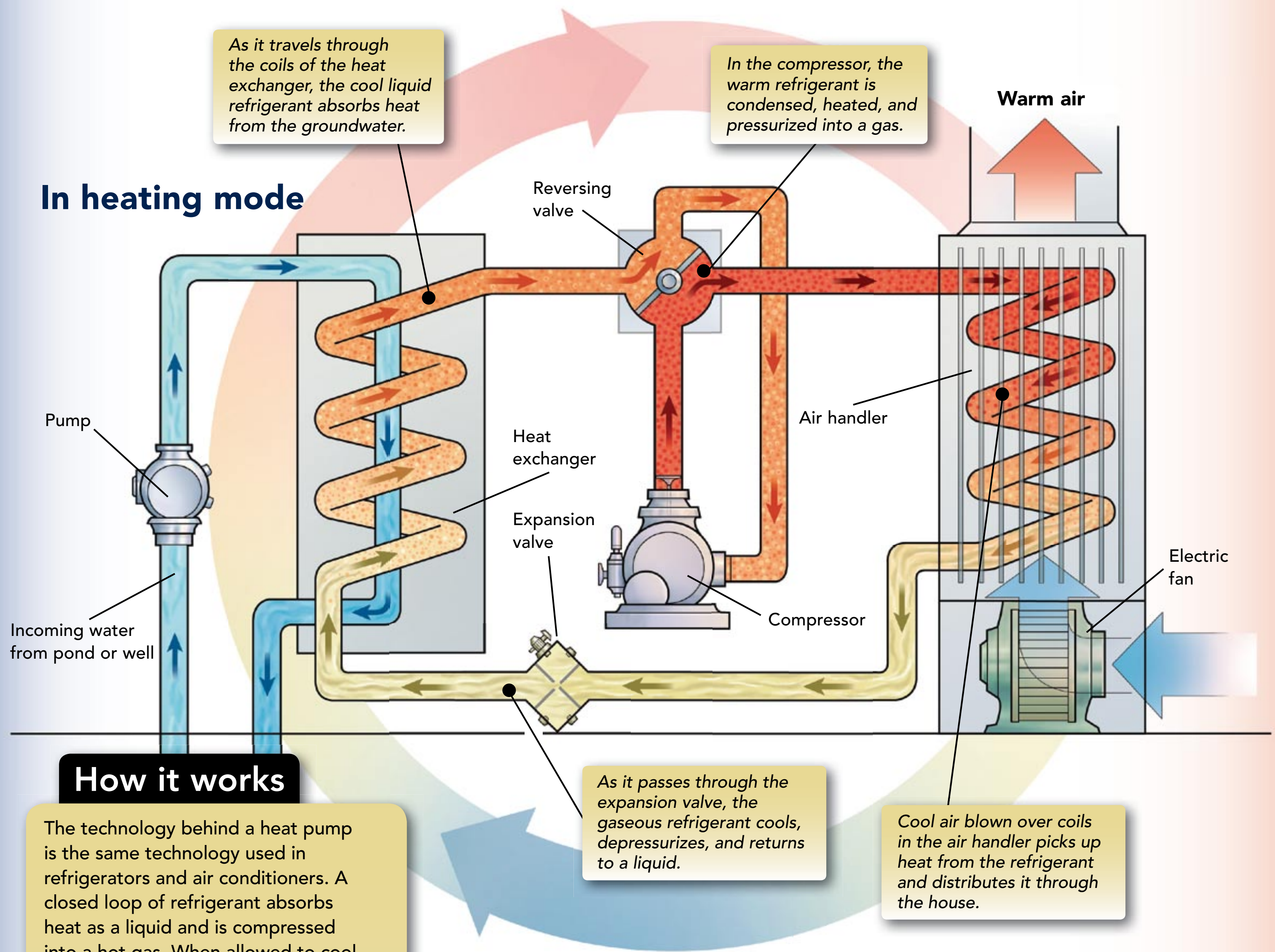
Is a Heat Pump

The high efficiencies and low operating costs of renewable **heating**



How it works

The technology behind a heat pump is the same technology used in refrigerators and air conditioners. A closed loop of refrigerant absorbs heat as a liquid and is compressed into a hot gas. When allowed to cool and return to a liquid, the refrigerant releases its heat. The open-loop ground-source heat pump shown in the drawings picks up or dumps heat into groundwater passing through the coils of a heat exchanger, depending on whether the heat pump is heating or cooling the house. An air-source heat pump uses outside air for this exchange. Because heat pumps can circulate the refrigerant in either direction, they can heat and cool your home.

