

# COMMERCIAL HEAT PUMP WATER HEATING:

## ENGINEERING DEEP DIVE

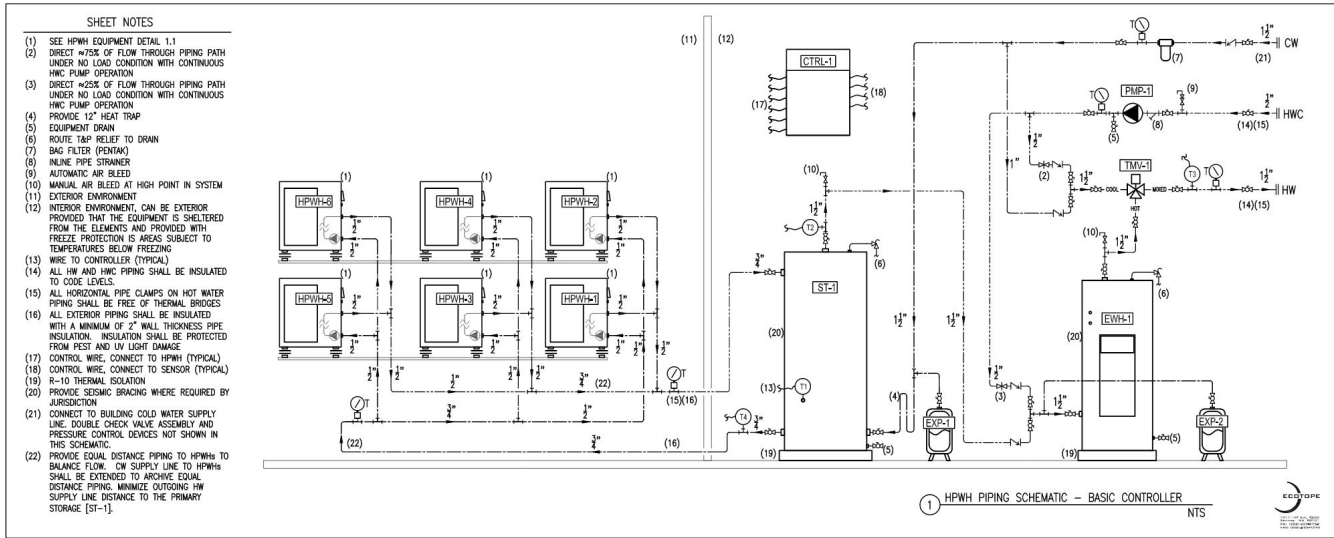
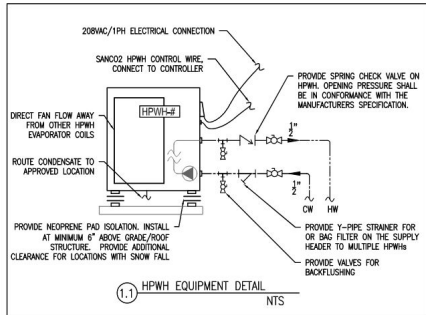
---

*Colin Grist, PE,  
Ecotope, Inc.*



BASIS OF DESIGN	
<p>THE SYSTEM WAS SIZED FOR:</p> <ul style="list-style-type: none"> <li>SANCOZ WITH SWING TANK CENTRAL HEAT</li> <li>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/AFW HWC LOSSES</li> </ul> <p>MINIMUM SYSTEM SIZE:</p> <ul style="list-style-type: none"> <li>285 GALLONS OF PRIMARY STORAGE</li> <li>66.8 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) SANCOZ, GS4-45HPC; 5 NOMINAL, 1 REDUNDANT UNIT</li> <li>[ST-1] PRIMARY STORAGE: ONE (1) SANCOZ, ECO-285G.NST; 285 GALLONS OF STORAGE</li> <li>[CTRL-1] CENTRAL HEAT PLANT CONTROLLER; SANCOZ, ECO-MESTR-G01</li> <li>[DWH-1] TEMPERATURE MAINTENANCE TANK (SWING TANK); 80 GALLONS, 6 KW ELEMENT</li> <li>[PMP-1] 0.5 GPM PER RISER, TARGET 110°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>[TMY-1] SIZED FOR THE THERMAL EXPANSION OF THE PRIMARY STORAGE VOLUME</li> <li>[EXP-1] SIZED FOR THE THERMAL EXPANSION OF THE TEMPERATURE MAINTENANCE STORAGE VOLUME AND THE VOLUME OF WATER IN THE HW DISTRIBUTION PIPING.</li> <li>[EXP-2]</li> </ul>

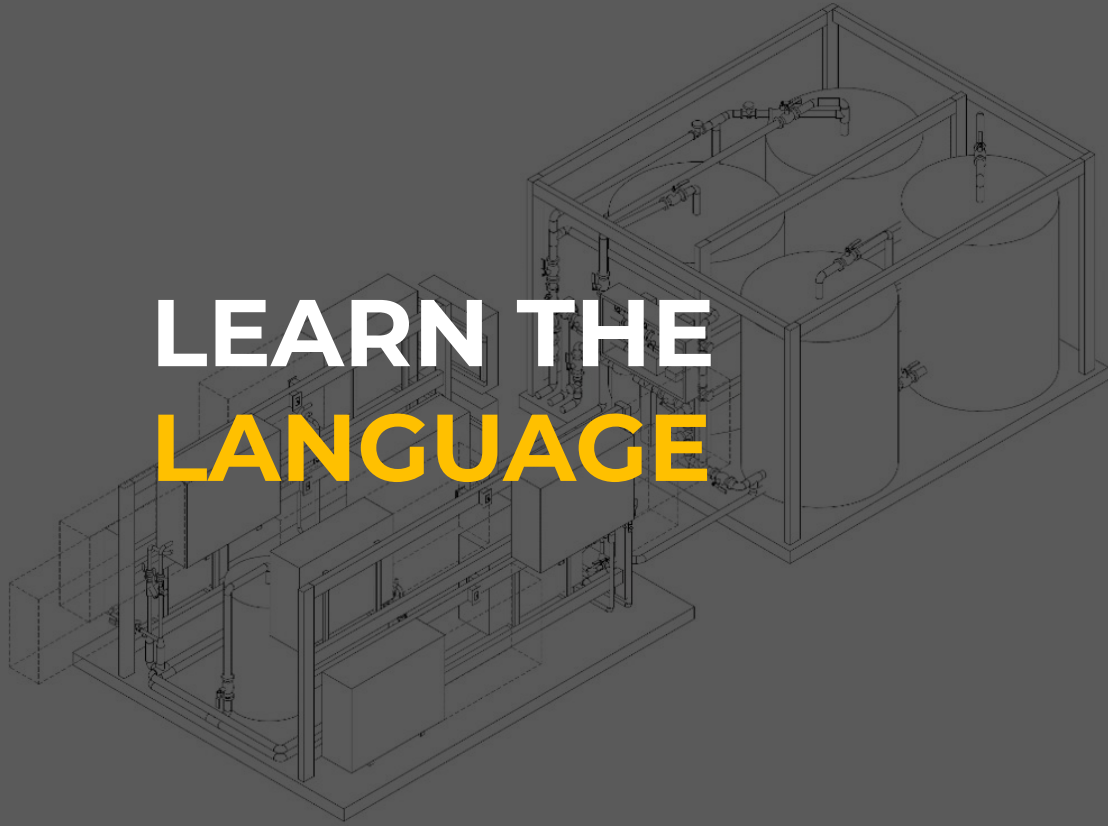
LEGEND	
SYMBOL	DESCRIPTION
	PUMP
	MIXING VALVE
	EQUIPMENT TAG
	TEMPERATURE SENSOR
	FLOW METER
	BALL VALVE
	BALANCING VALVE
	SPRING CHECK VALVE
	INLINE Y-STRAINER
	PIPE-T
	TAP RELIEF VALVE
	MANUAL AND AUTOMATIC AIR BLEED
	PIPE UNION
	PIPE FLOW DIRECTION
	PIPE SIZE
	CW PIPING
	HW PIPING
	HWC PIPING



# KEY QUESTIONS

- What policy drivers are pushing for adoption?
- What makes a **good CHPWH** candidate?
- What are the **key components of CHPWH** systems?

**LEARN THE  
LANGUAGE**





## PRODUCT TYPES: LEARN THE LANGUAGE



**Unitary**

- Compressor, tank, & controls in a single package.
- Typically small residential product.

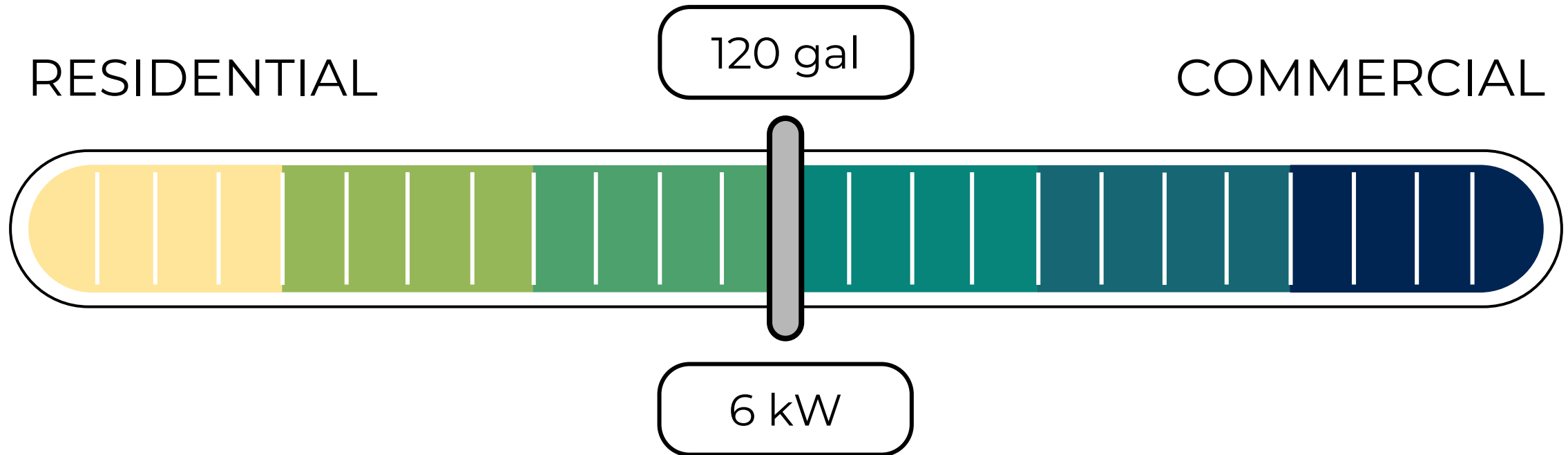


**Split System**

- Compressor, and tank in two separate packages
- Both residential and commercial products available

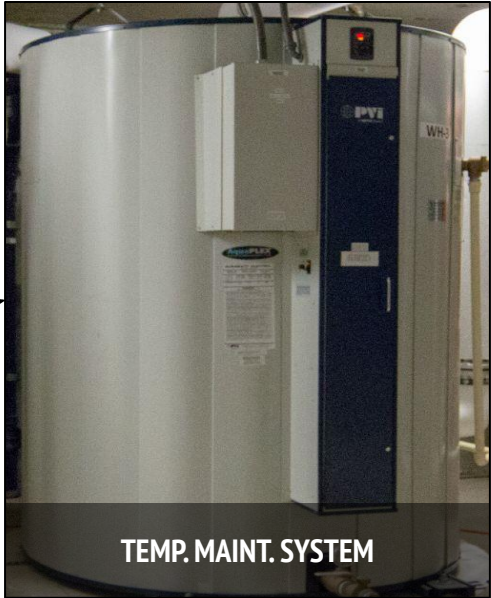
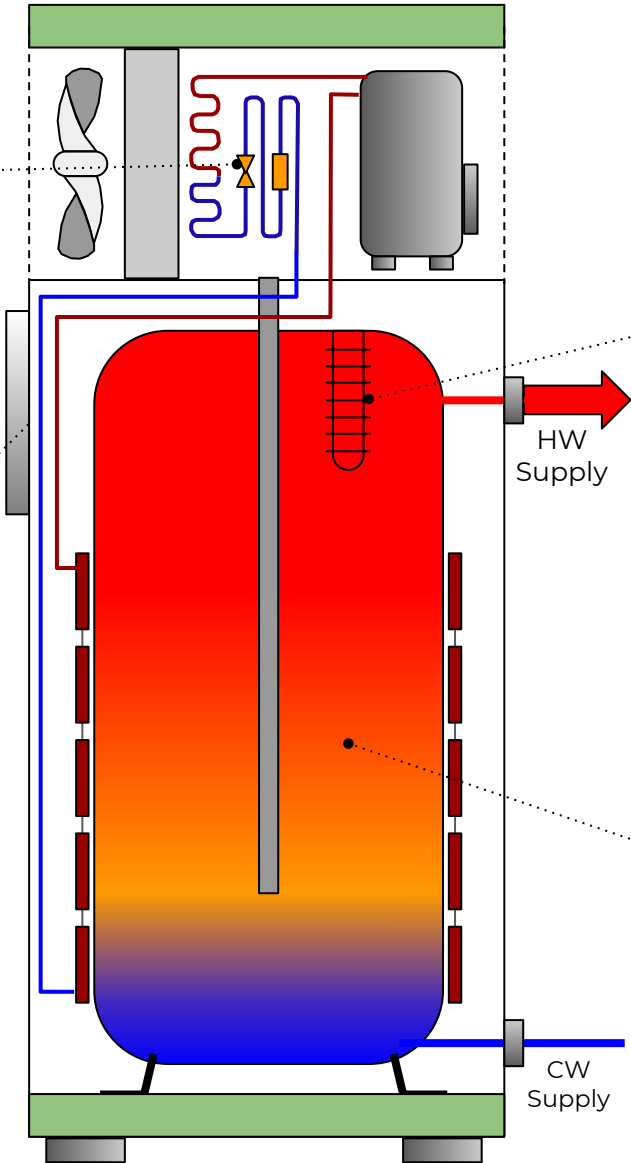


# RESIDENTIAL vs. COMMERCIAL **SYSTEMS**



A **CHPWH system** serves more than 4 dwelling units or commercial loads requiring  **$\geq 120$  gallons** of storage volume and/or  **$>6$  kW** of input power.

