ASPE American Society of Plumbing Engineers CEU PROVIDER

Understanding Heat Pump Water Heaters

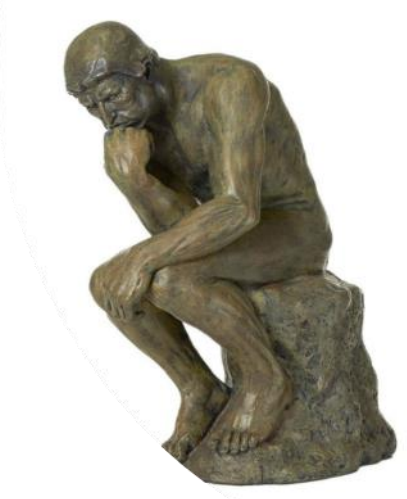
Impacts and opportunities for Residential and Commercial Applications

Presented by:

Learning Objectives

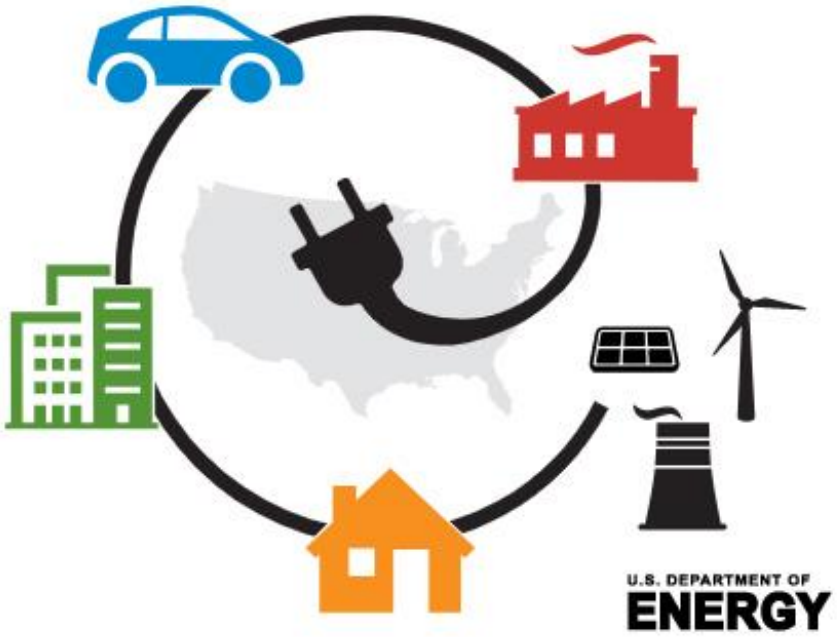
After completing this course, you should be able to:

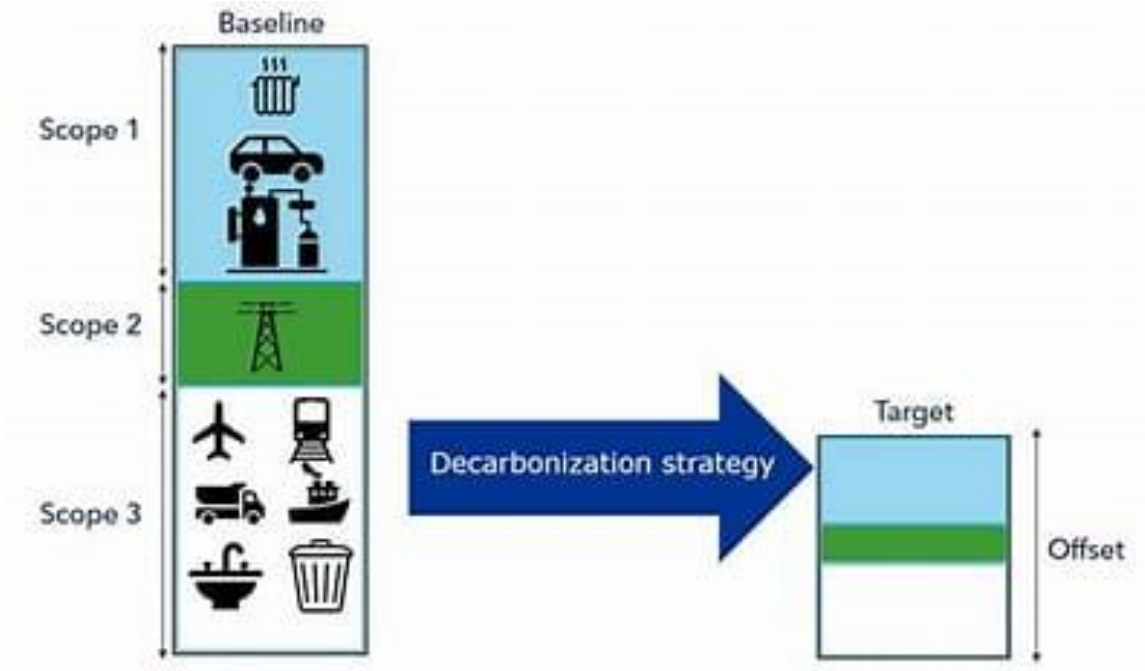
- Understand why Hybrid Electric Heat Pump Water Heaters are significant to the US market
- Understand how heat pump water heaters use the same principles of refrigeration to move heat rather than create heat.
- Identify proper site selection and typical installation
- Debunk common myths regarding Heat Pump Water Heaters
- Know the refrigerant types used in Heat Pump Water Heaters
- Have a basic understanding of Commercial Heat Pump Water Heaters
- Have a basic understanding of Commercial Heat Pump Sizing and Application



Electrification: Process of replacing technologies that use fossil fuels with electricity as a source of energy

Decarbonization: Reduce carbon footprint of a business with a focus on efficiency gains, renewable energy and minimizing waste





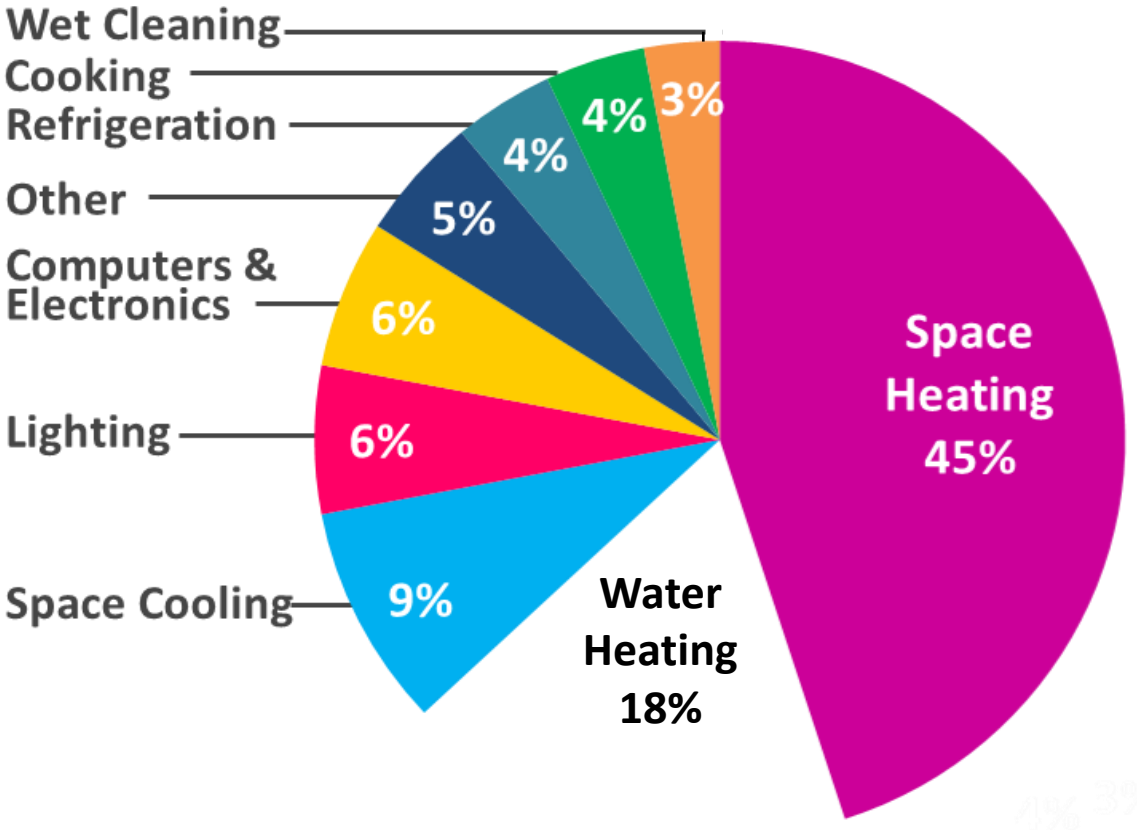
www.eia.gov. This is the website of the United States Energy Information Administration, and it includes individual energy profiles for each state.

Many States electric generation remains dominated by coal-fired and natural gas-fired power plants

Why it began….

Water heating is the
2ND LARGEST
expense in U.S. homes,
accounting for 14-18%
of homes utility bills

$400-600
The amount of
money the average
household spends on
water heating
EACH YEAR



Where it began…

Energy Star® begins – 1992

- Goal to reduce greenhouse gas emissions
- Computers/monitors first rated products

HVAC products 1st rated – 1995

- Highest energy user in home

Water heaters 1st rated – 2009

- HPWH first listed electric water heater

Why HPWHs are becoming the preferred choice

- Water heating is the 2nd highest user of energy in the average building
- An ENERGY STAR® certified water heater will reduce energy usage and costs for building owner
- Electric Heat Pump Water Heaters (HPWHs) are the most efficient water heating option available today
- The energy cost savings of a HPWH will more than pay for itself
- Electric HPWHs are environmentally-friendly and generate NO greenhouse gases or carbon emissions
- Net Zero Energy All Electric Buildings and Homes : Target 2030
- Pollution Reduction Mandates CA, NY, OR, WA etc., along with many cities (i.e. “Energize Denver Bill” 11/21)
- Rebate Incentives: Inflation Reduction Act (less than 80% median income $1,750, more that 80% $875)
- Eligible for many Local Utility, State & City Rebates

Terminology

- **Heat Pump Water Heater:** aka - HPWH, Hybrid Heat Pump Water Heater, or Hybrid Electric Water heater
- **Unitized HPWH:** One-piece, same look, ready to install, no HVAC license
- **Split HPWH:** Two pieces, Tank inside, HP outside. Typically uses C02, operates at lower ambient temps, much more expensive

Hybrid Electric Water Heaters

Four operating modes to save energy and satisfy consumer hot water needs

- **Heat Pump** ONLY mode- maximizes savings
- **Hybrid Mode-** saves while experiencing fast recovery
- **Electric Only Mode-** operates like a standard electric water heater
- **Vacation Mode-** drops tank temperature to most efficient energy use

