lighting design lab

CHPWH System Considerations in a Nutshell

Presented by
Evan Green, Research Engineer
Ecotope, Inc.

March 14, 2024

Seattle City Light

Webinar Procedures

- All attendees are on mute
- Submit questions at any time
- The webinar is being recorded
- Please take the after-class survey!

Look for the Questions icon in the top menu bar

Chat icon

What Is This “Lighting Design Lab”?

- Seattle City Light's go-to resource for lighting and lighting controls since 1989 – 30+ years
- Formed by BPA and NW utilities to fill education needs for the transforming market
- Expanded to include resources that support whole buildings

Upcoming Events

Course	Day	Time
Delivering High Performance Using VHE DOAS System	Thu Mar 28	10:00am-11:30am
Seattle City Light Controls Incentives	Thu Apr 4	10:00am-11:00am
The Decarbonization Countdown: What's in Store for Commercial HVAC Systems	Thu Apr 18	10:00am-11:30am

Stay up-to-date at LightingDesignLab.com and by subscribing to our newsletter.

CHPWH System Considerations in a Nutshell

Evan Green
Research and Design
Ecotope
Evan@ecotope.com

Agenda

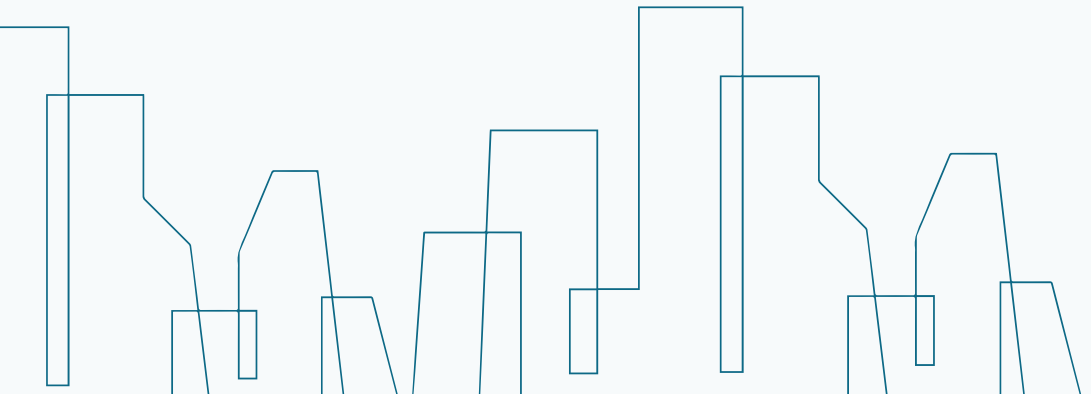
What is a CHPWH system?

Why use a CHPWH system?

Component Considerations

CHPWH System Sizing

Market Delivery



What is a CHPWH system?

Heat Pump Water Heater (HPWH)

Commercial Heat Pump Water Heating (CHPWH) System

NEEA Advanced Water Heating Specification

Anchoring the industry.

https://neea.org/img/documents/Advanced-Water-Heating-Specification.pdf

NEEA Qualified Products List

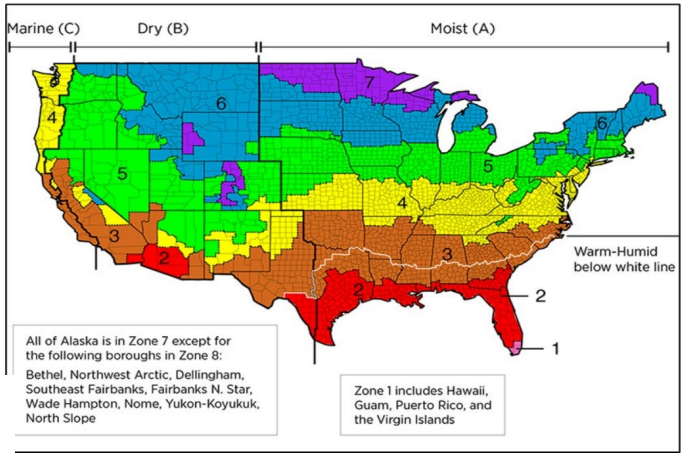


Table 1. HPWH System Efficiency Tiers

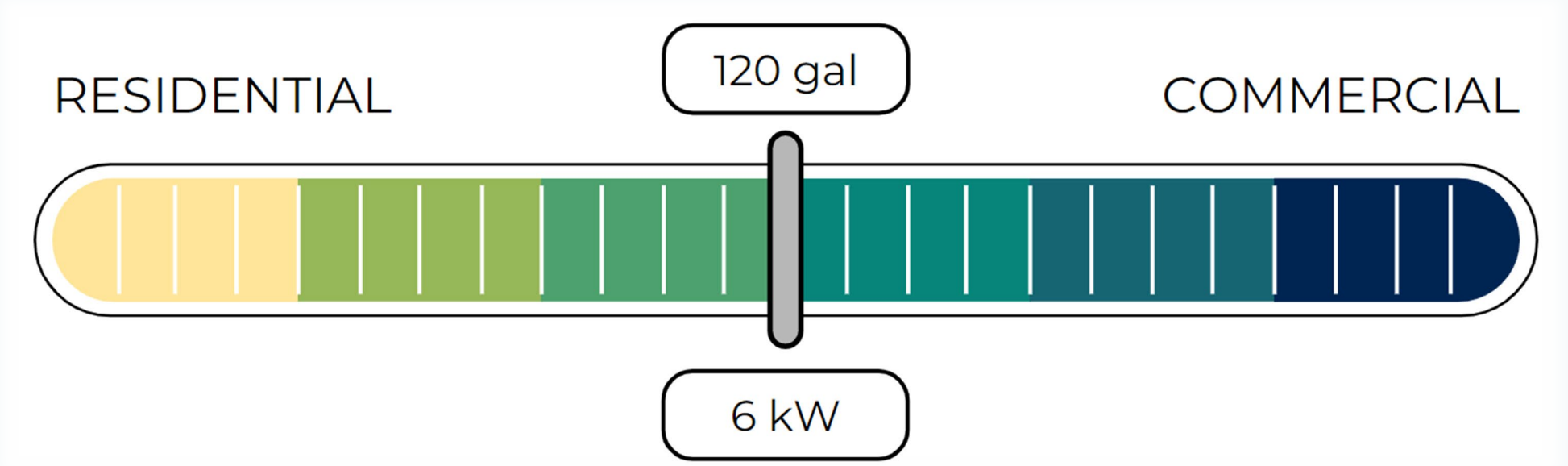
	Minimum SysCOP			
	Hot Climate (IECC Zones 1–2)	Mild Climate (IECC Zones 3–4)	Cold Climates (IECC Zones 5–6)	Extremely Cold Climates (IECC Zones 7–8)
Tier 1	1.75	1.50	1.25	1.15
Tier 2	2.25	2.00	1.60	1.50
Tier 3	2.75	2.50	2.25	2.15
Tier 4	3.50	3.00	2.75	2.50

Company	Identifier	Configuration	Market Delivery Method	Hot Climate Zone		Mild Climate Zone		Cold Climate Zone		Very Cold Climate Zone		EcoPort[a]	ANSI 1181.1 Performance Map	Performance Monitoring[b]
				Tier	SysCOP	Tier	SysCOP	Tier	SysCOP	Tier	SysCOP			
Johnson-Barrow with Colmac	CxA-25	Swing Tank	Fully Specified Built-Up	1	1.9	1	1.7	1	1.5	1	1.4	No	No	No
Johnson-Barrow with Colmac	CxA-30	Swing Tank	Fully Specified Built-Up	1	1.9	1	1.7	1	1.5	1	1.4	No	No	No
Johnson-Barrow with Colmac	CxV-5	Swing Tank	Fully Specified Built-Up	1	2.1	1	2.0	2	1.9	2	1.7	No	No	No
Laars Heating Systems Company	ECHV0325-A-X-A-1-XXXX	Swing Tank	Fully Specified Built-Up	2	2.5	2	2.4	3	2.3	2	1.9	No[1]	No	No[2]
Lochinvar, LLC	AHP060	Multi Pass Return to Primary	Custom Engineered	1	2.2	1	2.0	2	1.7	1	1.5	No	No	No
Lochinvar, LLC	AHP140	Multi Pass Return to Primary	Custom Engineered	1	2.1	1	1.9	2	1.7	1	1.5	No	No	No
Lochinvar, LLC	AHP200	Multi Pass Return to Primary	Custom Engineered	1	2.2	1	1.9	2	1.7	1	1.5	No	No	No
Lochinvar, LLC	AHP280	Multi Pass Return to Primary	Custom Engineered	1	2.1	1	1.9	2	1.7	1	1.5	No	No	No
Lochinvar, LLC	AHP350	Multi Pass Return to Primary	Custom Engineered	1	2.2	1	1.9	2	1.7	1	1.5	No	No	No
Mitsubishi Electric Trane US	Heat2O	Swing Tank	Fully Specified Built-Up	2	2.6	2	2.3	2	2.1	2	1.9	No	No	No
Nyle Water Heating Systems, Inc.	C185A	Swing Tank	Custom Engineered	1	2.0	1	1.7	1	1.5	1	1.4	No	No	No

+ AWHS-compliant HPWH manufacturers
+ Efficiency (COP) ratings specific to:
    + Piping configuration
    + Full DHW plant energy usage
    + Climate zone
    + Multifamily DHW usage
+ Simple tier structure

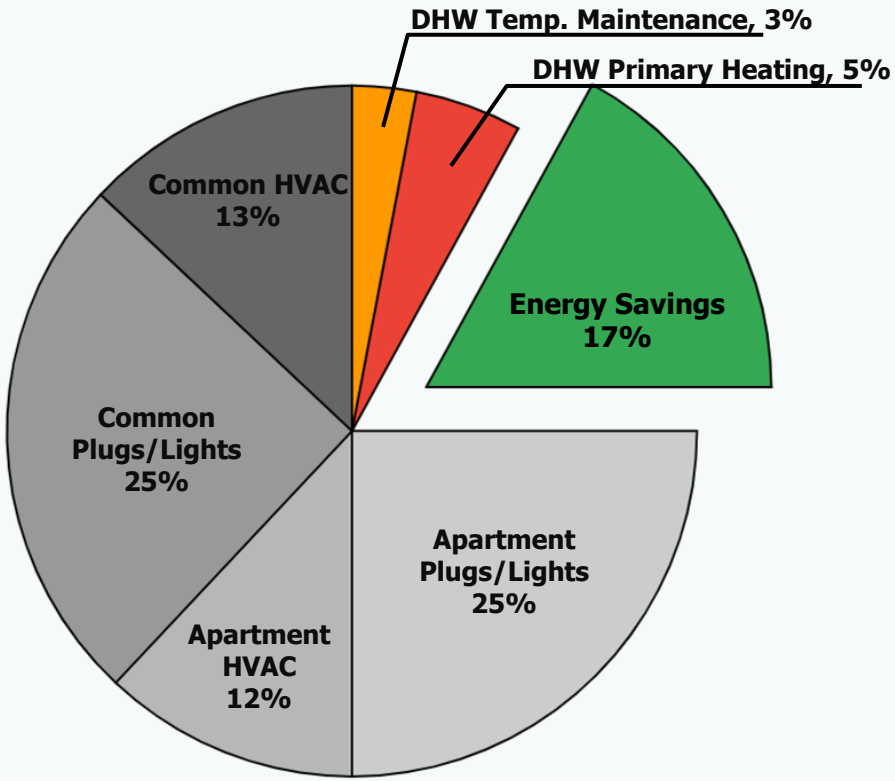
https://neea.org/img/documents/commercial-HPWH-qualified-products-list.pdf

Putting the “C” in CHPWH System



AWHS 3.2.1: Commercial systems are defined as those serving more than four dwelling units or serving commercial loads needing more than a total of 119 gallons of storage volume and/or more than 6 kW of input power.

Why install a CHPWH system?



Energy Savings

Zero Point-of-Use Emissions

Why install a CHPWH system?

