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FEATURE

With Gas Prices High, Heat Pumps Look Hot

Escalating gas prices and advancements in electric heat pumps have expanded the opportunities for this technology. Heat pumps mine the energy content of one source, typically air or water, and transfer it to another. Depending on ambient air or water temperatures, heat pumps perform the same job as electrical resistance space and water heaters, but they use only a fraction of the electric energy. More important, though, with natural gas prices high, electric heat pumps can compete more effectively with natural gas heaters for space- and water-heating loads.

Heat Pumps for Space Conditioning

In 2003, about 10 percent of commercial buildings used heat pumps for space heat and cooling.[1] Heat pumps are more attractive now than ever because efficiencies have improved. The minimum heating efficiency standard (as measured by coefficient of performance [COP]—higher numbers are better) for small commercial heat pumps was set at 3.0 in 1994 and will increase to 3.3 in 2010.[2]

Models that comfortably beat the 2010 standard are already available. In fact, the best available air-source heat pumps achieve a COP of 4.0.[3] And, unlike natural gas furnaces, heat pumps are not yet bumping up against a physical limit, so heat pump efficiencies will almost certainly continue to climb.

Ground-source heat pumps, also called "geothermal" heat pumps, are even more efficient than air-source heat pumps (up to a COP of 5.5)[4] and also work well in cold climates. They extract heat from the earth and pump it into the conditioned space. Like most heat pumps, they can also provide space cooling. They do, however, have higher first costs. More information on the various types of heat pumps can be found in the *E SOURCE Space Heating Technology Atlas*.[5]

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The high efficiencies available with heat pumps can make up for the higher first costs if fuel costs are significantly less. Fuel costs for space heating depend on many variables, including:

- Climate (structures in colder climates will use more heating energy),
- Building characteristics (for example, more insulation means less need for heating energy),
- The efficiency of the space-heating technology, and
- Fuel price.

At 2004 national average energy prices, fuel costs are lower for heat pumps than for gas furnaces. Specifically: (1) Geothermal heat pumps have lower fuel costs than even the most efficient gas furnaces; (2) the least-efficient air-source heat pump has lower fuel costs than the least-efficient natural gas furnace; and (3) the most efficient air-source heat pump has lower fuel costs than the most efficient natural gas furnace. Furthermore, for different climates or heat requirements, the magnitude of the fuel costs will change, but their relative positions will not.

Cost-effectiveness, of course, is about more than fuel costs: First costs are critical as well. It turns out, though, that air-source heat pumps can have significantly lower first costs than installations that use gas furnaces and electric space cooling. In other words, air-source heat pumps can be cheaper to buy *and* cheaper to run than systems with gas furnaces and electric cooling. This result is, of course, dependent on many assumptions and will vary widely depending on local fuel prices, equipment costs, and other variables.

When to choose a heat pump. Heat pumps can be cost-effective in many climates, so the most important factor to consider when deciding on the best system for space conditioning is the price of energy. Conditions are most favorable when a heat pump is installed in new construction or in a retrofit where the installed HVAC equipment has reached the end of its useful life.

In mild climates, air-source heat pumps can operate effectively as stand-alone heating and cooling systems. For large multizone buildings, water-source heat pump systems are appropriate. These heat pumps draw heat from the building's hydronic distribution loop, which is kept within a well-regulated temperature range. Each heat pump may add or remove heat from the water loop, depending on whether its zone needs to be heated or cooled.

Air-source heat pumps are inefficient in sub-freezing temperatures, so supplementary heat is often needed. The pumping capacity of fluorocarbon-refrigerant systems is known to decrease significantly with low ambient temperatures (less than 40° Fahrenheit [F]). Ground-source heat pumps can be used in colder climates because they use the earth as a stable source of heat (typically 45° to 70°F). If adequate land space is available on-site, ground-source heat pumps can be more cost-effective than air- or water-source heat pumps, because they are more efficient and require less maintenance. This type of heat pump is only appropriate for new buildings, however, because pipes must be installed beneath the ground, often running under a parking lot.

Case studies. Although heat pumps were cost-effective in some of the buildings in these examples, proper maintenance was crucial to achieving the expected energy savings.

