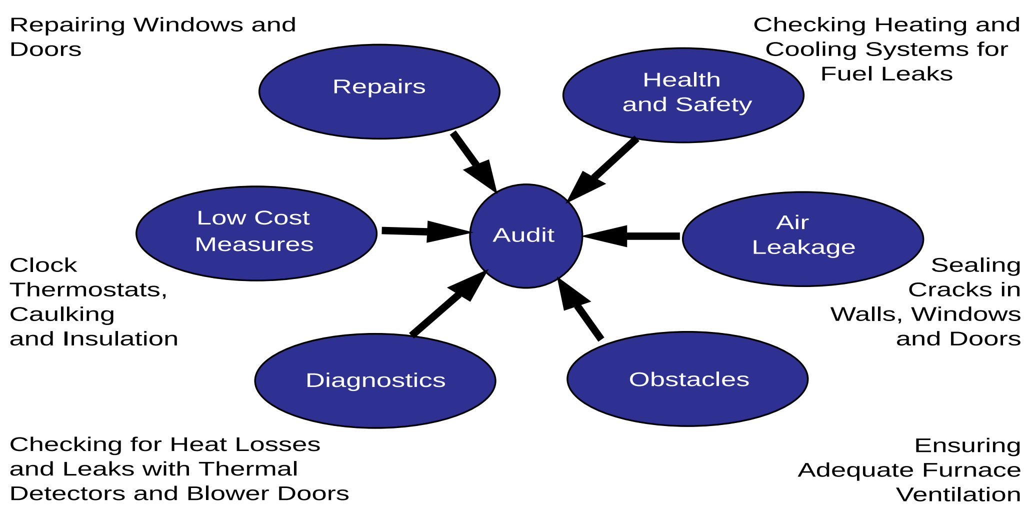
Homes need a periodic tuneup to reduce leaks and heat losses and thereby minimize heating bills.

Air-Leakage Control

The easiest way for a home to lose its warmth or gain humidity is through leaks around doors and windows; around openings in walls, floors, and ceilings; and around heating ducts.

An energy auditor has many tools to detect air leaks and heat losses.

Figure 2. Information Provided by an Energy Audit



Source: Marilyn Brown et al., *National Impacts of the Weatherization Assistance Program in Single Family and Small Multifamily Dwellings*, ORNL/CON-326, U.S. Department of Energy, May 1993.

WEATHERIZING THE HOME

The homeowner can stop many leaks from windows and doors by caulking and weather-stripping. During periods of severe cold, temporary sheet plastic storm windows fitted on the inside of larger windows work well. If the draft from the window is particularly bad and if the window rattles or is loose, a new storm window may have to be installed. However, auditors of energy efficiency have found that installing storm windows saves less energy than other simpler and less costly conservation measures. [2, p. 9.11]

In addition to caulking and weatherstripping, doors may need to be adjusted or a draft stop and edge seal added. In very cold and very hot climates, a new storm door may be advisable, but—like storm windows—storm doors may not be cost effective.

Sealing leaks often requires attention to detail. A small leak can lose a considerable quantity of heat over the year.

Walls, floors, and ceilings may also provide openings for drafts, especially at those points where plumbing or electrical wiring passes to the outside. Likely sources of drafts are around electrical outlets and ceiling fixtures and at openings to the attic.

Leaks around heating ducts can reduce the amount of heated or cooled air delivered into the living space. In many older houses with forced-air furnaces, an estimated 20 percent of the heated or cooled air is wasted. To compensate, homeowners turn up the thermostat to get the heat they need or turn it down to get the desired cooling, raising their heating-cooling bills considerably. Sealing any duct leaks can be a highly effective conservation measure.

Insulation

Many homes are losing a great deal of heat in winter and letting in a great deal of heat in summer because they lack proper insulation in their attics, walls, ceilings, basements, and crawlspaces.

Installing insulation in the attic is relatively easy, a task many homeowners will choose to do for themselves. However, they must take care not to insulate over eave vents or on top of recessed lighting fixtures or other heat-producing equipment on the attic floor, keeping insulation at least 3 inches away from the sides of these fixtures.

Insulating an attic will cost between $100 and $1,000—depending on whether the attic already has some insulation. Annual heating and cooling savings should range from around 5 percent—if insulation is being added to present insulation—to as much as 30 percent if the attic had no insulation at all. [22, p. 4]

The insulation of exterior walls is an expensive measure that requires the services of a contractor, but it may be cost effective for houses in climates that are very hot (like Texas) or very cold (like Minnesota). Costs range from 30 cents to $1.65 per square foot (about $1,500 for an average home), but savings could amount to 20 percent of heating and cooling costs. [22, p. 4]

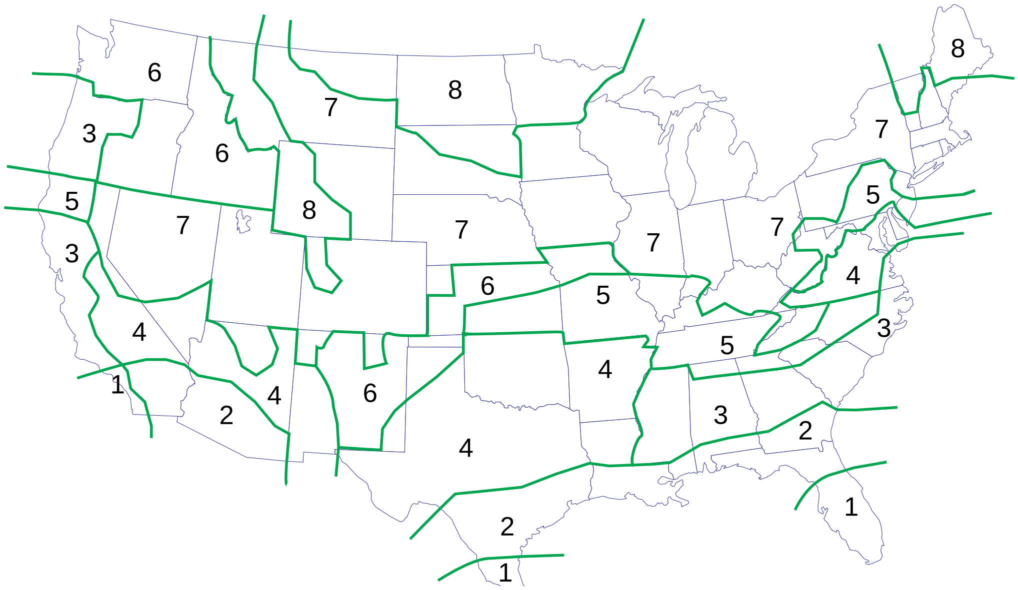
In some older homes, the exterior walls are not only uninsulated but the cavity between the inside and outside walls is often open to both the basement and the attic. As a result, a circulating column of air conducts heat from the basement, past the inner living space, up to the attic, and out of the house. One study showed that blowing high-density cellulose into the wall cavity of an old house can reduce air leakage by 50 percent. [2, p. 9.9]

Insulating floors over unheated spaces, such as basements and crawl spaces, could cost from $200 to $400. Savings could amount to 8 percent on previous heating and cooling costs. [22, p. 4]

Before buying insulation, homeowners should make sure they understand what R-values or R-numbers they need. R-values indicate the thickness of the insulation material and its resistance to winter heat loss or summer heat gain. The higher the R-number, the more effective the insulating capability.

The amount and type of insulation a house needs depends on the space to be insulated, the climate, and—to some extent—the type of heating system (Figure 3 and Table 1).

Figure 3. Eight Insulation Zones in the United States



Source: U.S. Department of Energy, *Tips for Energy Savers*, DOE/CE-231, October 1991.

Generally, the colder the climate the thicker the insulation should be and the higher the R-value needed.

Table 1. Recommended R-Values for Existing Houses in Eight Insulation Zones in the United States

Insulation Zone (Figure 3)	**Ceiling Below Ventilated Attics**	**Floors Over Unheated Crawlspaces, Basements**	**Exterior Walls** (wood frame)	**Crawlspace Walls**
1	19 - 30[a]	0	0 -11[a]	11
2	30	0	11	19
3	30 - 38	0 - 19[a]	11	19
4	30 - 38[a]	19	11	19
5	38	19	11	19
6	38	19	11	19
7	38 - 49[a]	19	11	19
8	49	19	11	19

[a]Higher figures apply to homes with electric resistance heating units.
Source: U.S. Department of Energy, *Tips for Energy Savers*, DOE/CE-0231, October 1991, p. 15.

