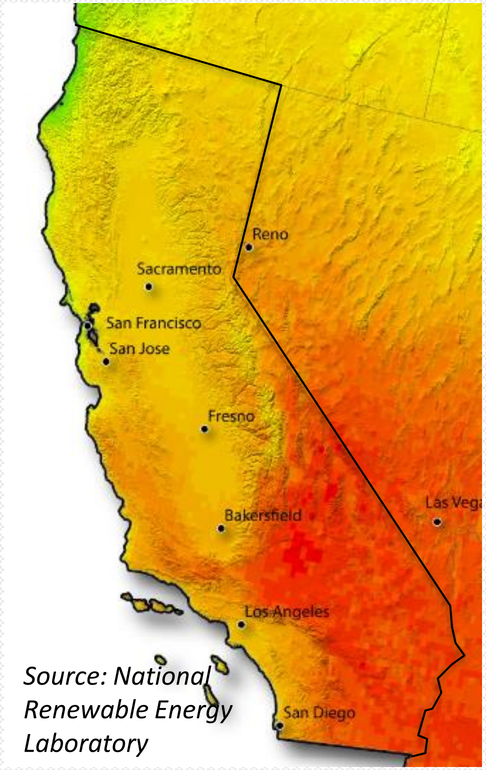

Source: National Renewable Energy Laboratory


Source: https://www.youtube.com/watch?v=N-aK6JnyFmk

Dan Johnson, AIA | BeyondEfficiency.us

CALIFORNIA DREAMIN'

REAL-WORLD IMPLICATIONS OF THE ELECTRIFICATION MOVEMENT FOR A CALIFORNIA PASSIVE HOUSE

Beyond Efficiency

PHIUS Conference 2017, Seattle WA

Overview of Presentation

- Two Case Studies
- Thermal Storage & Heat-Pump Water Heaters
  - Decarbonize space heating & water heating using one appliance
  - Piping arrangements to maximize thermal storage
  - Load-shifting value in each case
- Criteria for Designers
  - Applicability criteria
  - Sizing the storage tank
- Compare to Other Technology

CALIFORNIA ELECTRIFICATION MOVEMENT

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Core Principles of Electrification

Shift to Heat Pumps

- Heat pump (HP) COP at least 2.4, running on 40%-efficient gas-fired powerplant, produces less GHG than burning gas at building at 98% eff.
- HP equipment is cost-neutral to install, vs. gas
- HP equipment will have further efficiency gains, while gas equipment is already stuck at physical limit

Shift Loads to Midday

- HP equipment can be effectively solar powered if loads are shifted to midday.
- Can't serve loads with renewables in CA if loads occur after dark
- Grid-scale electricity storage is currently not economic (pumped hydro, compressed air underground, etc.)

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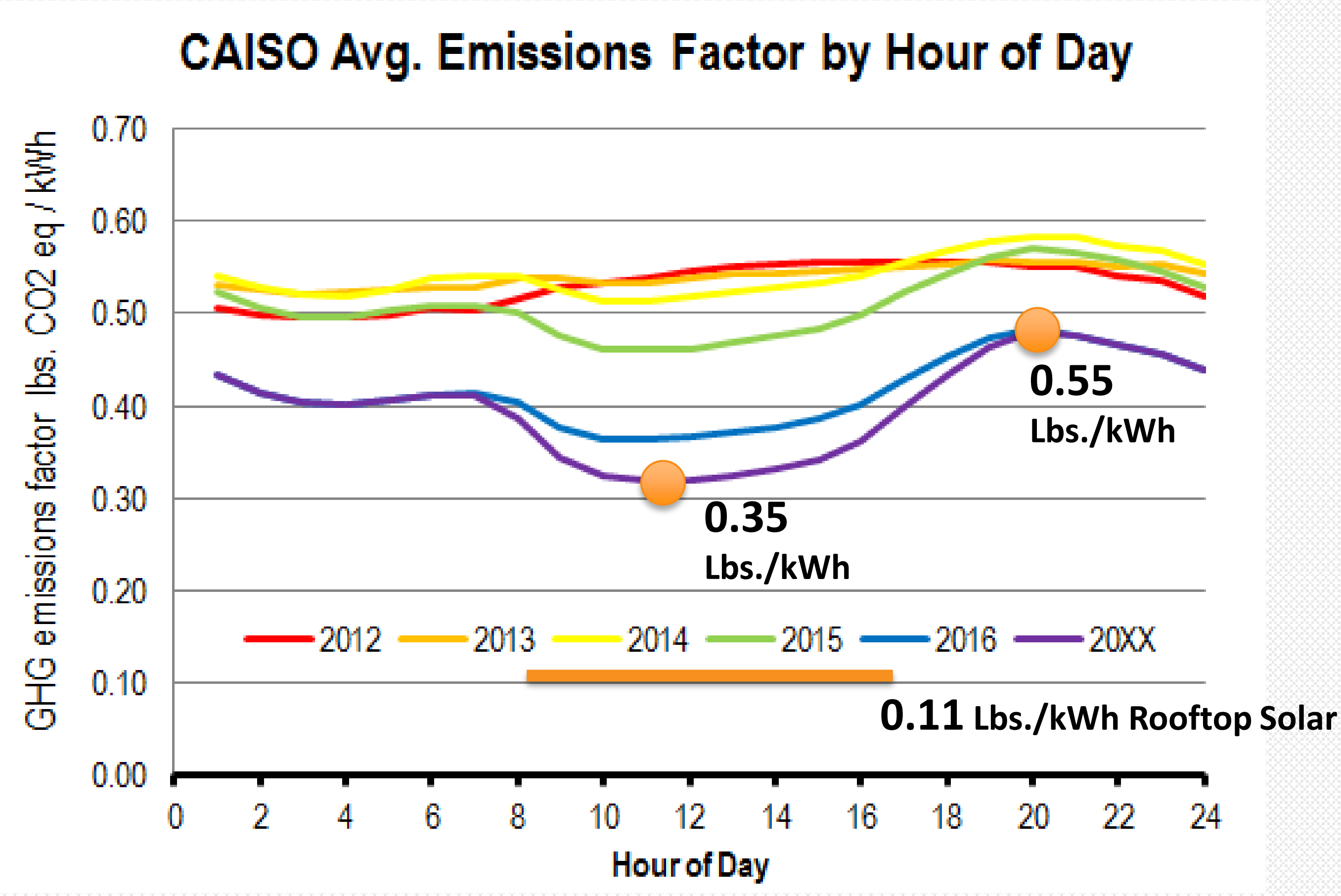
California Grid Getting Cleaner



