

# CENTRAL HEAT PUMP WATER HEATING:

## Sizing and Modeling

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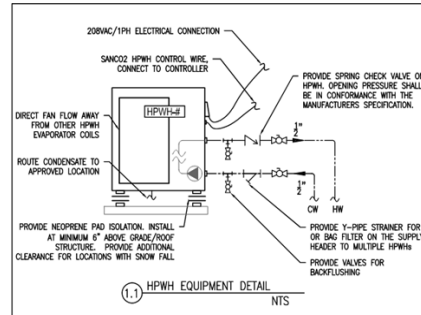
*Paul Kintner, paul@ecotope.com*  
*Ecotope, Inc.*

Energy Trust Building Energy  
Simulation Forum  
October 27<sup>th</sup>, 2021

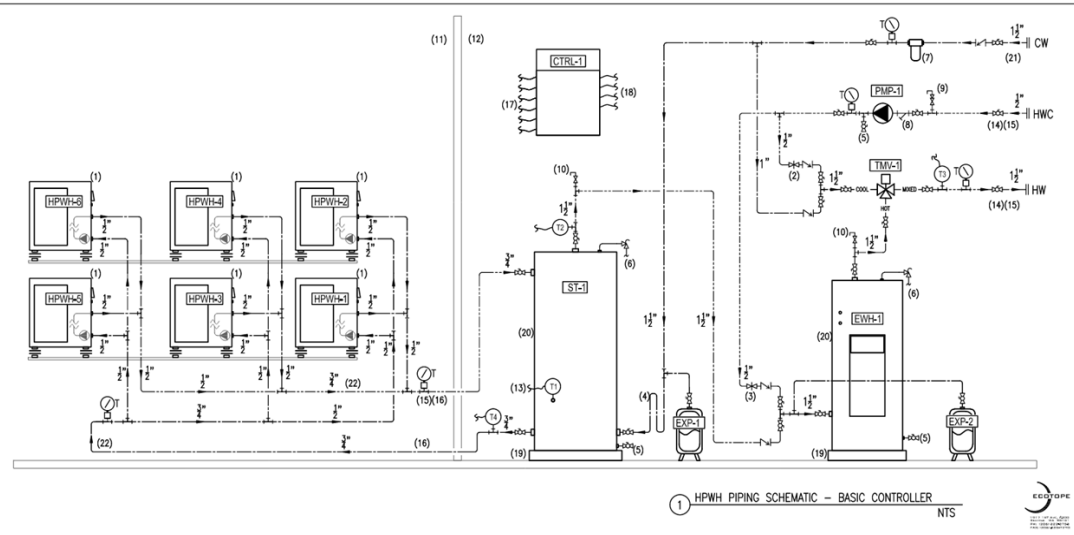


BASIS OF DESIGN	
<p>THE SYSTEM WAS SIZED FOR:</p> <ul style="list-style-type: none"> <li>SANCO2 WITH SWING TANK CENTRAL HEAT PLANT DESIGN</li> <li>MARKET RATE MULTI-FAMILY BUILDING</li> <li>60 FULL TIME OCCUPANTS</li> <li>30 RESIDENTIAL DWELLING UNITS</li> <li>25 GALLONS OF HW PER PERSON PER DAY (PEAK DAILY HOT WATER USAGE)</li> <li>1,500 GALLONS OF 120°F HW PER DAY (PEAK DAILY HOT WATER USAGE)</li> <li>16 HR PER DAY PRIMARY HPWH RUN TIME</li> <li>90 WATTS/APT HWC LOSSES</li> </ul> <p>MINIMUM SYSTEM SIZE:</p> <ul style="list-style-type: none"> <li>285 GALLONS OF PRIMARY STORAGE</li> <li>68.8 MBTU/HR OF PRIMARY HEAT CAPACITY</li> <li>80 GALLONS OF SWING TANK VOLUME</li> <li>4.7 KW SWING TANK RESISTANCE ELEMENT</li> </ul>	<p>EQUIPMENT SELECTION:</p> <ul style="list-style-type: none"> <li>[HPWH-1-6] PRIMARY HPWHs; SIX (6) SANCO2, GS4-45HPC; 5 NOMINAL, 1 REDUNDANT UNIT</li> <li>[ST-1] PRIMARY STORAGE; ONE (1) SANCO2, ECO-285G/INST; 285 GALLONS OF STORAGE</li> <li>[CTRL-1] CENTRAL HEAT PLANT CONTROLLER; SANCO2, ECO-NCTRL-001</li> <li>[DWH-1] TEMPERATURE MAINTENANCE TANK (SWING TANK); 80 GALLONS, 6 KW ELEMENT</li> <li>[PMP-1] 0.5 GPM PER RISER, TARGET 11°F OF HOT WATER CIRCULATION RETURN WATER TEMP.</li> <li>[TMV-1] RECOMMEND SIZING FOR 0.25 GPM PER PERSON PEAK; MINIMUM FLOWRATE SHALL BE LESS THAN THE CONTINUOUS FLOWRATE OF [PMP-1]</li> <li>[EXP-1] SIZED FOR THE THERMAL EXPANSION OF THE PRIMARY STORAGE VOLUME.</li> <li>[EXP-2] SIZED FOR THE THERMAL EXPANSION OF THE TEMPERATURE MAINTENANCE STORAGE VOLUME AND THE VOLUME OF WATER IN THE HW DISTRIBUTION PIPING.</li> </ul>

LEGEND			
SYMBOL	DESCRIPTION	SYMBOL	DESCRIPTION
	PUMP		PIPE-T
	MIXING VALVE		TAP RELIEF VALVE
	EQUIPMENT TAG		MANUAL AND AUTOMATIC AIR BLEED
	TEMPERATURE SENSOR		PIPE UNION
	FLOW METER		PIPE FLOW DIRECTION
	BALL VALVE		PIPE SIZE
	BALANCING VALVE		CW PIPING
	SPRING CHECK VALVE		HW PIPING
	INLINE Y-STRAINER		HWC PIPING



- SHEET NOTES
- SEE HPWH EQUIPMENT DETAIL 1.1
  - DIRECT  $\approx 75\%$  OF FLOW THROUGH PIPING PATH UNDER NO LOAD CONDITION WITH CONTINUOUS HWC PUMP OPERATION
  - DIRECT  $\approx 25\%$  OF FLOW THROUGH PIPING PATH UNDER NO LOAD CONDITION WITH CONTINUOUS HWC PUMP OPERATION
  - PROVIDE 12" HEAT TRAP
  - EQUIPMENT DRAIN
  - ROUTE TAP RELIEF TO DRAIN
  - BAG FILTER (PENTAK)
  - INLINE PIPE STRAINER
  - AUTOMATIC AIR BLEED
  - MANUAL AIR BLEED AT HIGH POINT IN SYSTEM
  - EXTERIOR ENVIRONMENT
  - INTERIOR ENVIRONMENT, CAN BE EXTERIOR PROVIDED THAT THE EQUIPMENT IS SHELTERED FROM THE ELEMENTS AND PROVIDED WITH FREEZE PROTECTION IN AREAS SUBJECT TO TEMPERATURES BELOW FREEZING
  - WIRE TO CONTROLLER (TYPICAL)
  - ALL HW AND HWC PIPING SHALL BE INSULATED TO CODE LEVELS
  - ALL HORIZONTAL PIPE CLAMPS ON HOT WATER PIPING SHALL BE FREE OF THERMAL BRIDGES
  - ALL EXTERIOR PIPING SHALL BE INSULATED WITH A MINIMUM OF 2" WALL THICKNESS PIPE INSULATION. INSULATION SHALL BE PROTECTED FROM PEST AND UV LIGHT DAMAGE
  - CONTROL WIRE, CONNECT TO HPWH (TYPICAL)
  - CONTROL WIRE, CONNECT TO SENSOR (TYPICAL)
  - R-10 THERMAL ISOLATION
  - PROVIDE SEISMIC BRACING WHERE REQUIRED BY JURISDICTION
  - CONNECT TO BUILDING COLD WATER SUPPLY LINE. DOUBLE CHECK VALVE ASSEMBLY AND PRESSURE CONTROL DEVICES NOT SHOWN IN THIS SCHEMATIC.
  - PROVIDE EQUAL DISTANCE PIPING TO HPWHs TO BALANCE FLOW. CW SUPPLY LINE TO HPWHs SHALL BE EXTENDED TO ARIEVE EQUAL DISTANCE PIPING. MINIMIZE OUTGOING HW SUPPLY LINE DISTANCE TO THE PRIMARY STORAGE [ST-1]



# OVERVIEW

- Why CHPWHs
- CHPWH Systems
- Sizing CHPWH Systems
- Modeling

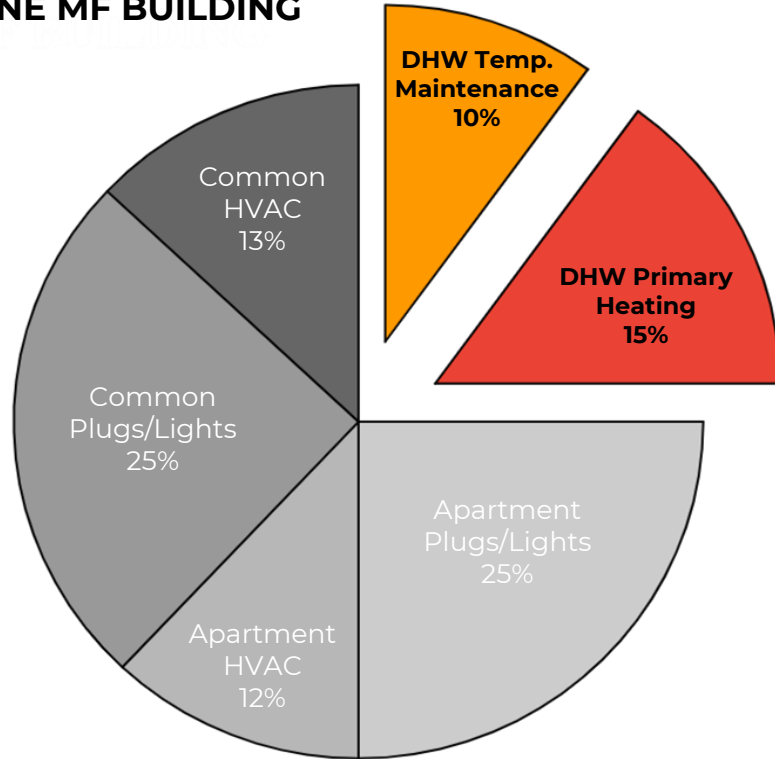
# WHY CHPWH?



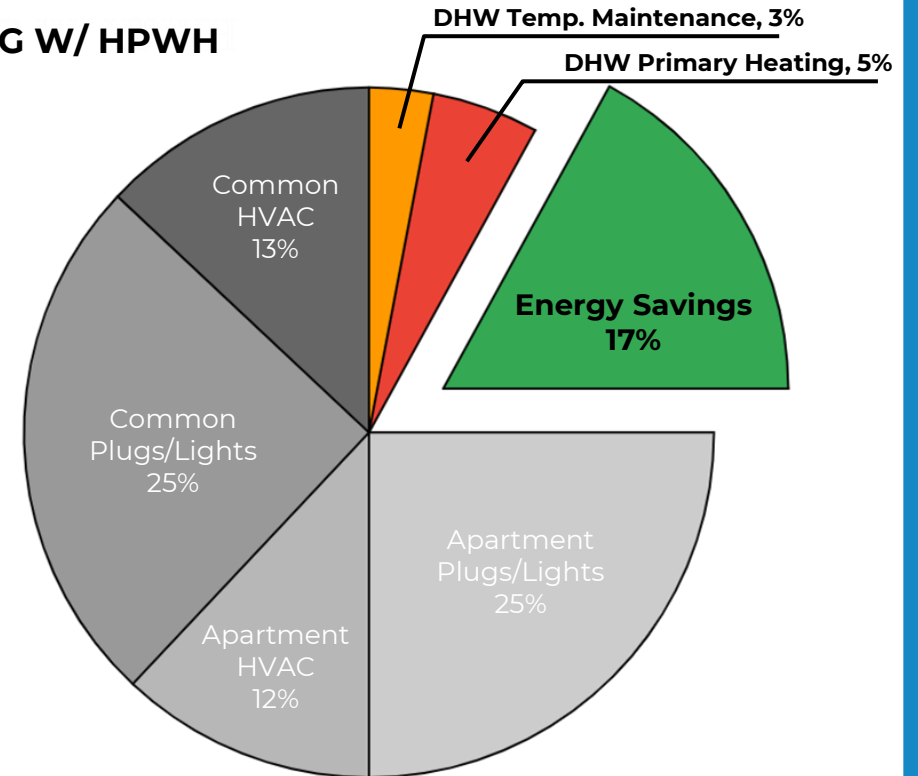
- ◆ Climate Change
- ◆ Global, federal, & state policies
- ◆ Codes & standards
- ◆ Capture incentives & rebates
- ◆ Lower operating costs
- ◆ Energy efficiency measures
- ◆ Societal changes

# WHY CHPWH?

## BASELINE MF BUILDING



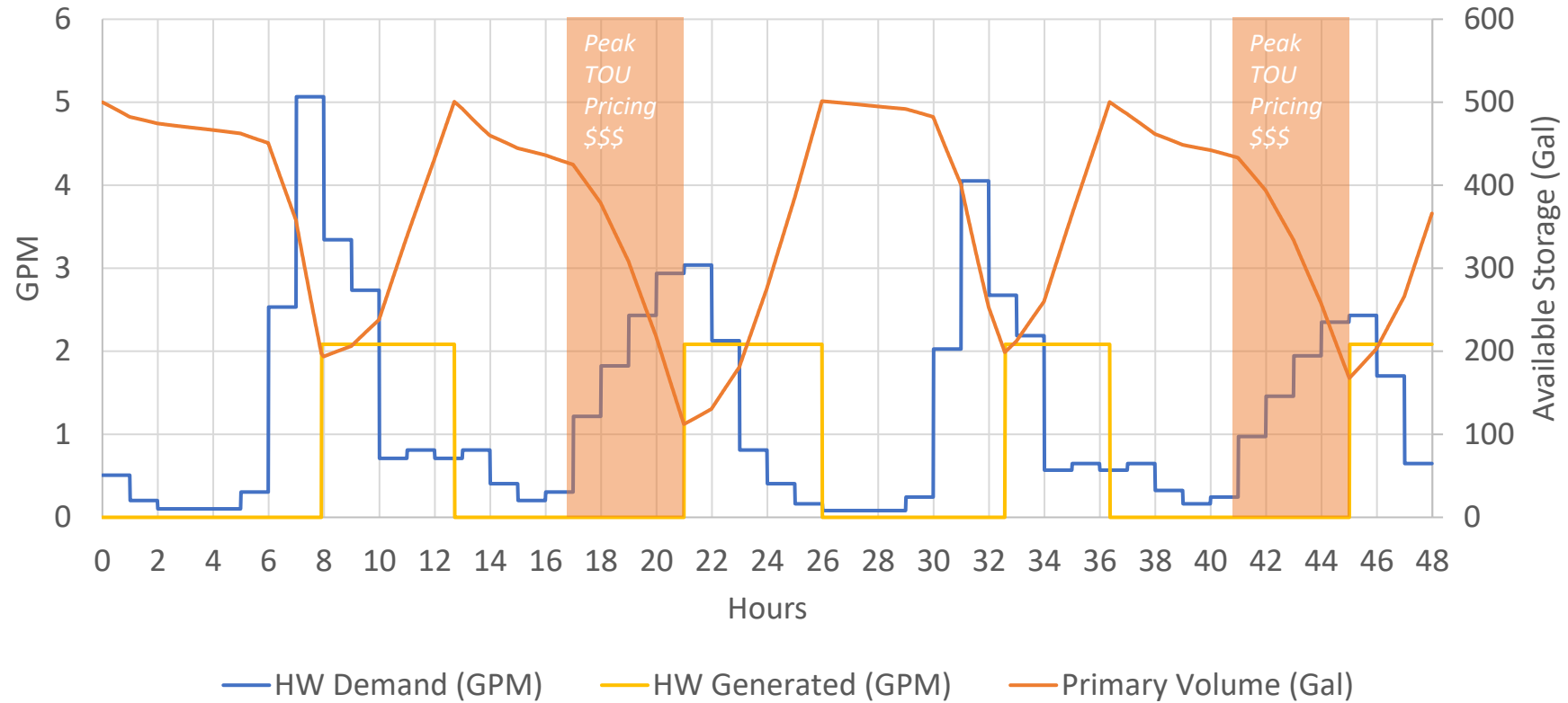
## MF BUILDING W/ HPWH




DHW represents 25% of annual building use

CHPWH systems cut energy usage down by 3x

# WHY CHPWH: TOU RATES & GRID FLEXIBILITY



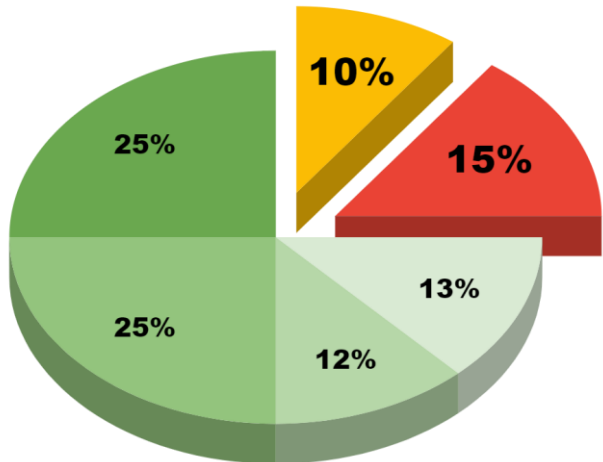


The background of the slide is a photograph of industrial machinery, specifically a complex network of pipes and structural beams. The image is split into two color-coded sections: the left side is a dark reddish-brown, and the right side is a dark blue. The pipes are metallic and run in various directions, some horizontally and some vertically. The overall scene is dimly lit, emphasizing the industrial and technical nature of the subject.

