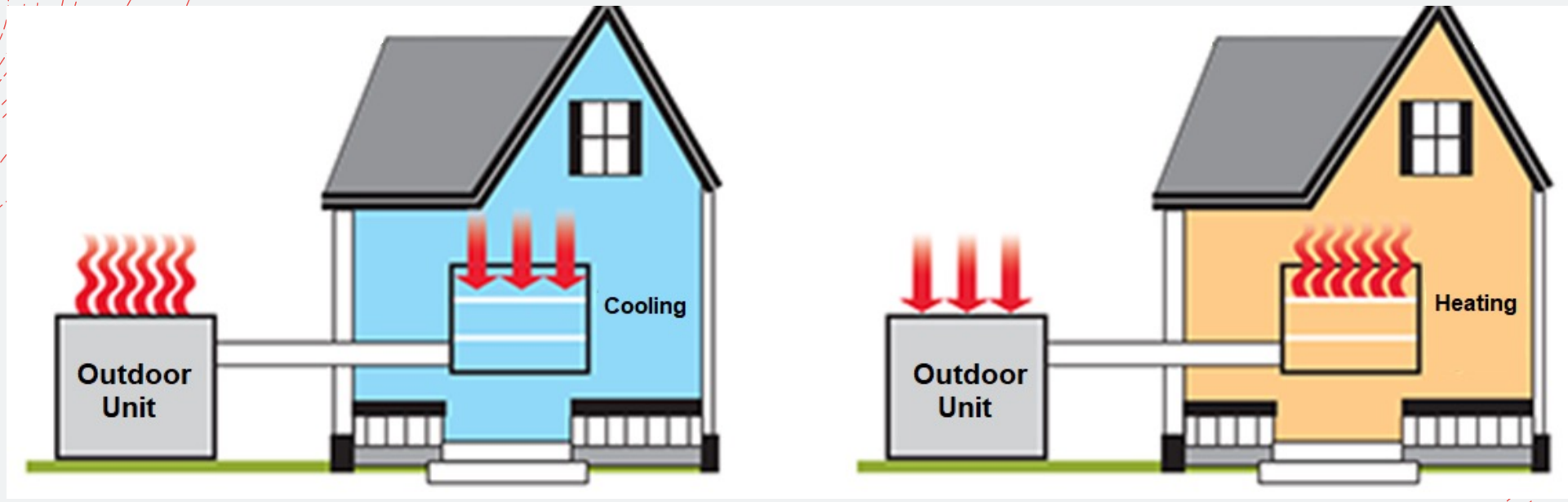
Heat Pumps

- Heat Pump Basics
- Right sizing
- System options
- Usage tips and tricks

Ben Weil, Ph.D.
Northampton Director of Climate Action and Project Administration

Heat pump basics



Summer

Acts as an air conditioner –
draws heat from indoors and moves it outside

Winter

Draws heat from outside
and moves it indoors

How Heat Pumps Work

Typical refrigeration system:

