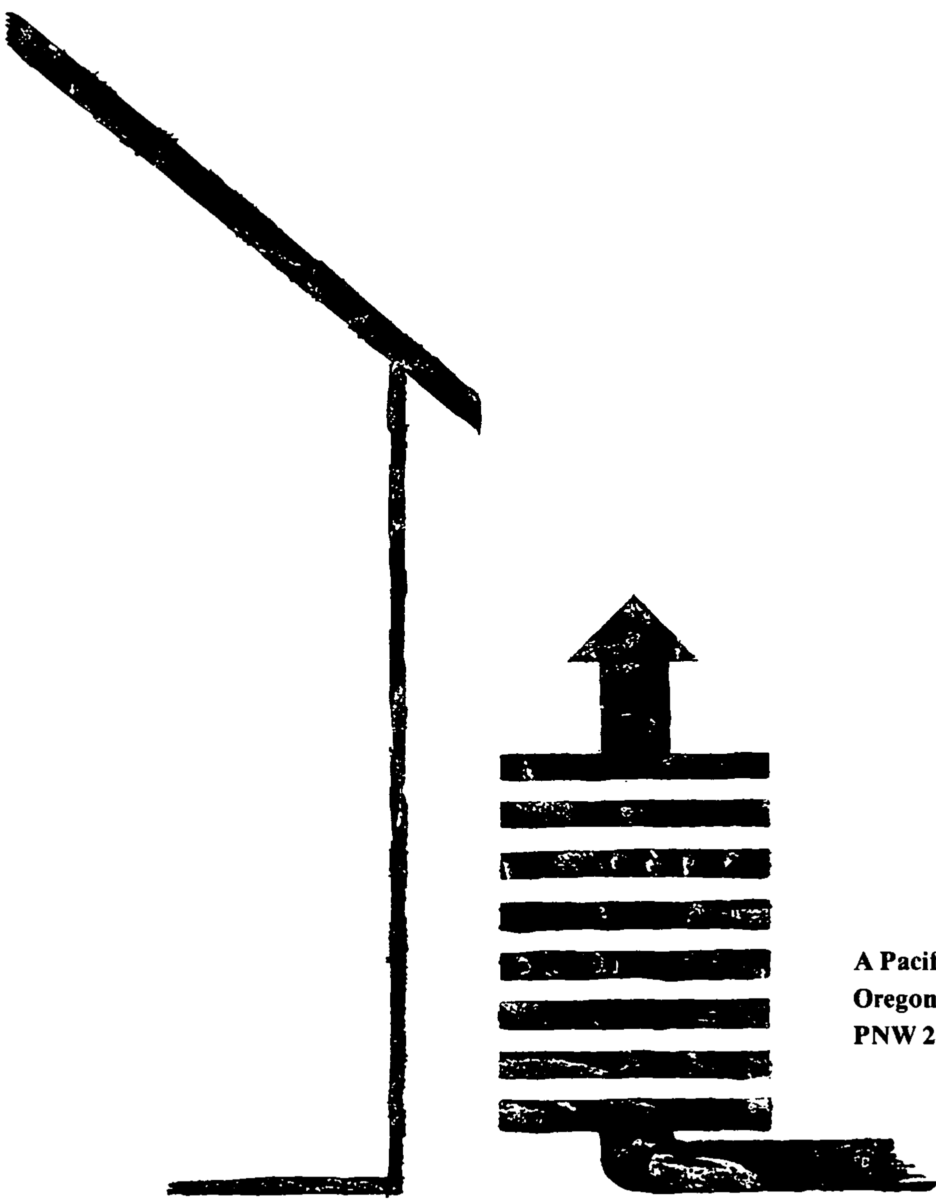
Heat Pumps for Homes
A *Guide for Decisions*



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How heat pumps work

Heat pumps are efficient heating systems because they use electrical energy to move heat rather than produce it. They move heat into your home from sources such as outside air, water, the ground, or even the sun.

As a result, heat pumps use 50 to 70% less energy than a standard electric furnace to heat your home. But they generally cost more than most other heating systems, too. In some cases, the savings justify the additional system cost.

Most heat pumps take heat from outside air. But how can cold air heat a home? Surprisingly, cold air contains a significant amount of heat. For example, air at 32°F still has 88% of the heat it had at 100°F.

This is because everything contains *some* heat until the temperature reaches 460°F below zero (–460°F). Heat pumps extract heat from air above 25 to 35°F and make it useful for home heating.

An additional benefit is that heat pumps can provide air conditioning during the summer. Your heating system selection can be strongly affected by how important air conditioning is to you.

This publication introduces you to the types of heat pumps available, their advantages and disadvantages, efficiency ratings, economics, and shopping tips. It is intended to help you determine whether a heat pump or another type of heating system might be more effective for you. The reading list (page 13) refers you to sources for more information.

Heat is a form of thermal energy that naturally flows from warmer to cooler areas, as from a warm house to the cooler outdoors. A heat pump reverses this natural flow and moves heat from cooler to warmer areas.

A good example of a heat pump is your refrigerator. The inside of a refrigerator is colder than room temperature. If you touch the coils on the back of a refrigerator, you will find them warm. The refrigerator is kept cold by pumping heat *out*, using exactly the same process as a heat pump.

The heat pump moves heat by circulating a fluid, called a *refrigerant*, through a closed cycle. There are a number of refrigerants that have the property of boiling at temperatures well below 0°F. The fact that liquids absorb heat when they boil and give off heat when they condense allows more heat to be transferred.

Let's see how the air-to-air heat pump illustrated in figure 1 uses these properties to heat your home. The *outdoor heat exchanger* contains liquid refrigerant that is colder than the outside air.

Heat flows from the outdoor air to the cooler refrigerant, causing it to boil and turn to a vapor. This heat exchanger is called the *evaporator*.

The *compressor* then compresses the vapor and raises its temperature to over 100°F. This high-temperature refrigerant moves through the *indoor heat exchanger*, where it transfers heat to the air inside your home. This heat exchanger is called the *condenser* because the refrigerant vapor condenses to a liquid as it loses heat.

Next, the liquid refrigerant passes through an *expansion valve*, where the pressure is reduced. This causes the refrigerant temperature to fall below 0°F in the outdoor heat exchanger, and the cycle begins again.

Most heat pumps have a *reversing valve* that allows the heat pump to operate as an air conditioner. The valve reverses refrigerant flow when cooling is needed. The evaporator and condenser exchange functions, and heat is pumped from the indoor air to the outside. Heat pumps and air conditioners provide additional comfort in the summer by dehumidifying the air, as water vapor condenses on the cold indoor heat exchanger.

Heat pumps have another characteristic that may affect your heating system decision. They generally deliver air to your home between 80 and 100°F. This is cooler than air delivered by combustion furnaces, which is typically between 130 and 140°F.

Some people prefer the more uniform temperature air delivered by a heat pump while others do not. You may want to visit a home with a heat pump system to make your own comparison. Ask your heating contractor if you don't know where to find one.