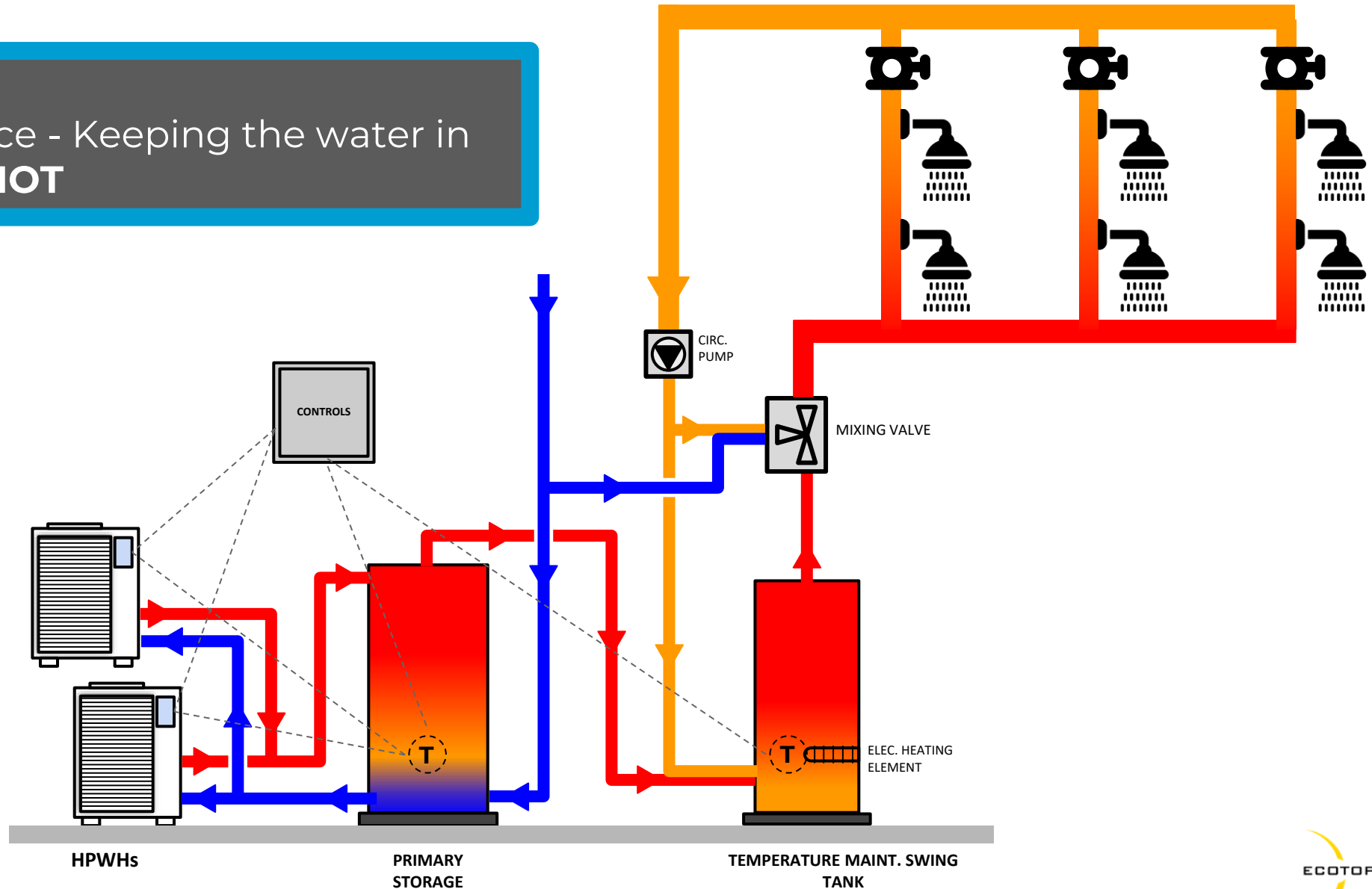
# CHPWH SYSTEMS

# CHPWH SYSTEM

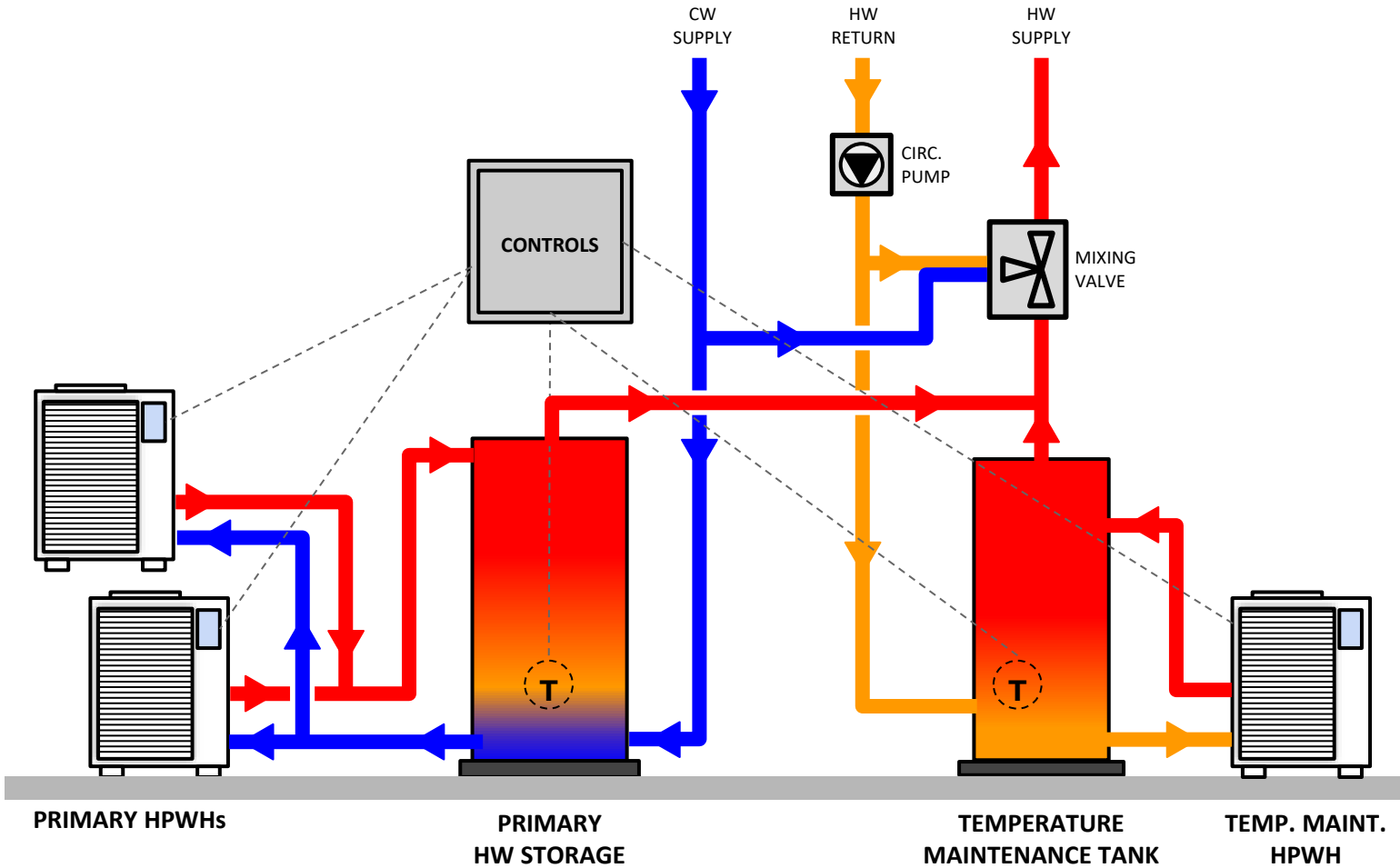
Hot Water Draws Temperature Maintenance - Keeping the water in the distribution system **HOT**



ENERGY USAGE IN MULTIFAMILY MIDRISE



# FOUR CHPWH SYSTEM COMPONENTS



- Primary heat pump water heater (HPWH)
- Primary HW storage
- Temperature maintenance system
- Controls



# CHPWH SYSTEMS: INTRO

## 4 OPTIONS

01

**Dedicated Parallel**

Dedicated HPWH connected by parallel piping

02

**Dedicated Series**

Dedicated swing tank connected in series

03

**Combined**

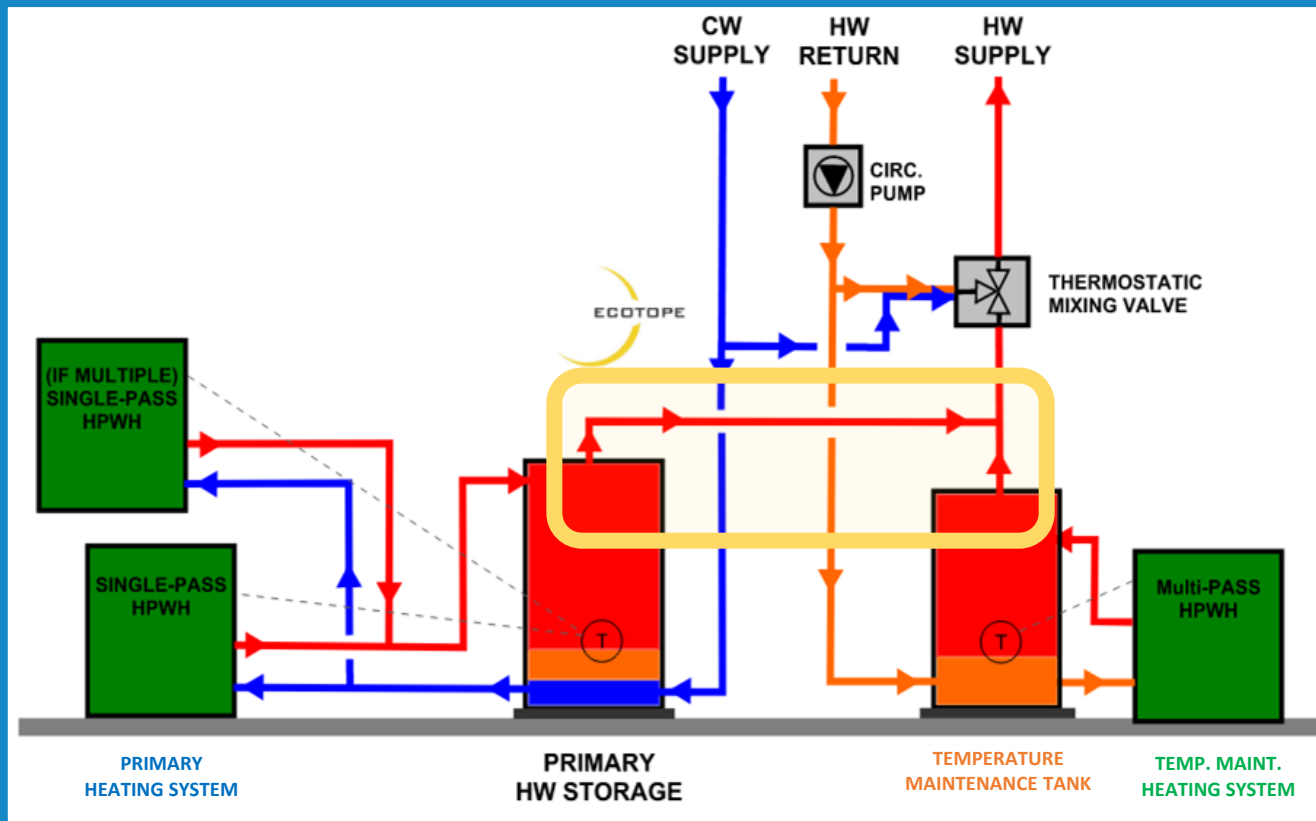
Primary & Temperature Maintenance System are combined

04

**No Recirculation**

Heat Tape

# SINGLE-PASS PRIMARY HPWH SYSTEM W/ PARALLEL TEMPERATURE MAINTENANCE TANK & MULTI-PASS HPWH

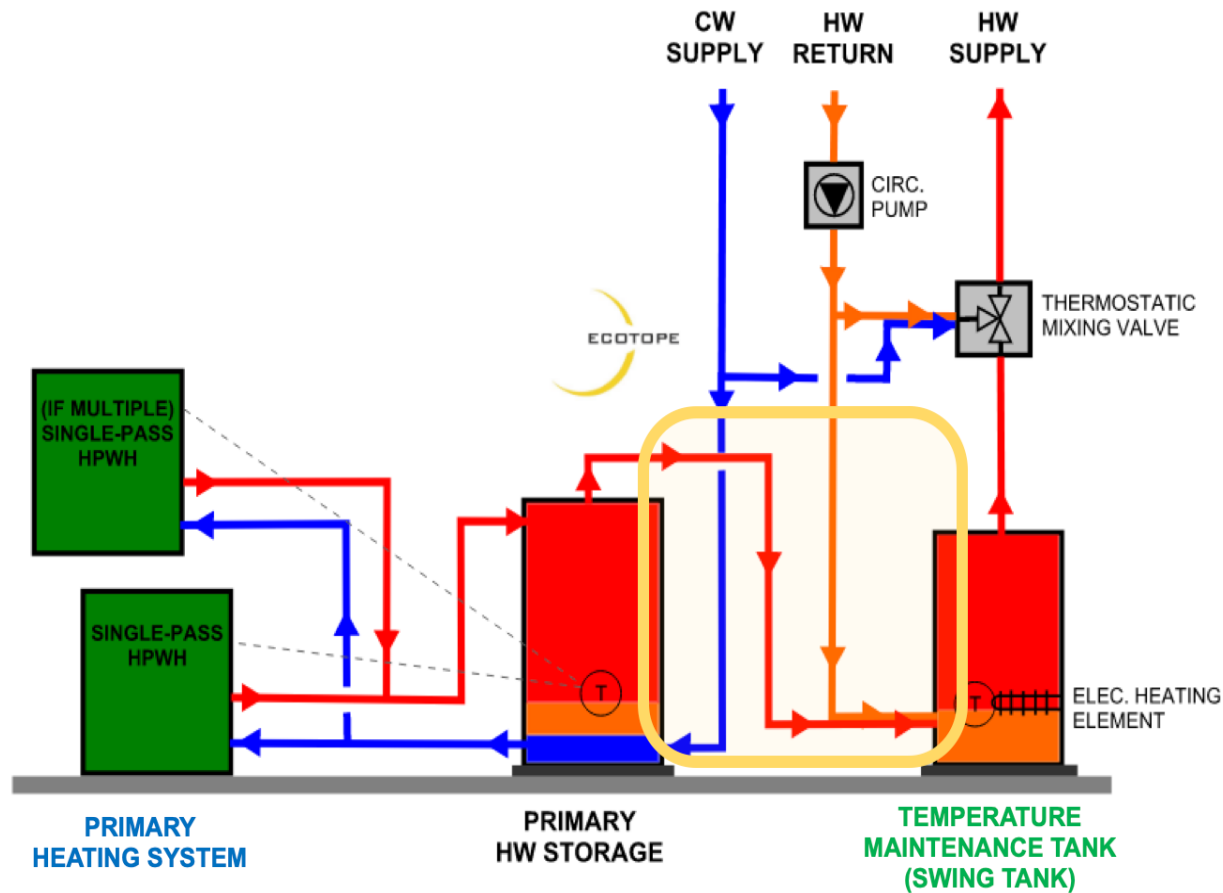


## KEY CONSIDERATIONS:

- Single pass heating system for primary
- Dedicated heating system for temperature maintenance
- Two systems work in parallel