- Compressor
- Condenser
- Expansion device
- Evaporator

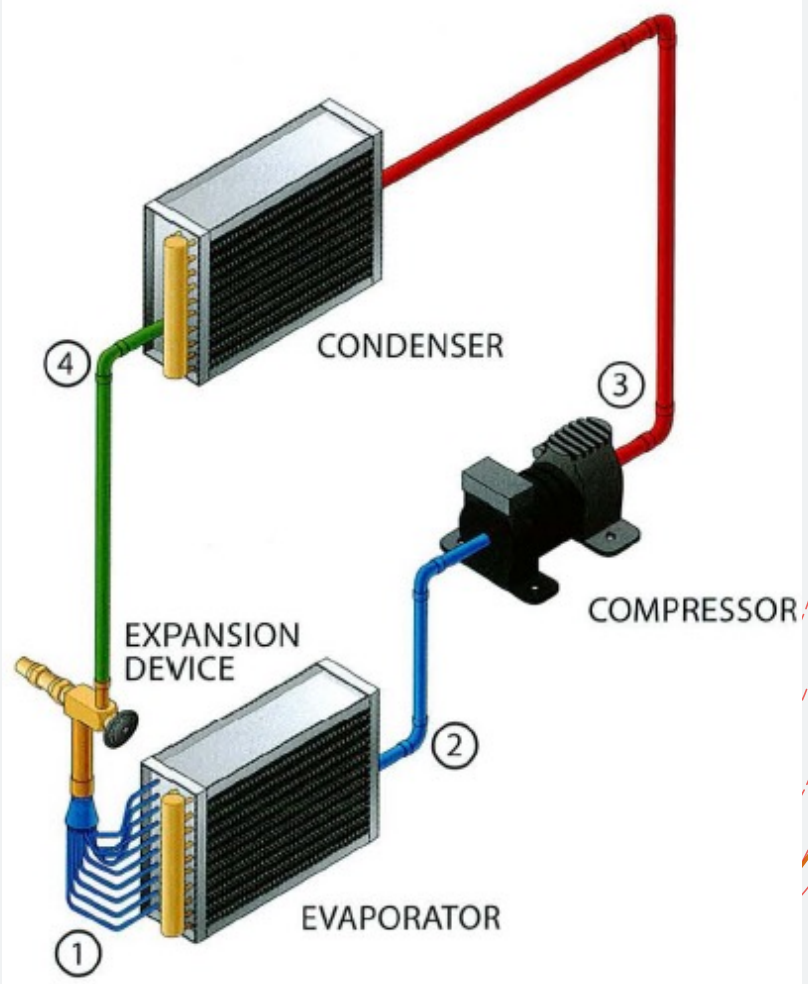
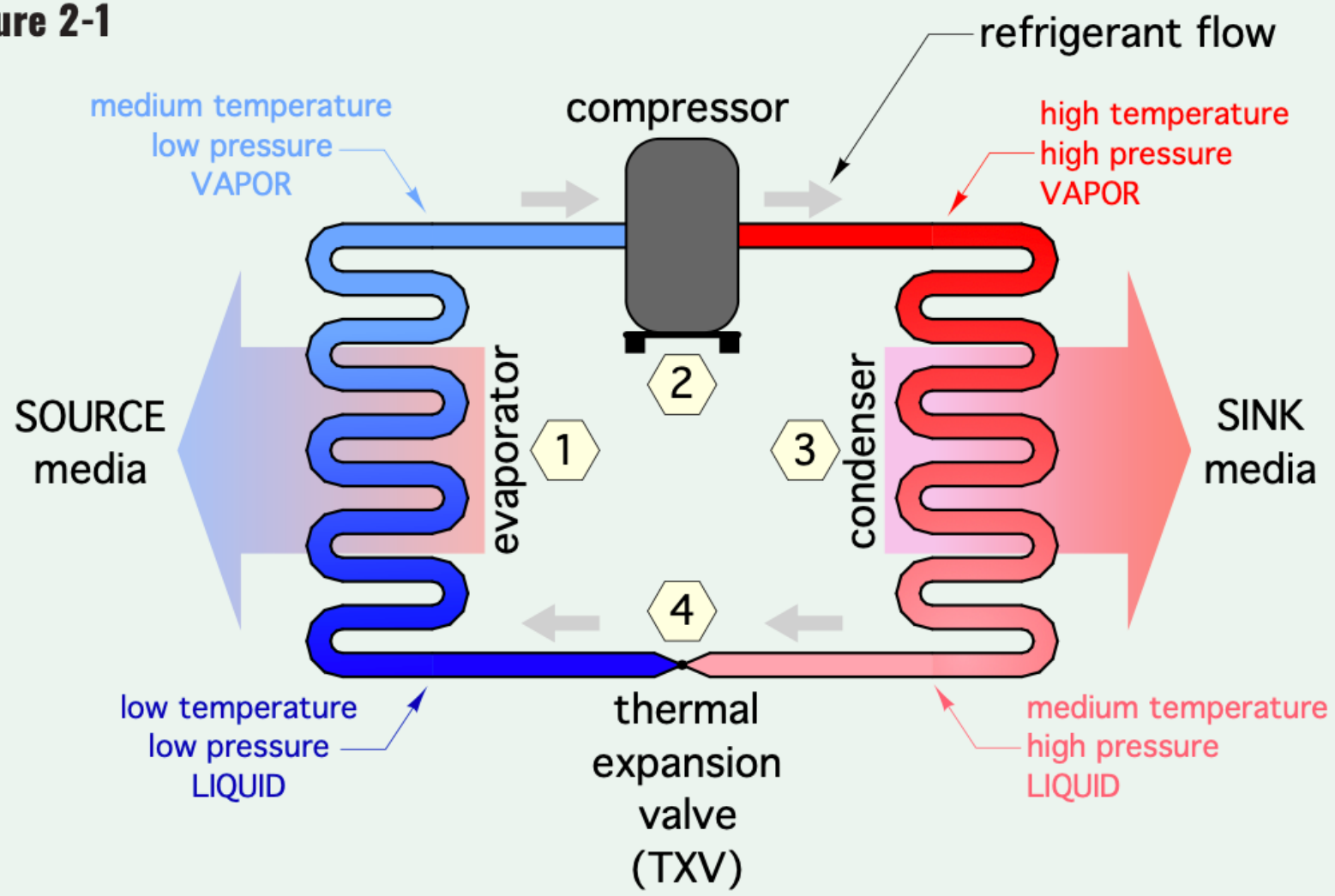
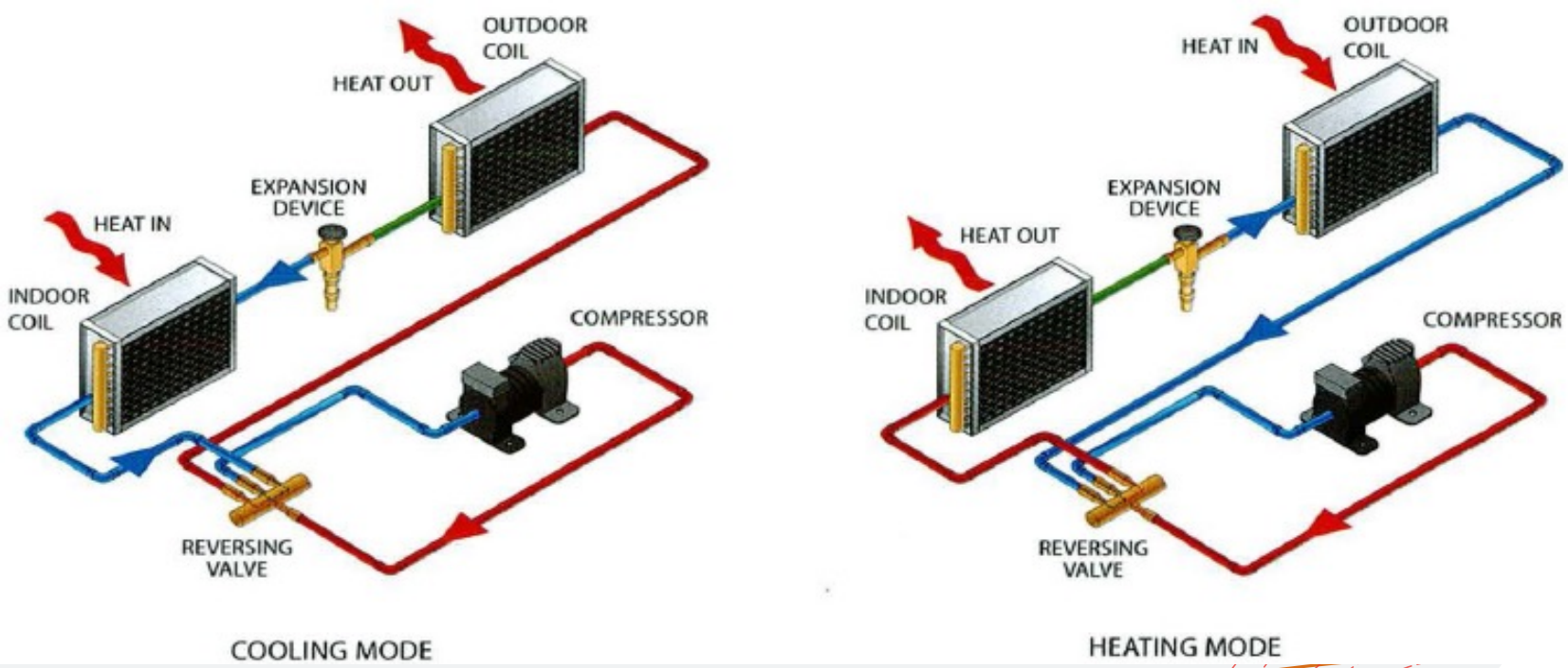


Figure 2-1


refrigerant flow
medium temperature
low pressure
VAPOR
compressor
high temperature
high pressure
