Head-to-Head: Choosing Between Gas and Electricity

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Now that natural gas prices have risen, is natural gas still the most cost-effective fuel for commercial or industrial building energy applications? In many parts of the U.S. and Canada, the gap between gas and electricity prices on a per-unit basis has diminished significantly over the last five years. The best fuel option for a given application depends on a handful of variables specific to each individual building, but two electricity-driven strategies for meeting thermal loads have recently become more cost-effective because of rising natural gas prices. The first is electric heat pumps for space or water heating, and the second is electric resistance heating in buildings that require very few annual heating hours.

Gas Prices Are Rising

The intense escalation of natural gas prices over the past several years is no secret. All gas consumers felt the heat as annual wholesale prices in the U.S. and Canada rose between 2000 and 2004—as much as 35 percent in the Pacific Northwest and 100 percent on the Ontario/New York border. The U.S. monthly average delivered commercial prices rose roughly US$0.40 per therm (US$3 per gigajoule) between April 2000 and April 2005—an increase of approximately 70 percent over five years.

Electricity prices, on the other hand, have remained relatively flat since the price spikes of the 1970s and early 1980s. Although some electricity is made with gas, complexities in the energy markets have kept electricity from experiencing the same volatility. And because only 18 percent of electricity in the U.S.—7 percent in Canada—is produced with natural gas, the link between average prices for natural gas and electricity varies from utility to utility.

Looking at the big price picture, we see that the ratio of the U.S. national average commercial price of electricity over that of natural gas has declined from 3.4:1 in 2000 to 2.6:1 in 2004, a drop of nearly 25 percent. Two strategies take advantage of this decreasing fuel price gap to enable electricity to compete more effectively with natural gas for space- and water-heating loads.

Strategy 1: Heat Pumping

Escalating gas prices and advancements in heat-pump technology expand the opportunities to use electric heat pumps. 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 while using a fraction of the electric energy.

The most common measurement of efficiency for the heating mode of heat pumps greater than five tons (17.6 kilowatts) and all sizes of heat-pump water heaters (HPWHs) is coefficient of performance (COP), which is the ratio of energy output over energy input. COP values for space-heating applications typically range between 2 and 3 (near 2 during cold conditions and 3 or above during mild conditions), meaning that the heat pump transfers two to three times more energy than it requires to operate. HPWHs typically transfer heat from hot indoor areas or waste heat streams, producing COPs in the 3 to 4 range. All heat-pump systems typically contain electric resistance elements to provide backup heat when the heat pump itself is unable to meet the load.

Commercial HPWHs may compete with natural gas—and certainly electric—resistance water heaters in most commercial and industrial water-heating applications. As a by-product of the heat-pumping process, HPWHs produce cool dry air that designers can duct throughout a building, either to offset other cooling equipment or provide spot cooling stations to employees in hot working conditions.

Applications where compressor-based space cooling may be cost-prohibitive—such as commercial laundry facilities and commercial kitchens—may benefit from increases in worker comfort and productivity. These systems initially cost more than other water heaters, but lower energy costs typically result in paybacks of two to three years.

Strategy 2: Electric Resistance

Space heating with individual room electric resistance elements can be the most cost-effective space-heating option over the life of a building, but only if the heating load and the number of annual heating hours are kept to a minimum. The energy savings typically gained from centralized systems may not justify the additional cost of a boiler or furnace if the system is in use very few hours each year. Whether or not a building has a significant heating load depends on three main attributes: the local climate, whether the architect incorporates passive solar design elements during design and construction, and how many heat-producing internal loads the building houses, such as lighting, computers, and manufacturing equipment.

How to Choose

No simple rule of thumb exists for building owners, designers, or engineers to rely on when choosing between natural gas–fired equipment and electrical equipment for space- and water-heating needs. If the price of either fuel has been historically expensive—as natural gas has been in Hawaii, where the commercial sector price is more than twice the national average—the decision is typically not time-consuming. In areas that rely on natural gas and those that have experienced high and volatile prices, however, choosing one over the other can be a vexing decision. The complexity of a simple payback or life-cycle cost analysis changes with the amount of variables in the calculation, and some variables are more difficult to estimate than others.

At a minimum, a handful of variables are needed for these types of calculations. Some are easy to find, but others may take some digging or require educated assistance. Specific variables to consider include:

Utility prices. The simplest and most accurate method of determining utility prices is to examine a monthly utility bill; include all surcharges and taxes to yield a comprehensive per-unit charge. It may be helpful to normalize the cost of energy for a price comparison, in which case a universal unit is the Btu. One Btu is the energy necessary to raise the temperature of one pound (lb) of water by one degree Fahrenheit (F) at sea level. To convert kilowatt-hours to Btu, multiply by 3,412. To convert therms to Btu, multiply by 100,000.

Equipment costs. Quick and reliable sources of equipment-cost information are construction cost-estimator books such as those published annually by RS Means Co. and Craftsman.