A less personal effect of lower air-supply temperatures is that to keep your home at the desired temperature, a heat pump must move more air than other heating systems. Therefore, the ducts must be larger.

In a new home it is a relatively simple matter to install larger ducts before the walls, ceilings, and floors are covered. For an existing home, however, it will cost more to replace the existing ducts. (Homes already designed for central air conditioning probably have large enough ducts.)

If your existing ductwork is inadequate for a heat pump to meet your present heating needs, you have two alternatives:

- *Weatherize your home.* A smaller heat pump may adequately heat your home if less heat is needed.
- *Size a heat pump to the existing ductwork.* This is sometimes called an *add-on* heat pump, because it is added on to your existing furnace (electric, oil, or gas). The furnace will continue to heat your home on colder days when the heat pump cannot provide enough heat. The add-on heat pump can reduce heating system costs in some cases—and cool and dehumidify your home during the summer.

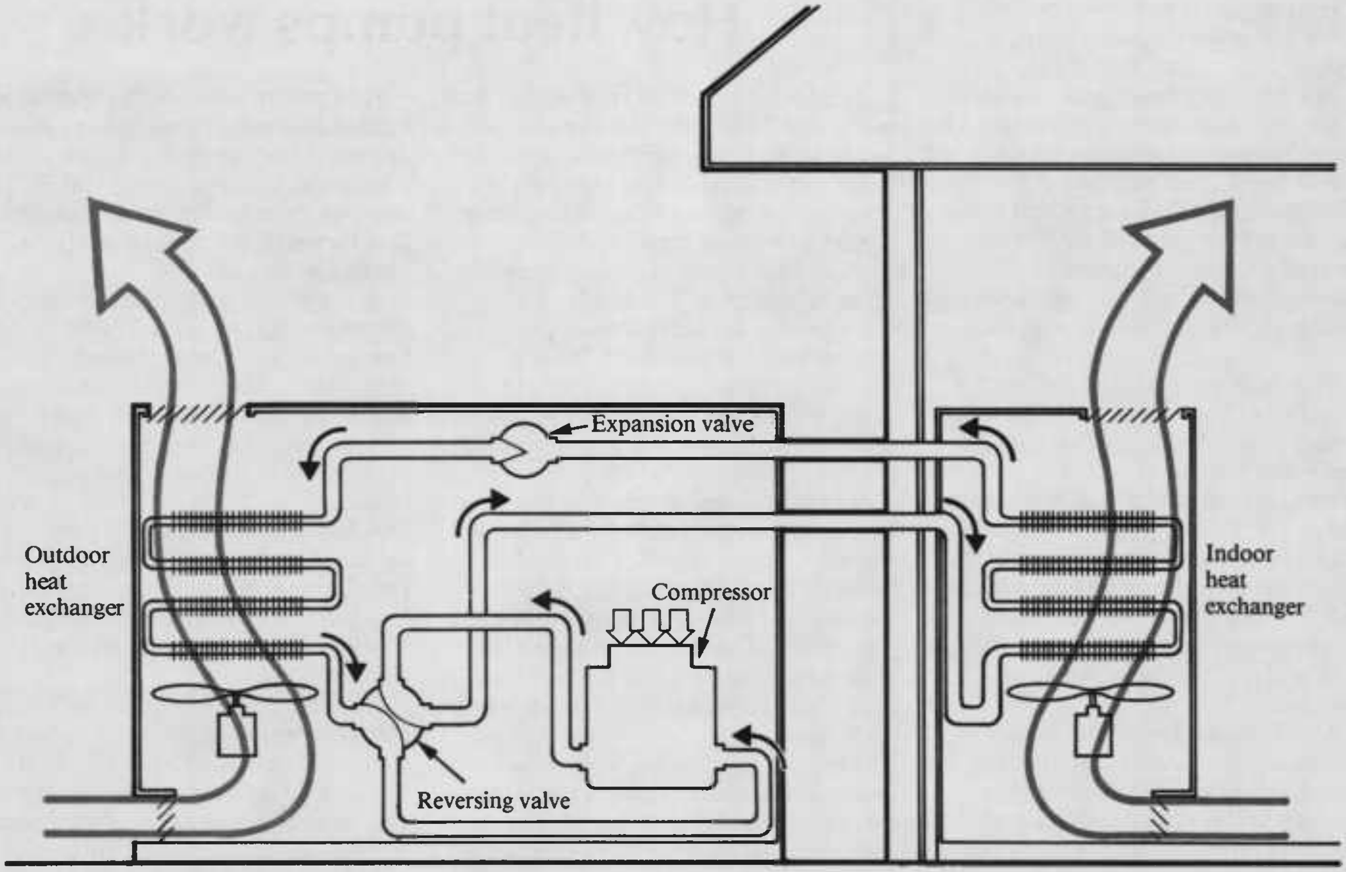


Figure 1.—Heating cycle for an air-source heat pump

Heat pump ratings

A heat pump is attractive because it is efficient. Heat pump efficiency is often rated by its coefficient of performance (COP). The COP is the ratio of heat output to the electrical energy required to pump that heat:

$$COP = \frac{\text{heat output}}{\text{energy input}}$$

For example, electric resistance heating systems produce an amount of heat equivalent to the electrical energy supplied. Therefore, the COP of electric heat is 1.

When gas and oil are burned, some heat is lost up the flue. Therefore, the efficiency of converting energy stored in the fuel to heat your home is between 60 and 90%. So the COP of these appliances would be between 0.6 and 0.9.

Heat pumps can have COP's much higher than 1. For example, when the outside air is around 50°F, efficient heat pumps will deliver about three times as much heat as the electrical energy required to pump it (COP = 3). Most of the electrical energy used to pump heat is also converted and delivered as heat.

Heat pump COP varies with source temperature. At lower temperatures, the heat pump delivers less heat for the electricity it consumes. For this reason, COP's are tested at two temperatures, 17 and 47°F. For example, a heat pump may have a COP of 3.0 at 47°F and of 2.0 at 17°F.

This decline of heat output with source temperature presents a special problem for air-source heat pumps. The colder the outside air, the more heat you need to be comfortable. At the same time, the heat pump is providing less. This is shown graphically in figure 2.

While it is possible to buy a heat pump capable of providing enough heat at low outside temperatures, it would be quite large and, therefore, expensive.

Because of these considerations, heat pumps are usually designed to provide enough heat until the outside temperature drops below what is called the *balance point* (usually between 25 and 35°F). Below the balance point, *supplemental heat* is required.

Supplemental heat is usually supplied by electrical resistance heating or by an oil or gas furnace. Regardless of the source of this supplemental heat, system efficiency is lower when supplemental heat is included.