Choose the thicker insulation when using electric resistance heating.

For example:

- Houses need the most insulation in ceilings below ventilated attics and the least in the exterior walls of wood-framed houses.

- Most houses need to insulate floors over unheated crawlspaces and basements; however, houses in warm climates like those in Florida, southern Texas, and southern New Mexico do not need to do so.

- For most houses, the type of heating system does not affect the amount of insulation needed; however, houses in some climates—like those of North Carolina and northern California, in Zone 3—need insulation having an R-value of 38 if the heating unit is electric resistance, but insulation having an R-value of 30 if the heating unit is oil, gas, or heat pump.

Weatherization Savings

A recent Department of Energy (DOE) analysis of its weatherization programs also found that most weatherization measures are well worth the money they cost, particularly in colder climates (Table 2). [2, p. 10.18] DOE weatherized about 200,000 single-family and small multi-family homes across the country in 1989. The typical dwelling weatherized was a 51-year-old single-family detached dwelling in the central region of the United States with 1,193 square feet of heating space. The typical house was heated by an old gas furnace, had significant air leakage, and had little insulation.

The weatherization savings are average. Since every home is different, there is a wide variation in savings across homes.

During an audit of the results of these weatherization programs, DOE found that the most significant savings occurred in homes heated by electric resistance furnaces, where the savings averaged 35 percent of the heating bill for the same average cost.

DOE also found the most significant savings in the colder and moderate climates. Programs in these areas used energy audits more frequently, and they tended to focus on high energy users. An average expenditure of just over $1,700 per home resulted in first-year savings of 25 percent of the natural gas heating bill, 42 percent of the electrical heating bill, and 17 percent of the fuel oil heating bill.

In States with a warmer climate, the programs cost about $1,500 per home but resulted in only a 15-percent savings on the heating bill for gas-heated homes and a 16-percent savings on the heating bill for electric-heated homes.

Table 2. Average Cost of Weatherization and Resulting Savings for Homes in the Department of Energy Weatherization Program

Category	Savings
Weatherization costs per dwelling (contracted)	$1,710
First-year energy savings per dwelling	16.4 million Btu
Energy savings as a percentage of space heating use	18.2%
Energy savings as a percentage of total energy use	13.5%
First-year dollars saved per dwelling	$130

Note: Costs and savings are in 1993 dollars.
Source: Marilyn Brown et al., *National Impacts of the Weatherization Assistance Program in Single-Family and Small Multifamily Dwellings*, ORNL/CON-326, U.S. Department of Energy, May 1993, p. 10.18.

Financial Assistance

There are two significant sources of funds to help homeowners weatherize their homes. Most States have a weatherization program partly funded by the Department of Energy, designed to help low-income homeowners lower their energy bills. Information on this program can be obtained from the State energy office. A local public library should be able to help locate the office.

Many utilities have "Demand Side Management" programs that will assist any utility customer. Depending on the local utility, these programs may include weatherization assistance, rebates for purchasing more efficient heating or cooling systems, or installation of load control devices. The local utility will be the best source of information on availability and extent of the program. Utilities have reported plans to expand these programs to a level of $4 billion dollars by 1997. [4, p. 174]

Generally, these are electrical utilities, but oil and gas customers are often eligible.

OIL, NATURAL GAS, AND ELECTRICITY: COMPARISON OF MAJOR FEATURES

Oil vendors offer to convert the homeowner's electric heating system to "safe, efficient oil heat," promising significant savings in a brief payback period. Natural gas vendors proclaim that natural gas is "cleaner, more dependable, and more economical than oil." And electric utility companies assert that "the new heat pump beats gas hands down."

Bombarded by such claims about the relative cost, safety, and health and environmental impacts of the three fuels, homeowners may feel some bewilderment when the time comes to replace their old heating-cooling system or to select a new one. This chapter aims at helping the homeowner examine some of the competing claims of the three major fuels.

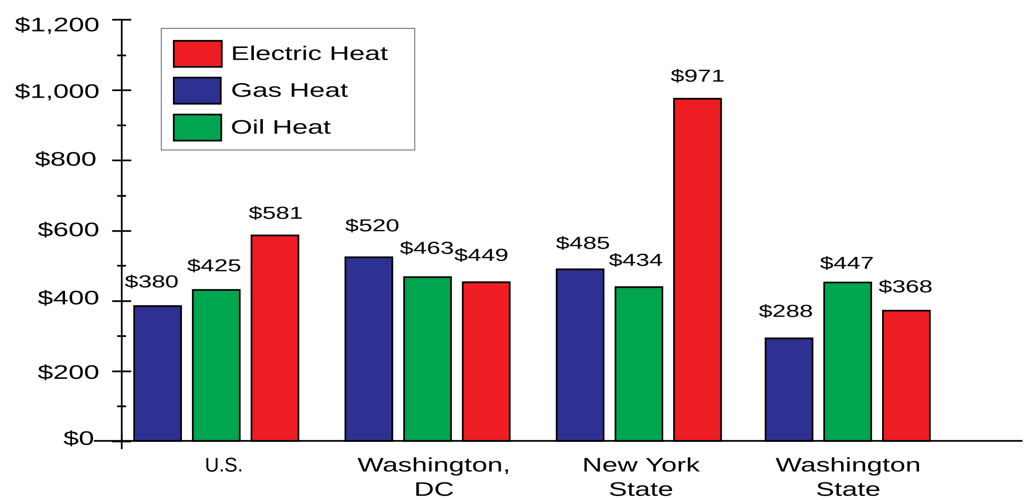
Cost

Each fuel supplier claims that his fuel is the cheapest. In reality, the price of a fuel depends heavily on where a home is located because fuel prices differ in each State, and even in each city in a State. If the same home, with the same heating system, could be transported to three different States having the same weather, the heating bills would be quite different just because of fuel prices (Figure 4).

Based on national average fuel bills in December 1993, for example, a typical home with natural gas heat would have had the lowest heating bills. [6, Table 9] However, based on State average prices, the same home in Washington, DC, would have had lower heating bills with an electric heat pump than similar homes with gas or oil heating units. But, in New York State, a scant 200 miles further north, heating costs would have favored fuel oil. And in Washington State, heating costs would have again favored natural gas. Based upon city average prices, the results would likely have been different again.

These typical bills are based upon national and State average prices for all users.

Figure 4. Typical Heating Bills for the Nation at Large, and for Three Specific Areas in December 1993



Note: Prices are the December 1993 average for all residential users in each region. Costs are evaluated with minimum standard efficiency equipment and the same heating requirement.

Another way to show how fuel prices can vary from place to place is to compare the average price of a fuel across the Nation with its average price in particular States:

- In the week ending January 3, 1994, fuel oil averaged about 92 cents per gallon across the Nation, but the average cost in particular States ranged between a low of about 67 cents in Iowa and a high of about $1.04 in New York and the District of Columbia. [5, Table 7]

- In December 1993, the average price of natural gas delivered to residential consumers across the Nation averaged $6.07 per thousand cubic feet, but the average cost in particular States ranged between a low of $3.86 in Alaska and of $4.51 in Colorado to a high of $9.84 in Florida and even $17.01 in Hawaii. [9, Table 60]

- In 1993, electricity averaged 7.9 cents per kilowatthour across the Nation, but the average cost in particular States ranged between a low of 4.7 cents in Idaho and Washington and a high of 12.4 cents in Vermont. [11, Table 24]

Fuel prices also vary over time. As some fuels have become deregulated, their prices have tended to fluctuate more as demand changes during different seasons of the year. This makes monthly comparisons of prices somewhat misleading unless a longer term view is taken. Over the long term, the Energy Information Administration projects that both oil and gas are expected to rise by about 5 percent per year for the next two decades, while electricity will rise only about 4 percent per year, with only minimal regional changes. [4, Table A3] Despite seasonal fluctuations, homeowners can be reasonably confident that the fuel that has tended to be the most economical in their area should remain the most economical for years to come.