Source: https://en.wikipedia.org/wiki/Life-cycle_greenhouse-gas_emissions_of_energy_sources#2014_IPCC.2C_Global_warming_potential_of_selected_electricity_sources

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Implications for Buildings

Homes use a lot of thermal energy

- Domestic hot water (DHW) and space heating are large end-uses in California
- We already have a thermal battery in the DHW tank
- Use thermal storage instead of chemical batteries

Electric water heating + thermal storage

- Therefore we want electric hot water (heat pump)
- Run mainly at midday using solar PV
- Focus on storing hot water for dark, cold hours
- Provide space heat from DHW storage

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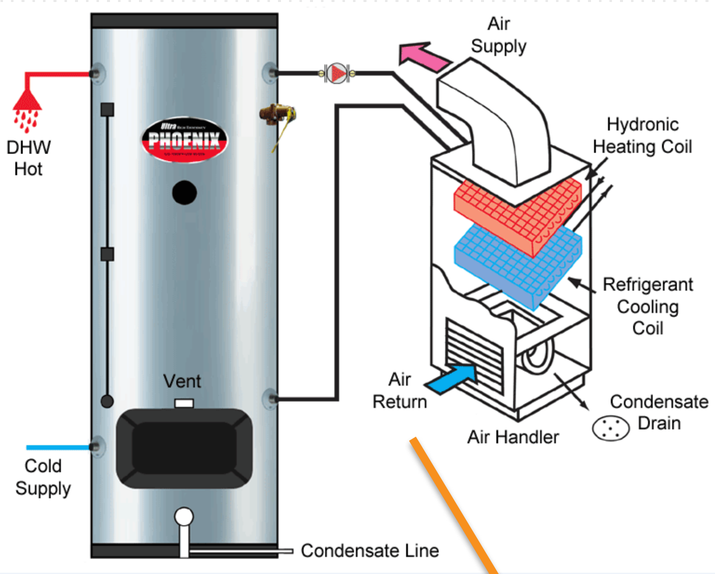
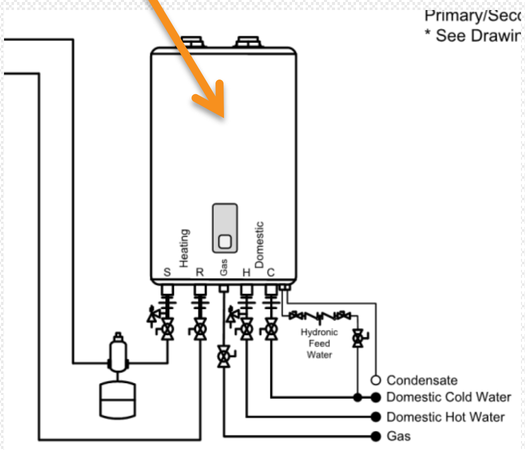
Brief History of "Combi" Systems



HTP Versa-Hydro

Daikin Altherma

Other Euro & Asian imports



Tankless Gas Combi Boilers

Sanden SanCO_2

Two Case Studies

#1 Berkeley Passive House (Berkeley, CA)

- Radiant floor heating

#2 Phased P.H.-Inspired Remodel (Kensington, CA)

- Forced-air heating

- Both under construction
- We hope to report data next year
- Now we'll look at storage design common to both

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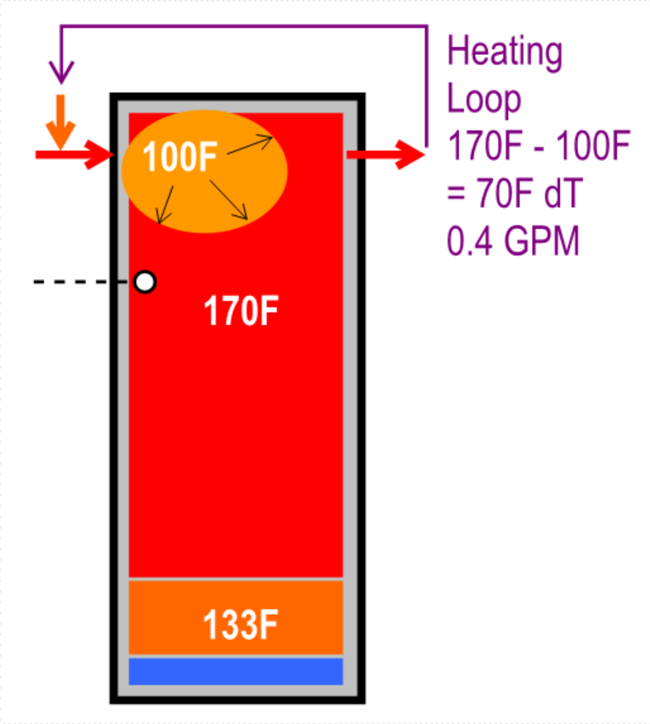
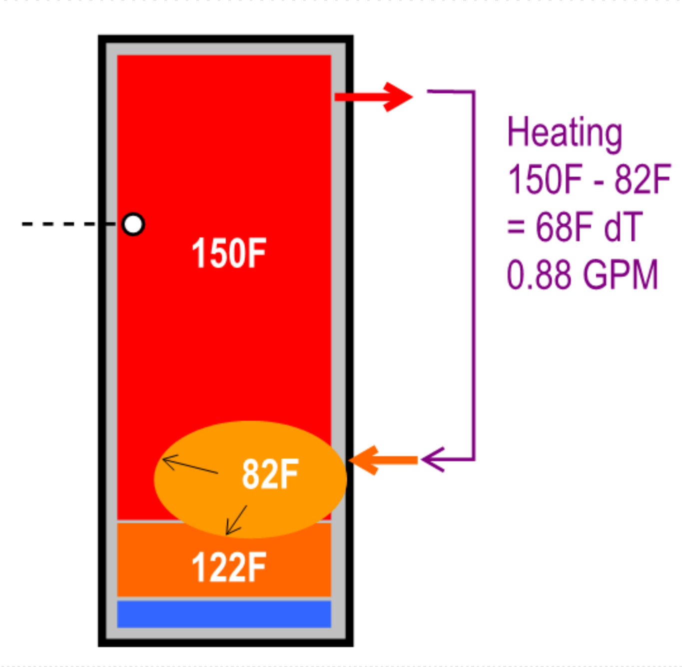
Adapting PNW Design for Load Shift

Top-Tank Return:
Perfect Mixing?