# HOW DOES IT COMPARE?



# EXAMPLES OF CHPWH SYSTEMS



**Small Commercial System**

(closet installation serving 5 apts)



**Large Commercial System**

(basement installation serving 250 apts)



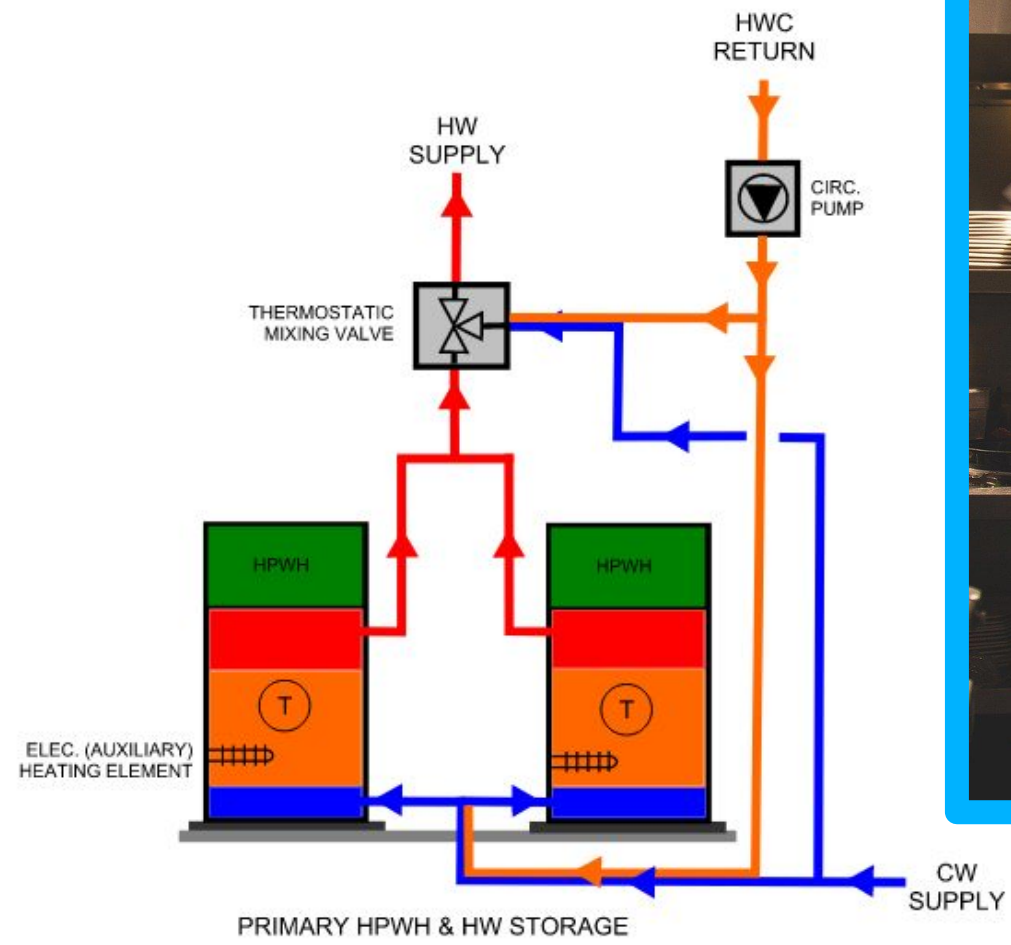
**Multiple Commercial Systems**

(residential equipment serving 4-5 apts)

**Multiple Sizes, Types, & Configurations**



# SMALL COMMERCIAL SYSTEM

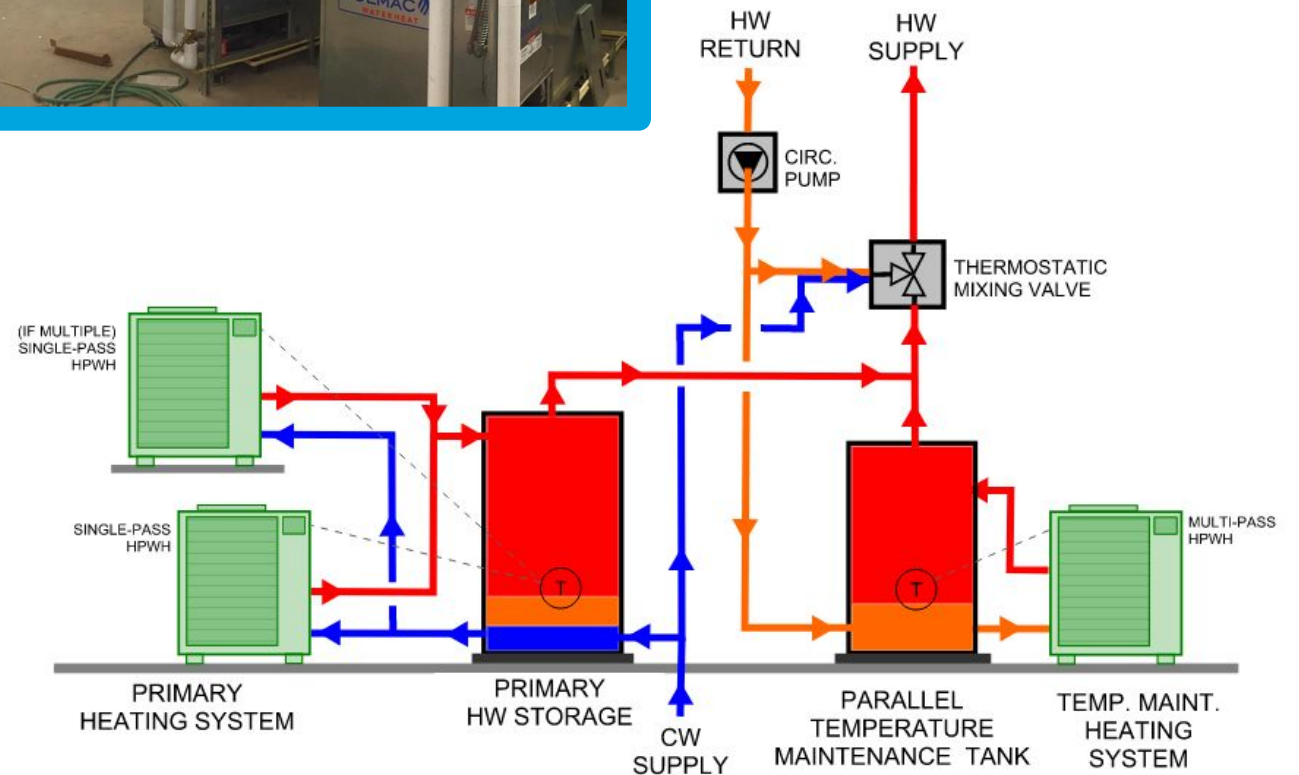




# LARGE COMMERCIAL **SYSTEM**

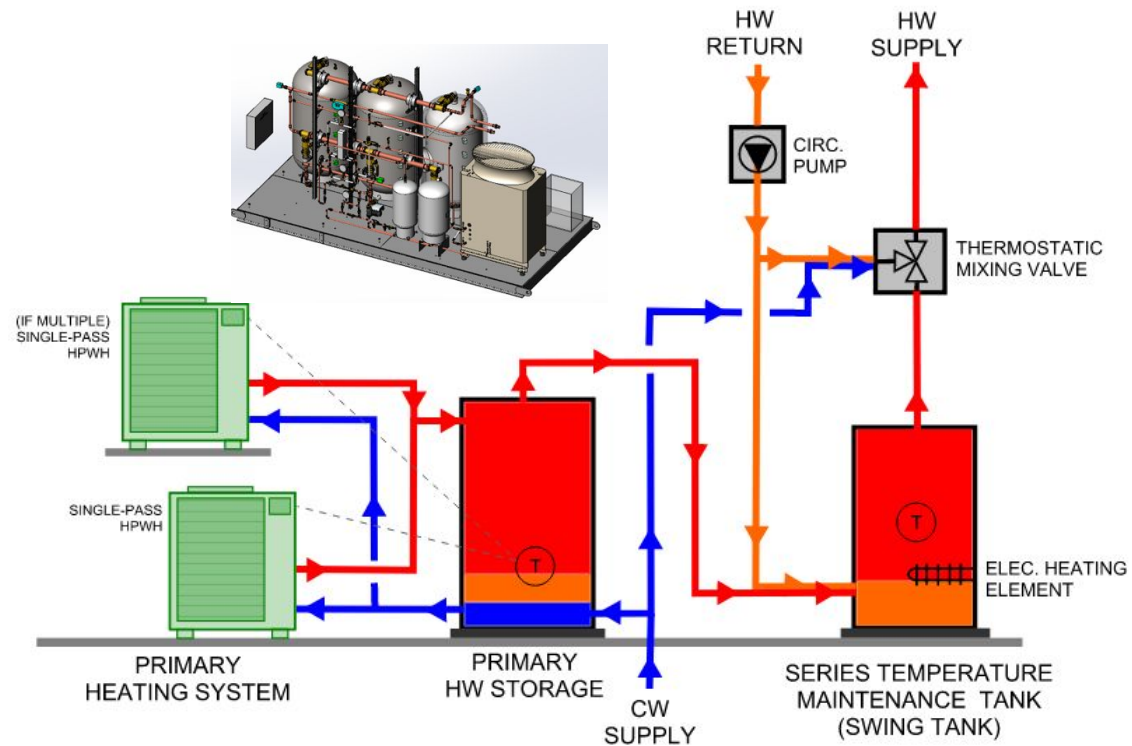


- Commercial equipment; engineered system
- 200 units
- Dedicated heating system:
  - Single pass primary HPWH
  - Multi pass temperature maintenance system



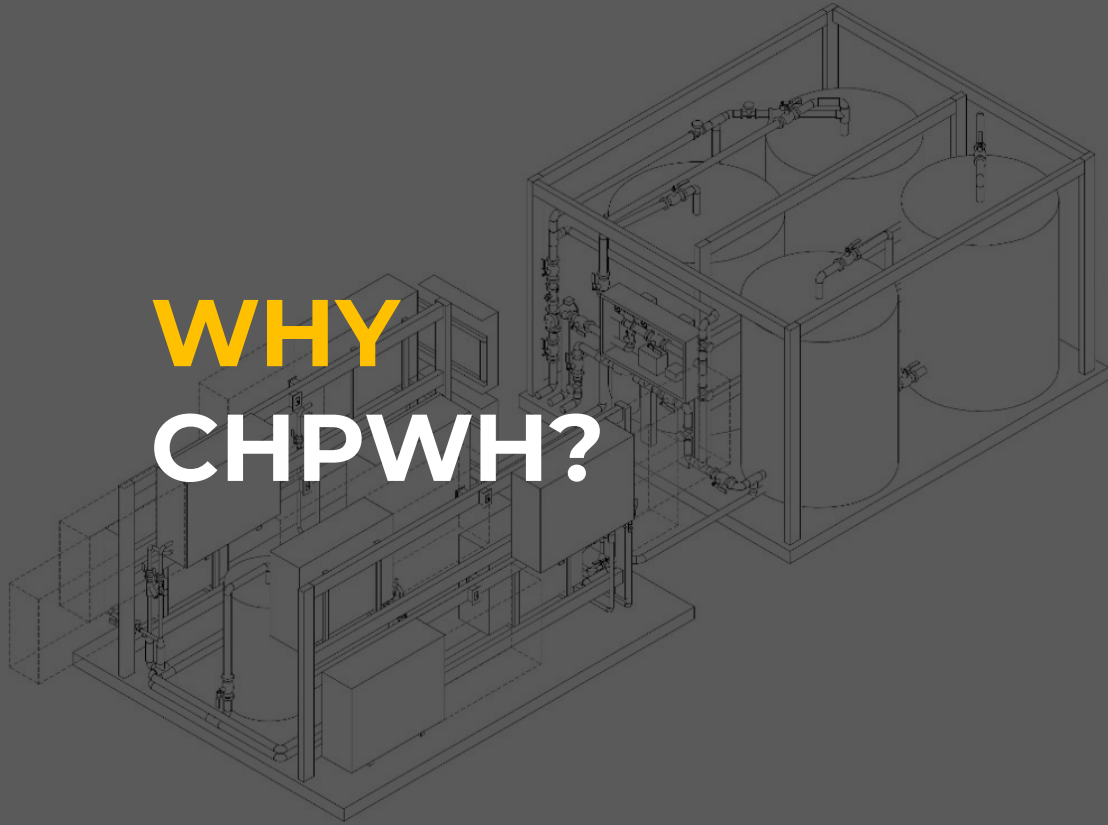
# MULTIPLE COMMERCIAL SYSTEMS

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





# WHY CHPWH?



# WHY CHPWH?



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

# SEATTLE COMMERCIAL **ENERGY CODE**

## **C404.2.3**

Group R-1 and R-2\* occupancies w/  
central service water heating  
systems.

Service hot water shall be provided  
by an **air-source heat pump water  
heating system**, not fossil fuel or  
electric resistance.



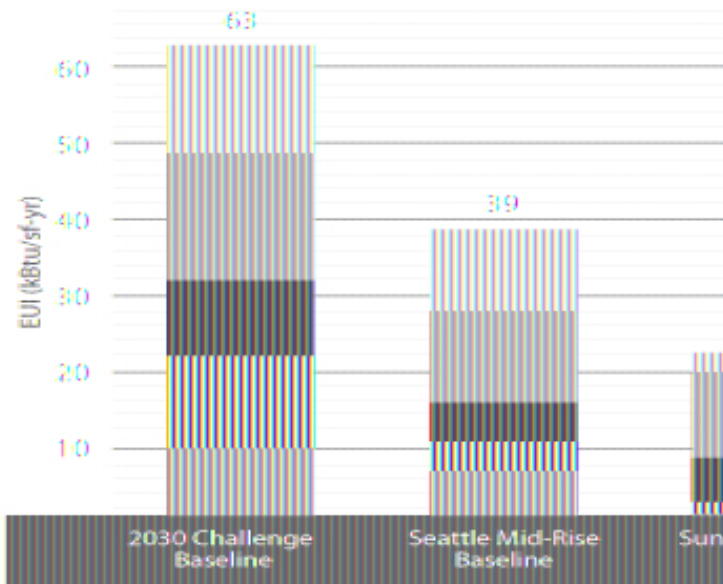
**\*R-1 and R-2:** Multifamily greater than 3 stories; any hotel/motel



# SUNSET ELECTRIC



## 70% Reduction in DHW Energy



**EUI**= Energy Use Intensity  
(Energy Use/Total Building Area)

- 67,000 ft<sup>2</sup>
- 92 apartments
- R-134a air-source heat pump water heaters in parking garage