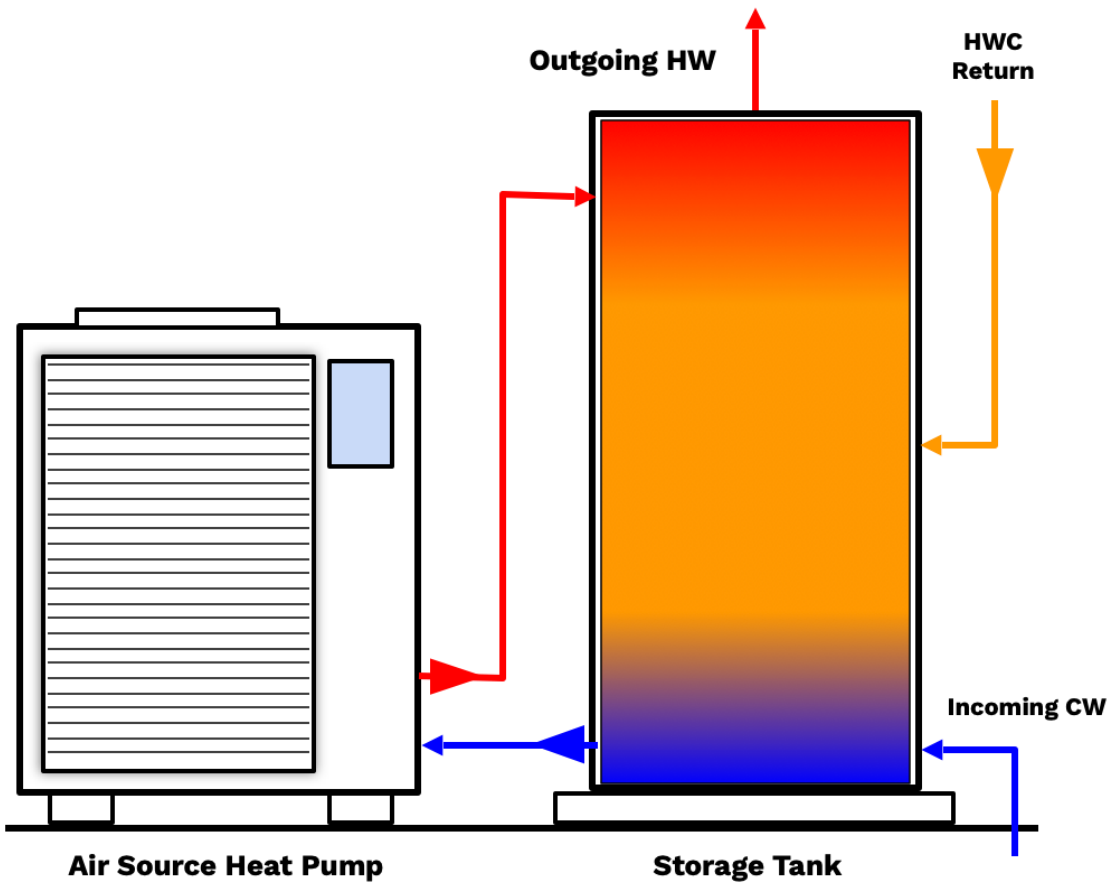
# SINGLE-PASS PRIMARY HPWH SYSTEM W/ SERIES TEMPERATURE MAINTENANCE TANK (SWING TANK)



## KEY CONSIDERATIONS:

- ◆ Single pass heating system for primary
- ◆ Dedicated heating system for temperature maintenance
- ◆ Two systems work in series

# COMBINED SYSTEM



## KEY CONSIDERATIONS:

- Both primary & maintenance loads done by one system.

## RISKS:

- Cycling & Sizing issues
- Low effective storage volume
- Low HPWH COP
- Technology dependent



# MARKET DELIVERY: LEARN THE LANGUAGE



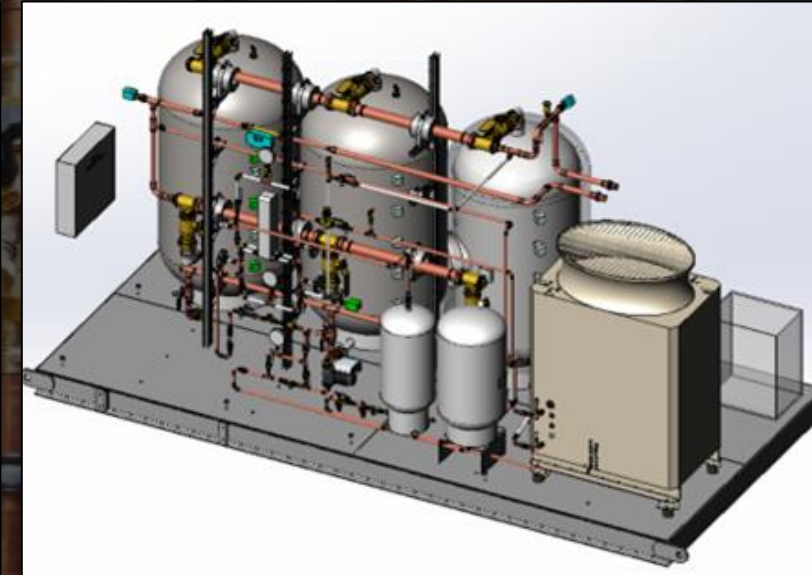
## CUSTOM ENGINEERED SYSTEM

All the pieces are separate & come from multiple distributors and/or manufacturers.



## SPECIFIED BUILT-UP SYSTEM

All the pieces are separate but come from a single distributors or manufacturer.



## PACKAGED/SKID

Everything is assembled & delivered in a single package.

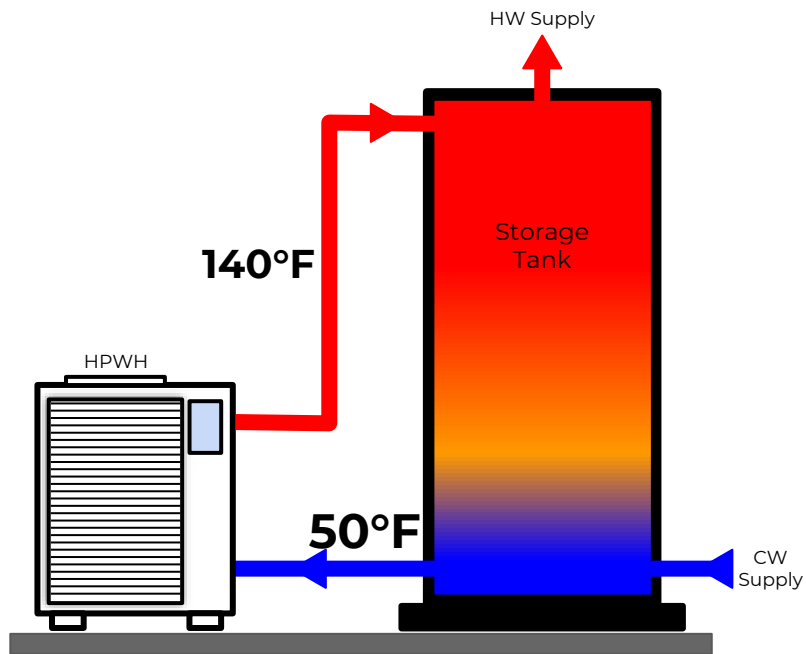


## HPWH CONSIDERATIONS



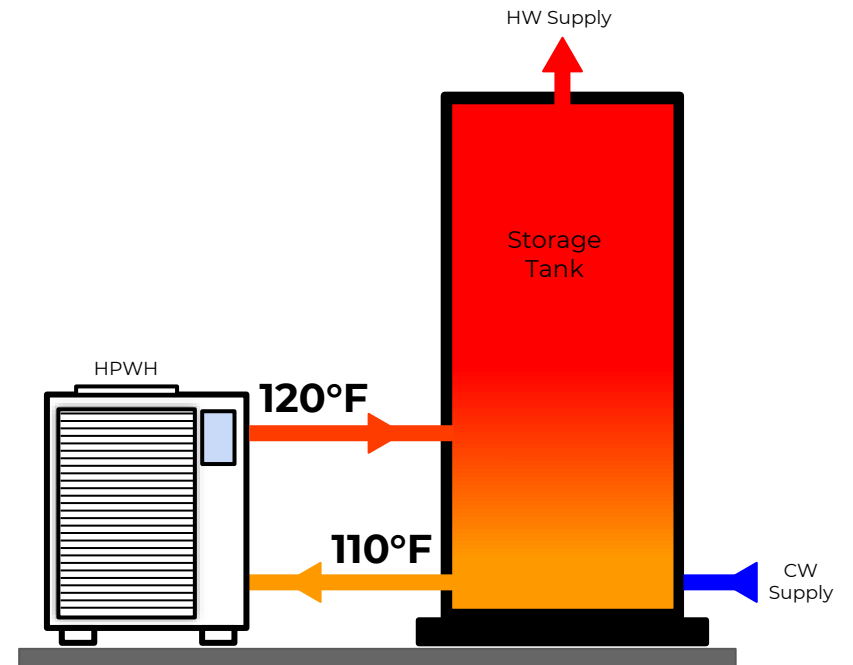
- ◆ Air source / heat source
- ◆ Heating cycle (single pass / multipass)
- ◆ Height of control sensor(s)
- ◆ Pipe connections, size & location
- ◆ Insulation level

# TWO TYPES OF HEATING CYCLES



## SINGLE-PASS

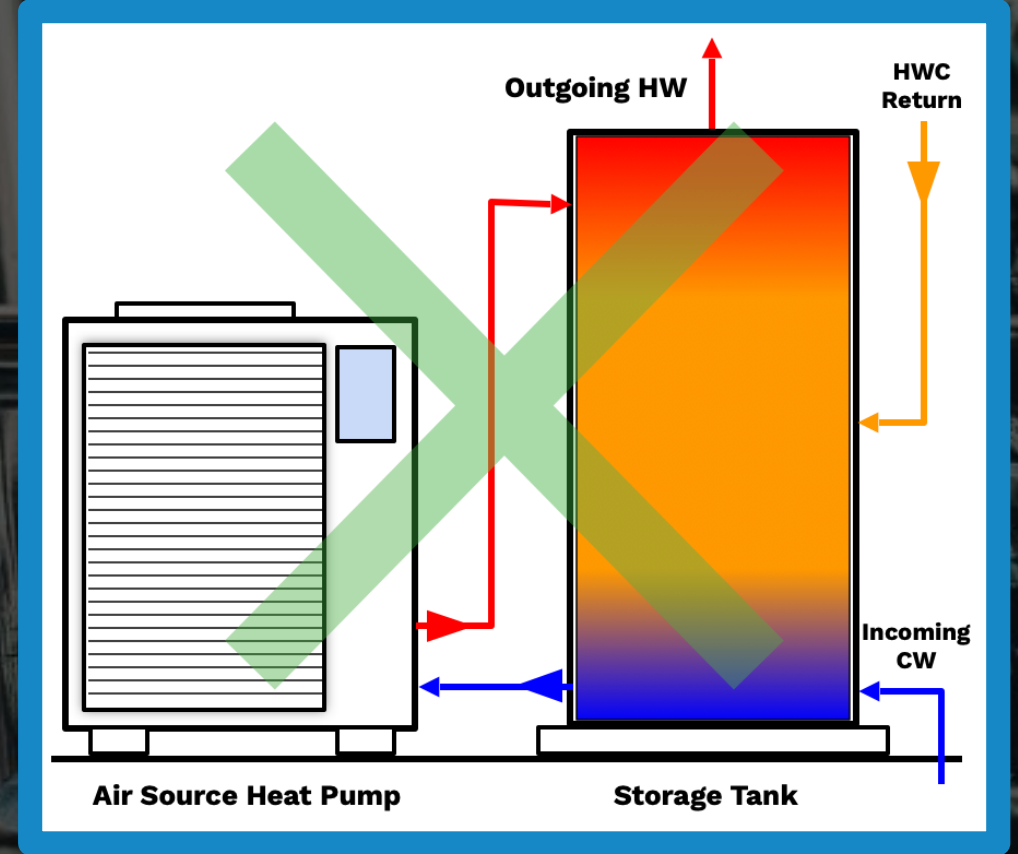
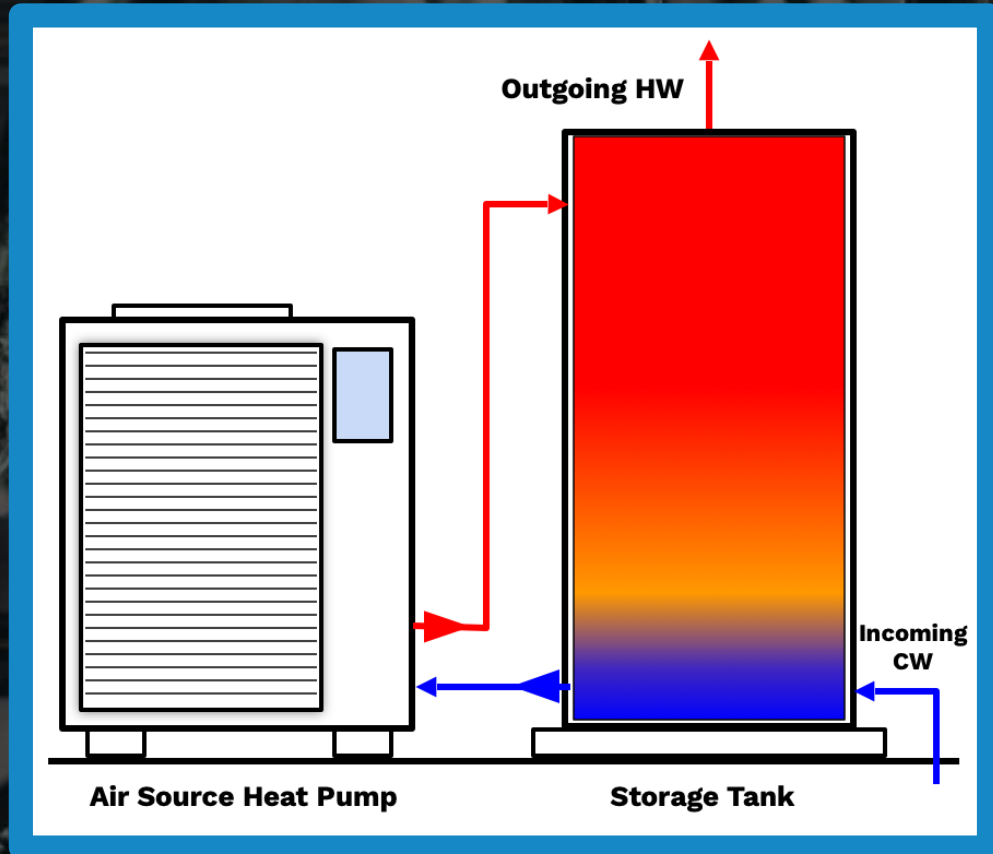
Heats water to working temp. in single pass  
*(usually for primary heating load)*



