DIY Electrification

Turning the Valve

Howdy Goudey
Dec 2021

Electrification DIY Cost and Complexity

Complexity /Price	$	$$	$$$
	• Small kitchen appliances • Thermonuclear Fusion Clothes Dryer • Level 1 EVSE    	  • Heat pump dryer • Resistance space heaters (high operational cost)	
	• Level 2 EVSE (with circuit) 	• Unitized HPWH (with circuit) • Induction range (with circuit) • Packaged in wall (PTAC/HPAC) • Mini-split (pre-charged)    	
	• Service panel upgrade 	• Mini-split (site-filled by contractor) 	• Combi system (water/space) • Heat pump space heating (central)  

Personal electrification story begins ~10 years ago

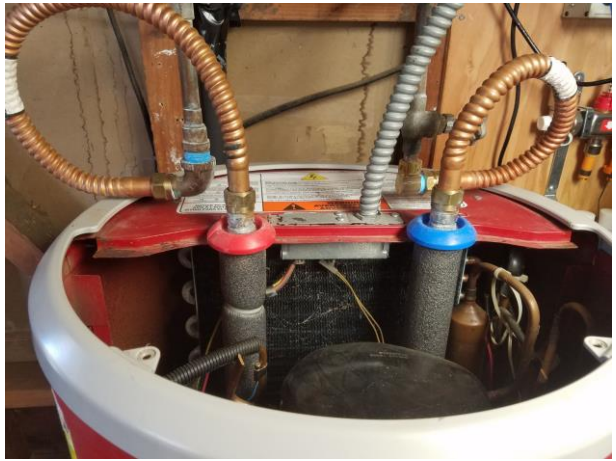
Reconnection to the grid

Bootlegged panel upgrade courtesy of the war on drugs

Heat Pump Water Heater 2013

Original gas water heater and furnace, ~20 years old?

Still a $300 utility rebate available to DIY, but $1000 from BayREN appears to be for contractor work



First install was tight to original plumbing, hence the elbows

A series of “temporary measures”

Human in the loop, manual condensate drain

Induction range 2015

Original gas range

Anachronistic modern “slide-in” where a wide range with a fue used to sit
Still haven’t built proper

Turned off gas valve to the whole house at the same time

Still a tired funky old kitchen, but the gas is gone

Biding time with electric resistance heat

Still had a gas furnace, but “it’s only about 3 months a year”

Excess PV production, makes it inexpensive to operate

Convection space heater

Radiant panel

“Spot” heating on demand, not thermostatic

Not super comfy or convenient, be we are used to somewhat spartan heating

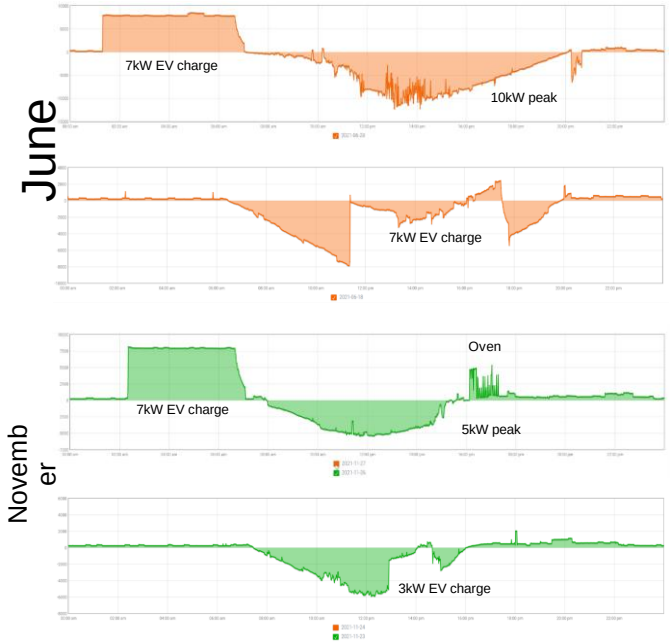
12kW Solar, 2017

~17MWh a year (46 kWh/day avg., over 80kWh/day peak)

Two 5kW inverters and sub-panel

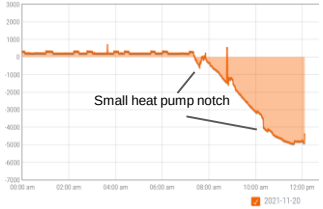
East-West same coverage

Utility meter profiles, night time versus daytime EV charging



Partial DIY approach is Sunwork (volunteers helping non-profit contractor) Now includes simple heat pump water heater installs

Growing interest in matching timing of generation to loads



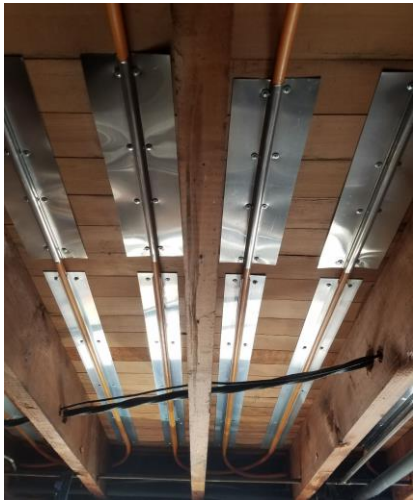
Hydronic Heat Pump 2019-2020-2021. . .

Languishing project

Winter doesn't seem to last long enough to keep me motivated to finish

- Sanden CO2 cycle Outdoor hot water unit
- Two 120 gal tanks
  - Time shifting load
- Various hydronic delivery methods
  - Under wood floor (one room done)
  - Radiator
  - Distributed fan coils

Heating through a wood floor offers modest heating rate (back to the ~1kW space heater), but might provide baseline comfort