In short, local prices and conditions determine the annual cost of heating. No fuel is the universally agreed-upon best choice. Any of the three major fuel systems—oil heat with central air-conditioning, gas heat with central air-conditioning, and heat pump heat with central air-conditioning—could conceivably be the cheapest overall system in a given area, at a given time. Homeowners who want the lowest possible energy bills need to find out how the various fuels have compared in price in their particular area. (See Appendix A for a worksheet and cost tables that cover a range of prices.)

Heating fuel prices have always fluctuated. However, an efficient heating system will minimize the effects of these changes.

Safety

Few deaths or accidents result from home heating equipment, no matter which fuel is used. Fires and deaths resulting from all heating equipment account for less than one-fifth of all home fires, and heating systems rank below smoking and arson in the list of principal causes of fires. Of the fires caused by home heating systems, most result from portable space heaters and chimney fires. These two sources account for three-fourths of all home heating fires and four out of five related deaths. [15]

Comparisons of the safety records are difficult because the statistics are not necessarily gathered in a way that points to the cause of the incident. Data exist on some explosions and electrocutions, for example, but not on the number resulting from home heating systems.

OIL, NATURAL GAS, AND ELECTRICITY: COMPARISON OF MAJOR FEATURES

The best sources for information on accidents and deaths resulting from home heating units are The National Fire Protection Association (NFPA) and the Consumer Product Safety Commission (CPSC). However, both sources combine statistics on oil and propane central heating systems, making it impossible to determine the statistics for oil central heating systems alone.

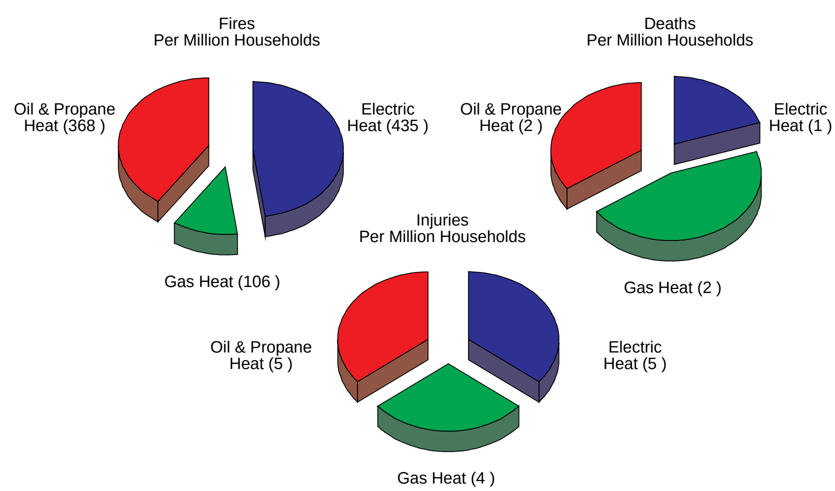
NFPA analyzes statistics on deaths and injuries resulting from fires in the home. The CPSC analyzes statistics on accidents and injuries that hospital emergency rooms report and that can be associated with various home appliances, including heating and cooling systems.

Based on these two sources, from 1987 to 1991, central heating systems caused an average of 909 fires per million households per year (Figure 5). During the same period, an estimated 2 deaths and 4 or 5 injuries occurred per million households per year as a result of the fires and of carbon monoxide poisonings resulting from central home heating units: [15, Tables 14, 19]

- Gas central heating systems caused an average of just over 2 deaths and 4 injuries from fires or carbon monoxide poisonings per million households per year.
- Liquid fuel central heating systems (oil and propane) caused an average of just under 2 deaths and 5 injuries per million households per year.
- Electric resistance and heat pump central heating systems caused an average of 1 death and 5 injuries per million households.

Electrical and mechanical problems tend to be the cause of many fires associated with electric and oil heating systems.

Figure 5. Fires, Deaths and Injuries per Year Caused by Home Central Heating Units, 1985-1991



Source: John R. Hall, Jr., *U.S. Home Heating Fire Patterns and Trends Through 1991*, National Fire Protection Association, September 1993, Tables 14, 19.

Another way to put these figures into perspective is to realize that, in the same period, automobile accidents caused over 450 deaths per million households per year. [21]

Health Impact

None of the fuels presents a health hazard when used in a properly installed and maintained heating unit. In most cases, the small amounts of toxic gases that heating units produce are vented harmlessly up the chimney.

Problems can occur, however, if (1) a house has been so tightly weatherized that too little outside air enters the house to provide sufficient oxygen for complete combustion or (2) walls have been built in the heating unit area, obstructing the normal flow of air to the unit, preventing the gases from rising up the chimney quickly, creating only a weak draft to draw inside air into the combustion chamber. [25, p. 1]

Very low combustion air and a weak draft can set the stage for a hazardous condition known as “backdrafting.” Backdrafting occurs when a different exhaust draft, such as a heavy-duty kitchen exhaust fan or a large fire in the fireplace, is stronger than the draft of the gas furnace vent and draws the combustion exhaust gases back into the house instead of up the vent. Backdrafting can cause serious health risks and even death.

Environmental Impact

Both natural gas and fuel oil burned in home heating units produce small amounts of nitrous oxide and carbon monoxide and even smaller amounts of soot, sulfur dioxide, methane, and volatile organic compounds (Table C5 in Appendix C). These fuels (both carbon based) also produce large quantities of carbon dioxide when they are burned in a home heating system. However, natural gas produces nearly 30 percent less carbon dioxide than either heating oil or the average electric utility generation plant, and there is concern that emissions of carbon dioxide and other greenhouse gasses are contributors to global warming. All of these emissions are normally vented through the chimney stack, and for this reason it is important that furnace ventilation be checked periodically.

Electricity used in home heating produces no atmospheric emissions at the home. However, electricity generated by the burning of fossil fuels—the most common source of electricity—produces somewhat larger quantities of pollutants at the generating plant sites (Table C5, Appendix C). This concerns not only the use of electricity for heating, but also the operation of oil and natural gas furnaces (the electric furnace fans and pumps) and all other electric devices in the home.

For all systems, the most efficient combustion leads to the least consumption and the lowest environmental emissions.

CHOOSING A HEATING AND COOLING SYSTEM

Electric and gas utility rebates and dealer discounts can substantially reduce the cost of high-efficiency equipment.

Different heating systems can be rated by comparing their payback time relative to the current system.

Replacing an old, inefficient central heating and cooling system with a new, efficient one can result in much lower energy bills. This chapter describes various heating and cooling options for the homeowner and calculates the annual costs of operating each, using a range of heating and cooling requirements and a range of fuel prices.

After determining their heating requirement and finding the fuel prices in their area, homeowners who want to replace an old central heating and cooling system must choose a new system. Most homeowners simplify this process by choosing the same type of unit as the one they are replacing. Still, homeowners will have to decide what "efficiency" to buy.

The efficiency of a heating unit is the amount of energy produced that is actually used for heat. A furnace having an efficiency of 78 percent, for example, would use 78 percent of the heat produced for heating, with the remaining 22 percent being vented up the chimney.

The efficiencies of furnaces and boilers, heat pumps, and air-conditioners are measured in different ways:

- The efficiency of furnaces and boilers is stated as an average over the heating season, the so-called "Average Fuel Use Efficiency (AFUE)."

- The efficiency of the heat pump has two measures: (1) its ability to extract heat from its heat source, usually the outside air, and to expel it into the home—called its "Heating System Performance Factor (HSPF)," and (2) its ability to extract heat from the home and to expel it into the outside air—called its "Seasonal Energy Efficiency Ratio (SEER)."

- The efficiency of the air-conditioner is also measured in terms of SEER.

Equipment bought before 1992—when efficiency standards for furnaces, boilers, or heat pumps were first established—is probably much less efficient than the heating and cooling equipment available today.

Generally, when it comes time to replace all or part of the home heating and cooling system, homeowners can save the most over the life of the unit by buying the most efficient system they can afford. To encourage homeowners to buy higher efficiency units, many utilities offer rebates to the homeowner who buys a better than minimum efficiency unit. These rebates can be substantial, paying half or more of the extra cost of the unit.

To determine whether it would be cost effective to replace an old heating unit with a new, high-efficiency one, homeowners should determine how much the new unit will reduce their annual energy bill and then divide the cost of the furnace by the annual savings to determine how many years it will take to pay for the upgraded unit.

