HEATING AND COOLING EQUIPMENT SELECTION

Care in selection is key to low-cost operation

Buildings for the 21st Century

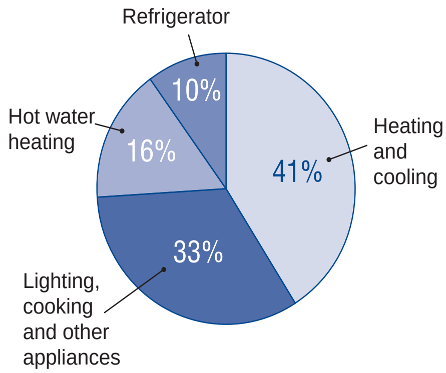
Buildings that are more energy efficient, comfortable, and affordable…that's the goal of DOE's Office of Building Technology, State and Community Programs (BTS). To accelerate the development and wide application of energy efficiency measures, BTS:

- Conducts R&D on technologies and concepts for energy efficiency, working closely with the building industry and with manufacturers of materials, equipment, and appliances
- Promotes energy/money saving opportunities to both builders and buyers of homes and commercial buildings
- Works with state and local regulatory groups to improve building codes, appliance standards, and guidelines for efficient energy use
- Provides support and grants to states and communities for deployment of energy-efficient technologies and practices

INTRODUCTION

A typical family may spend 60 percent or more of its annual utility budget on heating and cooling. Careful selection and sizing of heating and cooling (conditioning) equipment can reduce initial costs, increase homeowner comfort, increase operating efficiency, and greatly reduce utility costs.

HOME ENERGY COSTS



WHY SIZING IS IMPORTANT

A common mistake in the heating, ventilation, and air conditioning (HVAC) industry is to oversize heating and cooling equipment, especially air conditioners and heat pumps. Bigger does not always mean better. Overcapacity equipment has a higher initial cost, costs more to operate, and may be less effective than optimally sized equipment.

Because conditioning equipment reaches its highest operating efficiency only after about 5 to 15 minutes of continuous run-time, oversized units, which often run for shorter periods of time, are less efficient than properly sized units. This short cycling can result in cold, clammy indoor conditions during cooling seasons, large conditioned-space temperature swings, mechanical breakdown (due to frequent start/stop cycles), poor furnace heat exchanger life (due to flue gas water vapor condensation), and high operating costs. Oversized equipment may also be noisy because of large fans or undersized ductwork and may use more electricity to operate the blower fan.

SYSTEM SELECTION

Proper heating and cooling system selection takes into consideration fuel sources (e.g., natural gas and electricity), distribution mechanisms (e.g., air and hydronic), equipment options (e.g., furnace and heat pump), and equipment efficiency.

Perform a life-cycle analysis of various properly sized HVAC options to select a cost-effective system. Cost considerations include equipment and installation prices, annual heating and cooling expenses, and maintenance costs. Although more difficult to evaluate, equipment reliability, longevity, warranty coverage, and safety are also important.

For example, the heating fuel source directly impacts operating costs. Also, high-efficiency heating equipment often costs more than standard-efficiency models, but it costs less to run. So the life-cycle cost—rather than initial purchase price—may make high-efficiency equipment or one fuel rather than another the economical choice.

Some HVAC contractors and local utilities provide life-cycle analysis of various equipment options. A summary of many easy-to-use software products for estimating annual heating and cooling costs is compiled by DOE's BTS (www.eren.doe.gov/buildings).

SYSTEM TYPES

✓ Gas Furnaces

With a gas-fired, forced-air furnace, a blower forces conditioned air through supply ductwork to indoor spaces. Air is drawn back into the air handler through return ductwork or a plenum. A central air conditioner can be easily combined with the gas furnace system for cooling. A gas furnace has an average lifetime of between 18 and 20 years.

Backdrafting—the pressure-induced spillage of exhaust gases into interior living space—is uncommon but can be a health and safety concern when gas furnaces are used in combination with a tightly-sealed house. To minimize risk, employ one of the systems described in the following list; install a hard-wired carbon monoxide (CO) detector nearby; and annually inspect (clean, adjust, or repair as needed) the burners, the heat exchanger, the combustion chamber, and the flue.

When combustion appliances are used, the following may improve resistance to backdrafting.

- Combustion devices placed inside the conditioned space may incorporate a power venting system in which a fan expels exhaust gases through the flue, and/or a sealed combustion system that separately brings in outside air for combustion and exhausts combustion gases through pipes.
- Combustion devices may be placed outside the conditioned space of the house (e.g., in a garage).
- Combustion devices may be placed indoors in a sealed mechanical room having adequate exterior ventilation.