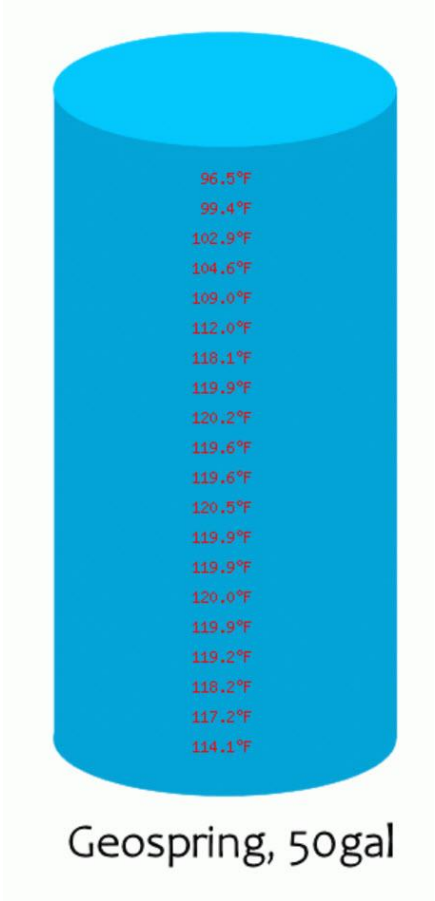
Different spreader plates

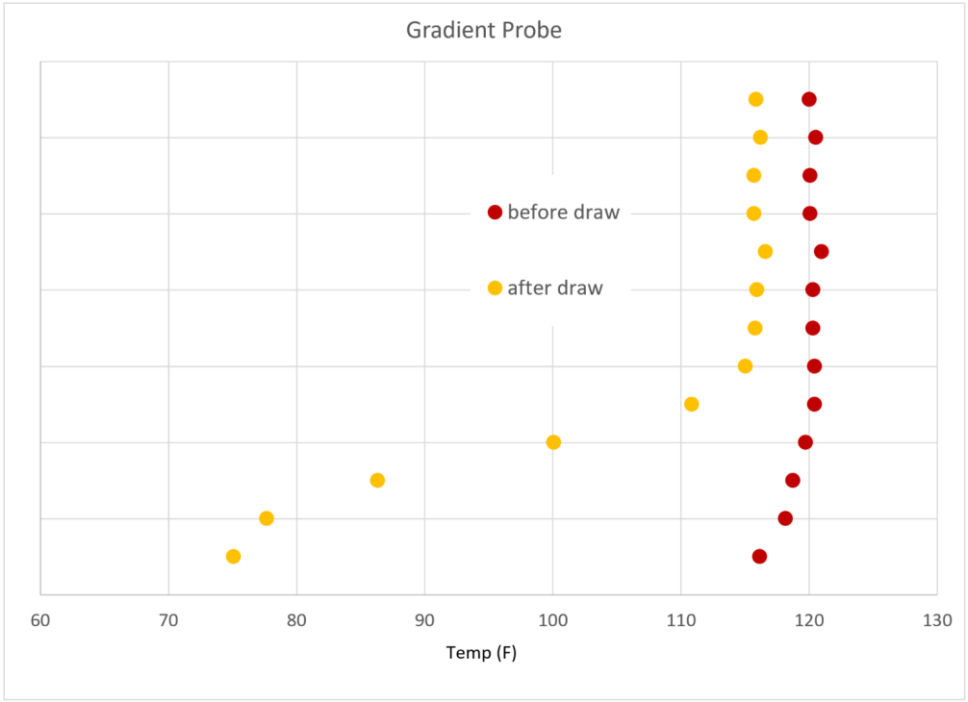
Counterflow routing

Temperature gradient probe

String of twenty DS18B20 “one-wire” digital temp sensors wired in a bus and slid into a stainless steel tube

Temperature gradient probe data





Before and after one shower

Free street art . . .

and maybe a capped pipe

Easy to get gas off account,
harder (at least for me) to get the pipe capped
3+ years since first contact

Adventures in electrification and home energy storage

LBNL Home Decarbonization Seminar
December 1, 2021

Spencer Dutton

Context

- North Berkeley location
- About 100 years old
- Three stories, ground floor separate apartment.
- 2.5 bath (1 in lower apartment)
- Remodel 1996, added wall insulation ground floor. 2015 cellulose injection.
- *Serious Windows* top two floors.
- Recent solar and related electrical upgrade.

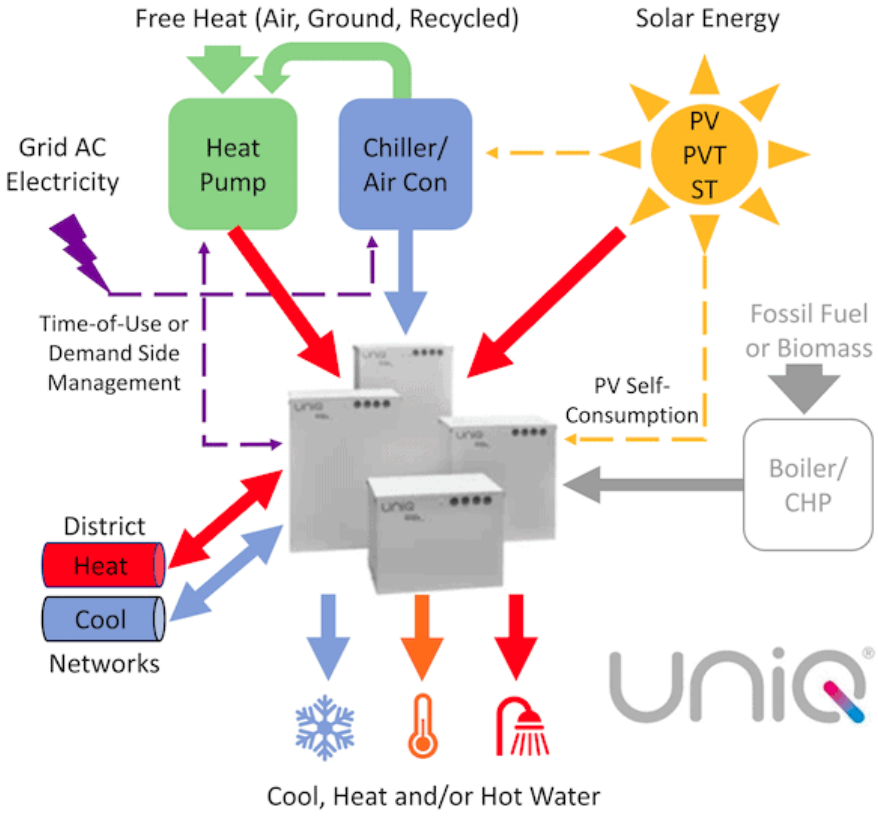
Existing system - installed 1997

- Two zone forced air heating system (top two stories, bottom story)
- Thermalboard upstairs; PEX underfloor downstairs
- 80 kBtu/hour AO smith boiler
- Basic Honeywell thermostatic controls
- Decent sized plant room in basement apartment

