

CENTRAL HEAT PUMP WATER HEATING:

ENGINEERING DEEP DIVE

Colin Grist, PE, Ecotope, Inc.



slido



What professions do we have joining us today?

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BASIS OF DESIGN

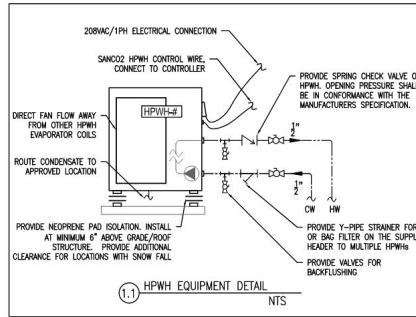
THE SYSTEM WAS SIZED FOR:
 PLANT DESIGN
 • SANCO2 WITH SWING TANK CENTRAL HEAT
 • MARKET RATE MULTI-FAMILY BUILDING
 • 60 FULL TIME OCCUPANTS
 • 30 RESIDENTIAL DWELLING UNITS
 • 25 GALLONS OF HW PER PERSON PER DAY
 (PEAK DAILY HOT WATER USAGE)
 • 1,500 GALLONS OF 120°F HW PER DAY (PEAK
 DAILY HOT WATER USAGE)
 • 16 HR PER DAY PRIMARY HPWH RUN TIME
 • 90 WATTS/AFW HWC LOSSES

MINIMUM SYSTEM SIZE:
 • 285 GALLONS OF PRIMARY STORAGE
 • 66.8 MBTU/HR OF PRIMARY HEAT CAPACITY
 • 80 GALLONS OF SWING TANK VOLUME
 • 4.7 KW SWING TANK RESISTANCE ELEMENT

EQUIPMENT SELECTION:
 • [HPWH-1-6] PRIMARY HPWHs; SIX (6) SANCO2, GS4-45HPC;
 5 NOMINAL, 1 REDUNDANT UNIT
 • [ST-1] PRIMARY STORAGE; ONE (1) SANCO2,
 ECO-285GALNST; 285 GALLONS OF STORAGE
 CENTRAL HEAT PLANT CONTROLLER; SANCO2,
 ECO-MESTR-001
 • [CTRL-1] TEMPERATURE MAINTENANCE TANK (SWING TANK);
 80 GALLONS, 6 KW ELEMENT
 0.5 GPM PER RISER, TARGET 110°F HOT WATER
 CIRCULATION RETURN WATER TEMP.
 • [PMP-1] RECOMMEND SIZING FOR 0.25 GPM PER PERSON
 PEAK; MINIMUM FLOWRATE SHALL BE LESS THAN
 THE CONTINUOUS FLOWRATE OF [PMP-1]
 • [TMV-1] SIZED FOR THE THERMAL EXPANSION OF THE
 PRIMARY STORAGE VOLUME
 • [EXP-1] SIZED FOR THE THERMAL EXPANSION OF THE
 TEMPERATURE MAINTENANCE STORAGE VOLUME
 AND THE VOLUME OF WATER IN THE HW
 DISTRIBUTION PIPING.
 • [EXP-2]

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

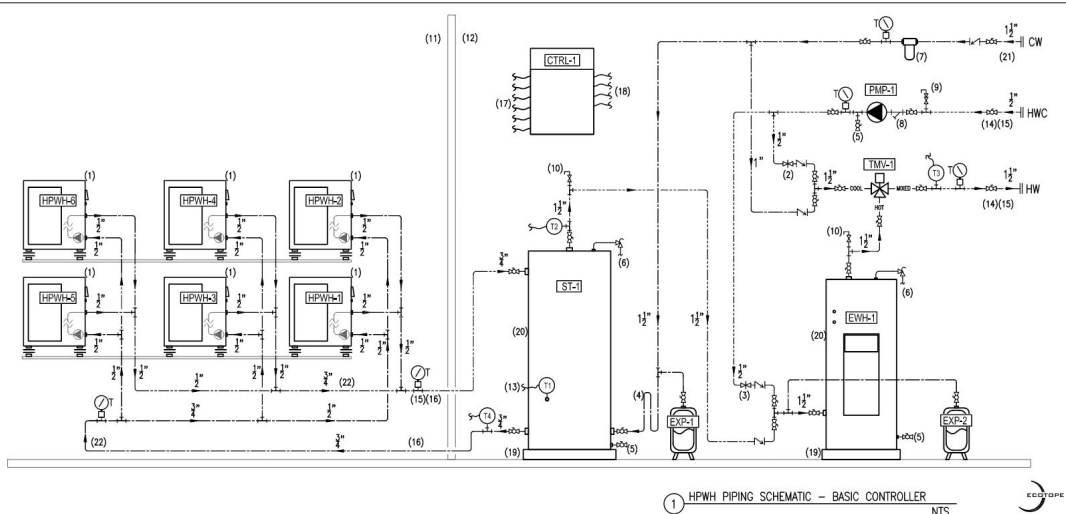


KEY QUESTIONS

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

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)
- 6-10 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 ACHIEVE EQUAL DISTANCE PIPING. MINIMIZE OUTGOING HW SUPPLY LINE DISTANCE TO THE PRIMARY STORAGE [ST-1]



Joining as a participant?

No account needed.

Enter event code



We want to hear from you!

GO TO [**SLIDO.COM**](https://www.slido.com)

Enter event code:

CHPWH1

slido

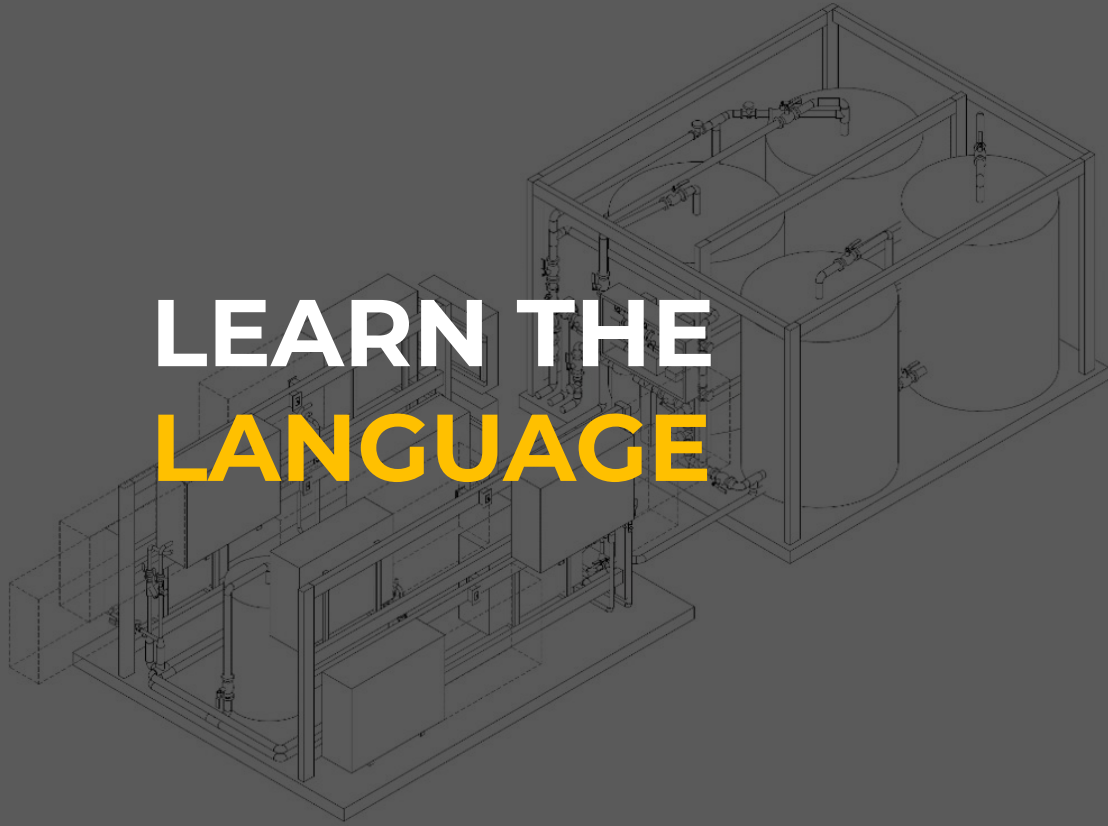
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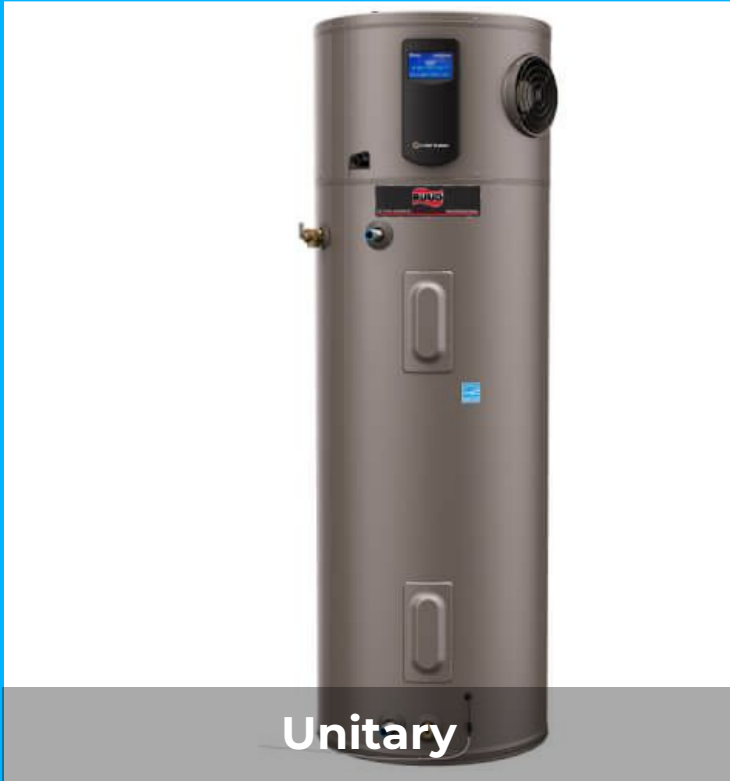
Introduction Survey

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**LEARN THE
LANGUAGE**



PRODUCT TYPES: LEARN THE LANGUAGE



Unitary

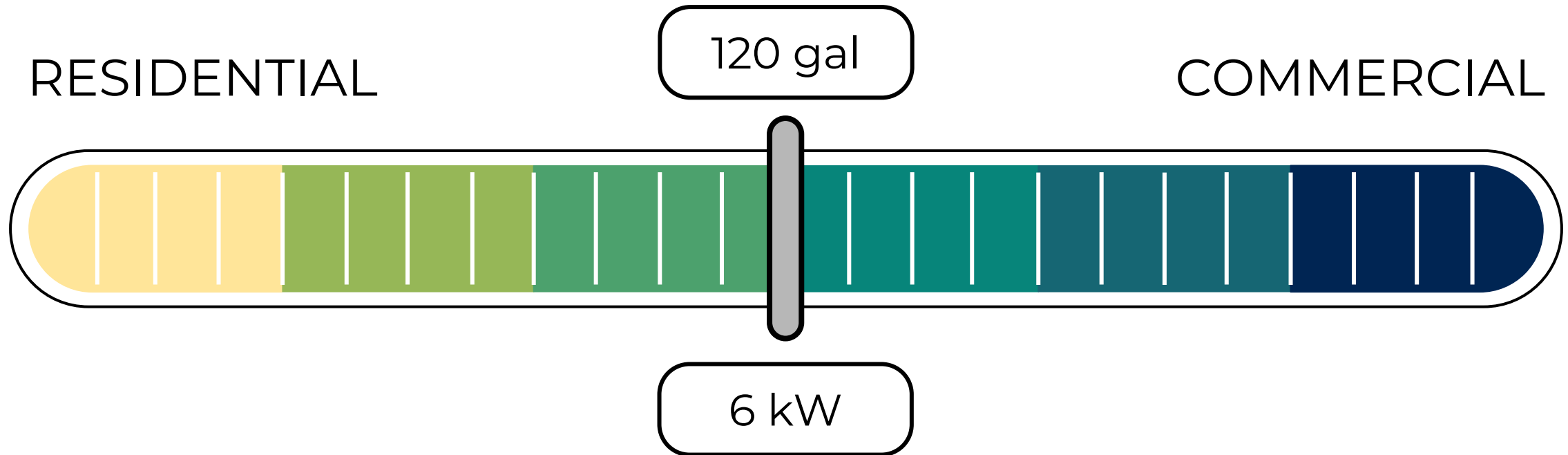
- Compressor, tank, & controls in a single package.
- Typically small residential product.



Split System

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

RESIDENTIAL vs. COMMERCIAL **SYSTEMS**

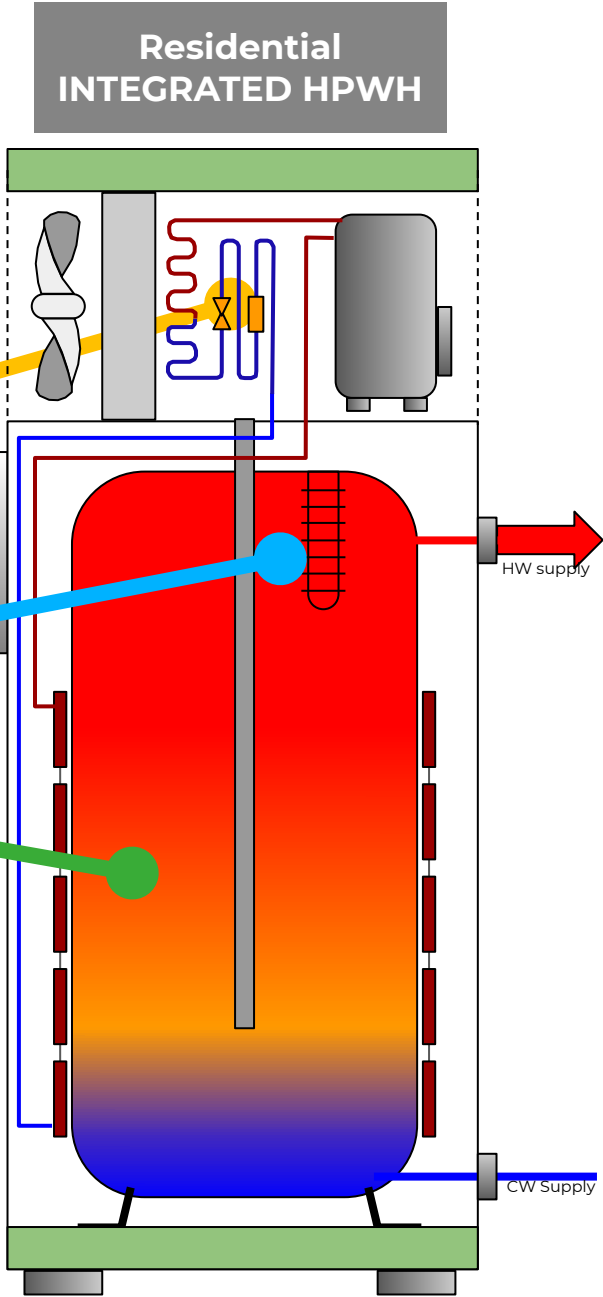


A **CHPWH system** serves more than 4 dwelling units or commercial loads requiring **≥ 120 gallons** of storage volume and/or **>6 kW** of input power.