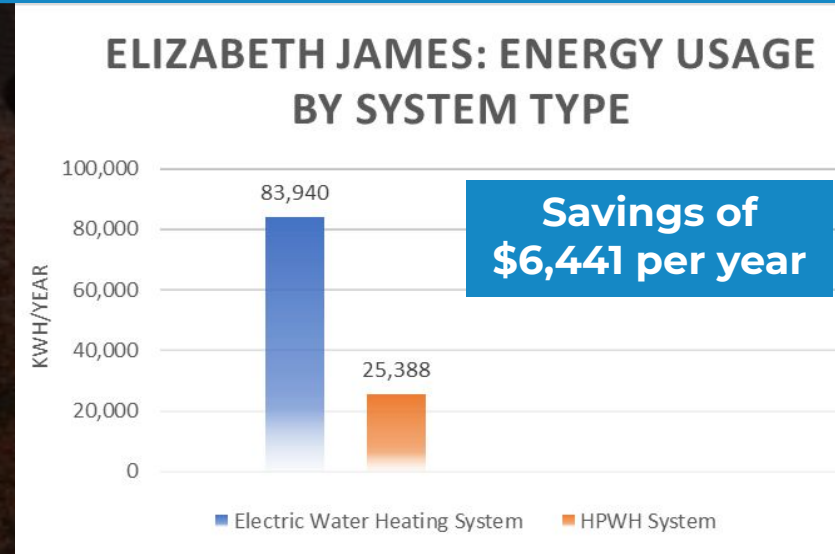


# ELIZABETH JAMES

**60 senior facility  
low-income units**

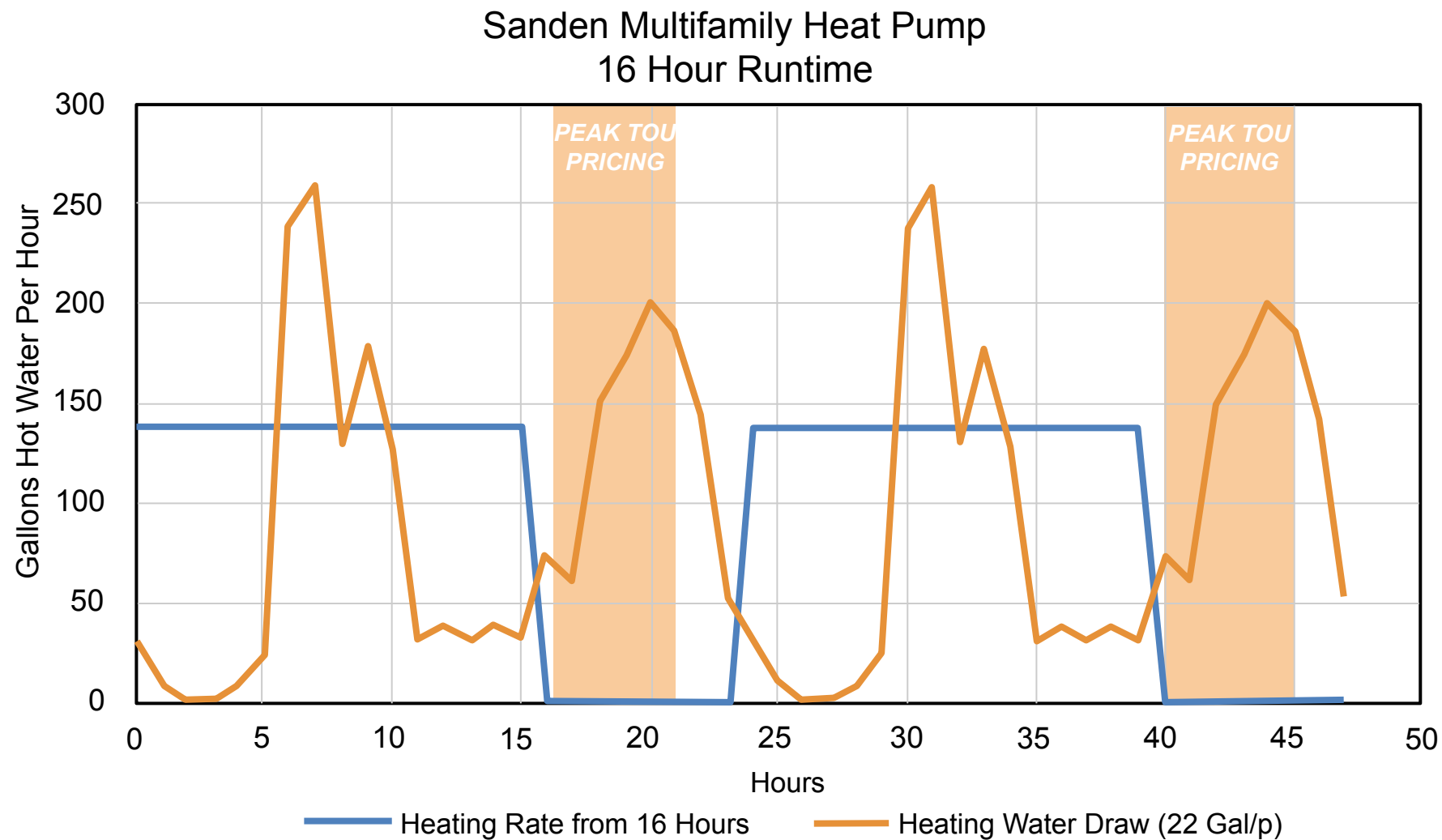
**4 CO2 Sanden Units  
(retrofit)**

**Zero GHG emissions**



**70% Reduction in DHW Energy**

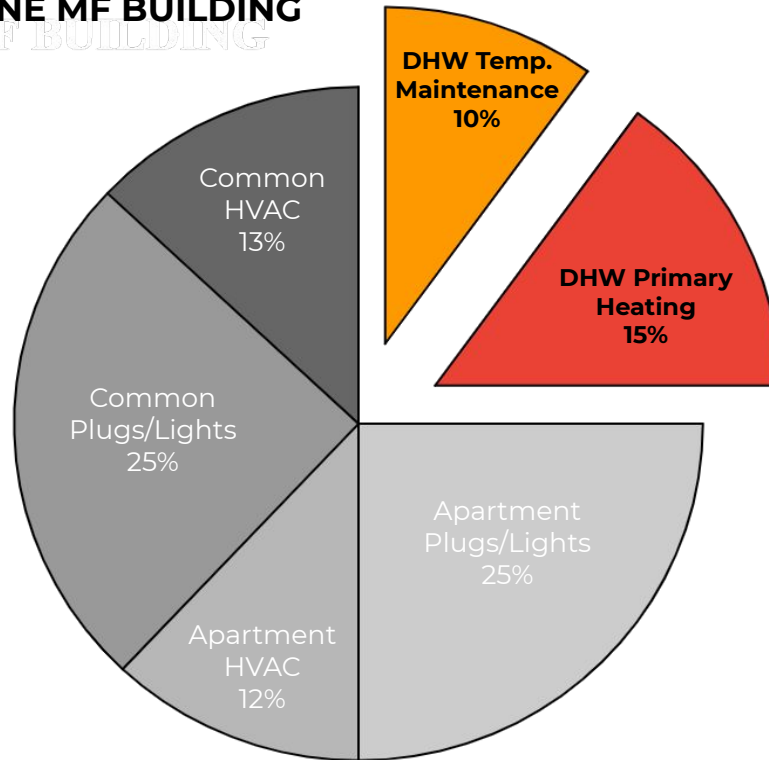
# WHY **CHPWH**: TOU RATES & GRID **FLEXIBILITY**



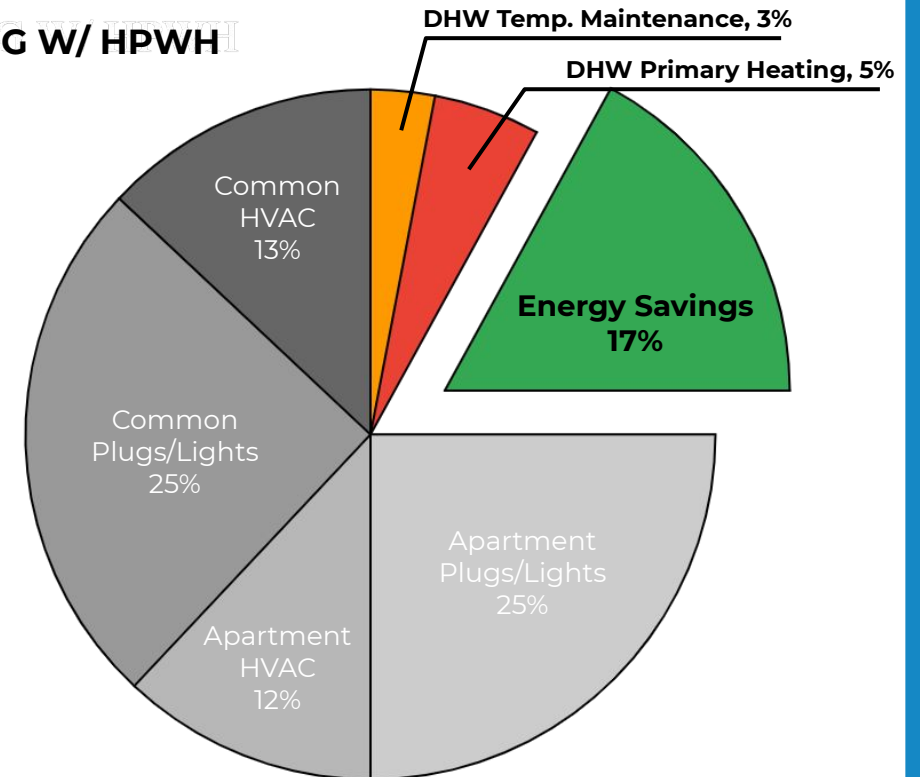


# WHY CHPWH?

**BASELINE MF BUILDING**



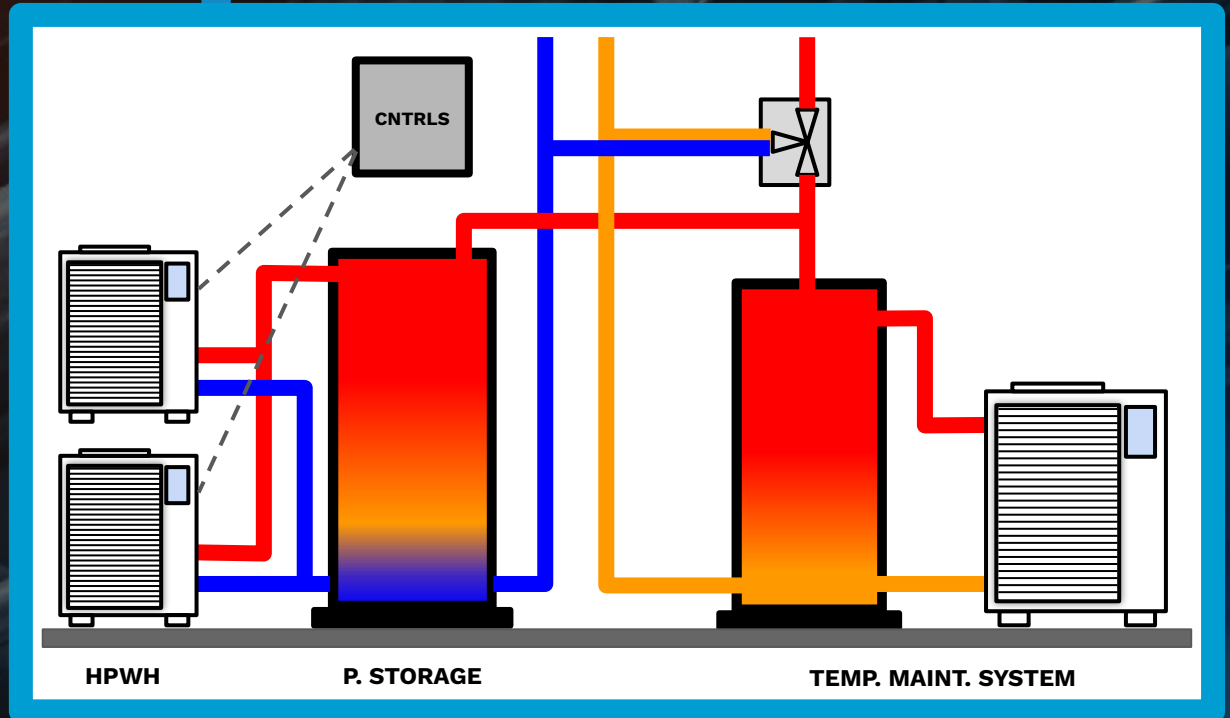
**MF BUILDING W/ HPWH**



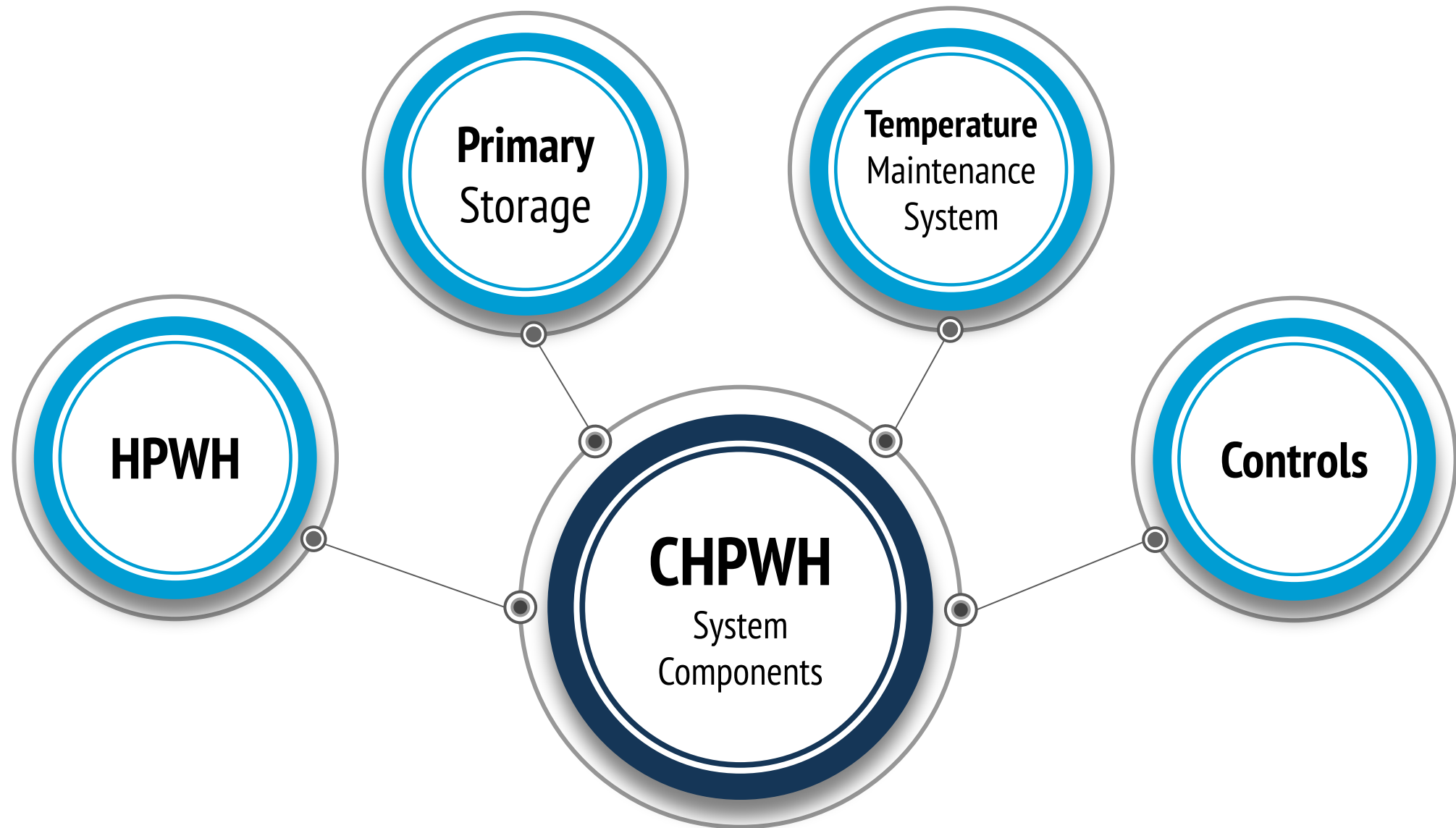
- ◆ DHW represents 25% of annual building use