Technologies: Phase change based thermal batteries

Sunamp

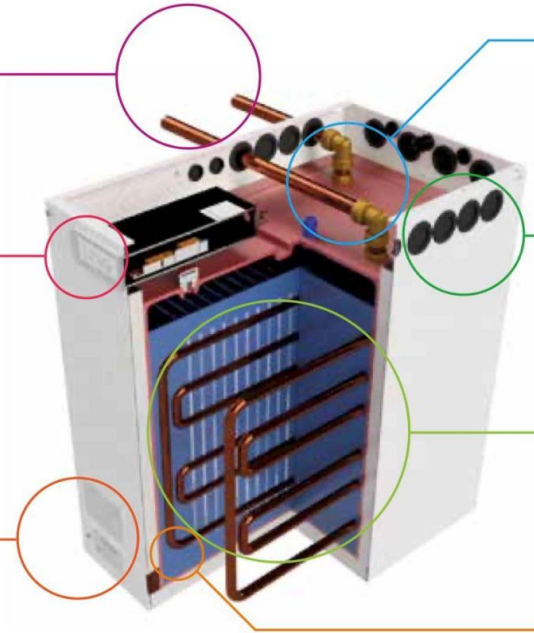
- Both cold and hot storage batteries
- Multiple heat/cold sources
- 58C PCM >60 k charge discharge cycles
- 4X thermal energy storage density



Super-Compact Thermal Energy Storage

Traditional hot water cylinder

Sunamp heat battery



Single and dual circuit models work with any energy source (electricity, PV, heat pumps and boilers)

Simple user interface shows heat battery state of charge and operation

Embedded heating element with 10 year warranty as a primary heat source or back-up

Quick and easy to install, with high quality brass push fit connectors supplied

Flexibility of orientation, with exits on three sides of the product

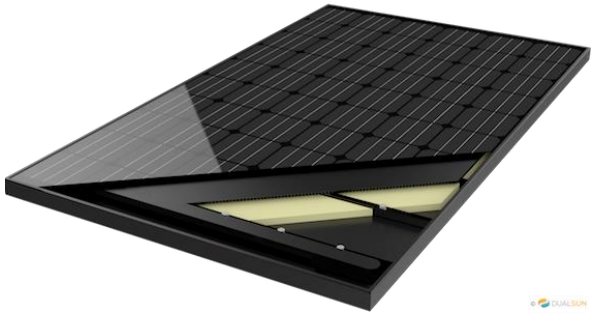
High powered heat exchanger for high quality, mains pressure showers

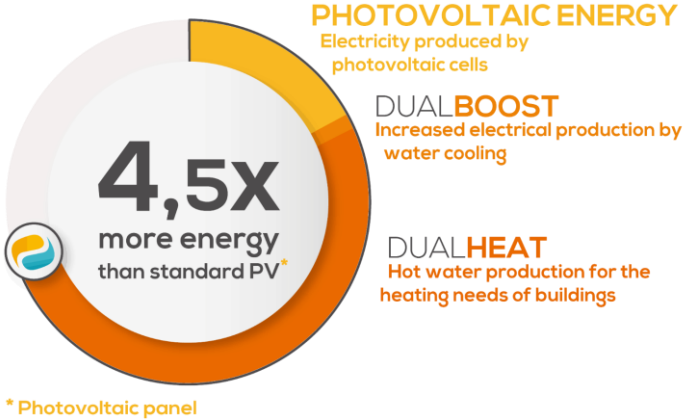
Sunamp's patented phase change material formulation – storing 4 x more energy than water

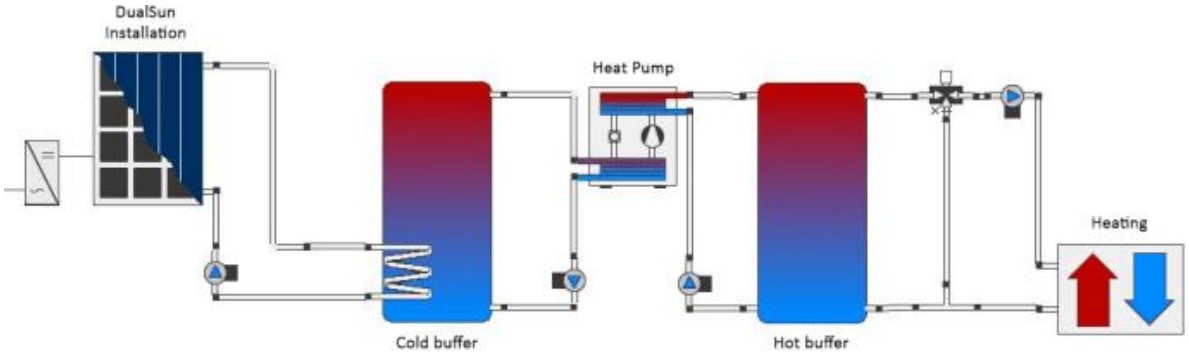
Technologies: Integrated photovoltaic and thermal

