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Heat Pump Water Heaters

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This is the 23rd article inspired by a recent DOE report covering energy-saving HVAC technologies.

Electric resistance water heaters are common in parts of the country that don't have gas service. Although they serve about 40% of all residences, the units account for nearly half of annual residential water heating primary energy consumption. This discrepancy reflects the low primary energy efficiency of electric resistance water heaters (about 0.27) compared to fuel-fired units (about 0.55¹). Heat pump water heaters (HPWHs), however, can achieve dramatic improvements in the energy efficiency by replacing purely dissipative heating with heat pumped from the surrounding air.

HPWHs operate the same way as heat pumps used for space heating (*Figure 1*). They use a vapor-compression cycle to move heat from the surrounding air to (in this case) the hot water tank. When the water temperature in the tank falls below its setpoint, the compressor turns on. Heat flows into the vapor-compression cycle from the surrounding air through an evaporator coil and is transferred to the hot water (which also serves as the condenser) via a heat exchanger. Some HPWH designs integrate the heat pump components with the hot water tank. In *Figure 1*, the heat exchanger is a tube wrapped around and affixed to the outside of the tank, while others have a separate add-on heat pump package. HPWHs also include backup resistance heating elements that provide heat when high draw rates rapidly deplete the hot water supply.

In the early 1980s, two major manufacturers introduced HPWHs and U.S. annual sales grew to between 8,000 and 15,000 units.^{2,3} The units had installed cost and warranty problems. The two major manufacturers soon pulled out, leaving only a few small players in the market. Sales dropped to some 2,000 units,⁴ where they remain today. Currently, HPWHs represent less than 0.1% of the nation's residential electric water-heater market.

Recently, a market-optimized HPWH arrived on the market. It is designed as a drop-in replacement for electric-resistance water heaters, with similar physical dimensions and a similar installation method. Relative to existing HPWHs, it has the potential for lower installed cost and only a modest efficiency penalty.²

Energy Savings Potential

A residential HPWH typically consumes half the energy used by a conventional, electric-resistance water heater. Taking into account supplemental resistance heating, an HPWH uses 40% to 60% less electricity than an electric-resistance water heater.^{2,4,5,6} Nationally, electric water heating accounts for about 6% and 2.5% of primary energy consumed in residential and commercial buildings, respectively.¹ HPWHs could reduce electric water heating energy consumption by 50%, or up to 0.9 quads.

Market Factors

Despite substantial energy savings potential, a significant residential HPWH market has not yet developed, primarily due to the high equipment and installation costs. Current HPWHs have an incremental cost of \$900 to \$1,000 relative to electric-resistance water heaters⁶ or an installed cost of about \$1,400.^{2,6} The market-optimized HPWH could improve the cost effectiveness of HPWHs. One study projects that the installed cost could drop to between \$1,100 and \$1,200, with production volumes of at least 10,000

units per year. If a large water heater or appliance manufacturer produced 10,000 or more HPWHs a year, the installed cost could decrease to around \$750 per unit. Several opportunities for further component cost reduction exist, including the evaporator fans, expansion device, control system, and shroud.²

At \$1,400 per unit, a residential HPWH has a simple payback period (SPP) of between five and eight years (assuming electricity costs \$0.08/kWh and a 43°C rise, for 40 and 64 gallons per day of hot water consumption, respectively). In parts of the

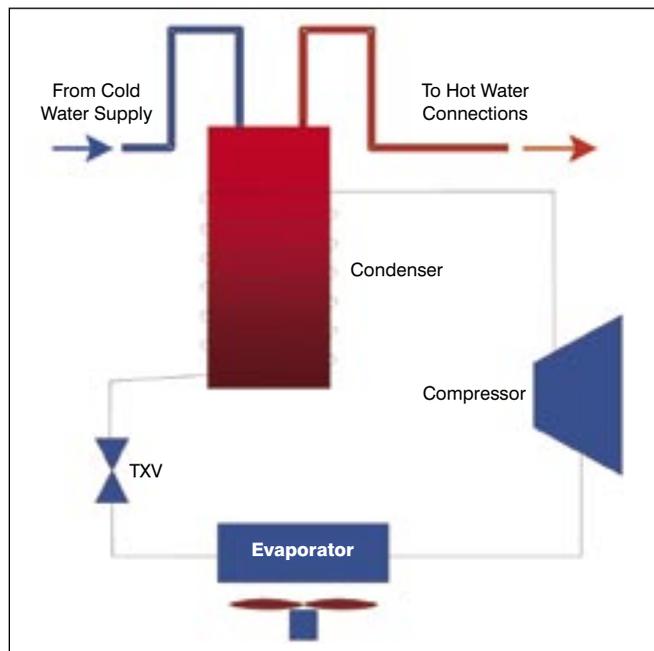


Figure 1: Heat pump water heater schematic.

country with high electric rates, e.g., the \$0.12/kWh average price in California, the SPP would be three to five years. At the \$750 installed cost point, the SPP would decrease to one and two years. HPWHs tend to have more attractive economics in commercial water heating applications with higher duty cycles, such as hotels and gyms.

HPWHs continue to suffer from several issues that have impeded their market penetration during the past two decades. Recent laboratory and field tests suggest that reliability concerns still remain.^{2,7} In addition, failed water heaters usually require emergency replacement to maintain hot water service, meaning that the contractor replaces the failing unit with whatever is in stock.

Few distributors stock HPWHs because of their small market share. Moreover, many HPWHs installations require a condensate drain to remove water that condenses at the evaporator. This can increase installation cost and complexity. Finally, noise from the evaporator fans for HPWHs installed near bedrooms can irritate building occupants.²

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