Heat pump efficiency over the heating season is expressed by the *Heating Seasonal Performance Factor*. HSPF includes system losses from cycling on and off, defrosting, variations in heat pump efficiency as the heat source temperature changes over the heating season, and supplemental heating efficiency.

$$HSPF = \frac{\text{total heat output}}{\text{total energy input}}$$

The value of HSPF depends on the units by which heat is measured. Heat is

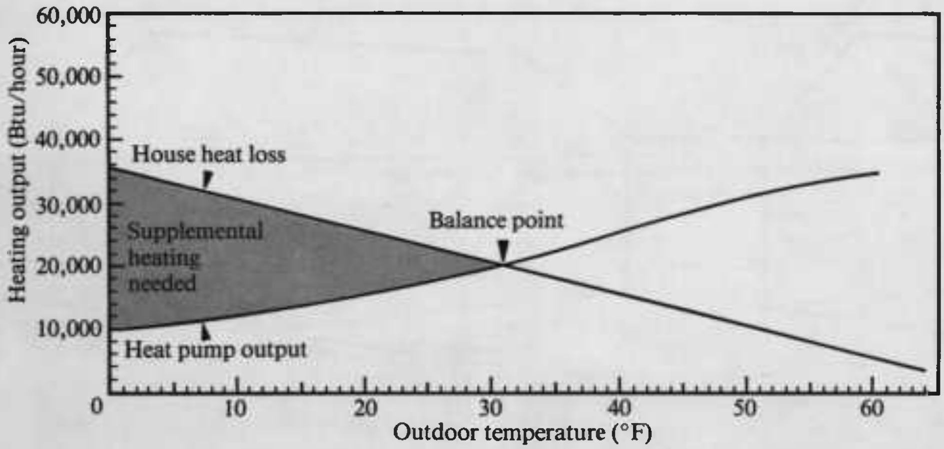


Figure 2.—Variation of heating output with outside temperature

often measured in British thermal units (Btu). One Btu is the heat required to raise the temperature of 1 pound of water 1°F, or about the amount of heat released by burning a wooden match. Electrical energy is generally measured in watt-hours (Wh).

The Air-Conditioning and Refrigeration Institute (ARI) rates most heat pumps on the market today. ARI defines HSPF as the ratio of heating energy delivered in Btu to the total energy consumed by the heat pump in watt-hours. The resulting HSPF is generally between 6 and 10 Btu/Wh.

For the purpose of comparing efficiencies of heat pumps with other heating systems, divide HSPF by the conversion factor 3.4 Btu/Wh to get a *seasonal efficiency*.

For example, divide HSPF of 6.8 by 3.4 to get a seasonal efficiency of 2. This heat pump would use half as much electricity as an electric resistance heating system.

HSPF is the best measure of heat pump performance for your home. A heating contractor should be able to provide the HSPF for any heat pump, either from product literature or from the latest ARI *Directory of Certified Heat Pumps*.

ARI also rates heat pump efficiencies over the summer cooling season by the *Seasonal Energy Efficiency Ratio* (SEER, also in Btu/Wh). You can obtain these ratings yourself from the Air-Conditioning and Refrigeration Institute, 1815 N. Fort Myer Drive, Arlington, VA 22209.

Heat pump output is often rated in *tons*. This term originated long before mechanical air conditioning, when cooling capacity was measured in tons of ice. The modern ton refers to moving heat at the rate of 12,000 Btu/hour. Most residential heat pumps range in size from 1 to 5 tons.

Types of heat pumps

Heat pumps are often categorized by *heat source* and *delivery fluid*. For example, a heat pump using outside air as a source to heat air as the delivery fluid in a central heating system is referred to as an air-to-air heat pump.

There are four main sources for heat pumps (air, water, ground, and the sun), and two delivery fluids (air and water).

The following sections summarize the different types of heat pumps by heat source and their advantages and disadvantages (the chart on pages 6-7 is a handy summary of these points).

Air-source

Most heat pumps sold are air-to-air, largely because air is abundant and easy to use. These usually have indoor and outdoor sections. This is called a *split* system.

The indoor section looks much like a standard furnace. The outdoor section usually contains the compressor, the outdoor heat exchanger, the expansion device, and a fan to move air through the heat exchanger.

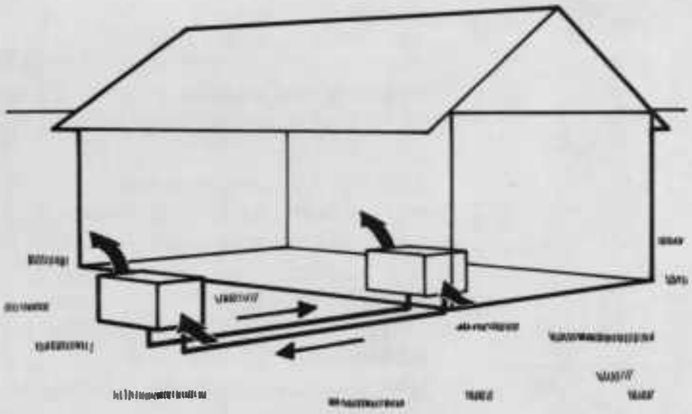
Air moving through the outdoor heat exchanger can cause noise. Noise levels vary, but generally the newer units are quieter. Listen to the noise an outdoor unit makes. If you would like to hear one, ask your heating contractor.

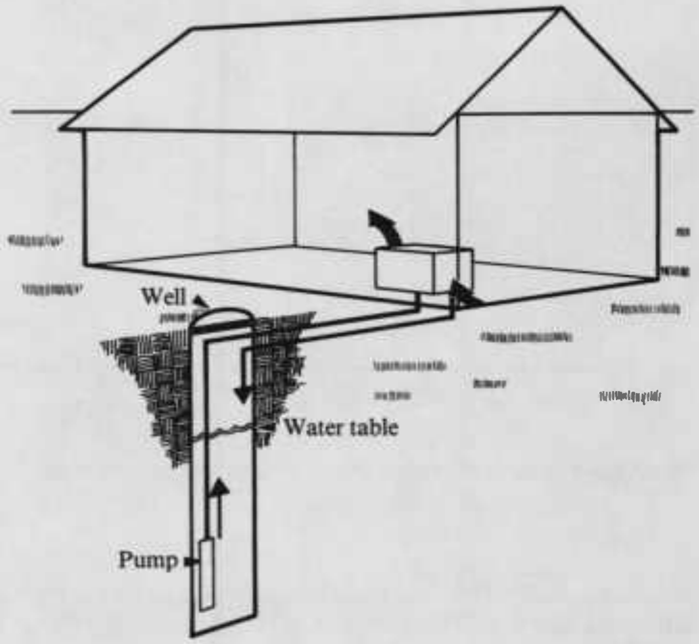
Consider noise levels before placing the outdoor unit near your or your neighbor's bedrooms. Fences and shrubbery can help if you feel noise is a problem, but try to avoid shading or restricting air flow to the heat pump.

Another characteristic is that moisture in the air condenses on the outdoor coil. This can freeze, even when the air temperature is above freezing. As the ice thickens, less air can pass through the coil, and heat flow to the coil is reduced. The result is decreased performance.