For example, upgrading from an old unit with an efficiency of 50 percent to a standard-efficiency furnace of 78 percent would save about $36 for every $100 of the annual fuel bill. If the annual fuel bill was $400 and the new unit cost $2,000, it would pay for itself in about 14 years.

Upgrading to the most efficient unit (95 percent) would save about $47 for every $100 of the fuel bill. If the new unit cost $2,500, it would also pay for itself in about 13 years (Appendices A and B).

CHOOSING A HEATING AND COOLING SYSTEM

By comparing the final installed costs of various units (oil, gas, and electric) after rebates and the savings in heating and cooling bills —which would of course depend on the local price of the various fuels—homeowners can determine which heating unit is the best buy. This chapter gives some examples of typical heating and cooling costs, but the appendices provide costs for a wider range of efficiencies.

Oil Heat

In 1990, the Energy Information Administration (EIA) estimated that approximately 12 million homeowners use an oil-fired furnace or boiler for home heat. Most users live in the Northeastern and Midwestern United States. [10, Table 32] According to the industry, oil-fired furnaces and boilers last an average of about 20 years before replacement. [18]

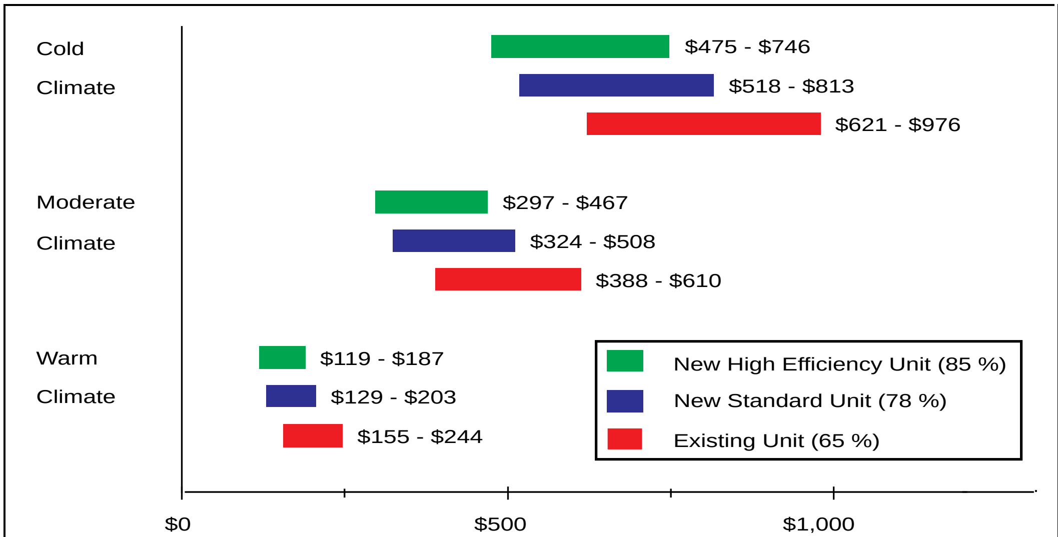
While not as large as it once was, the oil market is still strong. The new and replacement market for boilers and furnaces represents an industry with currently over 30 certified manufacturers, most of whom also manufacture gas-fired furnaces and boilers. [14]

New oil furnaces range from a year-round efficiency of 78 percent (the standard), up to about 86 percent. Boiler efficiencies can reach as high as 89 percent. [14] An 85-percent efficient oil furnace will cost an estimated $2,500. [17]

All furnace installation costs vary by locality and the difficulty of the project.

Homeowners living in a cold climate who have a 65-percent efficient oil furnace and an annual heat bill of $976 could save $230 a year by replacing their old furnace with a high-efficiency model (Figure 6). Thus, a new furnace costing $2,500 would have a payback period of about 11 years.

Figure 6. Range of Typical Heating Bills for Oil Heat in 1993 by Climate and Unit Efficiency



Source: Heating cost ranges for each climate from Table B1.

The bars represent the range of costs a homeowner might expect, solely because of the range in fuel prices across the United States.

Gas Heat

Gas is the most popular form of space heating. In 1990, EIA estimated that about 58 million homes used natural gas heat, about 60 percent of all homes. [10, Table 31] According to the industry, gas furnaces last an average of about 19 years before replacement. [19]

The average system is about 65-percent efficient, but older gas furnaces can be less efficient leading to higher savings from an upgrade.

New natural gas furnaces are available in a wider range of efficiencies than oil units. In addition to conventional furnaces that range up to an AFUE of about 85 percent, "condensing" furnaces are also available. These furnaces, which recover heat from the furnace exhaust, can achieve up to 96-percent efficiency. [14]

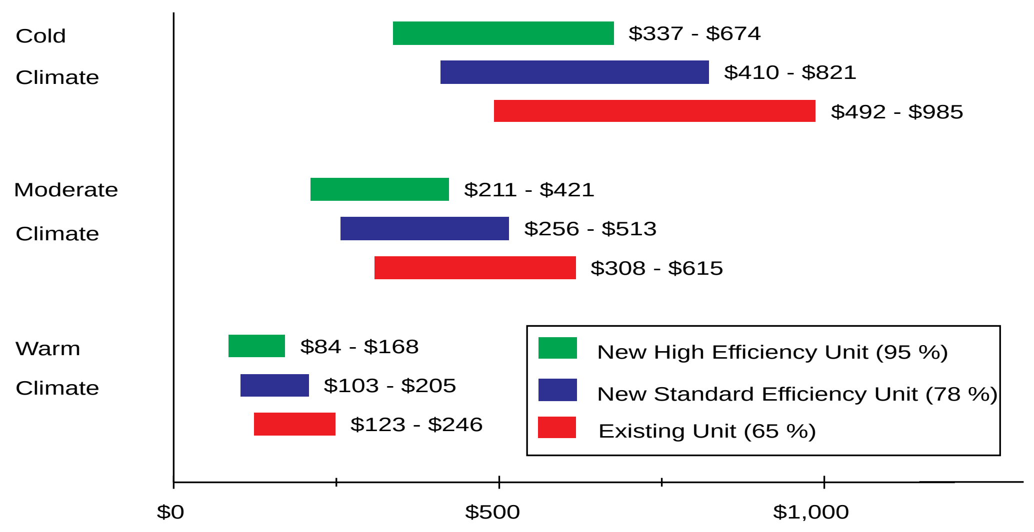
A 95-percent efficient furnace would cost about $2,800. [17] Homeowners living in a cold climate who have a 65-percent efficient gas furnace and an annual heating bill of $985 might save $311 a year by replacing their old furnace with a high-efficiency model (Figure 7). As a result, a new furnace would pay for itself in about 9 years.

Retrofitting Older Oil and Gas Systems

Older oil and gas furnaces and boilers can also be retrofitted with electronic ignition and a vent damper to reduce heating bills. Oil furnaces and boilers can also be equipped with a new, more efficient burner. These devices account for some of the improvement in efficiency found in a new system. For any of these options, homeowners should seek professional advice and installation to ensure that the improved system is safe.

Electronic ignition eliminates the pilot light on a gas system. It costs approximately $250 and can save its installation cost in 3 to 6 years. [25] A vent damper closes the exhaust vent of either an oil or gas system when it is not

Figure 7. Range of Typical Heating Bills for Gas Heat in 1993 by Climate and Unit Efficiency



Source: Heating cost ranges for each climate from Table B2.

Despite the range in fuel prices, the cheapest bills occur with the most efficient furnace.

operating. A vent damper costs about $400 and can save 3 to 10 percent of the heating bill. [25] A new oil burner, which produces a hotter flame than the older burners installed in the 1960's, costs about $500, and can save 10 to 15 percent of the heating bill. [16]

Electric Heat

Electric heat is of two types: electric resistance heat using an electric furnace and electric heat pumps. In 1990, EIA estimated that about 15 percent of U.S. households were using electric heat: about 6.7 million households were using electric furnaces, and 6.4 million households were using heat pumps. [10, Table 31] According to the industry, conventional heat pumps last an average of 11 years and electric furnaces 16 years before replacement. [19]

Electric resistance heaters are usually the most expensive form of heat, but they make sense in climates where little heat is needed because electric furnaces or base board heaters are generally cheaper to install. The efficiency of the electric furnace is close to 100 percent, since almost all the electrical energy ends up as usable heat. However, when the inefficiency of electricity generation by the power company and the transmission losses to the consumer are taken into account, the primary efficiency is close to 33 percent. [6, Table A8]

The standard efficiency for heat pumps is 6.8, but the most efficient heat pumps have an HSPF of 10 or more. Ground-source heat pumps can even reach an HSPF of 14 or more, because they rely on the ground for their heat source, and this is more uniform year-round. [1]

The most efficient heat pump (Figure 8) will cost about $3,900 to install, including the heat pump and the air handler but no significant duct work. [17] An existing furnace may substitute for the air handler, saving about $1,500. Choosing this heat pump to replace the existing old heat pump would save $187 per year with the most expensive electricity in the moderate climate.