DUALSUN

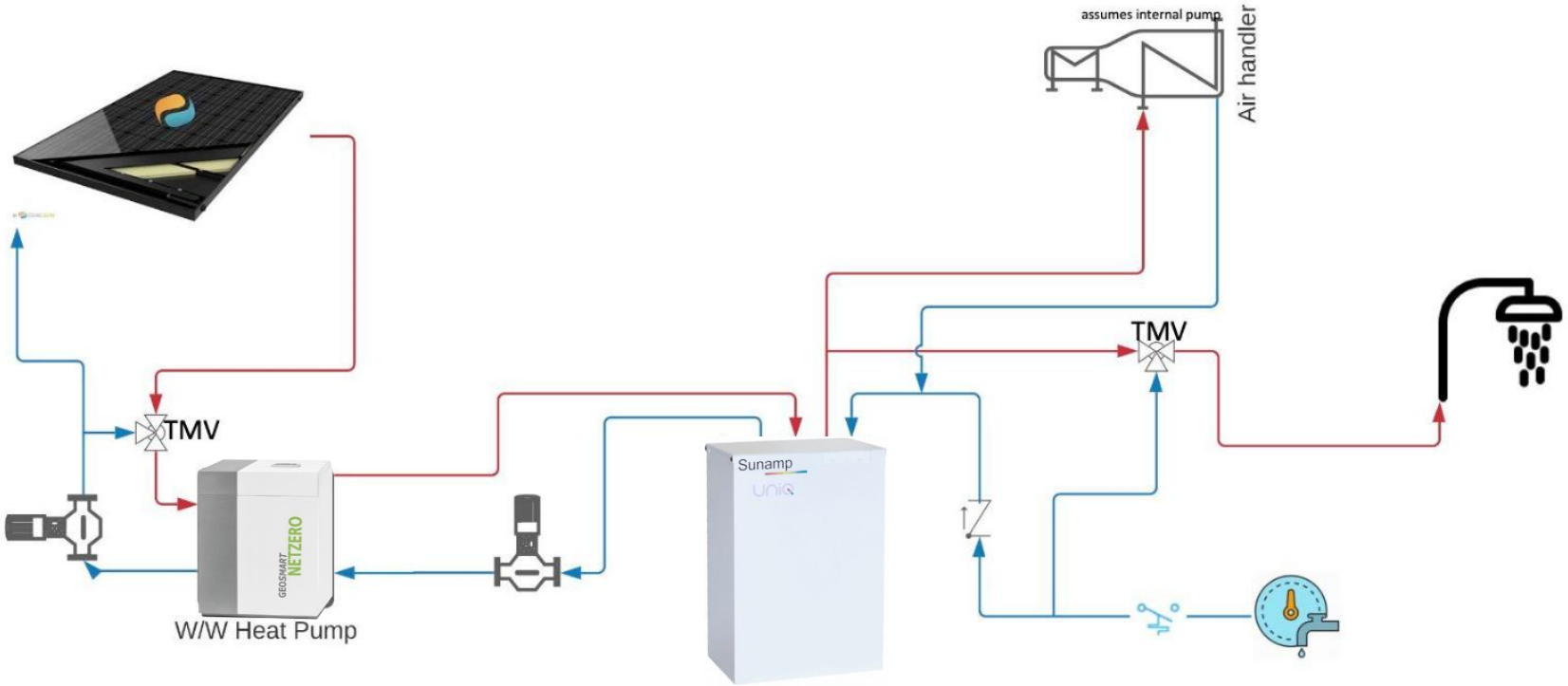
- Improved PV efficiency
- Large thermal capacity
- Maximizes roof space
- Easy (ish) installation