The solution is to defrost the outdoor coil periodically. The most common method automatically reverses refrigerant flow, pumping heat from inside your home to melt the ice outside. This requires extra energy, generally reducing HSPF between 5 and 15%.

The simplest defrost control is a timer that calls for defrost periodically, whether defrosting is needed or not. More sophisticated controls sense air and refrigerant temperature or air pressure drop. These are designed to defrost only when necessary and only until the ice has melted.





Air-source heat pump

Advantages
- Air is abundant and easy to use.
- The technology is well developed.

Disadvantages
- Defrosting outdoor coil reduces efficiency.
- Efficiency decreases as outside temperature falls.

Water-source heat pump

Advantages
- SPF greater than 3 is possible.
- Ground water temperature is nearly uniform.
- Defrost cycle is not necessary.
- Tax credits are available.

Disadvantages
- Add the cost of well drilling if needed.
- Mineral "scaling" can reduce efficiency and life.

Water-source

Water has several advantages over air as a heat source. One is the nearly uniform temperature year-round. Water also transfers heat to a heat pump more readily than air. Water can come from a well (ground water) or a river, lake, or stream (surface water).

Ground water temperatures above 50°F are common. HSPF greater than 3 is possible (however, pumping energy can reduce HSPF as much as 5%, depending on model, water level, and pressure). A home heating bill can be reduced to 30 to 40% of the cost of electric resistance heating.

How much water do you need? In general, about 3 gallons per minute per ton of capacity. Most homes would use between 5 and 15 gallons per minute. After water has been "used" to transfer heat to your home, it may be returned as surface water, to the same well, or to a second well if conserving water or not cooling the source well is important.

Finally, some wells have a high mineral content that can reduce both efficiency and life of a heat pump. A test is advisable. Mineral deposits or *scaling* on the heat exchange surfaces can be reduced by a *water-softening* process.

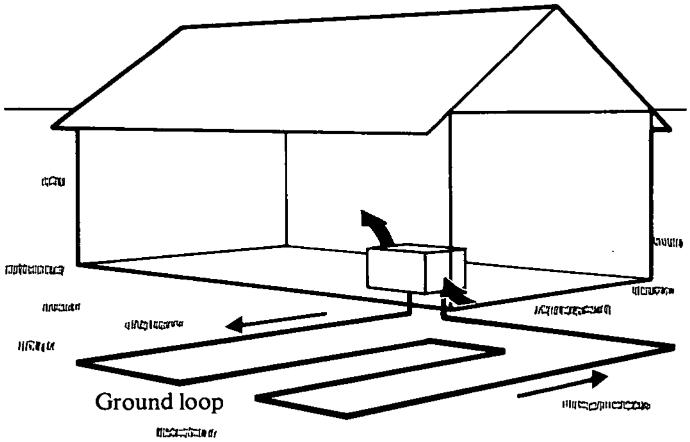
Surface water is usually low in mineral content. In rainy-winter areas, surface water is abundant during the heating season. A disadvantage is that surface water temperature follows the air temperature to some extent, even down to freezing. As water temperature falls, so does heat pump performance.

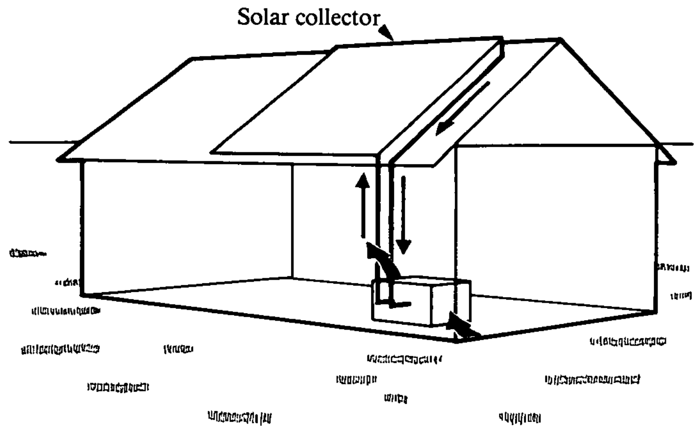
If you have access to surface water, first record the temperature each week for a winter. If your water temperatures exceed 45°F for most of the heating season, a surface water heat pump may be feasible.

Some areas are especially well suited for water-source heat pumps. Nearly constant water temperatures lead to greater reliability and to longer system life. No defrosting is necessary. Heat pump efficiency remains high as air temperatures drop because well water temperature remains nearly constant. And some systems are designed so that no supplemental heating system is necessary.

Ground-source

These heat pumps extract heat from the ground. Below 5 feet, ground temperatures are far more stable than the outside air temperature, ranging from 40°F in the northern United States to a high of 75°F in some southern states. In this range, heat pumps can operate at COP's from 2 to higher than 4.





Ground-source heat pump

Advantages
- Ground temperatures below 5 feet are more stable.
- SPF greater than 3 is possible.
- Tax credits are available.

Disadvantages
- Initial cost is high.
- Leaks are difficult to find and repair.
- There is limited performance information.

Solar-assisted heat pump

Advantages
- Solar energy can increase performance significantly.
- Solar components may be eligible for tax credits.

Disadvantages
- Initial cost is high.
- A sunny location is required.
- Air conditioning requires an additional heat exchanger.

Heat is extracted from the ground by burying a horizontal network of pipe at least 4 feet below the ground surface. An antifreeze solution is circulated through this pipe to the evaporator coil of a water-source heat pump. Copper, PVC, polyethylene, and polybutylene pipe have been used.

The success of the system depends strongly on soil type and moisture content, and on proper pipe-loop sizing, materials, and construction. You would need a ground area roughly the square footage of your home.

Ground loops can also be installed vertically, with smaller land area requirements than horizontal systems. If you are considering a ground loop, be sure to locate a heat pump dealer or an engineer with experience.

Solar-assisted

Solar energy can assist heat pumps in several ways. In one method, the heat pump circulates refrigerant through solar collectors. The sun provides additional energy, increasing the heat pump's efficiency. Collectors in this application are generally unglazed, to allow air to supply heat when the sun isn't shining.

Solar energy can also incrêase heat pump performance in a system that circulates water or an antifreeze solution through solar collectors. The warmed fluid is then stored in a large tank, pool, or the ground until needed.

The higher source temperatures allow heat pumps to operate with COP's higher than 4. When direct heating of the home by the solar-heated fluid is included, system COP's higher than 7 have been reported.

Water-heating

Heat pumps can also heat water for household use—in two ways. The first way is to add a *desuperheater* or an extra condenser to a space-heating heat pump. Additional heat is removed from the refrigerant to heat domestic water.

If you already have a heat pump or are planning to install one, investigate the option of adding a water-heating unit.

The second way to heat water is with a *water-heating heat pump* (WHHP). The most common models take heat from the air to heat domestic water and use about half the energy of an electric water heater. A good location for a WHHP is one where it can capture heat that would otherwise be lost.

However, the air temperature should rarely fall below 45°F because current models have no defrost cycles. Garages, crawl spaces, utility rooms, or unheated basements can make good locations.