Installation costs of heat pumps depend on what they are replacing.

Heat pumps and electric furnaces are usually installed in newer, more efficient homes for which the heating requirement is smaller than for the average home. For these "tighter" homes, the utility company will often quote a lower winter rate for "all electric" homes, perhaps with a rider allowing the installation of load controllers to limit peak summer use, or to control specific loads such as electric hot water heaters.

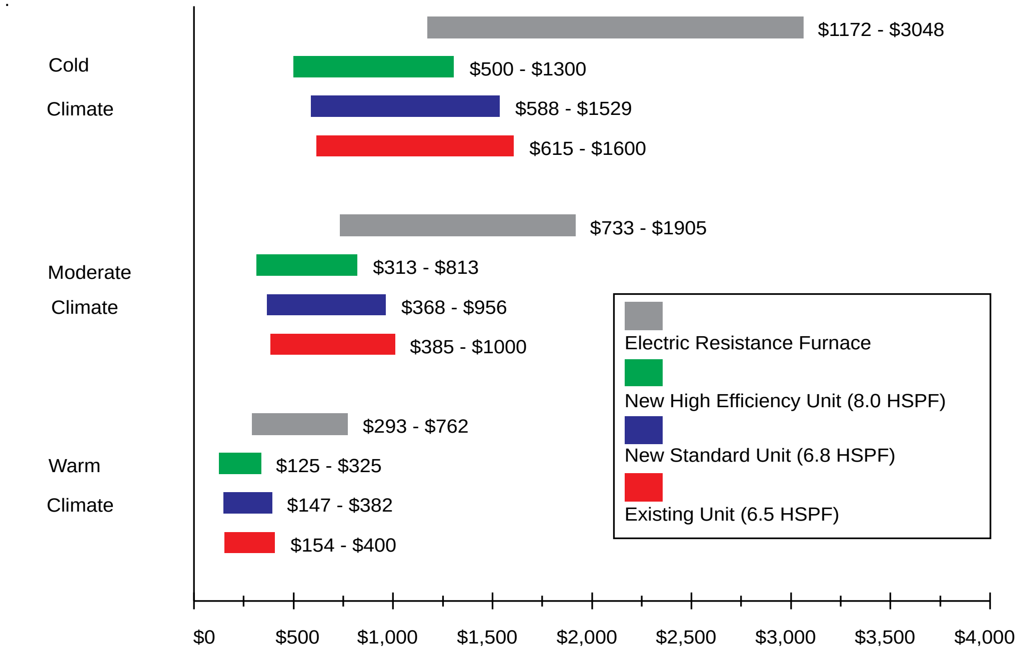
The operating costs of heat pumps depend significantly on how cold it gets in winter. [1] Unlike a furnace or boiler, the colder the weather becomes, the less heat a heat pump delivers. The heat pump cost ranges in Figure 8 do not show the effect of backup heat and thus understate the total operating cost for a heat pump system.

Heat pumps usually have a backup heat source that is switched on when the outside temperature falls below the freezing point. Since the use of backup heat is expensive, few houses in cold climates have heat pumps. However, ground-source heat pumps (which rely on the ground for their source of heat) are much less susceptible to cold weather and are promoted as the better choice in the colder climates of the Northern States. [17]

Heat pumps have the advantage that electricity is available nearly everywhere, and no special hookup is required.

The backup source for heat pumps is usually electric resistance heat. (The backup can, however, be an old furnace.) Electric backup heat can increase the cost of heating significantly, since an electric furnace costs twice as

Figure 8. Range of Typical Heating Bills in 1993 for Electric Heat by Climate and Unit Efficiency



Source: Heating cost ranges for each climate from Tables B3 and B4. The costs do not include the cost of auxiliary heat in the coldest climate.

The average operating heat pump has an HSPF of 6.7, not much lower than the current standard of 6.8. It is nearly twice as efficient as an electric furnace.

much to operate as the average heat pump. For example, if the temperature is below freezing for 10 percent of the winter season, then the total heating bill with electric resistance backup could be as much as 20 percent more than without use of backup. Using an existing oil or gas furnace as backup will generally reduce this cost substantially.

Air-Conditioning

In the warmer climates of the United States, air-conditioning is as standard as a heating system. However, in 1990 only 25 percent of the homeowners in the coldest climate owned central air-conditioning, compared to 60 percent in the warmest climate. [10, Table 37] According to the industry, an air-conditioner lasts an average of 12 years, about the same as a heat pump. [19]

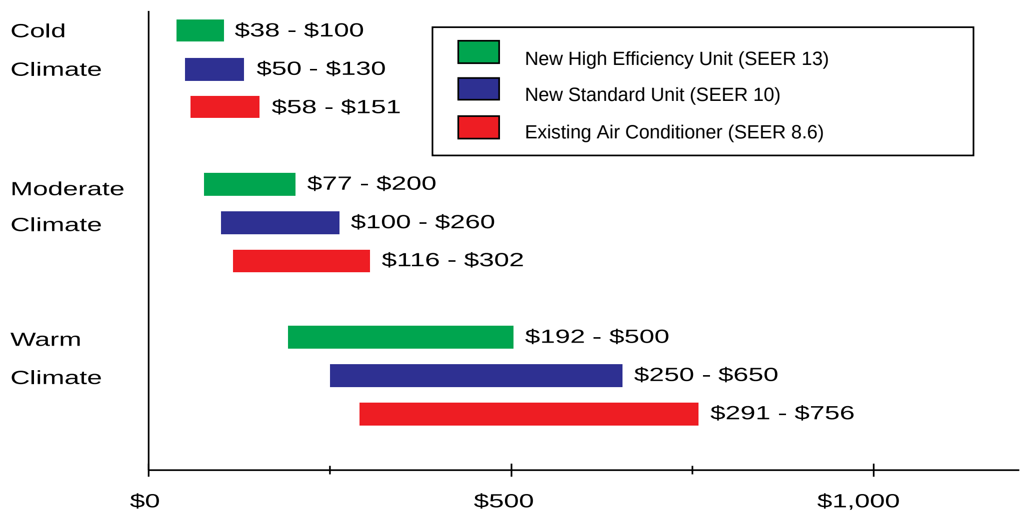
Air-conditioning serves two purposes: It lowers the inside air temperature to a comfort level of 78 degrees Fahrenheit or so, and it keeps the humidity in a more comfortable range. When cooling, air-conditioners and heat pumps operate alike. The standard SEER for central air-conditioners and heat pumps is 10, but many units exceed 16. Because the SEER is the ratio of the heat removed to the electricity used and there are 3.4 heat units in an electrical unit, a SEER of 10 means that the standard units remove three times as much heat as they consume in electric energy.

Higher efficiency leads to lower seasonal costs. For example, replacing an old air-conditioner with a SEER of 8.6 with a unit having a SEER of 13 could save about one-third of the old cooling bill (Figure 9).

The size of an air-conditioner or heat pump is measured in “tons” of cooling capacity, equivalent to tons of ice melted per day. Sizing the unit is a task that should be done by an experienced professional. Cooling experts suggest that the unit should be as small as possible, because if the unit is sized to run continuously in the hottest weather, it will run more efficiently and will dehumidify more effectively. Otherwise, an oversized unit can cool a home before it has dehumidified, making the home uncomfortable.

Only in the warmest climates are air-conditioning costs significant.

Figure 9. Range of Typical Cooling Bills in 1993 by Climate and Unit Efficiency



Source: Cooling cost ranges for each climate from Table B3.