## MULTI-PASS

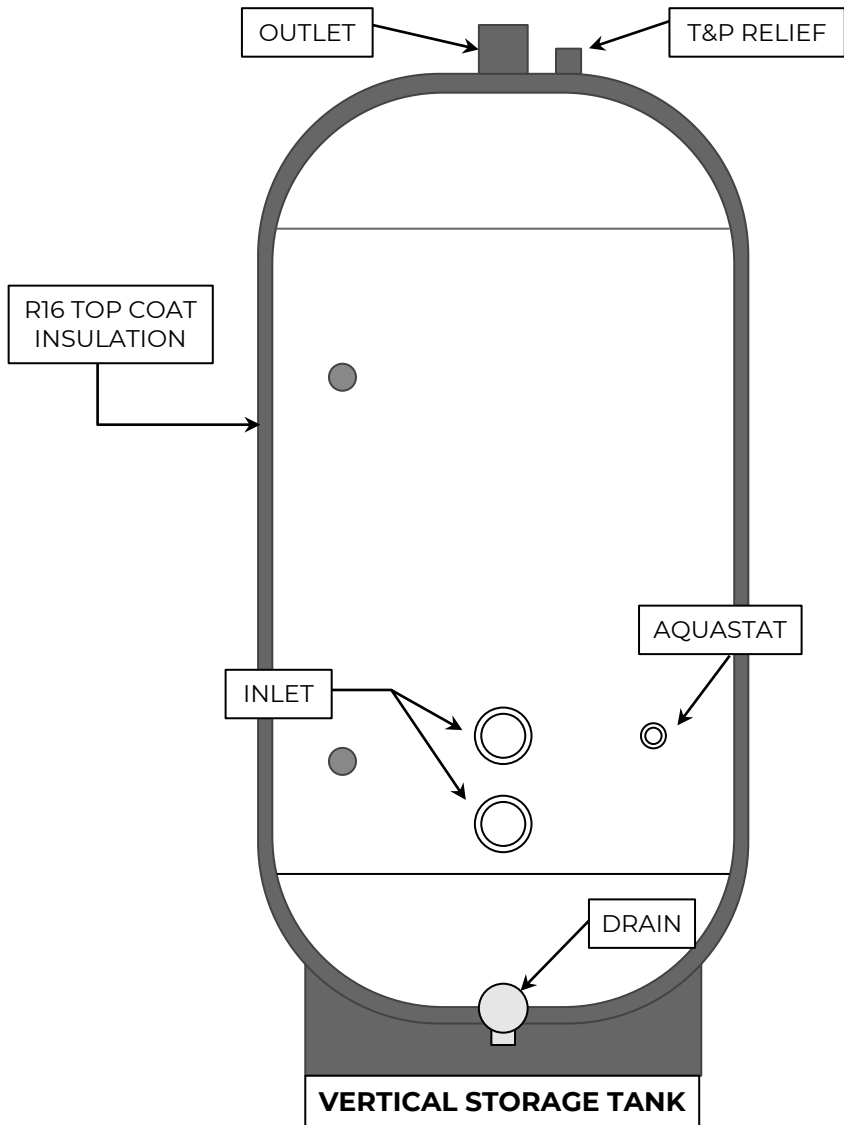
Heats water to working temp. in multiple passes  
*(typical temperature maintenance systems)*

# HW STORAGE SYSTEMS: THERMAL STRATIFICATION





## HW STORAGE CONSIDERATIONS



- ◆ Physical space, room & door size
- ◆ Multiple tanks, series or parallel?
- ◆ Vertical is better than horizontal
- ◆ Height of control sensor(s)
- ◆ Pipe connections, size & location
- ◆ Insulation level

# WHAT IS A CHPWH SYSTEM?



## Small Commercial System

(closet installation serving 5 apts)



## Large Commercial System

(basement installation serving 250 apts)



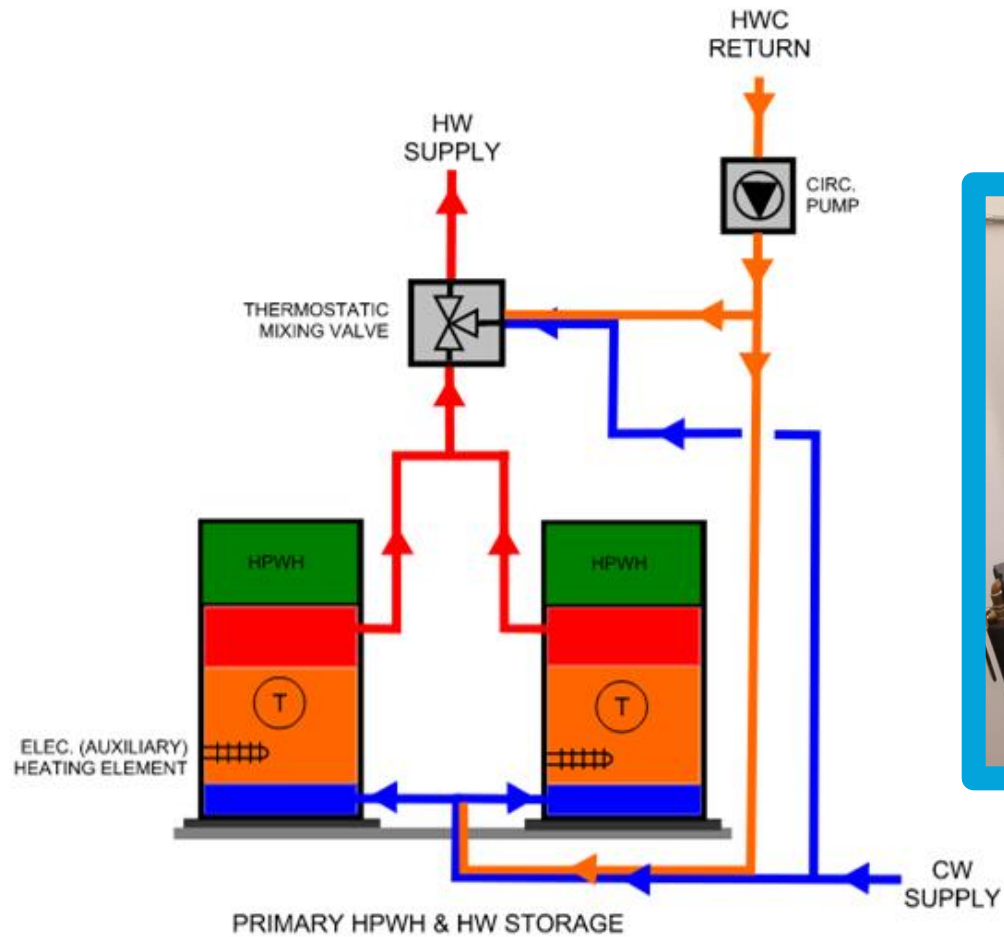
## Multiple Commercial Systems

(residential equipment serving 4-5 apts)

**Multiple Sizes, Types, & Configurations**



# SMALL COMMERCIAL SYSTEM

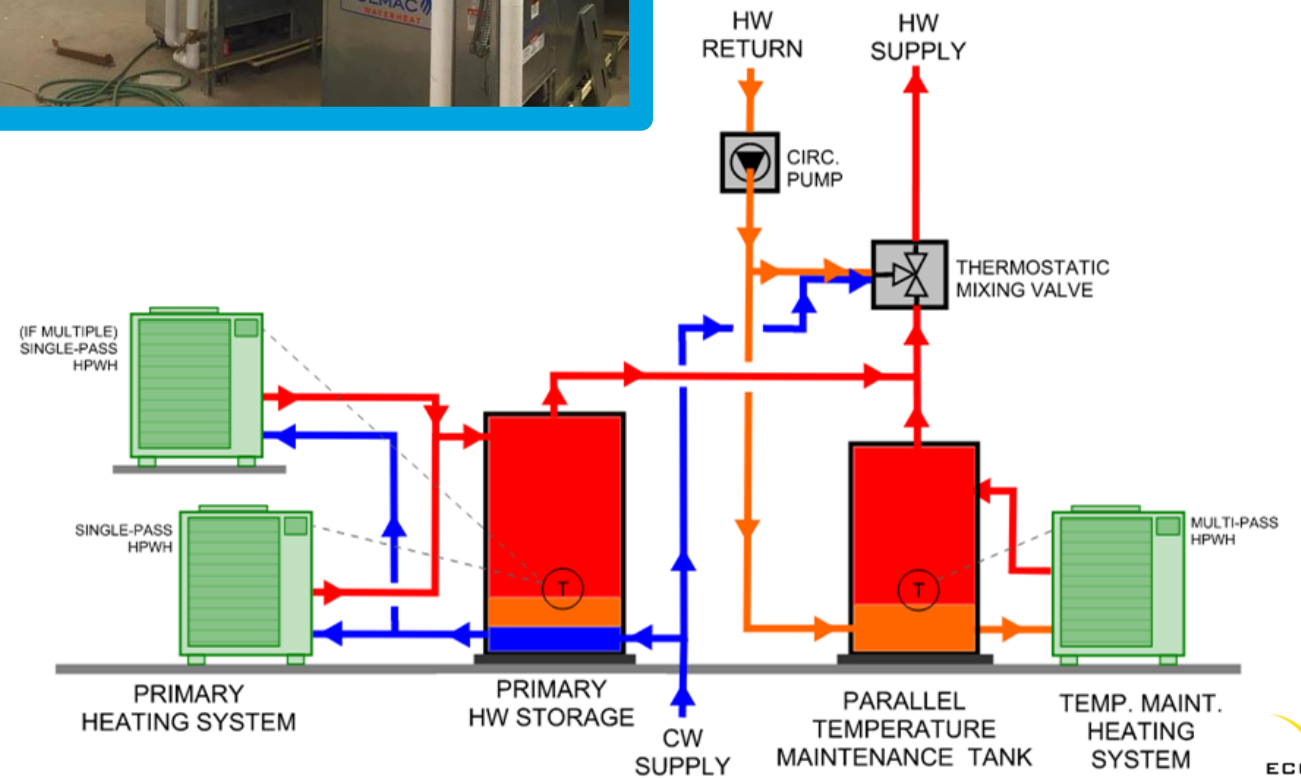


- Residential unitary equipment in a commercial building?!
- 2-6 units
- Multiple unitary HPs (in parallel)

# LARGE COMMERCIAL SYSTEM



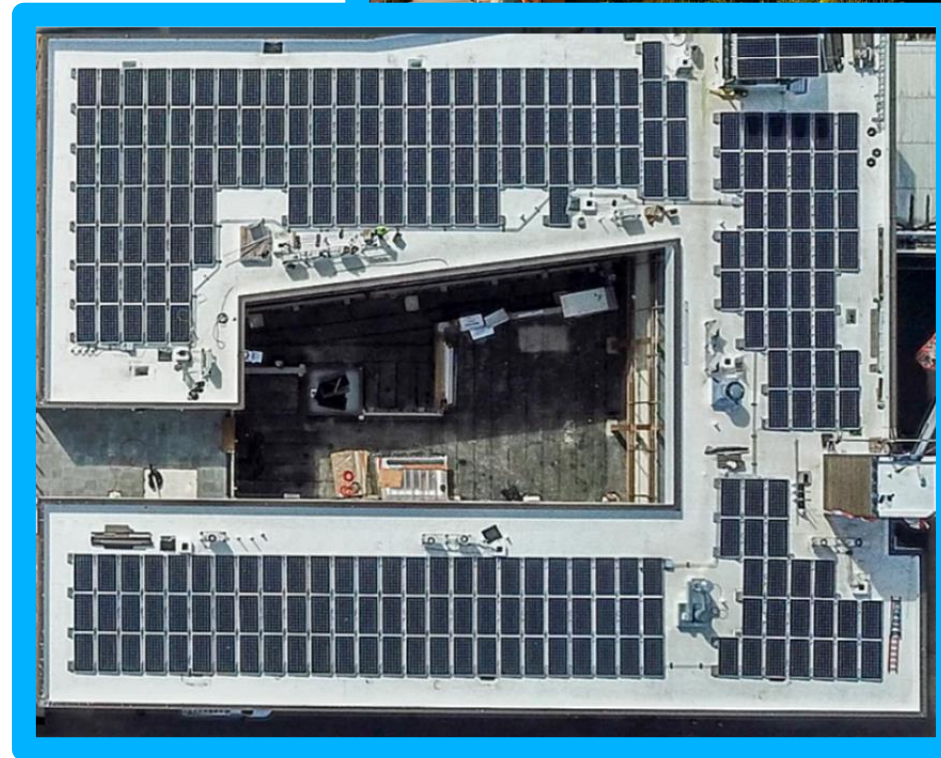
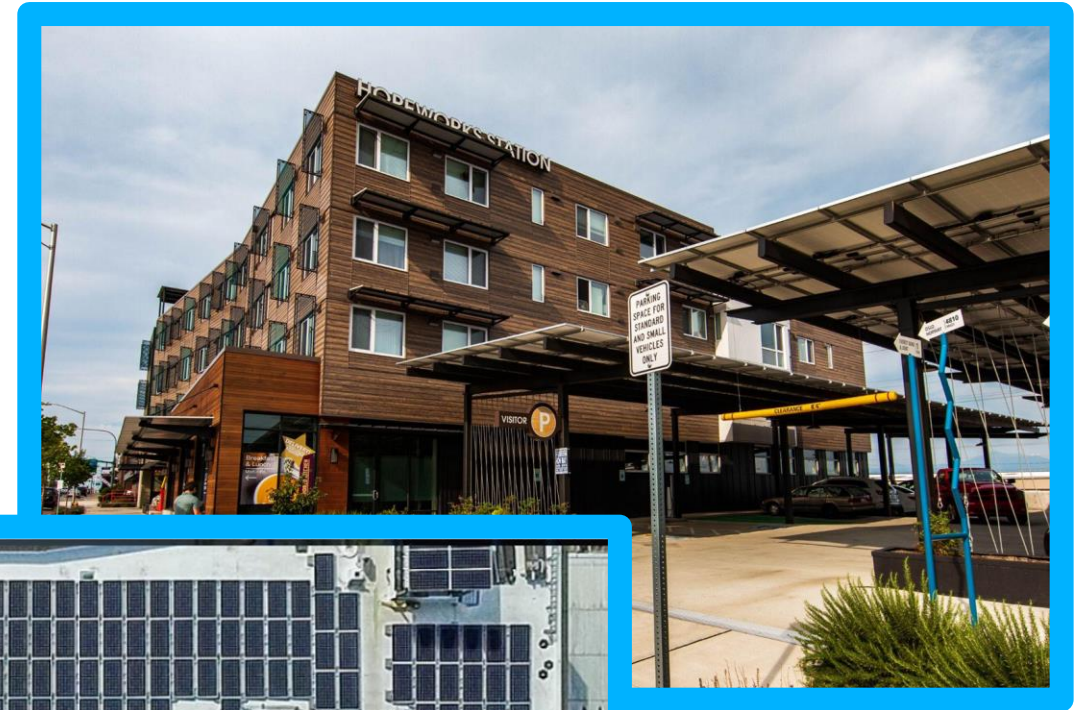
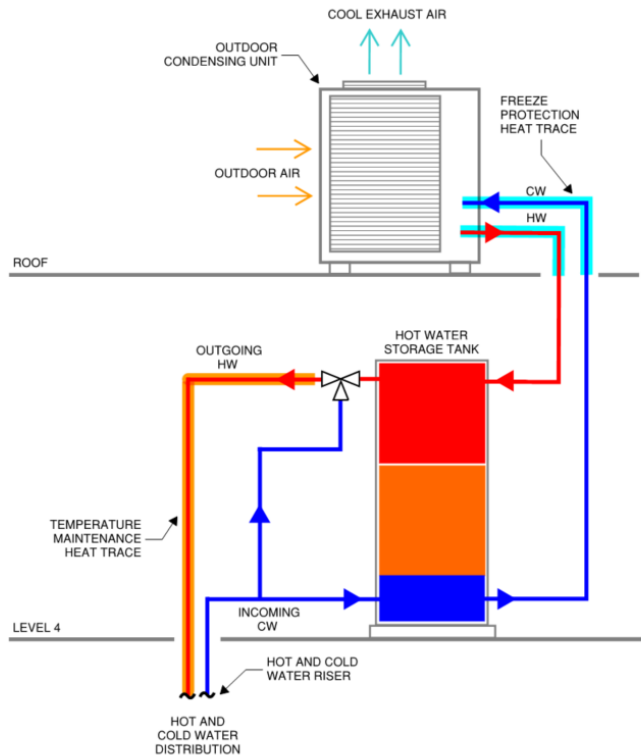
- Commercial equipment; engineered system
- 200 units
- Dedicated heating system:
  - Single pass primary HPWH
  - Multi pass temperature maintenance system