✓ Electric Heat Pumps

Electric heat pumps provide both heating and cooling from a single unit. Because, in the heating mode, air-source heat pumps draw energy from the outside air, they heat most efficiently when outdoor temperatures are above 30 to 35°F. At lower outdoor temperatures, built-in electric resistance heaters, with much higher operating costs, kick in to boost delivery air temperatures. Air-source heat pump equipment has a lifetime of about 15 years.

Ground-source, or geothermal, systems are heat pumps that use the relatively constant temperature of soil or groundwater as a heat source and sink. Although excavation costs for ground loops may be high, geothermal systems are more efficient than air-source heat pumps because the earth or groundwater is a warmer heat source than air in the winter and a cooler heat sink in the summer (overall efficiencies range from 1.5 to 2 times those of air-source units). Additional information on geothermal systems can be obtained from DOE at www.eren.doe.gov/geothermal.

Heat pumps (and air conditioners) with thermostatic expansion valves compensate for variations in airflow and refrigerant charge better than those with fixed orifice valves. A heat pump with a microprocessor defrost control can save energy by "learning" to defrost only as needed. A heat pump should have an outdoor-lockout thermostat that locks out the supplemental heat (but not the emergency heat) when the outdoor temperature is greater than the heat pump balance point (usually 25 to 40°F, depending on the climate) except during the outdoor coil defrost cycle.

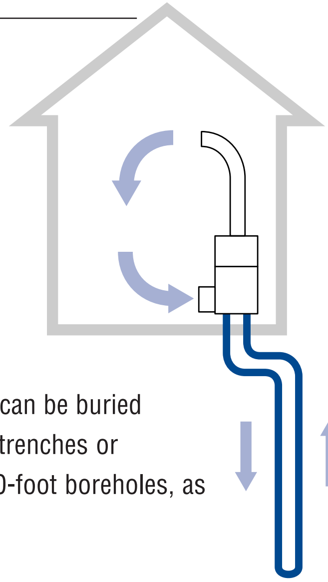
✓ Other System Options

Hydronic systems are quiet and efficient heating systems that are growing in popularity. With hydronic heating, boiler-heated water is transported through pipes to radiators, baseboards, or imbedded floor loops. In very dry climates, hydronic systems can be used for cooling, also. In more humid climates, they are not recommended for cooling because condensation can occur on cold pipes or floors.

Combined systems merge domestic hot water and space heating into a single appliance. Water is heated within the unit and piped through an air handler to supply space heating. Commonly available systems are high-efficiency, sealed combustion units. Some systems pair an efficient air handler system with a conventional, high-efficiency, hot water heater.

GEOTHERMAL HEAT PUMPS

A ground-source or earth-coupled heat pump uses a continuous loop of buried pipe filled with water or refrigerant to transfer heat to and from the soil. The pipe can be buried horizontally in shallow trenches or vertically in 100- to 200-foot boreholes, as illustrated here.



HEATING AND COOLING EQUIPMENT SELECTION

Conventional electric baseboard and electric furnace systems combine low first costs with elevated operating costs. Electric baseboard heaters do not use ducts and therefore eliminate duct energy losses. They also permit room-by-room temperature adjustments that can reduce energy needs through zoning. Electric furnaces offer neither of these potential advantages. Where central air conditioning is desired, a heat pump can be much more economical to operate than an electric furnace.

EFFICIENCY LEVELS

Equipment efficiency is a measure of how much energy is effectively converted into heating and cooling the home. More efficient systems use less energy to achieve the same degree of conditioning. Efficiency varies with operating conditions, so annual or seasonal efficiency ratings based on standard tests are included on product labels to aid purchasers. The yellow EnergyGuide label helps consumers compare the energy efficiency of similar products. It shows the estimated annual fuel consumption on a scale that compares similar products.

A medium-efficiency unit with an Energy Star® label is the most cost-effective choice in many applications. High-efficiency units become cost effective in homes with higher heating and cooling costs. Higher cost can be due to an inefficient building envelope, a severe hot or cold climate, high fuel costs, or larger house size.

✓ Gas Furnaces

Annual Fuel Utilization Efficiency (AFUE)—The seasonal or annual energy efficiency of fossil-fueled furnaces:

- 78% AFUE—minimum-AFUE natural gas furnaces.
- 80 - 82% AFUE—medium-efficiency furnaces employing efficient heat exchangers, better intake air control, and/or blowers to exhaust combustion products.
- >90% AFUE—high-efficiency (condensing) furnaces.

✓ Heat Pumps

Heating Seasonal Performance Factor (HSPF)—The energy efficiency of a heat pump during a full heating season:

- 6.6 and 6.8 HSPF—minimum-efficiency single-package and split systems, respectively.
- 7.2 - 7.8 HSPF—medium-efficiency units.
- >8.0 HSPF—high-efficiency units. Variable speed heat pumps have HSPF ratings as high as 10.