Seattle City Light

SEATTLE CITY LIGHT 2024 ENERGY CONSERVATION INCENTIVES Effective January 1, 2024

COMMERCIAL, INDUSTRIAL, AND MULTIFAMILY[1] RETROFIT PROJECTS

CONSERVATION ACTION	INCENTIVE ($/kWh)	MEASURE NOTES
WATER HEATING MEASURES		
Heat pump water heater systems	$0.24	Must meet NEEA's Advanced Water Heating Specification 8.0, commercial only. Systems <=120 gallons not eligible.
Electrically commutated motors	$0.27	Clean water circulator pumps <3.5 HP not eligible

https://www.seattle.gov/documents/Departments/CityLight/CommercialRetrofitIncentives.pdf
https://www.seattle.gov/city-light/business-solutions/large-commercial-and-industrial-business-solutions

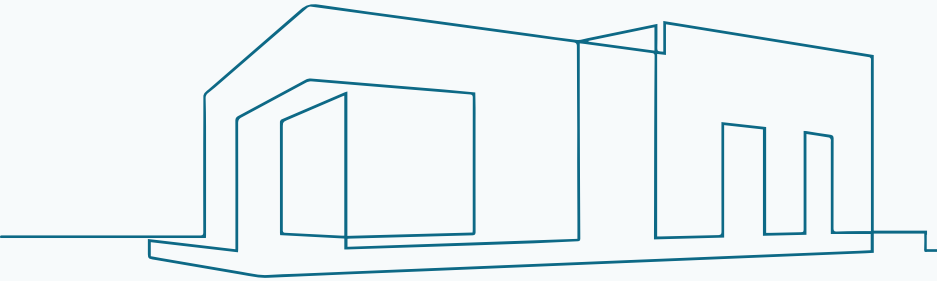
Why install a CHPWH system?

Seattle Energy Code 2018

C404.2.1 Service water heating system type. Service hot water shall be provided by an electric air-source heat pump water heating (HPWH) system meeting the requirements of this section. Supplemental service water heating equipment is permitted to use electric resistance or fossil fuel in compliance with Section C404.2.1.4.

Exceptions:

1. 24 kW plus 0.1 watts per square foot of building area of electric resistance service water heating capacity is allowed per building.
2. Solar thermal, wastewater heat recovery, other *approved* waste heat recovery, ground source heat pumps, water-source heat pump systems utilizing waste heat, and combinations thereof, are permitted to offset all or any portion of the required HPWH capacity where such systems comply with this code and the *Uniform Plumbing Code*.
3. Systems that comply with the Northwest Energy Efficiency Alliance (NEEA) Commercial Electric Advanced Water Heating Specification.
4. Service hot water systems served by a district energy system that serves multiple buildings and that was in service before the effective date of this code.
5. Commercial dishwashers, commercial food service equipment, and other *approved* process equipment are permitted to utilize electric booster heaters for supply water temperatures 120°F (49°C) or higher.
6. Systems connected to a *low-carbon district energy exchange system* or a *low-carbon district heating and cooling or heating only system*.
7. Essential facilities. Groups I-2 and I-3 occupancies that by regulation are required to have in place redundant emergency backup systems.



Washington State Energy Code 2021

C404.2.3 Group R-1 and R-2 Occupancies With Central Service Water Heating Systems

In buildings with central service water heating systems serving four or more Group R-1 or R-2 dwelling or sleeping units, the primary water heating equipment shall not use fossil fuel combustion or electric resistance. Service hot water shall be provided by an air-source heat pump water heating (HPWH) system meeting the requirements of this section. Supplemental service water heating equipment is permitted to use electric resistance in compliance with Section C404.2.3.4.

Exceptions:

1. Permits applied for prior to January 1, 2022.
2. Solar thermal, wastewater heat recovery, other *approved* waste heat recovery, ground source heat pump, water-source heat pump system utilizing waste heat, and combinations thereof, are permitted to offset all or any portion of the required HPWH capacity where such systems comply with this code and the Seattle Plumbing Code.
3. Systems meeting the requirements of the Northwest Energy Efficiency Alliance (NEEA) Advanced Water Heater Specifications for central service water heating systems.

Let’s check in:

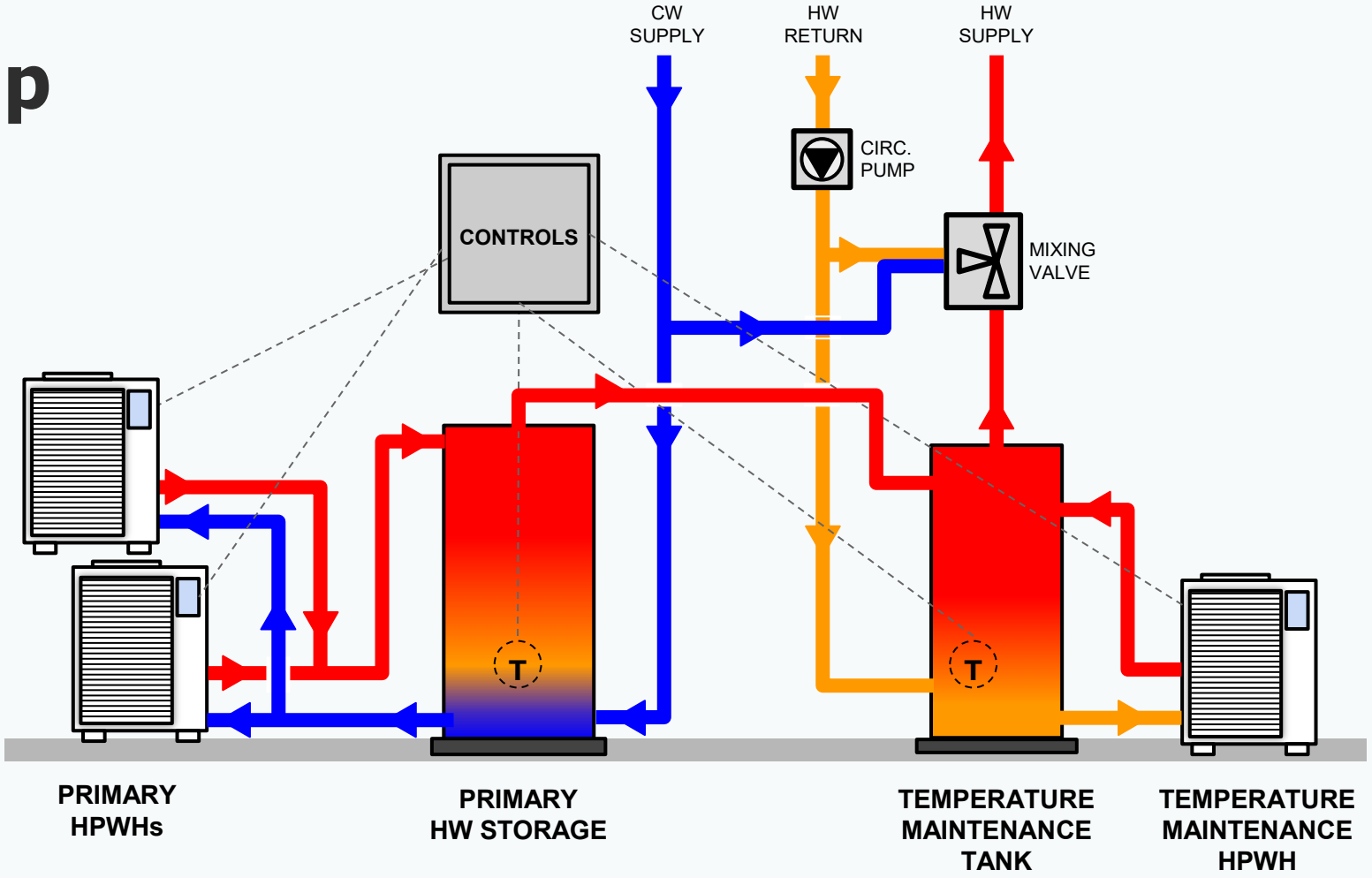
1. **Why do you like HPWHs?**
2. **What challenges have you been met with?**
3. **Does the AWHS make sense, and where else could it be referenced?**

Time to put our engineering hats on.

- CHPWH system components
- Understanding CHPWH System Components
  - HPWH
- Coffee Break
  - Storage
  - Temperature maintenance system
  - Controls
- System Sizing

CHPWH System Components

+ Primary heat pump water heater
+ Primary storage
+ Temperature maintenance system
+ Controls



Primary HPWH

The heart of the system.

Types:

Single pass, multi pass, integrated

Performance:

Capacity

Coefficient of Performance (COP)

Operating envelope

Defrost

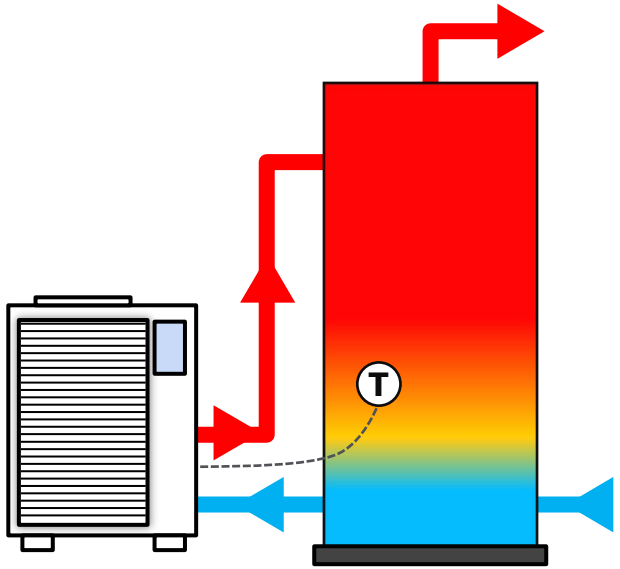
Refrigerants:

Driver of performance

Global warming potential

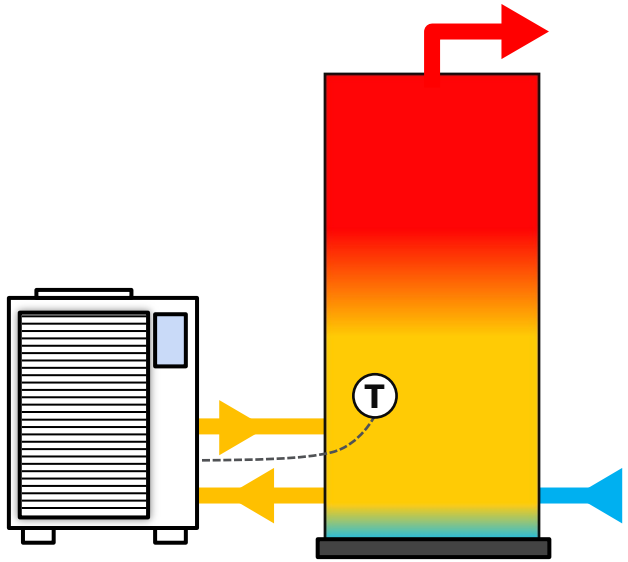
HPWH Types

SINGLE PASS HPWH



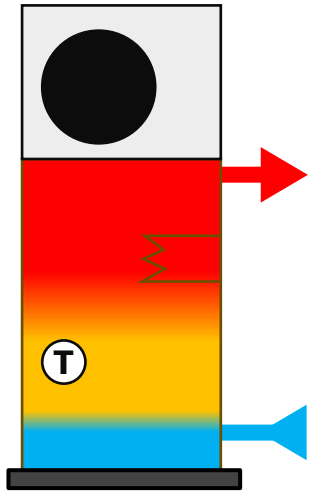
- Throttled flow through HPWH
- Highest efficiency
- More specialized storage connections

MULTI PASS HPWH



- Uncontrolled flow through HPWH
- Lower efficiency
- Lower effective storage capacity
- Same piping as gas water heater

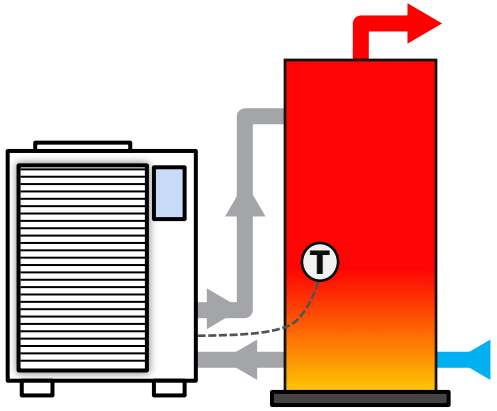
INTEGRATED HPWH



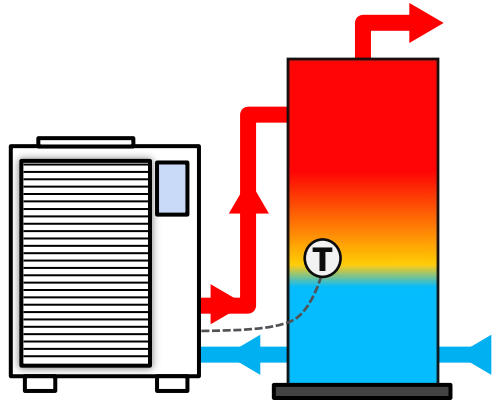
- Simplest install
- Lower effective storage capacity
- Potential ER usage

Single Pass Operation

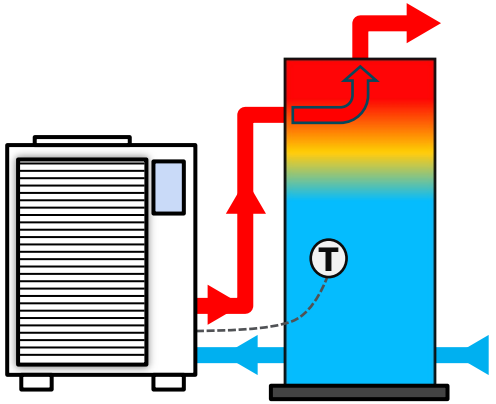
1. Tank is fully charged, HPWH is off.