Properly Size The Tank

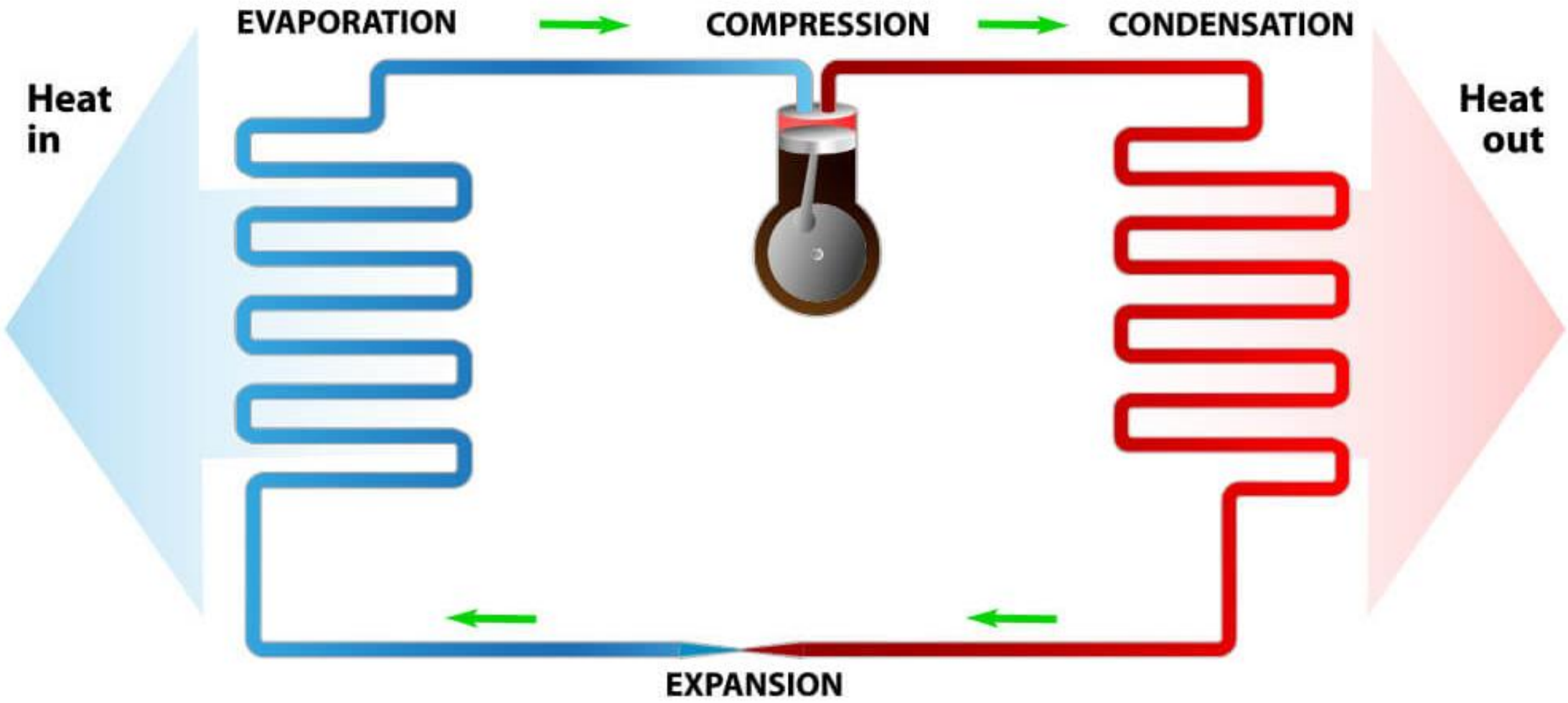
- A HPWH is a standard electric water heater with a heat pump – follow standard electric sizing protocol
- Residential Gas water heaters typically have a higher First Hour Rating (FHR) compared to a standard electric water heater of the same capacity. A larger electric tank may be needed to compensate. When HPWHs are sized properly, they will perform just as well
- Follow the manufacturers specific sizing guidelines provided by every manufacturer. Use their sizing tool.

Heat Pump Manufacturer sizing software tool asks simple questions about the home to determine the hot water needs and select the best unit for the application

- **Residential:** Bedrooms, Bathrooms, Washers, Dish Washers and Soaking Tubs
- **Commercial:** Offices, Food Service, Education, Retail etc..

Heat pumps are a proven technology. You'll find them all around your home in air conditioners, freezers and refrigerators.

How does a heat pump work?



Heat Pump Water Heaters work by moving *and* creating heat

Heat pump

- Evaporator draws in ambient heat using a fan
- Evaporator absorbs the heat, and the compressor increases the temperature and pressure of the **R-134A** refrigerant

Moving = 550-700 watts power used
Creating = 4500 watts power used

External condenser coils

- Heated refrigerant flows through the coils to heat water in the tank
- Coils are external and surround the porcelain lined tank to prevent corrosion and calcium build-up
- Can take tank temp up to 140 degrees

Tank and electric elements

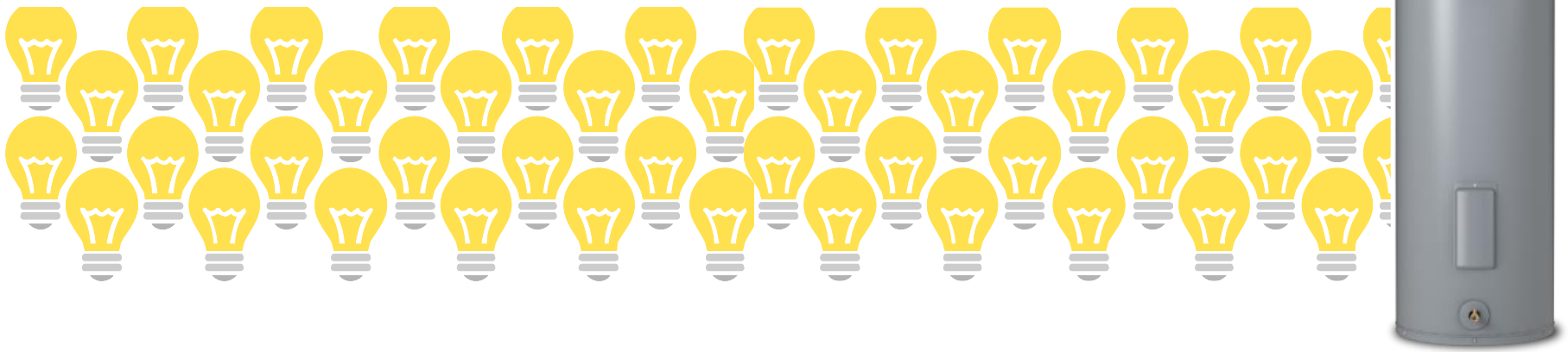
The heat pump is the first response for recovery as hot water is drawn from the tank. If tank is depleted, the HP cycles off and standard heating elements are activated to recover following each manufacturers proprietary sequence. In the Hybrid mode, a HPWH provides the same volume of hot water as the standard electric tank it replaces.

SEE THE LIGHT

about Heat Pump Water Heaters!

- HPWH's uses the same energy as **5 ½ incandescent 100 watt light bulbs** while in heat pump mode

- Standard electric heating elements use the energy of **45** bulbs!



No carbon emissions and pays for itself!

*Payback = Return on total investment of product including installation

Above UEF

4.0 UEF

3.0 UEF

2.0 UEF

1.0 UEF

Below

3.39
or higher

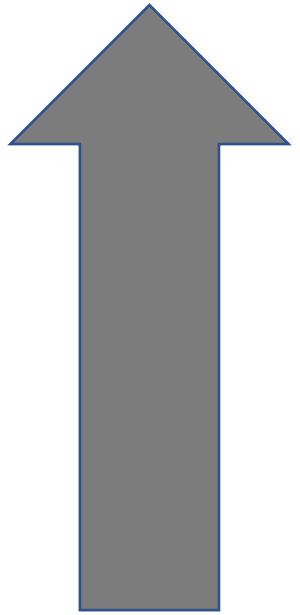
- Provides over $3.40 of hot water for every dollar spent
- Saves about $300 a year over standard electric water heater
- 10-year limited warranty