-OR-

Bottom-Tank Return:
Perfect Stratification?



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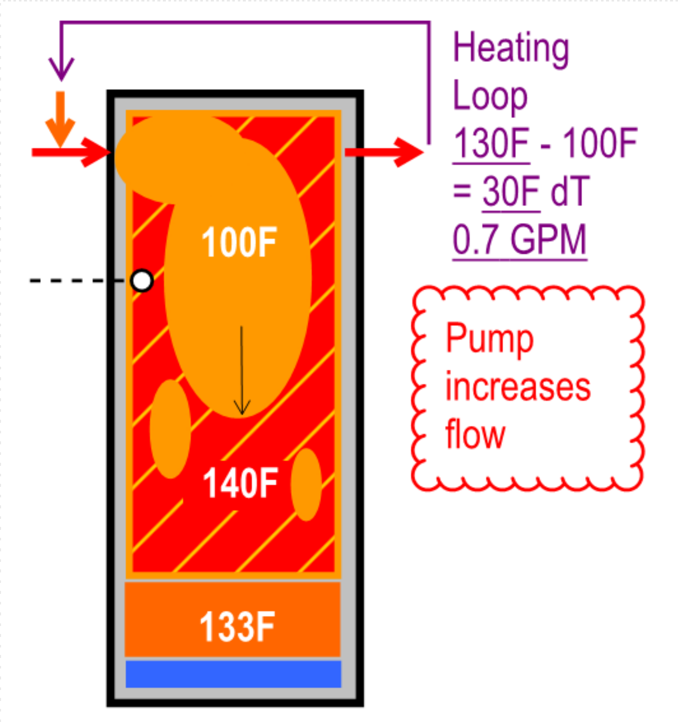
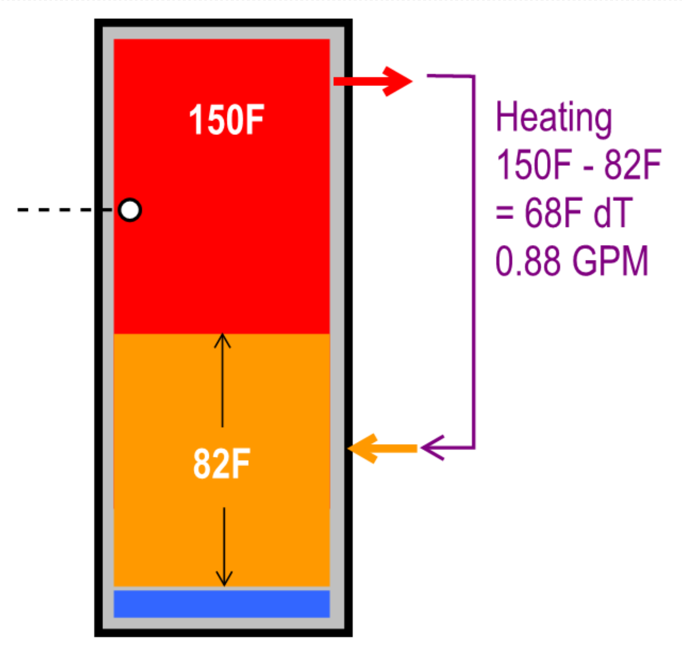
Piping the Storage Tank

Top-Tank Return:
Perfect Mixing?

-OR-

Bottom-Tank Return:
Perfect Stratification?





Time Elapsed +2 hours

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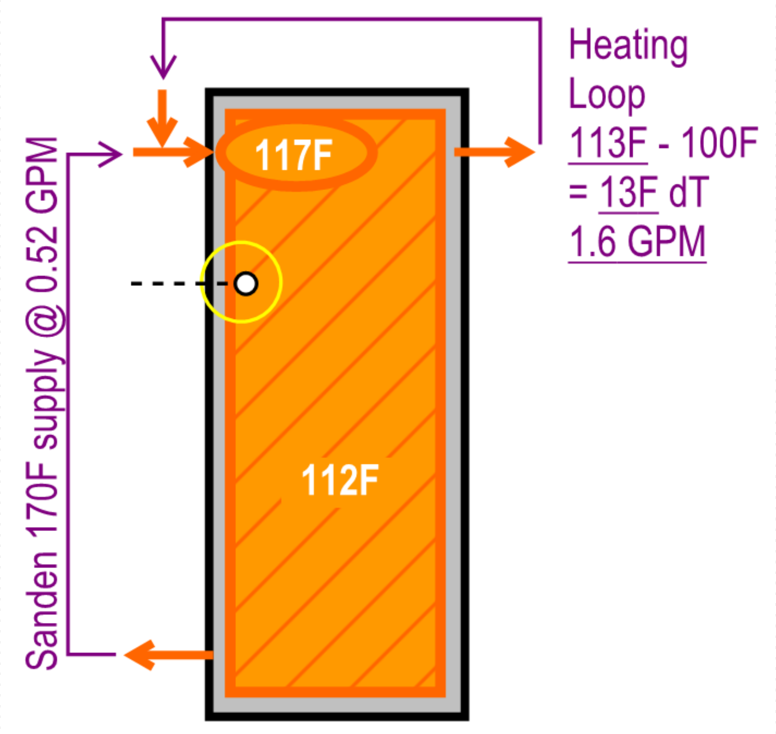
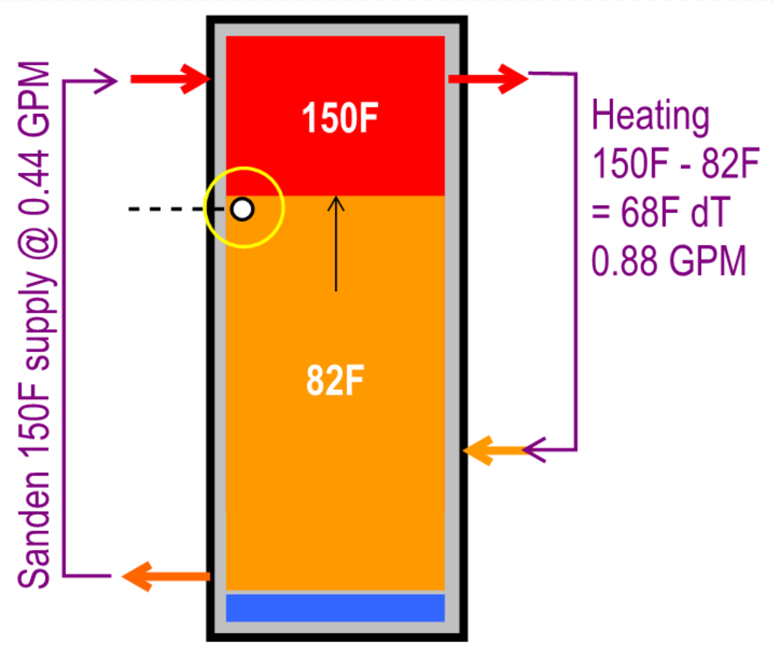
Piping the Storage Tank