- ◆ CHPWH systems cut energy usage down by 3x

# CHPWH SYSTEM COMPONENTS

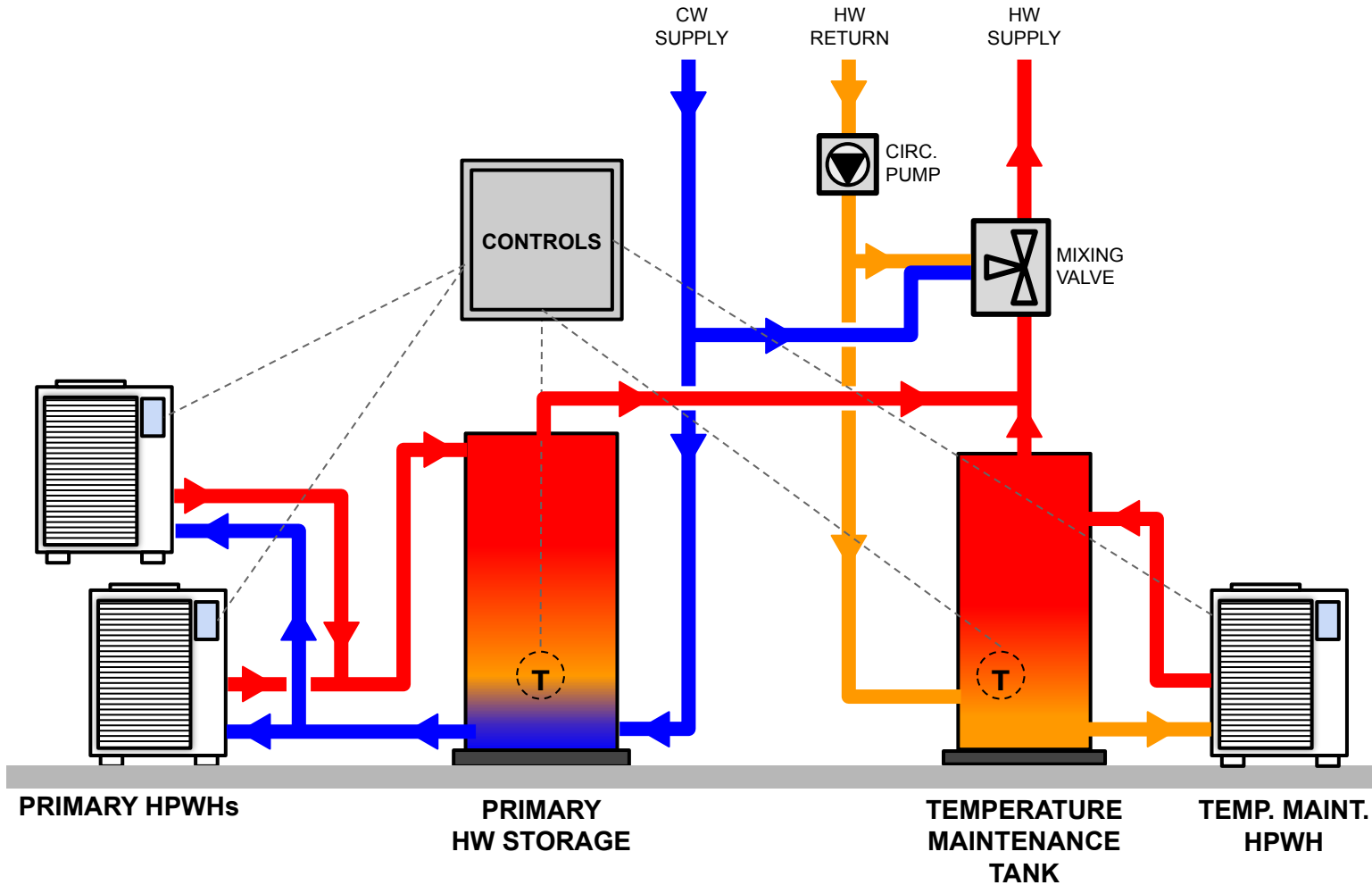


## FOUR **CHPWH** SYSTEM COMPONENTS





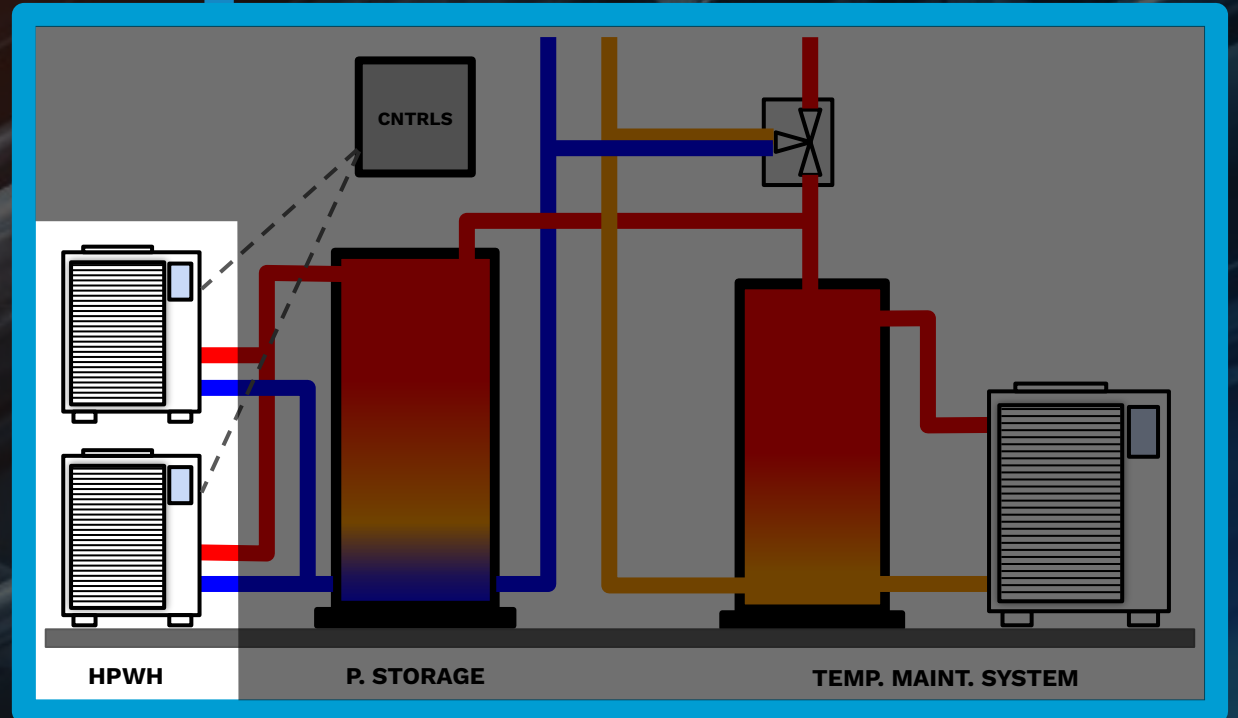
## FOUR CHPWH SYSTEM COMPONENTS



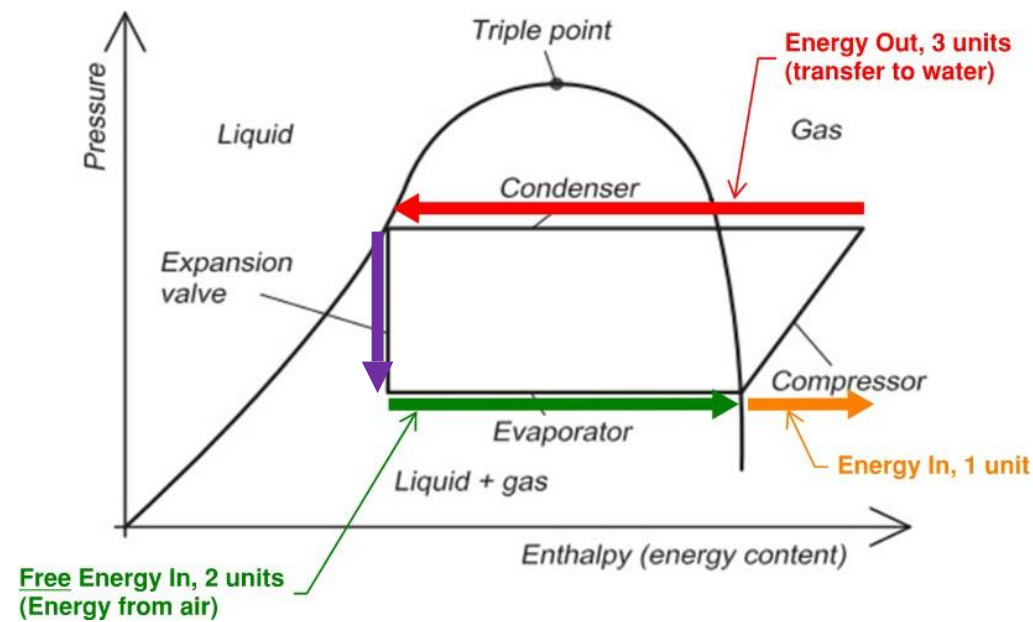
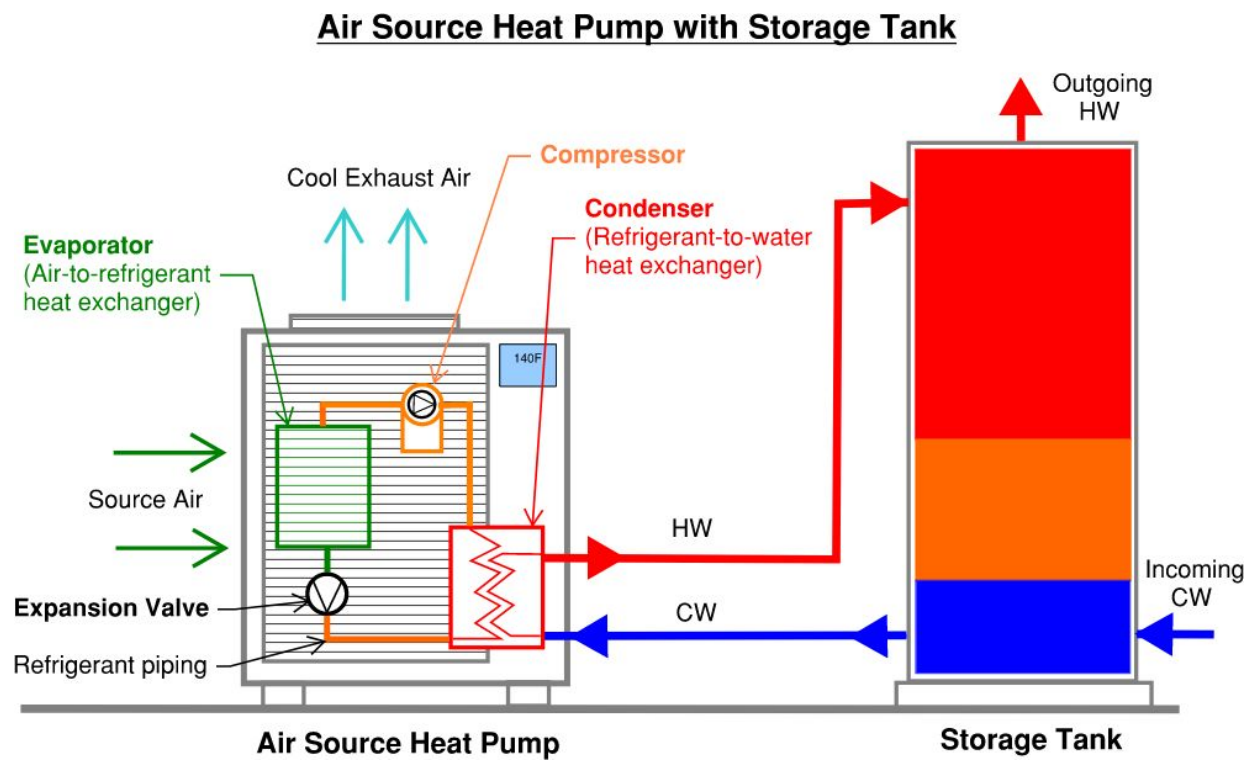
- Primary heat pump water heater (HPWH)
- Primary HW storage tank
- Temperature maintenance system
- Controls