Economic analysis

A home-heating system is a major investment that you should make carefully. The initial cost of the equipment can be significant, but that is only part of it. The operating cost, which includes the cost of fuel and maintenance over the life of your heating system, is generally much greater than the initial cost. Consider both costs carefully.

The decision on which type of heating system is best for your home is not an easy one. You have a variety of heating systems from which to choose: gas, oil, wood, electric resistance, or heat pumps.

In addition, there are a number of factors to consider when selecting a system: the length of time you expect to remain in your present home, the effect of the heating system on your home's resale value, differences in personal comfort that you perceive with different heating systems, and the value of having air conditioning.

Economic analysis can help you determine which heating system will heat your home most economically. There are several methods, but it is important to use a method that includes equipment and fuel costs.

One method estimates the *life-cycle cost* of buying and operating a heating system over its life. The system with the lowest life-cycle cost will heat your home most economically.

While this is a helpful tool in selecting a heating system, it requires accurate estimates of interest and inflation rates, and of fuel costs (gas, oil, and electricity) over the life of the heating system.

A simpler method compares the total cost to heat your home *this year*. You can find out current interest and fuel rates by making a few phone calls.

The disadvantage is that the lowest cost system depends strongly on interest and fuel costs. The best system for you may change over time as relative fuel costs change (for example, if gas and electricity prices change at different rates). You can include different rates of cost increase for each fuel, using a life-cycle cost analysis—if you feel confident predicting future interest, inflation, and fuel costs.

Example

Let's use the simpler method to determine which forced-air heating system has the lowest total annual cost. We estimate annual equipment cost by spreading payments equally over the life of the heating system. The heating costs are based on actual or estimated heating requirements at current fuel costs.

This example is divided into three sections. First, you select the heating systems you want to consider. Next, make some assumptions. Finally, analyze the results.

You can perform a similar analysis for your home by following the steps outlined in "The Procedure," page 12.

Selecting heating systems. There are numerous central, forced-air systems available, but we will consider six:

Option 1. Standard gas furnace.
Option 2. Condensing gas furnace. These efficient furnaces capture much of the heat that is normally lost up the flue.
Option 3. Oil furnace, with the more efficient flame-retention burner.
Option 4. Electric resistance furnace.
Option 5. Air-source heat pump.
Option 6. Water-source heat pump.

Assumptions. *We assume these conditions and costs for this example only—they are not intended to represent actual equipment and energy costs. Do not use them to select your heating system.*

1. The furnaces (Options 1 to 4) do not include air conditioning. However, air conditioning is a feature heat pumps offer.
2. No additional ductwork is required for any of the systems.
3. The existing electrical service is adequate.
4. The existing well and plumbing are adequate for the water-source heat pump.
5. The existing chimney is adequate for all the combustion furnaces.
6. Annual equipment costs are estimated by assuming you borrow the money to install the heating system. We assume a 15-year comparison period (15-year loan) at 10% interest. Uniform loan payments, including principal and interest, provide a good estimate of annual equipment cost, even if you choose not to borrow.
7. Assumed costs of energy, equipment, maintenance, and seasonal efficiencies are shown on the worksheet (page 14).

If we apply the steps in "The Procedure" section (page 12) to the six heating systems, using these assumptions, we obtain the total annual costs shown in figure 3a.

Analysis. Remember, the numbers we use in this example *are assumed*. One of the assumptions that has a major effect on the results is the energy required to heat your home. This depends on the energy efficiency and size of your home, the local climate, the number and ages of your family, your lifestyle, and even on your pets.

Annual heating energy can range from less than 10 million Btu (10 MBtu) for an energy-efficient home in a moderate climate (west of the Cascade Range) to over 100 MBtu for a conventional home in a colder climate (east of the Cascades).

The wide range of heating energy requirements emphasizes the importance of knowing your home's annual heating energy. For example, let's look at the effect of annual heating energy on finding the most economical heating system.

Remember, the total annual cost includes equipment, fuel, and maintenance costs. Total annual costs are shown graphically in figure 3a for each of six heating system options. The costs are grouped for annual heating energy (AE) requirements of 10, 30, 60, and 100 MBtu.

One thing we notice is that total costs are less for lower heating energy requirements. While this is not surprising, we also notice that the system with the lowest total cost changes as the annual heating energy changes.

For example, with an annual heating energy of 10 MBtu, the system with the lowest total annual cost is a standard gas furnace, followed closely by an electric furnace.