BY SCOTT GIBSON

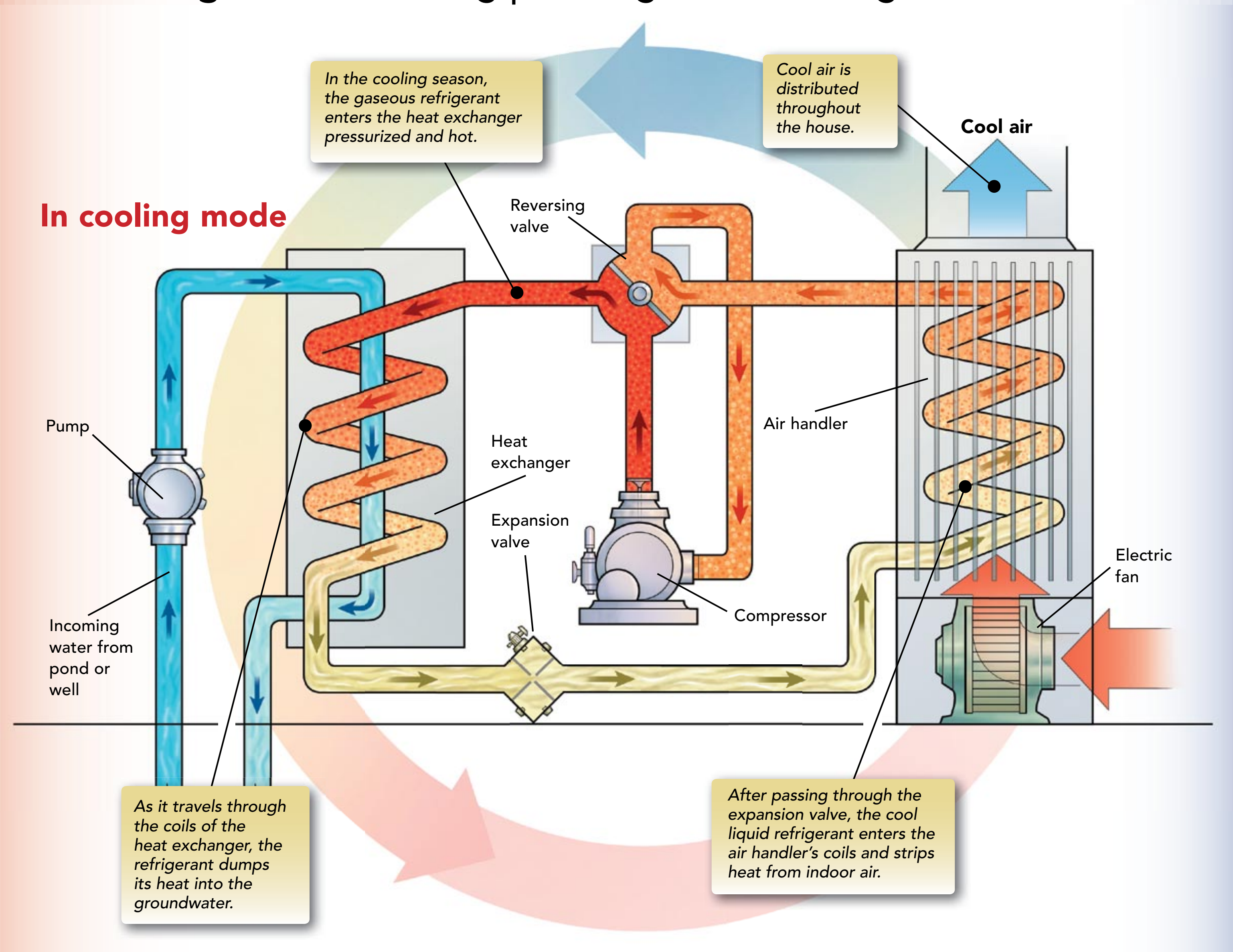
High-efficiency gas-fired furnaces turn more than 95% of the fuel's energy potential into usable heat. Energy losses are low, and so are greenhouse-gas emissions. But what about a heating appliance capable of operating at efficiencies over 100%, producing multiple units of heat for every unit of energy it consumes? And what if it also is able to cool your house in summer and warm your water? High efficiency and versatility are two advantages of heat pumps. And at least on paper, that should make choosing one a slam dunk. Unfortunately, it's not that easy.