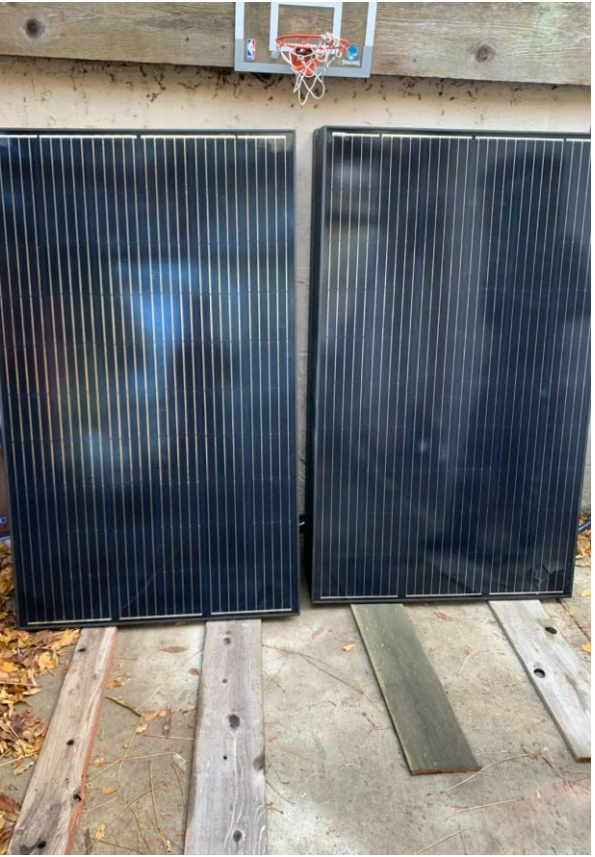




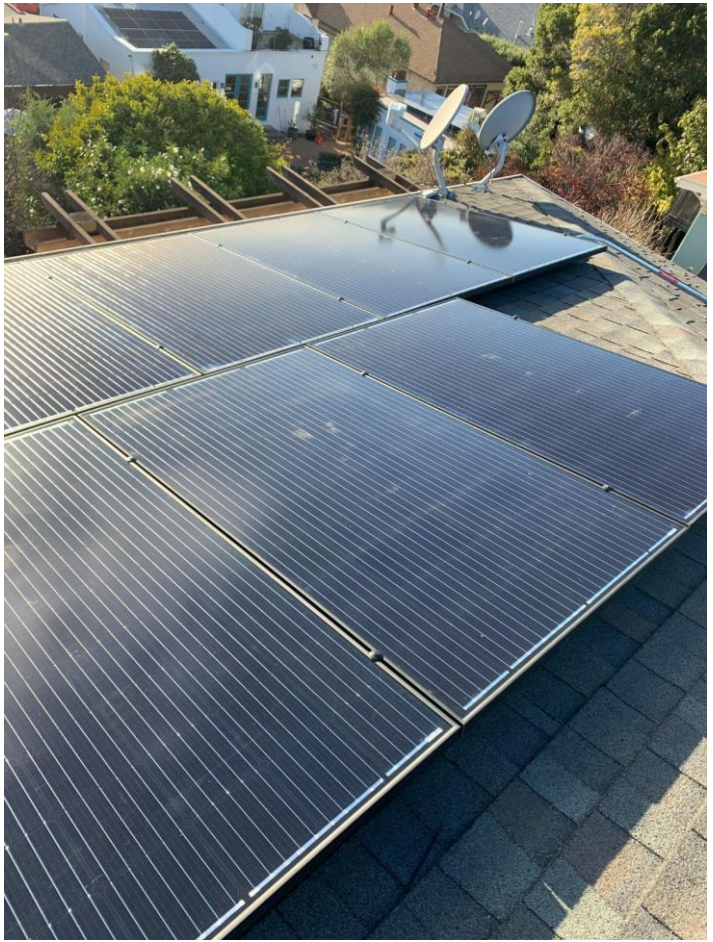
Proposed system configuration



DUALSUN Installation



DUALSUN Installation



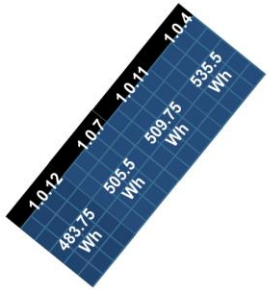
DUALSUN Generation

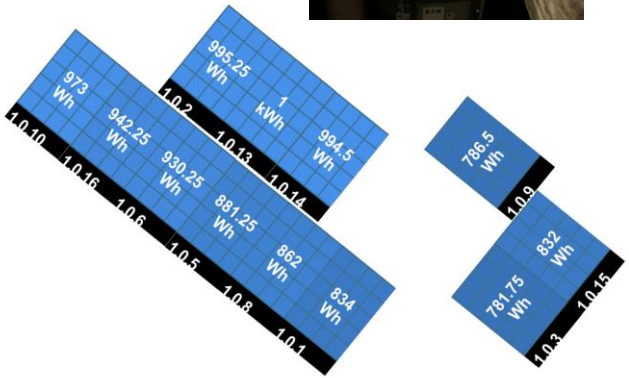
Environmental Benefits

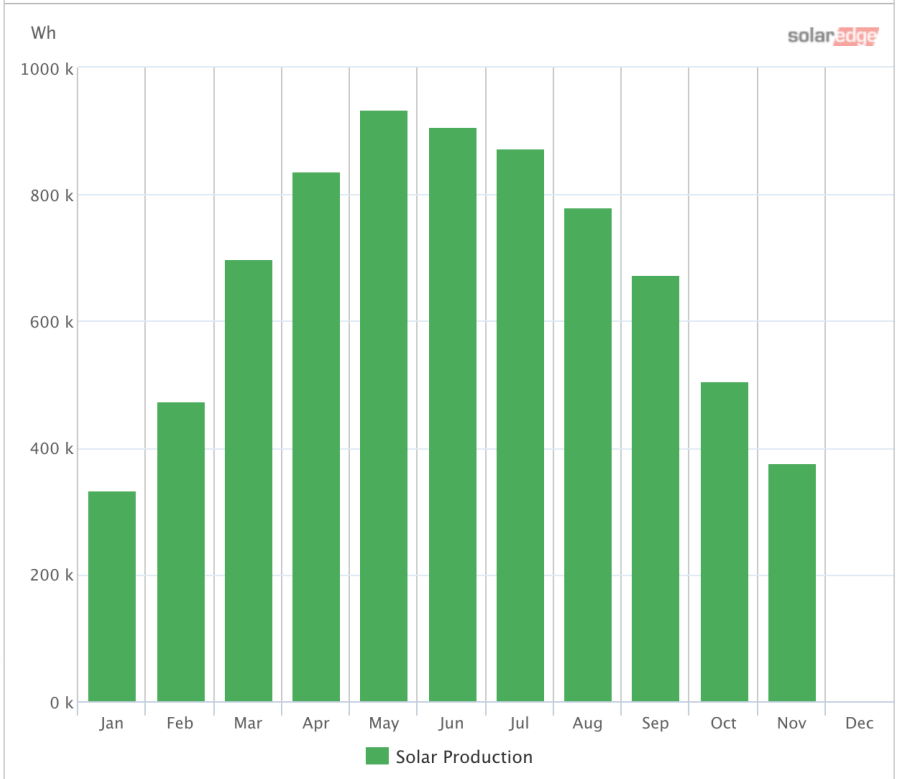
CO2 Emission Saved
11,688.24 lb

Equivalent Trees Planted
88.32

1/01/2021 - 12/31/21
System Production 7.39 MWh

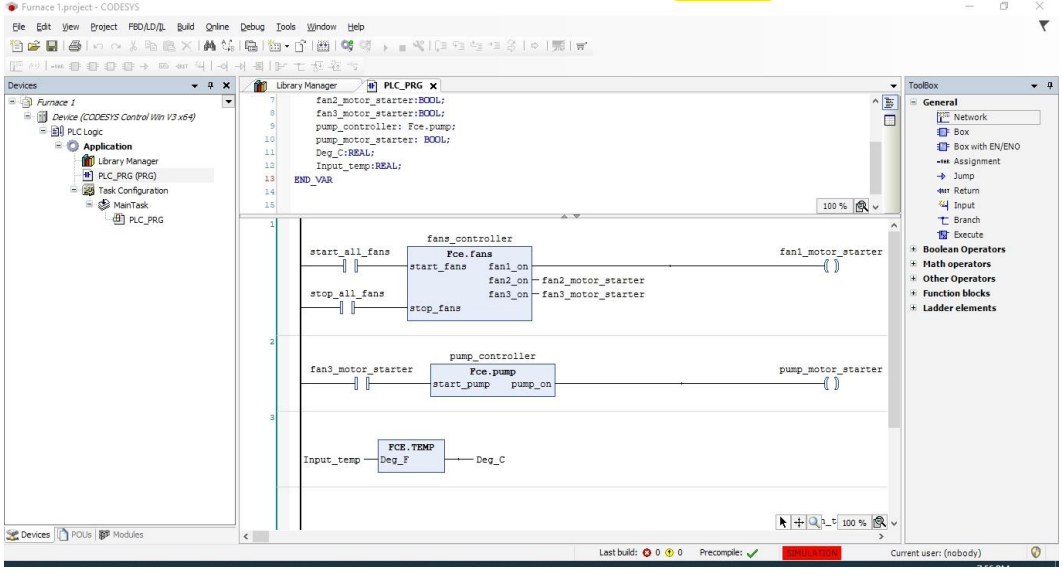


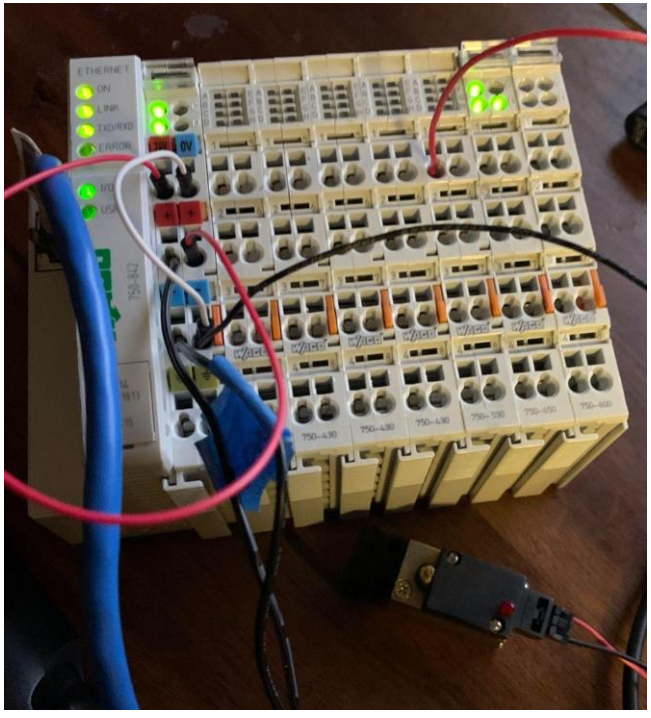




Controls - Wago based

- Costly new but reasonable on ebay
- Comes with extensive technical support
- Powerful GUI to design and implement controls
- Trnsys model development - University of Dublin





