Introduction

The United States has a long-term vision to decarbonize the electric grid, which will require market transformations on the supply and demand sides of multiple sectors. Utilities are pursuing renewable energy projects to supply the grid with electricity with a lower carbon footprint. Buildings will also play an important role in achieving decarbonization objectives, and eliminating the building systems that require the burning of fossil fuels will be a crucial step. In 2021, nearly 48% of energy consumed by the combined residential and commercial sectors came from directly burning fossil fuels.1 Electrifying building loads reliant on fossil fuels—primarily space heating and water heating systems—will be a necessary shift on the decarbonization path.

Heat pumps are high-performance, energy-efficient equipment that extract heat from air, water, or the ground and upgrade it to temperatures useful for space and water heating in buildings. If your building has a refrigerator or air conditioner, you’re already using heat pump technology. Heat pump water heaters (HPWHs) are an especially effective electric option for residential and commercial buildings’ hot water needs: when reviewing equipment ratings from key manufacturers, HPWHs can be up to four times more efficient than electric resistance water heaters.2 In recent years, manufacturers have increased offerings for residential HPWHs along with informational and educational guides for homeowners and contractors. Commercial hot water system requirements can be larger and more demanding than residential systems, and some manufacturers are bringing these higher output heat pump systems to market.

This guide is intended for building owners and facility managers interested in electrifying commercial building water heating systems via new building systems or system retrofits. This guide is also a resource for contractors becoming familiar with commercial HPWHs. This guide focuses on integrated air-source HPWH equipment, and background information, best practices, and key considerations are included here. A building owner or facility manager should review project considerations with an engineer or contractor.

Heat Pump Water Heaters

Most heat pump water heating equipment relies on extracting heat from ambient air, also known as an air-source heat pump.3 The extracted heat is then used to heat water in a tank.
Types of HPWHs
There are two primary types of heat pump water heating equipment: integrated systems and split systems. Integrated systems consist of a single piece of equipment: the heat pump and storage tank are integrated into one unit, including the heat pump’s evaporator, which extracts heat from the air where the tank is installed. This type of equipment can be used in many building types assuming the tank storage volume and recovery rate are sufficient to meet the hot water demands. Split systems allow the evaporator to be installed outside, which can help in tight spaces or in situations where the cool air exhausted by the heat pump would cause discomfort or increased heating load. Figure 1 provides examples of these equipment types.

HPWH System Configurations
There are also two primary water heater system configurations: integrated and central systems. Integrated systems are analogous to most residential water heaters—a stand-alone unit supporting hot water supply. These are common in many building types but are more applicable where hot water usage is low to moderate and intermittent (offices, retail, multifamily, etc.). An integrated heat pump system is the typical equipment for these systems.

Central Systems
Central systems are typically found in larger buildings or those with high hot water demands (hotels, hospitals, etc.) and combine multiple storage tanks and heaters engineered to meet specific hot water usage demands. Central systems with heat pumps can include split system equipment and/or integrated equipment.

Integrated Systems
This guide focuses on integrated systems that could be found in small businesses or buildings. Figure 2 diagrams the common configuration of most integrated systems. Integrated systems typically pull heat from the surrounding air, but it is possible to install ducts so the heat pump can pull from other spaces if that is beneficial to the building. For instance, hot air could be drawn from an IT closet and cool air could be returned to that space, reducing air conditioning loads.

Electric heating elements are installed at the top and bottom of the tank, similar to what is found in a conventional electric resistance water heater. These are available as a boost during high hot water demand.

Operational Modes
Onboard controls are often included and can be used to set the tank operational mode. Tank operational modes may vary by manufacturer, but most offer an energy-efficient setting (or heat-pump-only mode); a hybrid mode, where the heat pump is prioritized and the electric resistance heating elements are only energized in high demand situations; and an electric resistance-only mode where the tank operates identically to an electric resistance tank. Certain manufacturers may provide a boost mode where multiple heating elements are energized. The flexibility allows users to choose the most appropriate operational mode to meet business needs as well as energy and climate goals and to adjust modes if needed.