Seasonal Energy Efficiency Ratio (SEER)—The heat pump and air conditioner energy efficiency during a full cooling season:

- 9.7 and 10 SEER—minimum-efficiency single-package and split systems, respectively.
- 12 - 13 SEER—medium-efficiency units.
- > 14 SEER—high-efficiency units. Some super high-efficiency units are as high as 18 SEER.

OPERATING COSTS

Using U.S. average fuel costs in the year 2000, annual heating and cooling costs for various fuel sources and equipment efficiencies are estimated in Table 1 for three climates. System selection includes consideration of operating costs together with equipment price, longevity, and other factors. A 1,500 square-foot house with a building envelope that meets the International Energy Conservation Code 2000 was assumed in performing the calculations for Table 1.

Table 1. Annual Heating and Cooling Costs in Dollars

U.S. City	Atlanta	St. Louis	Minne-apolis
HEATING			
Gas Furnace - Minimum (78% AFUE)	$190	$300	$458
Gas Furnace - Medium (80% AFUE)	$185	$294	$448
Gas Furnace - High (92% AFUE)	$165	$262	$400
Heat Pump - Minimum (6.8 HSPF)	$274	$425	$647
Heat Pump - Medium (7.4 HSPF)	$252	$391	$594
Heat Pump - High (8.0 HSPF)	$233	$361	$550
COOLING			
Minimum (10 SEER)	$212	$210	$121
Medium (12.5 SEER)	$170	$168	$97
High (14 SEER)	$152	$150	$86

Costs are calculated at $0.081/kWh and $0.72/therm. Actual costs will vary based on many factors, including local fuel costs, house specific heating and cooling loads, and occupant behavior.

HEATING AND COOLING EQUIPMENT SELECTION

For more information, contact:

Energy Efficiency and Renewable Energy Clearinghouse (EREC)
1-800-DOE-3732
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Or visit the BTS Web site at www.eren.doe.gov/buildings

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SIZING

Individual heating and cooling system sizes should be selected based on the building design loads for the house. Avoid using simplistic rules of thumb (e.g., Btu per square foot of conditioned floor area). Some HVAC contractors and local utilities provide sizing calculations for customers. Finding smaller-sized components for a small, energy-efficient home may be difficult, however.

The Air Conditioning Contractors of America (ACCA) Manual J and Manual S have become industry standards (www.acca.org). ACCA's *Manual J Residential Load Calculation* estimates design heating and cooling loads by considering climate and house-specific variables such as insulation levels; window sizes, tint, and orientation; shading; air infiltration; duct location; and number of occupants. ACCA's *Manual S Residential Equipment Selection* matches selected equipment to calculated design loads. Sufficient built-in safety factors in ACCA's methodologies accommodate most conditioning needs, so do not deviate from ACCA recommendations and/or add margins of safety on your own. A summary of energy analysis programs that simplify the Manual J calculations is compiled by DOE's BTS (www.eren.doe.gov/buildings).

Manual S criteria for sizing HVAC systems includes:

- ✓ **Gas Furnace**
  A unit with a total heating capacity between 100 and 140 percent of the calculated design heating load is selected. Some energy experts recommend selecting a slightly larger unit (capacity between 120 and 150 percent of the design heating load) to encourage aggressive thermostat setback without significantly impacting performance (because the house can heat up quickly).

- ✓ **Air Conditioner**
  A unit is selected with sensible and latent cooling capacities that exceed the respective sensible and latent design cooling loads and with a total cooling capacity between 100 and 115 percent of the total design cooling load. An air conditioner with a latent capacity of 25 to 30 percent of the total capacity (a sensible heat ratio of 75 to 70 percent, respectively) can be effective in most areas, although very humid or very dry climates may require respectively higher or lower latent capacity.

- ✓ **Heat Pump**
  A unit is selected that meets the air conditioner requirements provided in the previous item. Resistance heaters are added to supplement the unit heating capacity to meet the design heating load, but they should not exceed 120 percent of the design heating requirement. In cold climates, total cooling capacity can be up to 125 percent of the total cooling design load. This builds in more heating capacity and greater seasonal heating efficiency but limits summer dehumidification.

THERMOSTATS

Programmable thermostats automatically allow different temperature settings during the day and week to save energy, although not all users are comfortable with their complexity. Setback can be performed manually using standard thermostat models, but a consistent pattern is usually not achieved in practice. If a programmable thermostat is desired, choose a model with an Energy Star® label to ensure essential programming features and accuracy.

For heat pumps, a thermostat compatible with such systems must be chosen. Changeover between heating and cooling should be performed manually rather than automatically. The thermostat should be equipped with an emergency heat switch that permits all supplemental heaters to be energized when the refrigerant system is inoperative and activates an indoor indicator light. Programmable models for heat pumps that meet Energy Star requirements ensure that costly back-up heat is not engaged under routine conditions or in using setback practices.

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