COMMERCIAL HPWH SYSTEMS



Jackson Apartments



EXAMPLES OF CHPWH SYSTEMS



Small Commercial System

(closet installation serving 5 apts)



Large Commercial System

(basement installation serving 250 apts)

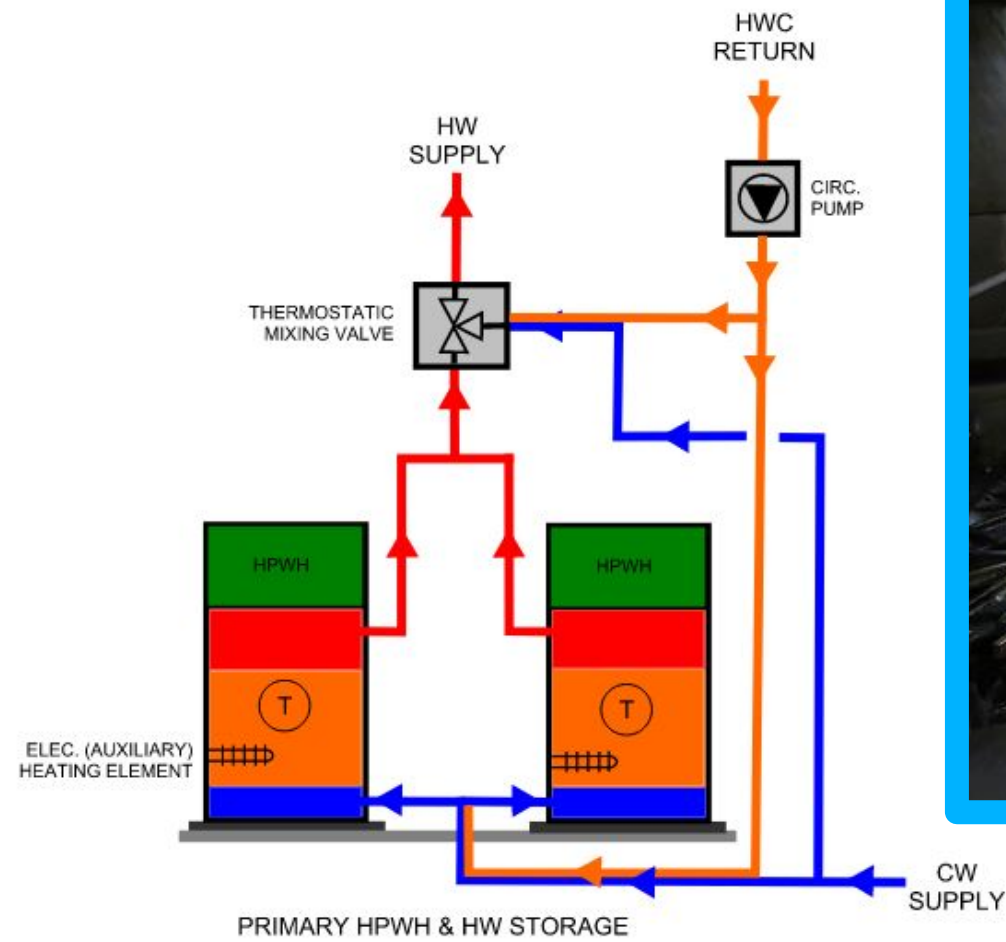


Multiple Commercial Systems

(residential equipment serving 4-5 apts)

Multiple Sizes, Types, & Configurations

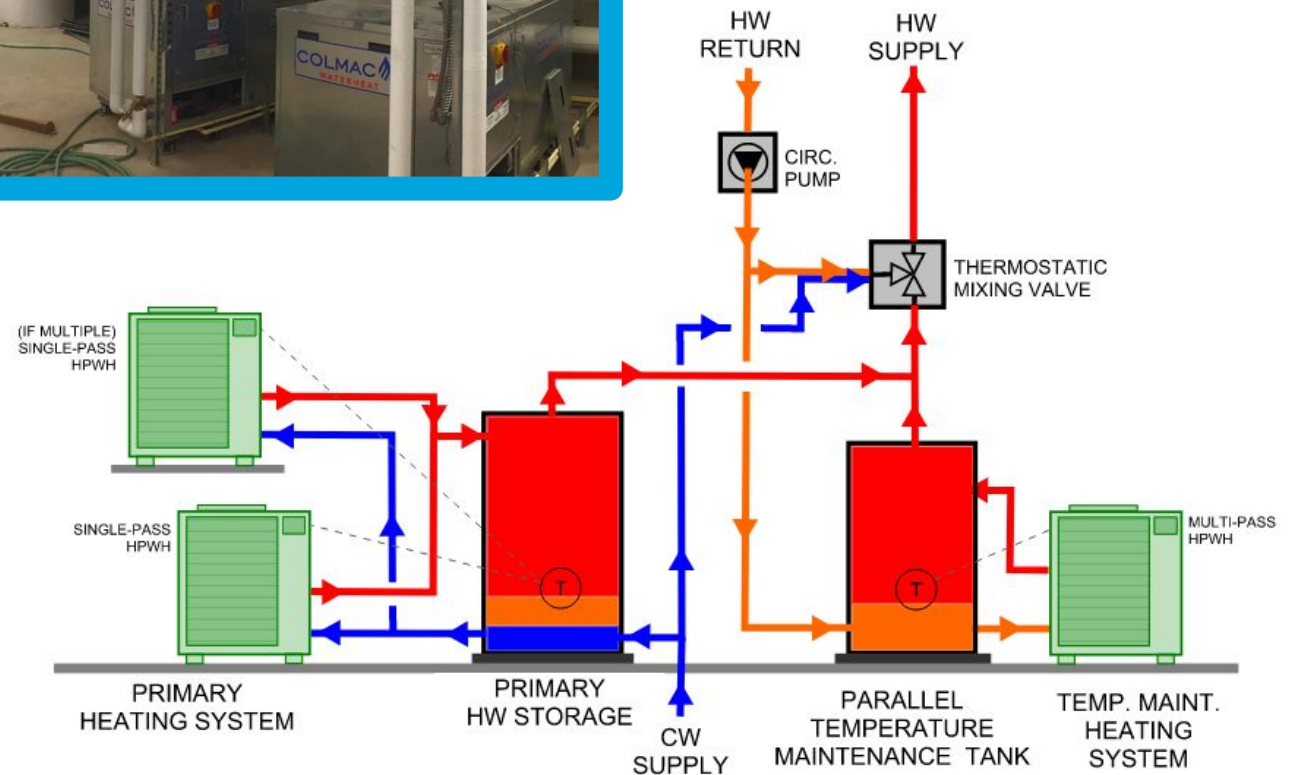
SMALL COMMERCIAL SYSTEM



LARGE COMMERCIAL SYSTEM

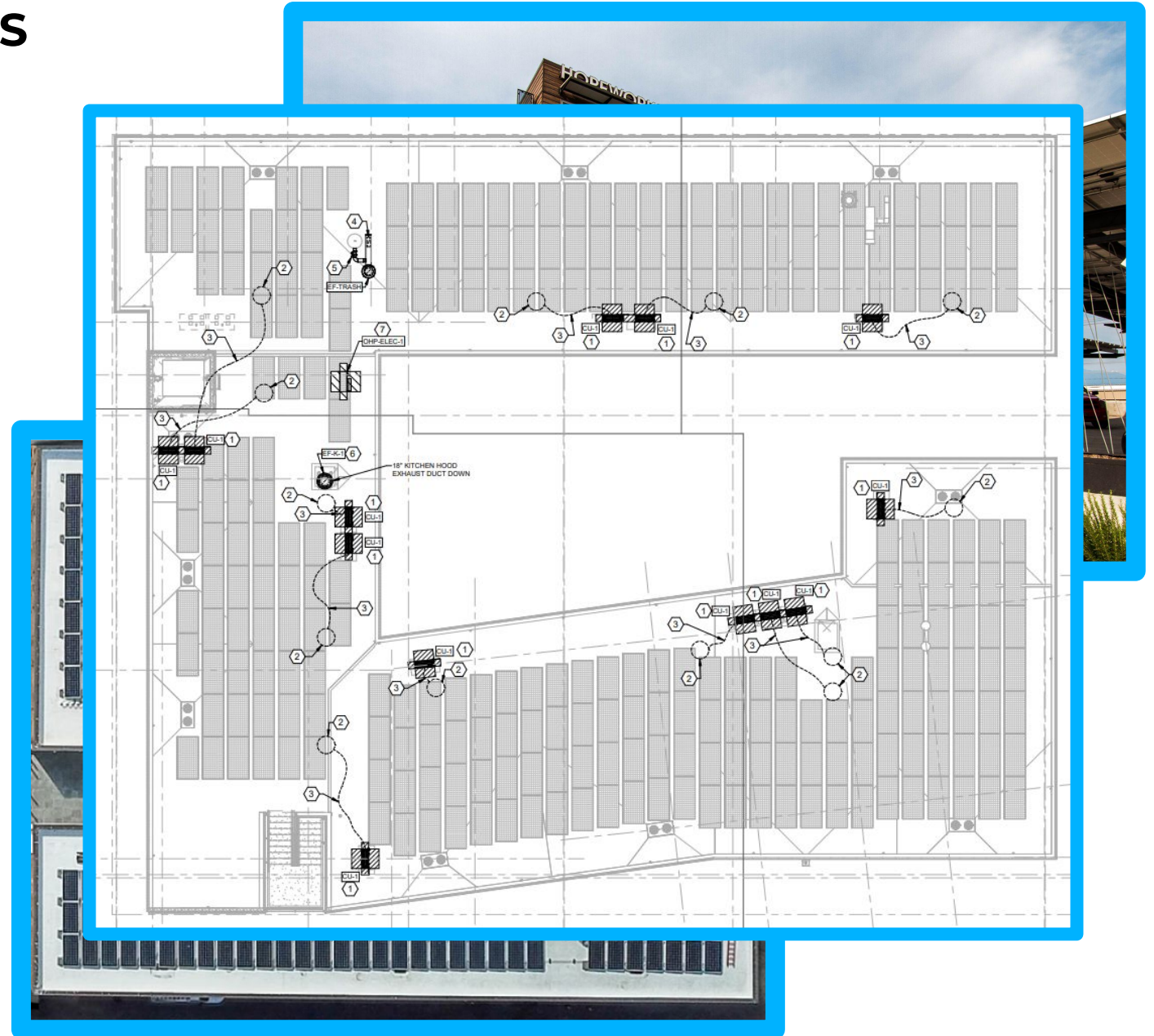
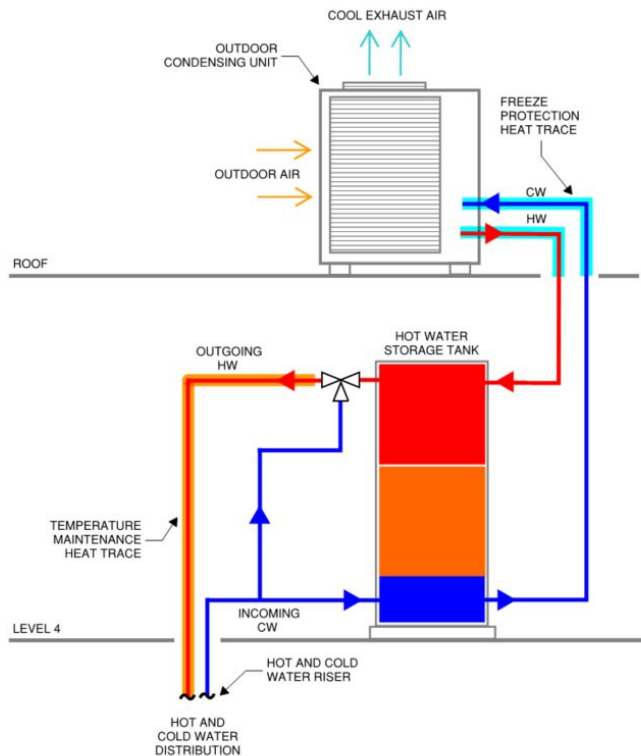


- Commercial equipment; engineered system
- 200 units
- Dedicated heating system:
 - Single pass primary HPWH
 - Multi pass temperature maintenance system

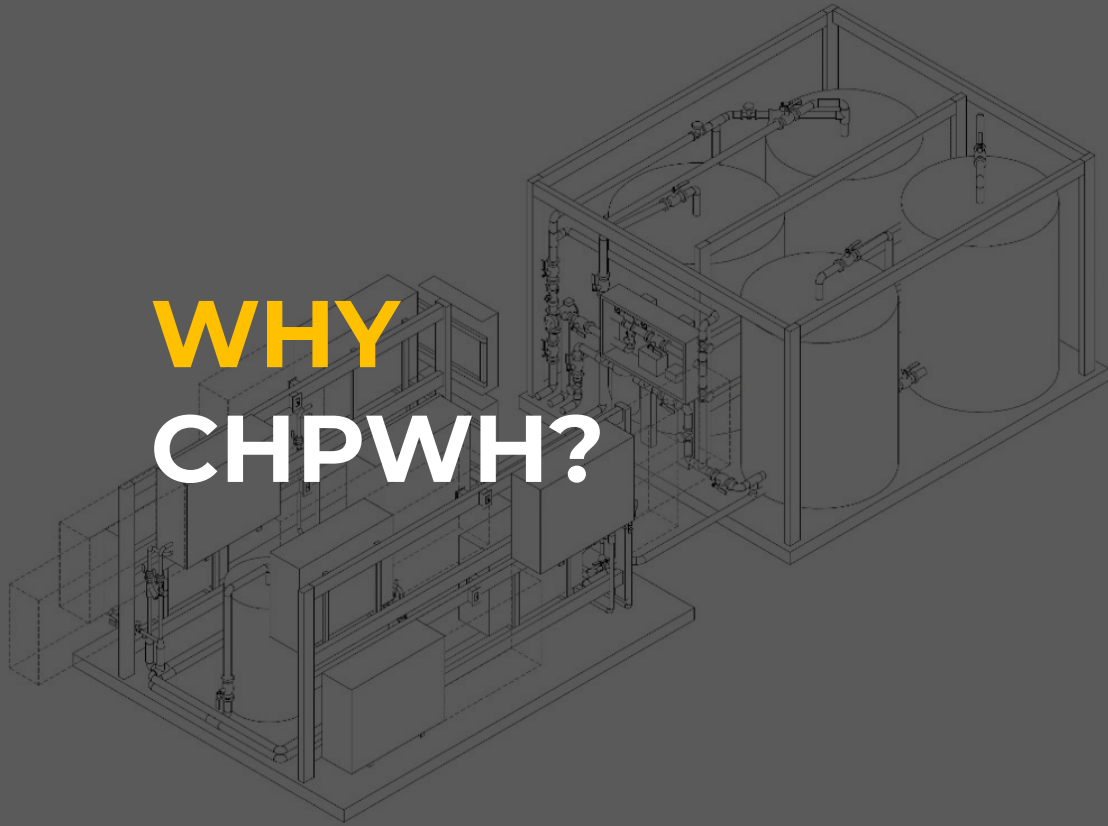


MULTIPLE COMMERCIAL **SYSTEMS**

- 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.