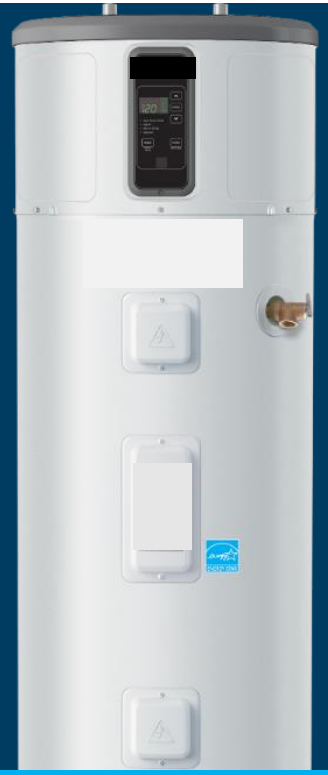
Payback above the line

.82-.97

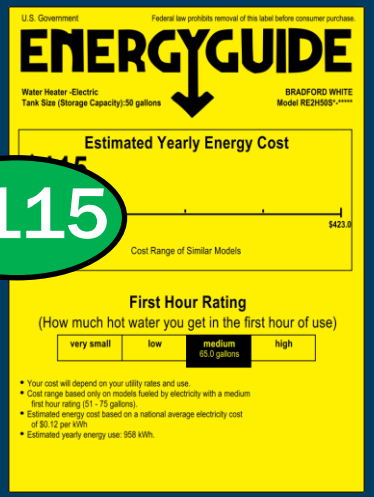
.93

.60

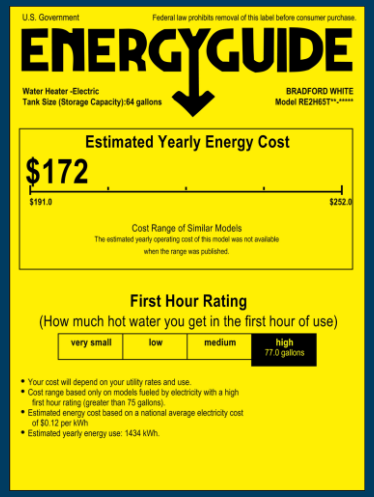




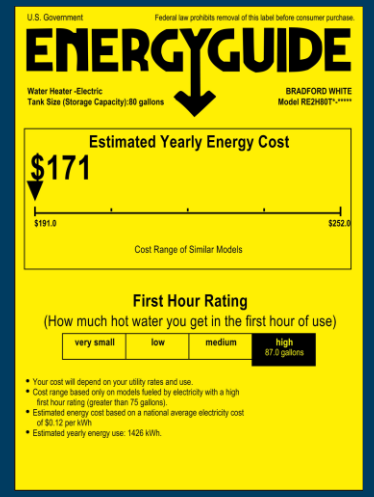
Standard Electric .93 UEF
50 Gallon



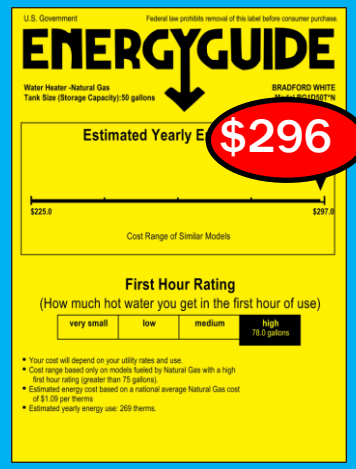
Typical HPWH
50 Gallon



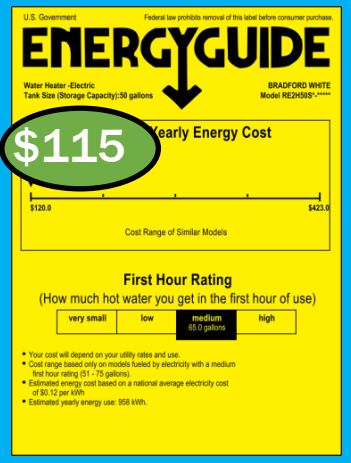
Typical HPWH with 3.45 UEF
65 Gallon



Typical HPWH with 3.48 UEF
80 Gallon

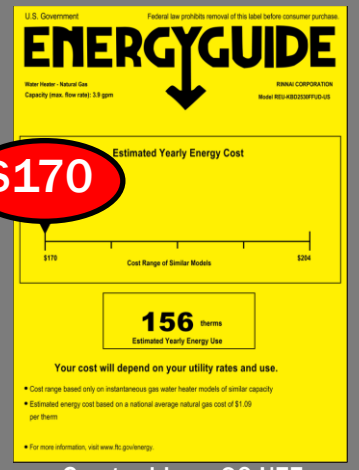


Standard gas tank .63 UEF

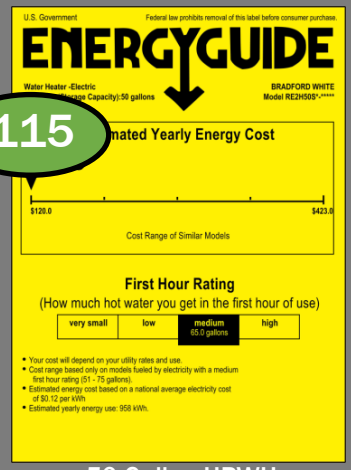


50 Gallon HPWH

Saves $181 Per Year vs. Gas!



Gas tankless .90 UEF



50 Gallon HPWH

Saves $55 Per Year vs. Tankless!

Best Locations

Basement

- Non-conditioned space, inside a conditioned home
- Heat in basement comes from the FREE warm earth outside the walls (50^{o}-60^{o})

Laundry Room

- Warm and damp due to dryer
- May be next to HVAC
- May be in closet with full louvered door

Garage

- Non-conditioned space that stays above freezing
- Less efficient in winter, more efficient in summer – should average out to shown UEF listed by manufacturer
- Easy to run condensate line

Closet

- Most require 36” closet for adequate space
- Need full louvered door for proper air flow

What's the Same as a Standard Electric Water Heater?

Same volume of water as standard electric water heaters

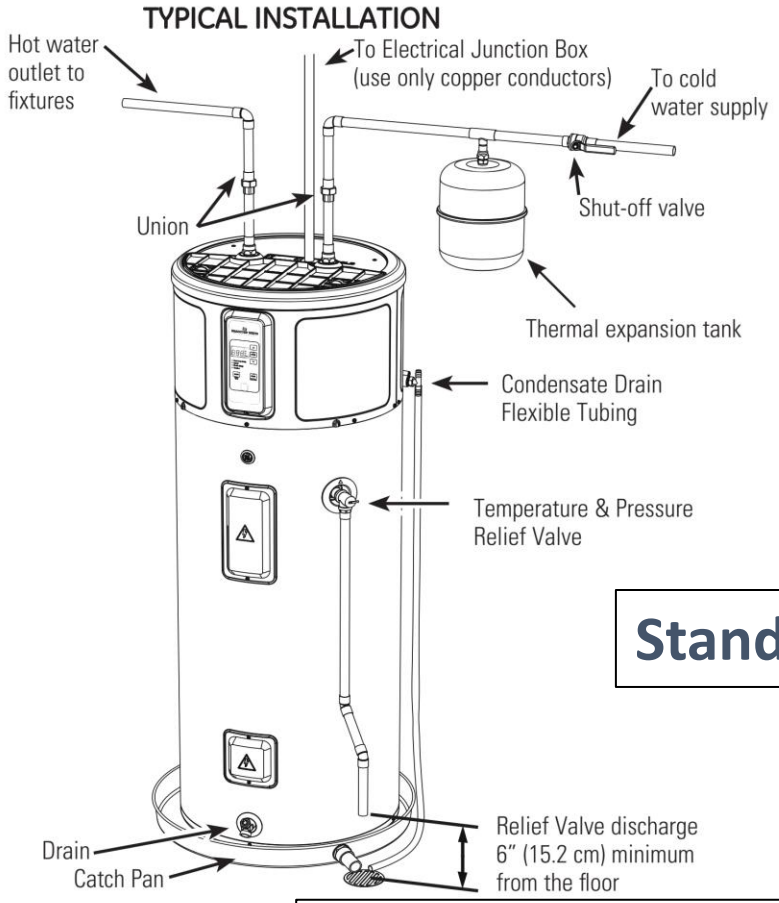
- 65–67-gallon first hour delivery (50 Gallon)
- 77-gallon first hour delivery (65 Gallon)
- 87-gallon first hour delivery (80 Gallon)

Designed for installation in similar footprint as standard electric units

- basement, garage, closet, utility room, attic

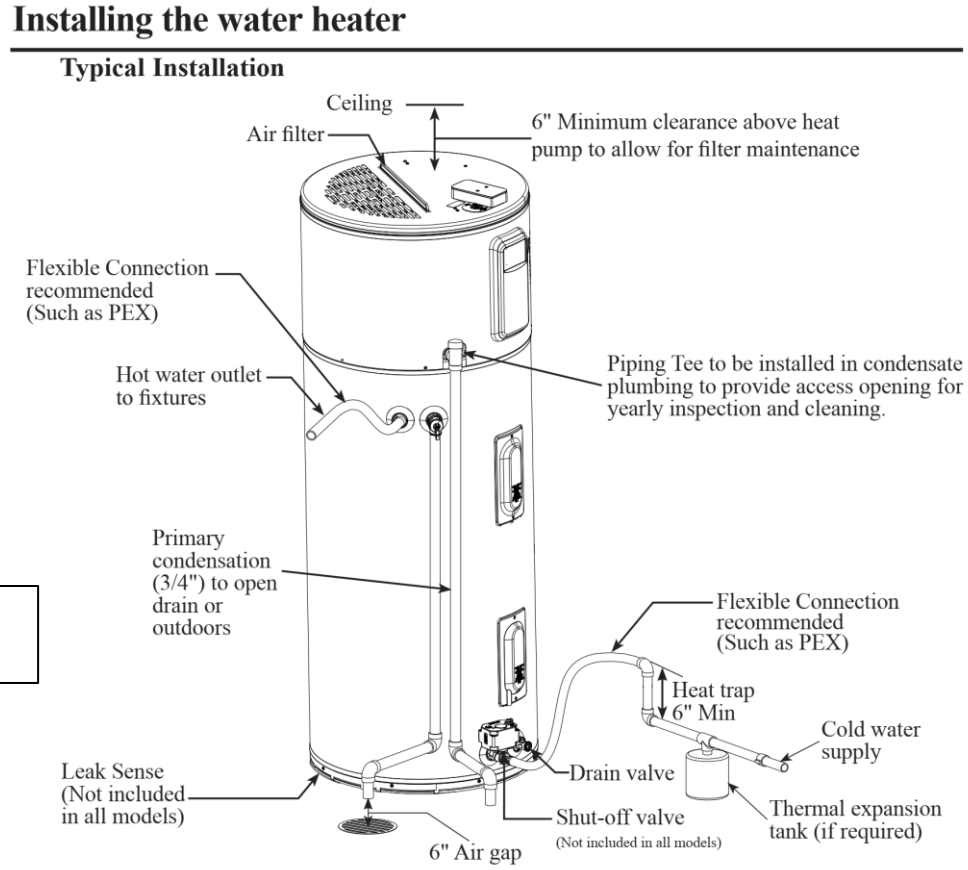
What's the Same as a Standard Electric Water Heater?

Top Water Connections



or

Bottom Water Connections



Standard T & P Valve

Electrical Connection: 25- or 30-amp breaker 208/240v

What's Different from a Standard Electric Water Heater?

Optional Ducting Kit

Air/Space Requirement

- 700 cubic feet or louvered door
- w/240 sq. in free air space

Clearance for Service

- 7" around heater
- 0" on left side, 2" behind
- Check manufacturers instructions

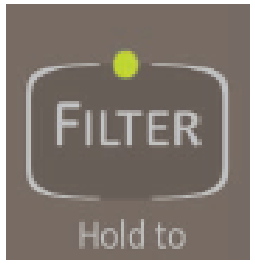
What's Different from a Standard Electric Water Heater?

Condensate Drain Line

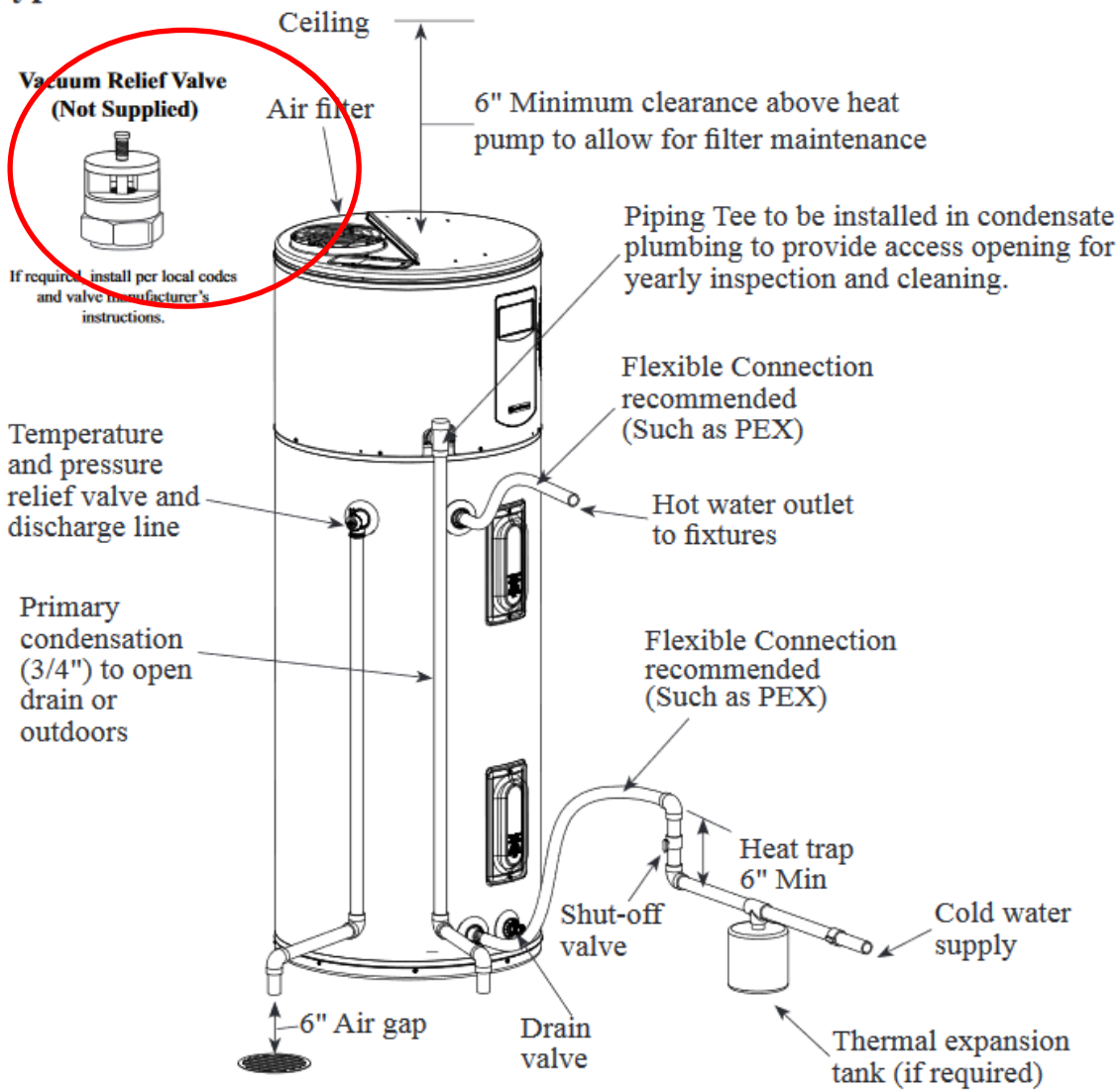
- Removes up to 2 qtrs. of moisture
- Can be tied to HVAC drain
- ¾" male fitting on heater