VAPOR
SOURCE
media
evaporator
1
2
3
condenser
SINK
media
4
low temperature
low pressure
LIQUID
thermal
expansion
valve
(TXV)
medium temperature
high pressure
LIQUID

How Heat Pumps Work

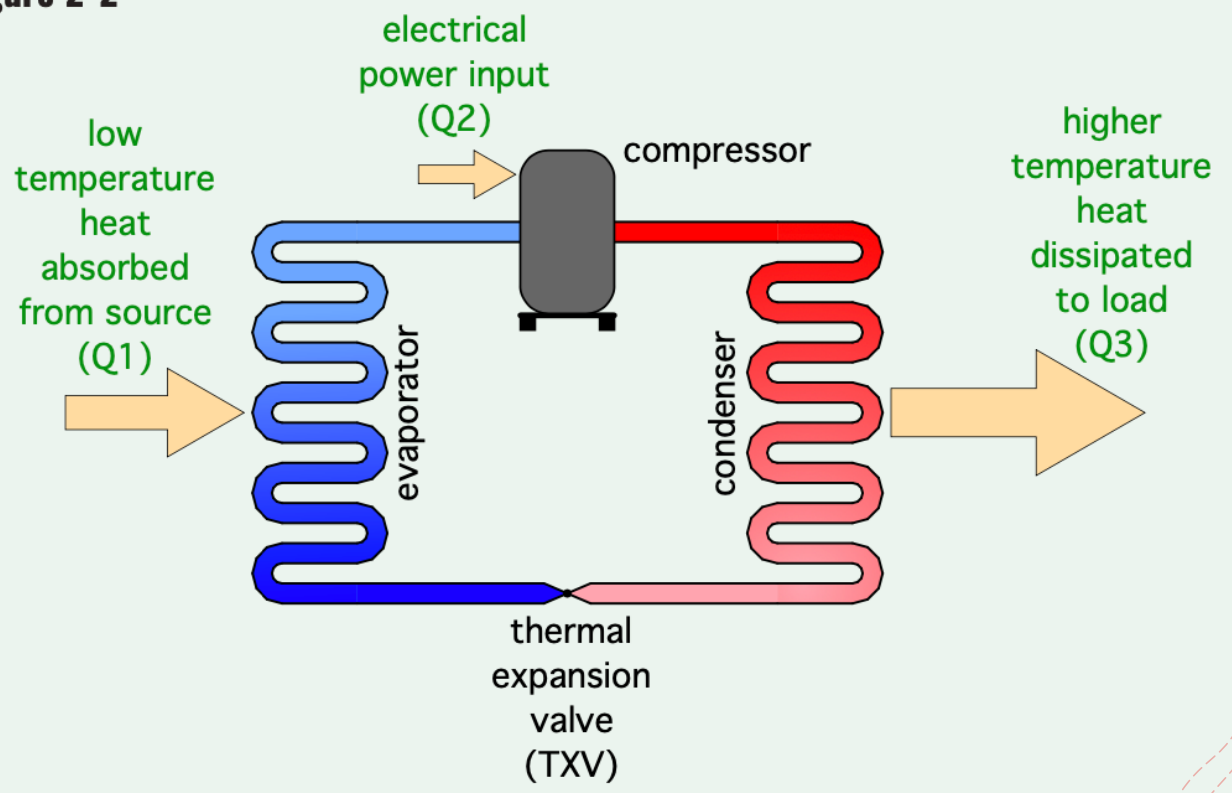
Heat pumps introduce a reversing valve to the refrigeration cycle