- *K–12 schools, Nebraska.* Four identical elementary schools built in Lincoln,

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Nebraska, in 1998 use ground-source heat pumps for space conditioning. In 2000, researchers at Oak Ridge National Laboratory collected performance data from these sites and other schools in the area. They found that, based on first costs, measured energy consumption, and maintenance costs, heat pumps were the most cost-effective choice for the sites, with a life-cycle cost that was 13 percent lower than any other technology. Compared with other new Lincoln schools, the ground-source heat pumps used 26 percent less source energy per square foot (ft^2) per year.[6] Source energy includes all of the energy used in delivering energy to a site, including power generation, transmission, and distribution losses.

- *Office building, Ontario.* The Metrus building, a two-story, 35,000-ft^2 office building, was built in 1988 with a ground-source heat pump system for space conditioning. Technicians from Ontario Hydro Energy monitored the building after it was first built to ensure that the system was performing well. In 2002 they again monitored the system and determined that the heat pumps continued to perform at a comparable level. The building uses 28 heat pump units, ranging in size from 3 to 5 tons, which are hidden in the suspended ceiling. (Using many small units enables the system to heat or cool as needed for each individual zone.) The technicians calculated that the simple payback period was two years compared with a natural gas rooftop unit with conventional air conditioning and five years compared with electric resistance heating with air conditioning (**Table 1**).[7]

- *Visitors' center, Maine.* The visitors' center at the Maine Audubon Society's Gilsland Farm Nature Center uses a 15-ton ground-source heat pump system. The installed cost of the geothermal HVAC system was $105,000, or $19.60 per square foot of conditioned space. In 1997, the Geothermal Heat Pump Consortium funded a study in which technicians installed a data acquisition system

Table 1: Comparison of space conditioning systems for the Metrus building in Ontario

Significant energy-consumption reductions made this geothermal heat pump system cost-effective compared with other space conditioning options, with a payback period of two to five years.

	Capital cost ($)	Expected life (years)	Energy costs ($/year)	Maintenance costs ($/year)	Total cost ($/year)	Simple payback (years)	Annual CO_2 emissions (kg/year)[a]
Case 1							
Ground-source heat pump	322,000	20+	15,317	3,261	18,578		192,143
Gas alternative with standard air conditioning	296,000	15	25,442	7,115	32,557		205,518
Difference	26,000	5+	–10,125	–3,854	–13,979	2	–13,376
Case 2							
Ground-source heat pump	321,000	20+	15,317	3,261	18,578		192,143
Resistance heat with standard air conditioning	220,000	18	32,118	5,336	37,454		402,900
Difference	101,000	2+	–16,801	–2,075	–18,876	5	–210,758

Notes: CO_2 = carbon dioxide; kg = kilogram; MWh = megawatt-hour.
All dollar values in this table are in U.S. dollars.
a. Assumes 850 kg/MWh of electricity production.

Source: E SOURCE; data from Natural Resources Canada [7]

> ***At current and forecasted energy prices, HPWHs have lower fuel costs than any commercially available water-heating technology, gas or electric.***

and sensors at the visitors' center for detailed data collection. Performance monitoring revealed several HVAC system operational problems that were corrected before data collection continued throughout 1998.

The field-test data showed that the standing-column well, used for heat-exchange with the earth, was a stable source of moderate-temperature water that only varied from 48° to 54°F throughout the year. The measured data showed that the energy used to heat and cool the visitors' center during 1998 totaled 7.3 kilowatt-hours (kWh) per square foot. However, the technicians found several problems with the heat pumps and the controls that increased energy use; they estimated that correcting these problems could reduce energy use to 5.2 kWh/ft^2.[8]

- *Elementary school, Maryland.* When the 45,900-ft^2 Choptank Elementary School in Cambridge, Maryland, was built in 1997, it incorporated a ground-source heat pump for space conditioning. The installed cost for the system, including the ground loop, was $20 per square foot. Upon completion of the building, the Geothermal Heat Pump Consortium funded a study of the system's performance. Technicians monitored the system for a full year and found that the annual energy consumption of the system was 277,000 kWh, or 6.0 kWh/ft^2. These figures include the electrical usage by the main circulating pump, which amounted to 54,500 kWh for the year—nearly 20 percent of the total HVAC energy usage. For all loads besides HVAC, the electrical usage was 489,000 kWh, or 10.7 kWh/ft^2. The technicians found that the heat pump used more energy than necessary because the control system failed to reduce flow rates through the main circulation pump sufficiently during periods of partial or total heat pump inactivity.[9]

Resources. The Federal Energy Management Program provides a free calculator you can use to determine whether a heat pump is right for your facility at www.eere.energy.gov/femp/technologies/eep_comm_heatpumps_calc.cfm.