Air Filter

- Needs periodical cleaning



Typical Installation



A new combination temperature and pressure relief valve, complying with the Standard for Relief Valves for Hot Water Supply Systems, ANSI Z21.22/CSA 4.4, is factory installed and must remain in the opening provided and marked for the purpose on the water heater. No valve of any type should be installed between the relief valve and the tank.

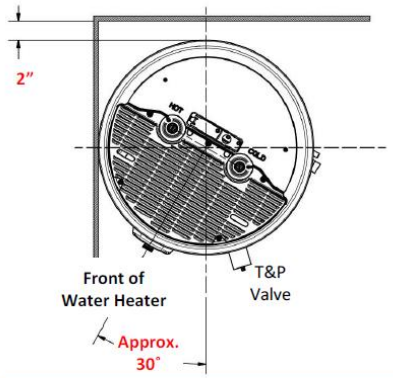
HPWH Clearances are Critical - Read Installation Manual

MINIMUM REQUIRED CLEARANCES:

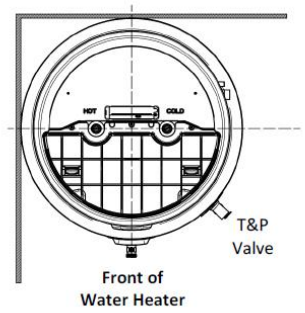
NOTE: Installations in a confined space, or installations where the recommended service clearances are not met, will lead to higher power consumption (increased use of resistance heating elements and/or heat pump efficiency reduction).

Corner Installation

Model #: RE2H50S

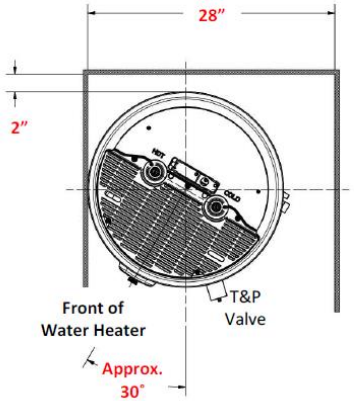


Model #: RE2H65T & RE2H80T

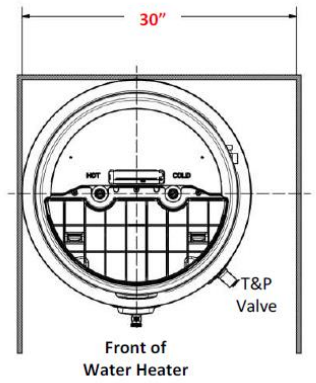


Alcove Installation

Model #: RE2H50S



Model #: RE2H65T & RE2H80T

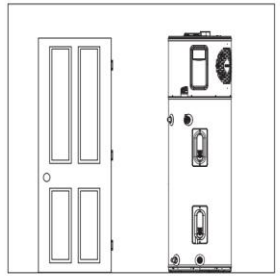


Installing the water heater

Locations that provide optimal efficiency

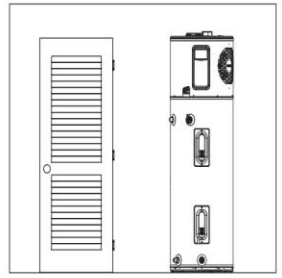
Heater: Not Ducted

Room size: Larger than 700 ft³ (e.g. 7' x 10' x 10').
Requirements: No additional ventilation needed.



Heater: Not Ducted

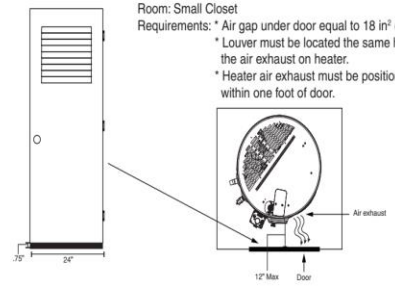
Room size: Smaller than 700 ft³ (e.g. 7' x 10' x 10').
Requirements: Full louvered door OR two louvers top and bottom. See below.



NOTICE: If air temperature in installed location drops more than 15°F (8°C) during heating, air circulation is insufficient for efficient operation. Utilize ducting to direct cold exhaust air to another location.

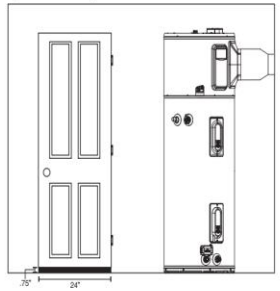
Heater: Not ducted

Room: Small Closet
Requirements:
* Air gap under door equal to 18 in² (0.75" clearance).
* Louver must be located the same height on door as the air exhaust on heater.
* Heater air exhaust must be positioned towards louver within one foot of door.



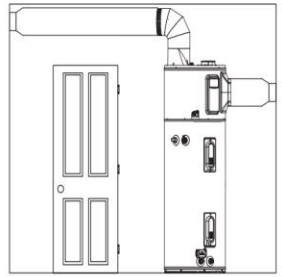
Heater: Ducted with inlet OR outlet duct

Room size: Any size room
Requirements: Air gap under door equal to 18 in² (0.75" clearance)



Heater: Ducted with inlet AND outlet duct

Room size: Any size room
Requirements: No additional ventilation needed.

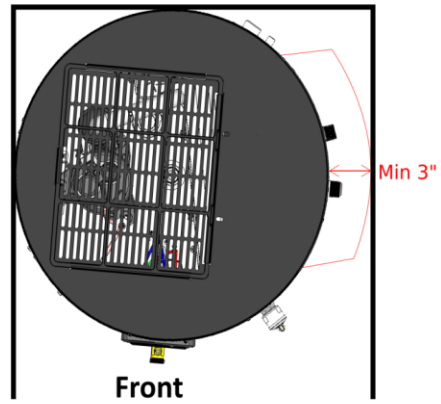


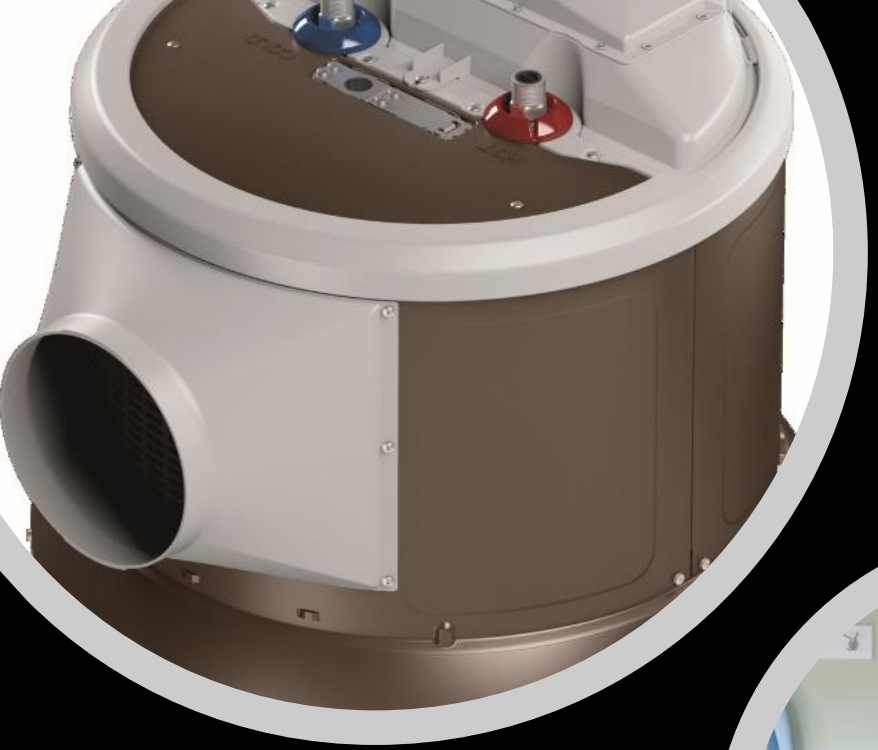
Amendment to the Hybrid Electric Heat Pump Water Heater Use and Care Guide

The clearance requirements on pages 9 and 11 of the Residential Hybrid Electric Heat Pump Water Heater Use and Care Guide have been restated as follows:

Minimum Required Clearances			
Rear	Left Side	Right Side	Top
0"	0"	3"	6"

50-gallon models may need to be rotated clockwise slightly to provide clearance for the condensate drain elbow. This is not necessary for the 66 or 80-gallon models.





Ducting a HPWH

- **For air flow management in living spaces**

- Cooling affect without venting is about only about 3-5 degrees when running, depending on manufacturer
- Provides flexibility of installation in living areas and confined spaces for maximum comfort
- Meets Northern Climate Specification Tier 4 requirements

Common Myths about HPWHs

- **Does not make enough hot water** – Same performance as standard electric in Hybrid mode
- **Challenging to install** – Same top or side connections, depending on manufacturer
- **Won't work in cold climates** – Ambient temps from 35^0 /40^0-120^0
- **Make too much noise** – 55db or less– same as most dishwashers
- **Won't work in garages** – Needs to be above 35^0 /40^0 or switches to elements
- **You must prevent condensate from freezing** – The water heater should switch modes to properly function in electric only mode
- **Need to be a Refrigeration Technician** – Not to install, only to service if needed. Sealed system is like a refrigerator
- **Cost too much** – Pays for itself, price shouldn't be a problem! REBATES

What is a Commercial Heat Pump System?