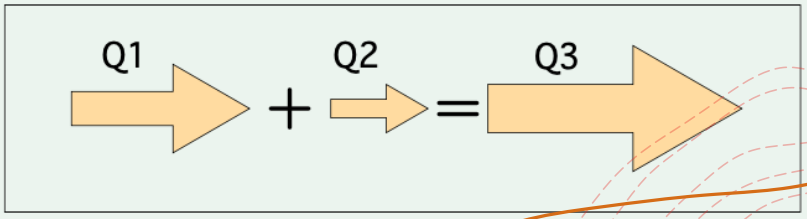


Efficiency: Coefficient of Performance (COP)

- Heating COP = Q3/Q2
- Cooling COP = Q1/Q2
- Q2 = heat of compression

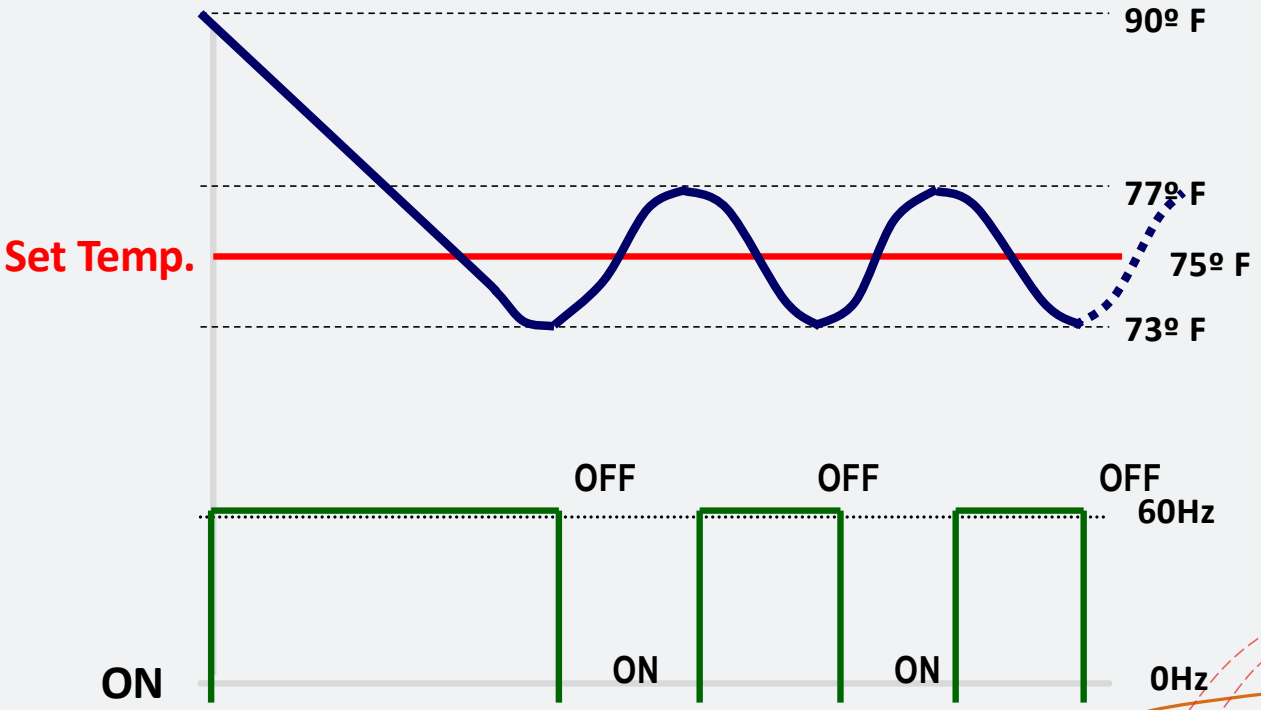
Figure 2-2



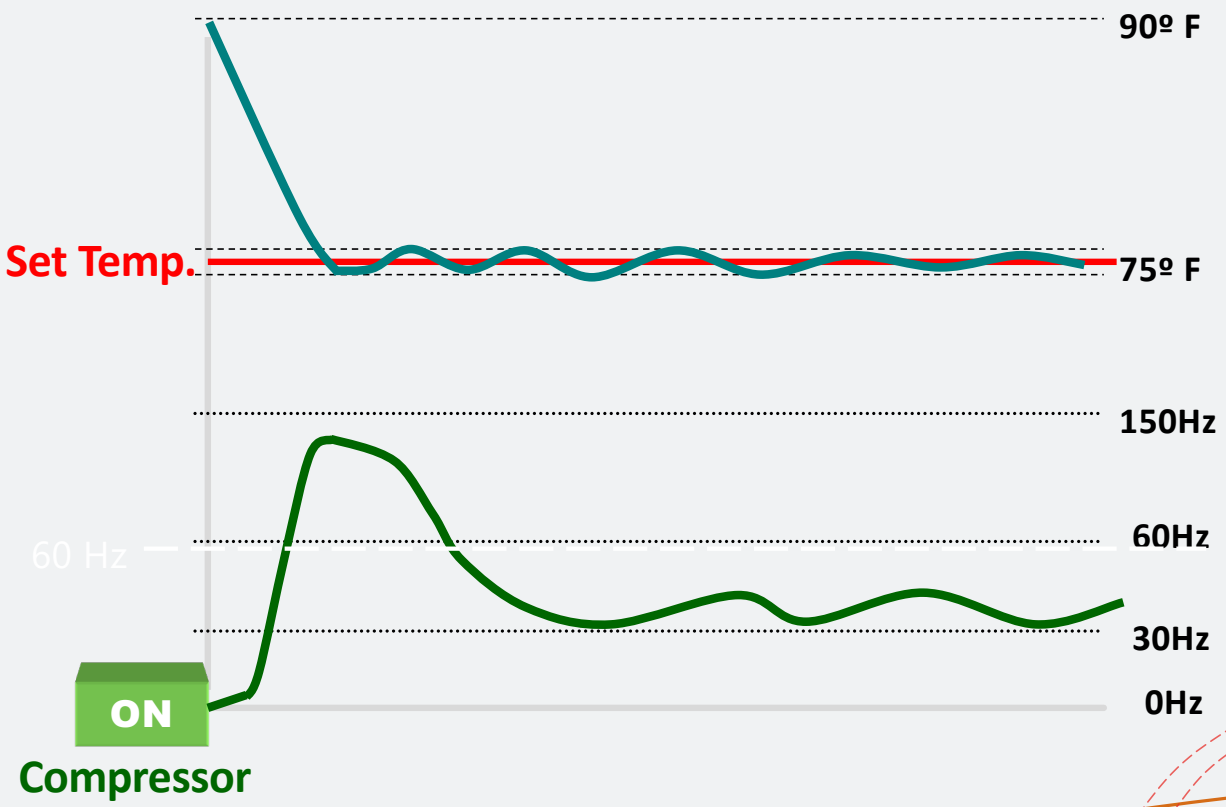


Efficiency – Traditional Systems

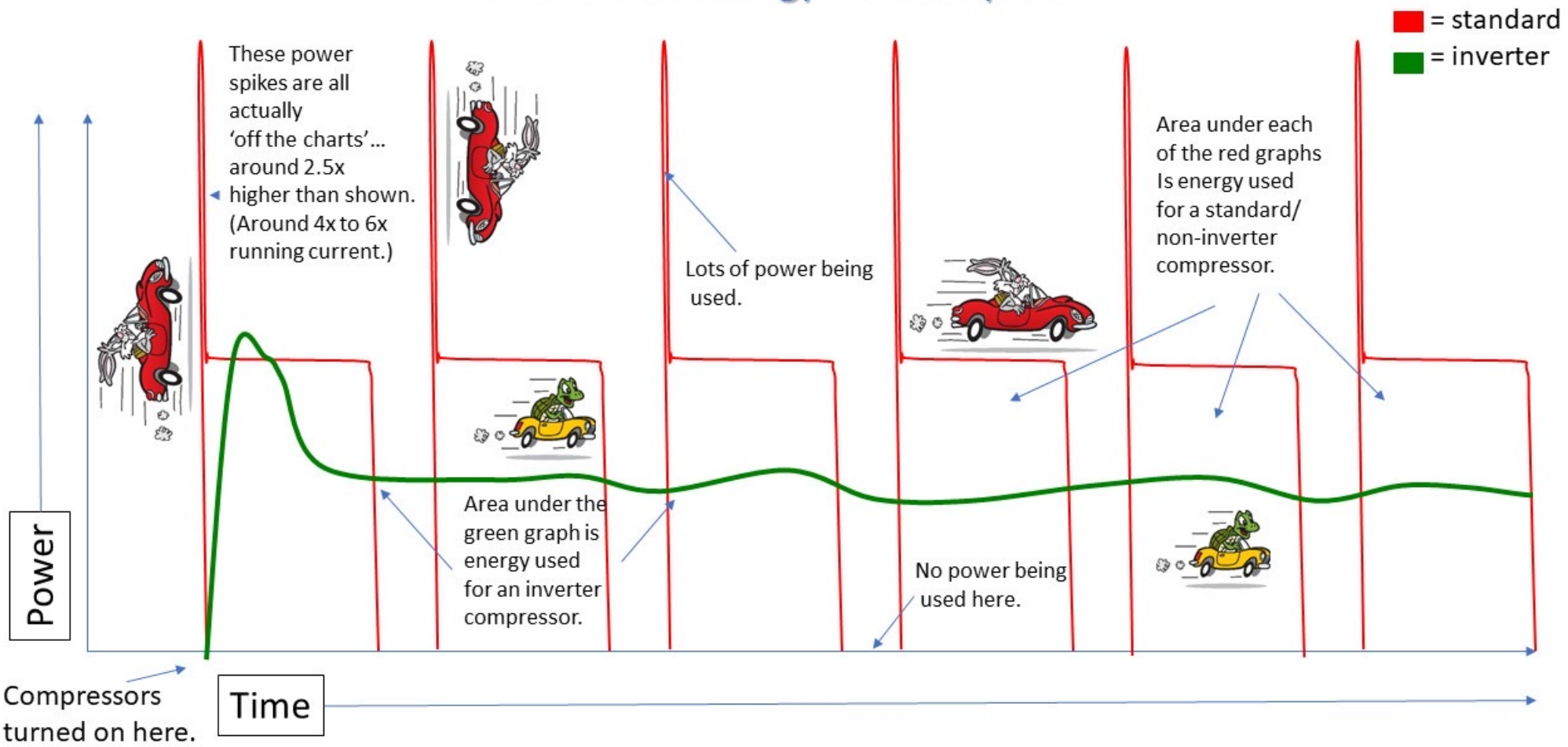
Constant speed ON/OFF compressors



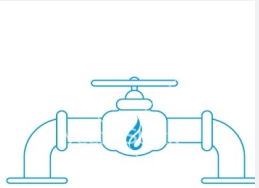
Efficiency – Variable Speed Systems

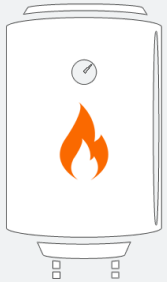


Standard vs. Inverter Compressor Air Conditioner/Heat Pump Power and Energy Consumption

