Heat Pump Water Heater Applications for New, All-Electric Multifamily Buildings

Fact Sheet

Introduction

There is rapidly growing interest in designing high performance, all-electric multifamily buildings to realize energy efficiency, energy cost savings, and carbon emission reduction benefits. However, there is often a gap in understanding the potential application of heat pump water heaters in all-electric multifamily buildings. This is a critical gap because of the significance of the water heating energy use in multifamily buildings. In addition to a general understanding of the technology and its performance benefits, stakeholders need to be aware of application considerations for heat pump water heaters (HPWHs).

This fact sheet is for designers, contractors, engineers, and building owners on Heat Pump Water Heater applications for All-Electric Multifamily Buildings. It discusses the air-source HPWH technology option; explains advantages and limitations; and offers references to point stakeholders to some examples of innovative multifamily projects using HPWHs.

Air-Source Heat Pump Water Heaters

Air-source heat pump water heaters, commonly referred to as heat pump water heaters, extract thermal energy from the surrounding air and transfer this energy to the water tank. HPWHs are comprised of the heat pump components (i.e., compressor, evaporator), a storage tank, and usually include electric resistance heating elements to provide added water heating capacity. Units with both a heat pump and electric resistance elements are often referred to as hybrid HPWHs reflecting that they utilize both water heating technologies.

HPWHs are typically three times more efficient compared to electric resistance water heaters. This boost in efficiency generates significant utility cost savings for building owners and residents, reduces GHG emissions, and reduces the load for the local electric grid. [https://www.energy.gov/energysaver/heat-pump-water-heaters]

HPWH System Option/Configurations

There are two basic configuration options for air-source HPWHs: Individual HPWHs in each unit and Central Systems.

1.1 In-Unit Systems

Some multifamily buildings have dedicated water heaters installed in each dwelling unit. The actual size of the HPWH will depend on the size of the dwelling unit and designed occupancy, and are typically 40 -80 gallons. These units need an air temperature range of 45°F-120°F for the heat pump to operate efficiently and may be configured as follows:

- A standard integrated HPWH in a closet or mechanical room within the conditioned space of the unit that draws warm air from the space and uses the air to heat the water. This configuration needs 700-1,000 cubic feet of surrounding space to operate efficiently. Smaller closets can still accommodate a HPWH with louvers (properly placed and sized) on the door. EPA offers some additional guidance on using HPWH for colder climates.[i] The drawbacks to this configuration include: cool air exhausted from the heat pump can cause comfort issues, noise from the heat pump, and the need for dedicated space which is at a premium in multifamily buildings. The HPWH could be located outside on a balcony in some climates but that would also be taking up valuable space.

- An integrated unit ducted to the outdoors or a common space like a hallway (intake, exhaust or both) can help to alleviate the comfort impact and reduce the space requirement. However, ducting each individual multifamily unit may not be practicable, and noise is still a consideration.

- A split HPWH system has an outside compressor that heats an indoor water tank. The advantage of a split system is that the cold air generated by the heat pump stays outside, the noise is also kept outside, and the indoor tank requires much less floor space and does not have any requirement for access to a large volume of ambient air. Designers will still need to find a suitable location for the outdoor heat pump components and provide a connection to the tank. For split systems in which the entire heat pump is located outdoors, there will be water lines run between the outdoor heat pump and the indoor water storage tank, which may require freeze protection.

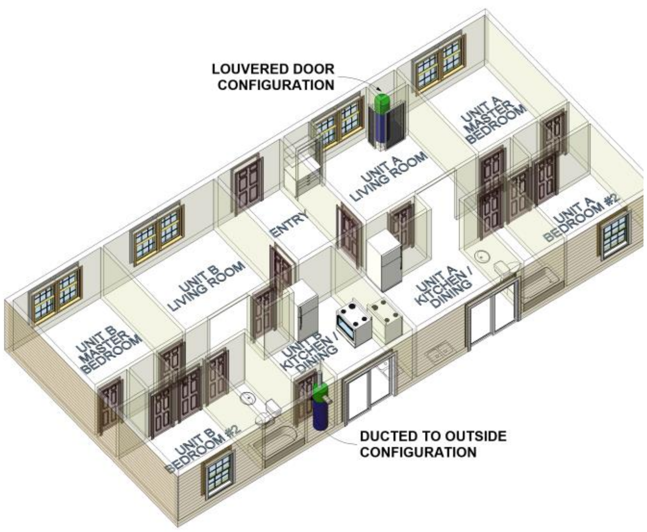

Figure 1. Shows 2 possible configurations in 3 D Unit A has a louvered door and Unit B is ducted to the outside.