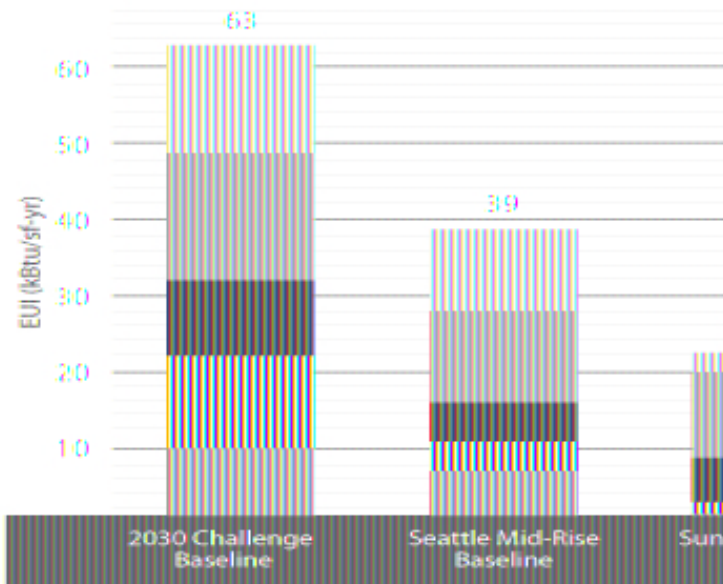


***R-1 and R-2:** Multifamily greater than 3 stories; any hotel/motel

SUNSET ELECTRIC



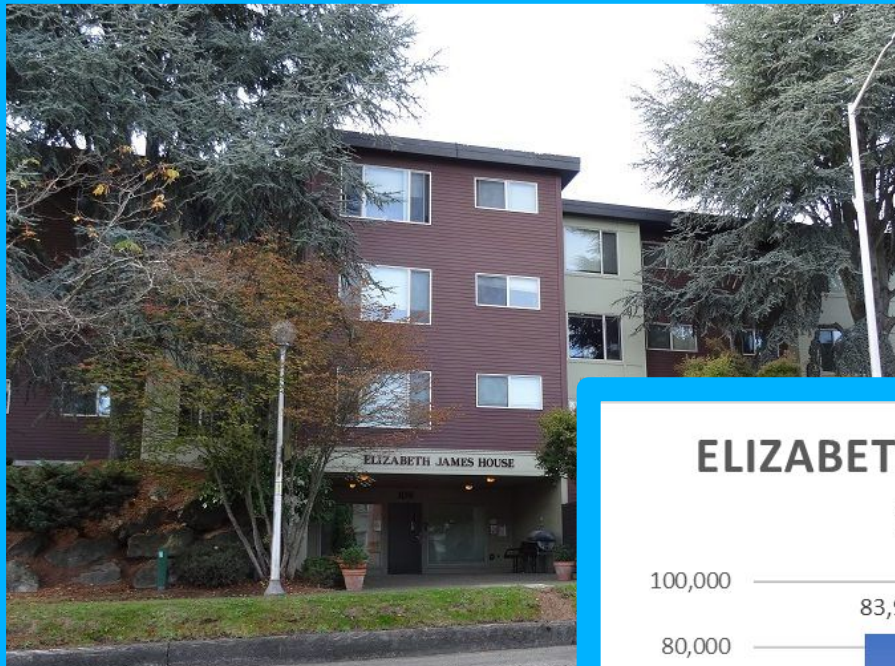
70% Reduction in DHW Energy



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

- 67,000 ft²
- 92 apartments
- R-134a air-source heat pump water heaters in parking garage

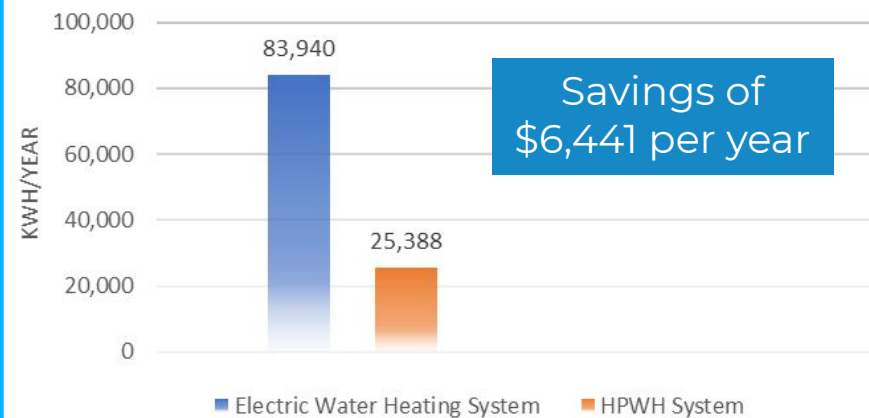
ELIZABETH JAMES



Elizabeth James House

70% Reduction in DHW Energy

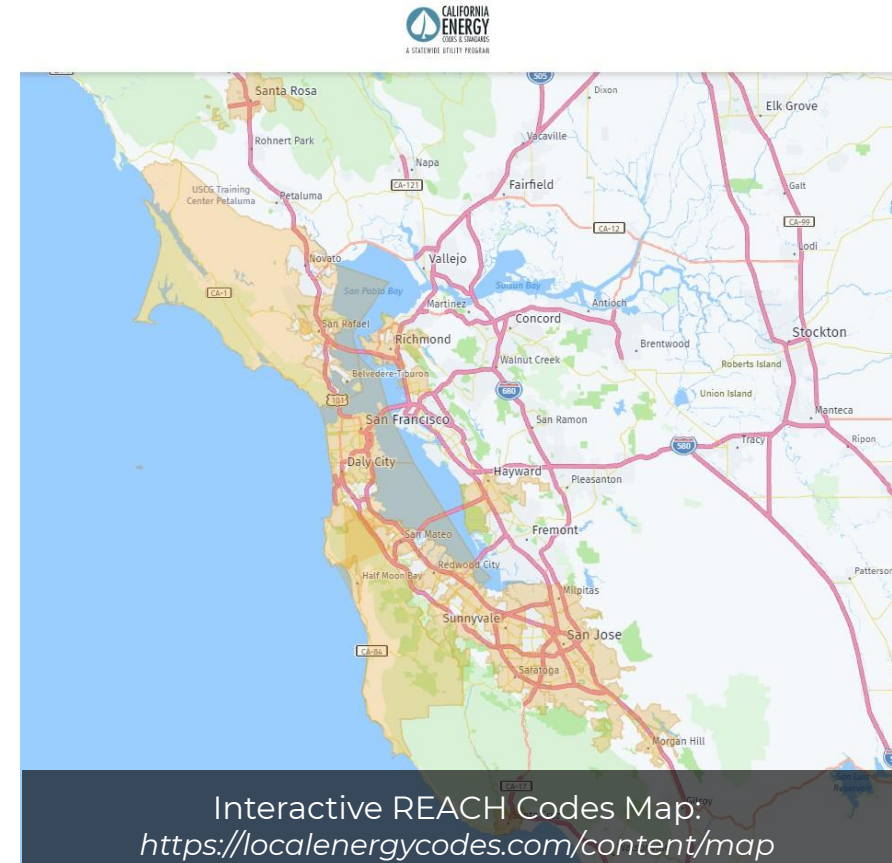
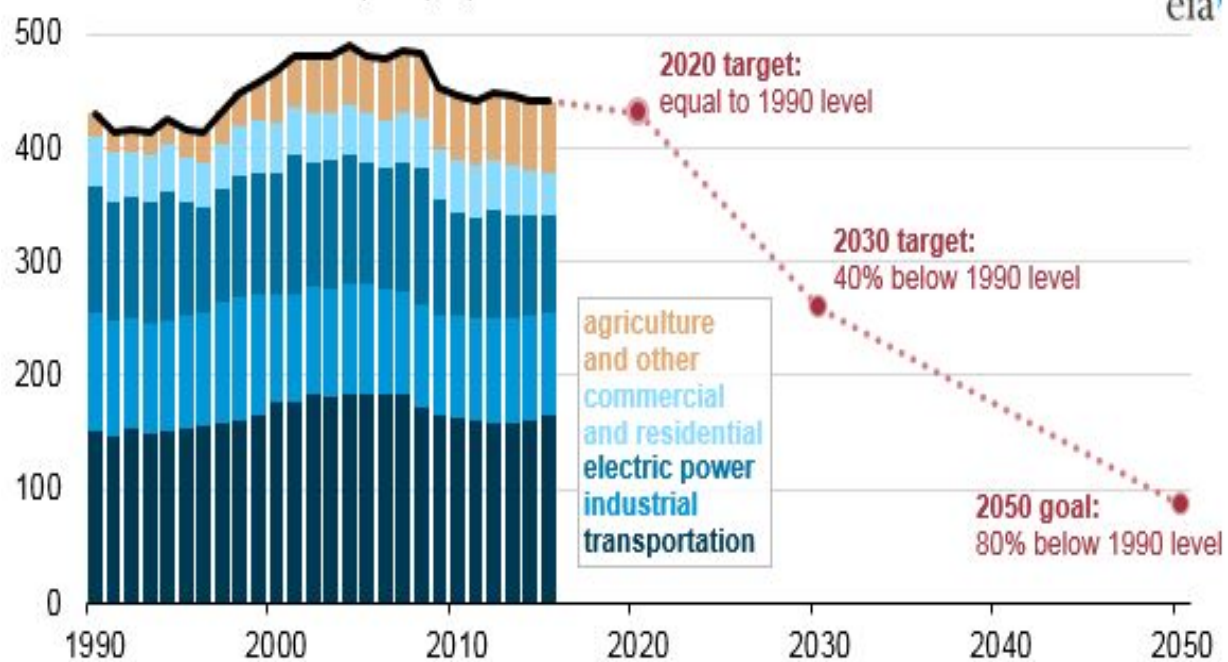
ELIZABETH JAMES: ENERGY USAGE BY SYSTEM TYPE



- Senior/low income
- 60 apartments
- 4 Sanden CO₂ HPs
- ZERO GHG emissions

WHY CHPWH?

California greenhouse gas emissions by sector (1990-2015) and targets through 2050
million tons carbon dioxide (CO₂) equivalent



LOWER FIRST COSTS

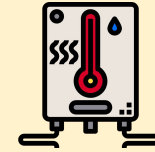
965 Weeks Street, East Palo Alto, CA

Affordable apartment homes that include
at least 30% extremely low-income units
and 50% low-income units

FOSSIL
GAS

vs

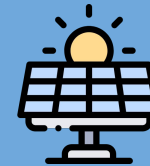
AIR TO H₂O
HPWH



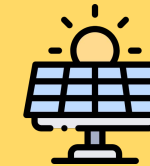
4 hot water plants serve 4 buildings

- Plants contain gas water heaters with integral storage tanks

- Storage tanks on roof
- Outdoor unit on roof or in mechanical room



Solar thermal collector w/ PV system



Solar PV system

Equipment cost:
\$192,000

Utility connection cost:
\$84,800

Total cost: \$276,800

Equipment cost:
\$169,262

Utility connection cost:
\$27,000

Total cost: \$196,262

OPERATING COST COMPARISON

FOSSIL GAS SYSTEM

VS

AIR TO WATER CO₂ HPWH

Gas usage/year:
18,722 therms

Average estimated
cost/therm: \$1.75

Estimated gas
cost/year: **\$32,829**

(no load shifting)

Electricity usage/year:
130,154 kWh

Time-of-use rate
(peak, partial peak, off-peak)