Figure 1. Integrated versus split heat pump water heating equipment
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HPWHs: Key Considerations

Electrifying building loads should occur in conjunction with improving energy efficiency. Choosing energy-efficient equipment is one step, but it is also important to find ways to improve overall system efficiency and performance. Figure 2 diagrams the common configuration of most integrated systems.

Key steps to optimizing efficiency when electrifying water heating systems are below. HPWH can heat up more slowly and may need additional hot water storage to supply the same demand.

There are equipment considerations to keep in mind for all HPWHs.

Figure 2. Integrated HPWH components

Figure 3. Key steps to optimizing efficiency
Water Heating Needs
Are you sure you need to replace your current water heater with one of the same size? Become familiar with your hot water usage by estimating your peak hour demand: evaluate when you use the most hot water (morning, midday, evening) and then use an online tool, such as Energy Saver from the U.S. Department of Energy, to estimate the volume of water you use during that peak hour. Then, you can compare this peak hour demand (also referred to as a first hour recovery) to manufacturer information to determine which unit may be a good fit. You can also engage a contractor to assist in this assessment.

Opportunities to Reduce Hot Water Usage
After familiarizing yourself with your building’s usage, think about needed supply.

- Consider potential changes in need. For instance, if your operation expands.
- Evaluate your fixtures and end uses for efficiency improvements. Maybe there are leaks that can be addressed and replacement opportunities.
- Examine your hot water distribution piping for appropriate insulation.
- Investigate employee training resources to improve awareness and water use behaviors.
- Think about upgrading your recirculation pumps, if you have them, to intelligent models that operate only when needed.

Depending on the type of business, there are specific online resources to help you assess your options, such as these commercial kitchen resources from the Department of Energy and the Environmental Protection Agency.

Right-Size Your Equipment
Determining your building’s hot water needs today and seeking opportunities to reduce hot water usage of the entire system can help lead you to an appropriately sized HPWH. It is important to discuss options with your engineer and contractor. There are several ways to identify installers familiar with HPWHs, including via ENERGY STAR and manufacturers’ and local utilities’ websites.

Space, Location, and Airflow
HPWHs are larger than traditional water heaters. You may be shopping for a new water heater with the same gallon capacity as your current unit, so make note of any size differences you will need to account for and plumbing adjustments that may need to be made.

Integrated HPWHs are typically installed indoors and need sufficient airflow to operate effectively and efficiently. Manufacturers typically provide recommendations, but between 750-1,000 ft³ of air is typically sufficient. This is approximately the air contained in a 10 x 10-ft room with an 8–10-ft-high ceiling. If the existing water heater location does not have enough room, a duct or louvered vent or door can be installed to increase air availability. Certain manufacturers may require filters that need maintenance and replacement over the lifetime of the integrated HPWH. Ensure there is sufficient space and accessibility when finalizing the location of the installed water heater.

Also consider the year-round temperature in the space: the room temperature should remain between 40°F and 90°F. Cooling is a byproduct of HPWHs and can be used to cool adjacent spaces, such as corridors through louvers or IT closets or other spaces via ducting.

Condensate
Mild, nontoxic condensate water is produced as part of normal HPWH operation. Place the HPWH in a space with an existing floor drain or purchase a unit that includes a condensate pump. Be sure to follow all local codes to properly handle condensate.

Electrical Infrastructure
The HPWH will need electrical service, and you or your contractor can find the power requirements in the manufacturer’s specifications on their website. If you do not already have the appropriate circuit size (for instance, if you are replacing a gas water heater), your electrical panel may need to be upgraded. Consult an electrician for advice and request the circuit needed for your new equipment.