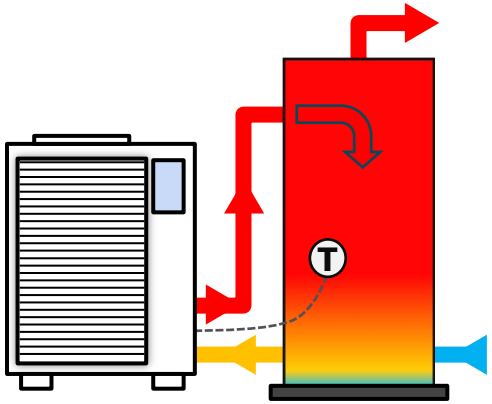
2. Building uses DHW, HPWH turns on.



3. Building HPWH and storage satisfy peak DHW load.



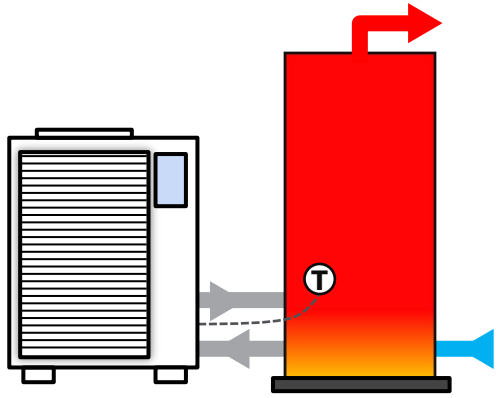
4. Peak DHW load subsides, HPWH recharges tank.



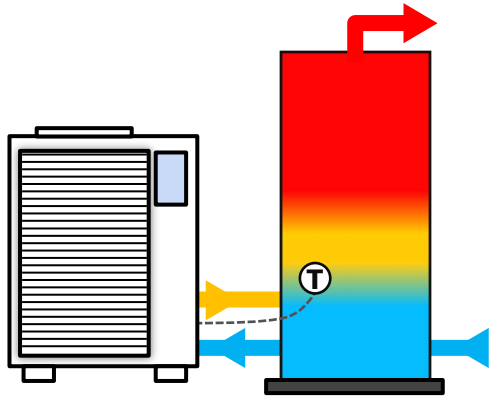
ECOTOPE

Multi Pass Operation

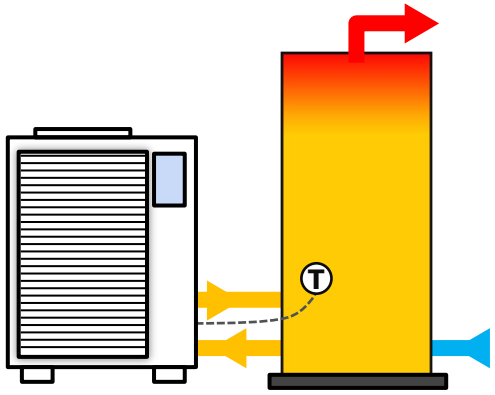
1. Tank is fully charged, HPWH is off.



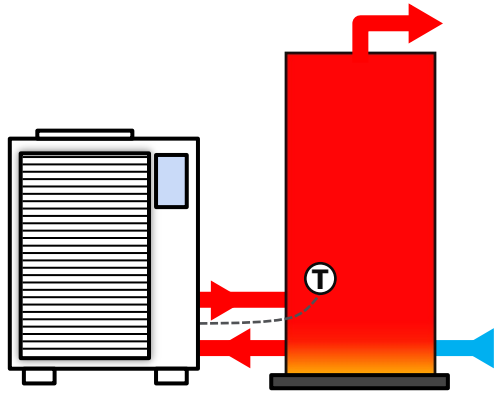
2. Building uses DHW, HPWH turns on.



3. Storage satisfies peak load.

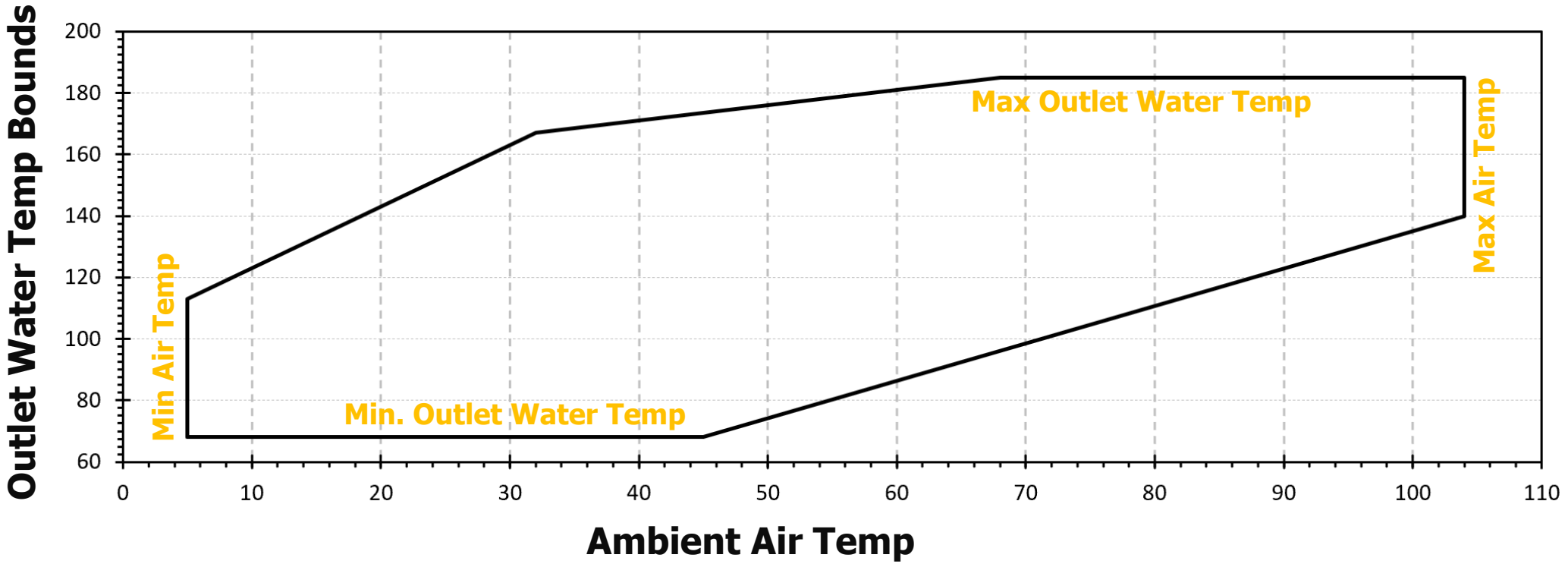


4. Peak DHW load subsides, HPWH recharges tank.



ECOTOPE

HPWH Operating Envelope



DO NOT REFERENCE THIS FOR DESIGN! ENVELOPE VARIES BY MFR.

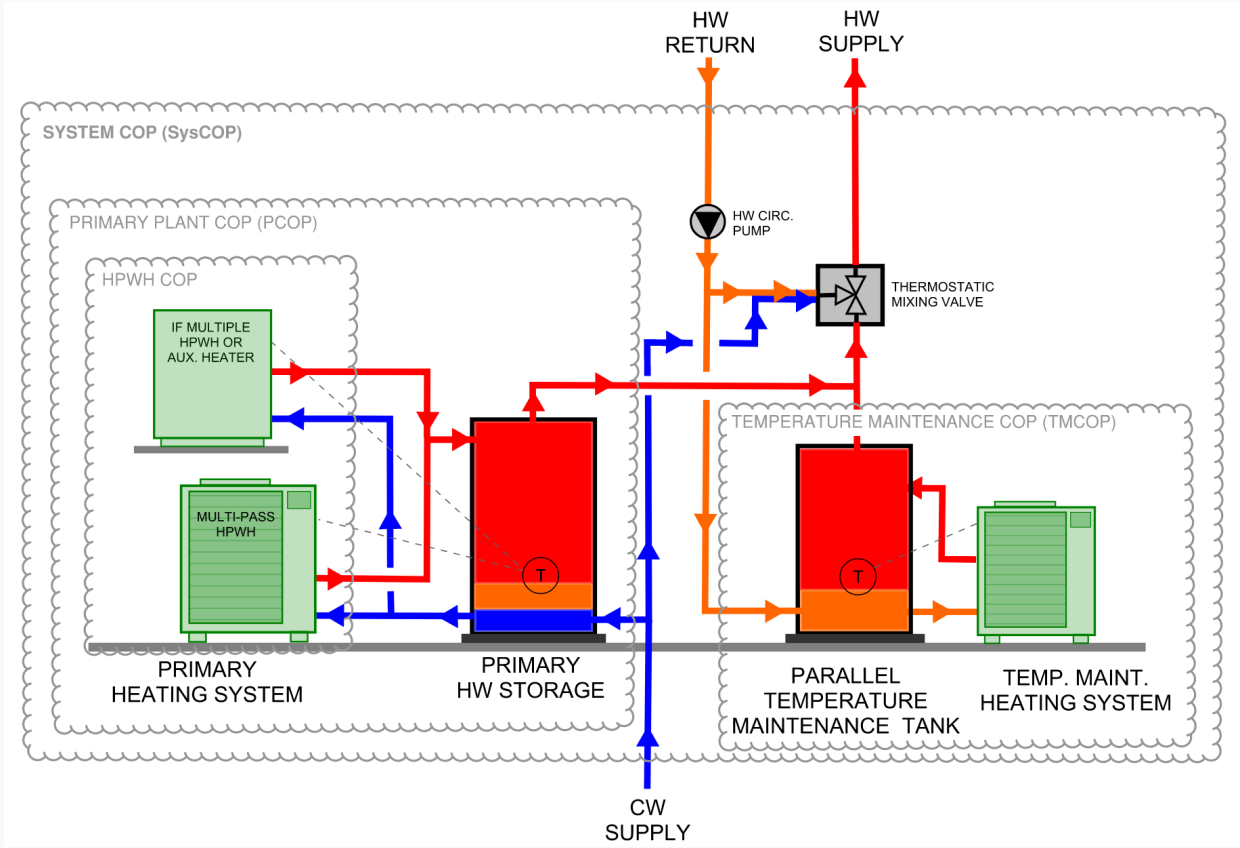
HPWH Performance

Capacity:

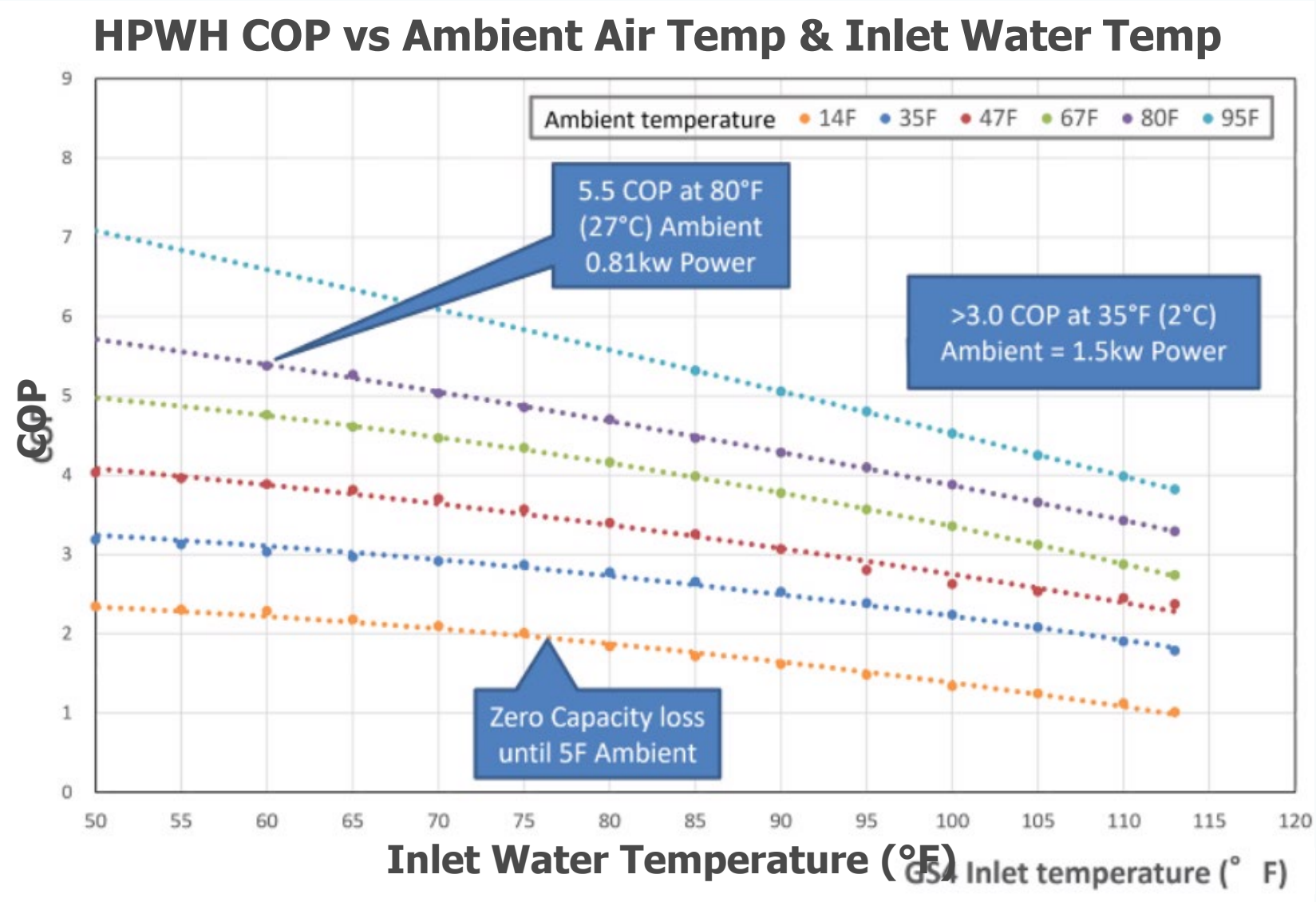
- How much heat is provided?
- Units: BTU/h, kBTU/h, MBH, kW
- Impacted by air and water temperatures

Coefficient of Performance (COP):

- How efficiently is heat provided?
- COP = heat provided / energy used (unitless)
- Impacted by air and water temperatures



HPWH COP



Warmer air:

Increases HPWH COP

Warmer inlet water:

Decreases HPWH COP*

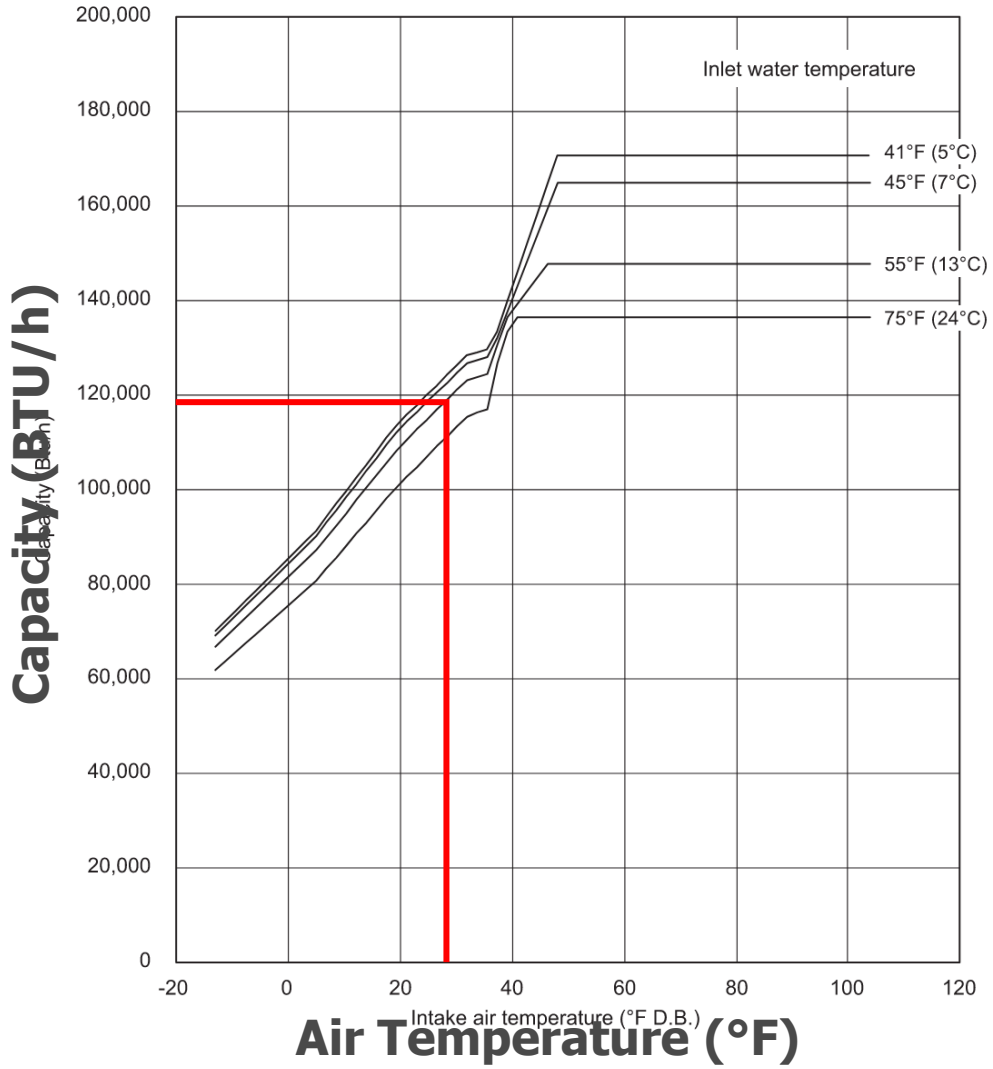
Warmer outlet water:

Decreases HPWH COP*

***Many factors are refrigerant-specific.**

HPWH Capacity

HPWH Capacity vs Ambient Air Temp & Inlet Water Temp



- **Warmer air:**
- **Increases capacity**

- **Warmer inlet water:**
- **Variable capacity impact***

- **Warmer outlet water:**
- **Negligible capacity impact**

- ***Many factors are refrigerant-specific.**

Refrigerants

Refrigerant type impacts every aspect of HPWH performance. Let's compare CO2 and R134a:

	R134a HPWH	**CO2 HPWH**
High inlet water temperature	Minor COP and capacity reduction. Capable of multi pass heating	Major COP and capacity reduction. Single pass heating only.
High outlet water temperature	Major COP reduction. Some models will produce up to 180°F in high ambient temps.	Minor COP reduction. Some models will produce up to 180°F in a wide range of ambient temps.
Low ambient air temperature	Will not operate below ~40°F air	Operates down to ~-20°F
High ambient air temperature	Major COP and capacity increase up to ~100°F air.	Minor COP and capacity increase above ~60°F air
Global warming potential	Very high GWP: 1300	Very low: 1
Phase out	2035 or sooner	Here to stay

ECOTOPE

But wait, there's Defrost!

- Coil builds ice in air temps below ~45°F
- Various ways to melt this ice:
  - Electric resistance coils
  - Hot gas defrost
  - Proprietary logic
- Impacts COP and capacity to varying degrees.

Let’s check in:

1. Any questions about HPWH capacity and COP?
2. Have you seen an application where multi pass beats single pass?
3. Any promising new refrigerants?

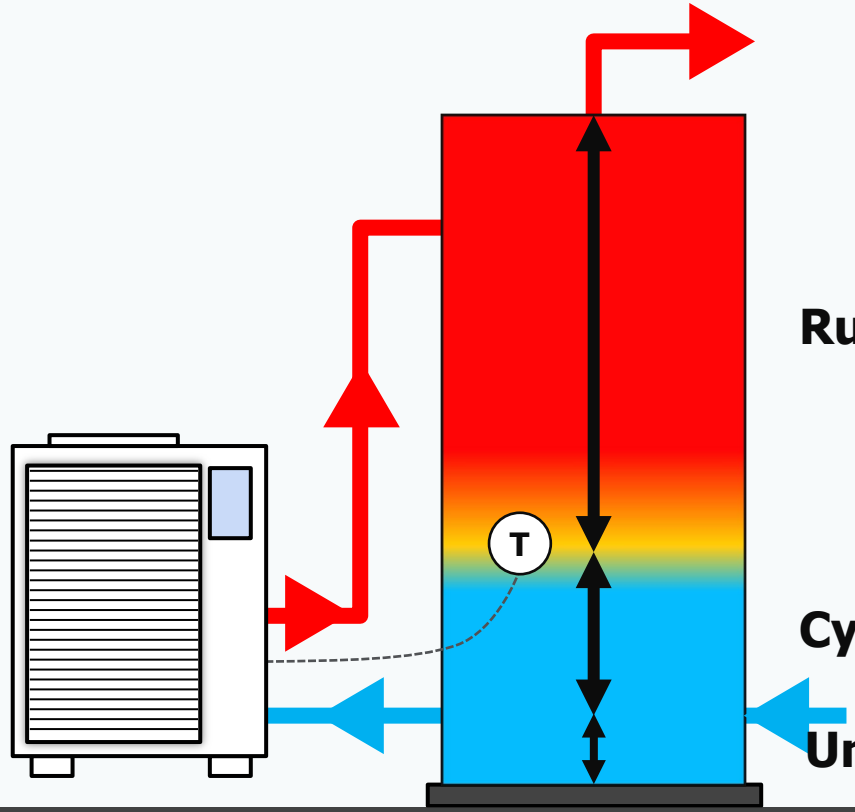
DHW Storage

A HPWH's inseparable partner.

We'll focus on single pass:

- **Storage functions**
- **Connection locations**
- **In-series vs parallel**

Functional Volumes



Running volume: helps HPWH satisfy peak DHW load.

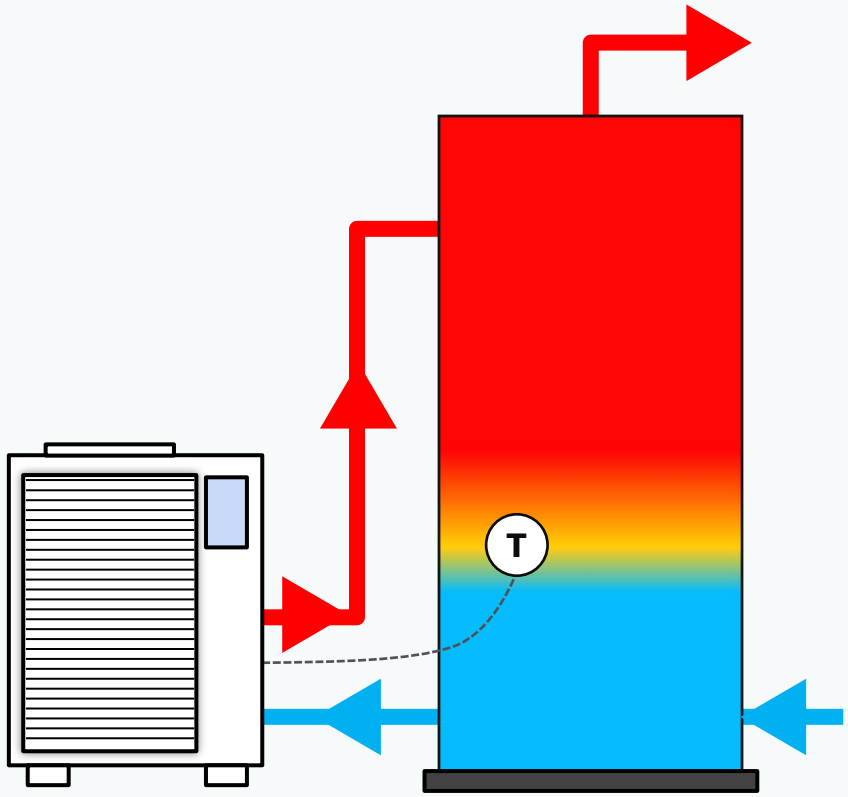
Cycling volume: prevents HPWH from short-cycling.

Unusable volume: wasted space below HPWH connection.

Aquastat Fraction: $\frac{Unusable\ volume + cycling\ volume}{total\ volume}$

Drawdown %: $90\% - \frac{unusable\ volume}{total\ volume}$

Connection Locations



Note: Supply dedicated HPWH connections!

DHW Supply: top of tank or as high as possible.