Lessons learned

- Check electrical upgrade cost/ feasibility

Bruce’s Heat Pump Adventure

LBNL Home Decarbonization Seminar
December 1, 2021

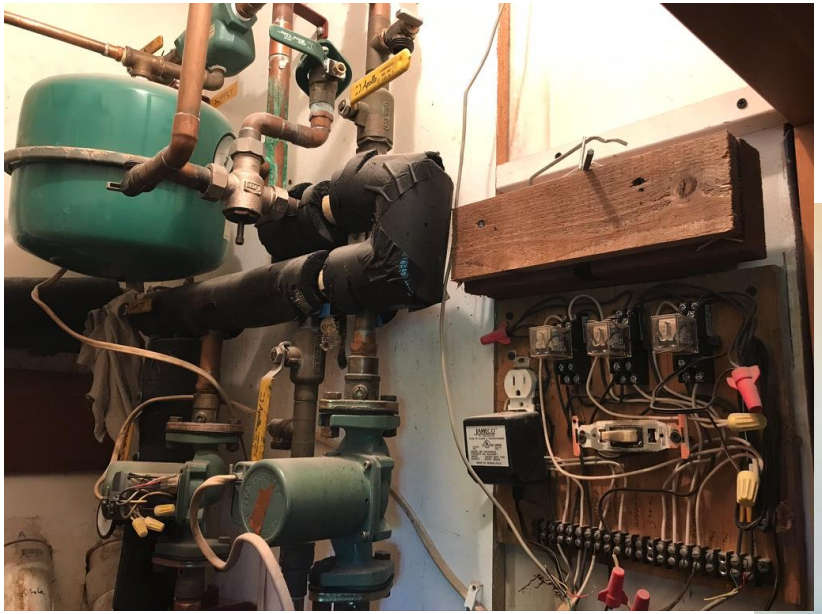
Bruce Nordman

Context

- Central Berkeley location
- About 100 years old
- Second floor added ~20 years ago
- Downstairs single-paned windows
- Upstairs all double
- Insulation good - not great
- Until 2003: single wall heater and gas water heater
- Currently adding PV

First retrofit

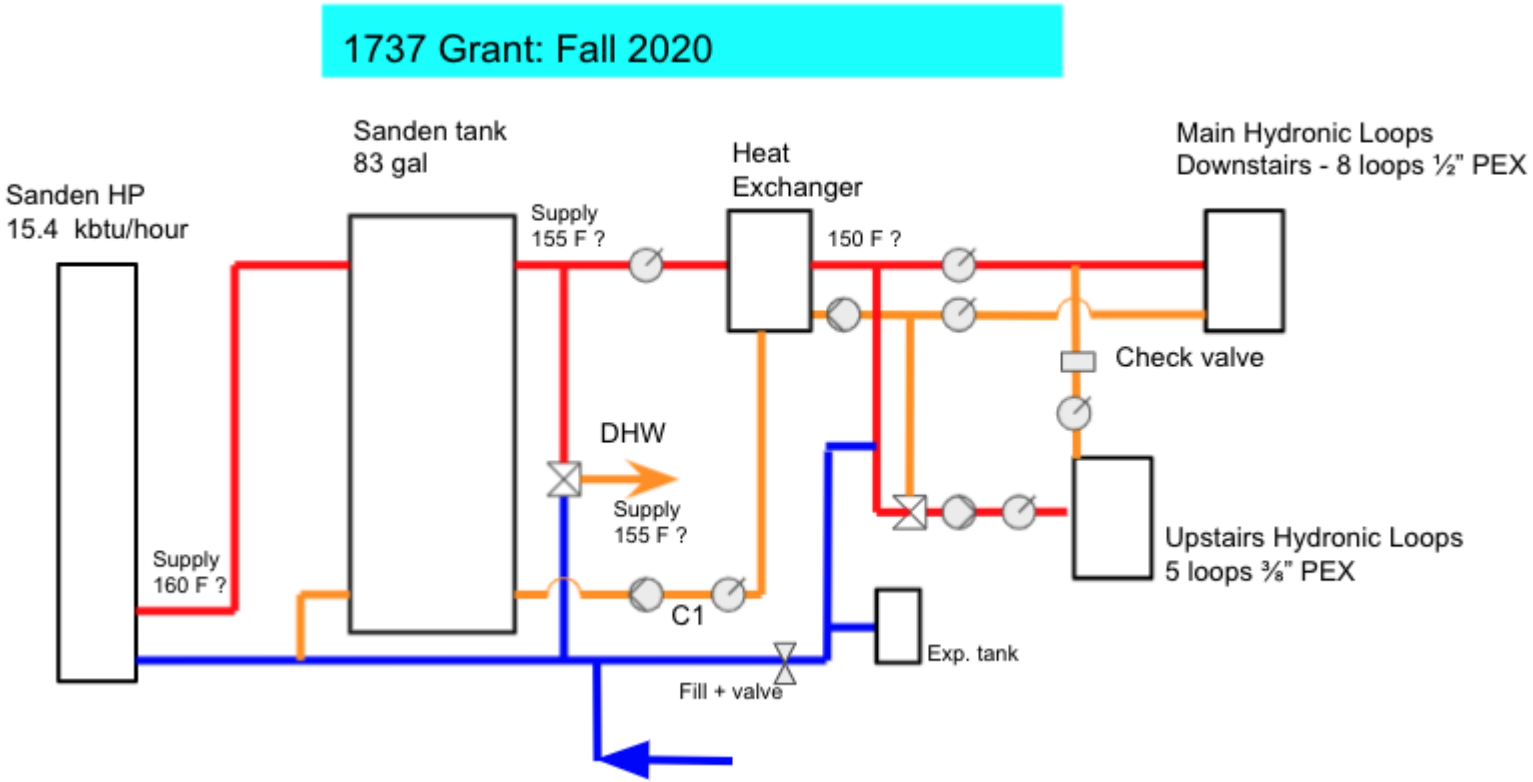
- Combined hydronic space heat plus DHW (indirect)
- Thermalboard upstairs; PEX underfloor downstairs
- 80 kBtu/hour boiler
- Homemade controls
- Tight space



Electrification

- Started summer 2020
- Expected sudden boiler failure
  - Timing unknown
- Also wanted to electrify
- Sanden known solution for combined system
  - But all examples I found were forced air - fan-coil unit
- From meter data, 26 winter days with 4 Therms gas, about five with 5 Therms, and two with 6 Therms
  - No visibility into gas system efficiency
- Sanden running continuously puts out the equivalent of about 4 Therms (my estimate)
- Remaining gas: cooktop and outside grill (very little)