Top-Tank Return:
Perfect Mixing?

-OR-

Bottom-Tank Return:
Perfect Stratification?





Time Elapsed +4 hours
(Steady State Equilibrium)

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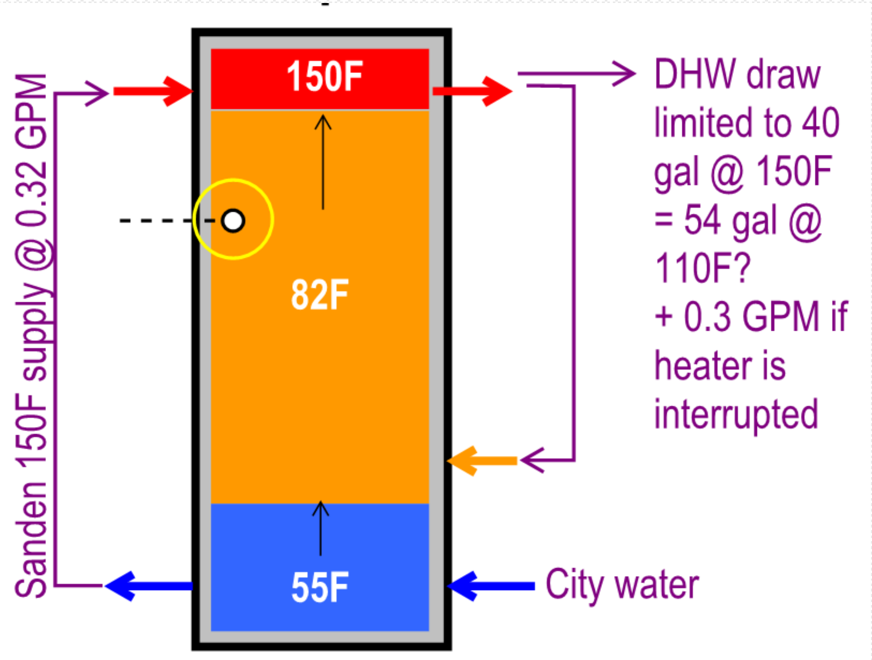
Piping the Storage Tank

Bottom-Tank Return Advantages:

- **Requires low return temp** on heating loop
- Can supply **very hot water to heating loop**
- No supply-temp-oscillation
- **Cooler return** to Sanden = higher efficiency
- HOT water reserve for domestic



Time Elapsed +4 hours

40 gal @ 150ºF still available

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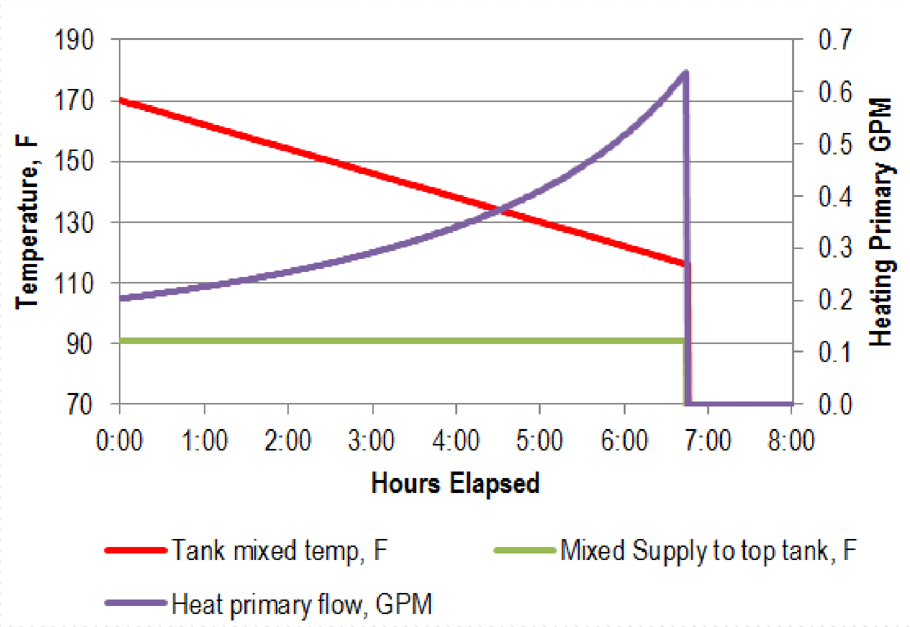
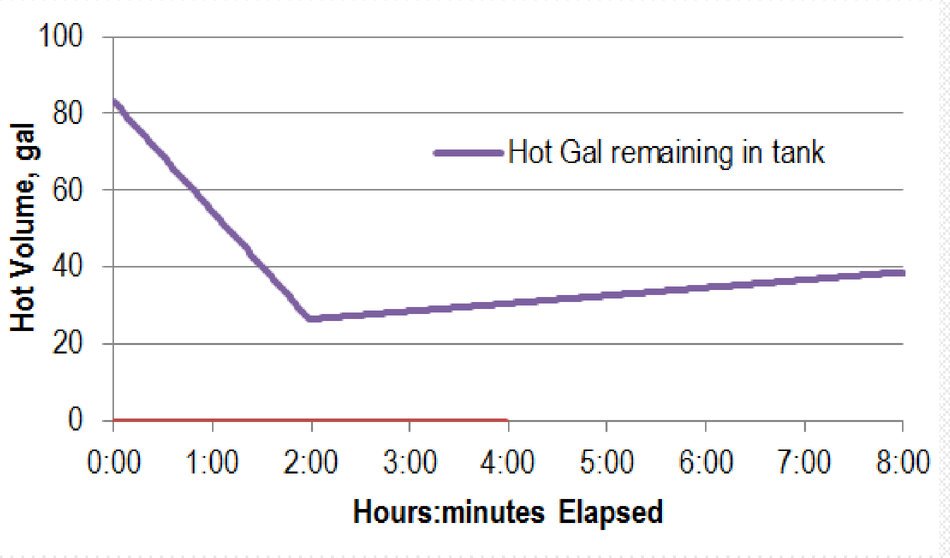
Spreadsheet Model