Grid Connectivity
Some residential integrated HPWHs are equipped with the ability to link with the electricity provider through a device that supports the EcoPort communication standard (ANSI/CTA-2045). This enables communication between the utility grid and end-use devices for electricity demand response and future integration opportunities. The EcoPort communication standard has not yet been prevalently adopted for larger commercial integrated HPWHs, nor has a corresponding alternative been
established. These could be controlled through a building automation system and could be programmed to respond to demand response signals from a utility.

**HPWHs and Energy Efficiency**

HPWHs can be up to four times more efficient than electric resistance water heaters. How much more efficient depends on the efficiency of the unit you are replacing, and the performance of the HPWH. Common industry terms used to describe and rate the performance of water heaters and heat pumps include the uniform energy factor (UEF) rating and the coefficient of performance (COP). The UEF rating is the current standard communicating the energy efficiency of residential water heaters. The COP is an overall efficiency ratio comprising the thermal heat output supplied to heat the water divided by the electrical input required to operate the system. In both cases, the higher the UEF or COP, the more energy efficient the unit will be.

**Energy Efficiency, Carbon Emissions, and Utility Costs**

Figure 4 provides a comparison of source energy use, utility cost, and carbon emissions for three types of water heaters: natural-gas-fired, electric resistance, and heat pump. Energy use is based on the heat required to raise water temperature from 65°F to 140°F. For reference, a typical shower is 105°F, and 140°F is the average temperature of water in a dishwasher. Range of utility costs and carbon emissions are based on state average rates available at time of publication and marginal emissions data from 2021, respectively. Carbon emissions are changing as more renewable energy sources are contributing to electricity generation. This provides additional advantages to transitioning away from fuel-fired water heating. Results shown in Figure 4 assume 15-year long-run marginal emissions based on the Cambium mid-case renewables scenario.

<table>
<thead>
<tr>
<th></th>
<th>Integrated HPWH</th>
<th>Electric Resistance</th>
<th>Gas-Fired</th>
</tr>
</thead>
<tbody>
<tr>
<td>Source Energy</td>
<td>0.14 – 0.23</td>
<td>0.50</td>
<td>0.20-0.24</td>
</tr>
<tr>
<td>CO₂ Emissions</td>
<td>0.019 – 0.088</td>
<td>0.068 – 0.194</td>
<td>0.076 - 0.090</td>
</tr>
<tr>
<td>Operating Cost</td>
<td>$0.005 - $0.016</td>
<td>$0.019 - $0.058</td>
<td>$0.004 - $0.098</td>
</tr>
</tbody>
</table>

Figure 4. Relative comparison of water heater types

a. Numbers presented in this table reflect energy required to heat 1 gallon of water from 65°F to 140°F. Additional energy loss to tank skin loss, or others is not considered in this comparison.

b. National average site to source conversion factors. SOURCE: [EnergyStar](https://portfoliomanager.energystar.gov/pdf/reference/Source%20Energy.pdf). Regional factors may be higher or lower depending on the energy sources.

c. Range represents COP average between 2.2-3.6. Actual operation numbers may vary.

d. Range of thermal efficiency 80%-95%. Actual thermal efficiency may vary.


Paying for New Equipment: Rebates and Incentives

Many utility companies and local programs offer rebates or incentives for switching to electric HPWHs. Begin by contacting your utility provider to learn about your options and use the ENERGY STAR Rebate Finder as another resource. Your local jurisdiction may be providing rebates or incentives as well: many cities have hotlines, email addresses, and notification lists so you can ask questions and stay informed of new funding. Additionally, you may be eligible for commercial building tax deductions. If you lease your business space, engage the building owner or manager on the benefits of updating the water heater and the energy-efficient options available.

Conclusion

Although there may be some upfront costs to switching your commercial water heater to a heat pump system, there may be ongoing energy, emissions, and cost savings. Every business has unique hot water needs, so it is important to discuss options with your engineer and contractor if you are buying new or replacing old equipment. HPWHs are a highly efficient electric option to replace gas-fired or electric resistance units, and beyond saving energy, they contribute to important market transformation in the pursuit of a carbon-free energy grid.


Photo from Samuel Wordley, Pond5.com