# COMPONENTS:

## HPWH

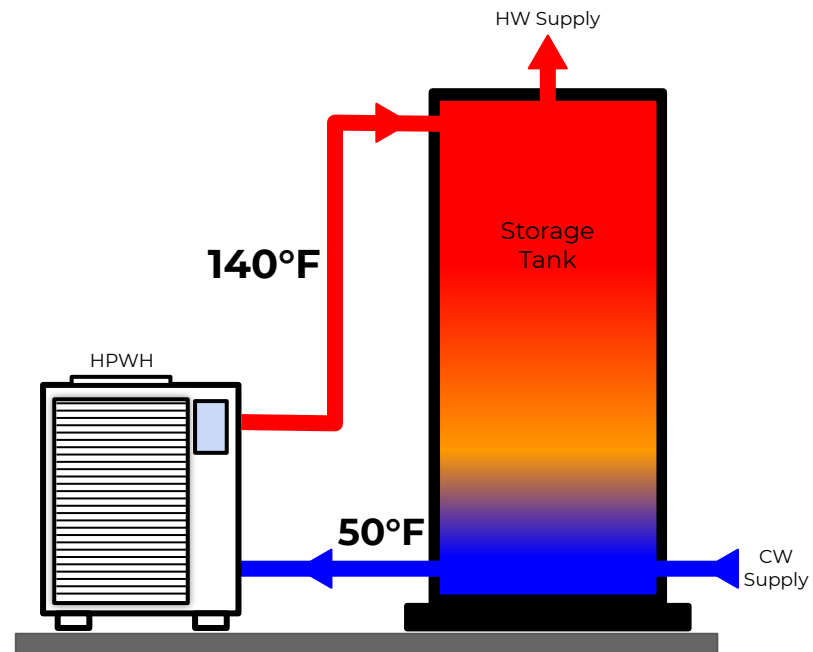


# HOW HEAT PUMPS WORK



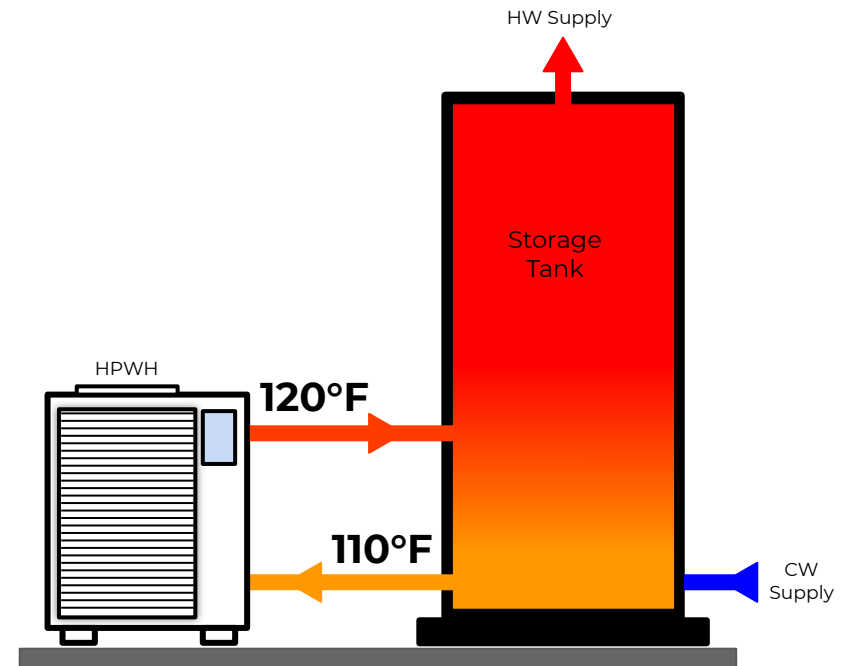


## TWO TYPES OF HEATING CYCLES



### 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)*

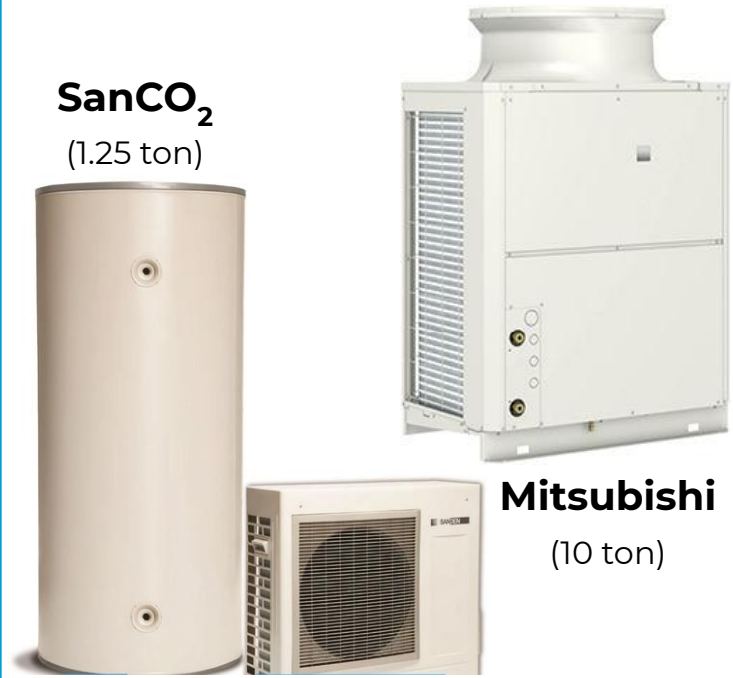
# AVAILABLE PRODUCTS



**AO Smith**  
(2.5 ton)

**Rheem**  
(> 1 ton)

Multi-Pass Unitary  
Residential/Small Commercial  
R-134a



**SanCO<sub>2</sub>**  
(1.25 ton)

**Mitsubishi**  
(10 ton)

Single-Pass  
CO<sub>2</sub>/R-744



**Colmac**  
(10 - 30 ton)

**Nyle**  
(10 - 30 ton)

Single- or Multi-Pass  
R-134a



# HPWH **CONSIDERATIONS**



**Rheem**  
(> 1 ton)

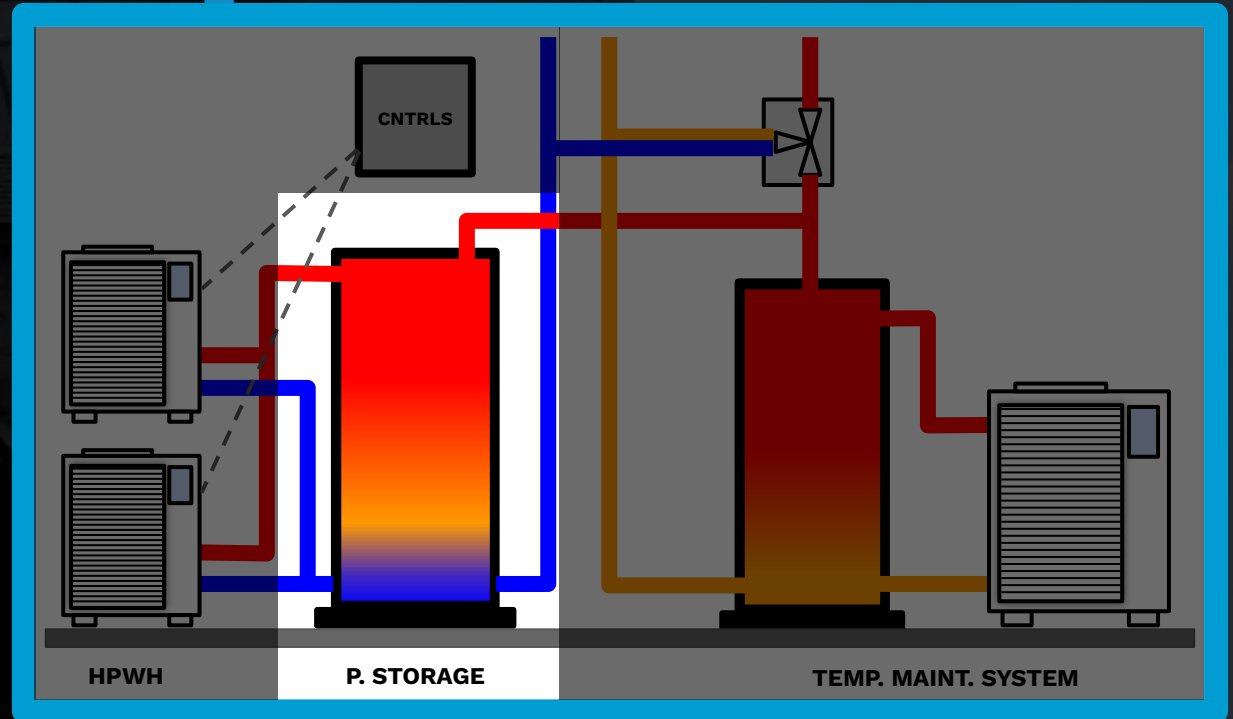


**Nyle**  
(10 - 30 ton)

- Air source / heat source
- Heating cycle (single pass / multipass)
- Electrical connection
- Water connections (freeze protection required?)
- Condensate management
- Maintenance and access
- Sound level, noise considerations



# COMPONENTS: PRIMARY STORAGE



## PRIMARY STORAGE TANK(S)

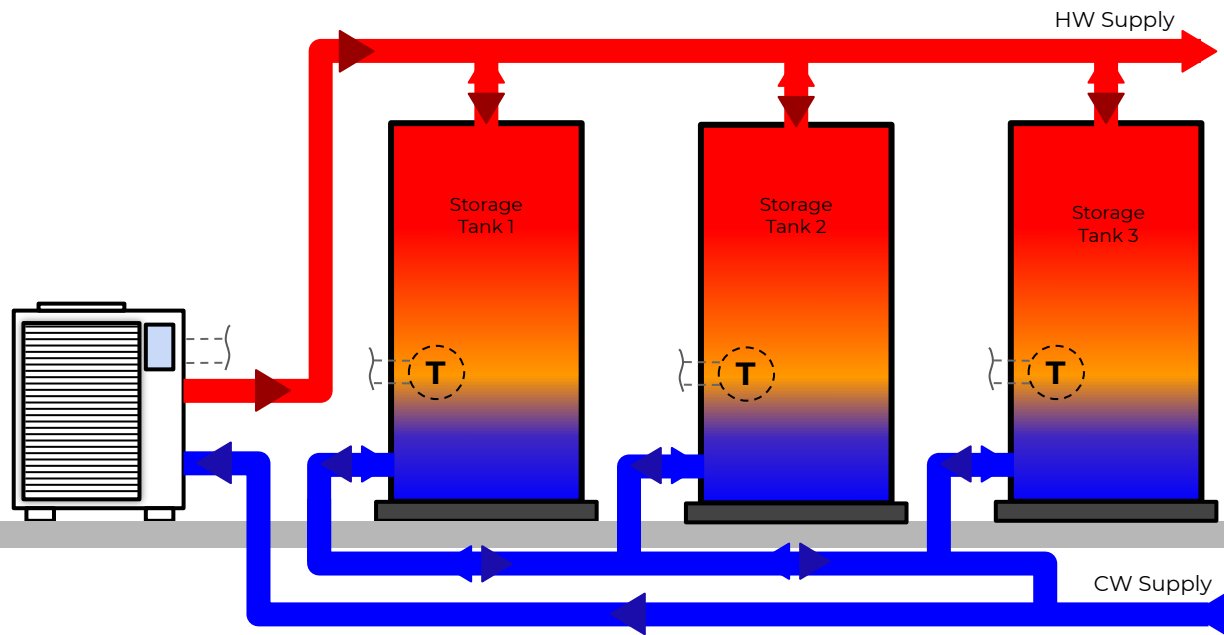


## A BATTERY BANK



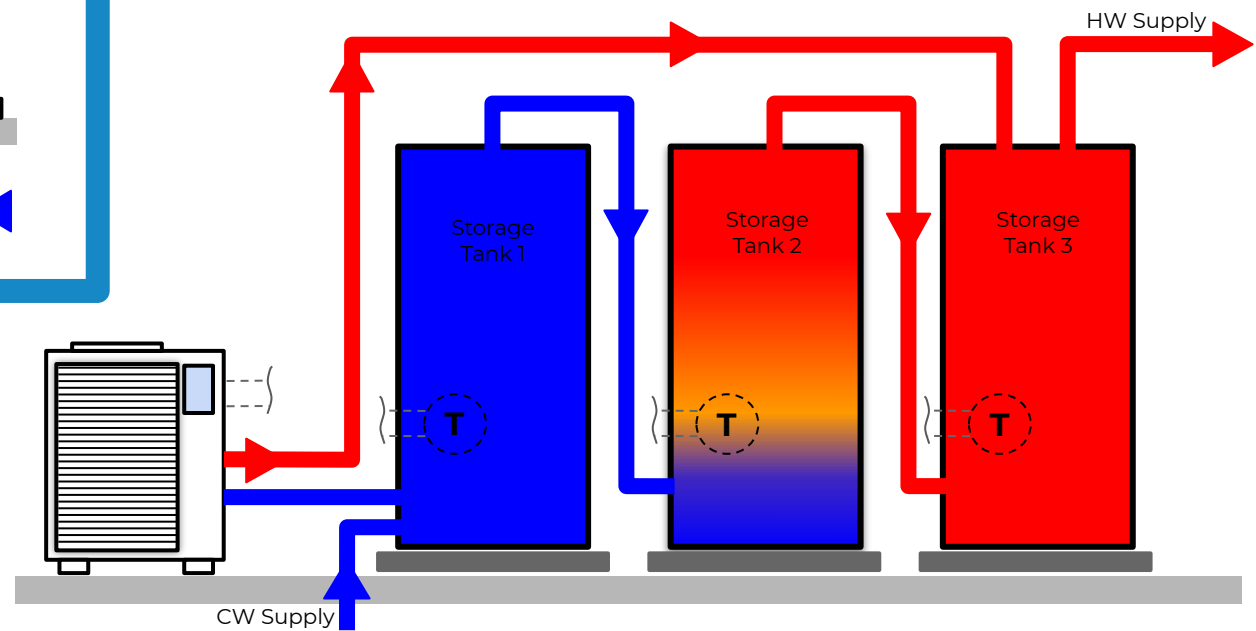


# PRIMARY STORAGE PLUMBING

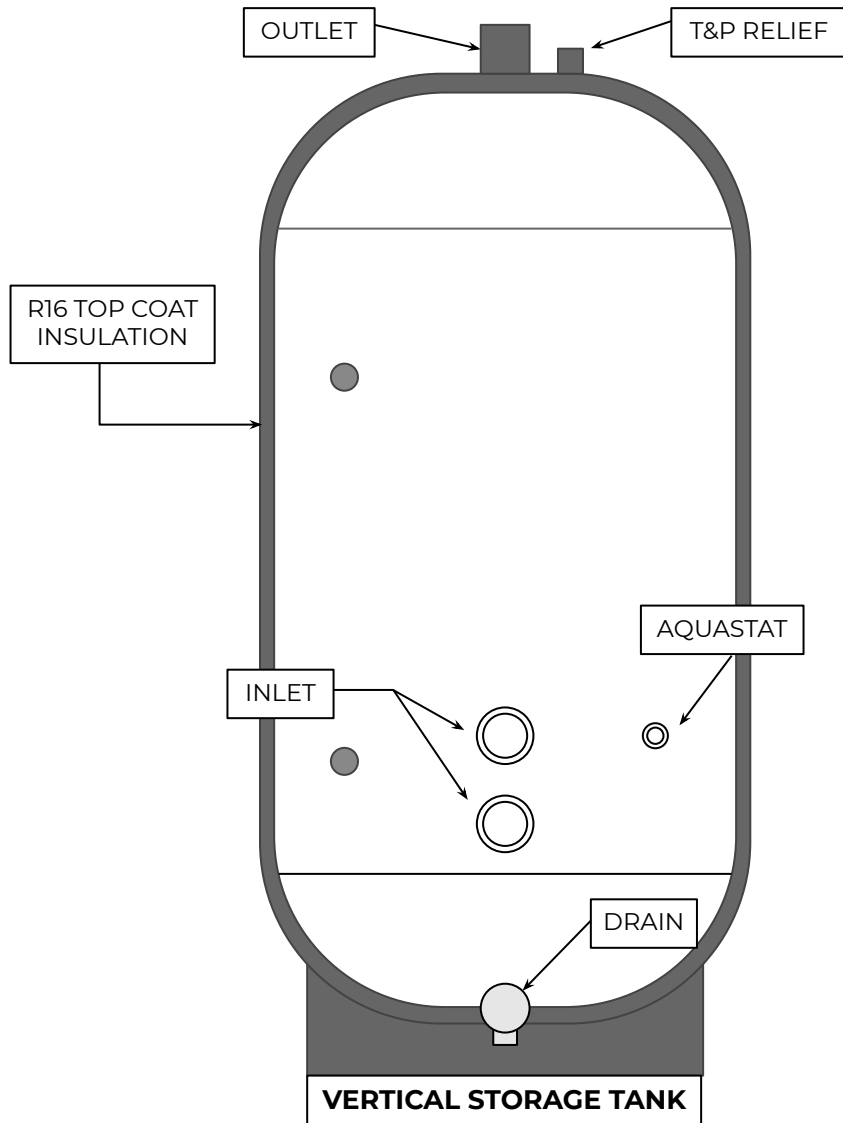


**IN SERIES**

**IN PARALLEL**



# HW STORAGE **CONSIDERATIONS**



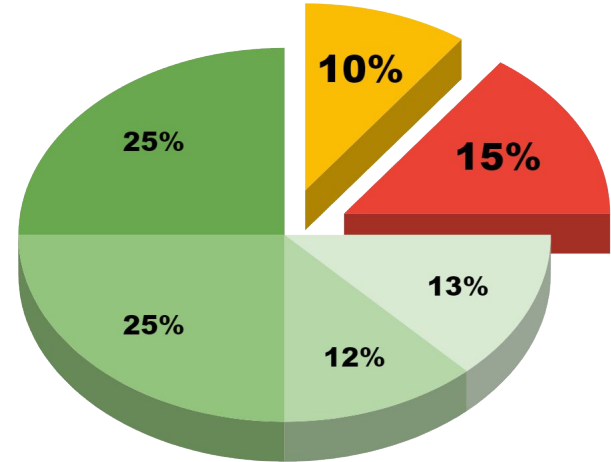
- Physical space, room & door size
- Vertical is better than horizontal
- Multiple tanks, series or parallel?
- Height of control sensor(s)
- Pipe connections, size & location
- Insulation level
- Thermal isolation
- Maintenance & access