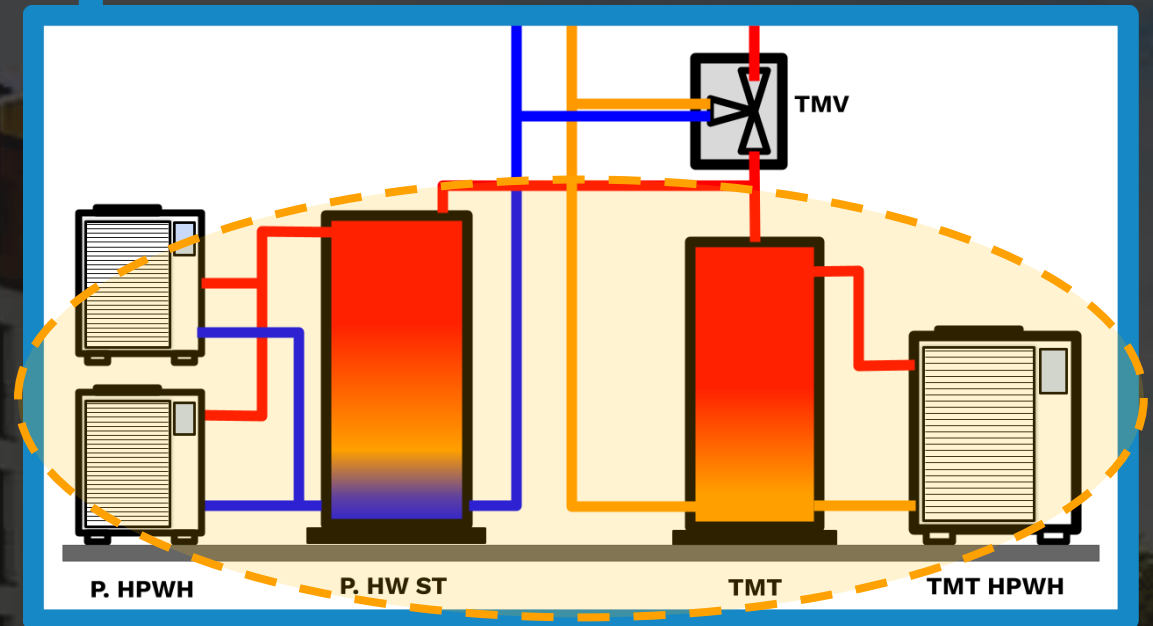


# MULTIPLE COMMERCIAL SYSTEMS

- Smaller residential equipment used in a commercial application
- 100 units
- Multiple central/commercial HPWH systems



# HW SYSTEM DESIGN: **SIZING**





# SYSTEM SIZING IMPACTS

55 Tons  
1,000 Gallons



5 Tons  
520 Gallons





# SYSTEM SIZING

- Gas systems are sized w/ low storage and high heat capacity
- HPWH systems are sized w/ high storage and low city

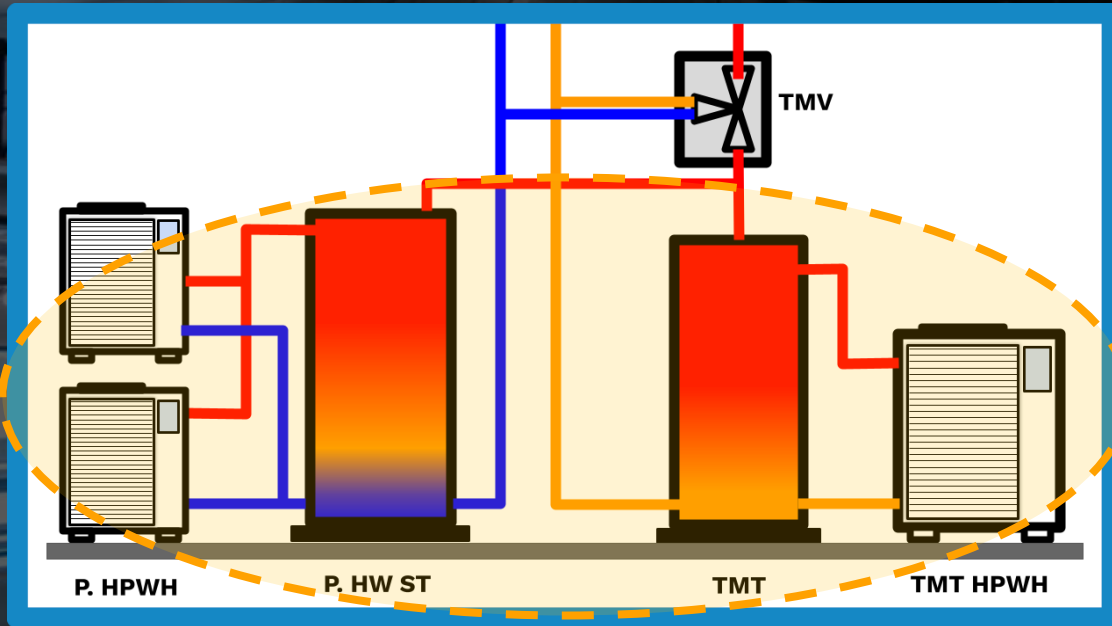


< H<sub>2</sub>O STORAGE  
> HEAT CAPACITY



> H<sub>2</sub>O STORAGE  
< HEAT CAPACITY

# SYSTEM SIZING

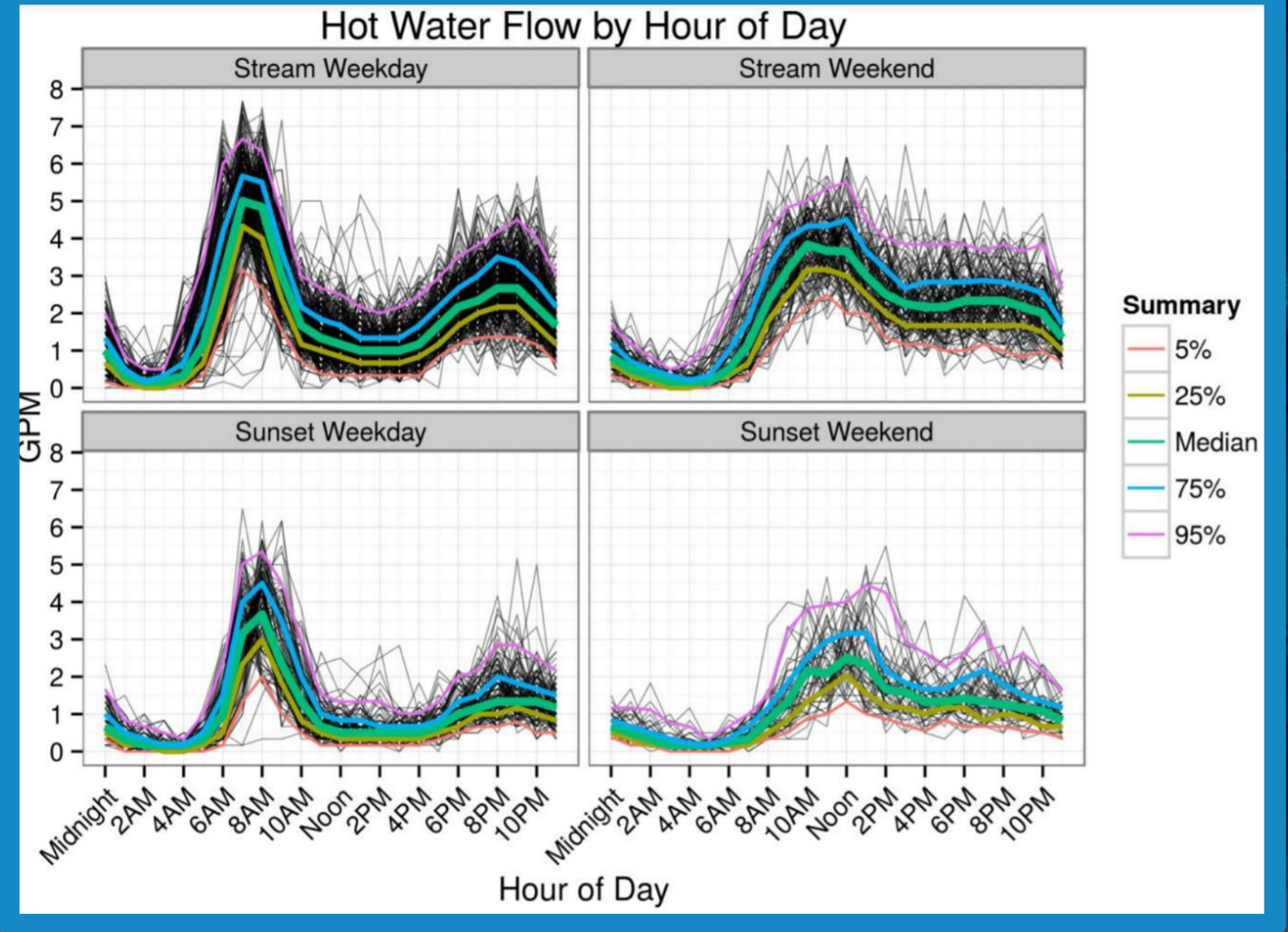
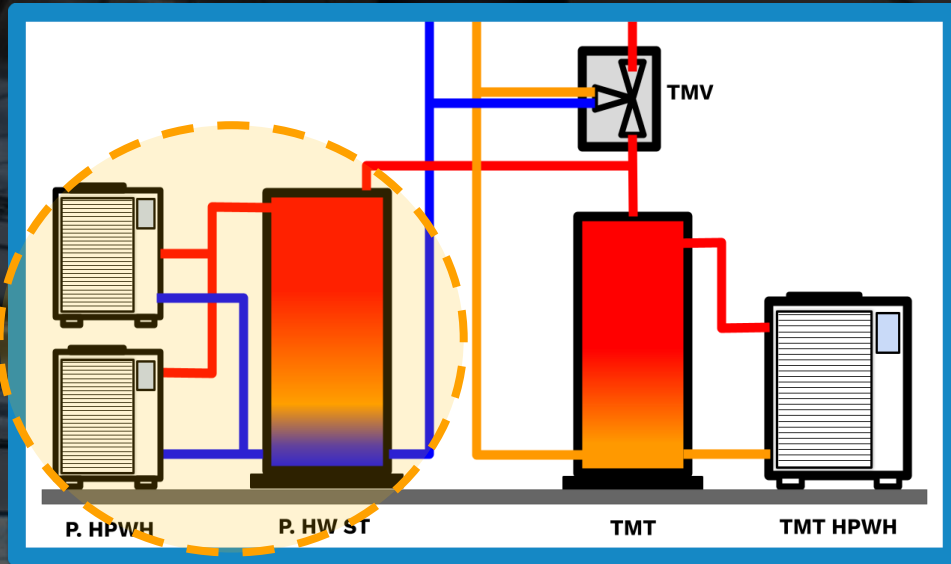


## Two Loads

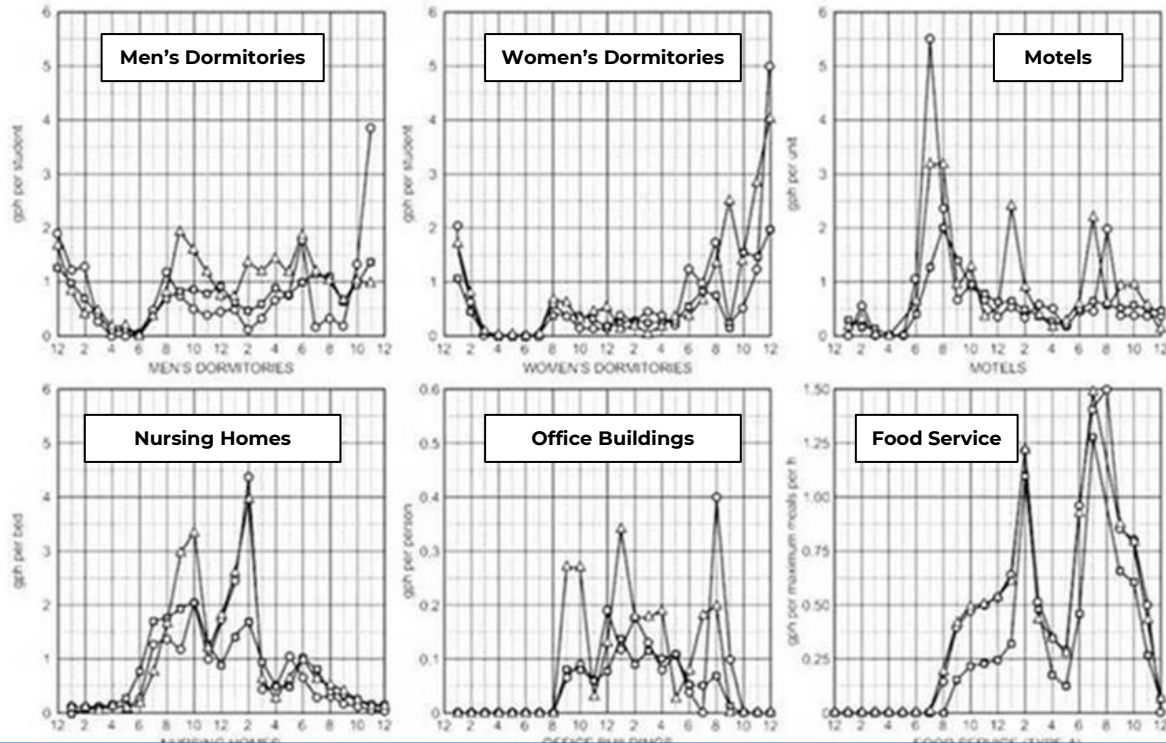
- ◆ Occupancy and Hot Water Load
- ◆ Temperature Maintenance