Estimated electric
cost/year: **\$33,065**

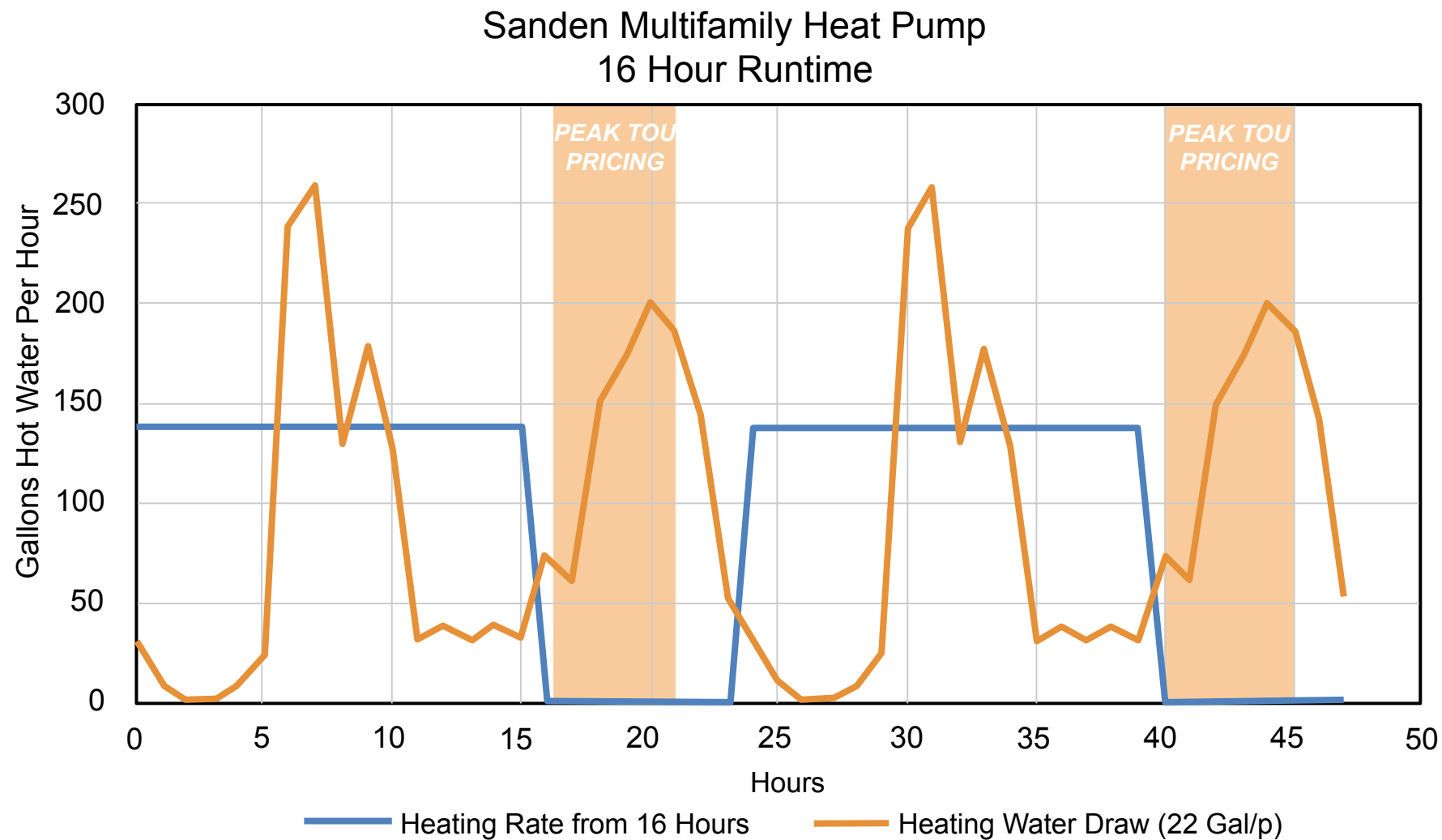
(load shifting)

Electricity usage/year:
130,154 kWh

Time-of-use rate
(peak, partial peak, off-peak)

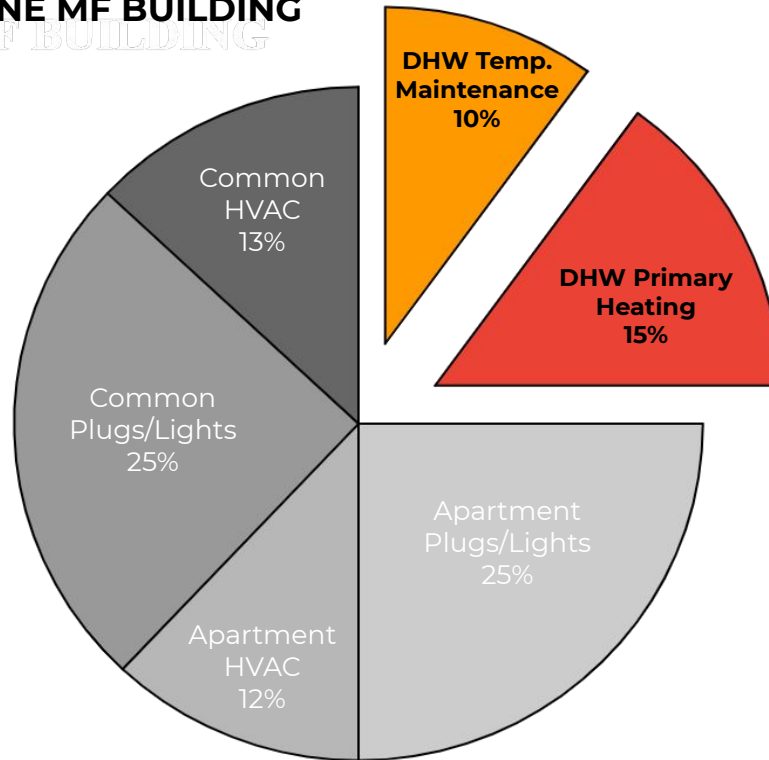
Estimated electric
cost/year: **\$31,672**

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



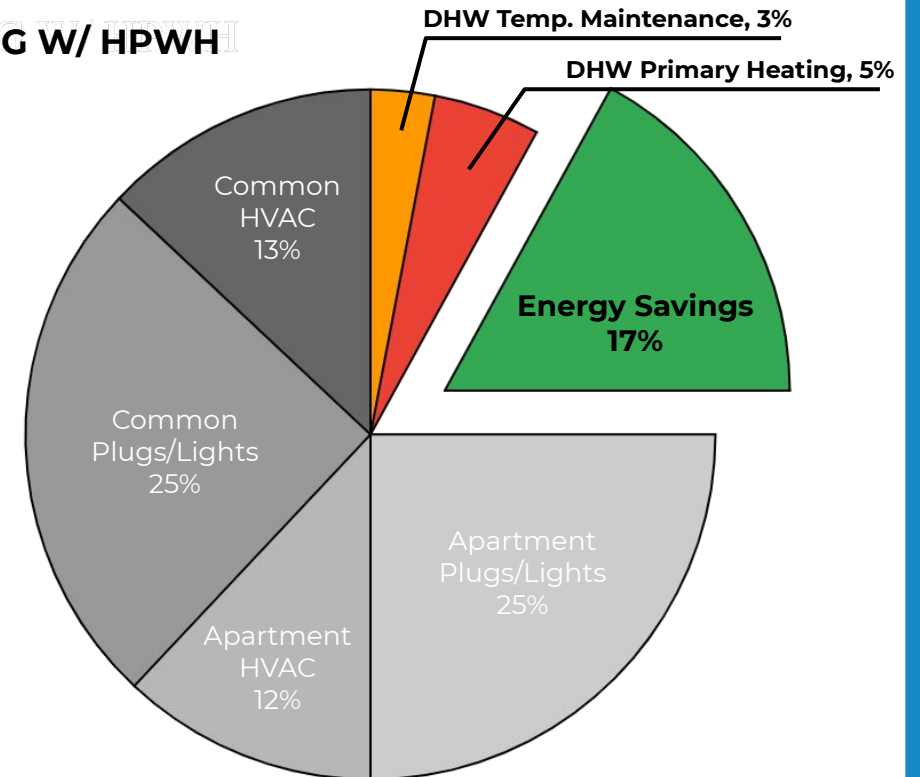
WHY CHPWH?

BASELINE MF BUILDING



- ◆ DHW represents 25% of annual building use

MF BUILDING W/ HPWH



- ◆ CHPWH systems cut energy usage down by 3x

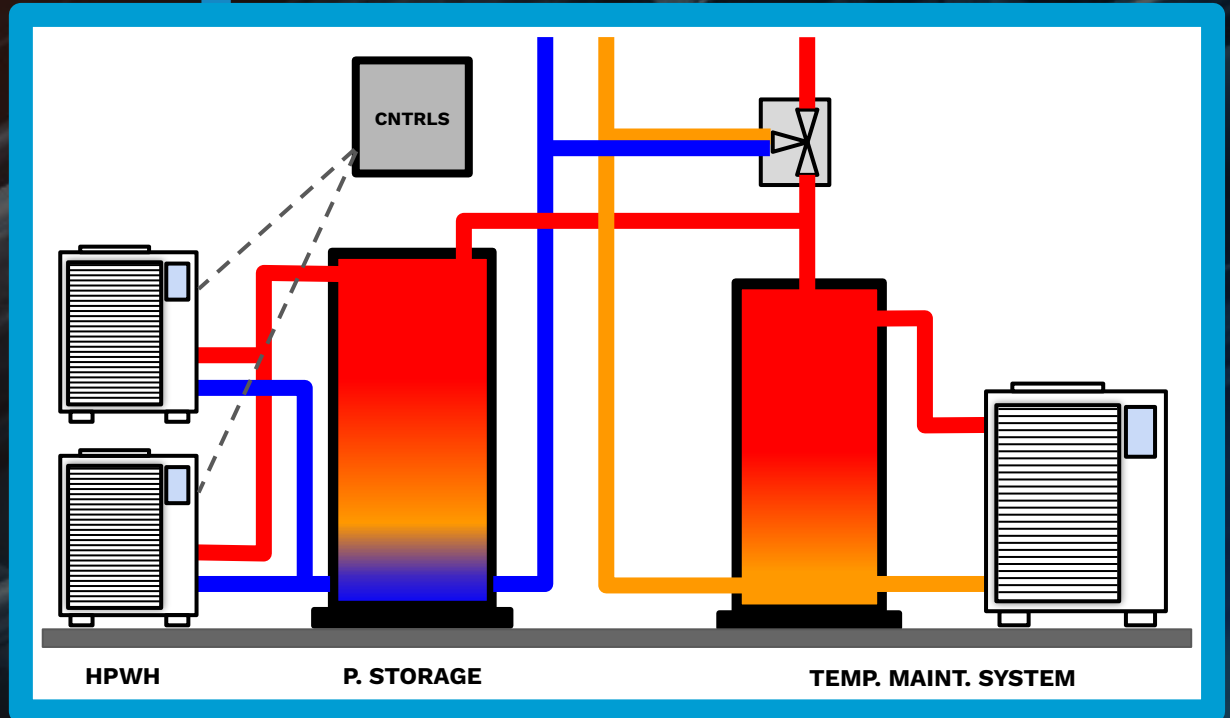
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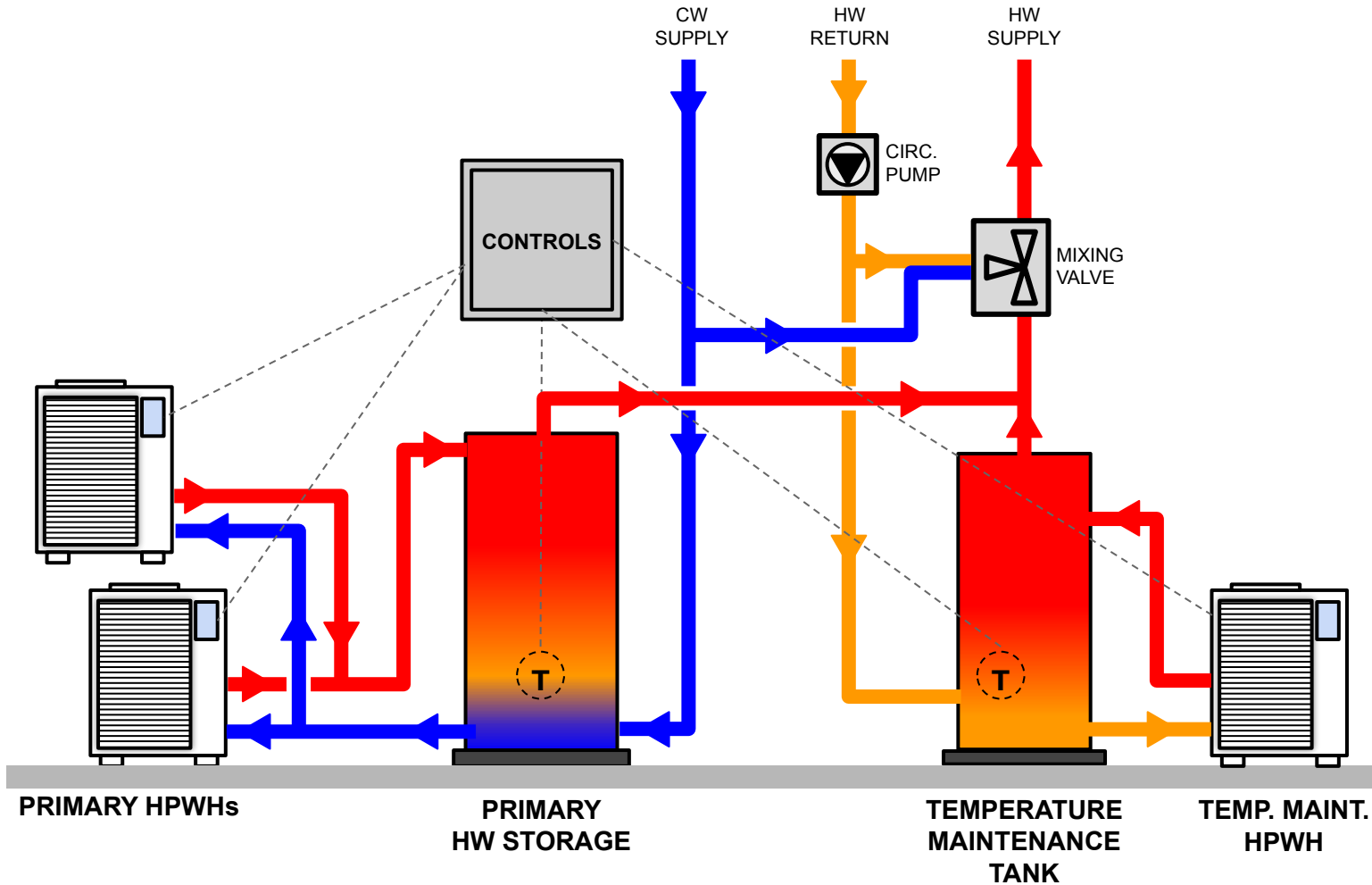
What aspects of CHPWH systems are most appealing to you?