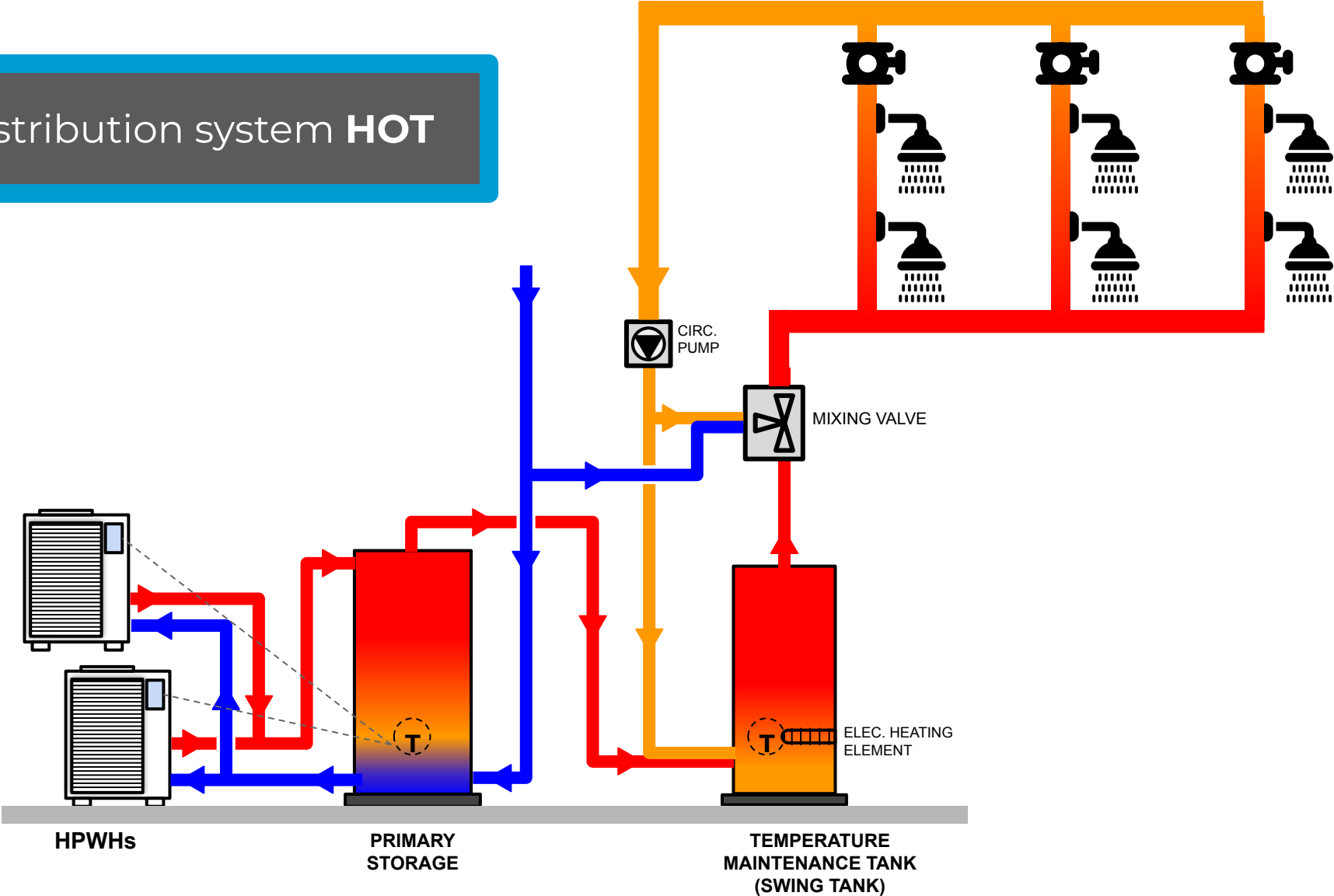


# TEMPERATURE MAINTENANCE SYSTEM

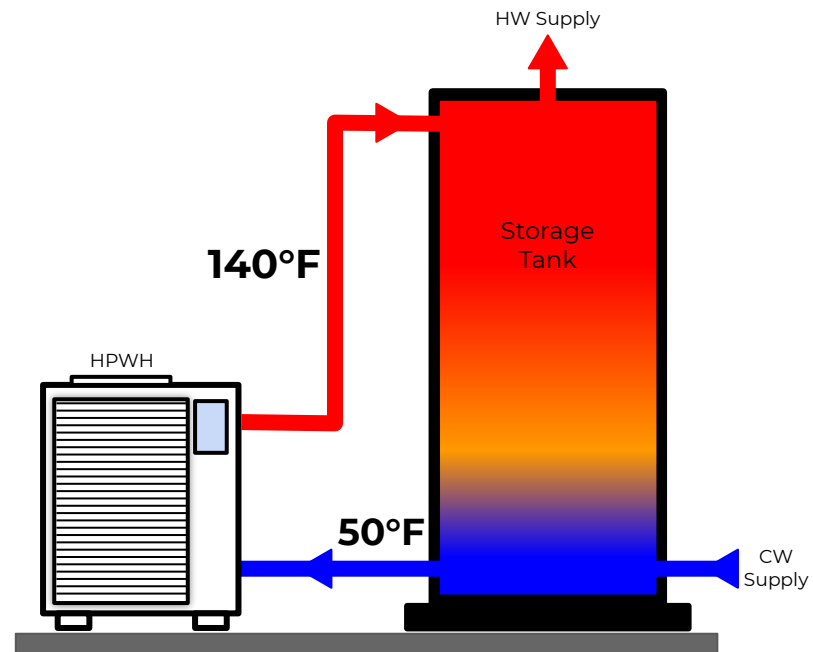
Keeping the water in the distribution system **HOT**



ENERGY USAGE IN  
MULTIFAMILY MIDRISE

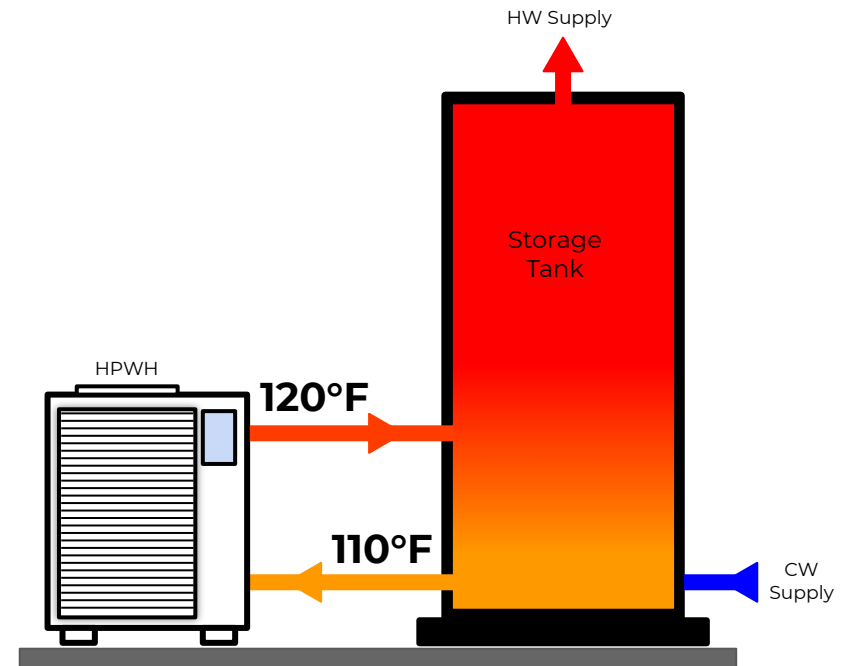


## TWO TYPES OF HEATING CYCLES



### SINGLE-PASS

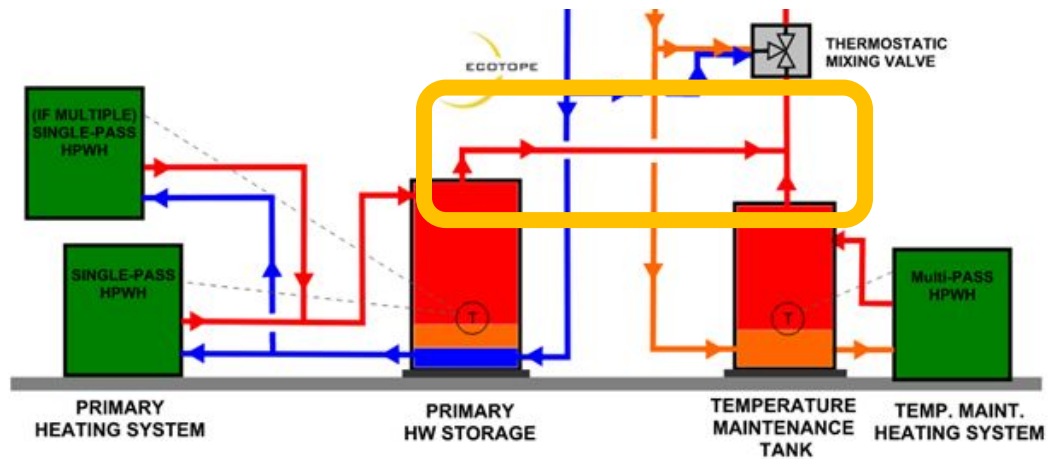
Heats water to working temp. in single pass  
*(usually for primary heating load)*



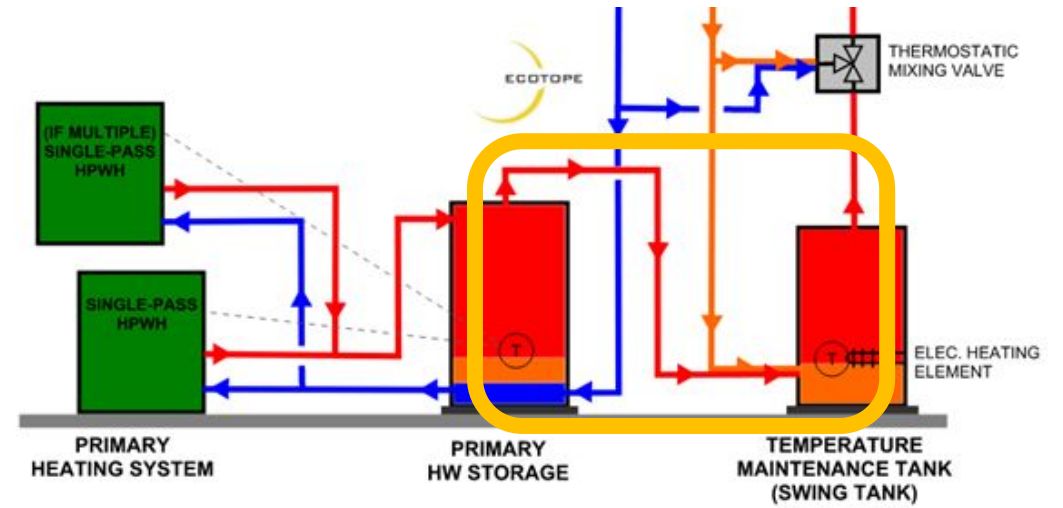
### MULTI-PASS

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

# TWO RELIABLE TEMPERATURE MAINTENANCE REHEAT STRATEGIES



**"Parallel Loop Tank"**



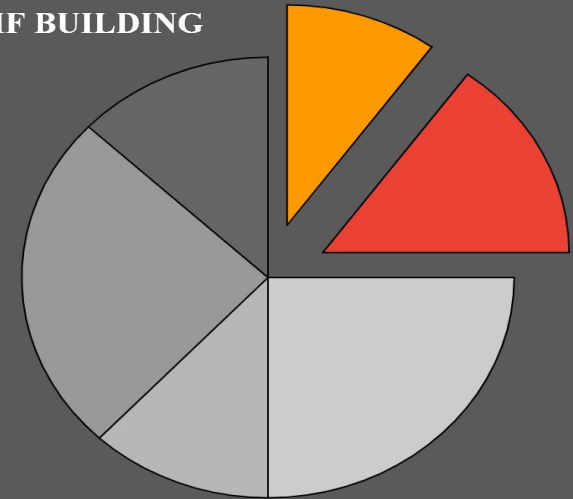
**"Series Loop Tank"  
or "Swing Tank"**



## TEMPERATURE MAINTENANCE: **HW CIRCULATION**

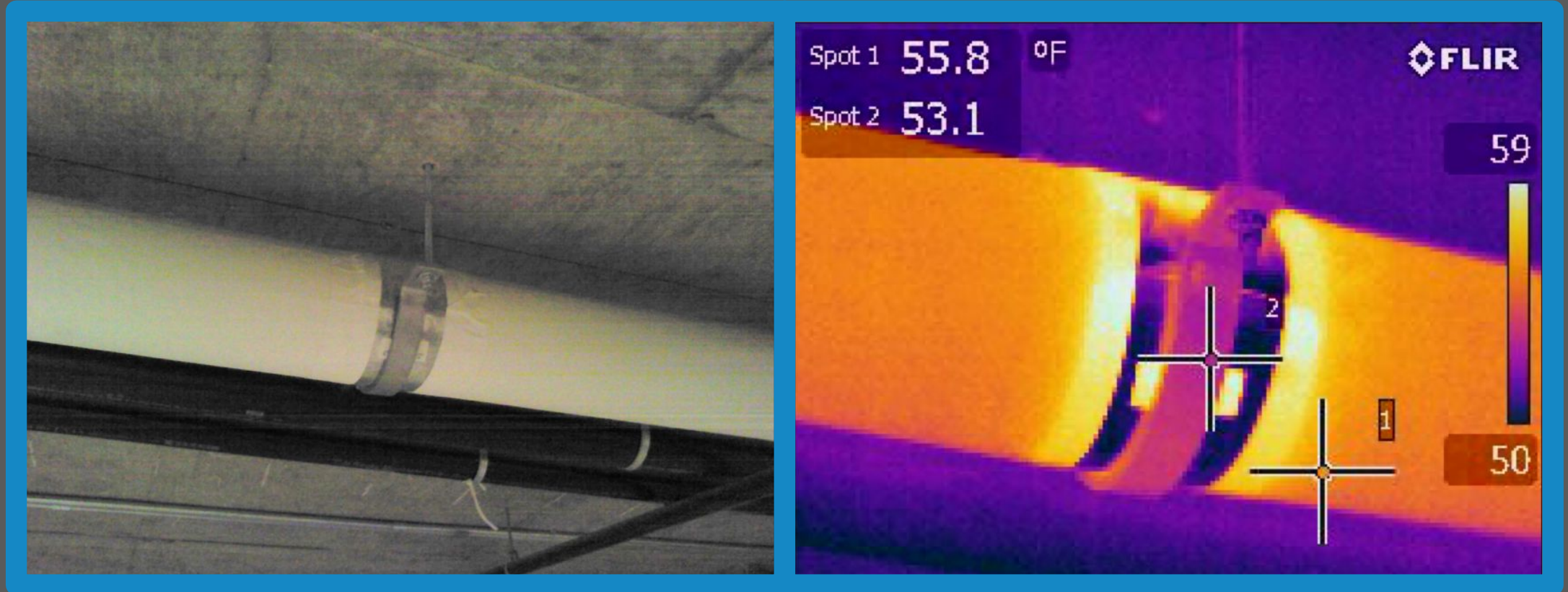


MF BUILDING



A SMALL CONSTANT LOAD THAT **ADDS UP**

## OPTIONS FOR REDUCING THE **TEMPERATURE MAINTENANCE LOSSES**



**GOOD EXAMPLE:** PIPE CLAMP ACTS AS A THERMAL BREAK



## OPTIONS FOR REDUCING THE **TEMPERATURE MAINTENANCE LOSSES**



**GOOD**



**BAD**



# HIGH EFFICIENCY PLUMBING DISTRIBUTION SYSTEMS

## APPENDIX M SIZING (UPC 2018)

- Reduces pipe size in building
- Reduces volume of water & associated losses
- Jurisdiction dependent in CA

## 2018 UNIFORM PLUMBING CODE®

AN AMERICAN NATIONAL STANDARD  
IAFMO/ANSI UPC 1 - 2018

### Sizing Method

Flowrate  
(GPM)

CW  
main

Appendix A

260

4"

Appendix A + C

205

3.5"

Appendix M

54

2"

### APPENDIX M PEAK WATER DEMAND CALCULATOR

#### M 101.0 General.

**M 101.1 Applicability.** This appendix provides a method for estimating the demand load for the building water supply and principal branches for single- and multi-family dwellings with water-conserving plumbing fixtures, fixture fittings, and appliances.