APPENDIX A

COMPARING COSTS OF HEATING AND COOLING SYSTEMS

Using the worksheet on the opposite page, homeowners can compare the installation and operating costs of the various heating and cooling systems on the market. With this information in hand, they will be able to choose the best system for their home. The following are the instructions for completing the worksheet, with an example worked out using a natural gas furnace and an electric air-conditioner.

1. The dealer should provide the cost of the finished installation excluding any rebate. (The example gas furnace might cost $2,500 and air-conditioner $2,000 for a total installed cost of $4,500. Actual costs may well be different).

2. Check with both the dealer and the fuel utility for any installation rebate, usually given for heating and/or cooling efficiencies higher than the standard. (In the example, the total utility rebates are $300 for buying a better air-conditioner than the SEER 10 standard. The actual rebate could be different).

3. The dealer will provide the heating efficiency of the unit—the AFUE value for a furnace or boiler or the HSPF for a heat pump. (The example AFUE is 85 with no assumed rebate).

4. The utility company or the dealer will provide the winter heating fuel price for oil, gas, or electricity in cents per gallon, cents per therm, or cents per kilowatthour, the usual units on the utility bill. (The example natural gas is 60 cents per therm).

5. Consult Tables B1 through B4 for standard heating bills for particular fuels, climates, and heating requirements. (The example gas cost is $353 from Table B2, for a moderate climate).

6. The dealer will provide the cooling efficiency—the SEER value for the heat pump or air-conditioner. (The example SEER is 12).

7. The electric utility will provide the summer price of electricity in cents per kilowatthour. Winter and summer prices are usually different. (The example electricity costs 9 cents per kilowatthour).

8. Consult Table B3 for standard cooling bills using either an air-conditioner or a heat pump, for particular climates and cooling requirements. (The example annual cost is $150 in a moderate climate).

9. Add the heating bill and cooling bill for the total annual bill. (The example heating bill is $353 and the cooling bill is $150, for a total annual bill of $503).

Table A1. Worksheet for Comparing Heating and Cooling Costs

Row	Step	*Example*[a]	Option 1	Option 2	Option 3
1	Installed Cost	*$4,500*			
2	Dealer/Utility Rebates	*$300*			
3	Heating Efficiency	*85%*			
4	Heating Fuel Price	*60 cents per Therm*			
5	Standard Heating Bill	*$353*			
6	Cooling Efficiency	*12 SEER*			
7	Electricity Price	*9 cents per Kwh*			
8	Standard Cooling Bill	*$150*			
9	Total Annual Bill	*$503*			

[a]The example is a gas furnace plus an air-conditioner in a moderate climate that requires 50 million Btu of heat and 20 million Btu of cooling.

APPENDIX B
TABLES OF HEATING AND COOLING COSTS

The tables that follow give comparable heating and cooling bills for a typical house having a specified heating requirement for each climate. The heating requirement is stated in British thermal units (Btu), a measure of the energy each fuel provides. (One Btu is the heat needed to warm a pound of water 1 degree Fahrenheit.) The calculation procedure is illustrated in Appendix C. The heating and cooling requirements of a home depend on the climate, the home size and other factors such as its age, state of weatherization and exposure to the elements. Strictly to provide some basis for comparison of heating and cooling systems, a series of average requirements were estimated for a 1,700 square foot home in each of the climates in Figure 1. The requirements estimate the heat delivered by a heating system by dividing fuel consumed for heating by the average efficiency of all heating systems in use. Individual homes could require more or less heating and cooling than these average figures. [10, Tables 31, 32 and 33],[17]

- For homes in cold climates in the Northern States, the heating requirement is assumed to be 80 million Btu for heating and 10 million Btu for cooling. Tables B1 through B4 give comparable heating costs for the amount of heat needed in these climates. Table B3 values are for 20 million Btu, and should be halved to give the costs for the cooling needed.

- For homes in moderate climates, the heating requirement is assumed to be 50 million Btu and the cooling requirement to be 20 Btu. Tables B1 through B4 give comparable heating costs for the amount of heat needed in these climates. Table B3 gives the costs of the amount of cooling needed.

- For homes in warm climates, the heating requirement is assumed to be 20 million Btu, and the cooling requirement is assumed to be 50 million Btu. Tables B1 through B4 give comparable costs for the amount of heat needed in these climates. Table B3 gives the costs for the amount of cooling needed.

To compute the annual heating or cooling cost in one of the tables, use the unit efficiency (furnace, boiler or heat pump) for the row, and the fuel price column to locate the appropriate table entry. In a given location, any one of the systems may offer the cheapest annual heating bill based upon current fuel costs.

The heat pump tables cover both heating and cooling because HSPF and SEER are defined in the same way. Note that in most utility service areas, the electricity price in summer will most likely not be the same as in winter.

Working out the heating bill for the old system works the same way except that the efficiency and fuel price are for the old system. The auditor or the heating engineer should be able to measure the efficiency of the old system if it still operates. The efficiency of the average furnace or boiler is about 65 percent, the average heat pump HSPF is about 6.7 and the average SEER is about 8.3. [17] These average values will suffice, and will underestimate savings because older unit efficiencies can be much less than these values. In most climates where heating is significant, it suffices to focus on heating when choosing between an oil, gas or heat pump unit. Air-conditioning costs will be the same for an air-conditioner or a heat pump. Installation costs will however be different.

Table B1. Annual Cost of Oil Heat in Various Climates for a Range of Heating Oil Prices and System Efficiencies

Cost in a Cold Climate With an 80-Million-Btu Annual Heat Requirement

AFUE	Heating Oil Price (Cents per Gallon)								
	70	75	80	85	90	95	100	105	110
55	$734	$787	$839	$891	$944	$996	$1,049	$1,101	$1,154
60	$673	$721	$769	$817	$865	$913	$961	$1,009	$1,058
65	$621	$666	$710	$754	$799	$843	$887	$932	$976
70	$577	$618	$659	$700	$742	$783	$824	$865	$906
75	$538	$577	$615	$654	$692	$731	$769	$808	$846
78	$518	$555	$592	$629	$666	$703	$740	$776	$813
80	$505	$541	$577	$613	$649	$685	$721	$757	$793
85	$475	$509	$542	$576	$610	$644	$678	$712	$746

Cost in a Moderate Climate With a 50-Million-Btu Annual Heat Requirement

AFUE	Heating Oil Price (Cents per Gallon)								
	70	75	80	85	90	95	100	105	110
55	$459	$492	$524	$557	$590	$623	$655	$688	$721
60	$421	$451	$481	$511	$541	$571	$601	$631	$661
65	$388	$416	$444	$471	$499	$527	$555	$582	$610
70	$361	$386	$412	$438	$464	$489	$515	$541	$567
75	$336	$361	$385	$409	$433	$457	$481	$505	$529
78	$324	$347	$370	$393	$416	$439	$462	$485	$508
80	$315	$338	$361	$383	$406	$428	$451	$473	$496
85	$297	$318	$339	$361	$382	$403	$424	$445	$467

Cost in a Warm Climate With a 20-Million-Btu Annual Heat Requirement

AFUE	Heating Oil Price (Cents per Gallon)								
	70	75	80	85	90	95	100	105	110
55	$184	$197	$210	$223	$236	$249	$262	$275	$288
60	$168	$180	$192	$204	$216	$228	$240	$252	$264
65	$155	$166	$177	$189	$200	$211	$222	$233	$244
70	$144	$155	$165	$175	$185	$196	$206	$216	$227
75	$135	$144	$154	$163	$173	$183	$192	$202	$212
78	$129	$139	$148	$157	$166	$176	$185	$194	$203
80	$126	$135	$144	$153	$162	$171	$180	$189	$198
85	$119	$127	$136	$144	$153	$161	$170	$178	$187

Table B2. Annual Cost of Gas Heat in Various Climates for a Range of Natural Gas Prices and System Efficiencies