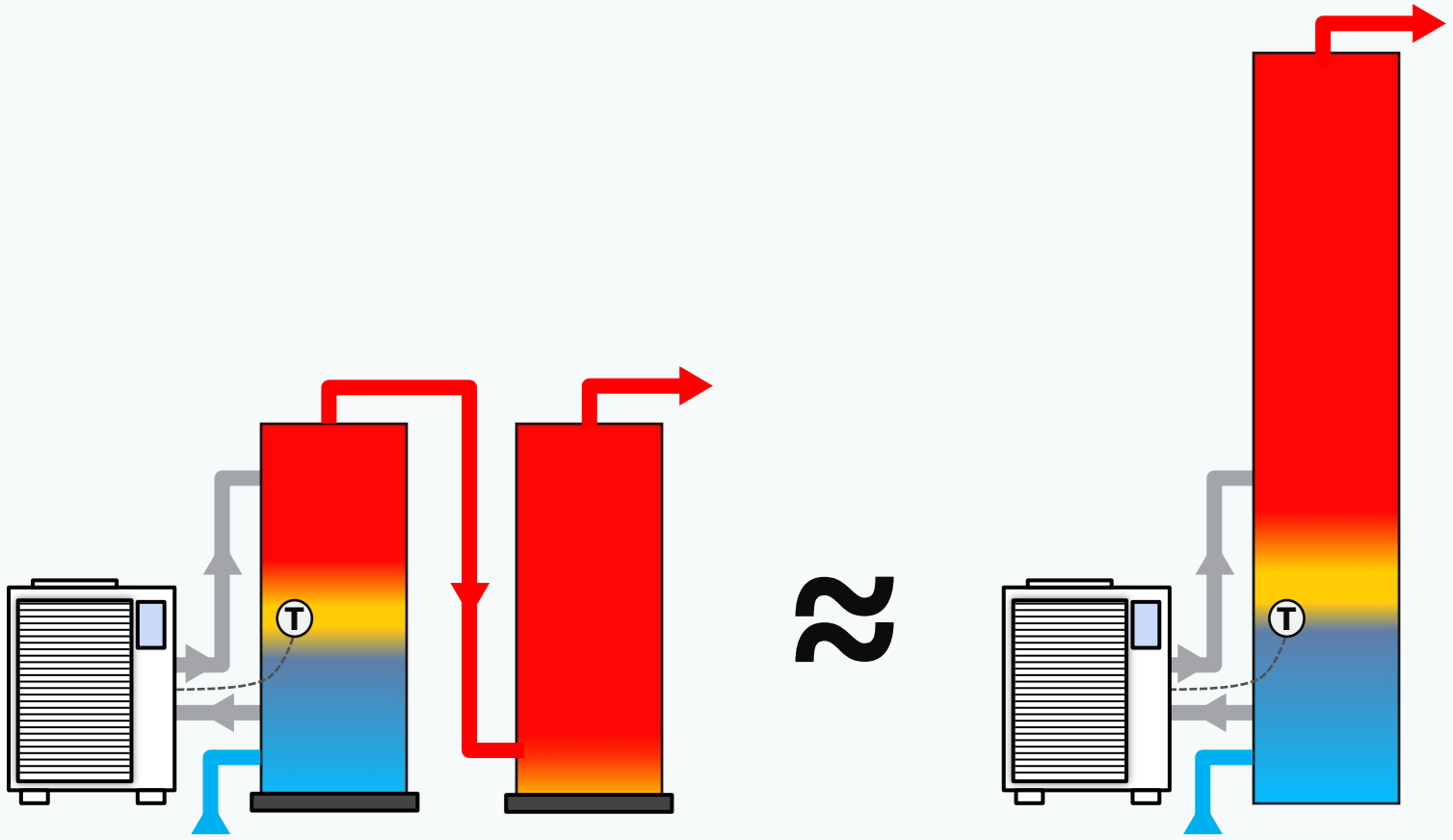
HPWH Hot: as high as possible on side wall.

Thermowell: high enough to prevent short-cycling, low enough to maximize running volume.

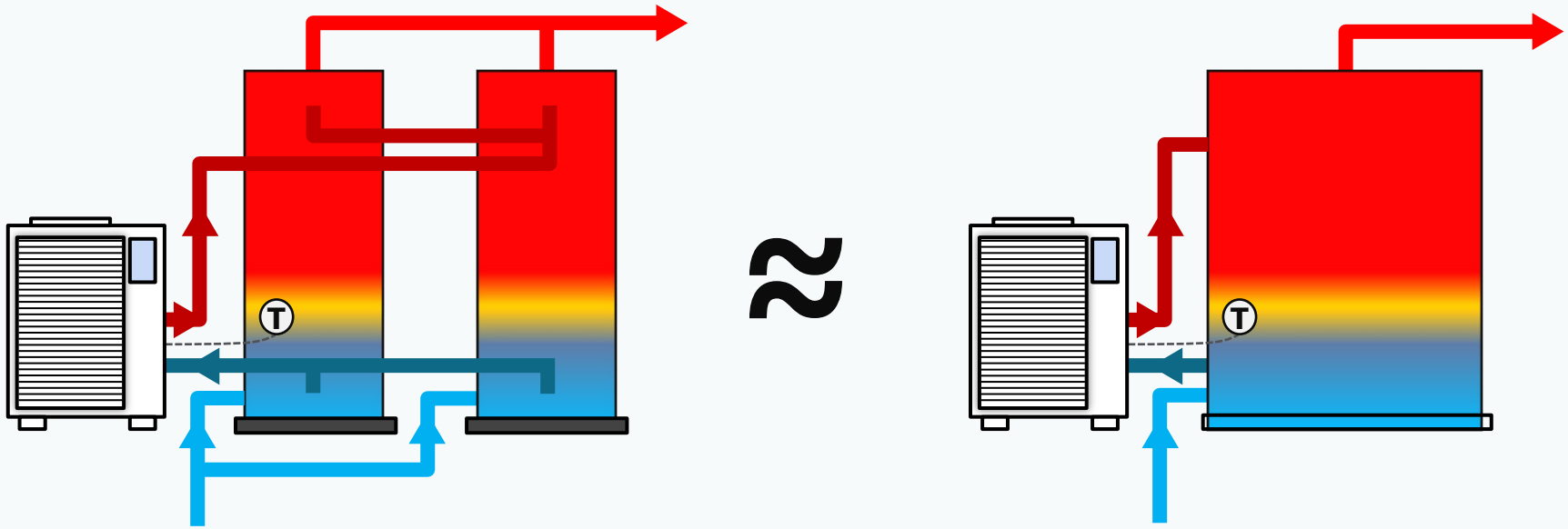
HPWH Cold: As low as possible on side wall or bottom of tank.

DCW inlet: as low as possible on side wall (higher than HPWH cold if needed)

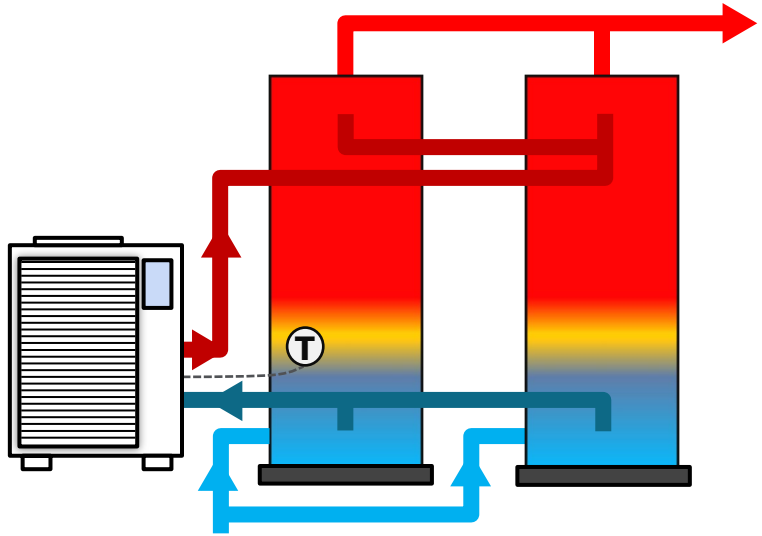
In-series Storage Tanks



Parallel Storage Tanks

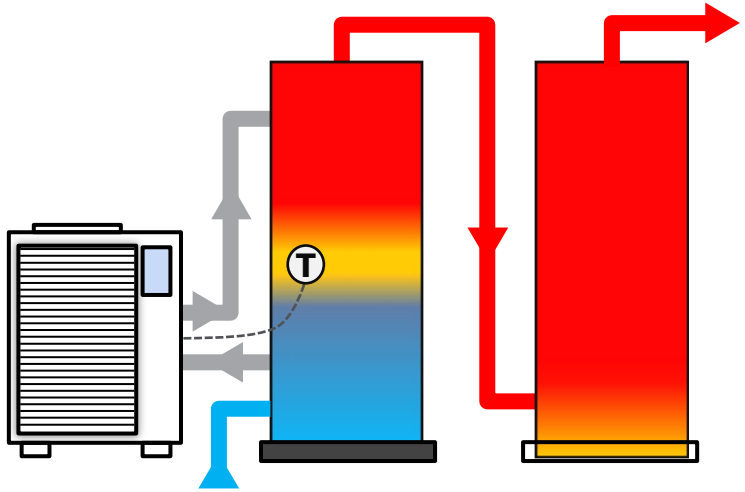


In-series vs Parallel Storage



- Lower pressure drop
- Less granularity in thermowell height
- Higher effective storage capacity (?)
- More sensitive to imbalanced piping*

*stratified, parallel tanks are self-balancing in low flow periods.



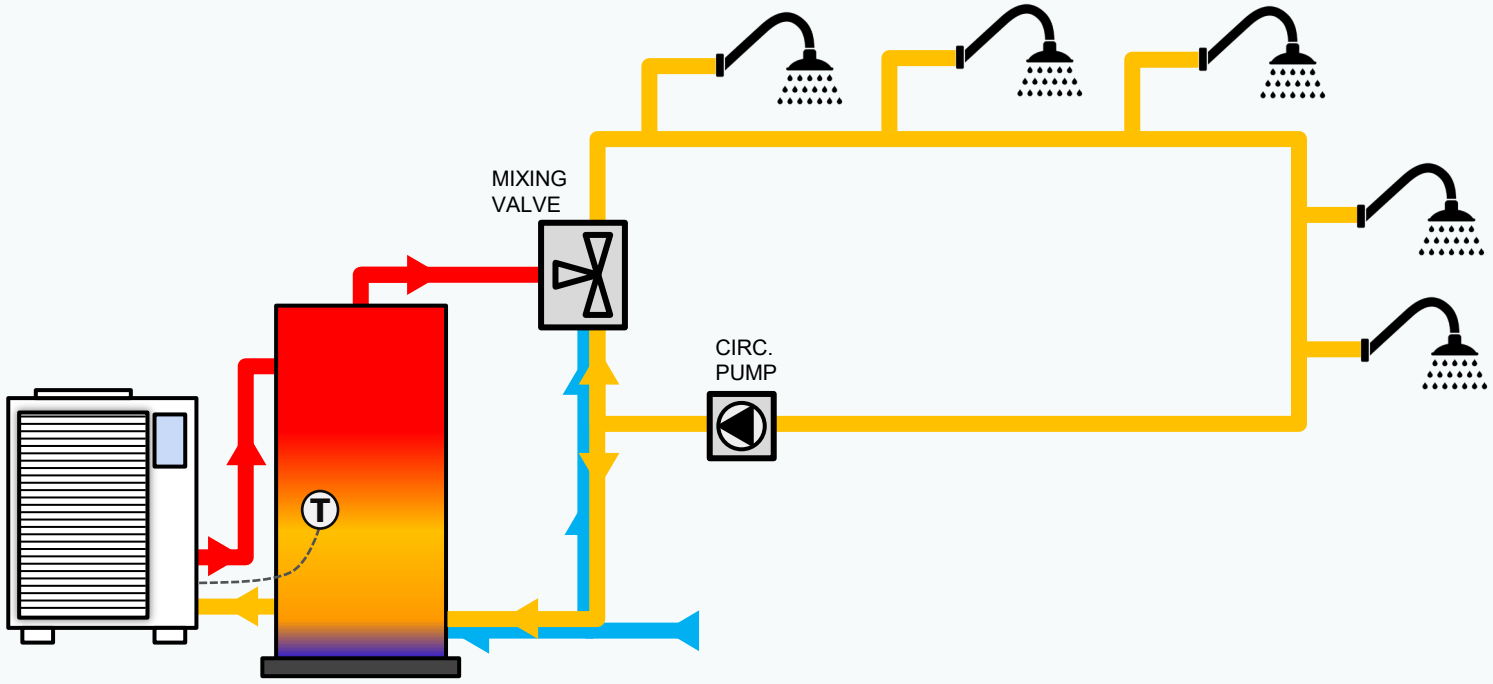
- Higher pressure drop
- More granularity in thermowell height
- Lower effective storage capacity (?)
- Very different from gas water heater piping

Let’s check in:

1. **Any questions about storage?**
2. **Any more important storage considerations?**