Commercial Heat Pump Systems are defined as:

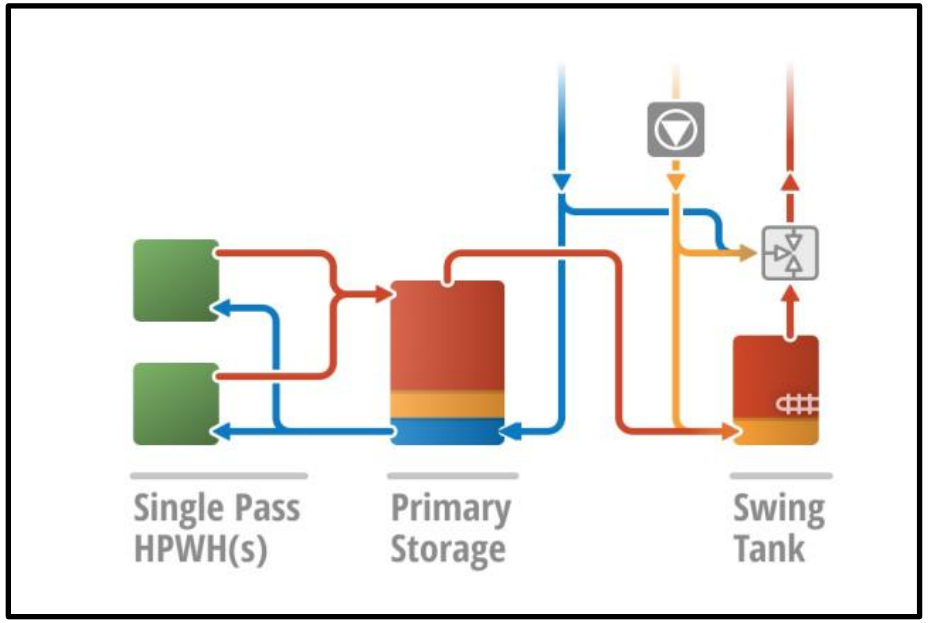
- Systems in buildings of four dwelling units or larger

  OR

- Systems for commercial loads with greater than 120 gallons of storage and/or more than 6 kW of input power.

Most commercial heat pumps are “split systems”

- Large heat pump or multiple heat pumps
- Large storage tanks to handle building DHW demand



Refrigerants Used in Heat Pump Systems

- Synthetic refrigerants such as hydrofluorocarbons (HFCs) and chlorofluorocarbons (CFCs) are man made and pose a threat to the environment if released into the atmosphere.
- Synthetic refrigerants have some limitations when used in cold weather applications

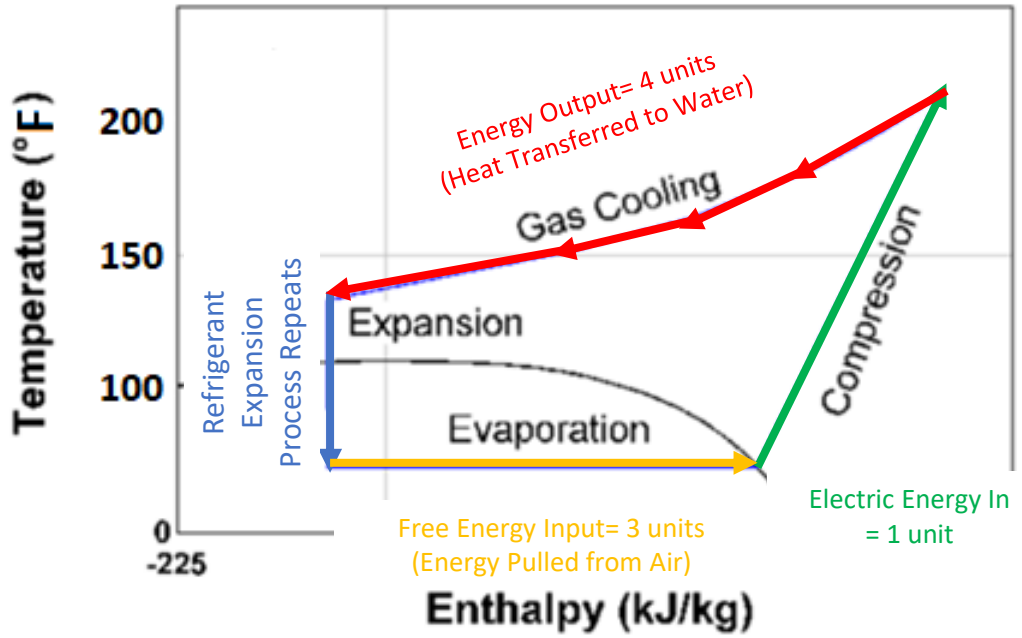
  - Synthetic refrigerants : R410a, R134a Phase Out 2024
  - Synthetic refrigerants: R513a, R454a Phase Out 2040

Refrigerants Used in Heat Pump Systems

- Natural refrigerants are materials that naturally occur in the environment.
- Natural refrigerants pose a minimal threat to the environment and include
  - Ammonia (NH3 or refrigerant name R717a),
  - Carbon Dioxide (CO_2 or refrigerant name R744a)
  - Propane (refrigerant name R290a)
- We will focus on R744a Carbon Dioxide, CO2 , in this presentation.

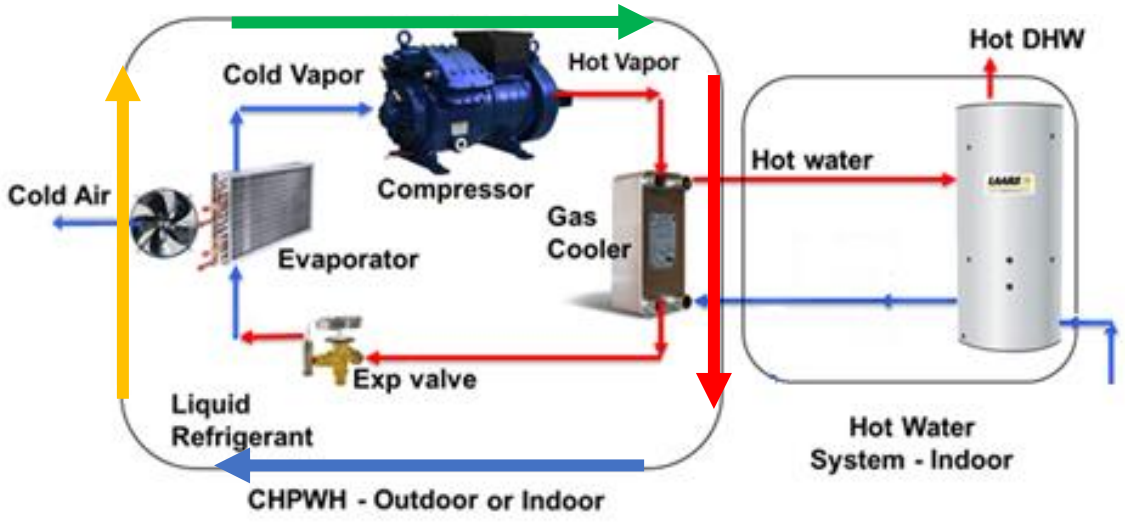
How Natural Refrigerant Heat Pumps Work

R744 Refrigerant (CO_2) Refrigeration Cycle



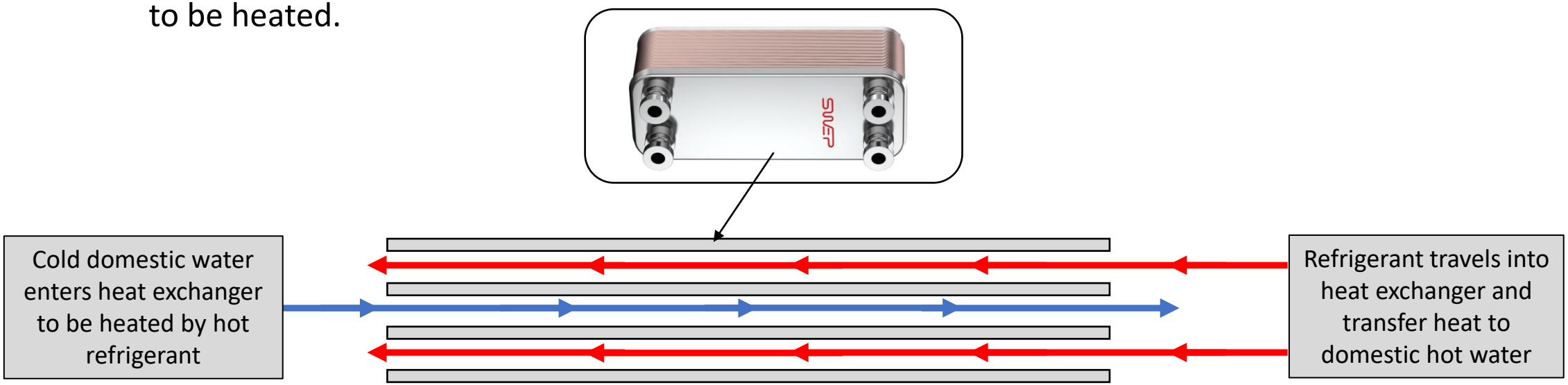
"ENERGY" (Enthalpy)