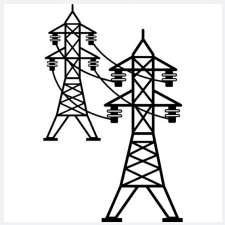


Efficiency of heaters depending on source

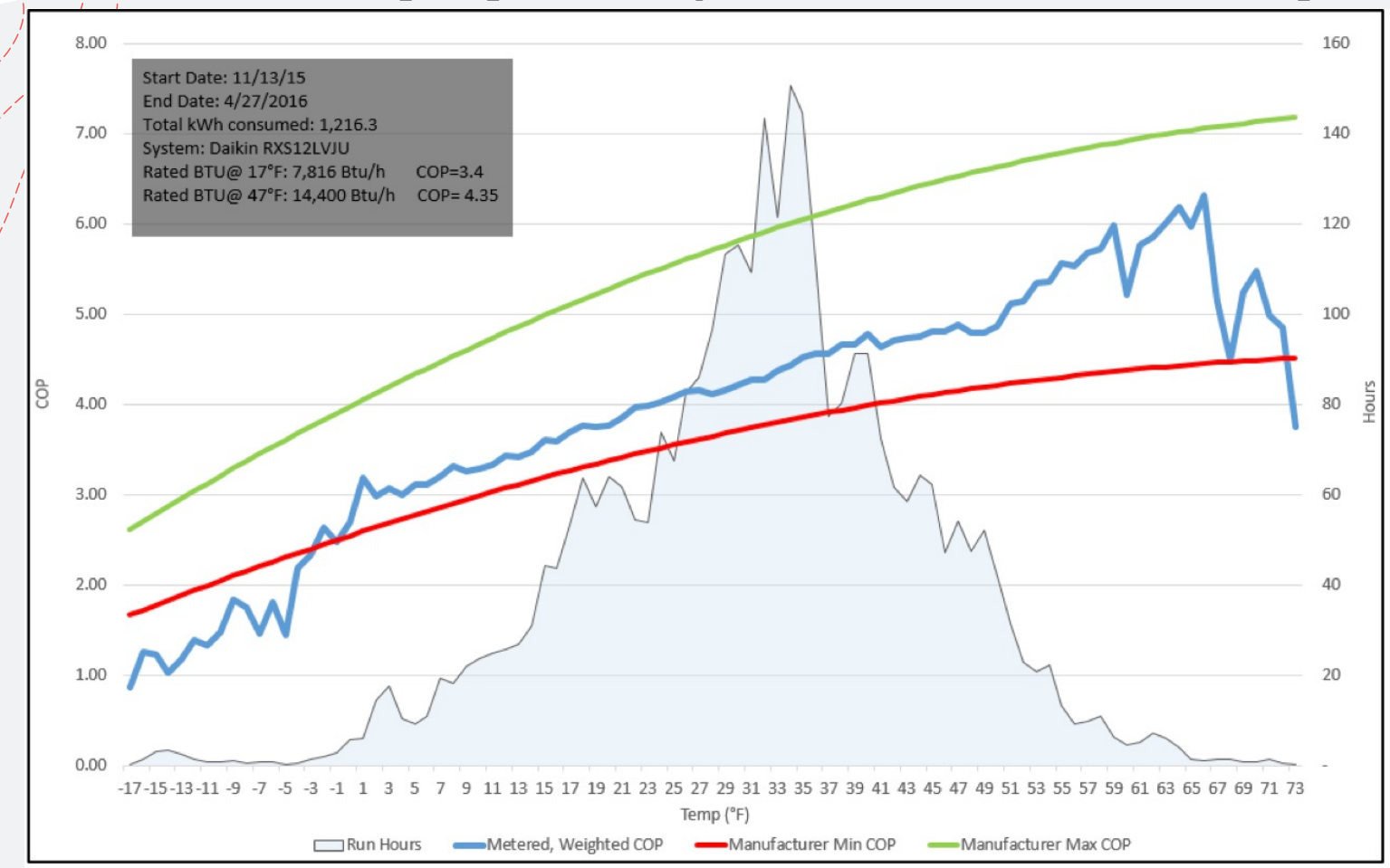




	Power Plant	Transmission	Heater	System
Gas heater		97%	96%	93%
Gas CC	55%	94%	320%	165%
Oil IC	33%	94%	320%	99%

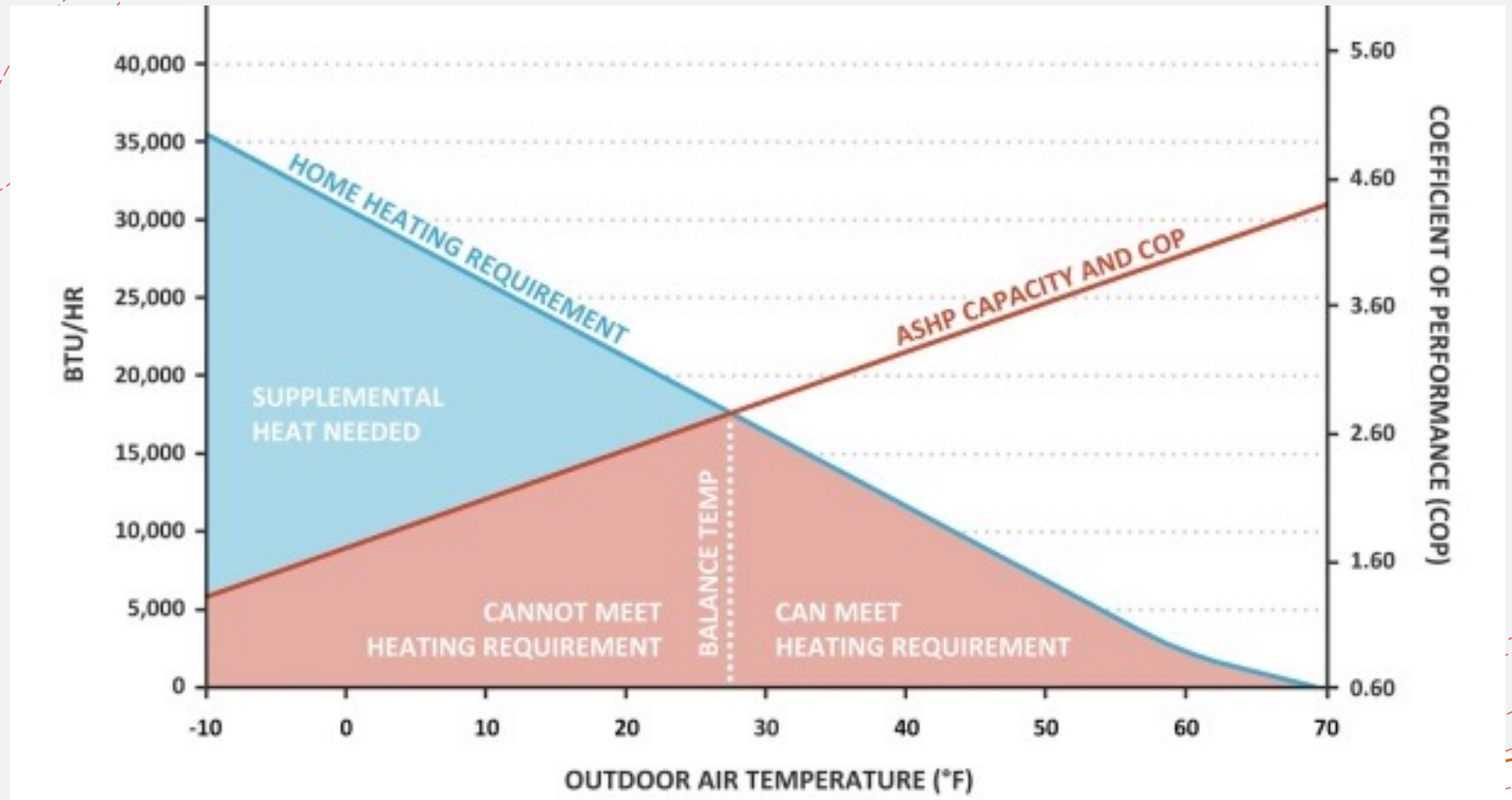


Air source heat pump efficiency declines with outdoor air temp



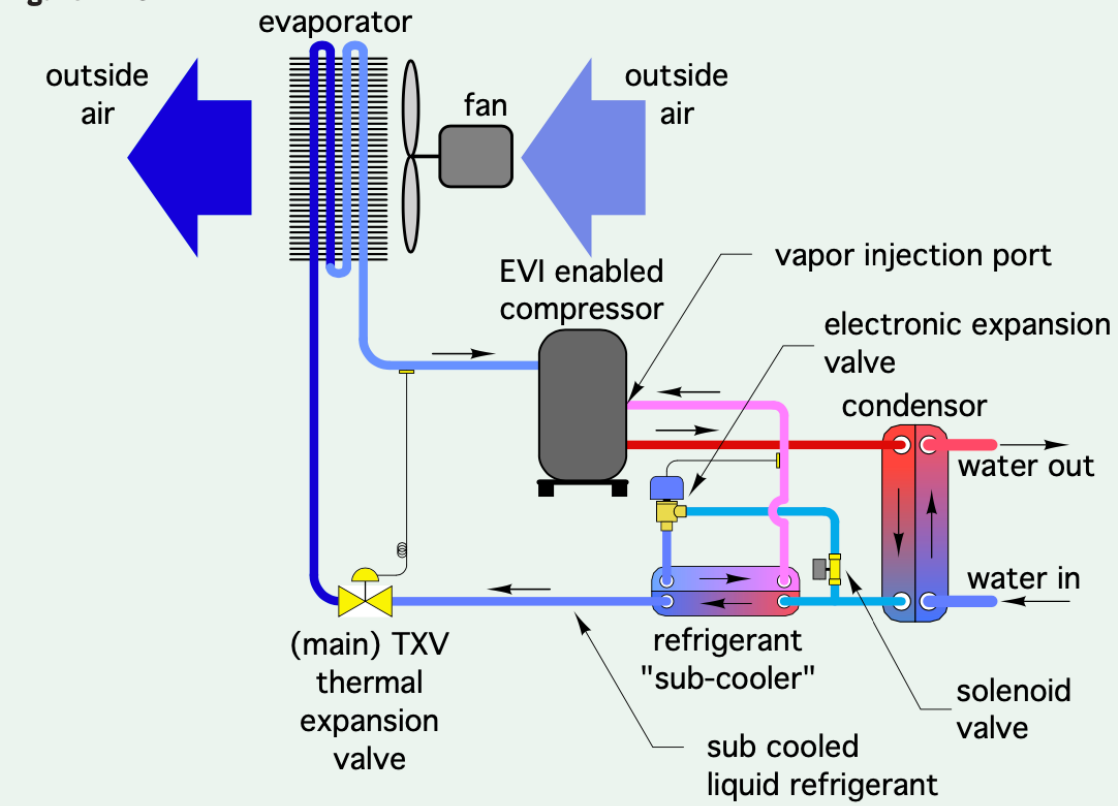
Walczyk & Larson, Ductless Mini-Split Heat Pump Systems: The Answers to Questions about Efficiency You Didn't Know You Had 2016 ACEEE Summer Study on Energy Efficiency in Buildings https://www.aceee.org/files/proceedings/2016/data/papers/1_836.pdf