Cost in a Cold Climate With an 80-Million-Btu Annual Heat Requirement

AFUE	Natural Gas Price (Cents per Therm)								
	40	45	50	55	60	65	70	75	80
55	$582	$655	$727	$800	$873	$945	$1,018	$1,091	$1,164
60	$533	$600	$667	$733	$800	$867	$933	$1,000	$1,067
65	$492	$554	$615	$677	$738	$800	$862	$923	$985
70	$457	$514	$571	$629	$686	$743	$800	$857	$914
75	$427	$480	$533	$587	$640	$693	$747	$800	$853
78	$410	$462	$513	$564	$615	$667	$718	$769	$821
80	$400	$450	$500	$550	$600	$650	$700	$750	$800
85	$376	$424	$471	$518	$565	$612	$659	$706	$753
90	$356	$400	$444	$489	$533	$578	$622	$667	$711
95	$337	$379	$421	$463	$505	$547	$589	$632	$674

Cost in a Moderate Climate With a 50-Million-Btu Annual Heat Requirement

AFUE	Natural Gas Price (Cents per Therm)								
	40	45	50	55	60	65	70	75	80
55	$364	$409	$455	$500	$545	$591	$636	$682	$727
60	$333	$375	$417	$458	$500	$542	$583	$625	$667
65	$308	$346	$385	$423	$462	$500	$538	$577	$615
70	$286	$321	$357	$393	$429	$464	$500	$536	$571
75	$267	$300	$333	$367	$400	$433	$467	$500	$533
78	$256	$288	$321	$353	$385	$417	$449	$481	$513
80	$250	$281	$313	$344	$375	$406	$438	$469	$500
85	$235	$265	$294	$324	$353	$382	$412	$441	$471
90	$222	$250	$278	$306	$333	$361	$389	$417	$444
95	$211	$237	$263	$289	$316	$342	$368	$395	$421

Cost in a Warm Climate With a 20-Million-Btu Annual Heat Requirement

AFUE	Natural Gas Price (Cents per Therm)								
	40	45	50	55	60	65	70	75	80
55	$145	$164	$182	$200	$218	$236	$255	$273	$291
60	$133	$150	$167	$183	$200	$217	$233	$250	$267
65	$123	$138	$154	$169	$185	$200	$215	$231	$246
70	$114	$129	$143	$157	$171	$186	$200	$214	$229
75	$107	$120	$133	$147	$160	$173	$187	$200	$213
78	$103	$115	$128	$141	$154	$167	$179	$192	$205
80	$100	$113	$125	$138	$150	$163	$175	$188	$200
85	$94	$106	$118	$129	$141	$153	$165	$176	$188
90	$89	$100	$111	$122	$133	$144	$156	$167	$178
95	$84	$95	$105	$116	$126	$137	$147	$158	$168

Table B3. Annual Cost of Heating or Cooling Using a Heat Pump in Various Climates for a Range of Electricity Prices and System Efficiencies

Cost in a Cold or Hot Climate With an 80-Million-Btu Annual Heating or Cooling Requirement

HSPF SEER	Electricity Price (Cents per Kilowatt-hour)								
	5.00	6.00	7.00	8.00	9.00	10.00	11.00	12.00	13.00
6.00	$667	$800	$933	$1,067	$1,200	$1,333	$1,467	$1,600	$1,733
6.50	$615	$738	$862	$985	$1,108	$1,231	$1,354	$1,477	$1,600
6.80	$588	$706	$824	$941	$1,059	$1,176	$1,294	$1,412	$1,529
7.00	$571	$686	$800	$914	$1,029	$1,143	$1,257	$1,371	$1,486
8.00	$500	$600	$700	$800	$900	$1,000	$1,100	$1,200	$1,300
9.00	$444	$533	$622	$711	$800	$889	$978	$1,067	$1,156
10.00	$400	$480	$560	$640	$720	$800	$880	$960	$1,040
11.00	$364	$436	$509	$582	$655	$727	$800	$873	$945
12.00	$333	$400	$467	$533	$600	$667	$733	$800	$867
13.00	$308	$369	$431	$492	$554	$615	$677	$738	$800
14.00	$286	$343	$400	$457	$514	$571	$629	$686	$743
15.00	$267	$320	$373	$427	$480	$533	$587	$640	$693
16.00	$250	$300	$350	$400	$450	$500	$550	$600	$650

Cost in a Moderate Climate With a 50-Million-Btu Annual Heating or Cooling Requirement

HSPF SEER	Electricity Price (Cents per Kilowatt-hour)								
	5.00	6.00	7.00	8.00	9.00	10.00	11.00	12.00	13.00
6.00	$417	$500	$583	$667	$750	$833	$917	$1,000	$1,083
6.50	$385	$462	$538	$615	$692	$769	$846	$923	$1,000
6.80	$368	$441	$515	$588	$662	$735	$809	$882	$956
7.00	$357	$429	$500	$571	$643	$714	$786	$857	$929
8.00	$313	$375	$438	$500	$563	$625	$688	$750	$813
9.00	$278	$333	$389	$444	$500	$556	$611	$667	$722
10.00	$250	$300	$350	$400	$450	$500	$550	$600	$650
11.00	$227	$273	$318	$364	$409	$455	$500	$545	$591
12.00	$208	$250	$292	$333	$375	$417	$458	$500	$542
13.00	$192	$231	$269	$308	$346	$385	$423	$462	$500
14.00	$179	$214	$250	$286	$321	$357	$393	$429	$464
15.00	$167	$200	$233	$267	$300	$333	$367	$400	$433
16.00	$156	$188	$219	$250	$281	$313	$344	$375	$406

Cost in a Warm (or Cool) Climate With a 20-Million-Btu Annual Heating (or Cooling) Requirement

HSPF SEER	Electricity Price (Cents per Kilowatt-hour)								
	5.00	6.00	7.00	8.00	9.00	10.00	11.00	12.00	13.00
6.00	$167	$200	$233	$267	$300	$333	$367	$400	$433
6.50	$154	$185	$215	$246	$277	$308	$338	$369	$400
6.80	$147	$176	$206	$235	$265	$294	$324	$353	$382
7.00	$143	$171	$200	$229	$257	$286	$314	$343	$371
8.00	$125	$150	$175	$200	$225	$250	$275	$300	$325
9.00	$111	$133	$156	$178	$200	$222	$244	$267	$289
10.00	$100	$120	$140	$160	$180	$200	$220	$240	$260
11.00	$91	$109	$127	$145	$164	$182	$200	$218	$236
12.00	$83	$100	$117	$133	$150	$167	$183	$200	$217
13.00	$77	$92	$108	$123	$138	$154	$169	$185	$200
14.00	$71	$86	$100	$114	$129	$143	$157	$171	$186
15.00	$67	$80	$93	$107	$120	$133	$147	$160	$173
16.00	$63	$75	$88	$100	$113	$125	$138	$150	$163

Table B4. Annual Cost of Electric Furnace Heat for a Range of Electricity Prices and Heating Requirements

Million Btu	Fuel Price (Cents per Kilowatt-hour)								
	5.00	6.00	7.00	8.00	9.00	10.00	11.00	12.00	13.00
80	$1,172	$1,407	$1,641	$1,876	$2,110	$2,345	$2,579	$2,814	$3,048
70	$1,026	$1,231	$1,436	$1,641	$1,846	$2,052	$2,257	$2,462	$2,667
60	$879	$1,055	$1,231	$1,407	$1,583	$1,758	$1,934	$2,110	$2,286
50	$733	$879	$1,026	$1,172	$1,319	$1,465	$1,612	$1,758	$1,905
40	$586	$703	$821	$938	$1,055	$1,172	$1,290	$1,407	$1,524
30	$440	$528	$615	$703	$791	$879	$967	$1,055	$1,143
20	$293	$352	$410	$469	$528	$586	$645	$703	$762
10	$147	$176	$205	$234	$264	$293	$322	$352	$381

CALCULATIONS IN THIS REPORT

Heating and Cooling Costs

The bills for heating and cooling shown in Tables B1 to B4 are computed using the steps in Table C1. In general, a homeowner needs to know the fuel price, the furnace or boiler efficiency and the climate's heating or cooling requirement. The examples in Tables C1 and C2 assume the average 1993 fuel prices, average efficiencies and a moderate climate.

