**Building Science Education Solution Center – Introduction to Heat Pump Water Heaters**

Proficiency Level 1: Remember

**Learning Objective 1.1:**

* Recognize what a Heat Pump Water Heater is

**Lecture Notes 1.1:**

# References:

DOE. *Heat Pump Water Heaters*. n.d. 2022. <https://www.energy.gov/energysaver/heat-pump-water- heaters#:~:text=Heat%20pump%20water%20heaters%20use%20electricity%20to%20move,heat %20pumps%20work%20like%20a%20refrigerator%20in%20reverse.>.

Hot Water Solutions. *HotWaterSolutionsNW.org: Heat Pump Water HEaters Cut Electric Bills*. n.d. 2022. <https://hotwatersolutionsnw.org/>.

National Center for Construction Education and Research. *HVACR Curriculum* . n.d. <https://www.nccer.org/workforce-development-programs/disciplines/craft-details/hvacr>.

**What is a Water Heater?**
Water heaters, as the name implies, are appliances dedicated to heating water used by people, either directly via water fixtures (e.g., sink) and other appliances that require hot water draws (e.g., dishwasher). Water heaters themselves vary in the fuel they use, whether they store hot water or create it on-demand, the size of the storage tank, and the efficiency of their energy usage. [[1]](#footnote-2)

**What is a Heat Pump?**
Heat pumps use electricity to transfer heat from one space to another, which is a more energy efficient process than creating heat itself. Reversible heat pumps can provide both heating or cooling to a space by using a reversing valve, which determines the direction in which refrigerant flows from the compressor through either the evaporator or condenser coils. Because they transfer heat rather than generate heat, heat pumps can efficiently provide comfortable temperatures for your home. Heat pumps are typically used in heating, ventilation, air conditioning and refrigeration (HVAC&R) systems.[[2]](#footnote-3)

**What is a Heat Pump Water Heater?**Using a similar concept, a Heat Pump Water Heater (HPWH), also referred to as hybrid electric water heater when designed to use 240 volts, uses heat pump technology to produce hot water. This is done by using electricity to move heat from one place to another. A HPWH creates hot water by capturing heat and humidity from the surrounding air, transferring it to a working fluid (e.g., refrigerant), and using a heat exchanger to transfer the heat from the refrigerant to water. Because HPWHs use electricity to move heat rather than creating it directly, they are generally regarded as one of the most energy efficient methods for water heating. [[3]](#footnote-4)

Problem Set 1.1

1. What are some characteristics that can vary between water heaters?
2. What is the fundamental difference in the water heating process between a conventional water heater and a heat pump water heater?

**Learning Objective 1.2:**

* Recall the different modes of a HPWH

**Lecture Notes 1.2:**

# References:

Pacific Gas and Electric. "PG&E Education Classes." n.d. *PG&E.* (Requires free registration) <https://pge.docebosaas.com/learn/course/external/view/webinar/762/overcoming-installation- challenges-for-heat-pump-water-heater-retrofits>.

**HPWH Modes of Operation**

HPWHs supplied by 240 V typically have four operating modes: heat pump (also referred to as “efficiency” mode), electric, hybrid, and vacation. The four modes allow occupants to adjust HPWH operation to suit their needs.

**Heat Pump Operating Mode**

Heat pump mode is the most efficient mode for a HPWH to heat water and provides the most energy and utility bill savings to the household. In this mode, only the heat pump operates to heat water. The drawback of using heat pump mode is that it takes longer to heat water (referred to as recovery) once the tank is depleted. For this reason, if a household plans to use heat pump mode predominantly, it’s important to identify a HPWH model with a larger tank size to prevent a hot water run out. [[4]](#footnote-5)

Depending on how the HPWH is sized to the home’s hot water load, heat pump mode may meet all of the household’s hot water needs. However, in certain circumstances, heat pump mode may be insufficient. For example, if the household has high hot water needs on a particular day (e.g., overnight guests visiting), heat pump mode may not produce enough hot water to fulfill the household. 4

**Hybrid Operating Mode**

When heat pump mode is insufficient to meet a household’s hot water needs, then hybrid mode should be selected. Hybrid mode is the default mode for HPWHs when shipped. Hybrid mode uses the HPWH’s control logic to shift between heat pump and electric resistance to heat water. When the household uses hot water to the point in which the heat pump cannot recover quick enough and there is the risk of a hot water run out, the HPWH uses the electric resistance back-up to heat water. This approach allows the HPWH to be efficient when demand is typical while also meeting the household’s hot water needs when demand is high. 4

**Electric Operating Mode**

When hybrid mode still may not meet a household’s hot water needs, electric mode can be used. In this mode, electricity is used to directly heat water using an electric resistance element (the lower heating element) like a conventional electric resistance water heater. This mode of operation is the least efficient. If a household needs to use electric mode often, it’s a sign that either the HPWH was poorly sized or not installed properly. 4

**Vacation Operating Mode**

The last mode of operation is vacation mode. This mode is applicable when no one is home for an extended period of time. During such time, there is little need for the production of hot water, so the water heater will keep the water in the tank at a moderate temperature range. Certain HPWH models may allow the user to set a duration for vacation mode, whether using the HPWH’s digital display or the manufacturer’s mobile app. 4

Problem Set 1.2:

1. What mode is the most efficient for the production of hot water?
2. What mode should the HPWH be set to when occupants are planning to be away from the residence for an extended period of time?