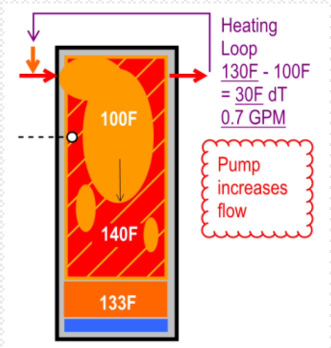
Top-Tank Return:
Perfect Mixing?

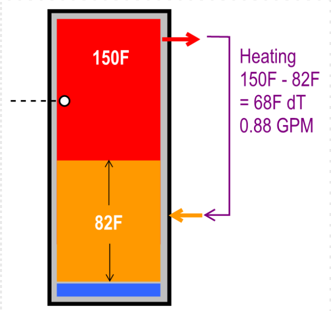
-OR-

Bottom-Tank Return:
Perfect Stratification?









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CASE STUDY #1
BERKELEY PASSIVE HOUSE

2900 sq.ft. gut remodel
33ºF Winter design temp
7,000 BTU/hr peak heating load (Manual J)

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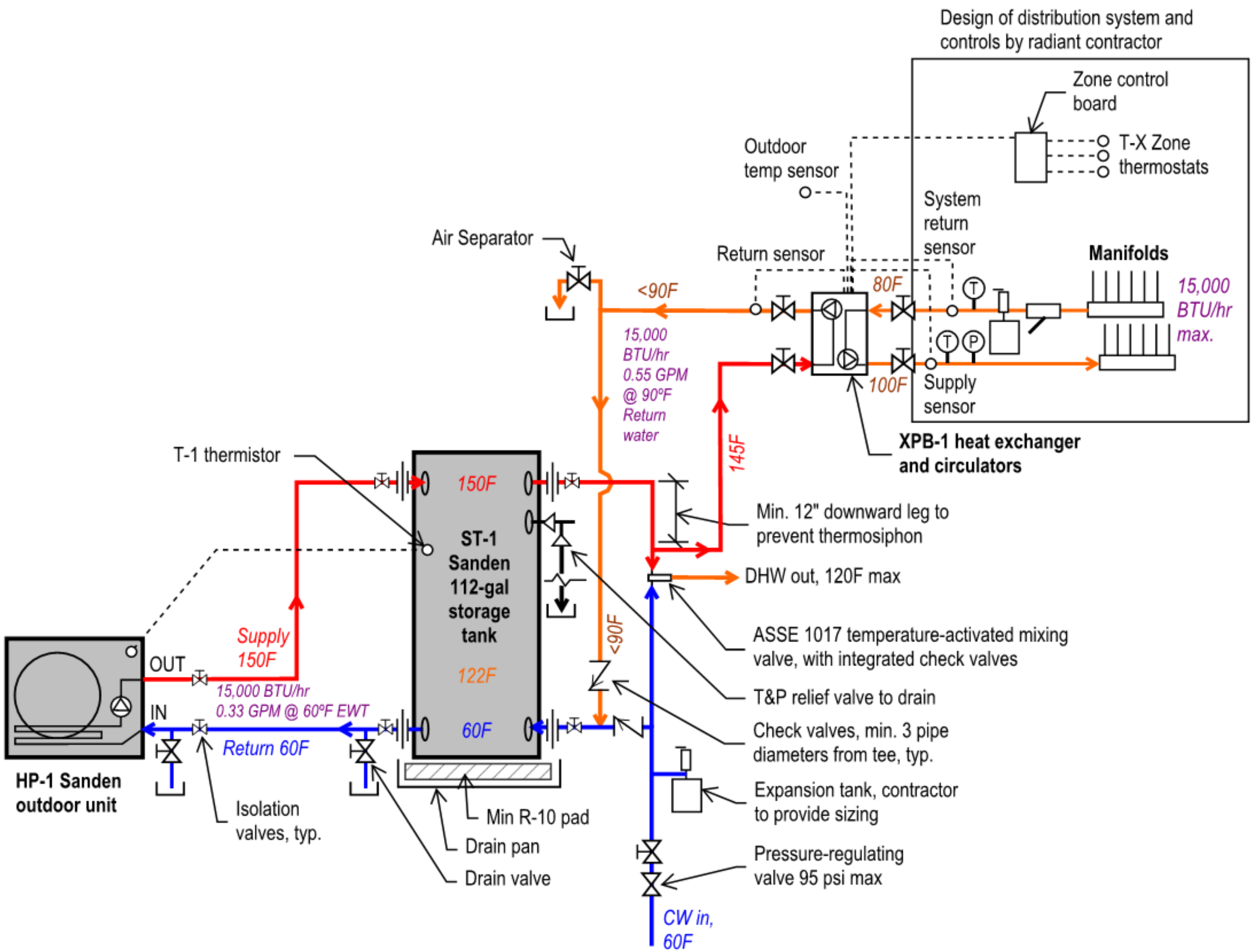
Radiant Floor Heating