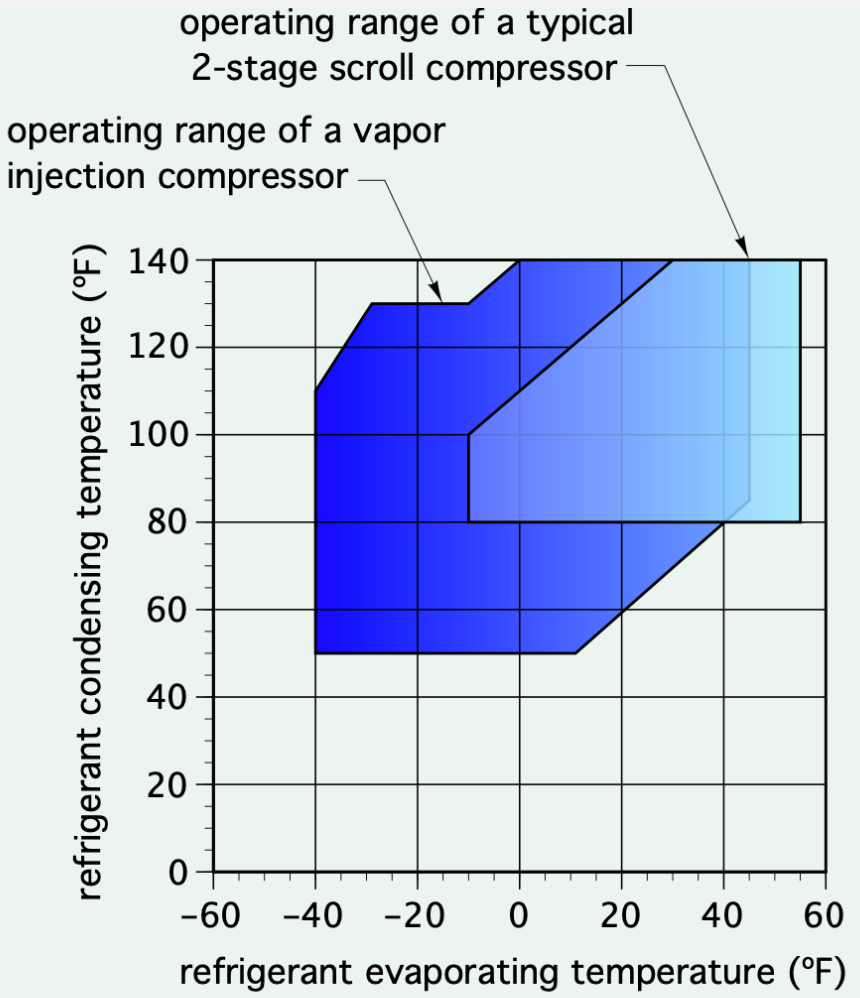
Old News: Air Source Heat Pump capacity and efficiency declines with outdoor temperature



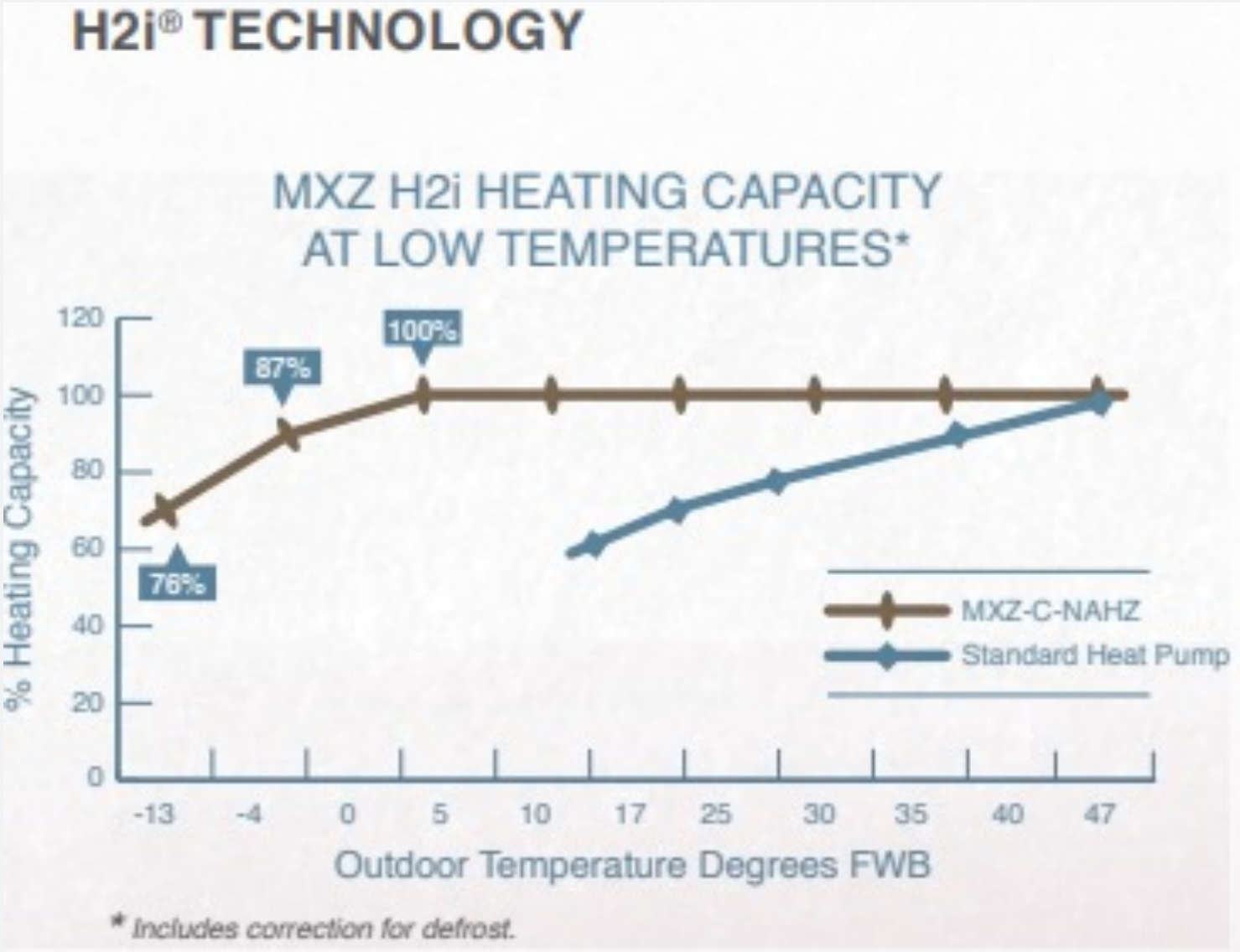
Newer News: Enhanced Vapor Injection (EVI)