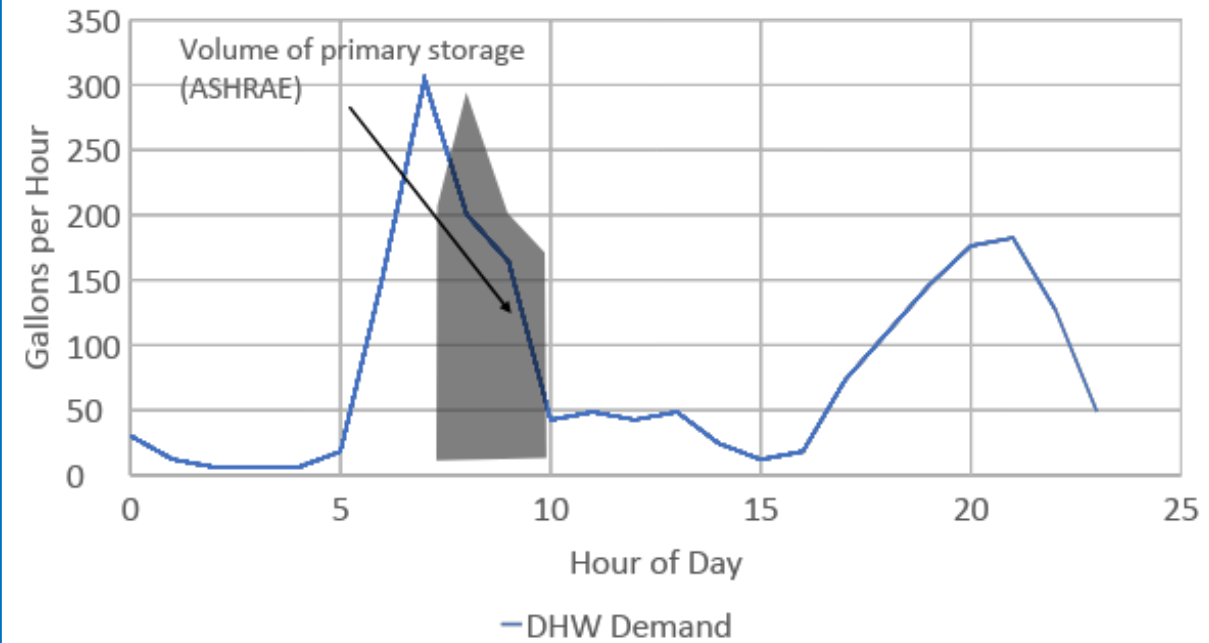
# SYSTEM SIZING : Hot Water Load



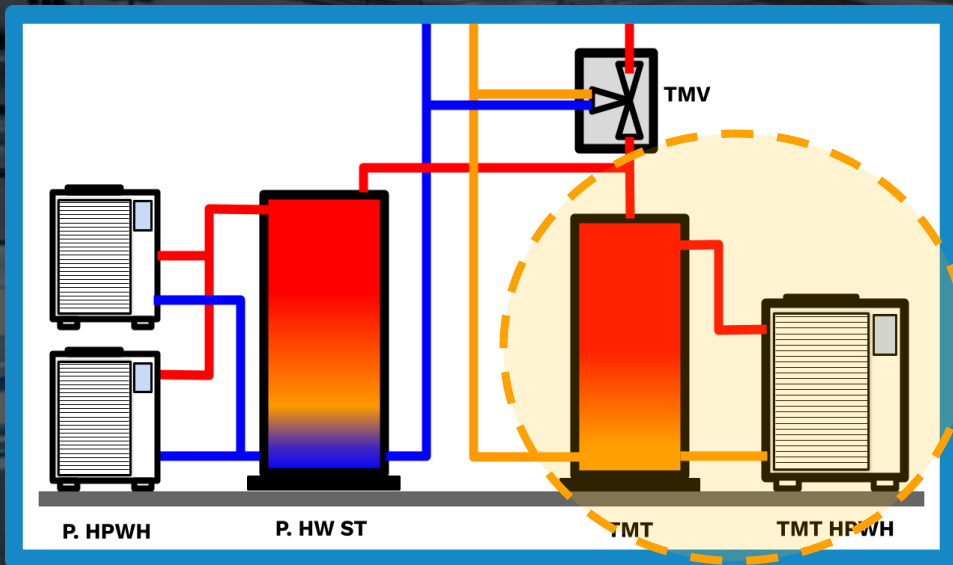
# SYSTEM SIZING



Multi Family **Domestic Hot Water (DHW)** Demand

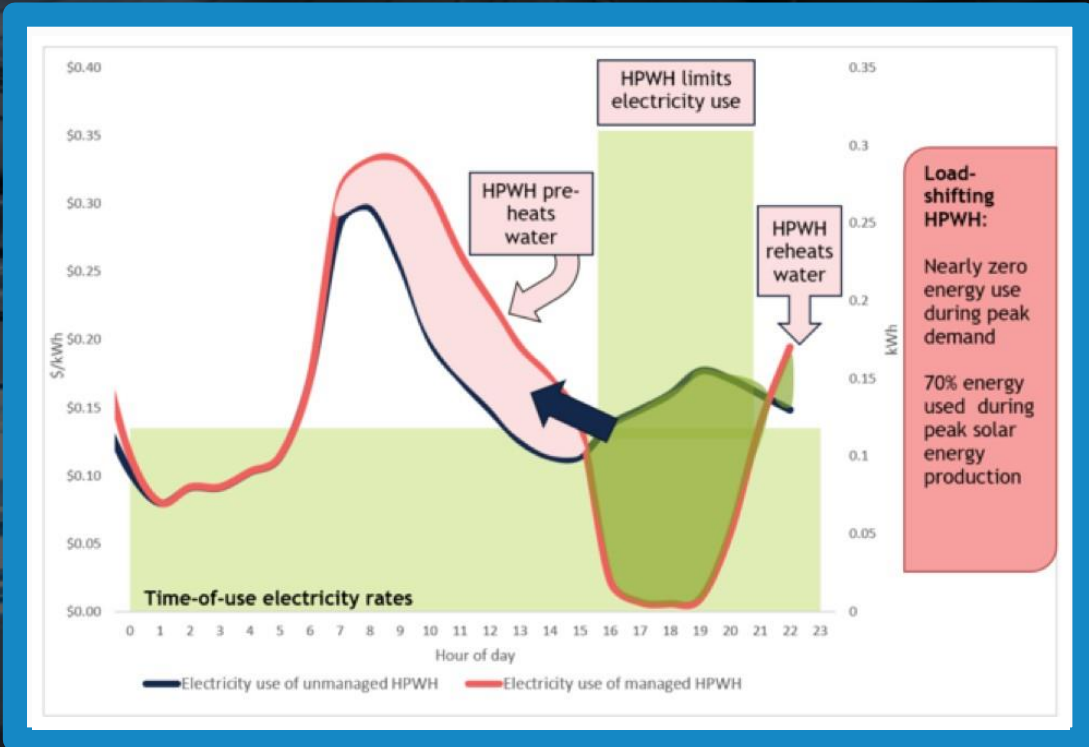


# SYSTEM SIZING : Temperature Maintenance

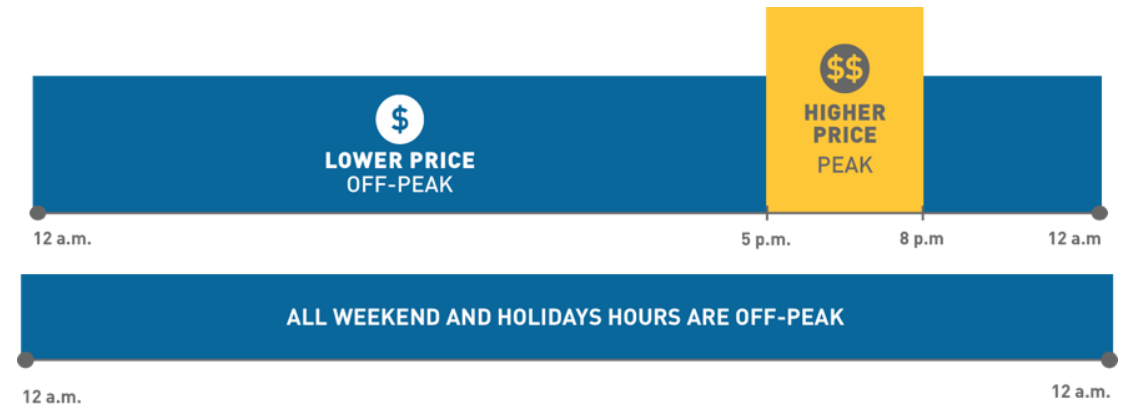




# SIZING FOR LOAD SHIFT

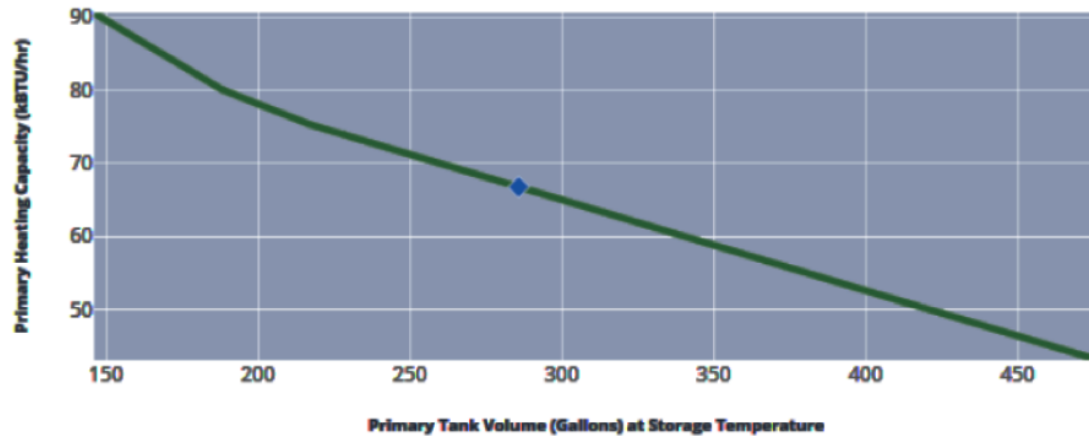


	What's changing?	Details
<b>Starting January 1, 2021</b>	Longer winter season:	October 1 to May 31 (currently November 1 to April 30)
	Shorter summer season:	June 1 to September 30 (currently May 1 to October 31)
<b>Starting June 1, 2021</b> Summer Hours Changes (Winter Hours do not change)	Peak Hours:	3–8 p.m. weekdays
	Partial Peak Hours:	12–3 p.m. and 8–10 p.m. weekdays; 5–8 p.m. weekends
	Off-Peak Hours:	All other hours including most holidays
<b>Starting January 1, 2022</b> Summer Hours Changes (Winter Hours do not change)	Peak Hours:	4–9 p.m. weekdays
	Partial Peak Hours:	2–4 p.m. and 9–10 p.m. weekdays 5–8 p.m. weekends
	Off-Peak Hours:	All other hours including most holidays



# ECOSIZER

<https://calbem.ibpsa.us/resources/ecosizer/>



Primary System Size, Storage: 286 Gal, Capacity: 66.8 kBTU/hr



Tank Volume  
**285 Gallons**

Heating Capacity  
**66.8 kBTU/hr**

Swing Tank Volume  
**80 Gallons**

Swing Resistance Element  
**4.7 kW · 15.9 kBTU/hr**


## THIS SYSTEM WAS SIZED FOR

Occupancy  
**60.0 People**

Apartments  
**30.0 Units**

Daily Hot Water Usage  
**25.0 Gallons per Day per Person**

Total Hot Water  
**1500 Gallons per Day**

A photograph of a complex industrial piping system, likely a CHPWH system, with various pipes, valves, and structural elements. The image is split into two color-coded sections: a dark brown/red on the left and a dark blue on the right. The text is overlaid on the left section.

# **MODELING** **CHPWH SYSTEMS**



# HEAT PUMP PERFORMANCE

Residential Ratings

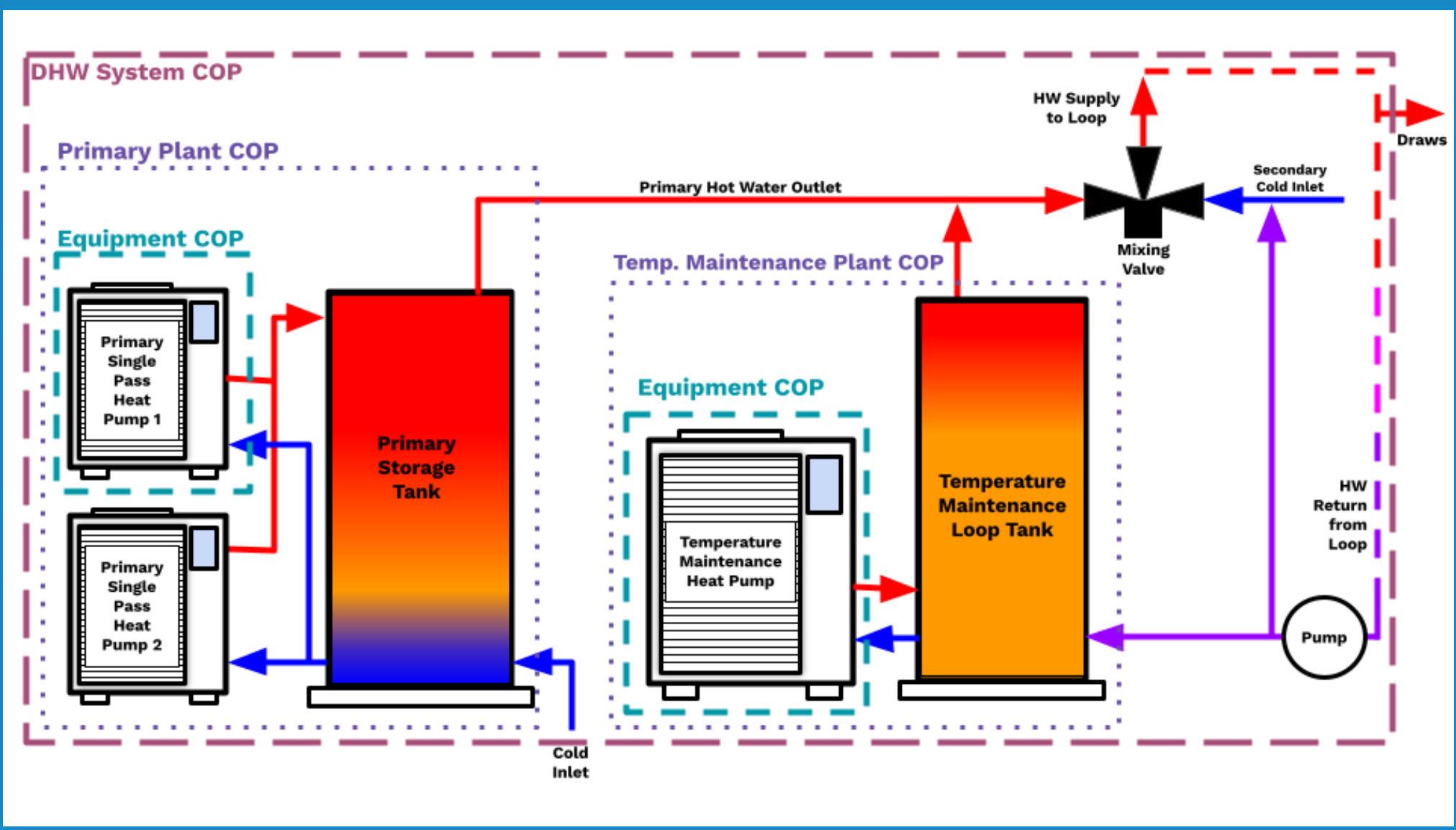
Constant COP

Outdoor Unit (Heat Pump) Model No. **GUS-A45HPA**

Performance	43-gal. system	83-gal. system
Energy Factor	2.65	3.35
First Hour Rating	69 gallons	97 gallons
Specifications		
Water Temperature Setting	149°F	
Ambient Air Operating Temperature	-15°F to +110°F	
Heat Pump Capacity	15,400 Btu/h	
Heat Pump Capacity	4.5 kW	
Heat Pump COP	4.5	
Refrigerant Type	R744 (CO <sub>2</sub> )	
Compressor Type	Inverter	
Power Voltage	208/230v -1Ph - 60Hz	
Breaker Size	15 Amps	
MCA	7.7 Amps	
Outdoor Operating Noise Level	38 dB	
Weight	123 lbs	
Pipe Size (Tank to Heat Pump)	1/2" (Cold & Hot)	
Max Length Inc Vertical	25 ft	
Max Vertical Separation	10 ft	
Max Water Pressure	95 Psig	

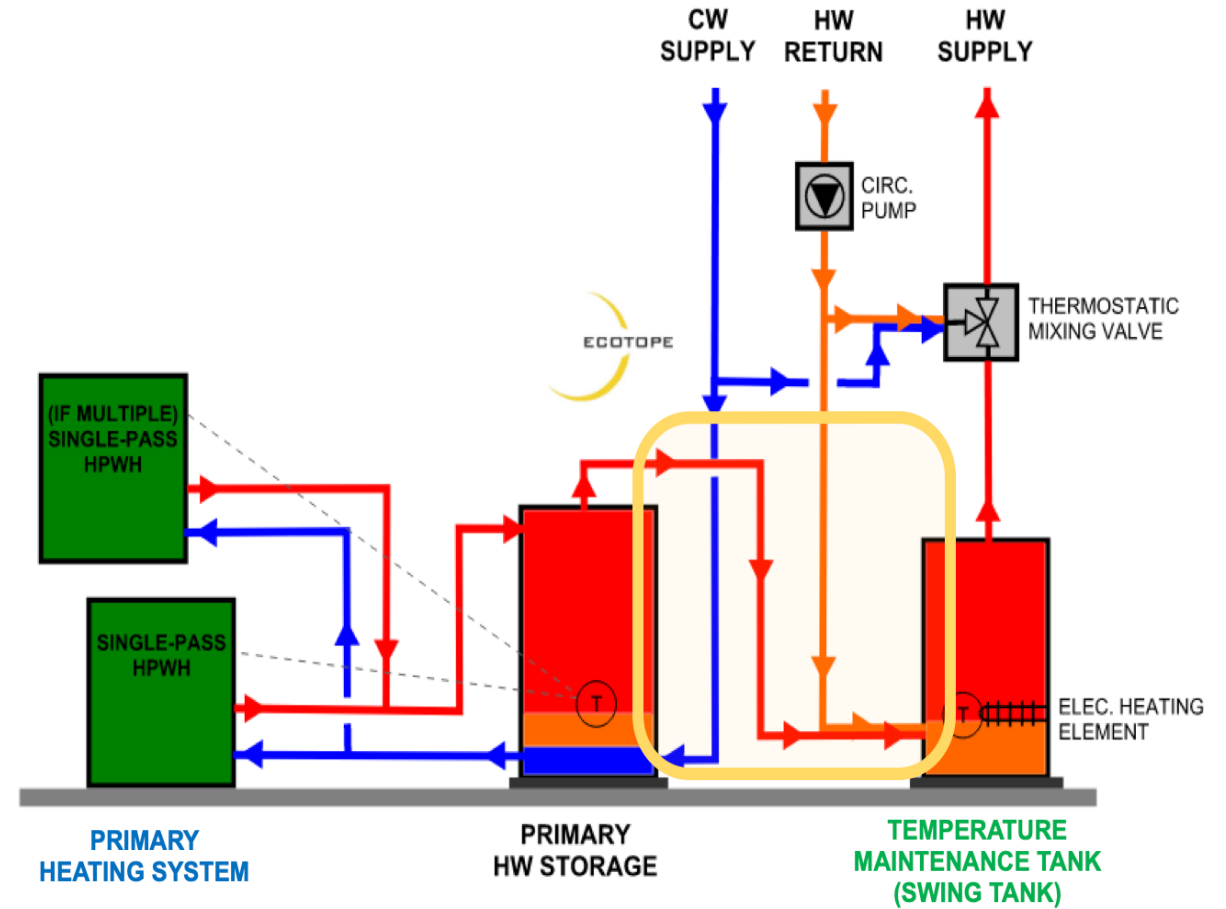


# EQUIPMENT EFFICIENCY BOUNDARIES



# What goes into a HPWH model

- ◆ Climate Zone
- ◆ Hot Water Draws
- ◆ Specific HPWH Equipment
- ◆ Schematic
- ◆ Temperature Maintenance System