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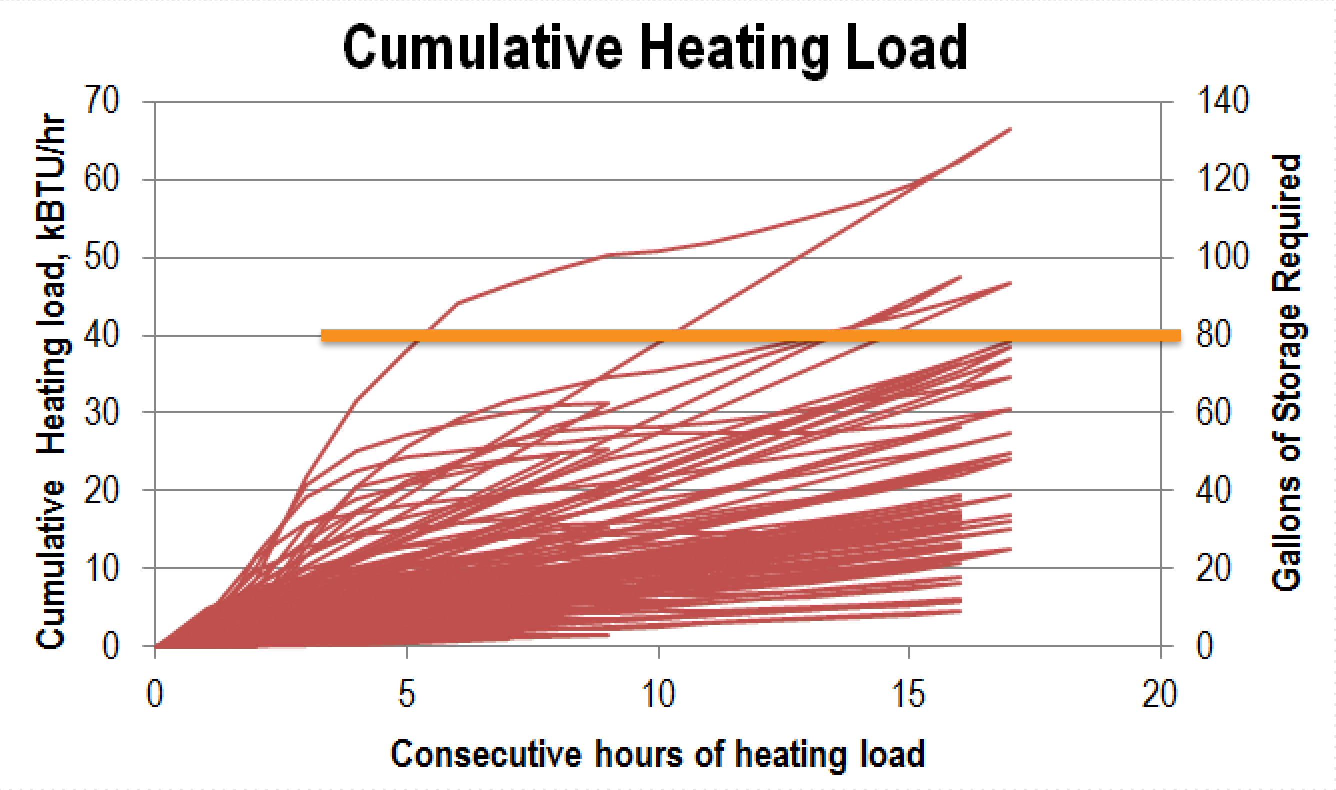
#1 Sizing the Storage Tank



From hourly simulation of Berkeley passive house in EnergyPro (CBECC-RES v.2.1)

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#1 Load-Shifting Value

Does the design meet the goals?

Tank capacity: 112 gal. (about 42 gal DHW reserve, 70 gal load-shift volume).

- About 40 minutes showering
- 35 kBTU for space heating, about 5 hour peak load @ 7,000 BTU/hr.
- Simulated duration of heating events is max. 16 hours at 2000 BTU/hr = 32 kBTU
- 2.5 hours to recover the 70 gal volume, 90F -> 150F lift
- Equivalent to about 4 kWh chemical battery storage

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CASE STUDY #2
PHASED, P.H.-INSPIRED RETROFIT

3400 sq.ft. phased remodel
33ºF Winter design temp
30,000 BTU/hr initial heating load -> 15,000 BTU/hr @ completion