There are a variety of heat-pump types to choose from, with a proportionally wide range of prices. Here, I'll take a look at both air-source (ASHPs) and ground-source, or geothermal, heat pumps (GSHPs) and some variations on both. Operating costs will vary depending on where you live, what type of

Drawings: Don Mannes. Photo this page: courtesy of www.altren.net.

Right for You?

and **cooling** come with a big price tag and some regional limitations



heat pump you install, and your local electricity prices. Finally, there are significant caveats when comparing efficiency ratings between heat pumps and conventional heating and cooling equipment. If you're considering a heat pump, you'll have to wade deeply into these details before you can make an informed decision.

Move heat instead of burning fuel

Unlike most heating equipment that burns fuel to create warmth, heat pumps use a vapor-compression cycle to move heat from one place to another. In winter, heat is extracted from the air or the ground, concentrated, and distributed inside via air ducts or radiant-floor tubing. In summer, the same equipment runs in reverse to remove heat from indoor air and dump it outside.

Vapor compression is the same technology that makes a freezer or air conditioner work. With the help of a compressor and an evaporator, a refrigerant circulated through a closed loop absorbs and releases heat as it changes from a gas into a liquid and back again. Because the refrigerant has a low boiling point, it can extract heat even from air or water at or below freezing temperatures.

As the name suggests, ASHPs use outside air as the source of heat in winter and as the heat sink in summer. GSHPs use the earth for this exchange, either through tubing installed in wells or trenches or through a water source like a pond.

ASHPs are popular in the southeastern United States, where cooling is a bigger issue than heating and where winter temperatures are relatively mild. They cost less to install than ground-source heat pumps, but most don't operate as efficiently, especially in cold weather. When temperatures fall below 40°F, they may need a boost from either electric-resistance heaters or fuel-fired furnaces, though there are some exceptions (sidebar p. 52).

GSHPs can be designed either as "open loop" or "closed loop" systems. An open-loop system circulates water from a pond or well through the heat pump and returns it to the source. In a closed-loop system, water or an antifreeze solution circulates through tubing buried in the ground, picking up or dumping heat. There are also GSHPs that circulate refrigerant in buried copper tubing. No matter what the configuration, heat is transferred from the ground loop to a sealed refrigerant loop inside the heat pump. The site work required to install underground tubing makes ground-source heat pumps among the most expensive heating and cooling options, but they operate at very high efficiencies.

Glossary

ASHP: Air-source heat pump

GSHP: Ground-source heat pump

HSPF: The heating seasonal performance factor is the heating-efficiency rating for ASHPs, which equals the total heat output, in Btu, divided by the electricity required to run the heat pump, in watt-hours.

SEER: The seasonal energy-efficiency ratio is the cooling-efficiency rating for ASHPs, which equals the total heat removed from the house, in Btu, divided by the power to run the device, in watt-hours.

COP: The coefficient of performance measures the heating efficiency of GSHPs. The COP equals heating output divided by some of the unit's electrical inputs, both in Btu. A heat pump with a COP of 5 delivers 5 Btu of heat for every 1 Btu of energy used to operate the device. The COP may not consider the electricity needed for pumps, fans, and other necessary mechanicals.

EER: The energy-efficiency ratio describes the cooling performance of GSHPs and equals the cooling load in Btu per hour divided by the electrical input in watts.

Efficiency ratings are not apples to apples

If the basics of how heat pumps work are relatively simple, their efficiency ratings are anything but. ASHPs and GSHPs use different rating systems, and each is measured separately for heating and cooling efficiency. In addition, the efficiency ratings don't necessarily reflect how a heat pump will actually perform in a specific house at a particular location.

ASHP efficiency is gauged by the heating seasonal performance factor (HSPF), which estimates efficiency over an entire heating season, including the need for supplemental heating in cold temperatures. Cooling efficiency is measured by the seasonal energy-efficiency ratio (or SEER), just like an air conditioner.

For both HSPF and SEER ratings, the higher the number, the more efficient the heat pump. Federal law requires a minimum HSPF of 7.7 and a SEER of 13. The best units on the market these days have an HSPF of about 10 and a SEER of 22.