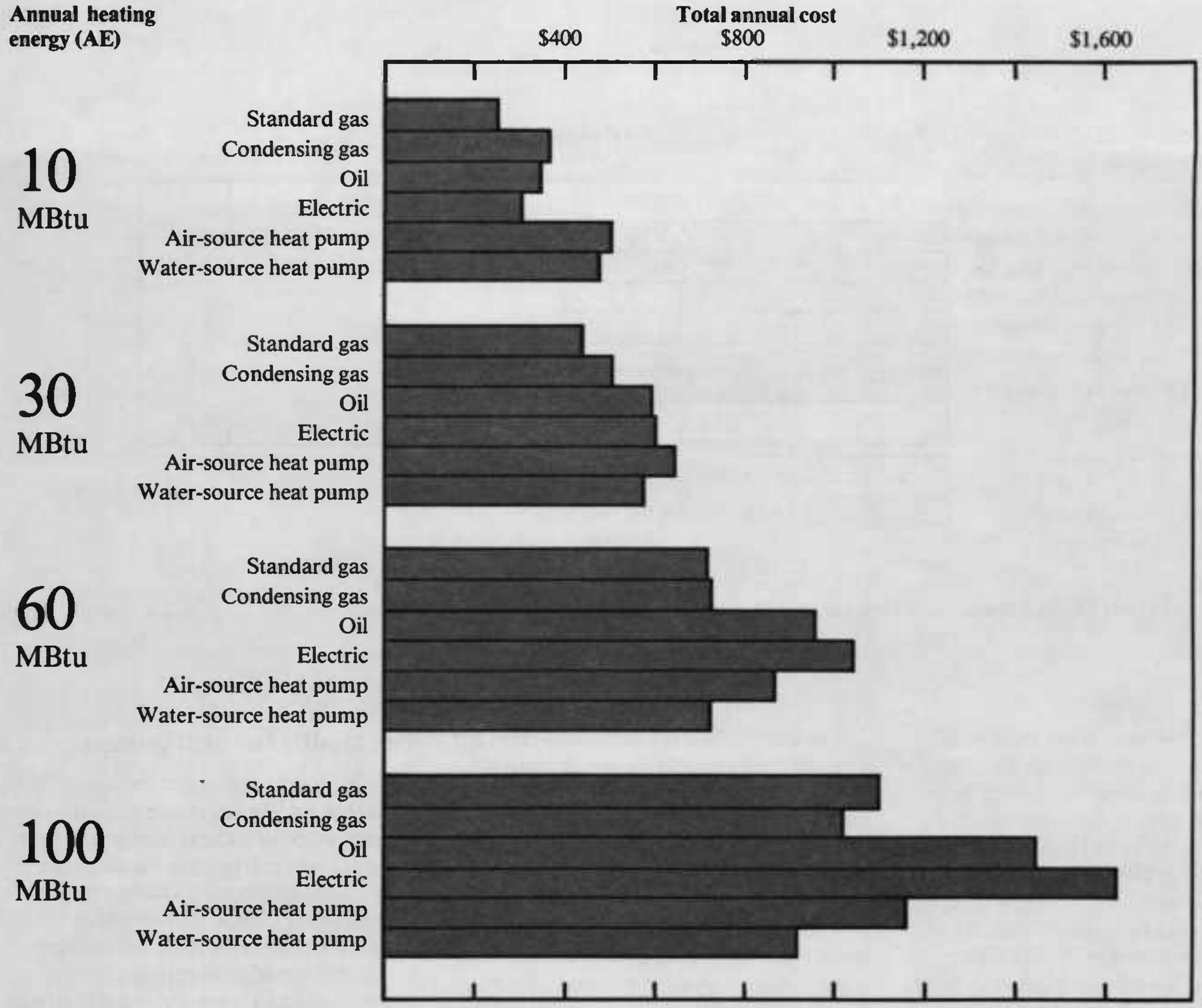


Figure 3a.—Total annual cost for different heating requirements

The reason: annual heating bills are so low (between $50 and $150 a year in this case) that the savings can't justify much additional initial expense. The lowest-cost systems are hard to beat!

As the heating energy increases to 60 MBtu, a condensing gas furnace and water-source heat pump become economical compared with a standard gas furnace. Lower operating costs compensate for the higher initial costs.

Finally, for larger heating requirements of 100 MBtu, the system with the lowest operating cost, a water-source heat pump, has the lowest total annual cost.

There's a message here. If you have a fairly large heating bill, you can probably justify the expense of a more efficient heating system that will save significantly on your heating bills.

But your best investment will be to insulate and weatherize your home *first!* Reduce your heating bills as much as you can—and *then* select the most effective heating system.

Other initial costs can also have a significant effect. The cost of a flue may be necessary for combustion furnaces (Options 1 to 3) if you don't already have one.

You may have to upgrade your electrical service and add wiring to convert to a heat pump or electric furnace.

You may have to modify existing ductwork to accommodate the larger air volumes required by heat pumps.

Any of these "other" expenses may be necessary at an additional cost up to several thousand dollars.

For example, heat pumps provide air conditioning, but you must add it to the furnace systems. Let's assume an air conditioner might increase the cost of the furnace systems (Options 1 to 4) by $2,000 when installed at the same time.

You might also find that your existing ductwork and electrical service are adequate for a heat pump, but you don't have a well. You'll have to add the cost of drilling and plumbing a well to the initial cost of the water-source heat pump (Option 6). Let's assume the well costs $2,000.

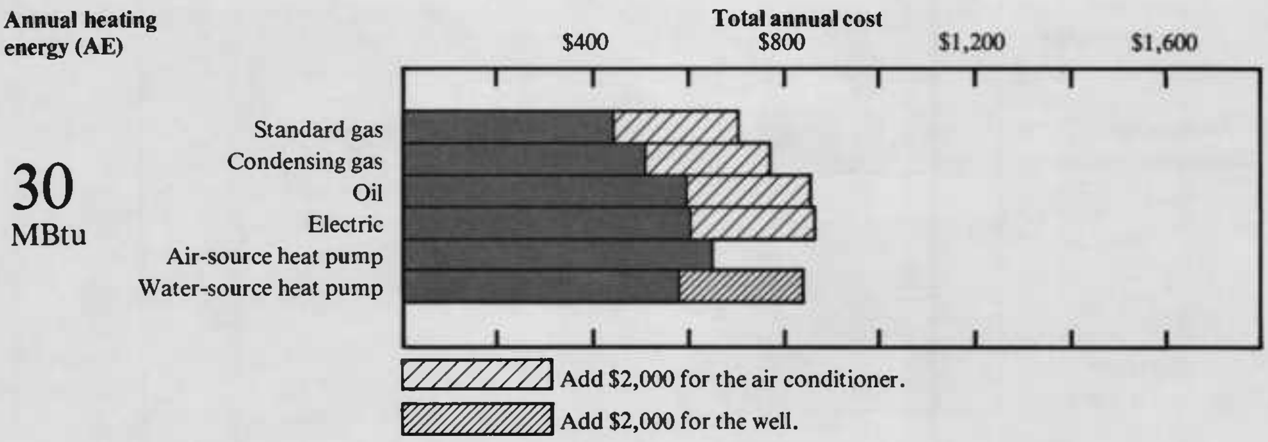


Figure 3b.—The effect of other initial costs on total annual cost

The effect of increasing the initial cost by $2,000 to include air conditioning and a well is shown graphically in figure 3b. The total annual costs for Options 1, 2, 3, 4, and 6 increase by $262 ($2,000 at 10% for 15 years).

The air-source heat pump, which was the *highest* cost option in figure 3a for annual heating energy of 30 MBtu, becomes the *lowest* cost option in figure 3b. The most economical heating system changed because you want air conditioning and do not have a well.

In general, heat pumps are most effective if you have large heating requirements, if you want air conditioning, and if you do not need to enlarge ductwork, upgrade electrical service, or drill a well. A heat pump sized to your existing ductwork can also be effective.

The most effective heating system for your home certainly depends on the costs of energy, equipment, and maintenance in your area. But it can depend even more on the conditions in your home and on your personal requirements.

This is why it is important for you to perform a similar analysis for your home. A step-by-step method is outlined in "The Procedure" (page 12).

Tax credits for heat pumps

Federal tax credits are currently available for the solar components only of a solar-assisted heat pump that does not circulate refrigerant through the collectors. Tax credits change from year to year. Check with the U.S. Internal Revenue Service for current Federal tax credit information.

The State of Oregon currently offers several tax credits for heat pumps. In general, solar-assisted, water-source, and water-heating heat pumps can qualify for the 25% tax credit. The requirements vary, and not all heat pump systems are eligible. Contact the Oregon Department of Energy for current tax credit information. Call toll-free within Oregon 1-800-221-8035; or dial 378-4040 in Salem.

In Idaho, to get current tax credit information, call 1-800-334-SAVE.

Shopping tips

There are several factors you should consider before you buy and install a heat pump. These apply to the equipment, installation, and contractor you select.