#### M 102.0 Demand Load.

**M 102.1 Water-Conserving Fixtures.** Plumbing fixtures, fixture fittings, and appliances shall not exceed the design flow rate in Table M 102.1.

#### DESIGN FLOW RATE FOR WATER-CONSERVING PLUMBING FIXTURES AND APPLIANCES IN RESIDENTIAL OCCUPANCIES

FIXTURE AND APPLIANCE	MAXIMUM DESIGN FLOW RATE (gallons per minute)
Bar Sink	1.5
Bathtub	5.5
Bidet	2.0
Clothes Washer*	5.5
Combination Bath/Shower	5.5
Dishwasher*	1.3
Kitchen Faucet	2.2
Laundry Faucet (with aerator)	2.0
Laundry Faucet	1.5
Shower, per head	3.0
Water Closet, 1.28 GPF Gravity Tank	3.0

For SI units: 1 gallon per minute = 0.06 L/s.

\* Clothes washers and dishwashers shall have an energy use label.

**M 102.2 Water Demand Calculator.** The estimated design flow rate for the building supply and principal branches and risers shall be determined by the IAPMO Water Demand Calculator available for download at <http://www.iapmo.org/WDCandPages/WaterDemandCalculator.aspx>.

**M 102.3 Meter and Building Supply.** To determine the design flow rate for the water meter and building supply, enter the total number of indoor plumbing fixtures and appliances for the building in Column [B] of the Water Demand Calculator and run Calculator. See Table M 102.3 for an example.

**M 102.4 Fixture Branches and Fixture Supplies.** To determine the design flow rate for fixture branches and risers, enter the total number of plumbing fixtures and appliances for the fixture branch or riser in Column [B] of the Water

Demand Calculator and run Calculator. The flow rate for one fixture branch and one fixture supply shall be the design flow rate of the fixture according to Table M 102.1.

**M 102.5 Continuous Supply Demand.** Continuous supply demands in gallons per minute (gpm) for lawn sprinklers, air conditioners, hose bibbs, etc., shall be added to the total estimated demand for the building supply as determined by Section M 102.3. Where there is more than one hose bibb installed on the plumbing system, the demand for only one hose bibb shall be added to the total estimated demand for the building supply. Where a hose bibb is installed on a fixture branch, the demand of the hose bibb shall be added to the design flow rate for the fixture branch as determined by Section M 102.4.

**M 102.6 Other Fixtures.** Fixtures not included in Table M 102.1 shall be added in Rows 12 through 14 in the Water Demand Calculator as Other Fixtures. The probability of use and flow rate for Other Fixtures shall be added by selecting the comparable probability of use and flow rate from Columns [C] and [E].

**M 102.7 Size of Water Piping per Appendix A.** Except as provided in Section M 102.0 for estimating the demand load for single- and multi-family dwellings, the size of each water piping system shall be determined in accordance with the pressure-loss method in Appendix A. After determining the permissible friction loss per 100 feet (30 480 mm) of pipe in accordance with Section A 104.0 and the demand flow in accordance with the Water Demand Calculator, the diameter of the building supply pipe, branches and risers shall be obtained from Chart A 105.1(1) through Chart A 105.1(7), whichever is applicable, in accordance with Section A 105.9 and Section A 106.0. Selection shall be in accordance with Section A 107.0, Appendix L, Figure 3 and Figure 4 shall be permitted when using PEX systems.

**M102.7.1 Minimum Fixture Branch Size.** The minimum fixture branch size shall be 1/2 inch (15 mm) in diameter.

### APPENDIX M

#### TABLE M 102.3 WATER DEMAND CALCULATOR EXAMPLE

(A) FIXTURE	(B) ENTER NUMBER OF FIXTURES	(C) PROBABILITY OF USE (%)	(D) ENTER FUTURE FLOW RATE (GPM)	(E) MAXIMUM RECOMMENDED FUTURE FLOW RATE (GPM)
1 Bar Sink	0	2.0	1.5	1.5
2 Bathtub	0	1.0	5.5	5.5
3 Bidet	0	1.0	2.0	2.0
4 Clothes Washer	1	5.5	3.5	5.5
5 Combination Bath/Shower	1	5.5	5.5	5.5
6 Dishwasher	1	0.5	1.3	1.3
7 Kitchen Faucet	1	2.0	2.2	2.2
8 Laundry Faucet	0	2.0	2.0	2.0
9 Laundry Faucet	1	2.0	1.5	1.5
10 Shower, per head	0	4.5	2.0	2.0
11 Water Closet, 1.28 GPF Gravity Tank	1	1.0	3.0	3.0
12 Other Fixture 1	0	0.0	0.0	6.0
13 Other Fixture 2	0	0.0	0.0	6.0
14 Other Fixture 3	0	0.0	0.0	6.0
Total Number of Fixtures		6		
90th Percentile Demand Flow		8.5 (GPM)		
			RESET	WATER DEMAND CALCULATOR

#### M 102.8 Examples Illustrating Use of Water Demand Calculator with Appendix A.

**Example 1: Indoor Water Use Only.** Use the information given below to find the pipe size for the building supply to a residential building with six indoor fixtures as shown in Figure 1 [Page Section 4].

#### Given Information:

Type of construction: Residential, one-bathroom  
Type of pipe material: L-copper  
Friction loss per 100 ft: 15 psi  
Maximum velocity: 10 ft/s  
Fixture number/type: 1 combination bath/shower  
1 laundry faucet  
1 kitchen faucet  
1 clothes washer  
1 WC

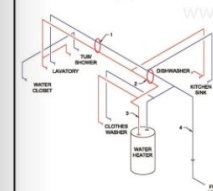


FIGURE 1  
RESIDENTIAL BUILDING WITH SIX INDOOR FIXTURES

#### Solution: Step 1 of 2 - Find Demand Load for the Building Supply.

The Water Demand Calculator (WDC) in Figure 2 is used to determine the demand load expected from indoor water use. The WDC has white-shaded cells and light gray-shaded cells. The values in the light gray cells are derived from a national survey of indoor water use at homes with efficient fixtures and cannot be changed.

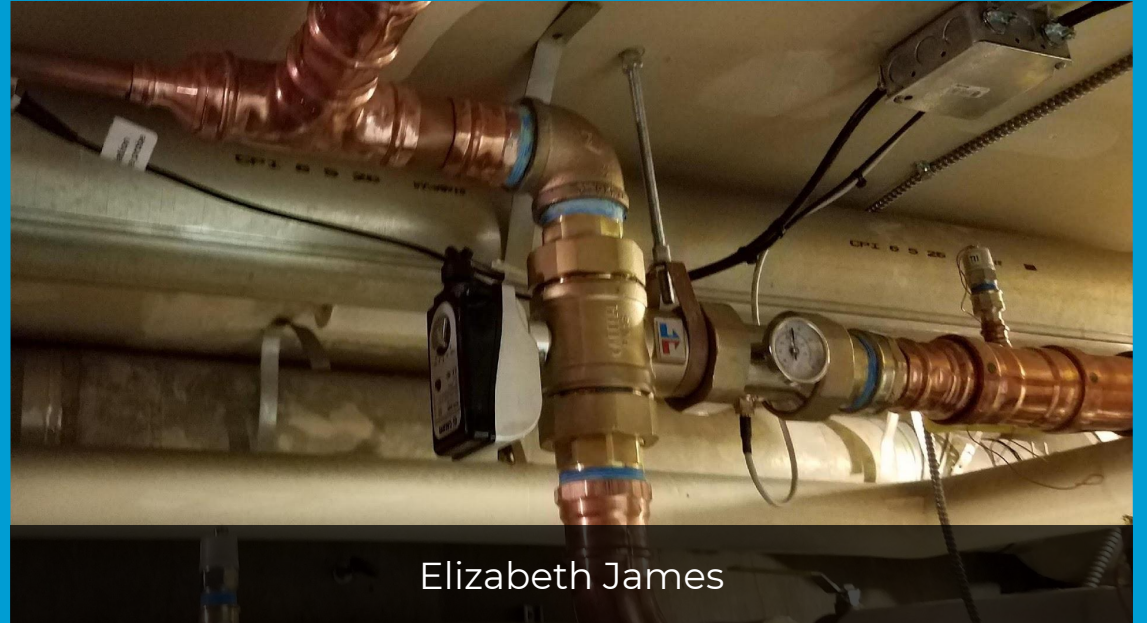
The white-shaded cells accept input from the designer. For instance, fixture counts from the given information are entered in Column [B]; the corresponding recommended fixture flow rates are already provided in Column [D]. The flow rates in Column [D] may be reduced only if the manufacturer specifies a lower flow rate for the fixture. Column [E] establishes the upper limits for the flow rates entered into Column [D]. Clicking the Run Water Demand Calculator button gives 8.5 gpm as the estimated indoor water demand for the whole building. This result appears in the dark gray box of the WDC in Figure 2.



# THERMOSTATIC MIXING VALVE **SIZING**



Jackson Apartments

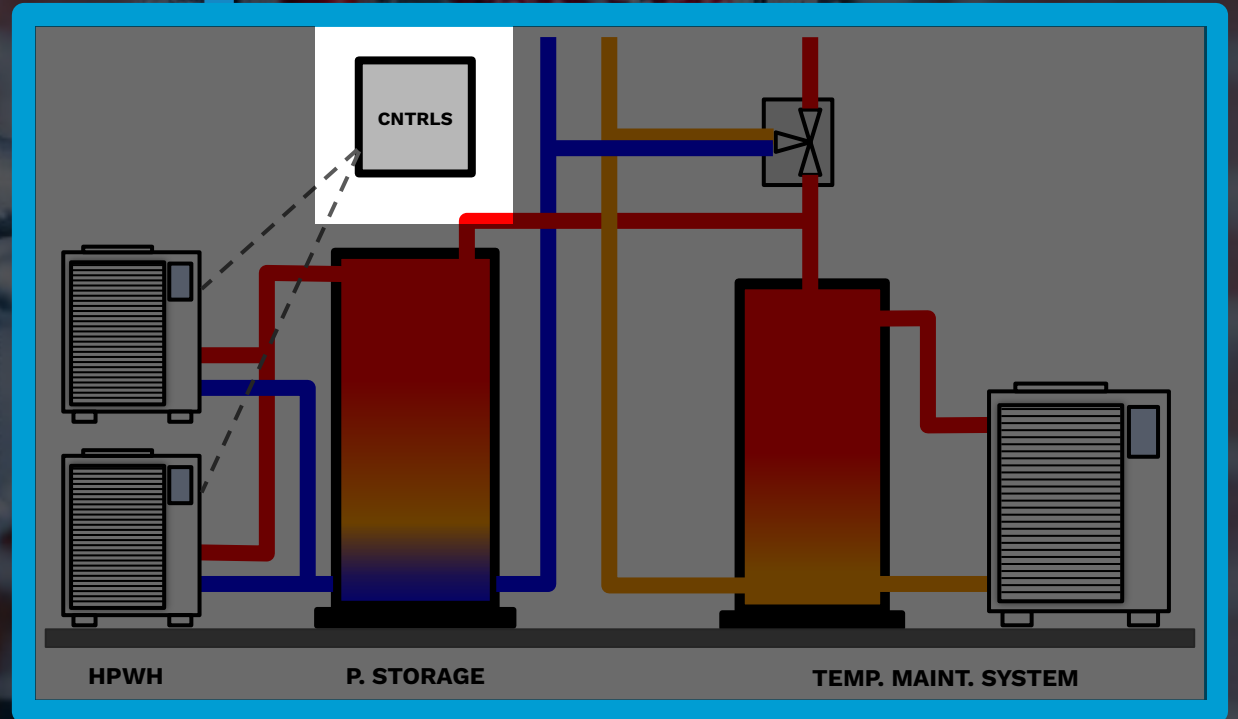


Elizabeth James

Requires **accurate sizing** for DHW load.  
Response time is **essential**.



# COMPONENTS: CONTROLS





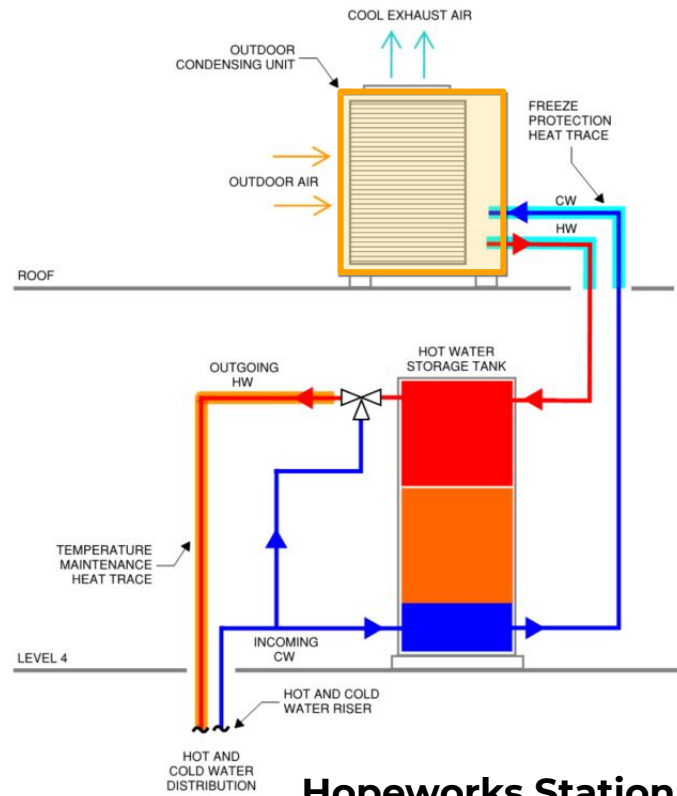
# CONTROLS **OPTIONS**

Equipment communicates through **CONTROLS** to fulfill design intent.