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CHPWH SYSTEM COMPONENTS



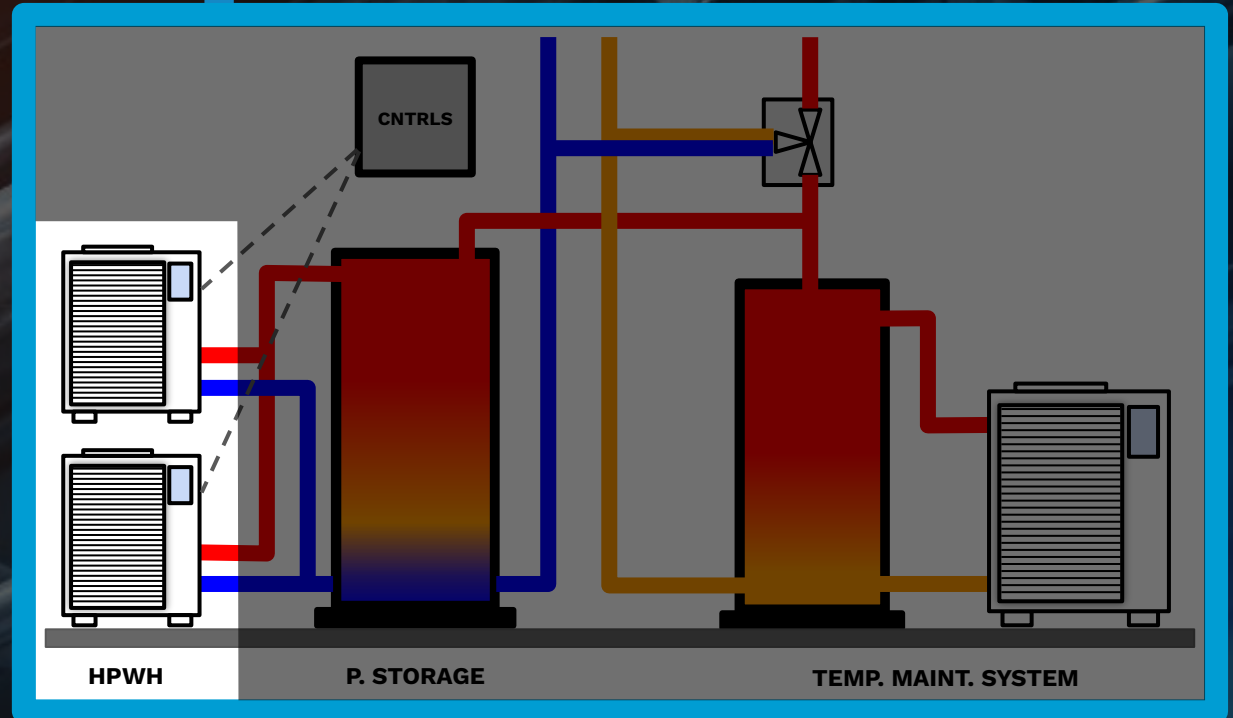
FOUR CHPWH SYSTEM COMPONENTS



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

COMPONENTS:

HPWH



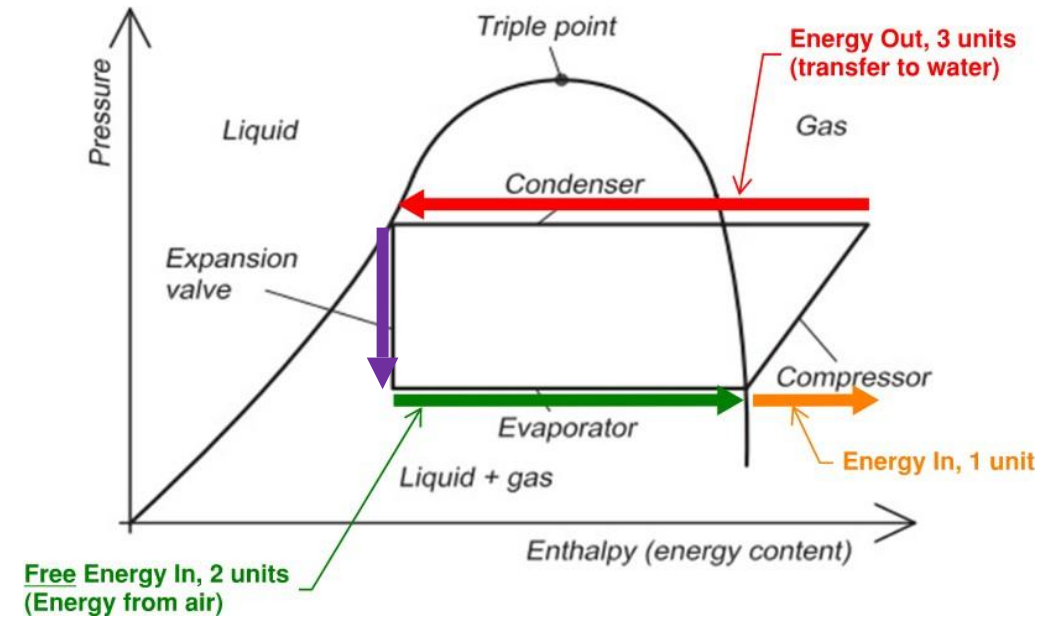
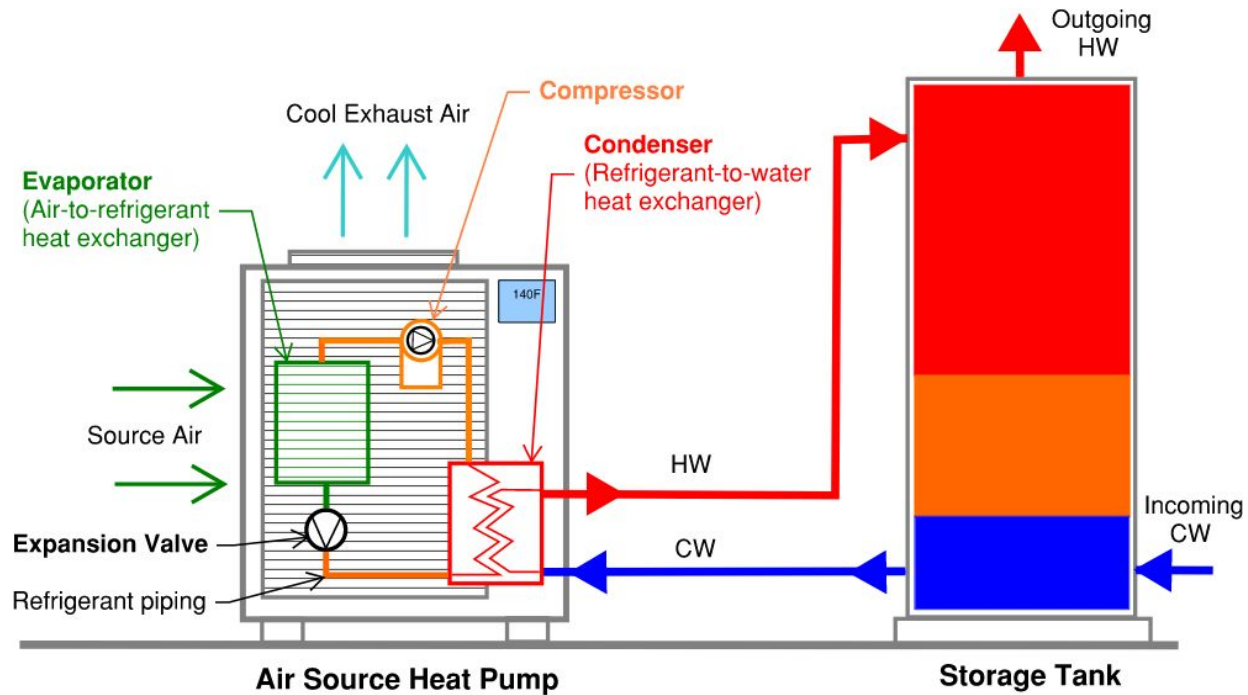
PRIMARY HEAT PUMP



PRIMARY HP = ENGINE

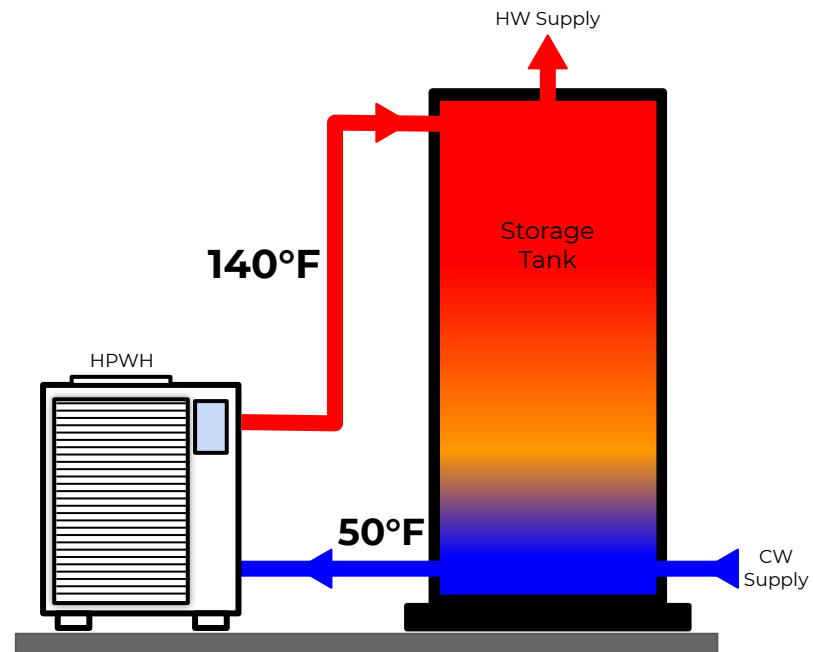
HOW HEAT PUMPS WORK

Air Source Heat Pump with Storage Tank



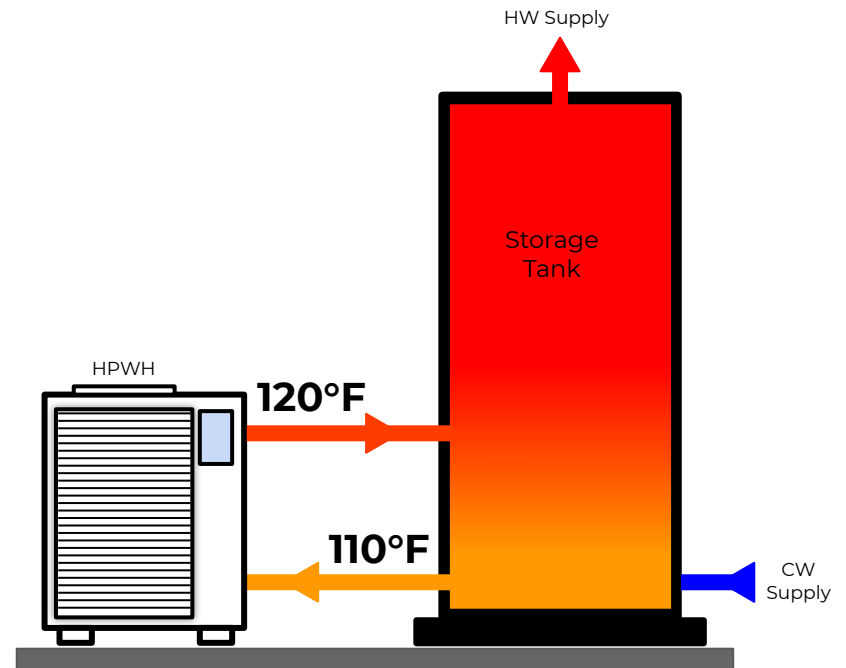
Moving HEAT
(not making heat)

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



SanCO₂
(1.25 ton)

Mitsubishi
(10 ton)

Single-Pass
CO₂/R-744



Colmac
(10 - 30 ton)

Nyle
(10 - 30 ton)

Single- or Multi-Pass
R-134a



HPWH CONSIDERATIONS



Rheem
(> 1 ton)



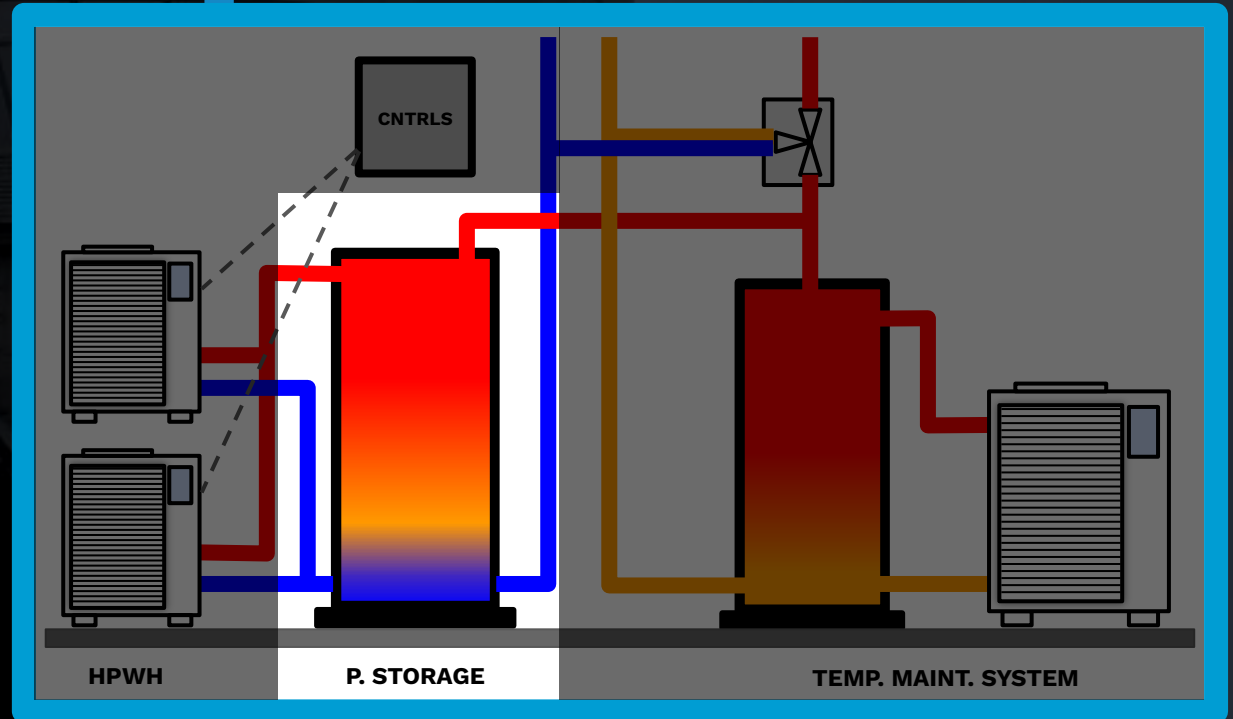
Nyle
(10 - 30 ton)

- 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

The background of the slide is a photograph of an industrial facility, likely a refinery or chemical plant. It features a complex network of large, dark-colored pipes and structural steel beams. The lighting is somewhat dim, with a blueish-grey tint overall, and a darker, reddish-brown gradient overlay on the left side. The text "LET'S PAUSE FOR QUESTIONS" is centered in a bold, white, sans-serif font.