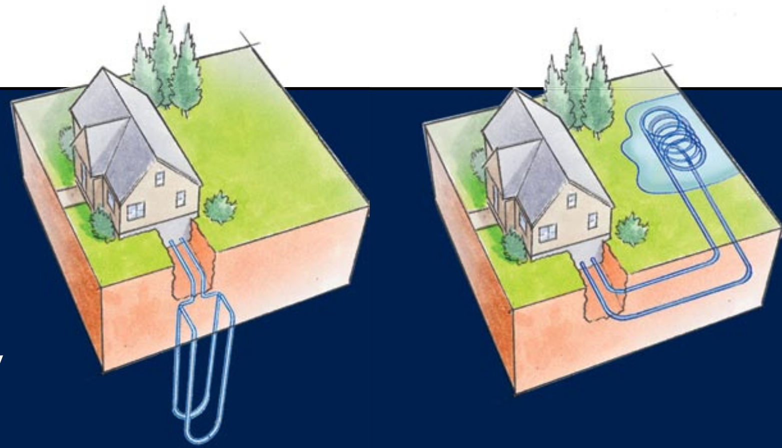
Ground-source heating efficiency is measured as the coefficient of performance (COP), and cooling performance is described as the energy-efficiency ratio (EER). Based on the two different efficiency ratings of both ASHPs and GSHPs, the most important number will depend on how much of the year that you spend heating or cooling your home.

Unfortunately, these efficiency ratings are based on narrow test conditions, not actual site conditions (see "Taking Issue," p. 10). The

Photos: this page, courtesy of www.altren.net; facing page, courtesy of Lennox. Drawings facing page: Dan Thornton.

THREE WAYS TO TAP THE EARTH FOR HEAT

A ground-source heat pump can tap into latent heat stored in the earth in several ways. Open-loop systems draw water from a well or nearby pond and pump the water back to its source. In closed-loop systems, plastic tubing containing antifreeze is submerged in a pond or lake, or is buried horizontally or vertically in the ground.



Slinky loop

It may be tough to beat the efficiency of geothermal heat pumps, but the installation is long, labor intensive, and disruptive to the property. The slinky coils shown here are part of a closed-loop, 8-ton retrofit.

Vertical loop

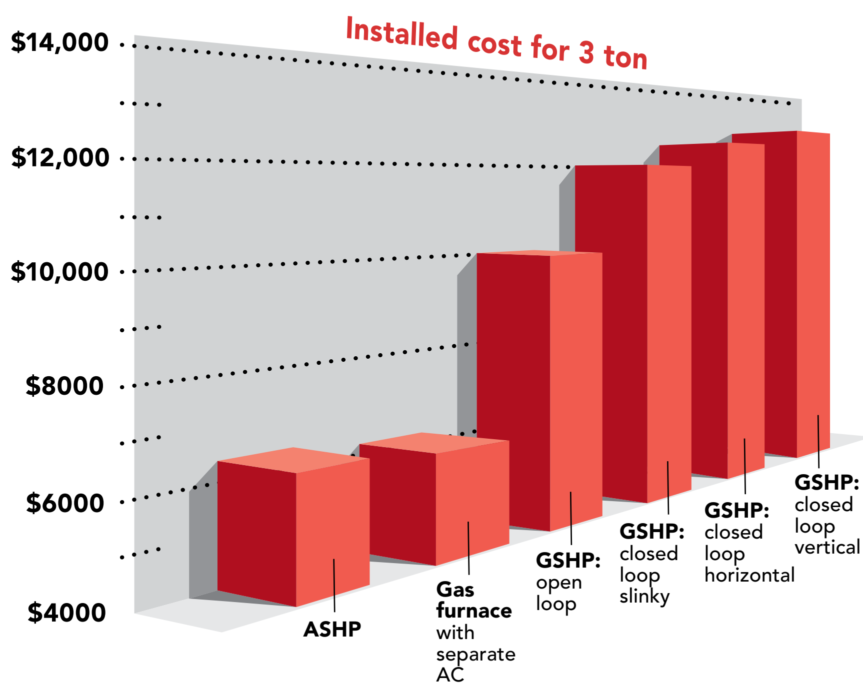
If you don't have a lot of property, you can drill a vertical-loop system. These closed-loop systems are often as deep as 400 ft. You can go vertical with an open-loop system by drilling two wells, one to draw groundwater, the other to return it.

Pond loop

Typically the most cost-effective and least disruptive installation is a pond loop. If you have a sufficiently deep pond, you can run either closed-loop horizontal pipes or an open-loop system that draws and returns pond water.