Figure 2. Floor Plan of Unit A with louvered door.

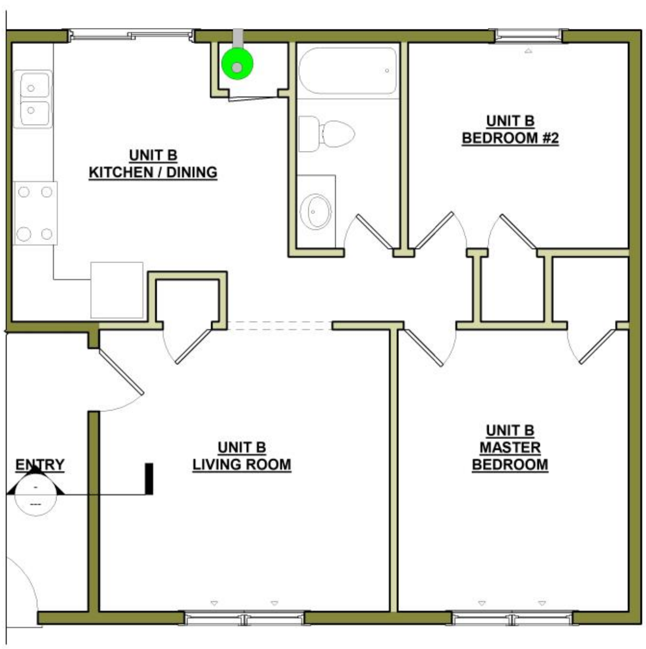

Figure 3. Floor Plan of Unit B ducted.

Individual In-Unit systems offer an alternative to larger
central system. They reduce the size of the distribution system and can provide flexibility when

replacing or repairing individual broken units in the future. The most appropriate system will vary based on the hot water needs of the building, the floor plan, the climate, and space within the dwellings, common areas such as basements, and/or outside.

For good examples of innovative projects using in-unit HPWHs in Multifamily buildings, see the following:

- Rancho Verde Apartments, Ventura, CA, ICC Climate Zone 3C
- Spring Lake Phase 2 in Woodland, CA, ICC Climate Zone 3B
- Revive Development, Fort Collins, CO, ICC Climate Zone 5B
- Sol Lux Alpha Project, San Francisco, CA, ICC Climate Zone 3C

1.2 Central Systems

Commercial HPWHs (> 12kW rated electric power input or >120 gallons/day) for larger multifamily buildings are usually configured as central systems. Central systems are whole-building HPWHS that use a recirculation system shared by all residences in a multifamily building. Typical designs might include multiple heat pumps and a large storage tank, or a single heat pump and large tank serving all the units.

Central systems can save space, reduce maintenance and take advantage of fluctuations in demand, however, the longer runs of piping can have a negative impact on efficiency.

For a good explanation of the HPWH units and design configurations, see the following references and case studies:

- *Heat Pumps for Hot Water: Installed Costs in New Homes*, Rocky Mountain Institute, Bank Flats, Philadelphia, PA, p. 12 28 dwelling Units. ICC Climate Zone 4A

- *CO2 Heat Pump Water Heater Multifamily Retrofit*: Elizabeth James House, Seattle, WA Washington,60 dwelling units ICC Climate Zone 4C

- *A Zero Emissions All-Electric Multifamily Construction Guide*,
    - West Village Multifamily Building, Davis, CA, 12 dwelling units: ICC Climate Zone 3B, and,
    - Jones Street apartments, San Francisco, CA, 50 dwelling units, p. 13 ICC Climate Zone 3C

- Three Case Study References PowerPoint presentation by Shawn Oram of Ecotope at the Hot Water Forum 2019

Metrics

The performance of a residential HPWH is measured using the Uniform Energy Factor (UEF). The UEF is a standardized metric of overall water heater efficiency established by the Department of Energy's test method, to make it easier to compare water heater efficiency across product lines. The UEF is roughly the percentage of energy that is turned into hot water. The higher the UEF, the more efficient the water heater is, and the less it will cost to operate. The current criteria for ENERGY STAR certified water heaters is UEF ≥ 2.00 for units ≤ 55 gallons, and UEF ≥ 2.20 for units > 55 gallons.