Basic R744 Heat Pump System

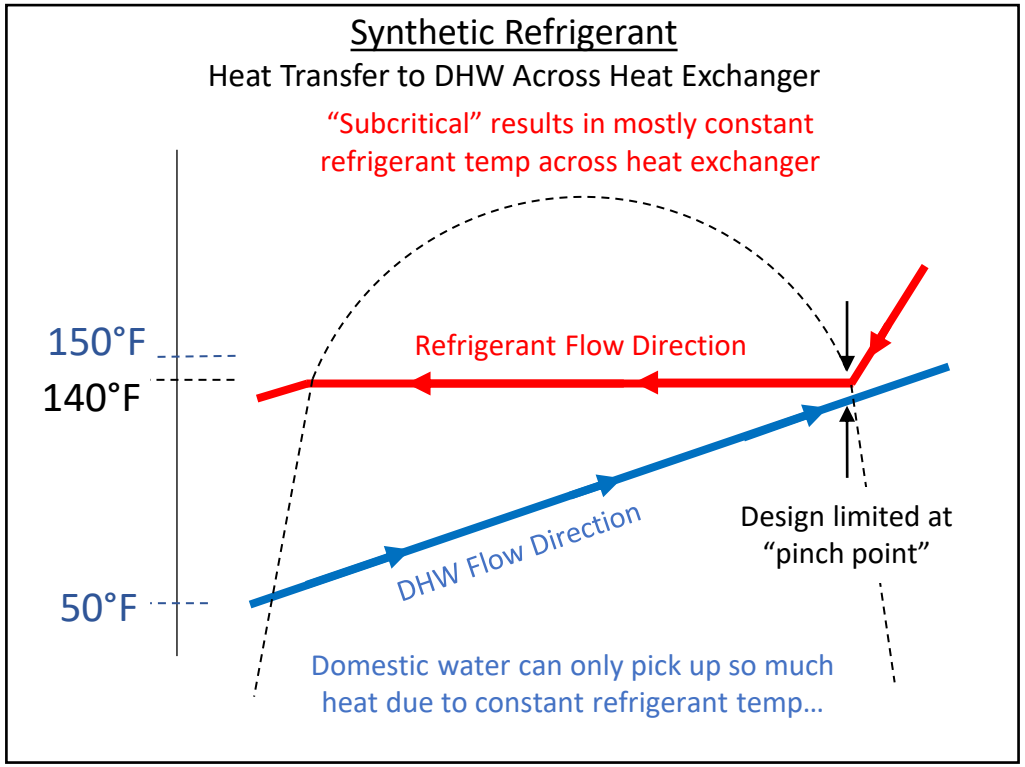


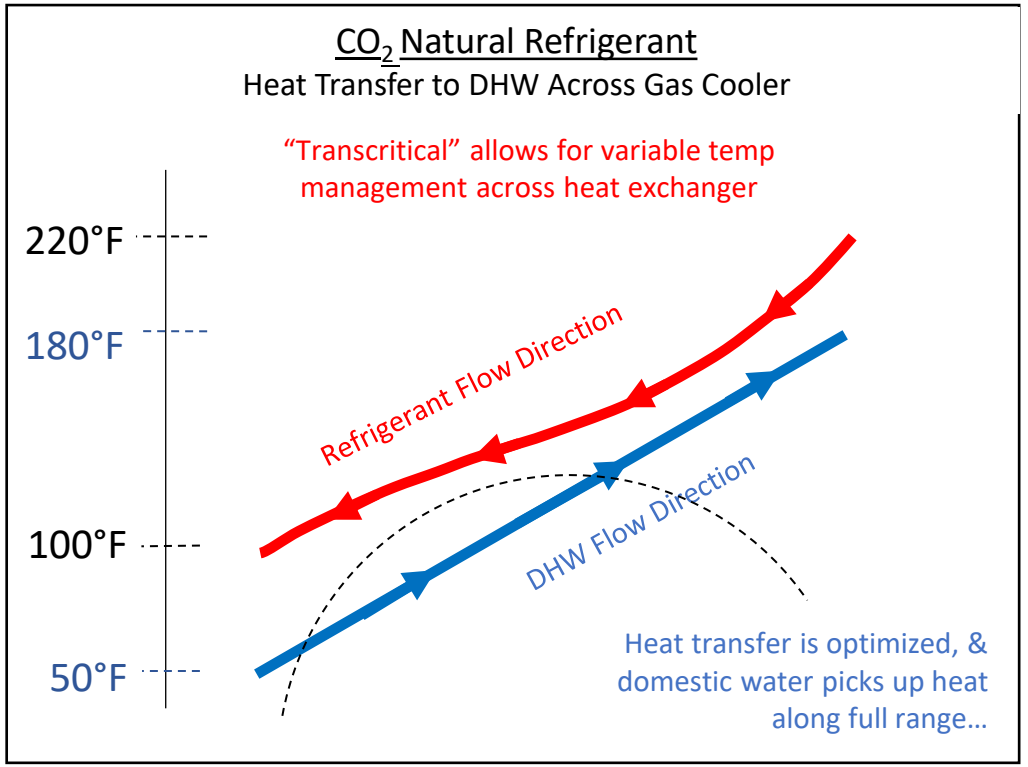
How CO2 Natural Refrigerant Heat Pumps Transfer Heat From Refrigerant to Domestic Water

- Both natural and Synthetic refrigerant-based heat pumps use heat exchangers to transfer heat from refrigerant to domestic water.
  - Synthetic based systems use traditional “condenser” heat exchangers
  - CO_2 systems use “gas cooler” heat exchangers
- In both cases the hot refrigerant passes in opposite direction of the incoming domestic water to be heated.



How Natural Refrigerant Heat Pumps Transfer Heat From Refrigerant to Domestic Water





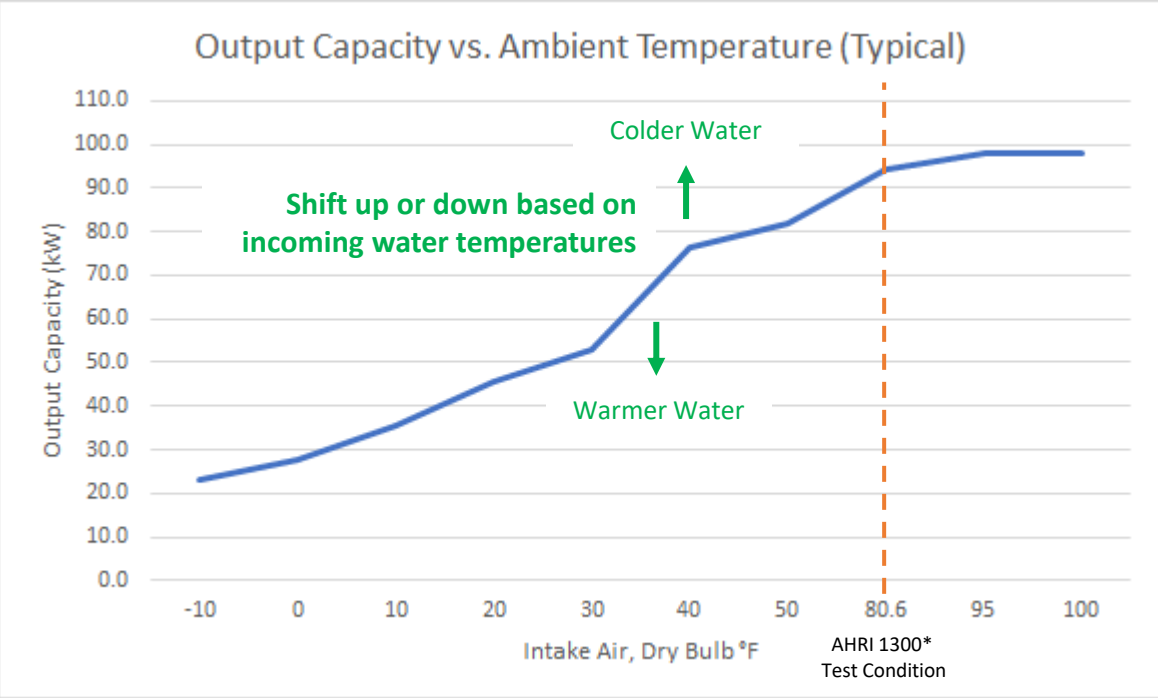
- Transcritical CO_2 cycles have inherent advantages where large "temperature lifts" exist for the fluid being heated…
- Exact application type for volume water heating – cold water heated to very hot water!!

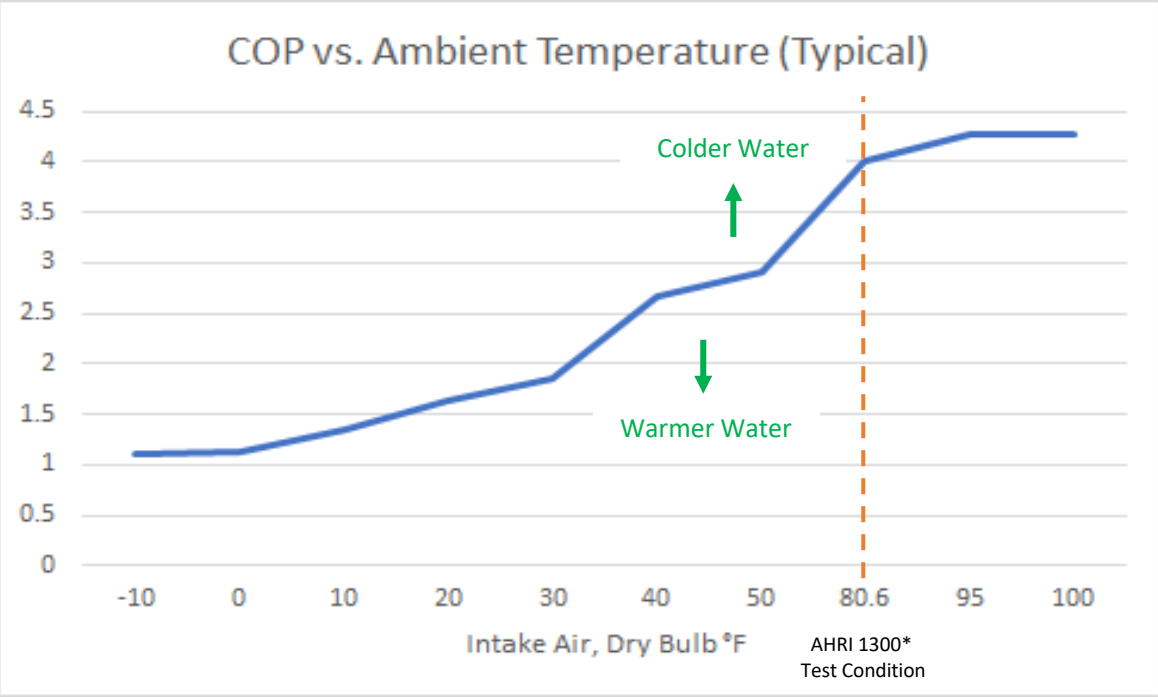
Typical Heat Pump and Tank System

Commercial Split Heat Pumps
Require a Centralized Tank System

- Large storage volume needed to supply hot water over long period of time
- Typically takes 12-18 hours to re-charge tanks
- Tank stratification over multiple tanks optimizes performance

Performance Data for Sizing





- System should be sized for output of the coldest expected incoming air temperatures in order to meet the maximum system demand.
- Or have electric resistance or gas fired supplemental back-up systems to meet demand on the few weeks at selected design temperature.

* AHRI Standard 1300 test condition of 70°F inlet and 120°F outlet water temperature at 80.6°F incoming air temperature.

Natural Refrigerant Heat Pump Advantage

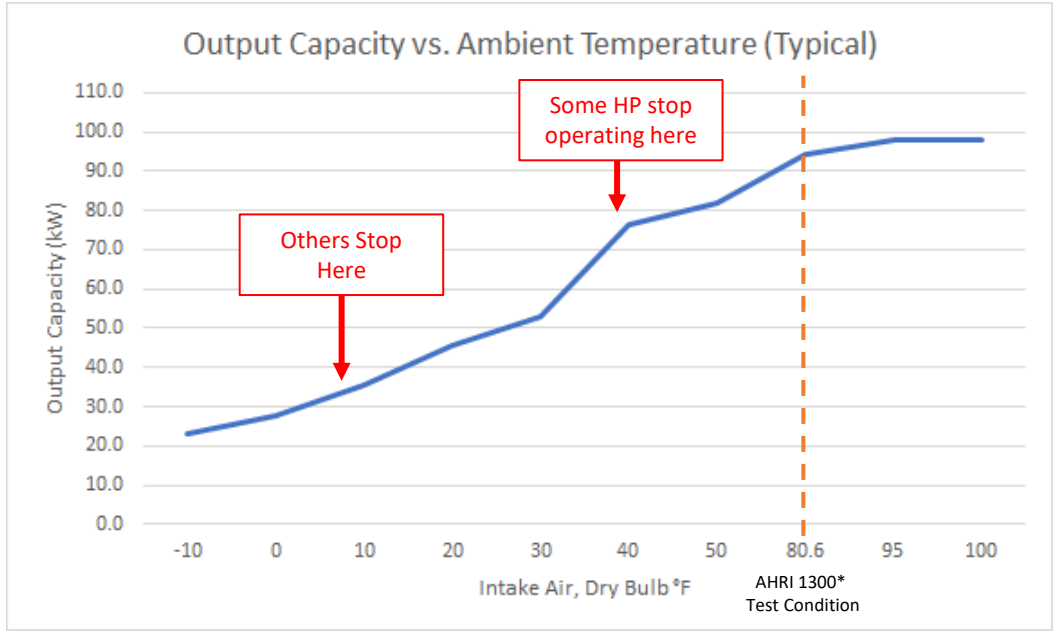
- **Natural refrigerant-based systems**
  - Refrigerant cycle is “Transcritical”- Part of the cycle is “subcritical” and part is “supercritical”