AIR-SOURCE HEAT PUMPS ARE COST-EFFECTIVE

With higher efficiency comes higher costs. Even the least expensive ground-source heat pump is likely to cost more than either an air-source unit or a conventional gas-fired furnace and separate air conditioner. The chart below shows estimates for the total installed costs of a 3-ton (36,000 Btu) system. Keep in mind that costs can vary dramatically by contractor, system design, and region.



rating systems for GSHPs, for example, do not consider the electricity needed for either the circulating pump to move fluid through tubing or for fans or pumps that distribute heat inside the house. Actual measured COPs (including pumping energy) for installed ground-source heat pumps typically fall between 70% and 74% of manufacturers' stated COPs. Other variables include temperature fluctuations in the earth around the tubing, and whether the system has been installed correctly.

Additionally, there's no simple way of comparing the rated efficiencies of GSHPs and ASHPs because they are, in effect, written in different languages.

The bottom line is that a heat pump may not perform as well as its efficiency rating would predict or, conversely, that it may do a little better than expected when site conditions are favorable. The best use of these performance numbers is for comparing similar heat pumps to one another.

Desuper ... what?

It won't likely be able to meet all your water-heating needs, but a desuperheater can be used to steal some of the heat produced by a heat pump and apply it to potable water. A desuperheater works only when the heat pump is running, and works best when used with ground-source heat pumps running in cooling mode.

Air-source heat pumps have quirks

Most ASHPs are designed for forced-air heating and cooling systems, so the same ducts that distribute the heat also cool the house in the summer. They're often configured as split systems, meaning that there is one condensing coil inside and one outside, with a central air handler inside.

ASHPs produce warm air, not scorching heat. And that, says Harvey Sachs of the American Council for an Energy-Efficient Economy, can leave some homeowners feeling chilly. Airflow at 90°F warms the house, but not with the same punch as a woodstove, a hydronic radiator, or a gas furnace.

In winter, the outdoor condenser needs periodic defrosting. Most ASHPs send hot refrigerant down the line to take care of the problem, but while the condenser sheds its layer of frost, the air handler has to switch to a supplemental heat source. Other common problems include thermostats that force the heat pump to switch to supplemental heat, ducts that are poorly sealed or run through unconditioned space, and systems charged with the wrong amount of refrigerant.

"I don't think we have any heating, ventilating, and air-conditioning technology out there that is more frequently screwed up by installers than heat pumps," Sachs says. "You need to have somebody who really understands heat pumps to get a satisfactory installation."

Ground-source heat pumps are expensive to install

Most GSHPs are connected to an air handler that distributes warm or cool air around the house. They can produce some of a home's hot water, and they also can be used for radiant-floor heating, although a duct system still is needed for air-conditioning in the summer. With water temperatures limited to about 130°F, GSHPs can't be used with most hydronic radiators, which require water that is at least 160°F.

There are lots of installation options for ground-source heat pumps. From a cost standpoint, the most attractive is an open-loop groundwater system, in which water is taken from and returned to a well or pond. According to a report by Kevin Rafferty, a consulting engi-

Two air-source heat pumps for chilly winters

Most air-source heat pumps switch to a supplemental heat source, either electric strip-heaters or a gas furnace, when outdoor temperatures fall into the 30s. But at least two manufacturers now offer models designed to operate at much lower temperatures. These products have the potential to extend the geographic reach of air-source heat pumps substantially; they're now largely limited to the southeastern United States. They are less expensive than ground-source heat pumps and don't require extensive site work.

Hallowell International's Acadia heat pump can operate at 0°F without tapping into a supplemental source thanks to a compression boost that allows the refrigerant to absorb more heat. The added compression doesn't kick in until air temperatures fall below 30°F. The Acadia produces air temperatures ranging from 95°F to 130°F. The company currently does not offer a hydronic model. Duane Hallowell, the company's founder, says the Acadia has an HSPF rating of 9.7 and a SEER of 15. But, he adds, standard industry tests are not an accurate reflection of the heat pump's performance. New cold-weather standards are under development.

Aqua Products's Reverse Cycle Chiller also operates down to 0°F without any supplemental heat source. The device heats or cools an insulated tank of water instead of running directly to a coil inside an air handler. The insulated tanks range in size from 25 gal. to 160 gal. The system uses some of the heated water to defrost the outdoor condenser instead of robbing heat from the refrigerant loop. As a result, the defrost cycle doesn't affect indoor comfort. The Reverse Cycle Chiller can be used for radiant-floor heating as well as forced-air systems. Company president John Seppamaki says the heat pump produces water from 38°F (for cooling) to 120°F (for heating).