Commercial HPWHs, which might be used for central systems, are not subjected to the UEF test method. Coefficient of Performance (COP) is the ratio of how much useful heat a heat pump produces given a certain energy input. As with the UEF, the higher the COP, the better the energy efficiency. The COP range is typically from 2 – 3.5 depending on the product, the building design, and location

Cost Considerations

The installed cost of a HPWH (both the hardware and installation) will be higher than an electric resistance water heater or a boiler; but the energy cost will be lower There may also be regular maintenance costs beyond what would be required with an electric resistance water heater. However, with the correct design and operation, HPWHs present significant opportunity for energy savings during its life cycle.

Some utilities offer incentives for purchasing efficient electric water heaters, which can offset some of the upfront cost. For more details check with your local utility or go to the federal Energy Star rebate finder and the Database of State Incentives for Renewables & Efficiency. For example, Baltimore Gas & Electric (BGE) offers rebates for heat pump water heaters. Although targeted at water heater replacements, any BGE account holder is eligible. For new multifamily construction being used as a rental property, a building owner who is the BGE account holder for a master-metered building could apply for the rebate for the HPWH units in their dwelling units. (https://bgesmartenergy.com/residential/rebates-and-discounts/heat-pump-water-heater). Additionally, multiple advanced building certification programs offer points for heat pump water heaters, so the technology may help a developer meet advanced certification goals.

Included under additional resources are a number of case studies that offer some cost information relevant to the building and installation. Designers might also consider if using HPWHs will alleviate the need for gas infrastructure which could create additional cost savings. A 2020 report prepared by the Rocky Mountain Institute with cost data can be accessed here.

Technical Challenges

Space: In addition, to the space needed for the HPWH, there may be a need for a larger storage tank to maintain consumer satisfaction. Large tanks can be tough to fit into multifamily dwelling units, which usually have significant space constraints compared to single family homes, so creative locations may be necessary, and careful consideration given to comfort and code issues. This issue applies to both in-unit and central systems.

Noise: For in-unit systems some occupants complain about noise, which could lead them to change the operating mode to reduce the noise. Switching from heat pump mode to electric resistance mode will eliminate the noise but will greatly reduce the efficiency. Check the unit rating on noise level shown as dBA where the lower number, the quieter the unit.

Climate: HPWHs may offer better payback in cooling dominated climates. However, as the technology continues to improve, the temperature range needed for effective operation will likely increase.

HVAC Impact: HPWHs located within a dwelling unit tend to cool the space where they are located, adding to the heat load and creating localized comfort issues. If located in a heating-dominated climate, designers should analyze the impact using a building energy modeling tool. The results will help identify whether the added space heating energy outweighs the savings from the HPWH. The effect on space heating/cooling can be demonstrated by examining what happens when the HPWH is ducted to the exterior– removing the added cooling load from the space. A study conducted by PNNL comparing ducted and unducted HPWHs found that a dwelling unit used 7.8% less heating energy during heating season but 9.3% more cooling energy during cooling season. [https://www.pnnl.gov/main/publications/external/technical_reports/PNNL-23526.pdf].

To avoid interaction with the space conditioning, cool exhaust air can be distributed to the room or outdoors using a duct system. This is more complicated in multifamily units than in single family homes so it is important to be aware of any code requirements.

Central System Specific: Design of a central HPWH is different than the design of a more traditional system like boilers. Design challenges raised specifically on central systems include:

- Need for the design to balance the system capacity with hot water storage; and,
- Unintended efficiency consequences resulting from the distribution system, both distribution piping and the circulation pumping system.

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[i]https://www.energystar.gov/products/water_heaters/high_efficiency_electric_storage_water_heaters/considerations