**Learning Objective 1.3:**

* Describe the consumer benefits of HPWHs

**Lecture Notes 1.3:**

# References:

DOE. *Estimating Costs and Efficiency of Storage, Demand, and Heat Pump Water Heaters*. n.d. 2022. <https://www.energy.gov/energysaver/estimating-costs-and-efficiency-storage-demand-and-heat-pump-water-heaters>.

Hot Water Solutions. *HotWaterSolutionsNW.org: Heat Pump Water Heaters Cut Electric Bills*. n.d. 2022. <https://hotwatersolutionsnw.org/>.

**Operating Costs**

The main benefit of installing a HPWH over a conventional electric resistance water heater is the operating cost savings. While the purchase price of a HPWH usually exceeds that of other water heaters for the same tank size, the savings in operating the water heater over the course of its lifetime makes up for its capital cost investment in approximately 3-5 years (for a 10–12-year HPWH expected lifetime). The lifetime energy savings become more significant the longer a household uses a HPWH to meet their hot water needs. Also, the household size affects the overall lifetime savings from utilizing a HPWH, where in a larger household with higher hot water needs will see more significant savings.

**Rebates**

To alleviate the initial purchase cost of a HPWH, utility providers and local government agencies (State, City, etc.) regularly offer incentives in the form of rebates or tax credits for residents to purchase the more efficient HPWH. Ultimately, it is the responsibility of consumers to find and apply for these rebates by contacting their local utility providers. The following tool can be used to facilitate the search for available offers: [Special Offers and Rebates from ENERGY STAR Partners | EPA ENERGY STAR](https://www.energystar.gov/rebate-finder?page_number=0). Federal tax credits are available now, with rebates coming in late 2023 through the Inflation Reduction Act.

**Cooling Loads and Combustion Safety**

Beyond monetary savings and incentives, HPWH also provide non-financial benefits. One benefit that a HPWH has over a conventional gas/oil water heater is in safety assurance. HPWHs are not subject to the combustion-based risks and failures that arise from utilizing natural gas/oil. Ventilation for gas and its associated risks are removed as well. Lastly, a HPWH uses the ambient humidity and heat to heat the water in the tank; as a byproduct, cold air is created. The cold air lowers the ambient temperature and could slightly offset the cooling burden on an HVAC system in warmer climates.

A list of previously discussed and additional benefits can be found below:

* Lower Operating Cost
* Available rebates and incentives
* Safer operating mechanism
* Lower greenhouse gas emissions
* Longer lifetime of the unit
* Easier Maintenance
* Demand response / grid interactive

Problem Set 1.3

1. Identify a benefit of HPWHs that is not financial.

**Learning Objective 1.4:**

* Discuss the business case for HPWHs (consumers)

**Learning Notes 1.4:**

# References:

ENERGY STAR. *Energy Star Ask Experts: When Should You Replace Your Water Heater*. n.d. 2022. <https://www.energystar.gov/products/ask-the-experts/when-should-you-replace-your-water- heater>.

Smarter House. *Replacing your Water Heater*. n.d. 2022. <https://smarterhouse.org/water-heating/replacing-your-water-heater#:~:text=The%20minimum%20efficiency%20of%20electric,to%20the%20high%20operating%20costs.>.

**Deciding to replace a HPWH**The extent of cost savings for installing an efficient HPWH over a conventional electric resistance water heater depends on the timing of when the HPWH is installed relative to the current water heater’s life. Water heaters are typically replaced every 10-15 years. If the current water heater is older or showing signs of damage, it’s a strong candidate for replacement. Examples of damage may include tank corrosion, water leakage, unexpected noises, and a lack of hot water production. For more information on decision guidance on whether or not to replace your current water heater, please refer to the HPWH Decision Guidance lessons.

When purchasing or replacing a water heater, choose an efficient HPWH that best meets your household hot water demand and home characteristics. While the initial purchase cost of the unit is higher than that of a conventional water heater, the operational cost is much less and capable of offsetting the incremental first cost in 3-5 years. For example, a household uses approximately 64 gallons of hot water a day (heated from 58°F to 135°F on average throughout the year) and is choosing between a HPWH and a conventional electric resistance water heater. The conventional electric resistance water heater will have an annual operational cost of $600, while the HPWH will have an annual operational cost of $250 (operational costs are based on the estimated energy cost of $0.13/kWh). Each year, the HPWH saves $350 in this scenario. If the installed cost of the HPWH is $1,500 greater, the simple payback for the HPWH is approximately four years.

Problem Set 1.4

1. What is an indicator that the water heater should be replaced?
2. In general, a HPWH is more expensive than a conventional electric resistance water heater. But they also have a lower\_\_\_\_\_\_\_\_.

1. (DOE) [↑](#footnote-ref-2)
2. (National Center for Construction Education and Research) [↑](#footnote-ref-3)
3. (Hot Water Solutions) [↑](#footnote-ref-4)
4. (Pacific Gas and Electric) [↑](#footnote-ref-5)