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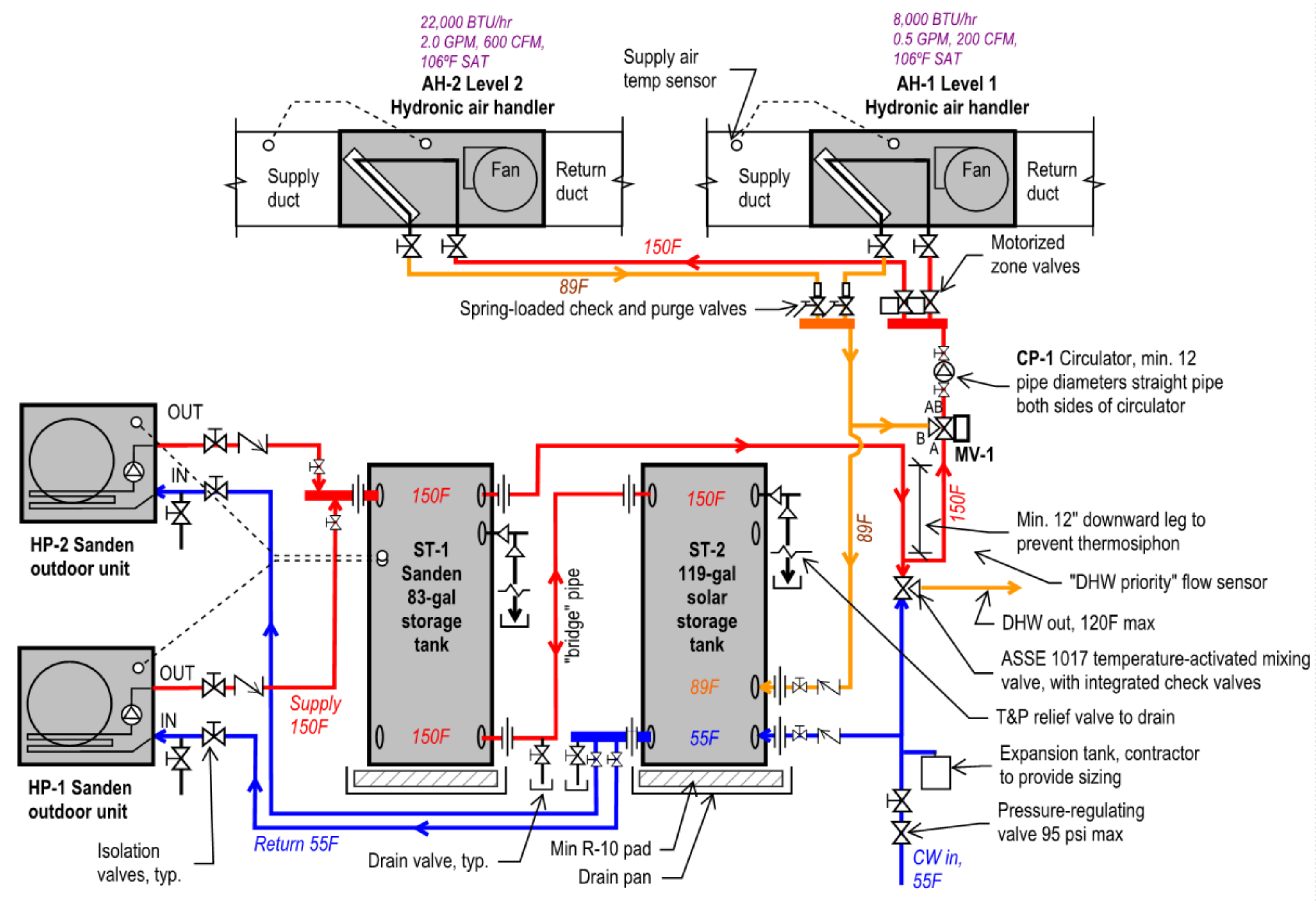
Forced Air Heating



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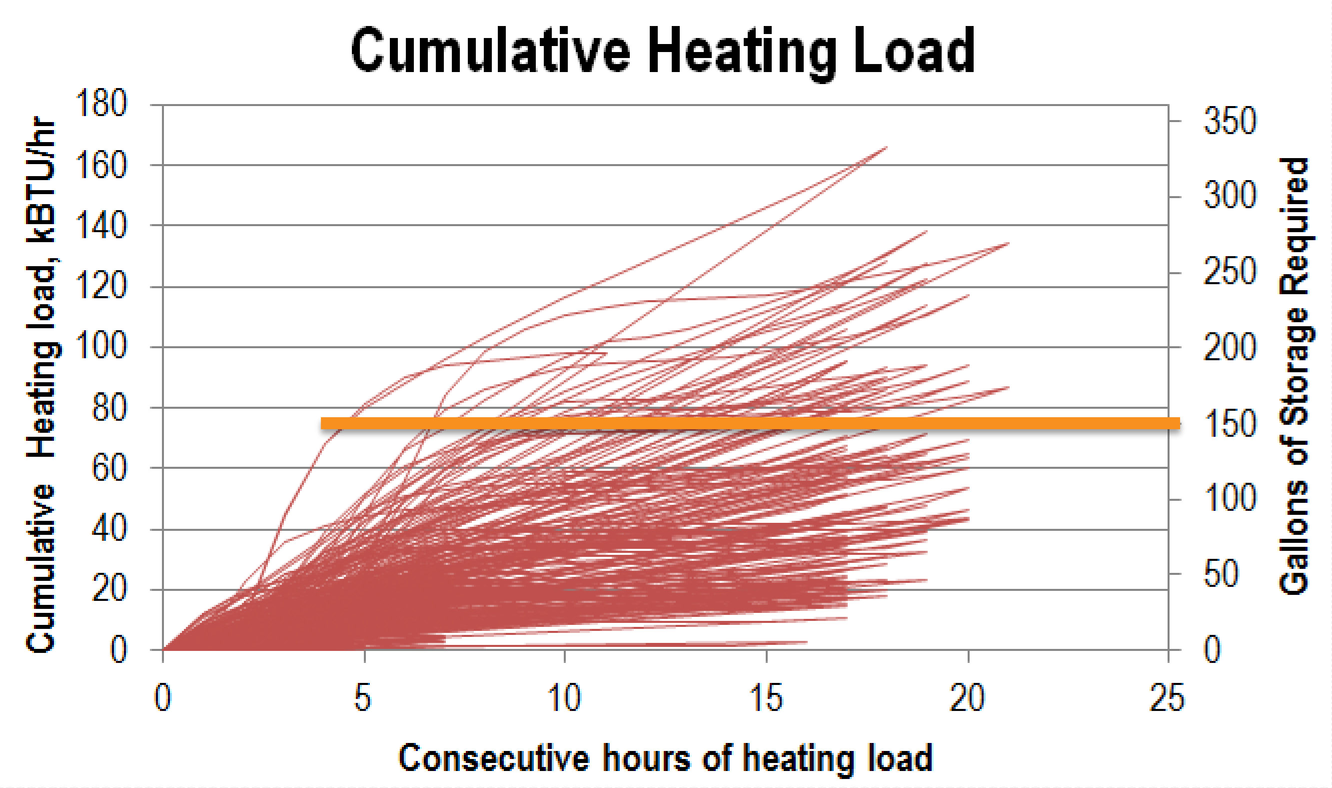
#2 Sizing the Storage Tank



From hourly simulation of Berkeley passive house in EnergyPro (CBECC-RES v.2.1)

Beyond Efficiency

#2 Load-Shifting Value

Does the design meet the goals?

Tank capacity: 80 + 120 gal. in series (about 50 gal DHW reserve, 150 gal load-shift volume).