Initial Design



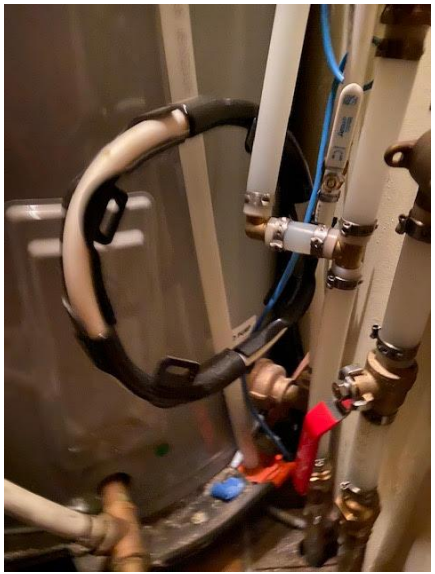
Final Design

- 120 gallon A.O. Smith tank instead of 83 gallon Sanden
- Initially only heated downstairs
- Upstairs loop now always on, but with some of return water from downstairs
- Sanden in front yard, behind wooden screen
- Re-used double circuit to mechanical closet

Details

Mixing valve

Anti-siphon loops



PEX pipe, fittings

Expansion tanks, gate valves, drain fittings

Controls - Current

- Heat pump self-controls based on tank temperature sensor
- $20 t-stat
  - No setback
- 24 VDC power supply
  - Two pumps (third is AC)
- 2 relays

Issues with system

- Return temperature from heating system too high
  - Often 90F - should be more like 60F
- Heat pumped out of tank faster than heat pump replaces it
  - Can run out of hot water for shower, dish washing
- I know temperatures, but not flows
  - Apparently good flow sensors are $$$$$
- Controls sub-optimal
  - No load shifting
  - HP should start immediately when heat loop starts

I have done

- Add some aluminum plates under ground floor to transfer more heat from PEX to floor
- Removed chimney

I should

- Replace single-pane windows
- Remainder of floor insulation
- Better controls

Controls - Future

Ideally

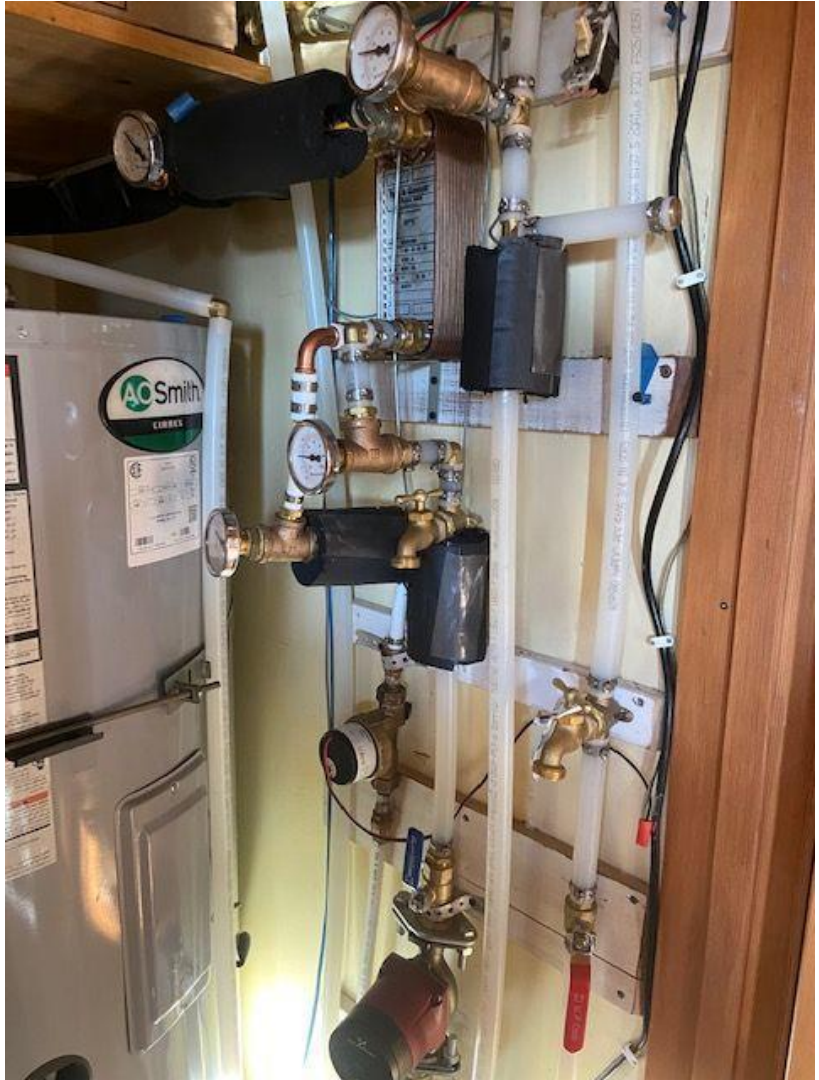
- Shift heat pump operation to daytime
- When heat needed
  - Start late afternoon when temp. may be 70F
  - Stop an hour later and go to 64F setpoint
  - Go even lower through morning
- Lock out heat a few minutes before a shower is wanted

Harvest Thermal

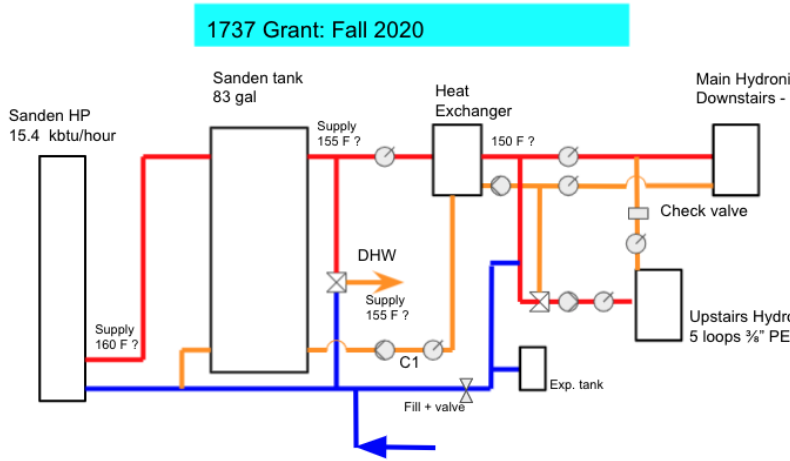
- Integrates valves, pumps, sensors, …
- Tracks flows & temperatures to accurately estimate tank status
- Ensures hot water for showers/etc.
- Shifts load to save $$, reduce GHG
- Part of Cal Flex Hub
- *But* currently optimized for air distribution systems