Equipment efficiencies. Manufacturers' web sites and your local supplier are the best sources for equipment-performance specifications. Specification sheets for gas-fired equipment typically show energy input and energy output in units of Btu for the various models and sizes. To calculate efficiency, simply divide the output by the input. Altitude can affect the performance of gas-fired equipment, so it's best to consult with the manufacturer to determine any necessary adjustments. Specification sheets for commercial heat pumps display two metrics, one for heating and one for cooling. The heating metric is typically COP and the cooling metric is typically energy-efficiency ratio, which is the amount of cooling in Btu per hour divided by the electrical power input in watts. HPWH efficiency is typically shown in units of COP.

Energy usage. The most challenging task can be determining an accurate estimate of energy use for space heating or hot water (see sidebar). Tabulating energy use from historical utility bills is one method, but creating

Calculating the Energy Needed to Heat or Cool a Substance

The equation to calculate the necessary energy to heat or cool a substance, such as air or water, to a specific temperature is: $q = mc(T_2 - T_1)$

Where (equivalent metric units are provided in parentheses):

- q = energy in Btu (joules)
- m = mass of the substance in lb (kilograms [kg])
- c = specific heat of a substance in Btu/lb-°F (joules/kg-°C)

  Note: The specific heat (c) for water is 1.0 Btu/lb-°F (4,180 joules/kg-°C); the specific heat for air is 0.24 Btu/lb-°F (1,000 joules/kg-°C).
- T_2 = the ending temperature of the substance in °F (°C).
- T_1 = the starting temperature of the substance in °F (°C).

Table 1: A comparison of water-heating systems for a 100-unit hotel

If this hypothetical hotel requires 1,000 gallons of hot water per day, and utility rates are equal to the 2004 national average U.S. prices, annual savings from using an electric heat-pump water heater (HPWH) will be approximately $1,500 per year, covering the equipment cost difference in approximately 10 months. This solution does not account for storage or distribution losses, which are assumed to be the same for both systems.

Variable	HPWH	Gas water heater
Water-heater efficiency[a]	3.50	0.82
Cost of fuel (US$/unit)[b]	0.08	0.90
Annual fuel cost (US$/y)	1,505	2,503
Equipment cost (US$)	12,500	11,750

Notes: F = Fahrenheit; y = year.

a. HPWH efficiency is expressed in coefficient of performance; gas water heater efficiency in annual fuel use efficiency.

b. Electricity cost is expressed in $/kilowatt-hour; natural gas cost in $/therm.

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an estimate is almost always difficult because tenants employ more than one end use for a particular fuel. One way around this is to individually meter an end use, even temporarily.

A thorough and trusted source for space- and water-heating load calculations is the *Handbook of Fundamentals*, which is published by ASHRAE (the American Society of Heating, Refrigerating, and Air-Conditioning Engineers). If you have never done these calculations, it's best to find an engineer with experience to assist you.

A third option is to model the building with one of several popular programs made for simulating commercial buildings. For example, Energy Design Resources offers eQUEST, which is available free at www.energydesignresources.com and includes a building-creation wizard to guide the user step by step. Other simulation packages with user-friendly, graphical interfaces are available for a fee, including Visual DOE, available from Architectural Energy Corp. at www.archenergy.com, and DesignBuilder, available at www.designbuilder.co.uk. It is helpful to have the past two or three years of utility bills on hand for calibrating any model.

Example Calculation

Table 1 shows a bare-bones calculation to compare a natural gas–fired water heater with a heat-pump water heater for a hypothetical 100-unit hotel. The average daily consumption parameter is from the ASHRAE *Handbook of Fundamentals*; the gas-fired equipment costs are from RS Means *Assemblies Cost Data 2005, 30th Edition*; the electricity and natural gas costs are 2004 national average prices from the U.S. Energy Information Administration (EIA); and the HPWH price estimate was given to us by a consultant. For more information, see "Useful Links and Contacts."

A more accurate analysis than the one shown in Table 1 requires a handful of additional variables. For example, electricity is not typically sold on a per-unit basis; demand charges, block rates, and time-of-use pricing can be incorporated into the calculation to get a more accurate estimate. Other factors include spatial requirements, flexibility for capacity adjustments, and equipment attributes such as free cooling from an HPWH. For a full life-cycle analysis it is helpful to consider the following:

- *Utility escalation rates*. The average annual percentage of fluctuation in utility costs over a length of time.
- *Discount rate*. A rate used to convert future costs to present values.
- *Equipment lifetime*. The expected length of time the equipment will last before needing to be replaced.
- *Maintenance costs*. An annual amount needed to keep the equipment in good working condition throughout the equipment lifetime.

Summary

Escalating natural gas prices are closing the gap between natural gas and electricity on a cost-per-unit basis, creating some opportunities for electricity-driven technologies. The primary technology to consider is the heat pump, for both space- and water-heating applications. Building owners or engineers looking to weigh their options should evaluate a handful of utility, product, building, and economic parameters to choose the fuel that is best for each individual application.

Useful Links and Contacts

HVAC cost estimation books can be purchased at www.rsmeans.com and www.craftsman-book.com. Your local public or university library may also have these resources.

ASHRAE reference books are available at www.ashrae.org.

Historical monthly and annual electricity and gas prices by state and utility are available from the EIA (www.eia.doe.gov).

Roberts Systems Inc. of Birmingham, Alabama, provides consulting services for commercial HPWH system sizing and design. For more information call 205-682-7373.