LET'S PAUSE FOR QUESTIONS

COMPONENTS: PRIMARY STORAGE



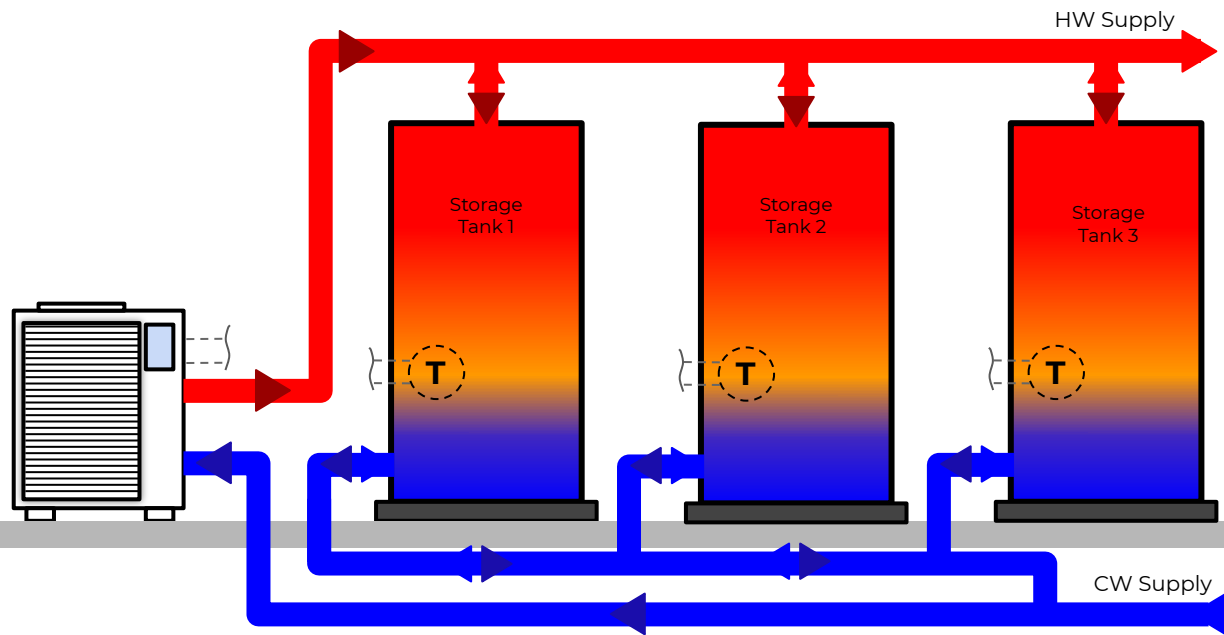
PRIMARY STORAGE TANK(S)



A BATTERY BANK

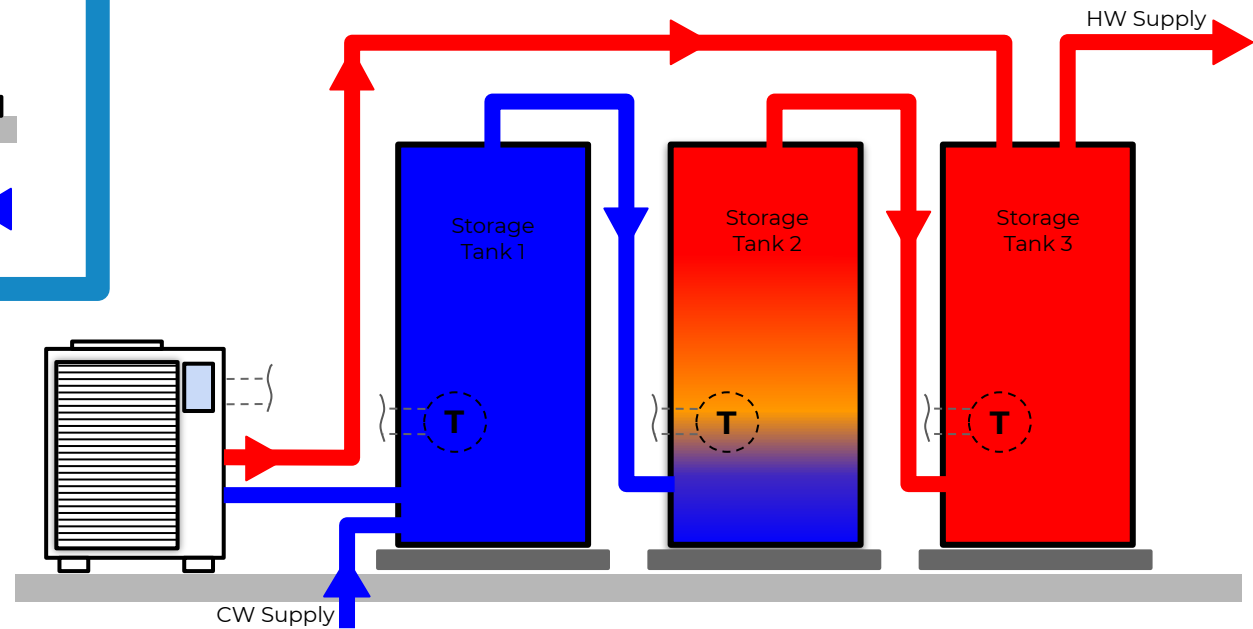


PRIMARY STORAGE PLUMBING

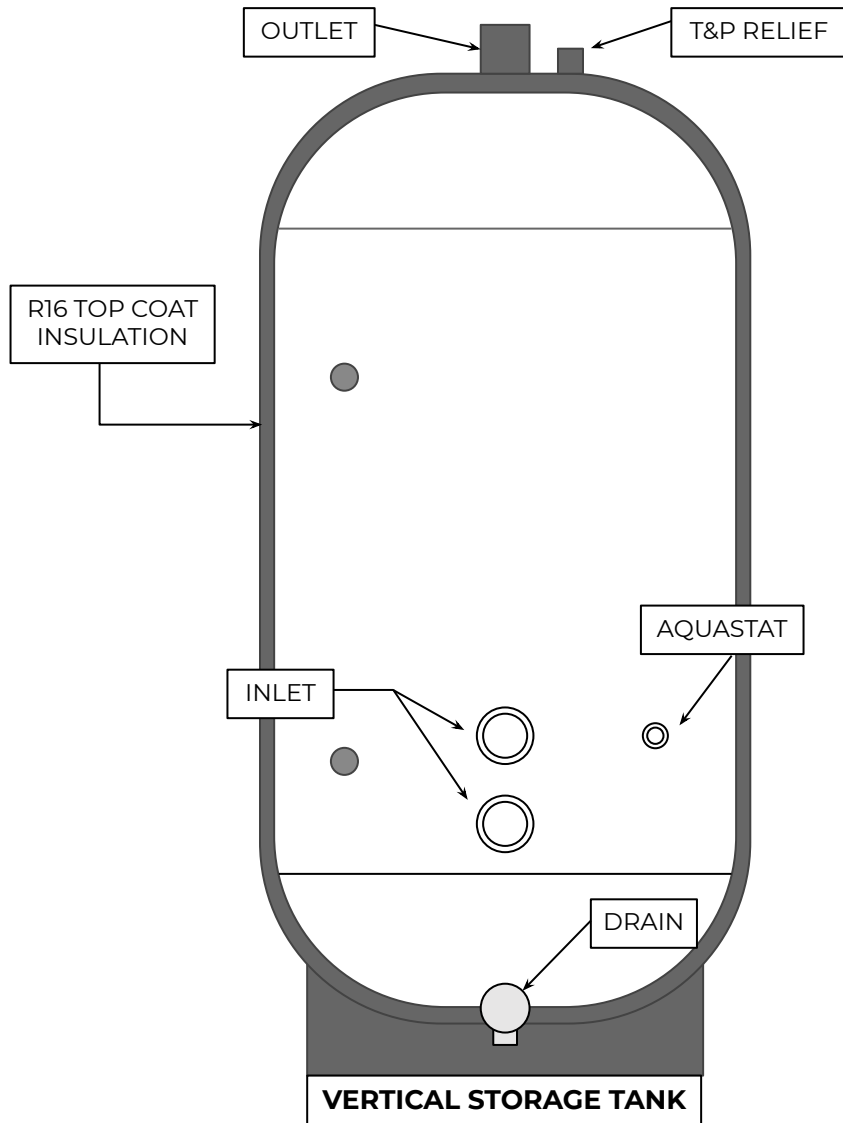


IN SERIES

IN PARALLEL



HW STORAGE **CONSIDERATIONS**

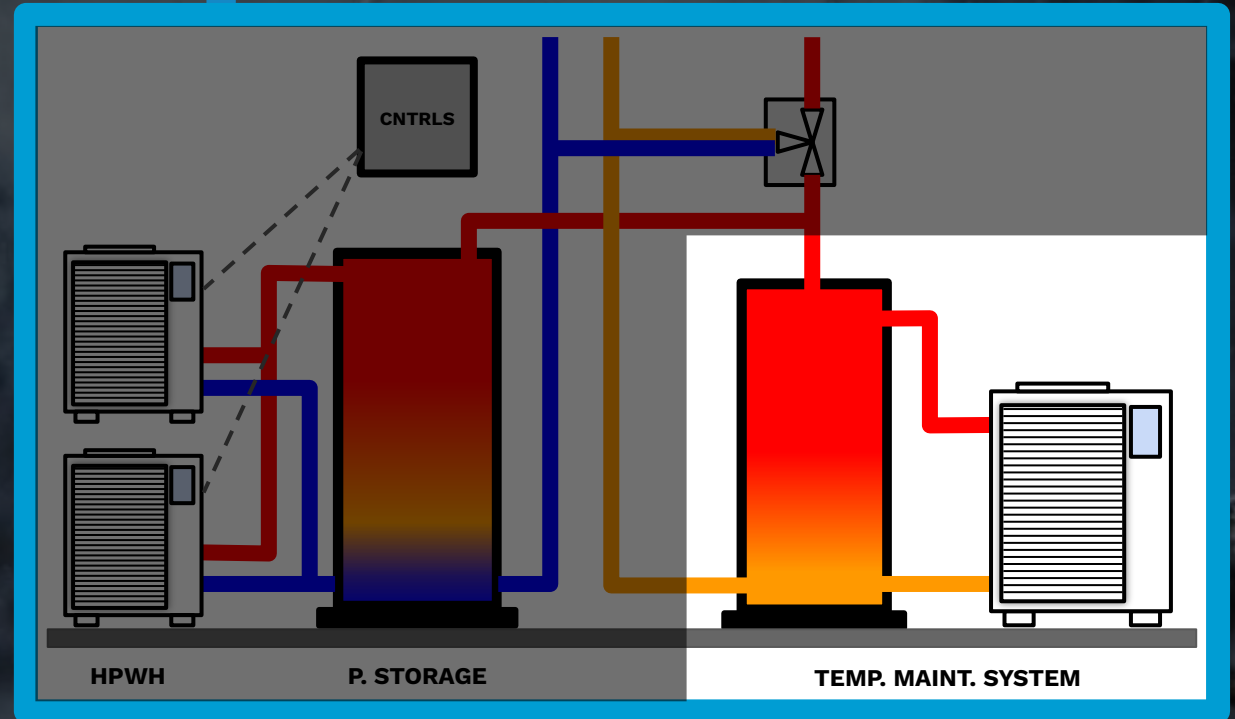


- Physical space, room & door size
- Vertical is better than horizontal
- Multiple tanks, series or parallel?
- Height of control sensor(s)
- Pipe connections, size & location
- Insulation level
- Thermal isolation
- Maintenance & access

The background of the slide is a photograph of an industrial facility, likely a refinery or chemical plant. It features a complex network of large, dark-colored pipes and structural steel beams. The lighting is somewhat dim, with a blueish-grey tint overall, and a darker, reddish-brown gradient overlay on the left side. The text "LET'S PAUSE FOR QUESTIONS" is centered in a bold, white, sans-serif font.