Photo: courtesy of Hallowell International

Getting better: **The environmental impact of refrigerants**

Refrigerators, freezers, air conditioners, and heat pumps rely on the ability of refrigerants to absorb and shed heat as they turn from liquid into gas and back again. Unfortunately, when they are released into the atmosphere, some refrigerants deplete the Earth's ozone layer.

Chlorofluorocarbons (CFCs) were proven to be the worst offenders, which led to the wider use of related compounds called hydrochlorofluorocarbons (HCFCs). R-22 is a common HCFC used in heat pumps. While much better for the environment, R-22 does not eliminate the ozone problem completely, and it is also scheduled for a phased withdrawal from the market.

Manufacturers are now turning to another refrigerant called R-410A. It contains no chlorine, so it will not damage atmospheric ozone, although it is considered a greater environmental threat than carbon dioxide. R-410A systems operate at higher pressures than those using R-22, so it's not simply a question of swapping one refrigerant for another. Some manufacturers, such as Water Furnace, switched to R-410A years ago, and all heat-pump makers were forced to do so as of January 2010.

neer and heat-pump specialist in Oregon, the ground loop alone costs between $600 per ton for a 5-ton system and $1000 per ton for a 3-ton system (a "ton" is 12,000 Btu per hour). A vertical, closed-loop system could cost nearly $1600 per ton because of the high cost of drilling. A horizontal closed-loop system comprised of straight tubing or coiled tubing, called a "slinky" ground loop, is somewhere in between. Current costs will vary from one system to another and between different parts of the country, but these numbers can still be useful for comparing the relative cost of one type of system to another.

Open-loop groundwater systems make the most sense in rural areas where a house will be served by its own well, providing the well produces enough water (2 gal. to 3 gal. per minute per ton). Even though a separate pump will be needed, this is commonly still the least expensive route.

Despite their higher cost, vertical closed-loop systems have one advantage over horizontal closed-loop systems: They don't need much property. Horizontal systems require long runs of trenches—not an option for every suburban homeowner.

Overall, even the cheapest installation option for a ground-source system puts it at a higher cost than either an air-source heat pump or a gas furnace with a separate air-conditioning unit. Rafferty's estimated installed costs for a 3-ton system range from about $6000 for an ASHP to more than $12,000 for a closed-loop, vertical-well GSHP. But he warns that costs can be much higher.

Assumptions and estimated operating costs

High efficiency doesn't automatically translate into low operating costs, which depend on the heating potential of each type of fuel and how much it costs locally. In comparing the cost of heating and cooling with either an ASHP or a GSHP and more conventional equipment, a useful common denominator is how much it costs to produce 1 million Btu of heat. These simple formulas estimate the operating costs, taking local energy prices into account (see "Estimate operating costs" above).

To see how two different heat pumps would compare to the 85% efficient oil-fired boiler I have at my house, I plugged in local energy costs: 14¢ per kwh for electricity and $2.25 per gallon for #2 fuel oil. On the heat-pump side, I assumed the ASHP would have an HSPF of 8.5 and that the GSHP would have a COP of 3.5. The results showed that heating with fuel oil would cost $19.19 per million Btu, by far the most expensive option. An ASHP would do the same thing for $16.47, and the ground-source heat pump for $11.72.

Keep in mind that these numbers include assumptions about climate, installation, and system design that wouldn't necessarily hold true; nor do they factor in the up-front cost of the systems themselves. For that, I'd need more specialized advice from a manufacturer, HVAC contractor, or energy designer. But they are a place to start. □

Scott Gibson is a contributing writer.

Estimate operating costs

If you can gather the local costs of fuel and the efficiency rating of the heating and cooling equipment you are considering, you can use these simple equations to compare estimated operating costs.

Fuel oil: (7.25 x $/gallon)/ Appliance efficiency

Propane: (11.1 x $/gallon)/ Appliance efficiency

Natural gas: (10 x $/therm)/ Appliance efficiency

Electric resistance: 293 x $/kwh

Air-source heat pump: (1000 x $/kwh)/ HSPF

Ground-source heat pump: (293 x $/kwh)/ COP

For more info

- For guidance on installing a heat pump, visit the Web site of the Air Conditioning Contractors of America (www.acca.org).
- For efficiency ratings of various heat pumps, try the Air-Conditioning, Heating, and Refrigeration Institute's Web site (www.ahridirectory.org).
- Information on federal tax credits for installing air- and ground-source heat pumps is available here: www.energystar.gov.
- The Geothermal Heat Pump Consortium's Web site offers a wealth of information, including a directory of contractors and manufacturers (www.geoexchange.org).