harvest thermal

The closet

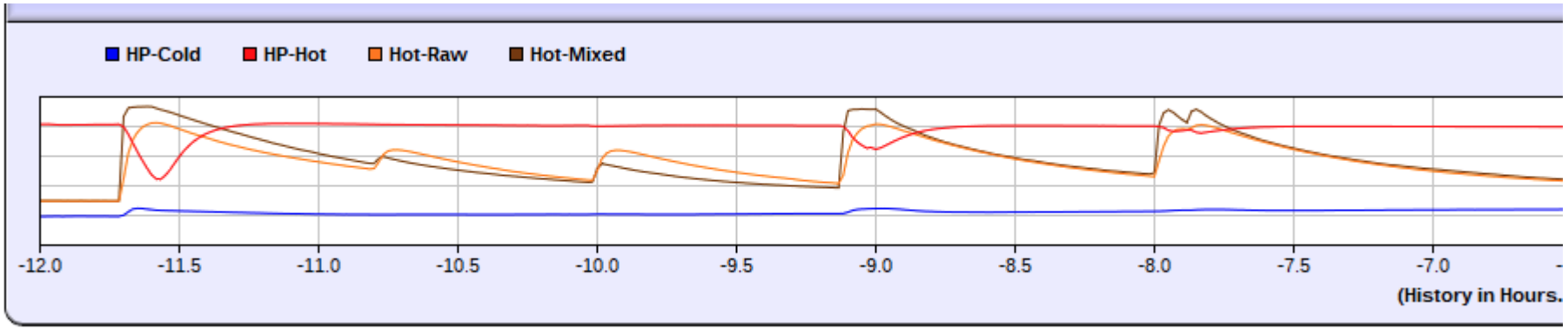


Monitoring



- WEL Server - 1 minute data for ~12 months
- Heating loop - primary in, primary out, secondary in, secondary out
- Heat pump - cold in, hot out
- DHW - raw out of tank; after mixing valve
- Air temperatures - never got around to installing….

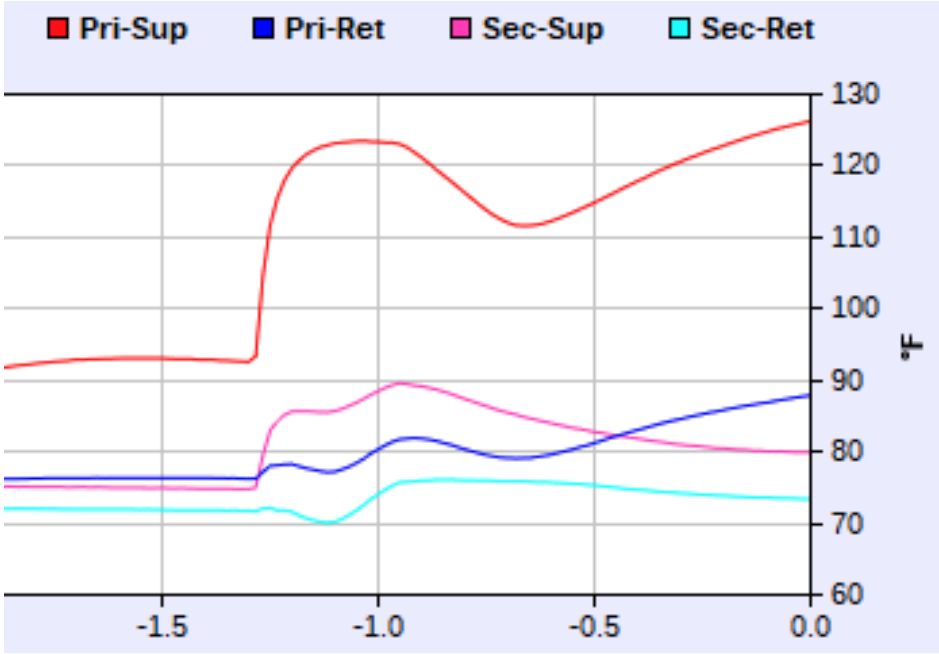
Example - **hot water use** - HP not running



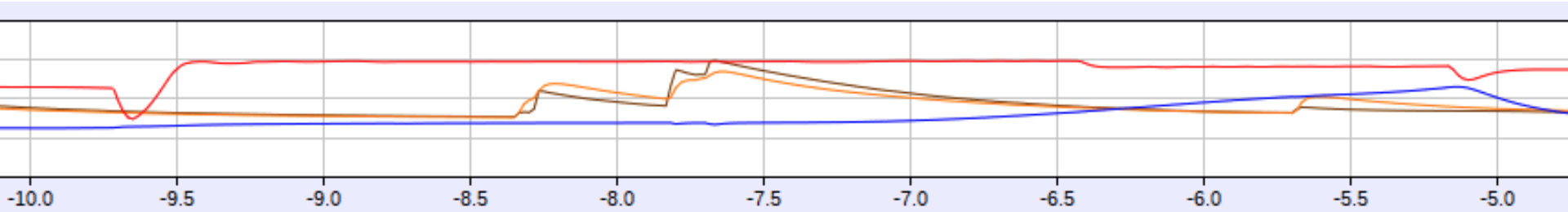
Monitoring - Heating and Heat Pump

- Secondary supply << Primary supply
  - Water to hydronic 100 at best
  - was maybe 170? with gas boiler
- Primary return too high
  - Reduces heat pump efficiency, capacity

Heating loop operation



Full heat-pump cycle



Lessons learned

- PEX is easy to work with
- Storage tank can’t be too big
- Bigger closet would be better
- Hydronic knowledge is low in industry
  - Unclear how to operate - flows, pump sizes, ...
- Controls are weak link
- With digital sensors, don’t bother with analog
- Efficiency still important!
  - Even more so than with gas
- Higher HP capacity would be handy
  - Fully meet load
  - Do more load shifting
- Someone should offer DHW rentals to buy time

Essential help from

- **Pierre Delforge**
- John Elliott
- Howdy Goudey
- Dan Johnson
- Steve Greenberg
- John Miles (Sanden)
- My understanding family
- Others whose I’ve lost track of