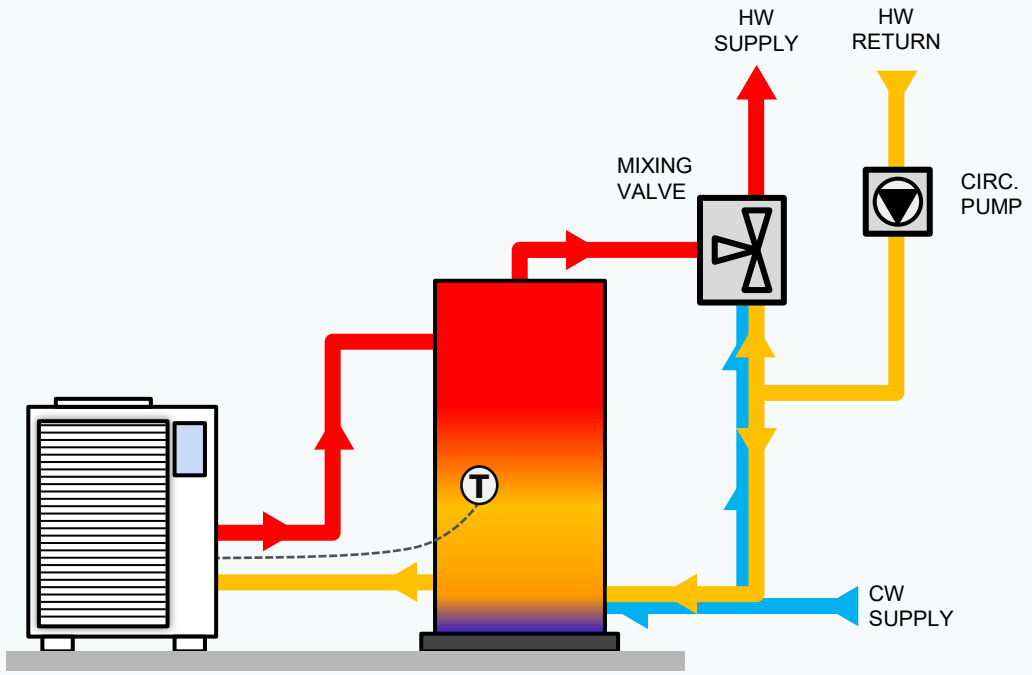
Temperature Maintenance

Keeping the pipes hot.



- Challenge: High HPWH inlet water temperature (IWT)
- HPWH System Configurations:
  - Return to primary
  - Swing configuration
  - Parallel loop configuration
  - Non-centralized

Return to Primary Configuration



HPWH Requirements:

- **Heat efficiently when IWT > 100°F**
- **Turn off when IWT > 130°F**

Special Considerations:

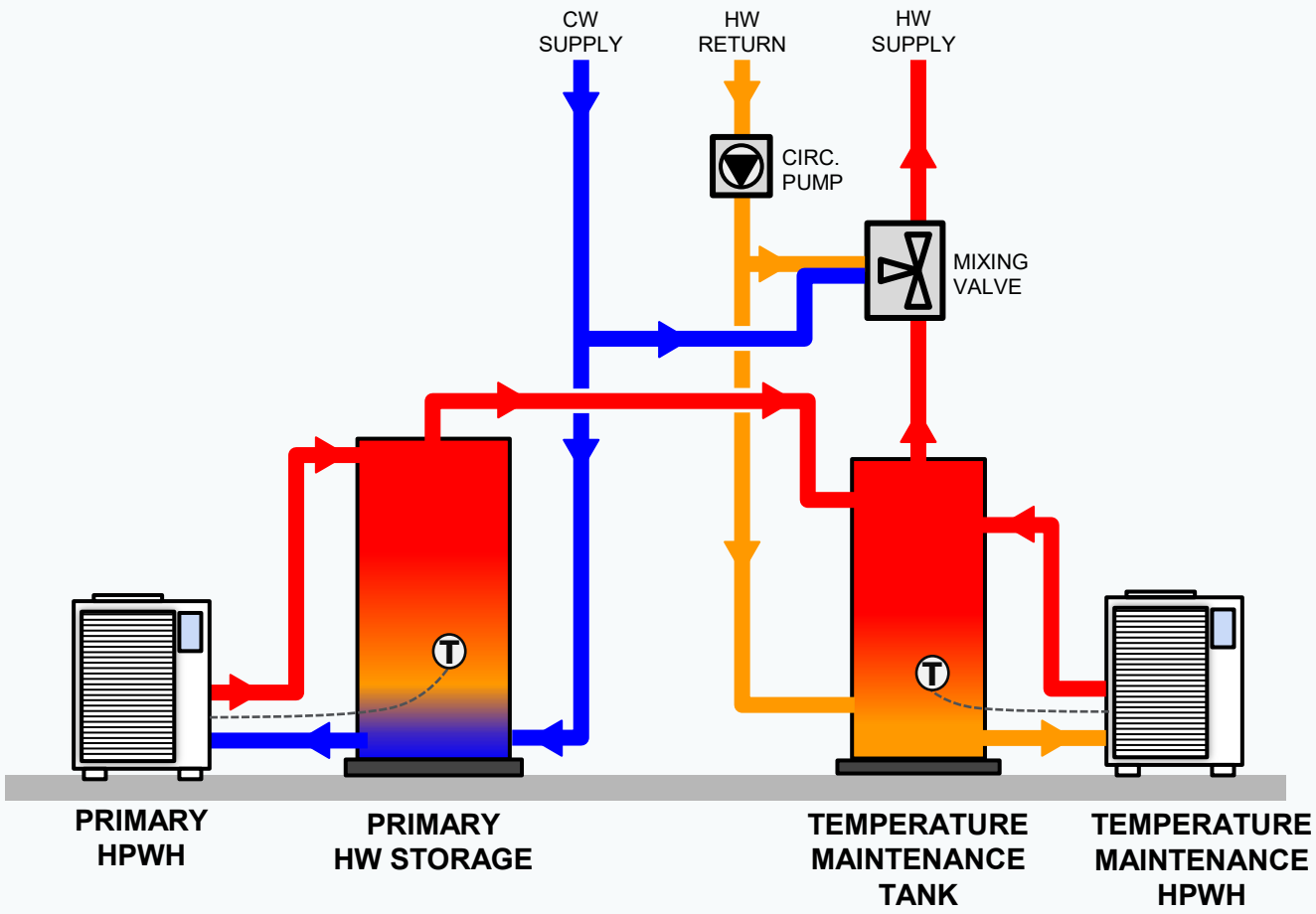
- **Minimize HWR temperature**
- **Place temp sensor high enough to prevent short-cycling**

Pros: Lowest cost, familiar plumbing

Cons: Equipment specific, short-cycling risk

Best Application: medium-to-high recirc losses, manufacturer approved configuration

Parallel Loop Tank Configuration



Primary HPWH Requirements:

- Heat efficiently when IWT > 60°F
- Turn off when IWT > 120°F

TM HPWH Requirements:

- Heat efficiently when IWT > 120°F
- Turn off when IWT > 130°F

Special Considerations:

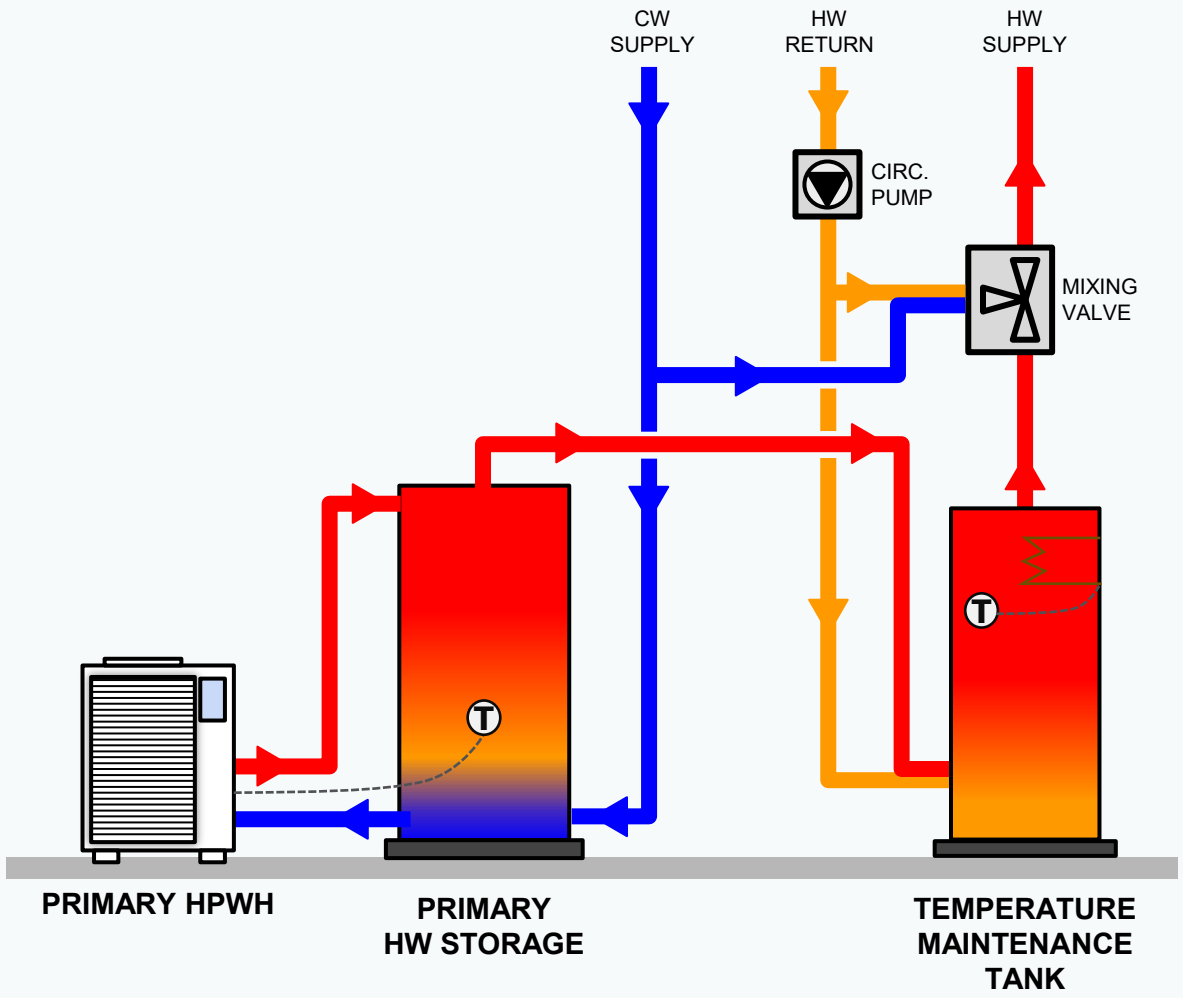
- Careful with TM tank connections

Pros: Efficient primary HPWH operation

Cons: Highest cost/complexity

Best Application: high recirc losses, manufacturer approved configuration, load shift

Swing Tank Configuration



Primary HPWH Requirements:

- **Heat efficiently when IWT > 60°F**
- **Turn off when IWT > 120°F**

ER Heater nice-to-have:

- **Staged heating**
- **Elements and sensor in upper-tank**

Special Considerations:

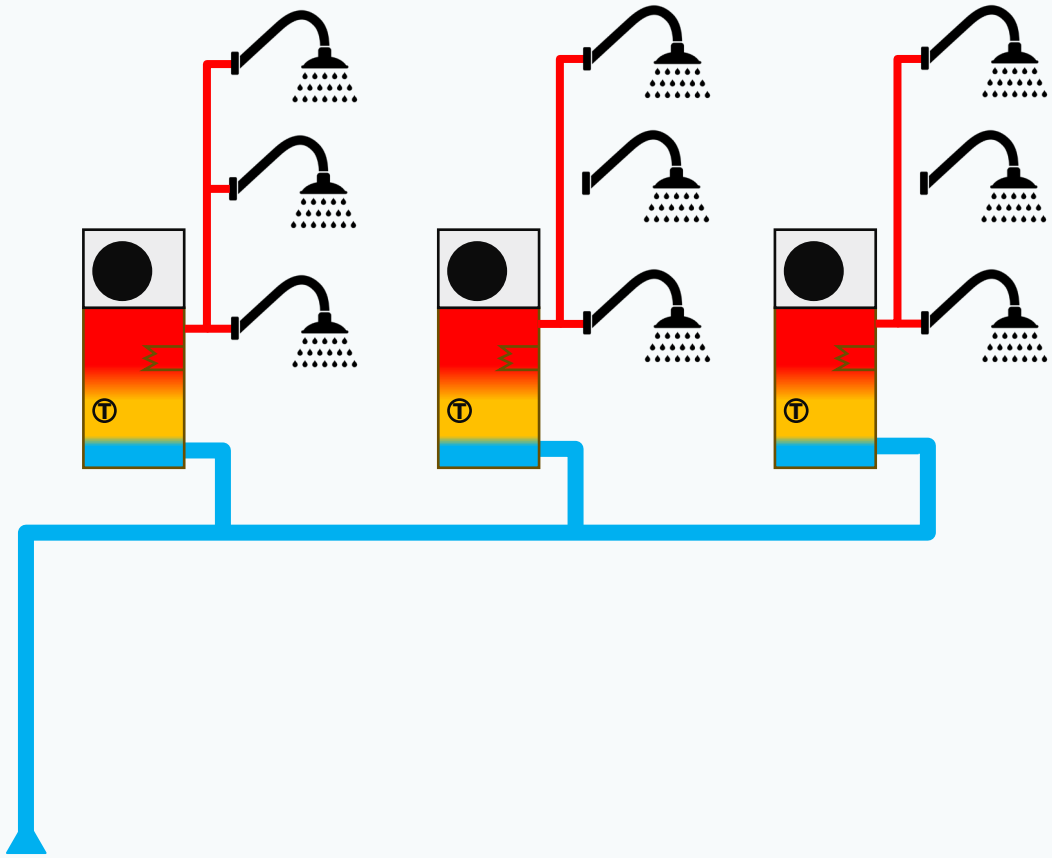
- **Careful with TM tank connections**

Pros: Efficient primary HPWH operation, standard EWH or existing heater can be used as swing tank.