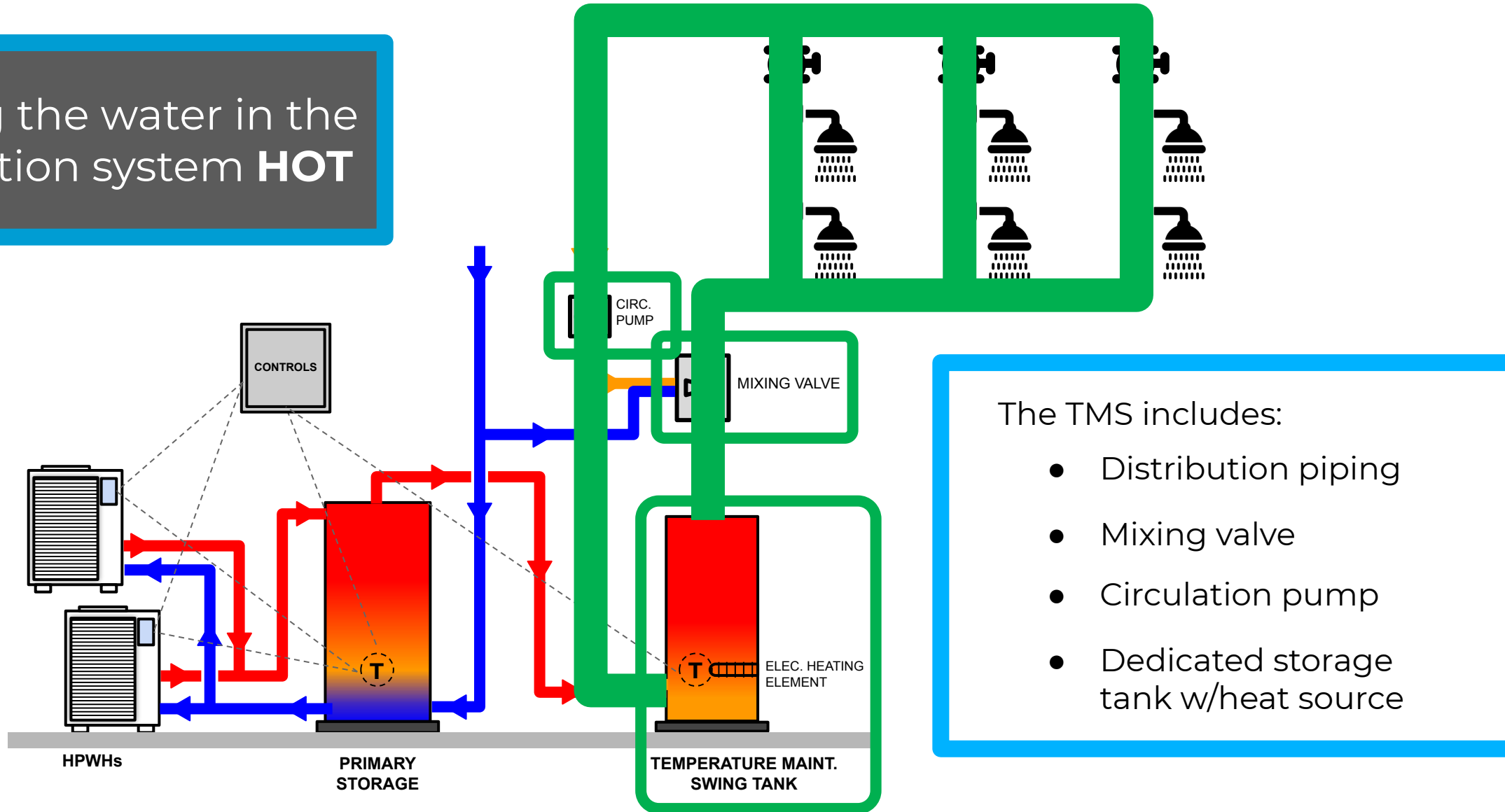
LET'S PAUSE FOR QUESTIONS

COMPONENTS: TEMPERATURE MAINTENANCE



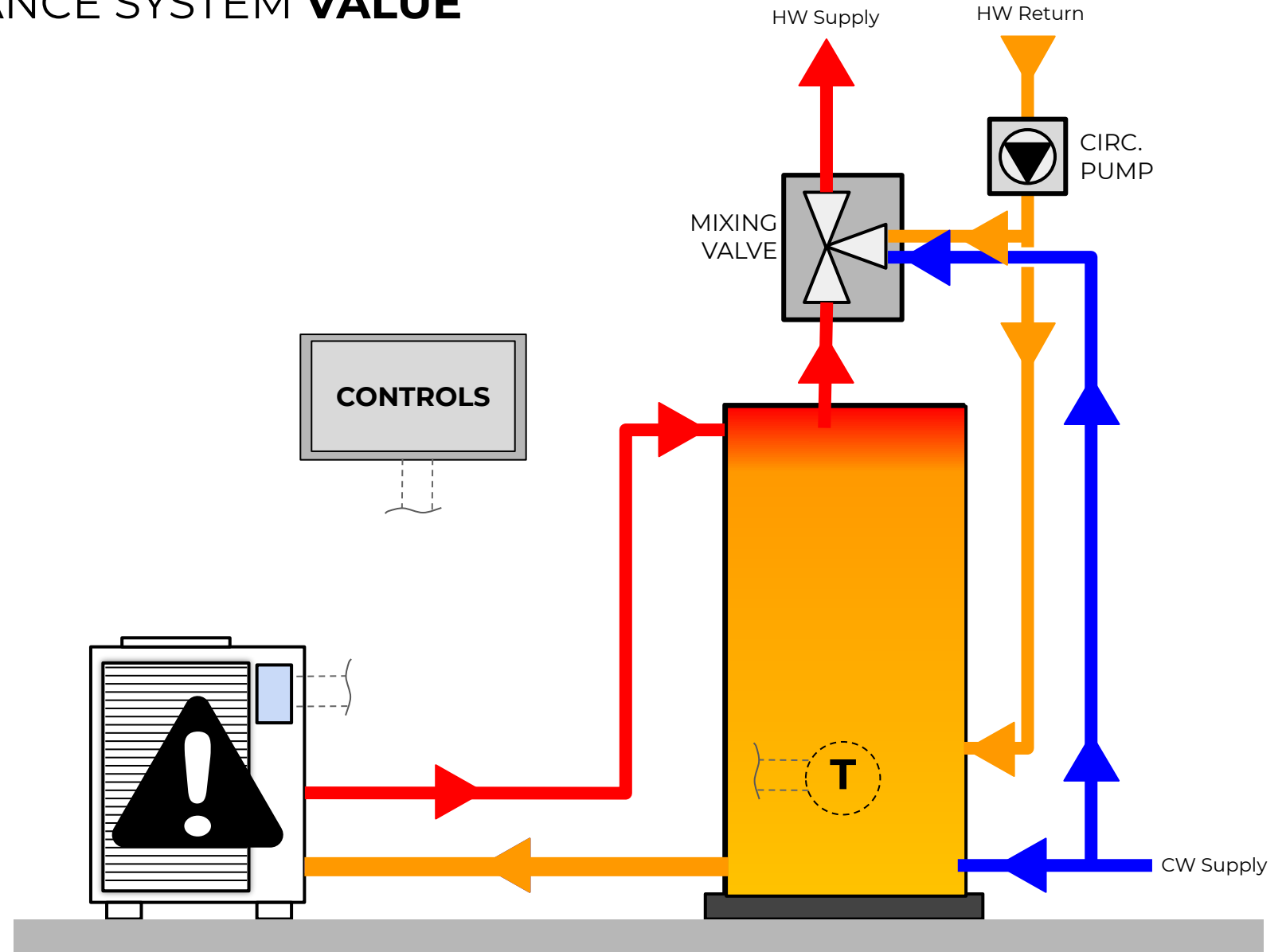
TEMPERATURE MAINTENANCE **SYSTEM**

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

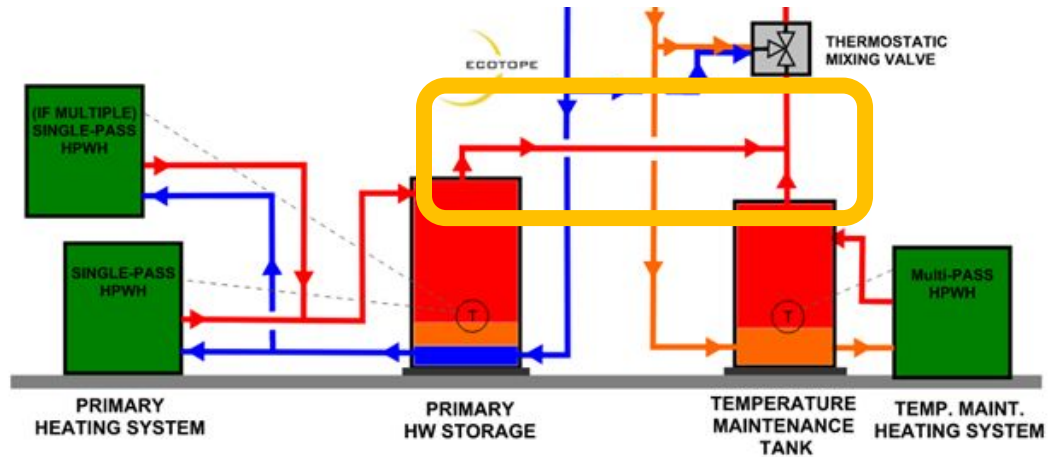


TEMPERATURE MAINTENANCE SYSTEM **VALUE**

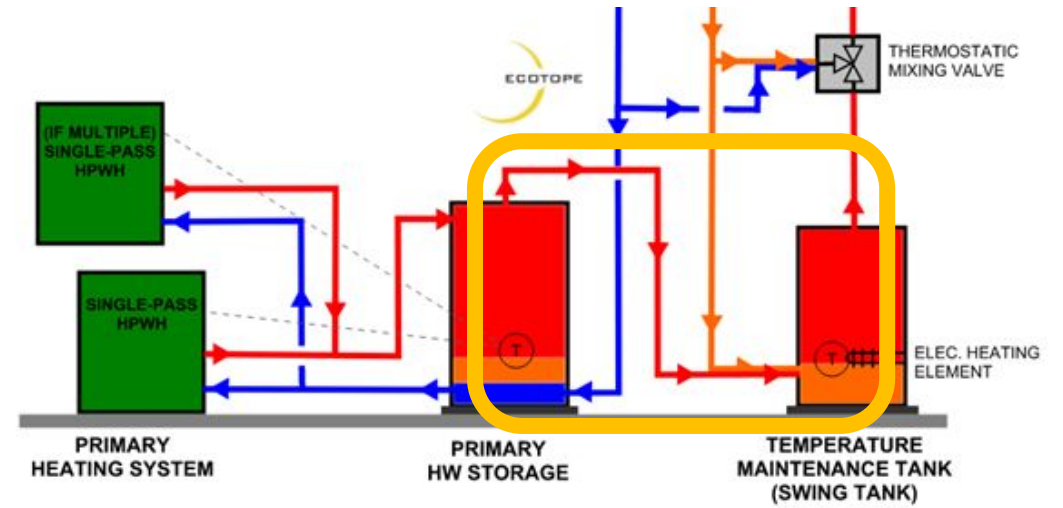
- HPs are very efficient at making **cold** water **hot**
- HW circulates through the distribution piping
- Water returns from the building slightly cooled
- Return water causes **mixing & destratification** in the storage tank
- HPs are not very good at making **warm** water **hot**



TWO RELIABLE TEMPERATURE MAINTENANCE REHEAT STRATEGIES



“Parallel Loop Tank”

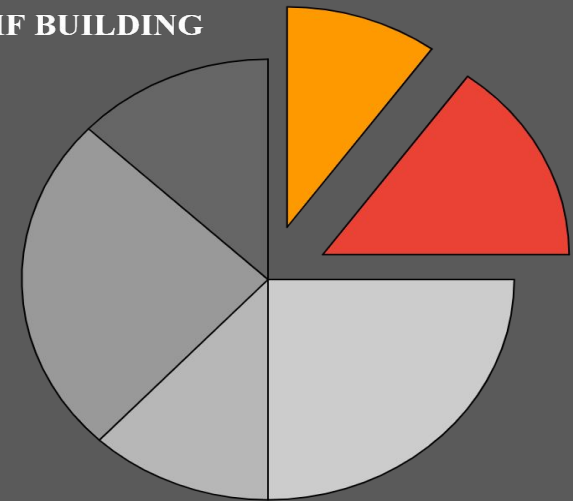


**“Series Loop Tank”
or “Swing Tank”**

TEMPERATURE MAINTENANCE: **HW CIRCULATION**

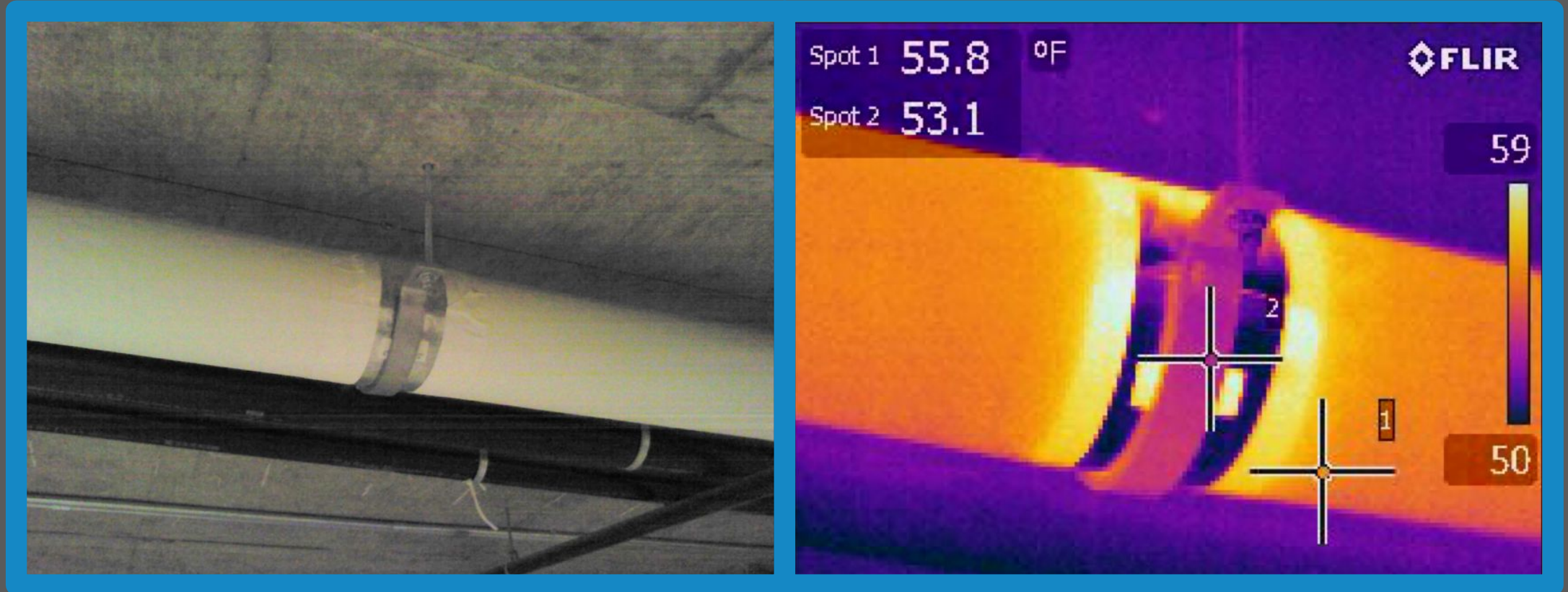


MF BUILDING



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*	1.5
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/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 set forth in Appendix A. After determining the permissible fixture flow rate 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	1.5	1.5
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	0.0
13 Other Fixture 2	0	0.0	0.0	0.0
14 Other Fixture 3	0	0.0	0.0	0.0
Total Number of Fixtures	6			
90th Percentile Demand Flow	8.5 (GPM)			

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 dishwasher
1 clothes washer
1 WC

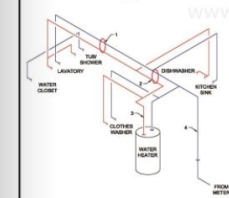


FIGURE 1
RESIDENTIAL BUILDING WITH SIX INDOOR FIXTURES

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

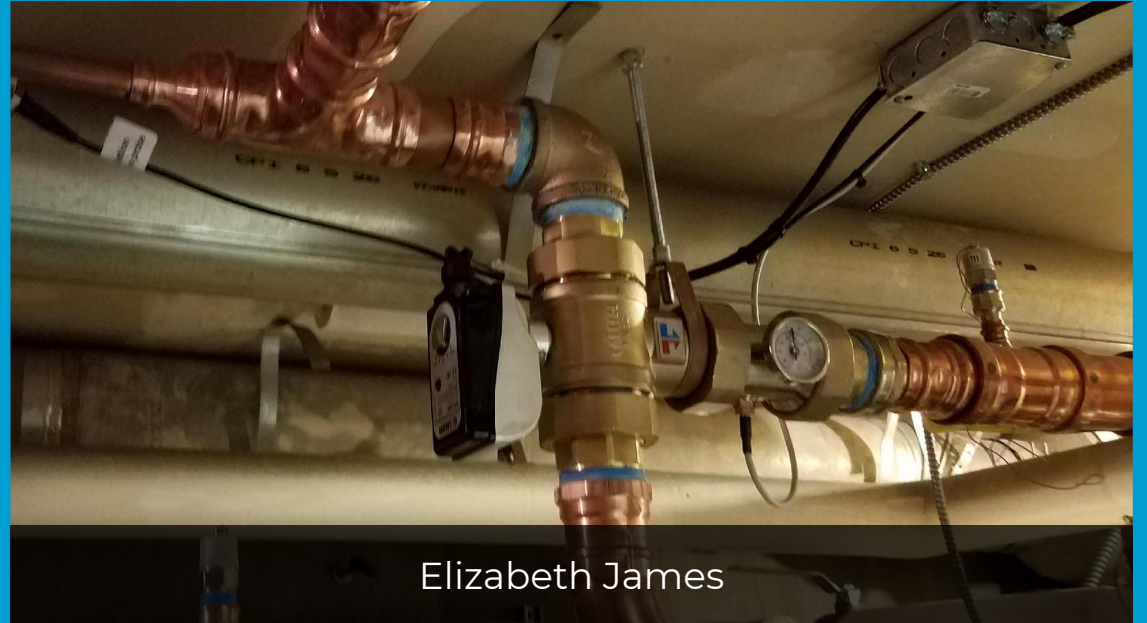
The Water Demand Calculator (WDC) in Figure 2 is used to determine the demand load expected from indoor water use. The WDC has white-shaded cells and light gray-shaded cells. The values in the light gray cells are derived from a national survey of indoor water use at homes with efficient fixtures and 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**.