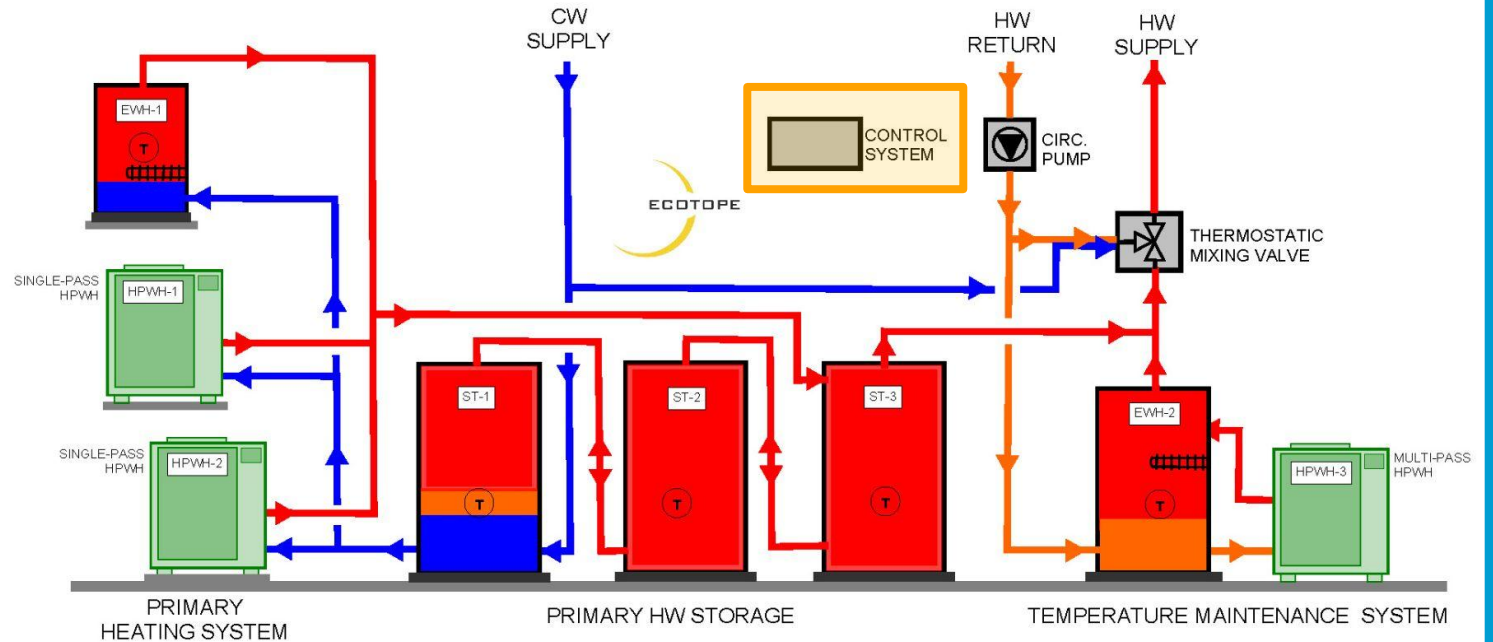


# CONTROL OPTIONS

Controls can be **INTERNAL** or **THIRD PARTY**



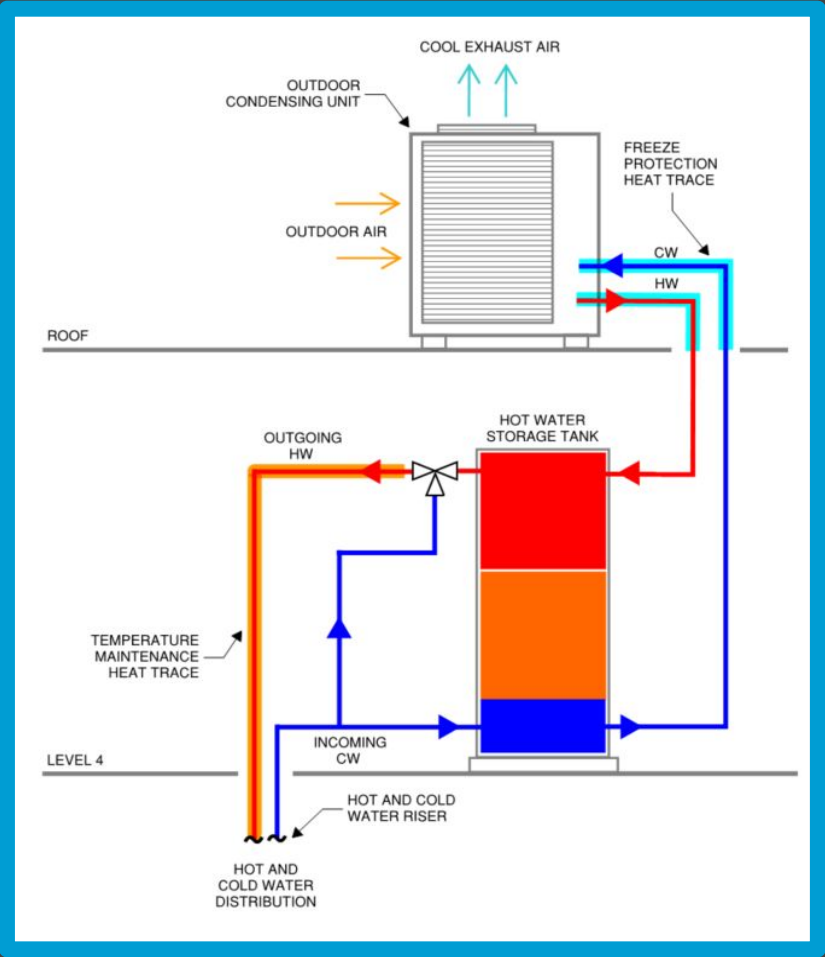
INTERNAL



**JACKSON APARTMENTS  
HEAT PUMP WATER HEATING SYSTEM**

THIRD PARTY

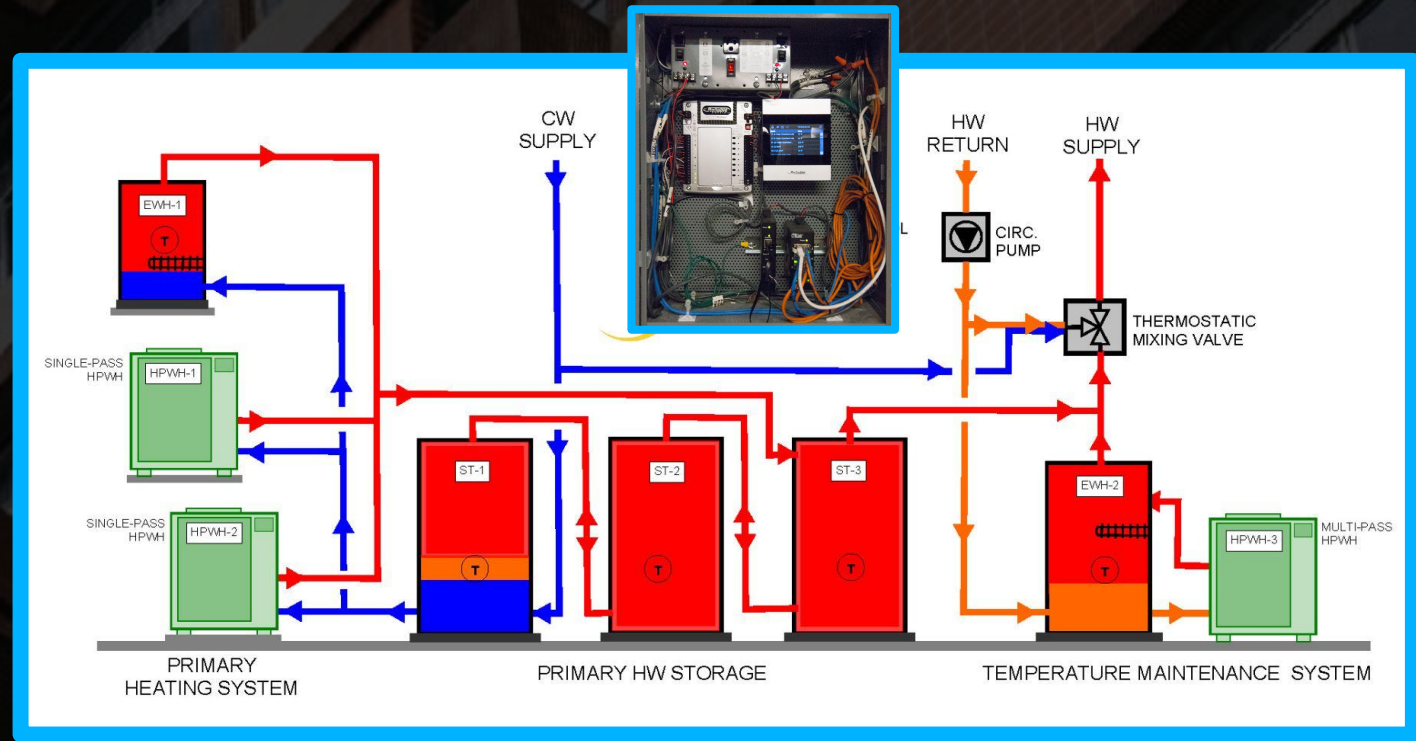
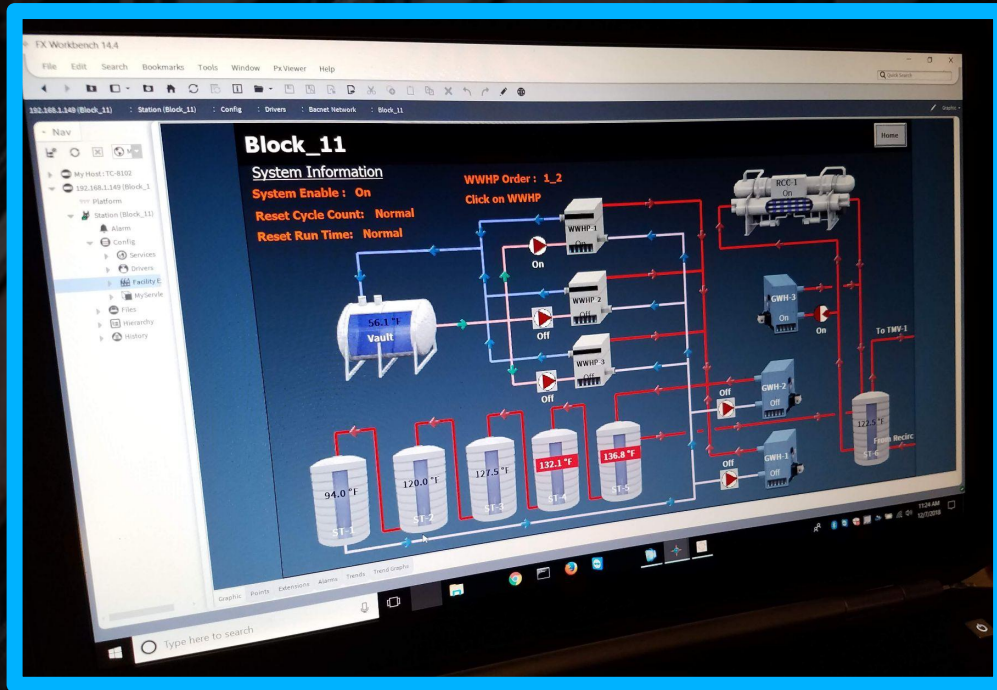
# CHPWH CONTROL SYSTEM: **INTERNAL**



INTERNAL



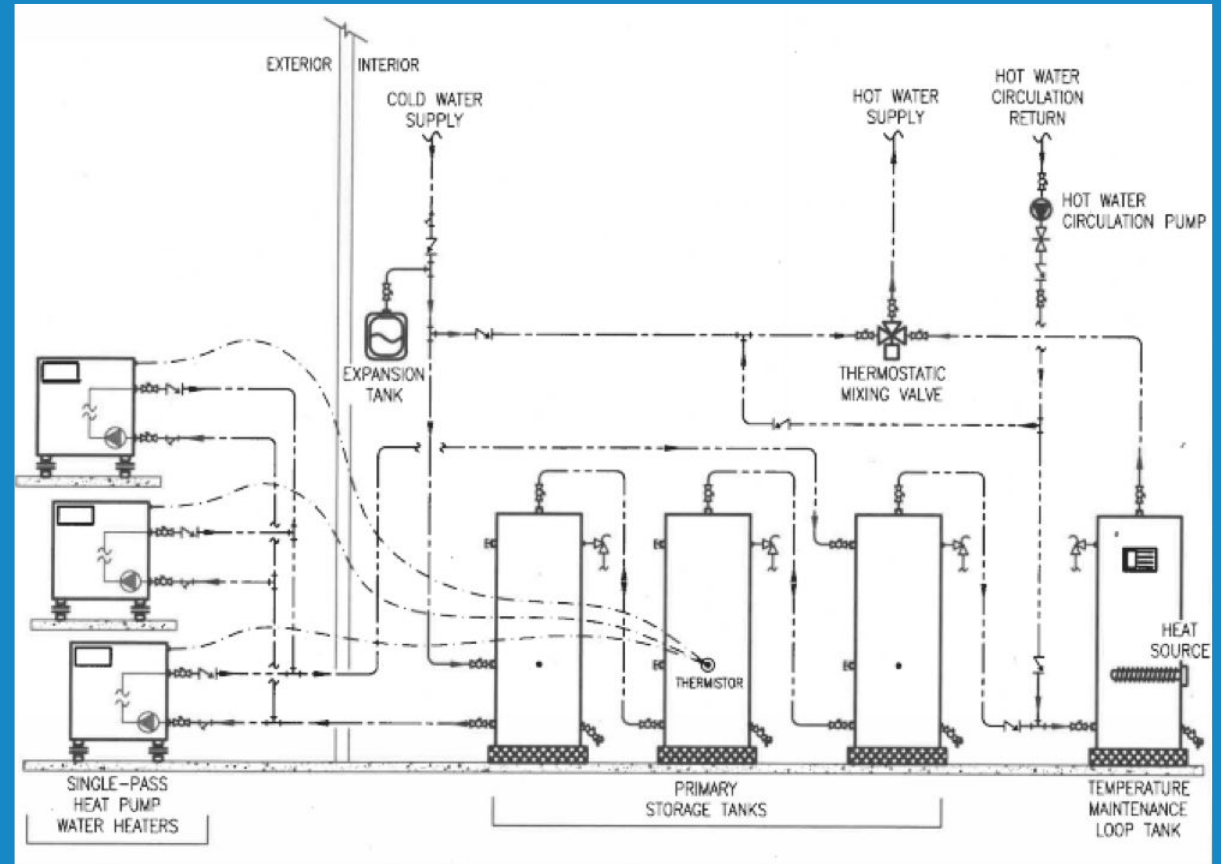
# CHPWH CONTROL SYSTEM: **THIRD PARTY**



THIRD PARTY

## RECAP:

- Language of CHPWHs
- Why?





## RECAP:

### CHPWH COMPONENTS:

- ◆ Heat pump
- ◆ Primary storage tank
- ◆ Temperature maintenance system
- ◆ Controls





## NEXT TIME

- HW System Designs
- Sizing
- Refrigerant Types & Equipment Selection
- Case Studies



## UPCOMING TRAINING & RESOURCES

### Seattle City Light, in collaboration with the Lighting Design Lab 2021

(<https://www.lightingdesignlab.com/education>)

### CHPWH: Design, Operations, and Maintenance

(8-hour seminar)

Oct 26, Nov. 3, 10, 17

10am-12pm

To host a training session, or for more information, contact:

Lauren Bhaskar at: [LBHASKAR@DRINTL.COM](mailto:LBHASKAR@DRINTL.COM)



**Seattle City Light**







THANK YOU







Bonneville  
POWER ADMINISTRATION



THANK YOU TO OUR **COLLABORATORS**