- About 86 minutes showering (could be an entire day of demand)
- 75 kBTU for space heating, about 2.5 hour peak load @ 30,000 BTU/hr. (After phased energy upgrade: 5 hrs @ 15 kBTU/hr).
- Max 24-hr space heating demand, from simulation, is about 80 kBTU over 20 hours
- 2.5 hours to recover the 150 gal volume, 90F -> 150F lift, using (2) Sanden heat pumps
- Equivalent to about 8 kWh chemical battery storage

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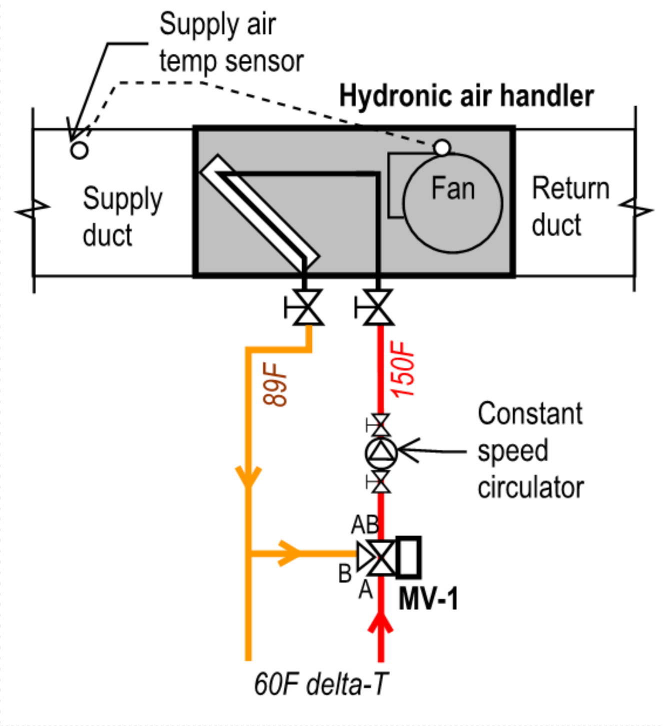
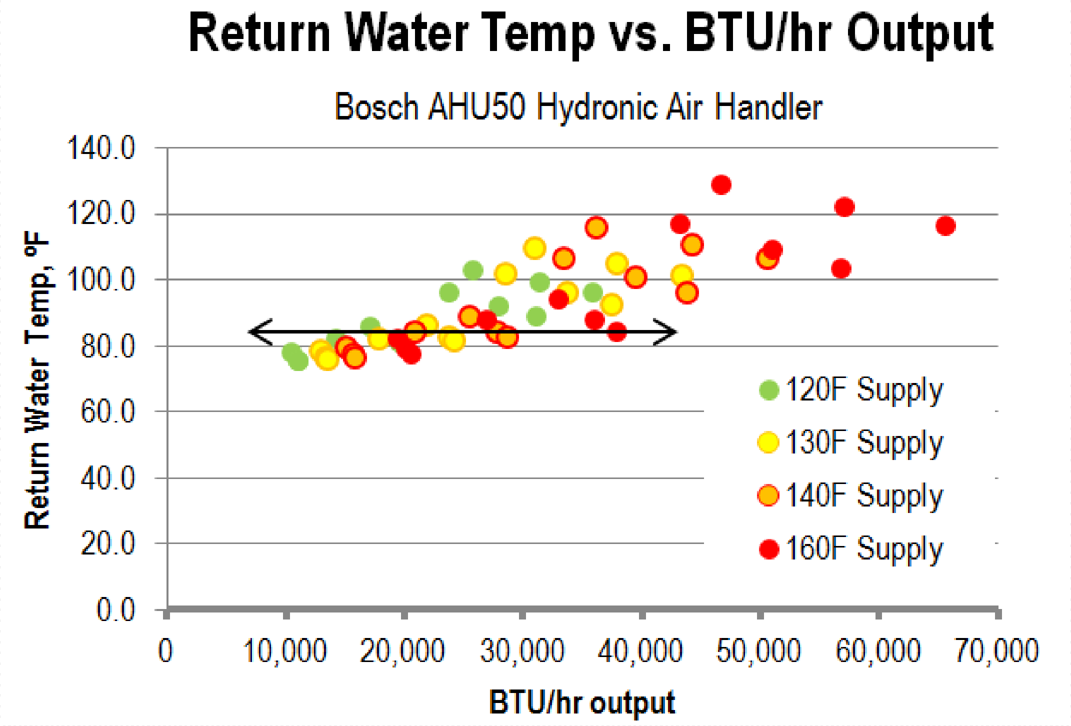
Hydronic Forced-Air Design

Goals:

- Achieve a cool return temp over range of heat outputs
- Hold 110ºF supply air over range of heat outputs
- Ideally no heat exchanger, for cooler return temps to Sanden





Vary the airflow and water temperature in parallel

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Hydronic Forced-Air Design

What equipment is inexpensive & sized for small loads?

Bosch AHU50 Hydronic Air Handler
(Shown with tankless gas water heater)

Sure Marine 6462 Boat Heater

Myson Whispa III Kickspace

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Application Criteria

Is this setup appropriate for your project?

- Owner desire for electric heat source & energy storage
- No cooling (A/C) required
- Heating load <15 kBTU/hr
- Hydronic heat emitters (radiant floors, radiators, fan coils, etc.), using slow pump, with cool return temperatures
- Architectural space for large storage tank
- Size the storage tank for the estimated 24-hr domestic hot water (DHW) usage & heating demand

Monitoring & follow up

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How Widely Could this Apply?

- No cooling required
  - 10 million people in coastal California (CA)
  - Pacific Northwest
- Heating load <15 kBTU/hr (Manual J equivalent)
  - CA Passive House, 4 kBTU/hr.ft^2, up to 3750 ft^2
  - CA-Code-built apartments, 6 kBTU/hr.ft^2, up to 2500 ft^2
  - CA-Code-built single-family, 9 kBTU/hr.ft^2, up to 1600 ft^2
  - CA Remodeled houses, 12 kBTU/hr.ft^2, up to 1250 ft^2
- Compare incremental cost of storage tank to chemical batteries

Questions?

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(415) 236-1333

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