To find out about incentives available for installation of a ground-source heat pump, visit the Geothermal Heat Pump Consortium's web site at www.geoexchange.org/incentives/incentives.htm.

Heat Pump Water Heaters

The heat pump water heater (HPWH) is not a new technology, but recent improvements suggest that it may be time to take it seriously. The air-source HPWH extracts heat from the air surrounding the unit and uses it to heat water. It's conceptually similar to an air-source heat pump used for space heating. At current and forecasted energy prices, HPWHs have lower fuel costs than any commercially available water-heating technology, gas or electric.

HPWHs achieved some market success in the early 1980s, when sales were in the tens of thousands per year. After this early surge, however, sales faded away. The decline in popularity was due to high first costs, historical reliability issues, and an uninformed design community. The complexities of HPWHs also make them more difficult to install, raising the price of installation as well as the opportunity for installation errors. For the most part, the only engineers today with the knowledge to properly design commercial systems are the manufacturers themselves.

When to choose an HPWH. Your building may be a good candidate for an HPWH if:

- You need to replace an electric water heater,
- You're looking to add air conditioning to spaces where it's normally cost-prohibitive,
- Natural gas is not available in your area, or
- You require a large, steady load of hot water throughout the day.

Because HPWHs produce cool, dry air as a by-product of heating water, the best applications are those that take advantage of both outputs simultaneously. Consequently, HPWHs are especially well suited for commercial-sector applications where the demand for hot water is relatively constant and the need for cooling or dehumidification is continuous, including:[10]

- Commercial laundries
- Commercial kitchens (place the HPWH evaporator in a location where it can take advantage of the heat from the dishwasher)
- Fast-food restaurants, particularly in climates where space cooling is essential
- Hotels and motels (place the evaporator of the HPWH near ice machines to improve their performance)
- Health clubs, for spa heating and service water heating
- Multifamily housing and apartments where hot water is provided by a single system for all residents

Although commercial HPWH applications are not limited by geography, air-source HPWHs do work best in mild climates where the ambient temperatures are hot enough in nearly every season to provide hot water.

The initial cost of a commercial HPWH is much greater than that for an electric or gas-fired boiler, but the annual savings are so large that paybacks typically range between two and three years. Water inlet and setpoint temperatures, HPWH location, air-conditioning and dehumidification loads, and water consumption rates are some of the parameters a commercial designer takes into account. This makes estimating commercial HPWH economics a trickier process, so contact a vendor or system designer to see if an HPWH is appropriate for your application.

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Case studies. The following two case studies identify performance problems that, although common in HPWHs, are correctable and demonstrate the need for regular maintenance.

- *Restaurant, New York.* The American Council for an Energy-Efficient Economy and its subcontractor monitored the performance of an HPWH from March through May 2002. The site was the 1,500-ft^2 kitchen of the full-service restaurant in the Geneva Lakefront hotel. The system uses four 10-ton water-to-water HPWHs that extract heat from the ground-source heat pump loop that provides space conditioning. The technicians collected performance data that indicated that one of the heat pumps was not working properly. The study concluded that this problem is likely the reason that the cost of water heating with this system was higher than it would have been with a natural gas system.[11]
- *Dormitory, Connecticut.* In 1995, Central Connecticut State University

The HPWHs reduced electricity usage by 60 percent (or 330 kWh/day) compared with the 90-kilowatt resistance water heater that the HPWHs replaced.