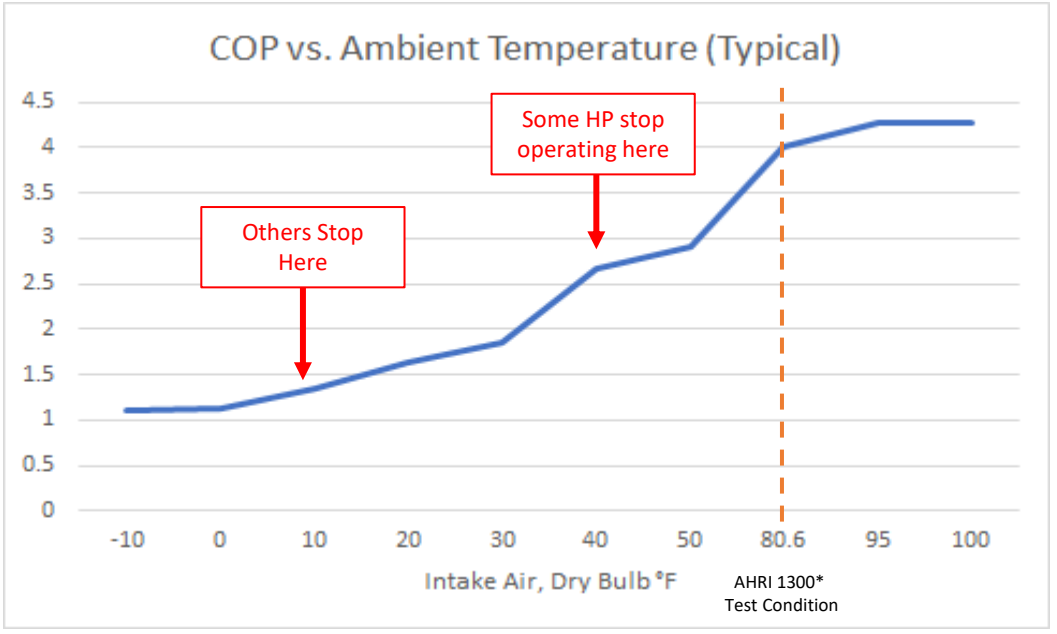
- **Synthetic refrigerant-based systems** are designed to be “subcritical”

So – Why does this matter?

- **CO_2 HPWH “Transcritical Cycle”**
  - Produces a higher service temperature with limited capacity loss
  - Can operate at lower incoming air temperatures while still outputting 180°F hot water
  - Can heat very cold water to hot water in one pass through the heat pump
    - Synthetic refrigerant systems often requiring multiple passes through the heat pump

Performance Data, Heat Pump Limits

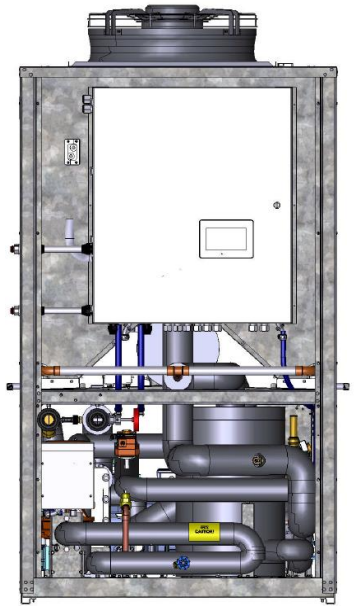




- Key to Check - What is the heat pump's maximum outlet Domestic Hot Water temperature at the expected low incoming air temperature?
- Many synthetic refrigerant heat pumps drop in DHW outlet temperature in cold weather, impacting DHW plant performance.

* AHRI Standard 1300 test condition of 70°F inlet and 120°F outlet water temperature at 80.6°F incoming air temperature.

Natural Refrigerant
Commercial Heat Pump Water Heater

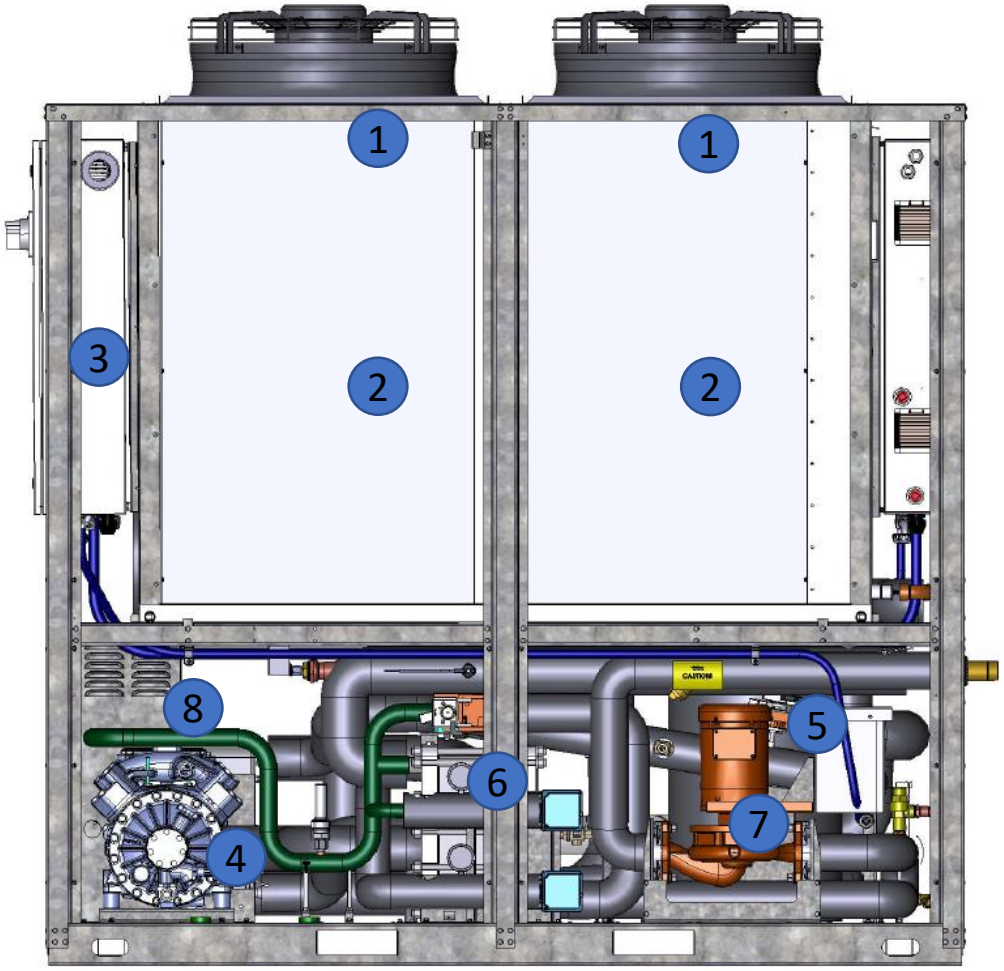


- Air-to-Water Heat Pump for Domestic Hot Water Production
- Nominal COP should be Tested per AHRI Standard 1300
  - Test condition of 70°F inlet and 120°F outlet water temperature at 80.6°F incoming air temperature.
  - Meets Department of Energy 10CFR431 energy efficiency requirements
- Nominal Heating Capacity of 325,000 BTU/hr.
- Advanced Control Enabled
  - BMS communication
  - CTA-2045 utility grid enabled for load shifting
  - Cascade up to 16 units for large heating plant of 5186 MBH (1520 kW)
- Indoor or outdoor installations

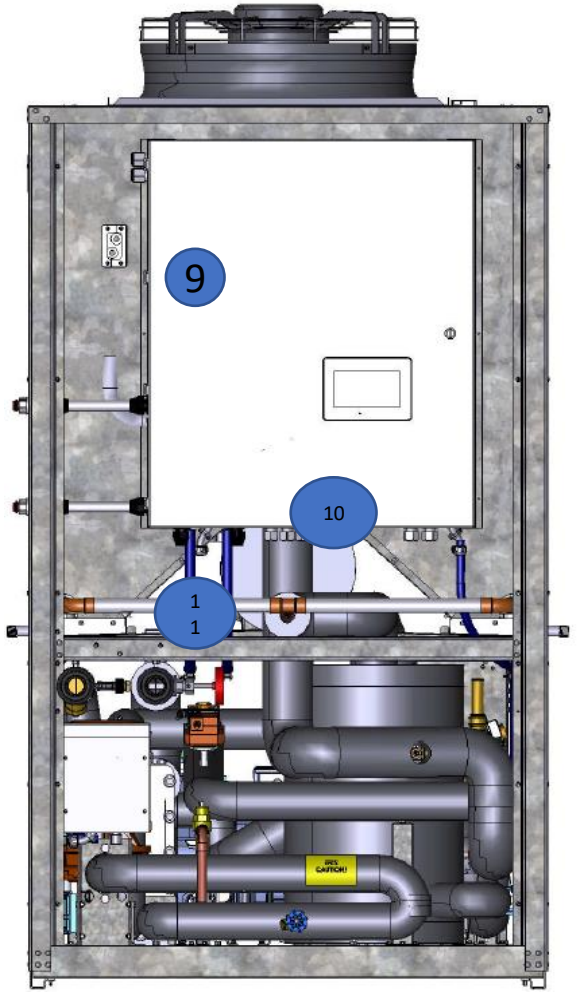
Natural Refrigerant R744 (CO_2) Advantages

- Operates with a COP greater than 1.0 at -10°F air temperatures.
- Outputs sanitizing 180°F hot water, even at cold air temps
- Has a GWP of 1.0
- Future proof – R744 will not be phased out over time like chemical refrigerants

Air-to-Water Heat Pump Major Components



1. Axial Fans
2. Evaporators
3. High voltage control panel
4. Compressor
5. Expansion valve
6. Double wall gas cooler
7. DHW pump
8. Variable frequency drive
9. Low voltage control panel
10. Touchscreen Interface
11. CO_2 Expansion tank



Application Examples

- Multi-Family Apartments and Condominiums
- Hotels / Hospitality
- College and Military Dormitories
- Athletic Facilities
- Commercial and Industrial High Volume Hot Water Applications
  - High Volume Laundries
  - Food and Beverage Production
  - Etc.