Heat pump features

1. *Compare the COP ratings* of several heat pumps. But remember that the Heating Seasonal Performance Factor gives a better indication of how the heat pump will perform over the heating season, including supplemental heat. Larger HSPF's mean lower heating bills.
2. *An outdoor thermostat* ensures that your less efficient supplemental heat will not turn on unless the outside temperature falls below the "balance" point. At air temperatures above the balance point, the heat pump can heat your home by itself. This allows you to take better advantage of your heat pump's energy saving features, and it increases the HSPF.
3. *Defrosting* an air-source heat pump can use 5 to 15% of your heating energy, including supplemental heat to heat your home during the defrost cycle. Some units defrost automatically with a timer. More efficient control systems sense temperature or pressure to defrost only when (and as long as) necessary.
4. *A crankcase heater and an accumulator* increase compressor life by preventing accumulation of liquid refrigerant in the compressor. Crankcase heaters with thermostats save energy as well.
5. *Low-pressure or low-temperature relays* protect against loss of refrigerant, which could cause compressor failure.
6. *High-pressure or high-temperature relays* also protect the compressor from clogged refrigerant lines, plugged filters, or low air flow.
7. *A warning light* on your control panel or thermostat can help you save energy by alerting you when less efficient supplemental heat is on. If this light is on often when outdoor temperatures are above freezing, you are not getting maximum benefit from your heat pump. It may indicate that (a) the control system or heat pump is not working properly and (b) adjustment or repair would improve performance.
8. *A night setback thermostat* can provide additional savings. Use one made specifically for your heat pump—the wrong one can actually *increase* energy use!
9. When shopping for a heat pump, consider using a *desuperheater or additional condenser* to heat your domestic water.
10. *An emergency heat switch* allows you to bypass the heat pump and heat with the supplemental system alone. This feature allows you to keep your home warm and to avoid the inconvenience and urgency of heat pump failure.
11. *A manual or time-delayed restart switch* protects the compressor after a power outage. This allows the crankcase heater to evaporate any refrigerant that may have condensed in the compressor during the power outage, before you restart the compressor.

Installation

Determine with the help of your contractor how your heat pump will be installed before you decide to purchase a heat pump.

1. Make sure your *ductwork* is adequate to accommodate the larger air volumes a heat pump delivers.
2. Check to see that your *electrical service* is adequate for a heat pump system.
3. The *location* of the outdoor coil can affect performance. A sunny location will improve heating performance. Locating the outdoor unit under a bush, hedge, or other dense shrub shades the unit from sun and restricts the free movement of air from which it extracts heat. Decide on the location of the outdoor unit before you purchase a heat pump.
4. Air-source heat pumps can be noisy. Consider *noise levels* before you select a location for the outside unit. Check with your local building department on ordinances that limit noise levels. Ask your contractor for noise ratings in the ARI *Directory of Certified Unitary Air-Source Heat Pumps.*
5. Make sure there is *easy access* to major components, the control panel, and the air filter. This will reduce service and repair costs.

Contractor

Selecting a contractor who will install and service your heat pump may have a greater effect on performance and reliability than the type of heating system you select.

1. *Shop around.* Get several estimates. Ask for local satisfied customers and be sure to contact them. Select a contractor with a proven record for both installation and service. This is top priority for a heat pump.
2. The contractor should do a *heat-loss calculation* for your home before choosing the size of the heating system. Many do not. Your home may be more or less efficient than average, so don't use floor area only to size a heating system. Many contractors routinely oversize the heating system, but this reduces efficiency. The most efficient heating system is sized for your home.
3. A *local contractor* should be able to provide better service than one farther away. Ask contractors if they stock a supply of parts. Does the distributor stock parts? If they do not, your heating system may not operate while you wait for parts to arrive.
4. Be sure you get a *contract* that answers *all* your questions and that clearly defines who is responsible for what, at what cost, and when.
5. The *warranty* should be as long as possible, but at least 5 years on the compressor.
6. In a *maintenance contract,* your contractor agrees to keep your heating system in good working condition for a certain number of years. Your cost may be in the form of a one-time payment or annual payments. Ask about it.
7. *Take your time.* Your decision will affect your heating bill for the next 15 to 30 years!

The procedure

The following procedure shows you step-by-step how to perform an economic analysis for your home. Summarize the results on a worksheet (page 14) as you complete each step. We used this procedure and the assumptions in the "Economic analysis" section (page 8) to produce the results shown in figures 3a and 3b.

Step 1. Weatherize your home first!

With few exceptions, this is the most effective measure you can take to reduce your heating bills.

Step 2. Select heating systems

You may wish to compare several different heating systems. Here we will consider the six systems identified in the economic example (page 8).

Step 3. Gather initial (IC) and maintenance (M) costs

Heating system costs vary depending on size, brand, and dealer. Contact several heating or mechanical contractors to get size, brand, price, seasonal efficiency, and annual maintenance costs of any systems you are seriously considering.

Your energy supplier may supply heating systems or be able to provide lists of local contractors. The prices you find may vary significantly from those used in this example.

Be sure to get complete *installed* costs for your home, including any ductwork, wiring, plumbing, flues, or wells that may be required.

Subtract any applicable tax credits from the initial cost (IC). See the section on tax credits (page 10) for more information.

Maintenance costs (M) also vary with heating system and contractor. We include higher maintenance costs for the heat pumps, although a central air conditioner requires comparable maintenance.

Step 4. Calculate annual equipment cost (P)

A heating system might last from 15 to 30 years. Yet payment might be made with a single check, spread over a 3- to 5-year loan period, or even added to your home mortgage.

The most uniform distribution of annual cost would occur over the life of the heating system, which we assume to be 15 years.

One way of estimating the annual system cost is to assume you borrow the money to install the system. This method gives you a good estimate of the annual system cost, even if you choose not to borrow. The loan payment includes principal and interest.

You can find the annual cost factor (F) in table 1 for your choice of loan period and interest rate.

You might also pay for your heating system from savings. Economic theory helps us by determining the amount of equal annual withdrawals over the system lifetime that is equivalent to a single payment.

In fact, the annual cost factors are the same as those in table 1 except that you would use the interest rate you earn in savings rather than the rate you would pay on a loan.

Let's assume a 15-year period at 10% interest with an annual cost factor (F) of 0.131 from the table. Now you can calculate the annual equipment cost (P) using the initial costs (IC) for the six heating systems: $P = IC \times F$.

Step 5. Determine energy cost per million Btu (E)

You can obtain the energy cost per unit (U) from your utility bills or from local energy suppliers. For example, a unit of gas is a therm, oil comes in gallons, and electricity is measured in kilowatt-hours (kWh). The cost per unit of gas is assumed to be $0.65/therm.

You'll find energy content (B), in million Btu (MBtu) per unit, printed on the worksheet. For example, the energy content of electricity is 0.0034 MBtu/kWh.

Seasonal efficiency (S) is the efficiency of your heating system over the heating season. It is lower than the peak or instantaneous efficiency—it includes losses from cycling off and on, and from using a less efficient supplemental heating system, such as electric resistance.

Seasonal efficiency has different names. Gas and oil systems are rated by annual fuel utilization efficiency (AFUE). Heat pumps are rated by the heating seasonal performance factor (HSPF). AFUE should be reduced by about 5% for the fan energy that is included in HSPF.

Heat pumps are rated by the Air-Conditioning and Refrigeration Institute (ARI) by HSPF, which is the ratio of heating energy delivered (Btu) to the electrical energy used (Watt-hours). The resulting HSPF is generally between 6 and 10.