Figure 2-13

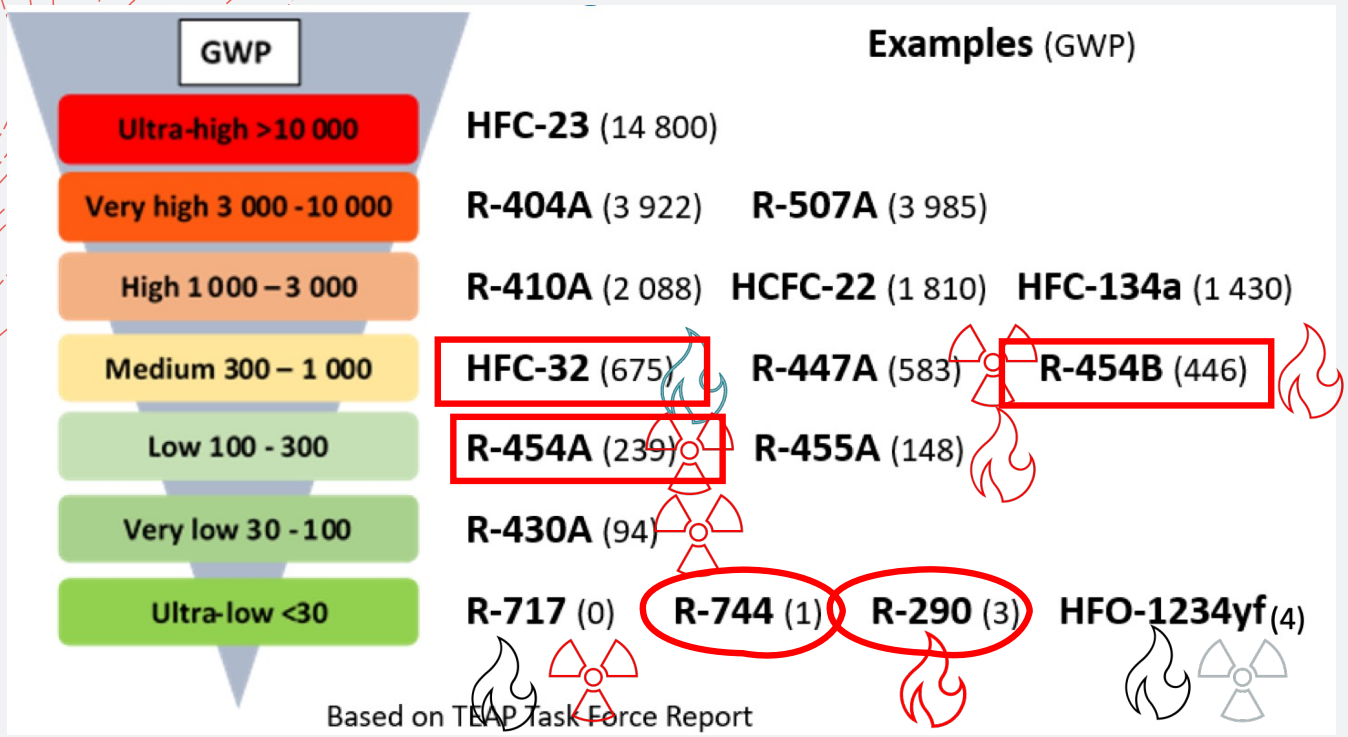




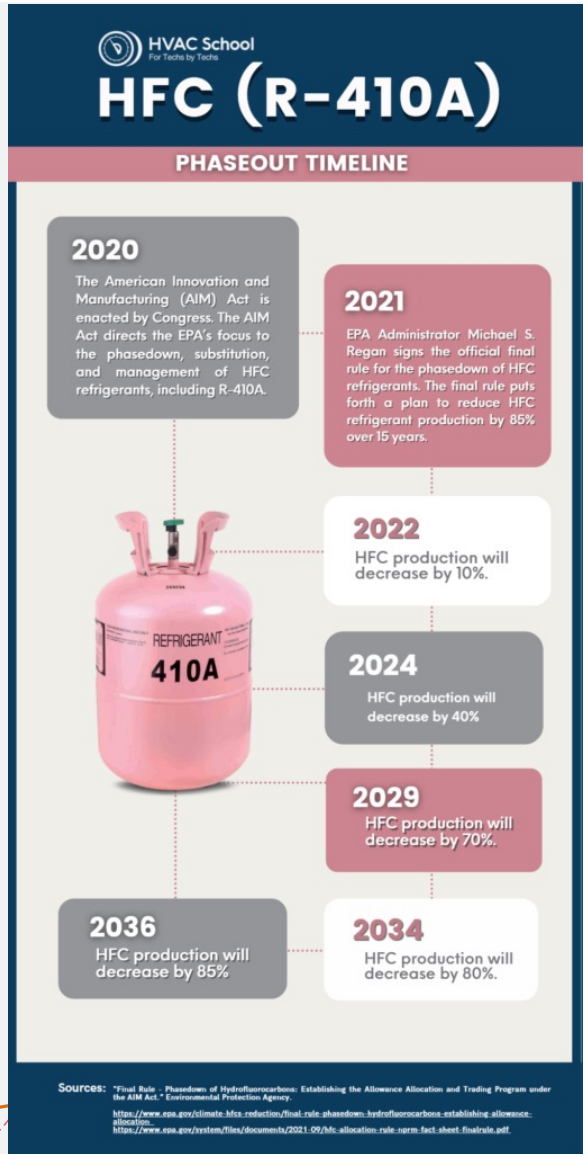
"Hyperheat" maintains capacity at very low outdoor temperatures



Common refrigerants have high GWP and are being phased out



As R-410a is phased out, replacements may not be compatible with existing equipment