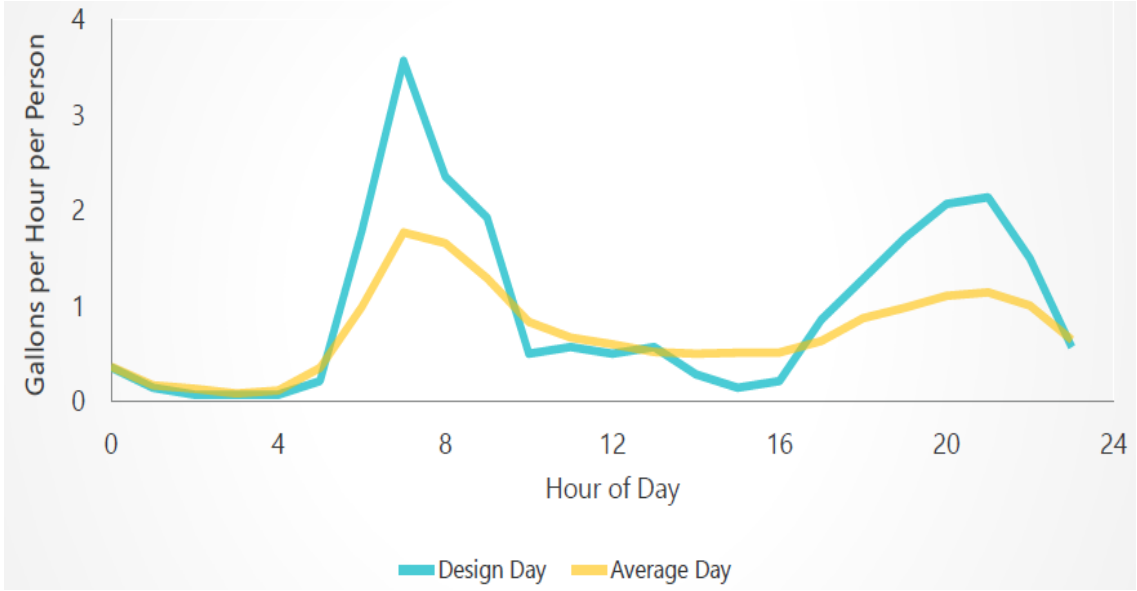
Multi-Family Building Example
Sizing the System

Two loads to consider

1. Primary Load: Heating cold water for use/storage
   - Determine required hot water load profile:
     - The number of occupants
     - How much hot water they use, and when
     - At the Design Conditions (cold incoming air temps)

2. Temperature Maintenance: Reheating distribution loop water
   - Calculate heating losses in recirculation loop

Typical Multi-Family Building Load Profile



Source: Bonneville Power Administration, Emerging Technologies

Gas-fired systems are sized with small storage, large heat source.

Heat pump systems are sized with large storage, small heat source

Tools like EcoSizer can be used to calculate required equipment sizes.

https://ecosizer.ecotope.com/sizer/

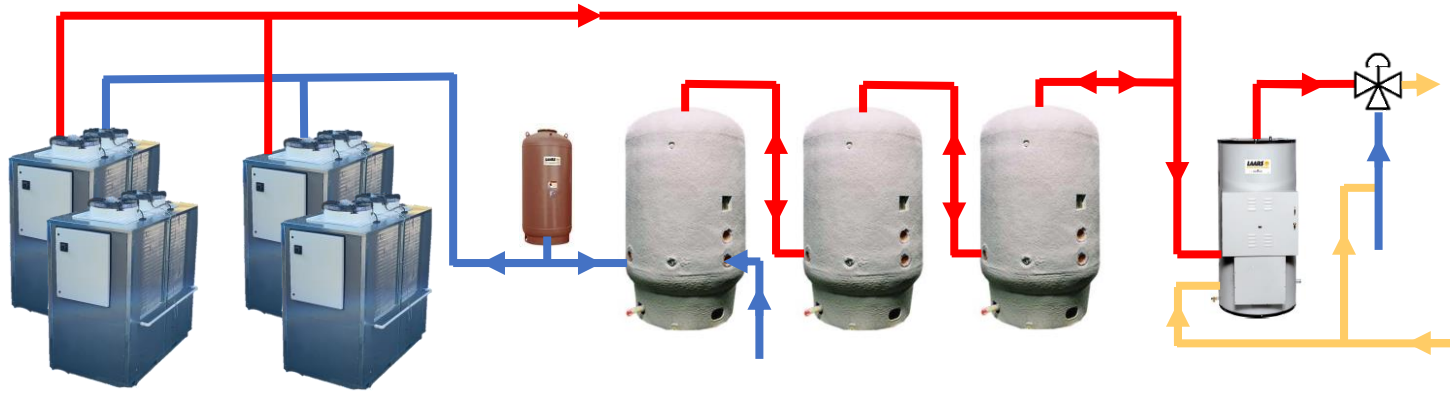
Multi-Family Building Example

Multi-Family Tower (25 Stories)

- 250 Suites
- 650 Occupants

Gas Offering Typical:
2 x 1600 MBH Volume Water Heaters
and, 2 x 325 US Gal tanks

Heat Pump Offering Typical:
4 x R744 325 MBH Heat Pumps, 3 x 1,400 US Gallon tanks, and
1 x 300 Gallon Electric Water Heater



https://ecosizer.ecotope.com/sizer/

Multi-Family Building Example

System Size

The selected minimum heating capacity shown below is the **minimum** needed average output capacity of the selected equipment at the design cold air temperature in your climate zone. Note that you must also account for manufacturer specific defrost penalty.

Tank Volume

4247.37 Gallons

Heating Capacity

674.6 kBTU/hr

Swing Tank Volume

120 - 300 Gallons

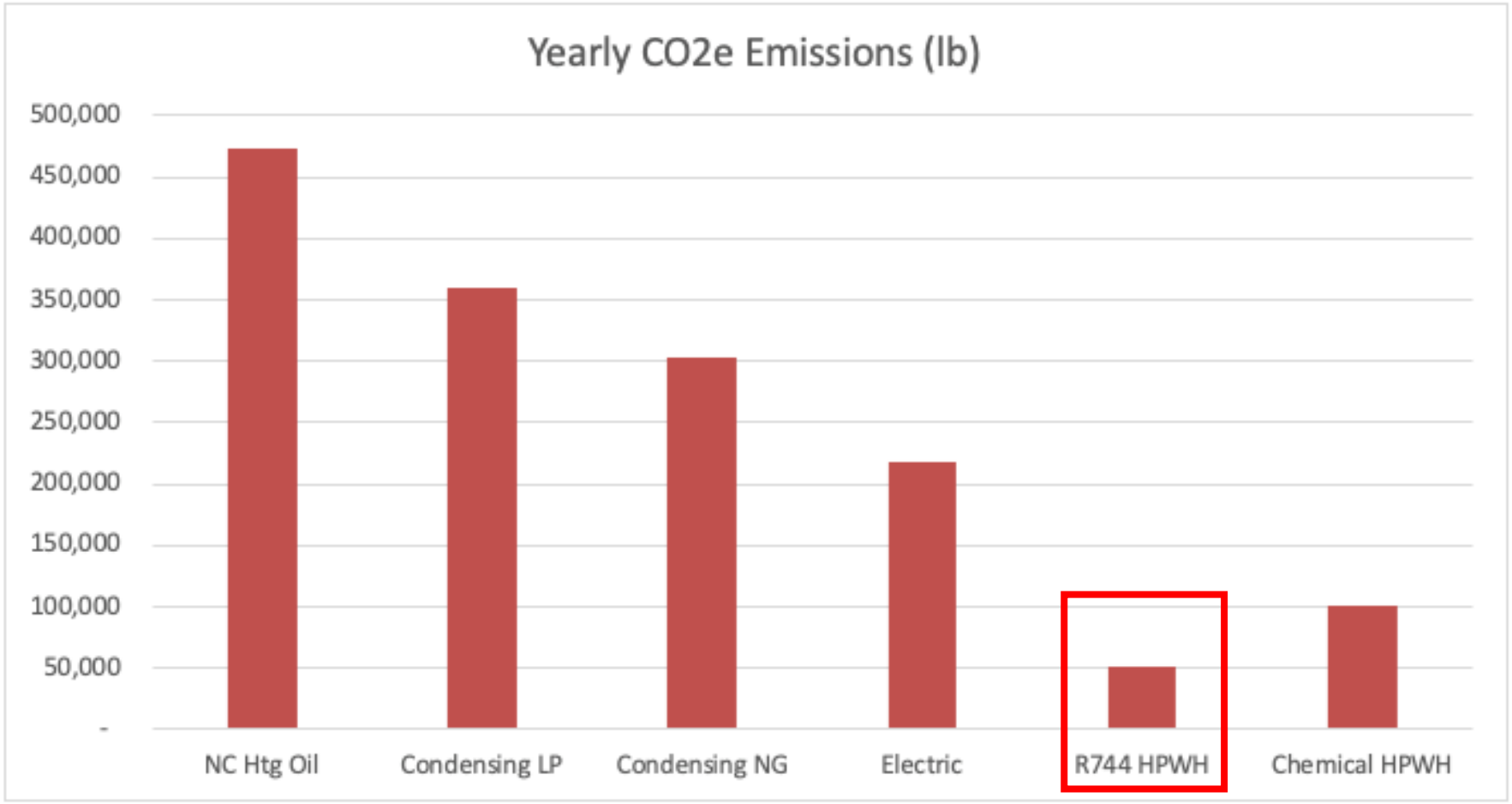
Swing Resistance Element

43.7 kW · **149.3** kBTU/hr

CA Title 24 Swing Tank Volume

480 Gallons

Multi-Family Building Example
Potential CO_2 Emission Reduction, Typical



Example in Climatic Zone 5A, 8,000 gallons per day DHW

R744 CO_2 Heat Pump for Cold Climates

Verses Synthetic Based Heat Pumps

- CO_2 heat pumps can output 180°F water down to -10°F or colder
- 180°F water temps allow for utility demand side management program flexibility
- Synthetic refrigerant units max water temp is 150 to 160°F, output drops with colder incoming air temps.
- Synthetic refrigerant heat pumps typically stop operating at incoming air temps between 15-40°F
- R744 will not be phased out over time like chemical refrigerants often are

CO_2 Heat Pump Considerations

- Look for double wall gas cooler (heat exchanger) built in. Otherwise, an external double wall water-to-water heat exchanger may be needed to meet local codes.
- Look for a fully charged, “plug and play” unit, CO_2 expansion tank included in package, on site CO_2 charging not needed
- Look for CTA-2045 utility grid enabled for load shifting

Review Questions

Question: Do heat pump water heaters match the performance of standard electric water heaters with equivalent tank sizes?
***Answer*:** Yes, in “hybrid mode”

Question: Do you need to be a refrigeration or HVAC technician to install a heat pump water heater?
Answer: No, only to service as needed, sealed system like a refrigerator

Question: Are heat pump water heater too expensive vs standard electric water heaters?
Answer: No, heat pump water heaters pay for themselves, plus there are generous rebates on heat pump water heaters.

Question: What are some of the benefits of using R744 CO 2 refrigerant in heat pumps?
***Answers*:** Can work in much colder incoming air temps (-10F) with COP greater than
Can output 180F hot water at all incoming air temps

Question: What are three major segments of multi-family commercial heat pump system?
Answer: Heat pumps, Primary Storage, and Recirculation Loop

Training Disclaimer

This training presentation is the property of ***Bradford White Corporation.***

Training designed and issued by ***Bradford White Corporation*** *or its subsidiaries are for plumbing and heating industry professionals and the content is the sole property of* ***Bradford White Corporation****. Any content alterations to this training material must be approved or pre-authorized by* ***Bradford White Corporation****.*

All ***Bradford White Corporation*** *residential and commercial water heating, space heating, and storage products are designed for professional installation and service only.*

ASPE American Society of Plumbing Engineers CEU PROVIDER

Thank you…