Cons: High cost/complexity, risk of high ER usage

Best Application: very low TM loss, retrofits

Non-centralized



Primary HPWH Requirements:

- **Heat efficiently when IWT > 60°F**
- **Low cost**

Special Considerations:

- **Space and source air for HPWHs near each cluster of dwelling units**

Pros: No HWC loop

Cons: High cost, high space requirements

Best Applications: in-unit ER heater retrofits where source air is accessible, clusters of dwelling units.

Let’s check in:

1. **Any questions about temperature maintenance?**
2. **Which of these systems do you see most potential for in Seattle’s buildings?**

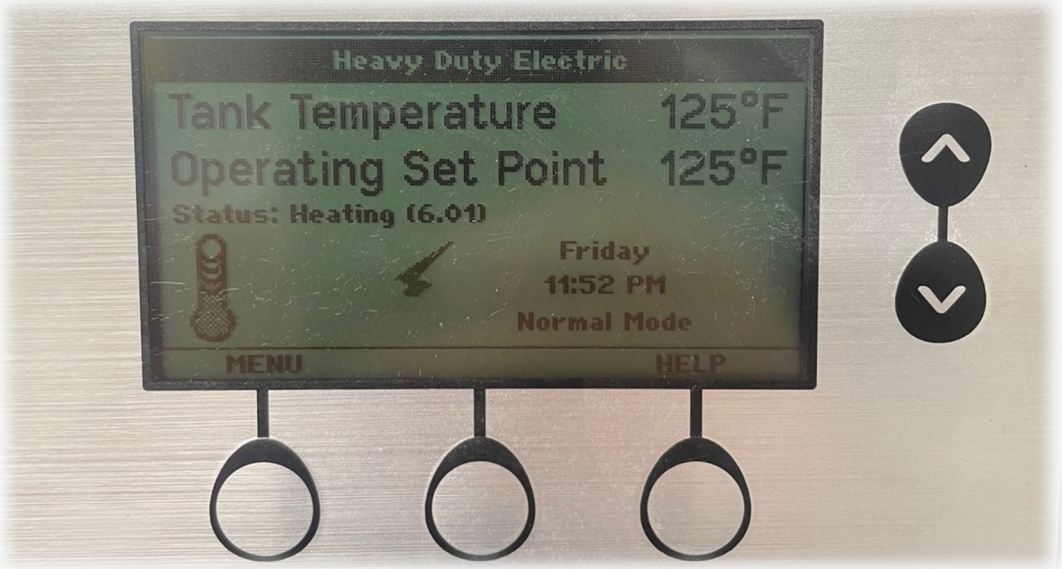
Controls

How HPWHs communicate.

+ **Key Functions**
+ **Levels of Control**
+ **Sample SOO**

Controls – Key Functions

1. **Turn equipment on and off**
2. **Monitor equipment status**
3. **Send alarms**



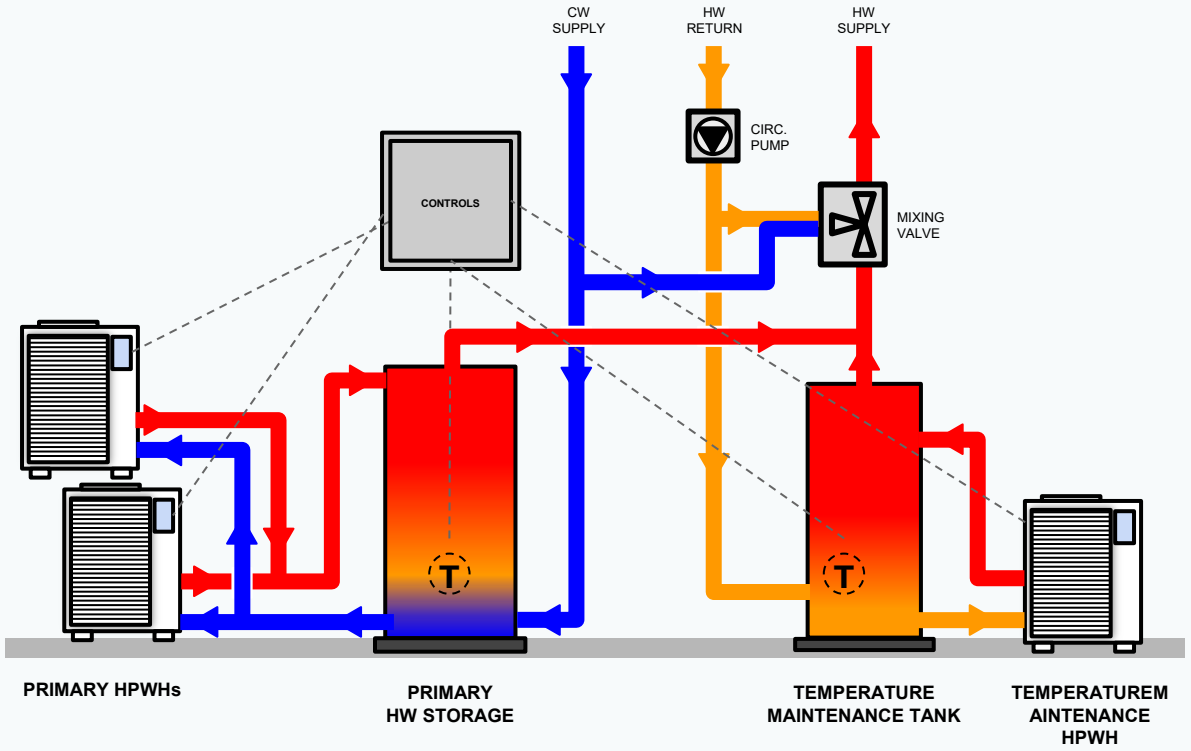
System Alarm (14) - RCC-2 Global Alarm: ALARM

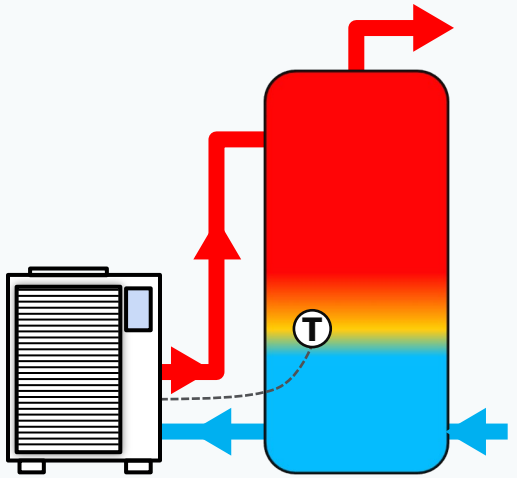
B bms.alarm.distributor@gmail.com

Evan Green

Source: (Device 100100) - System Alarm (14)
RCC-2 Global Alarm
Time of Alarm: 2022/Apr/26 07:58:24

Levels of Control





Central Controller

Onboard Equipment

Building Management System

Sample Sequence of Operation

Primary HPWH:

Maintain 140°F HPWH outlet temperature in single pass mode.

Turn on when lower tank temp < 115°F.

Turn off when HPWH IWT > 125°F.

Swing Tank:

Maintain 125°F setpoint temperature.

Back-up heater:

Turn on when upper tank temp < 115°F

Mixing Valve:

Maintain 125°F delivery temperature.

HWC Pump:

Set to constant temperature: target 115°F

Monitoring:

HPWH status, alarms, and supply temperature shall be visible on local user interface.

Alarms:

Send alarm notification via email if:

Any HPWH is in alarm state.

DHW supply < 120°F

DHW return < 110°F

Tips:

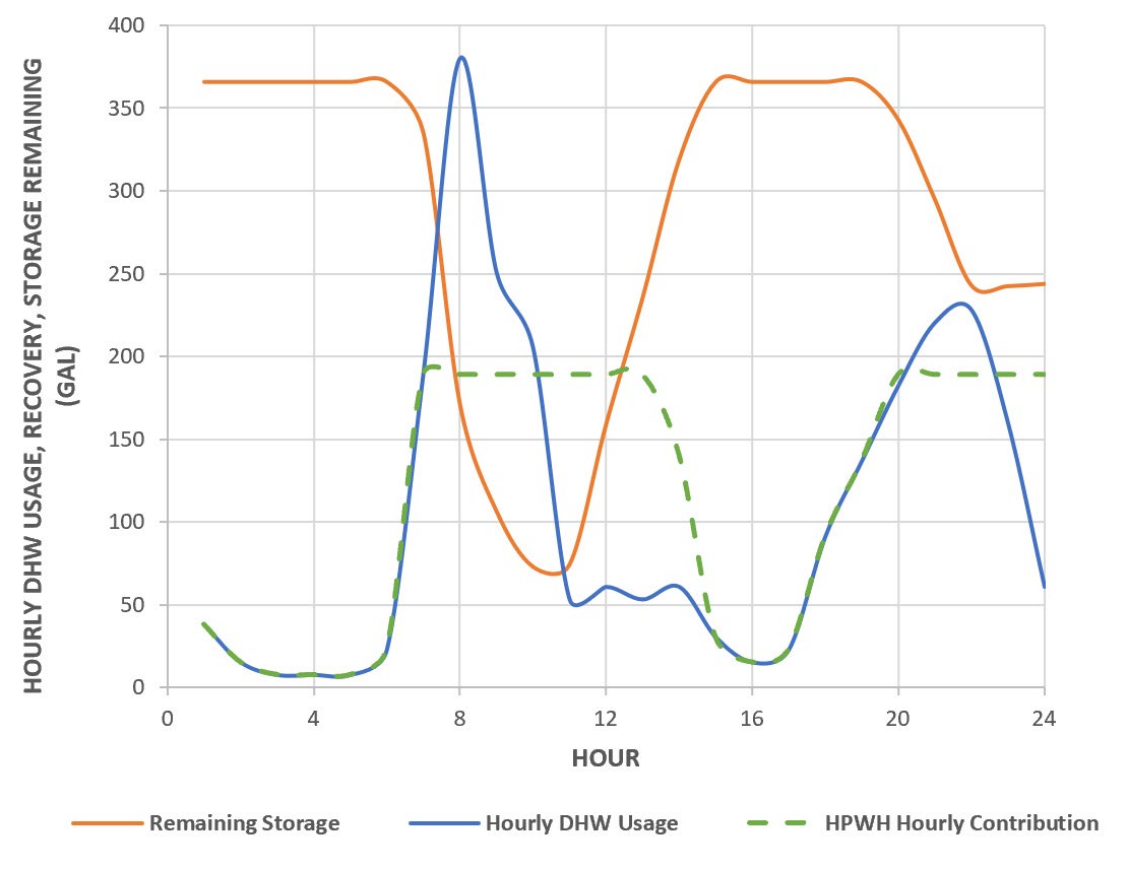
- **Include every DHW component.**
- **Consult with manufacturers.**
- **Label temperature sensors on schematic and in DHW plant to match SOO.**

Let’s check in:

1. **Questions about controls and SOO?**
2. **Any more pointers?**

System Sizing

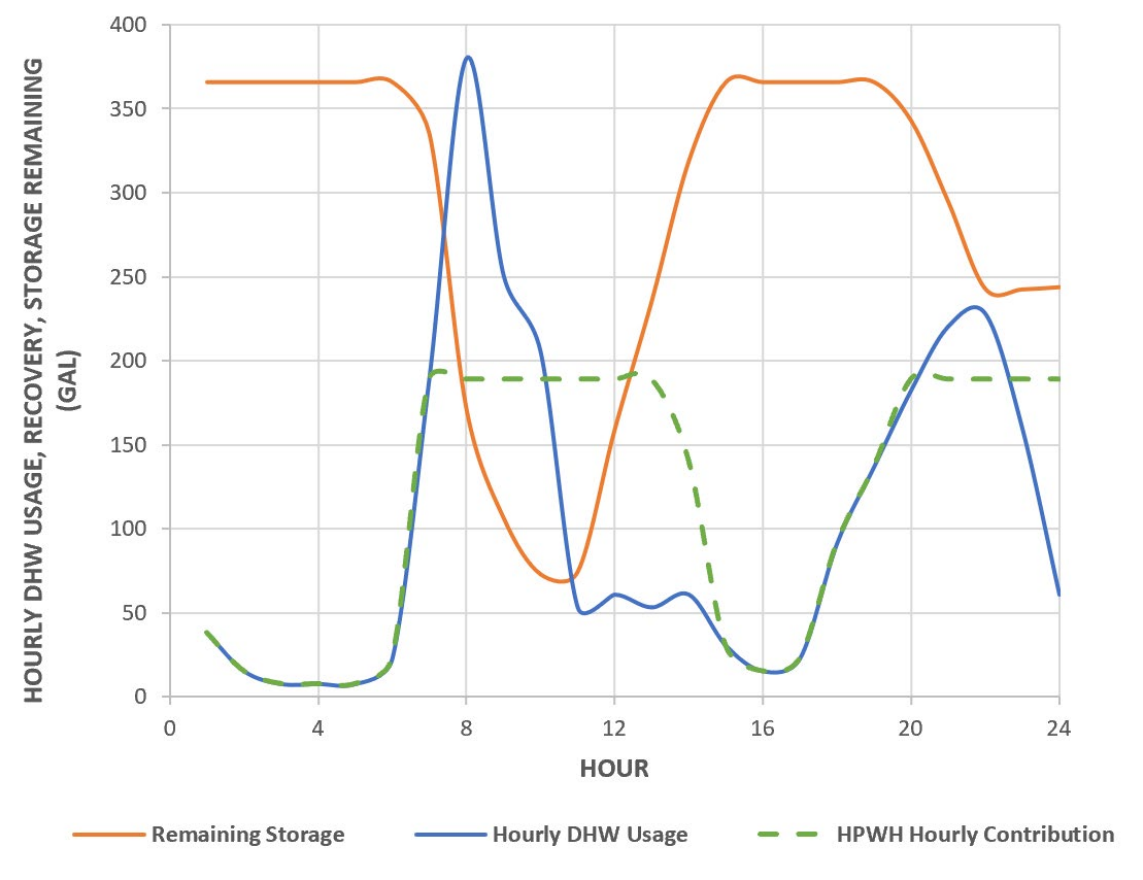
The whole day matters.



+ **Sizing Logic**

+ **Ecosizer**

Sizing Logic



Define building characteristics: DHW usage profile and total daily DHW usage

Size HPWH to run ~16hrs/day to satisfy total daily DHW load. Remember to account for ambient air de-rate.

Size storage to satisfy peak DHW usage period with HPWH's help.

Ecosizer inputs:

Building Type

Multifamily

- Multifamily
- Men's Dorm
- Women's Dorm
- Hotel/Motel
- Elementary School
- Junior High
- Senior High
- Nursing Home
- Full-Meal Restaurants and Cafeterias
- Drive-Ins, Grills, Luncheonettes, Sandwich, and Snack Shops
- Office Building

Market rate multifamily bu
Total hot water usage is ba
per person per day from ir

TOTAL PEOPLE & APARTMENTS | APARTMENT SIZE & OCCUPANCY RATES

Number of people: 100

Number of apartments: 50

Peak Gallons per Day per Person: 25 (1 – 49; ASHRAE Low; Ecotope Market Rate with Low Flow Fixtures; ASHRAE Medium)

Water Temperature

Design Cold: 50 °F

Supply: 120 °F

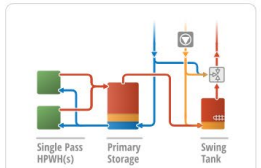
Hot Storage: 140 °F

ADVANCED OPTIONS

Aquastat Fraction: 40 %

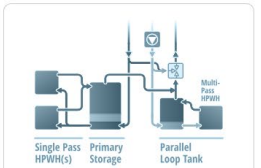
Drawdown: 85 %

Temperature Maintenance System



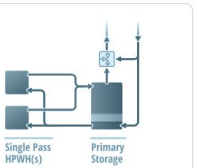
SWING TANK

Primary plant with a temperature maintenance plant in series



PARALLEL LOOP TANK

Primary plant with a temperature maintenance plant in parallel



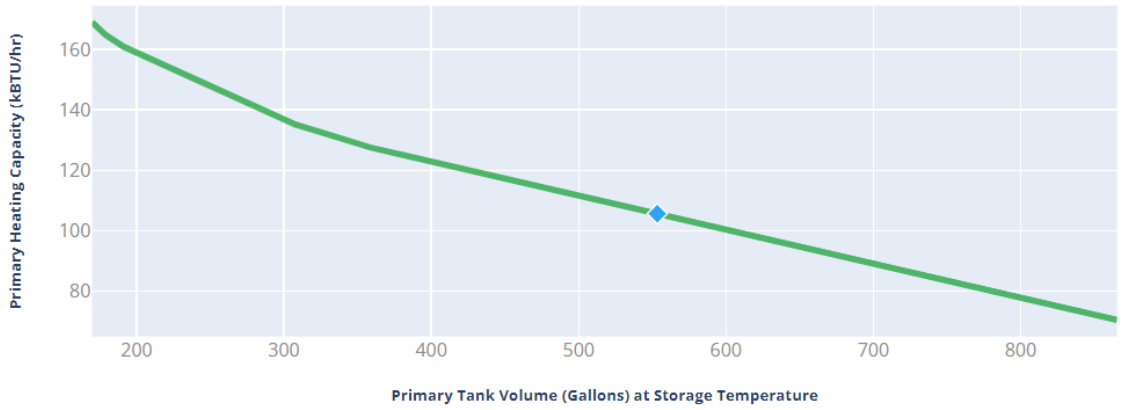
PRIMARY - NO RECIRCULATION

Just the primary plant without a temperature maintenance load

A temperature maintenance system provides hot water to the taps in a timely manner.

Ecosizer.ecotope.com

Ecosizer outputs:



Primary System Size, Storage: **553.41** Gal, Capacity: **105.6** kBTU/hr, Compressor Runtime: **16.0** hr

RECOMMENDATIONS

The recommended 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
554.00 Gallons

Heating Capacity
105.60 kBTU/hr

Swing Tank Volume
50 Gallons

Swing Resistance Element
8.7 kW · **29.9** kBTU/hr

CA Title 24 Swing Tank Volume
80 Gallons

THIS SYSTEM WAS SIZED FOR

Building Load
100.0 People

Apartments
50 Units

Daily Hot Water Usage
25.0 Gallons per Day per Person

Total Hot Water
2,500.00 Gallons per Day

Recirculation Loop
Heat Loss
100 Watts per Apartment

Ecosizer.ecotope.com

ECOTOPE

Let’s check in:

1. **Questions about sizing?**
2. **Know of any great DHW usage data?**

Time to select a system.

Be your own advocate.

+ **Market Delivery Structure**
+ **Probing Questions**
+ **Resources**

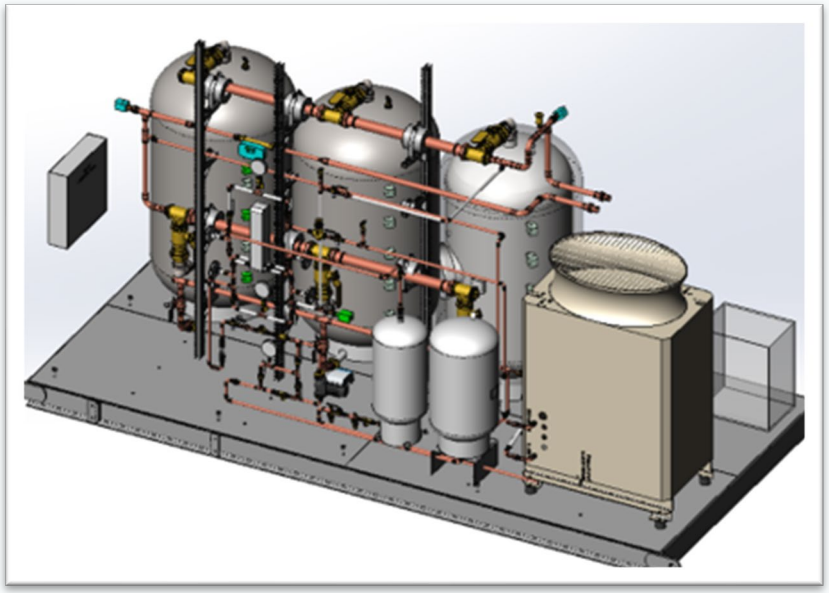
Market Delivery Methods

Custom Engineered System

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

Specified Built-Up System

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



Packaged / Skid

Everything is assembled and delivered in a single package.

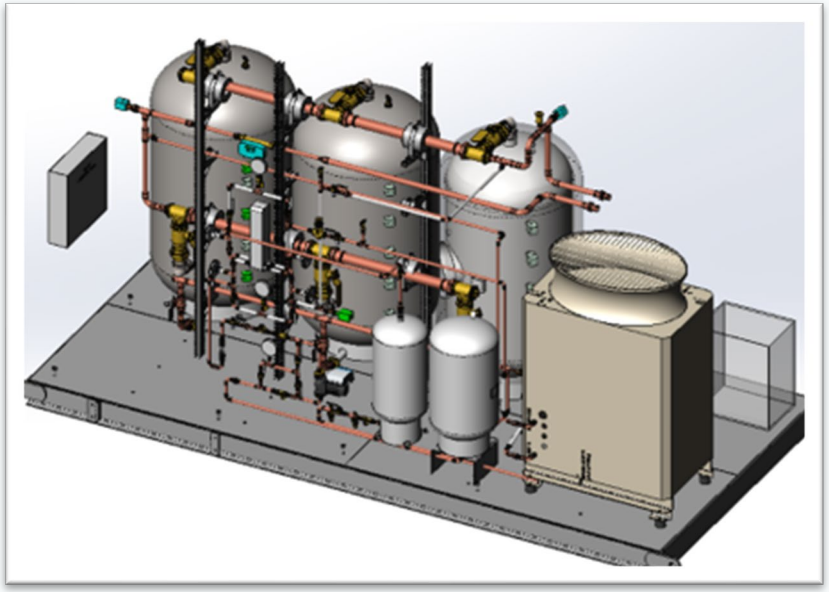
Market Delivery Methods

Custom Engineered

Designer holds the keys to success. Designer must coordinate extremely thoroughly with product manufacturers and installers to meet overlapping requirements. Highly recommend manufacturer-authorized equipment start-up.

Specified Built-Up

Product rep holds the key to success. Rep must provide a system-level warranty that includes service, start-up, and troubleshooting.



Packaged / Skid

Skid manufacturer holds the keys to success. Manufacturer must provide a system-level warranty that includes service, start-up, and troubleshooting.

Probing Questions:

1. Is your HPWH/system on the qualified products list?
2. Are additional items needed to satisfy AWHS requirements?
3. Can you send me the design guidance required by the AWHS?
4. Will this HPWH operate in my hottest and coldest design temperatures without back-up?
5. Which TM configuration do you use and why?
6. Does your warranty cover the full system; parts and labor?
7. Do you provide factory-authorized start-up and DHW plant-level functional testing?
8. How many installs are in my area? Can I see one?

Resources

ETO Design Guide

https://www.energytrust.org/wp-content/uploads/2023/04/New-Buildings_Design-Guide-for-Central-Heat-Pump-Water-Heaters.pdf

AWHS Qualified Products List

https://neea.org/img/documents/commercial-HPWH-qualified-products-list.pdf

Seattle City Light Incentives

https://www.seattle.gov/city-light/business-solutions/large-commercial-and-industrial-business-solutions

Building Solutions Center CHPWH System Design Guide

Coming soon.

Get to know your manufacturer.

There are no dumb questions!

ECOTOPE

Final Check-in

1. **Are you feeling confident?**
2. **What am I missing?**

Thank you!

Evan Green
Research and Design
Ecotope
Evan@ecotope.com