To get seasonal efficiency (S), divide HSPF by 3.4 Btu/watt-hour. For example, divide HSPF of 6.8 by 3.4 to get a seasonal efficiency of 2.0.

Now you can calculate energy cost (E) in $/MBtu using the formula on the worksheet: $E = U \div (B \times S)$. The cost of energy actually delivered to heat your home includes system efficiency.

Step 6. Determine annual heating energy (AE)

You can determine the annual heating energy required by your home over the heating season in several ways:

a. You may be able to determine heating energy from your utility bills for the last heating season. Utility bills represent total energy use for space and water heating, lighting, and appliances. However, you can often estimate heating energy by comparing summer and winter use. If your summer energy consumption for the fuel you heat with is fairly constant, you have an estimate of energy consumption for nonheating purposes. Subtracting your average summer consumption from the larger heating season consumption gives you an estimate of heating energy. Add heating energy consumption for each month in the heating season to estimate your annual

Table 1.—Annual cost factor (F)

	Interest rate					
Period	6%	8%	10%	12%	15%	20%
5 years	.237	.250	.264	.277	.298	.334
10 years	.136	.149	.163	.177	.199	.239
15 years	.103	.117	.131	.147	.171	.214

heating energy (AE). Your energy supplier may be able to help you interpret your bills.

For example, if your bills show you used 600 therms of gas last year, primarily to heat your home, your annual heating energy would be 600 therms × 0.1 MBtu/therm (line B on the worksheet, page 14) = 60 MBtu. This value of AE will be used in this example: AE = 60 MBtu.

b. Your heating energy supplier will perform a free audit on your home, which includes an estimate of annual heating energy.

c. Your local heating contractor also might be able to perform this calculation.

d. You can perform a heat loss calculation on your own home. Several books offer guidance, including the first book in the general section, "For further reading," righthand columns.

Step 7. Determine annual heating cost (C)

This is how much you will pay for the energy to heat your home at current fuel costs: C = AE × E.

Step 8. Determine total annual heating system cost (A)

Total Annual Cost is the sum of Equipment Cost (P), Maintenance Cost (M), and Heating Cost (C). (The values on this line on the worksheet are those shown in figure 3a, in the 60 MBtu section.)

The system with the lowest Total Annual Cost is the most economical for your home at current energy costs. A similar analysis for your home could guide your decision.

For further reading

General

Langley, Billy C., *Heat Pump Technology*, Reston Publishing Company, Reston, VA, 1983 ($22.95). This 370-page book covers the basics of heat pump systems in more detail than most books. Good descriptions and diagrams of many components are included. Definitely recommended if you plan to design, size, or install your own system. Guidance is offered for many useful calculations, including heat loss and gain, and seasonal performance. Eighty pages are devoted to troubleshooting.

McGuigan, Dermot, with Amanda McGuigan, *Heat Pumps, An Efficient Heating and Cooling Alternative*, Garden Way, Charlotte, VT, 1981 ($6.95). This 200-page book provides a good understanding of heat pumps for non-physics majors. The basics are covered, followed by sections on air-source, water-source, earth-source, and solar-assisted heat pumps.

Water-source

McCray, Kevin B., editor, *Understanding Heat Pumps, Ground-Water and Wells*, National Water Well Association, 500 W. Wilson Bridge Road, Worthington, OH 43085 ($10). This 40-page booklet answers many of the questions about water-source heat pumps. Diagrams and requirements for using ground water are included. A must for the person considering installing a water-source heat pump.

Ground-source

Cropsey, Myron G., *Engineering Aspects of Soil Heat Extraction*, Oregon State University Agricultural Experiment Station publication TB 109, is available from Bulletin Mailing Services, OSU, Corvallis 97331 (55¢ including postage). This technical report presents a method of predicting the amount of energy that a heat pump might extract from the earth, depending on soil type, air temperature, rainfall, and sunshine. A helpful publication if you have some technical experience and intend to design your own ground-source heat pump system.

Using the Earth to Heat and Cool Homes is available from the Superintendent of Documents, U.S. Government Printing Office, Washington, DC 20402 ($1.75). (The GPO Book number is #061-000-00620-6.) A good discussion of methods of using earth- and water-coupled systems. Six of its 22 pages offer step-by-step guidance for selecting an appropriate heating and cooling system, including a life-cycle cost analysis. The third section summarizes lessons learned from selected projects and answers common questions.

Solar-assisted

Lunde, Martin, "Solar-Assisted, Liquid-Coupled Heat Pumps for Residential Use," *Solar Age*, June 1980 ($2.50 for this issue of the magazine). The report describes the components and estimated performance of one type of solar assistance.

Water-heating heat pumps

Burtner, Dave, "Water Heating Heat Pumps," Oregon State University Extension Service Energy Note #E100, is available from Extension Energy, 303 Batcheller Hall, OSU, Corvallis 97331 (no charge). This publication describes how these pumps work and compares their performance with that of gas and electric water heaters. Heat pump location and expected life, as well as cost and savings, are also considered.

Total annual cost worksheet

Cost	Symbols and formulas	Heating system options					
		1 Standard gas	2 Condensing gas	3 Oil	4 Electric	5 Air-source heat pump	6 Water-source heat pump
Equipment							
Initial cost	IC	$1000	$2000	$1500	$1000	$2500	$2500
Annual cost	P = IC × F	$131	$262	$197	$131	$328	$328
Maintenance							
	M	$30	$30	$30	$30	$100	$100
Energy							
Cost per unit	U	$.65/therm	$.65/therm	$1.20/gal	$.05/kwh	$.05/kwh	$.05/kwh
Content (MBtu/unit)	B	0.1/therm	0.1/therm	0.14/gal	0.0034/kWh	0.0034/kWh	0.0034/kWh
Seasonal efficiency	S	0.7	0.9	0.7	1.0	2.0	3.0
Cost ($/MBtu)	E = U ÷ (B × S)	$9.3	$7.2	$12.2	$14.6	$7.3	$4.9
Annual heating cost	C = AE* × E	$558	$432	$732	$876	$438	$294
Total annual cost							
	A = P + M + C	$719	$724	$959	$1037	$866	$722

*Assumed value, AE = 60 MBtu (see Step 6, page 12).

Total annual cost worksheet

Cost	Symbols and formulas	Heating system options					
		1 Standard gas	2 Condensing gas	3 Oil	4 Electric	5 Air-source heat pump	6 Water-source heat pump
Equipment							
Initial cost	IC						
Annual cost	$P = IC \times F$						
Maintenance							
	M						
Energy							
Cost per unit	U						
Content (MBtu/unit)	B	0.1/therm	0.1/therm	0.14/gal	0.0034/kWh	0.0034/kWh	0.0034/kWh
Seasonal efficiency	S						
Cost ($/MBtu)	$E = U \div (B \times S)$						
Annual heating cost	$C = AE \times E$						
Total annual cost							
	$A = P + M + C$						

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