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**There will be A LOT more on this next time,
but what questions do you have now?**

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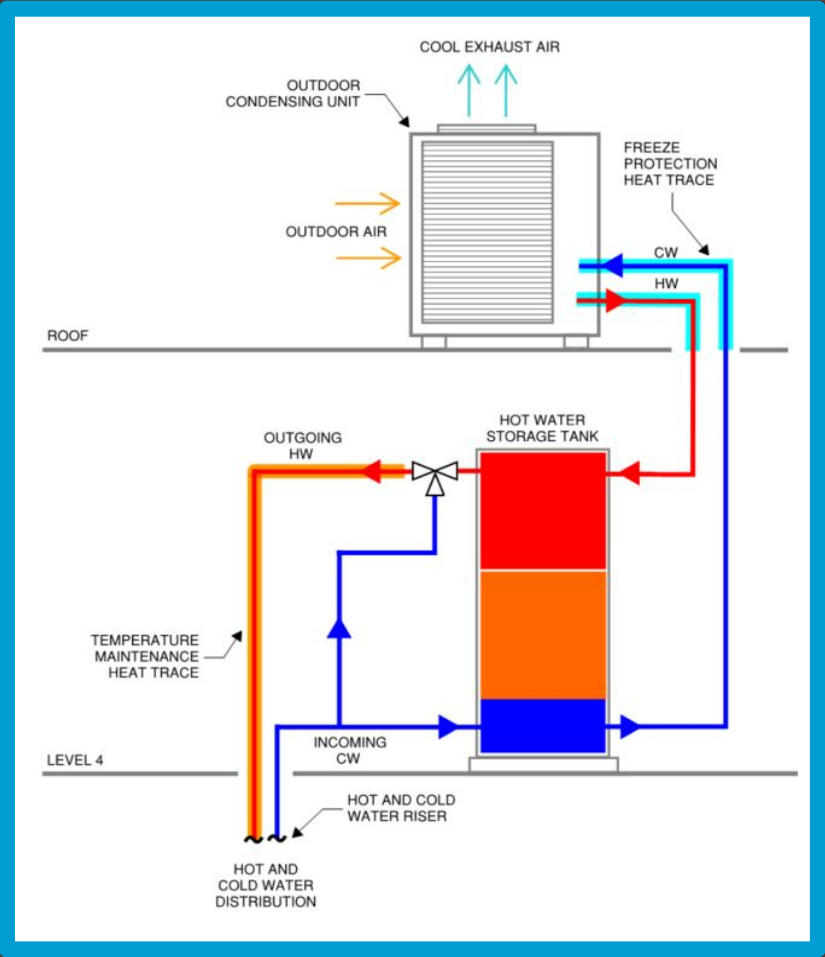
The diagram illustrates a hydronic heating system layout. It features three main components: an HPWH (Heat Pump Water Heater) on the left, a P. STORAGE (Pressure Storage) tank in the center, and a TEMP. MAINT. SYSTEM (Temperature Maintenance System) on the right. The HPWH and P. STORAGE are connected by red and blue pipes. The P. STORAGE is connected to the TEMP. MAINT. SYSTEM by red and blue pipes. A central control unit labeled 'CNTRL' is connected to the HPWH and P. STORAGE by dashed lines. The TEMP. MAINT. SYSTEM is connected to a circulator pump, which is connected to the P. STORAGE by red and blue pipes. The entire system is set against a light blue background.

CONTROLS **OPTIONS**

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

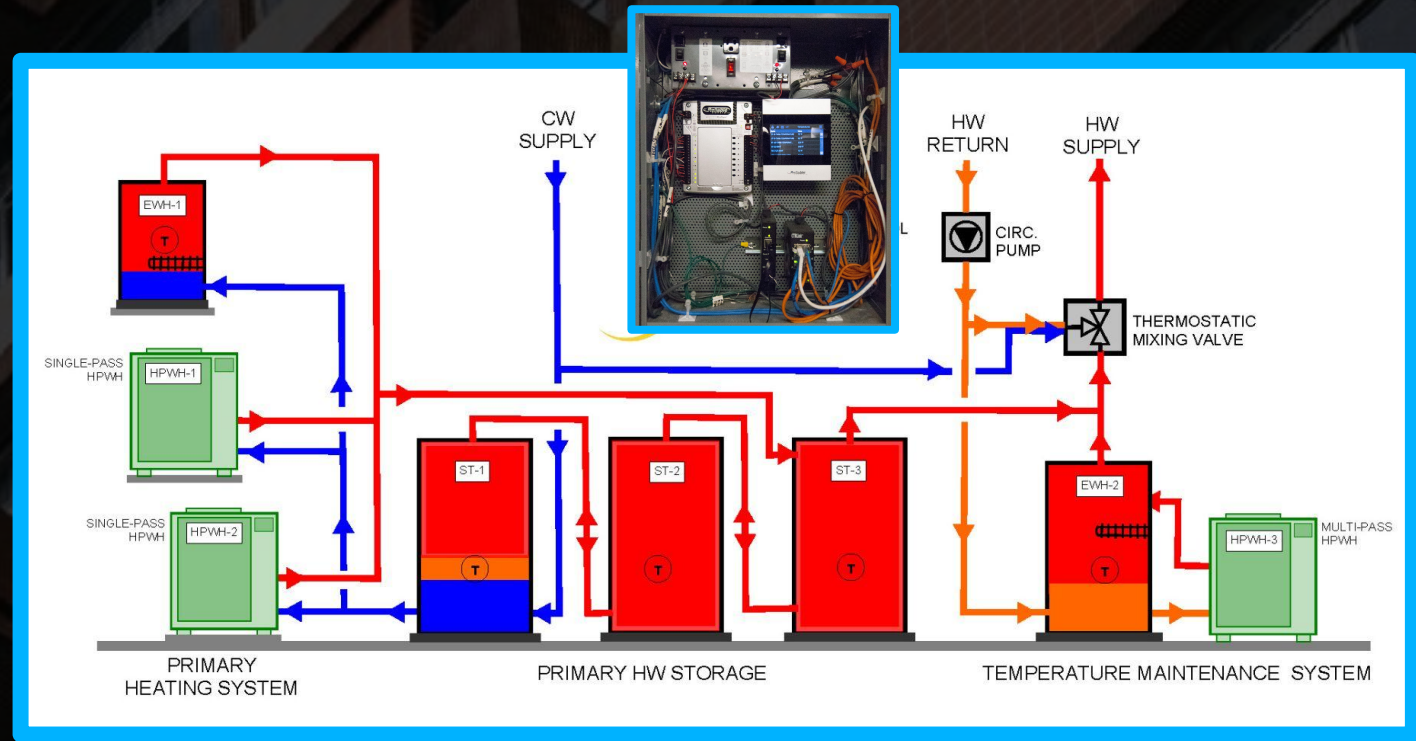
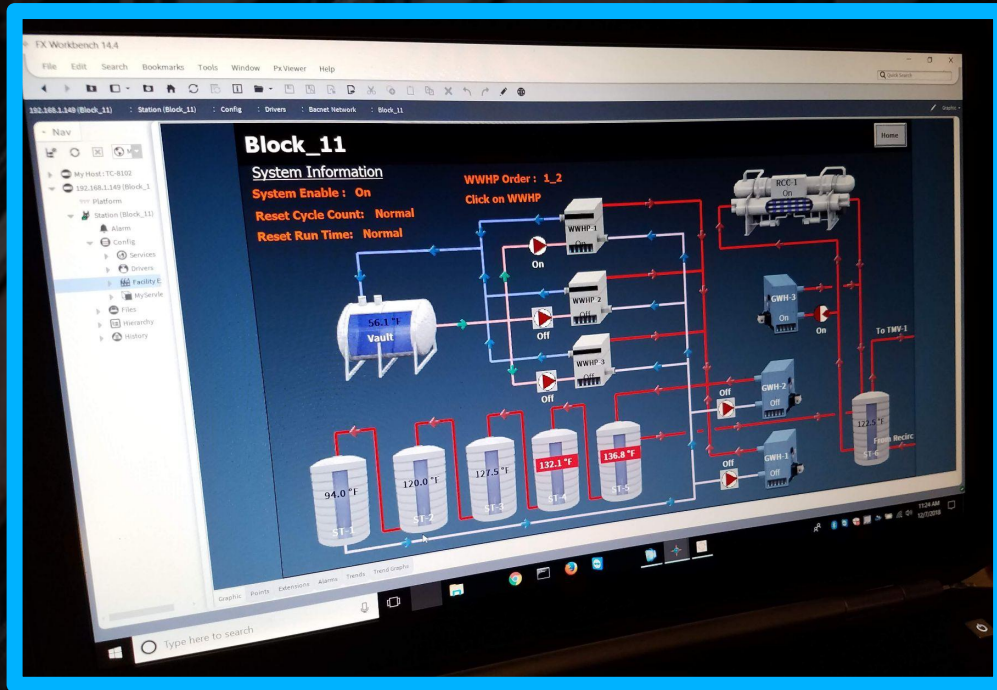


CHPWH CONTROL SYSTEM: **INTERNAL**



INTERNAL

CHPWH CONTROL SYSTEM: **THIRD PARTY**



THIRD PARTY

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Take a moment to reflect!

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RECAP:

- ◆ Why choose a CHPWH system?
- ◆ What is a CHPWH system?
- ◆ What makes a good CHPWH system candidate?
- ◆ CHPWH system components



RECAP:

CHPWH COMPONENTS:

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



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What questions remain for you? Write them here so we know to tackle them next time!

① Start presenting to display the poll results on this slide.

NEXT TIME

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



UPCOMING TRAINING & RESOURCES

**Seattle City Light, in collaboration
w/ the Lighting Design Lab 2022**

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

CHPWH: Engineering Deep Dive (Pt 2)

January 18th, 10AM-12PM

CHPWH: Design, Maintenance & Operation

January 25th, February 1st, 8th, 15th
10AM - 12PM

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

Thomasena Philen at: TPHILEN@DRINTL.COM

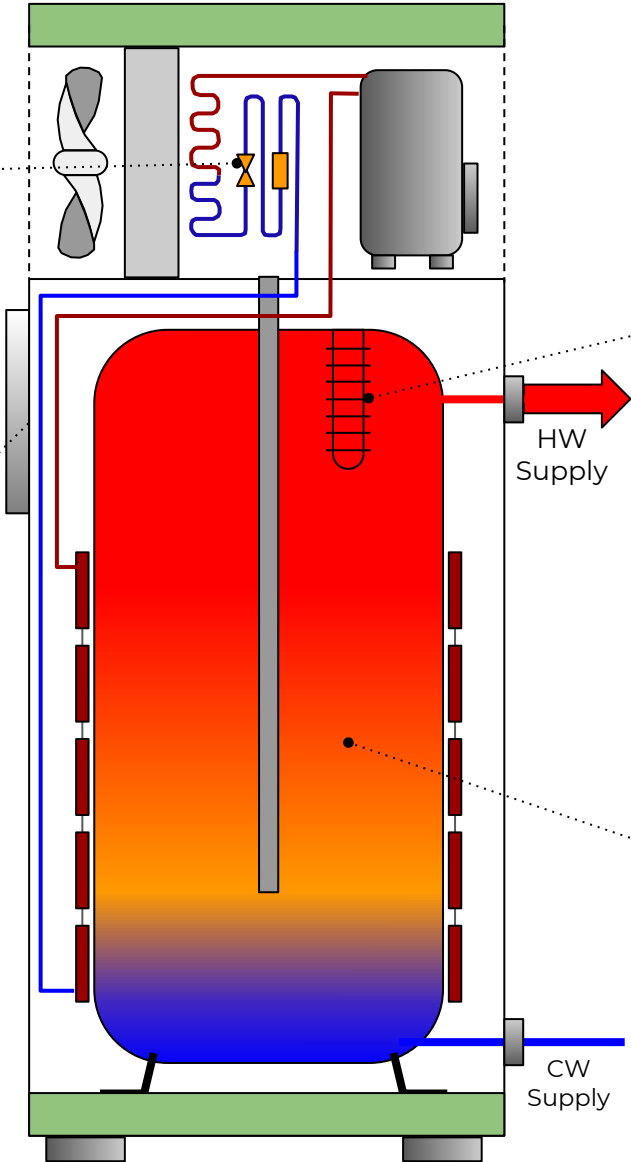




THANK YOU



HOW DOES IT COMPARE?



TEMPERATURE MAINTENANCE SYSTEM

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