# HEAT PUMP PERFORMANCE

## EFFICIENCY IMPACTS:

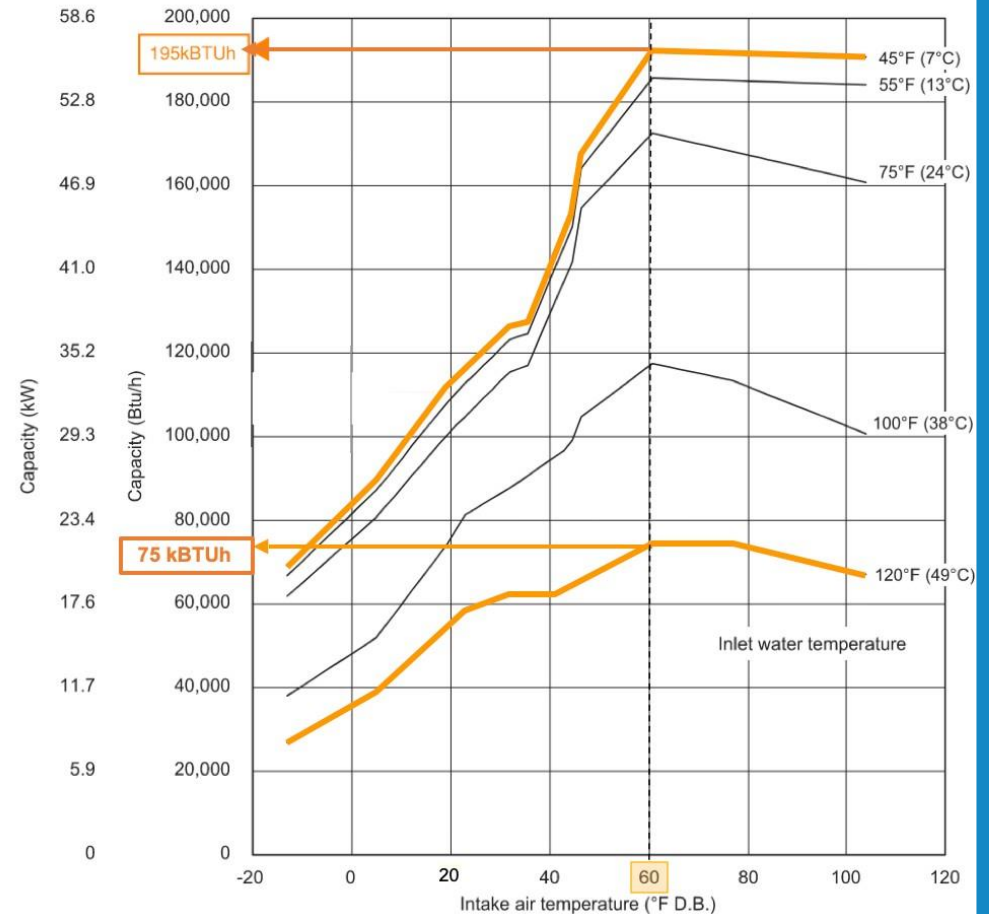
- Lower Air Temperature
- Warmer Entering Water
- Warmer Leaving Water

## CAPACITY IMPACTS:

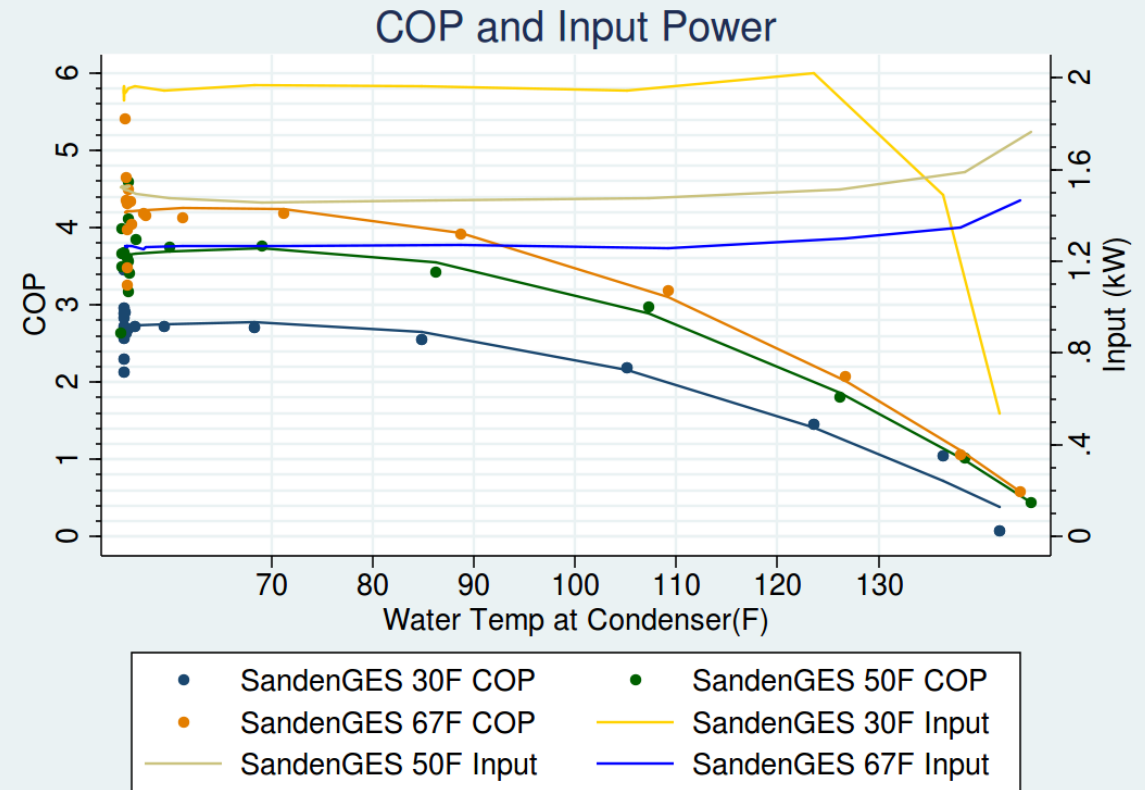
- Limits of Refrigerant
- Lower Air Temperature
- Defrost Effects

Outlet water temperature 150°F (66°C)

Max capacity operation mode



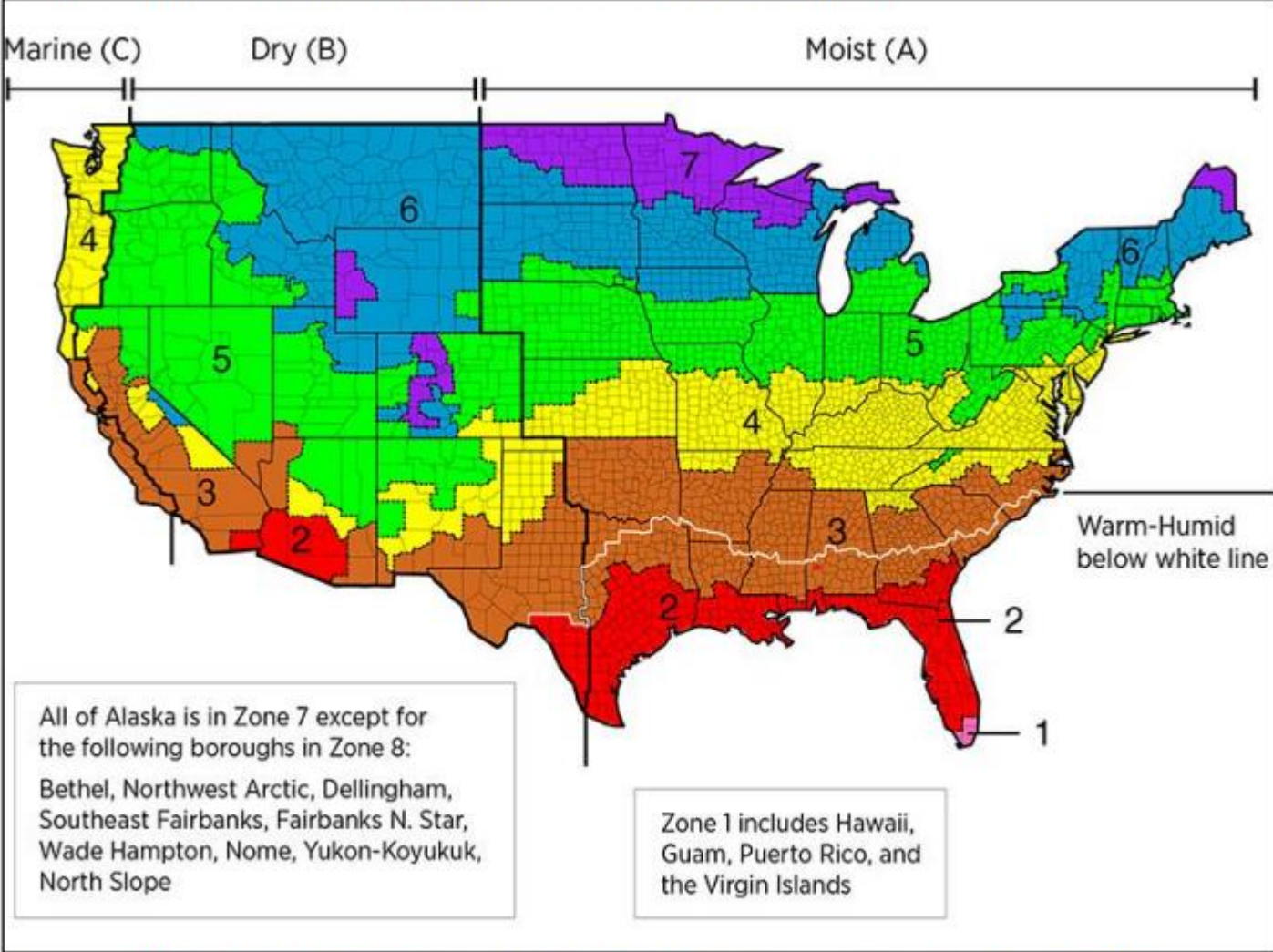
# HEAT PUMP PERFORMANCE





# Climate Zone

Figure 1. ASHRAE 90.1 U.S. Climate Zone Map by County



Source: [ANSI/ASHRAE/IES Standard 90.1-2019 -- Energy Standard for Buildings Except Low-Rise Residential Buildings](#)



# REFRIGERANTS | GWP OF SELECTED REFRIGERANTS (CARBON DIOXIDE EQUIVALENTS, CO<sub>2</sub>e)

BETTER



WORST

CO<sub>2</sub> Variable Capacity | SANDEN, MAYEKAWA, MITSUBISHI *Eco-Cute*

R-717 0  
**R-744 1**

R-1270 2  
 R-290 3

Proposed HFO replacement refrigerant

R-600a 3  
**R-1234yf 4**

R-1150 4  
 R-1234ze 6

R-170 6  
 R152a 124

Fixed Capacity | MOST HPWHs COLMAC, AO SMITH

R-32 675  
**R-134a 1430**

R-407C 1744  
 R-22 1810

Variable Capacity | PHNIX, ALTHERMA, VERSATI, VRF  
 Fixed Capacity | AERMEC, NYLE

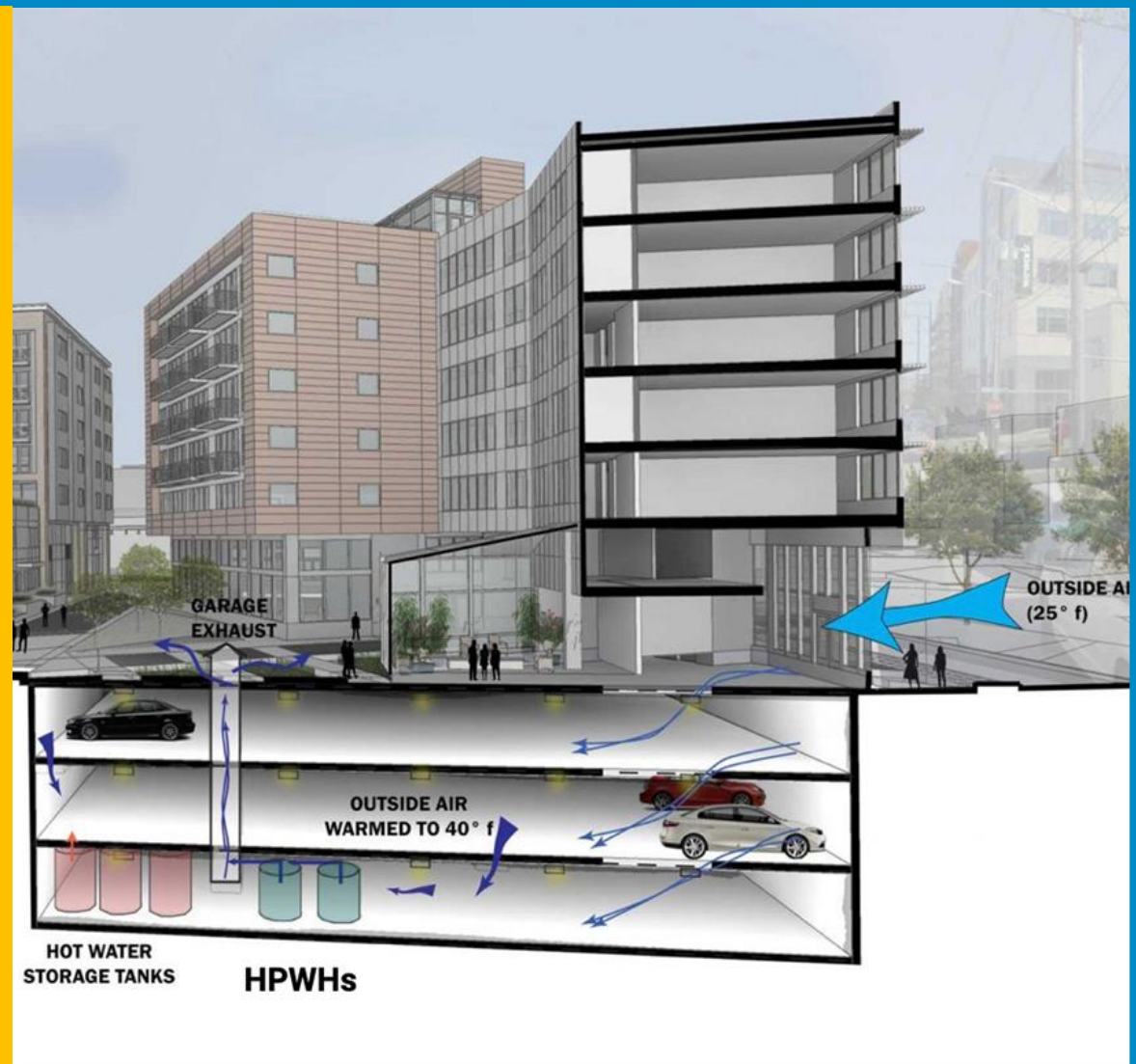
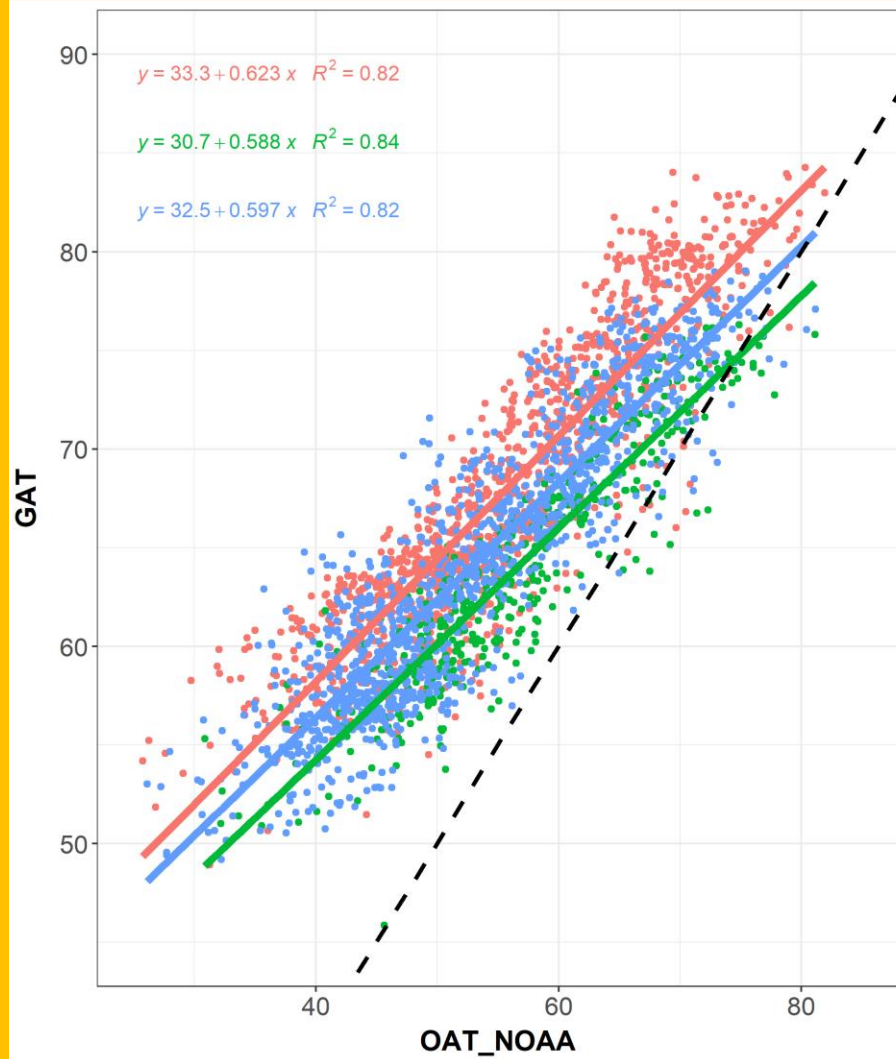
**R-410A 2088**