Table C1. Calculating Annual Heating Costs for an Oil or Gas Heating System

Step	Using Heating Oil	Using Natural Gas
Heat required	50 Million Btu	50 Million Btu
Fuel Price	91 Cents/Gallon	61 Cents/Therm
Fuel Price $/Million Btu	0.91 / 138,690 x 1,000,000 = $6.56	0.61 / 100,000 x 1,000,000 = $6.10
Heat Price $/Million Btu at 65 AFUE	6.56 / .65 = $10.09	6.10 / 0.65 = $9.38
Heating Bill	$10.09 x 50 = $505	$9.38 x 50 = $469

Note: Calculated assuming a 50 million Btu annual heating requirement. All calculations are independently rounded to the nearest 1993 dollar. A gallon of heating oil contains 138,690 Btu, a therm of natural gas contains 100,000 Btu.

Source: Average fuel prices for 1993 and Btu values from Energy Information Administration, *Monthly Energy Review*, DOE/EIA-0035(94/04) (Washington DC, April 1994), Section 9 and Table A1.

Table C2. Calculating Heating and Cooling Costs with a Heat Pump

Step	Example Calculation
Heat required	50 Million Btu
Electricity Price	8.3 Cents/Kwh
Electricity Required (HSPF of 6.7)	50 million / 6.7 = 7,463 Kwh
Annual Heating Bill	7,463 X $0.083 = $619
Cooling Required	20 Million Btu
Electricity Required (SEER of 8.3)	20 million / 8.3 = 2,410 Kwh
Annual Cooling Bill	2,410 X .083 = $200
Total Heating and Cooling Bill	$619 + $200 = $819

Note: Calculated, assuming a 50-million-Btu annual heating requirement, a 20-million-Btu annual cooling requirement. All calculations are independently rounded to the nearest 1993 dollar.

Source: Average fuel prices for 1993 from Energy Information Administration, *Monthly Energy Review*, DOE/EIA-0035(94/04) (Washington DC, April 1994), Section 9.

Not included in the oil and gas heating bills shown in Tables B1, B2, and C1, are the cost of annual maintenance, typically $50 to $100, and also the cost of running the heating system electric blower fan or pumps, typically another $50 to $100. [14]

Calculations for heating and cooling with a heat pump or air-conditioner follow the same procedure. While Table C2 combines heating and cooling for an average heat pump, the steps for an air-conditioner are similar to the cooling portion alone. Finally the costs for an electric resistance furnace can be computed using the heating portion of Table C2, but with an HSPF of 3.4 rather than 6.7.

CALCULATIONS IN THIS REPORT

The Effect of Improved Efficiency

The savings from upgrading a heating system can be calculated from Table C3, which shows the savings per $100 of heating bill. For example, upgrading from an old furnace or boiler with an efficiency of 50 percent to even a standard efficiency furnace of 78 percent would save $36 for every $100 of the fuel bill. Upgrading to the most efficient unit, 95 percent, would save nearly $47 for every $100 of the fuel bill.

Table C3. The Savings per $100 of Heating Bill from Upgrading a Furnace or Boiler

Old Efficiency	New Furnace or Boiler Efficiency				
	78%	80%	85%	90%	95%
50%	$36	$38	$41	$44	$47
55%	$29	$31	$35	$39	$42
60%	$23	$25	$29	$33	$37
65%	$17	$19	$24	$28	$32
70%	$10	$13	$18	$22	$26
75%	$4	$6	$12	$17	$21

Note: The savings per $100 are $100 x (1 - old efficiency / new efficiency).

Table C4. The Savings per $100 of Heating or Cooling Bill from Upgraded Efficiency

Old Efficiency	New Heat Pump or Air-Conditioner Efficiency								
	6.8	7.0	8.0	9.0	10.0	11.0	12.0	14.0	16.0
5.0	$26	$29	$38	$44	$50	$55	$58	$64	$69
6.0	$12	$14	$25	$33	$40	$45	$50	$57	$63
7.0		$0	$13	$22	$30	$36	$42	$50	$56
8.0			$0	$11	$20	$27	$33	$43	$50
9.0				$0	$10	$18	$25	$36	$44
10.0					$0	$9	$17	$29	$38

Note: The savings per $100 are $100 x (1 - old efficiency / new efficiency).

The savings from upgrading an electrical heating or cooling system, either a heat pump or an air-conditioner, can be calculated from Table C4. Starting with an old heat pump with an HSPF of 5.0 and upgrading to a standard one with an HSPF of 6.8 will save $26 for every $100 of the original heating bill. Table C4 works equally well for heat pumps and air-conditioners in heating and cooling modes. For example, if the old air-conditioner with a cooling SEER of 6.0 is replaced with a new air-conditioner with a standard SEER of 10.0, then the savings per $100 of air-conditioning bill will be $40.

Heating System Environmental Emissions

Heating systems emissions are vented to the atmosphere either at the home, or in the case of electric systems, at the generating station. Table C5 compares a year's worth of emissions from an oil furnace, a gas furnace, and an average heat pump. The values in Table C5 are calculated for heating in a moderate climate using 50 million Btu per year.

Table C5. A Year's Worth of Emissions from Various Heating Systems

Factor	Direct Residential Emissions (lb per year)		Indirect Electric Utility Emissions From Fossil Fuels (lb per year)
	Fuel Oil Furnace[a]	Natural Gas Furnace[a]	Heat Pump
Soot (Particulates)	0.14	n/a	n/a
Sulfur Dioxide (SO_2)	0.03 to 0.16	0.04	80
Nitrous Oxides (N_2O)	8.11	5.69	42
Carbon Monoxide (CO)	2.25	2.42	n/a
Organic Compounds	n/a	0.67	n/a
Carbon	2718	1979	2704

[a]The furnace and boiler emissions are for direct combustion and exclude the emissions from the generation of electricity required to power furnace fans and boiler pumps.

n/a = The data source does not provide this emission estimate.

Notes: • Assumes an annual heating requirement of 50 million Btu with 80-AFUE oil furnaces and gas furnaces, and 6.8 HSPF heat pumps; the ranges for heating oil indicate the effect of low- and high-sulfur fuel oil. • The heat pump emissions prorate national total SO_2 and NO_x emissions from steam electric plants across total sales of electricity in 1992.

Sources: Environmental Protection Agency, Compilation of Air Pollutant Emission Factors, Volume 1: External Combustion Sources, AP-42 Supplement F (Washington DC, July 1993, Tables 1.3-2,1.4-3); Energy Information Administration, *Electric Power Annual 1992*, DOE/EIA-0348(92), (Washington DC, January 1994, Table 44); Energy Information Administration, *Emissions of Green House Gases in the United States 1985-1990* DOE/EIA-0573 (Washington DC, October 1993, p. 73).

Using an 80-percent efficient furnace, the oil and natural gas systems consume 62.5 million Btu of fuel to provide 50 million Btu of heat. The emissions characteristics of the oil and gas furnaces are taken from the standard source on emission measurements, and those for furnaces represent average older furnaces in use, not new furnaces. [12,Volume 1] The calculation in each case is to multiply the number of gallons, or cubic feet of fuel consumed, by the emission coefficient for the fuel.

Electric utility emissions are more difficult to quantify because utilities in different regions of the country burn different fuels. Using a standard electric heat pump efficiency of 6.8, a heat pump would consume 7,352 kilowatthours of electricity to produce 50 million Btu of heat. Table C5 shows the national average emissions for three significant pollutants: sulfur dioxide, carbon dioxide, and oxides of nitrogen, averaged over national sales of electricity. This approach effectively assumes that every utility in the country burns the same mix of fuels. [8,Table 44] However, emissions could be less for a utility that used more than the national average quantities of either natural gas, hydro or nuclear generation, any of which cause less pollution than coal.

Comparisons of the totals in Table C5 depend on what is considered and where the emissions are generated. Since heating oil, natural gas and coal are composed principally of carbon, the most significant component is always carbon emissions in the form of the gas carbon dioxide. Carbon dioxide is emitted either directly at the home furnace vent, or indirectly at the electric utility chimney stack.

A comparison of the other emissions are not as simple as it may appear. The direct emissions from the home furnace vent for oil and gas furnaces are very similar and lower than the average indirect emissions at the utility to produce the electricity to power a heat pump. However, not considered in Table C5 is that the average oil or gas furnace also uses approximately 500 kilowatthours of electricity per year to power the fan and pumps and this electricity causes emissions at the generating station. [14] For example, this adds over 5 pounds of indirect emissions of sulfur dioxide per year for the furnace fan for either oil or gas heat, much higher than the emissions from the direct combustion of either oil or gas. The figure is higher because average electricity emissions are set by the use of coal.

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