upgraded the water heating system at a student dormitory. It installed two air-source HPWHs—each with a 150,000 Btu/hour heating rate—and a new 4,500-gallon storage tank. After the installation, Northeast Utilities commissioned technicians to monitor the performance of this water-heating system for one year. The technicians identified a control problem that led to poor HPWH performance due to the improper placement of a temperature sensor. They corrected the problem and, with further monitoring, concluded that the HPWHs reduced electricity usage by 60 percent (or 330 kWh/day) compared with the 90-kilowatt resistance water heater that the HPWHs replaced. The system also reduced the peak 15-minute electrical demand by about 80 percent, for an average demand reduction of 75 kilowatts per day.[12]

Resources. *E SOURCE Customer Connections* offers more information on HPWHs, including a list of manufacturers, in a Purchasing Advisor brief: "Water Heating: Heat Pump Water Heaters." You can find it online at www.esource.com/customerconnect/CC_esource/PA_26.html.

Find out more about how to perform calculations to compare heat pumps and conventional systems in the E SOURCE Customer Direct Pamplet, "Head-to-Head: Choosing Between Gas and Electricity" (MAS-P-4-ESCD), available on the *E SOURCE Corporate Energy Managers' Consortium* web site at www.esource.com/members/resources/cemc_energytips.asp.

IN BRIEF

U.S. Voluntary Green Power Market Report

Green power is growing in popularity, and large companies, institutions, and government organizations are the ones responsible for pushing its market growth in the United States. From 2000 to the end of 2004, installed renewable generating capacity climbed from 167 megawatts (MW) to more than 2,000 MW to meet the needs of voluntary green power purchasing. A report on this trend from the U.S. Department of Energy's (DOE's) National Renewable Energy Laboratory was released at the Tenth National Green Power Marketing Conference in Austin, Texas.

The report is divided into four sections, covering current trends and marketing activities for green power in the United States. The first section offers a summary of green power markets, including product pricing, sales, and consumer response; the second gives quick descriptions of utility green pricing programs; the third details a sample of companies that actively market green power and renewable energy credits; and the fourth features a number of large, nonresidential green power purchasers, including businesses, universities, and government entities.

The report is titled "Green Power Marketing in the United States: A Status Report" and is available for download at no cost from www.eere.energy.gov/greenpower/resources/pdfs/38994.pdf.

Comprehensive Guide to Energy Savings for Commercial Office Buildings

Commercial office buildings are one of the largest energy users in their sector, accounting for 28 percent of all commercial energy demand. In a continuing effort to increase energy efficiency in office buildings, Flex Your Power has released a new best-practice guide on energy savings for existing commercial office buildings. The guide covers topics including how to plan an energy program for your building and tips on getting funding for efficiency projects, as well as information on the building technologies that help save energy and reduce operating costs. The guide uses case studies to illustrate how some buildings transfer these ideas into practice and reap the potential savings.

Be on the lookout to catch future best-practice guides from Flex Your Power on such topics as food and beverage processors, warehouses and storage facilities, industrial and manufacturing facilities, institutional office buildings, and new home construction. The Commercial Office Buildings Best Practice Guide is available online at www.FYPower.org/com/bpg and paper copies can be requested from success@fypower.org.

Energy Policy Act of 2005: New Appliance Efficiency Standards

A new set of energy-efficiency standards for residential appliances was established as part of the comprehensive energy bill signed by President Bush this past August. A rule to codify these standards has been published in the *Federal Register*. The rule addresses equipment for which the Energy Policy Act of 2005 requires certain standards, including fluorescent lamp ballasts; ceiling fans and light kits; illuminated exit signs; torchieres; low-voltage dry-type distribution transformers; traffic signal and pedestrian modules; unit heaters; medium-base compact fluorescent lamps; dehumidifiers; commercial prerinse spray valves; mercury-vapor lamp ballasts; commercial-package air conditioning and heating equipment; commercial refrigerators, freezers, and refrigerator-freezers; automatic commercial ice makers; and commercial clothes washers.

The Building Technologies Program, part of the DOE's Office of Energy Efficiency and Renewable Energy, manages test procedures and energy conservation standards for consumer products and commercial equipment. To learn more about the Building Technologies Program's Appliances and Commercial Equipment Standards, visit www.eere.energy.gov/buildings/appliance_standards or call the DOE's Energy Efficiency and Renewable Energy toll-free hotline at 1-877-EERE-INF (1-877-337-3463).

Notes

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