R-125 3500  
 R-404A 3922  
 R-502 4657

R-12 10900

	Refrigerant			
	R-744 (CO <sub>2</sub> )	R-1234yf	R-134a	R-410A
<b>Low Ambient Air Temp</b>	-25 °F	35 °F ?	35 °F	-5 °F
<b>Max Discharge H<sub>2</sub>O Temp</b>	190 °F	160 °F ?	160 °F	140 °F

# Garage Air Temperatures





# Ecosim

Wireframes · Version 1.8

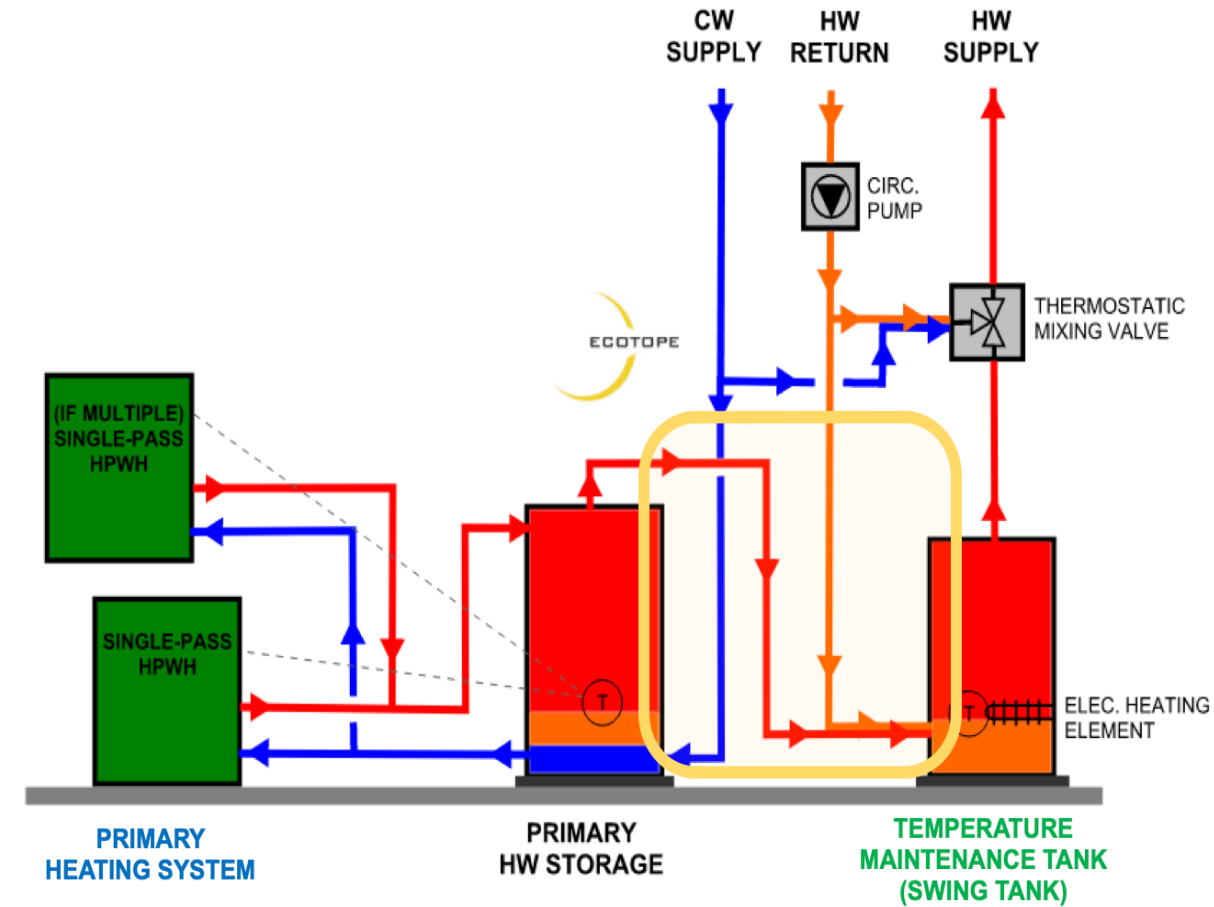
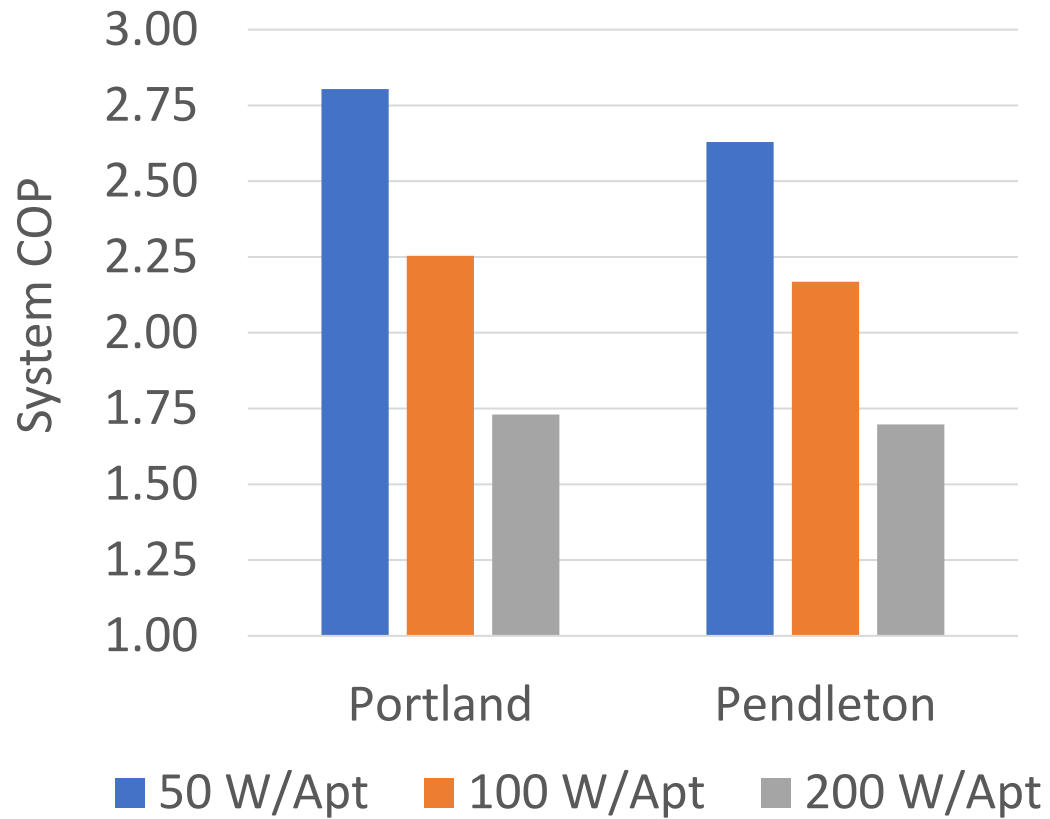
Website Coming Soon...



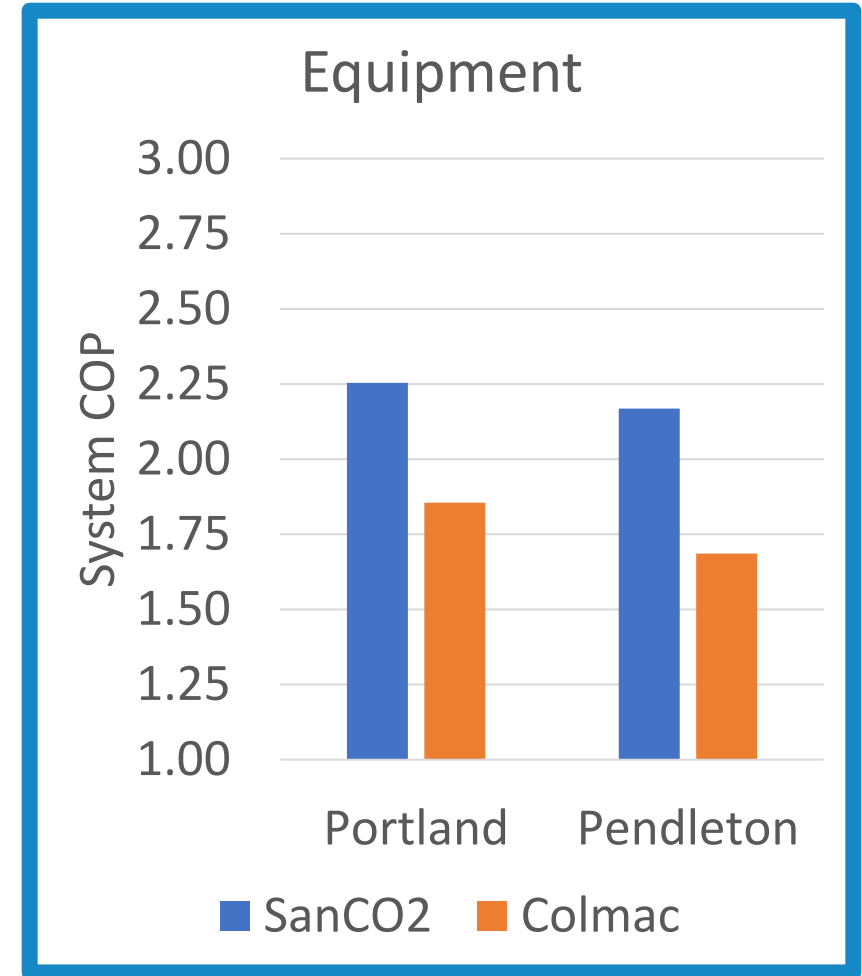
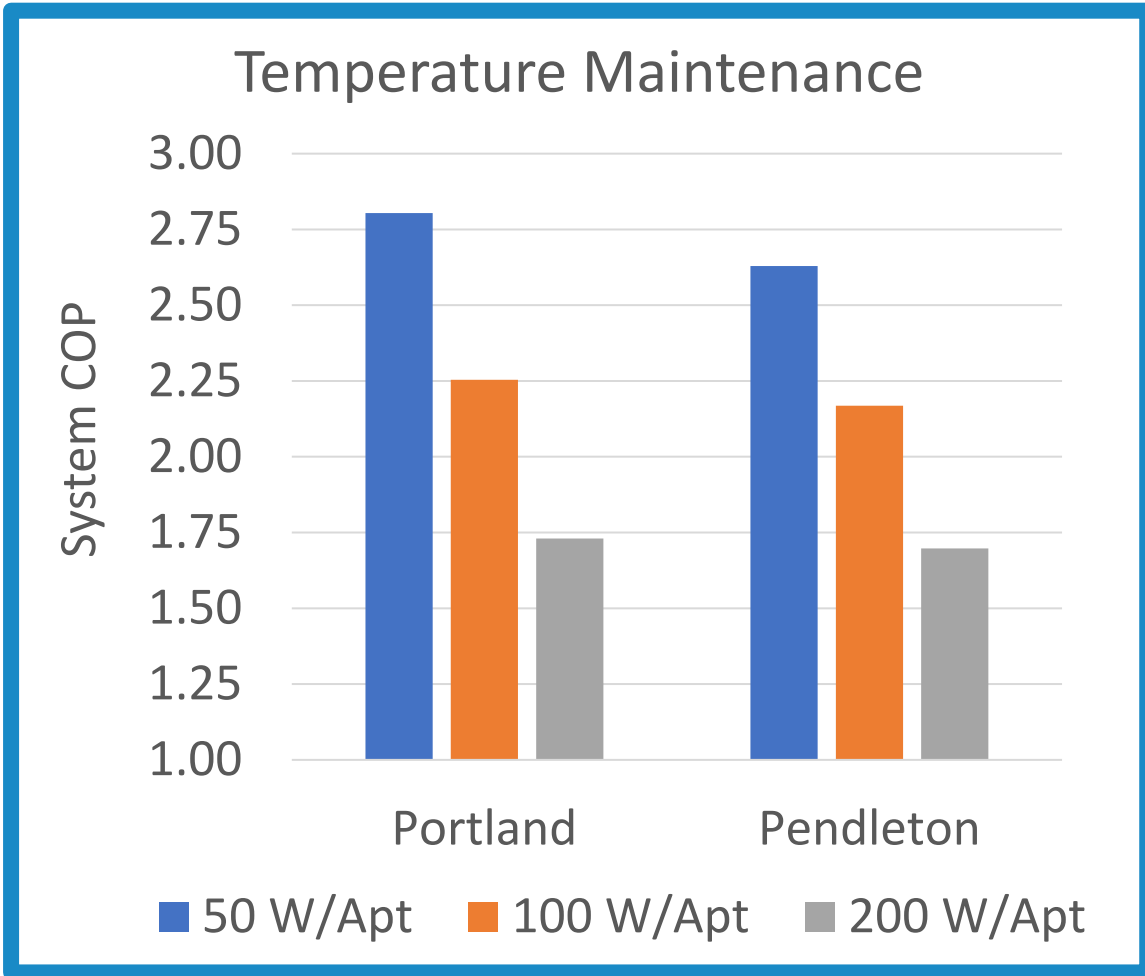


# System COP

## Temperature Maintenance



# System COP



# Advanced Water Heater Specification

- ◆ Characterize standardized systems across **Climates** by **Schematics** and **Equipment**
- ◆ Draft Version 8 - <https://neea.org/our-work/advanced-water-heating-specification>

	Minimum System Efficiency (SysCOP)				Other Requirements	
	Hot Climates (IECC Zones 1-2)	Mild Climates (IECC Zones 3-4)	Cold Climates (IECC Zones 5-6)	Extremely Cold Climates (IECC Zones 7-8)	Demand Response (CTA-2045- B)	M&V Points
<b>Tier 1</b>	2.25	2.0	1.5	1.25	Optional	Optional
<b>Tier 2</b>	3.0	2.5	2.0	1.5	Required*	Required
<b>Tier 3</b>	3.5	3.0	2.5	2.0	Required*	Required
<b>Tier 4</b>	3.75	3.5	3.0	2.75	Required*	Required

\*Demand response requirements are suspended through July 1, 2022.





**THANK YOU**