GWP comparison of R410A & R32

> 75% Reduction

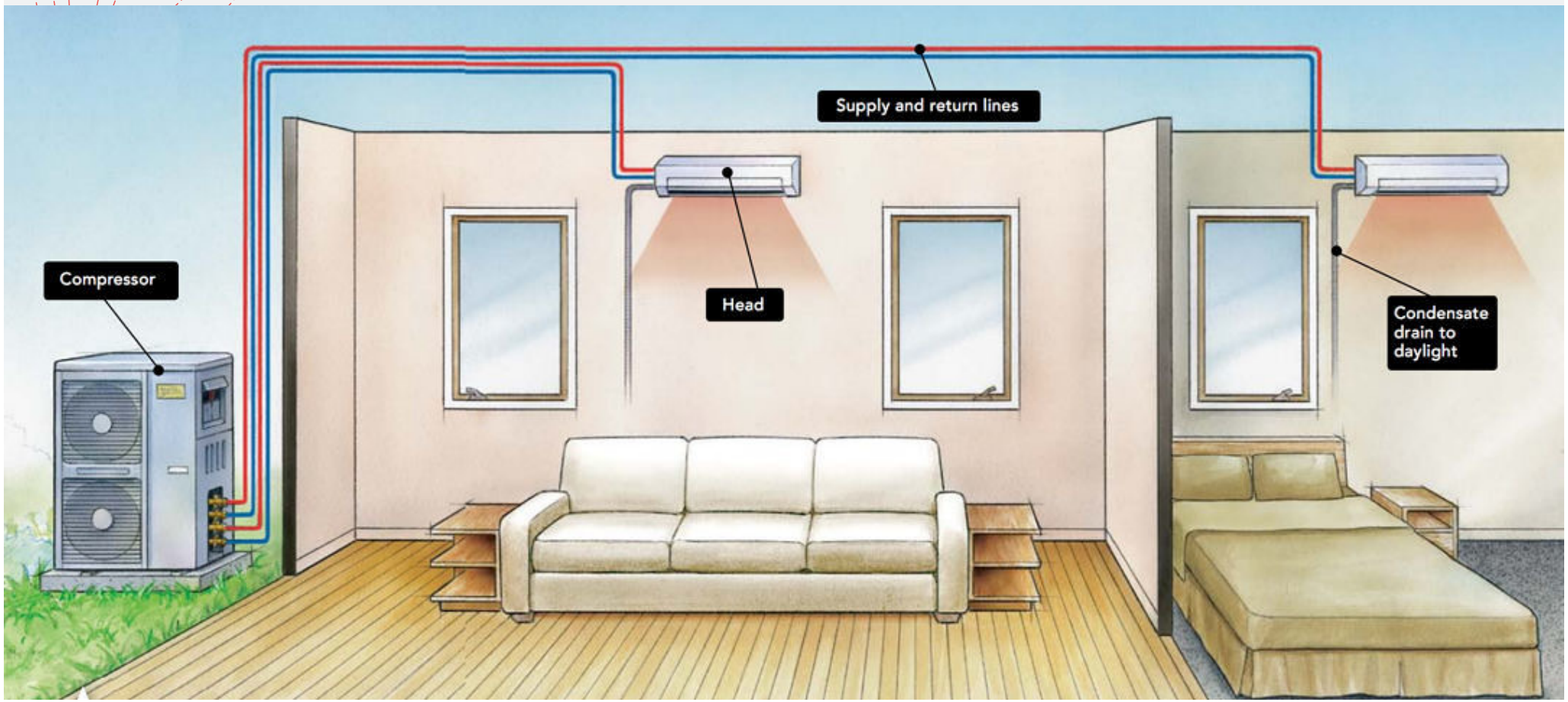
- The GWP of R32 is only 1/3rd of R410A
- Taking into account the refrigerant charge, the GWP is only 1/4th !

GWP Values according to IPCC 4th Assessment Report
For the EU F gas regulation the GWP values of IPCC 3rd report are valid
(R410A = 1975, R32 = 650)

New refrigerants are more efficient and allow full capacity at low temperatures

+ 10,049 models with greater than 100% of rated capacity at 5°F
+ Average COP at 5°F = 2.28

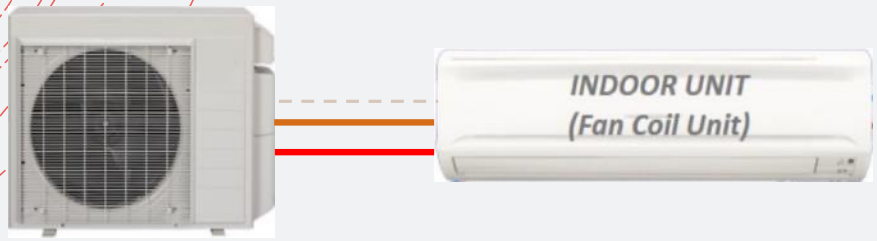
Mini-and-multi-split ASHPs



Typical Air-Source Heat Pumps

Mini-Split or Single-Split

- One indoor unit and one outdoor unit



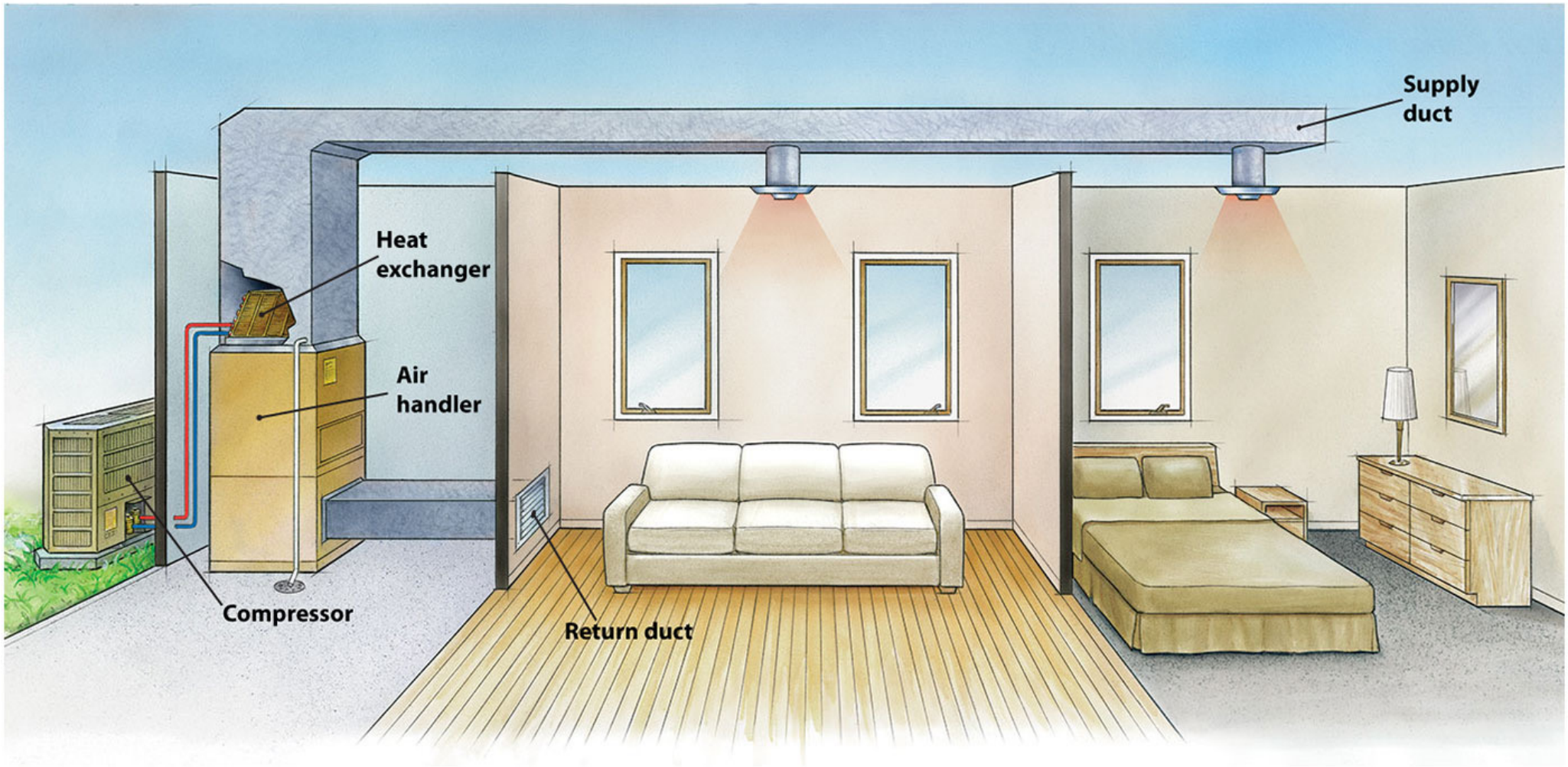
Multi-Split

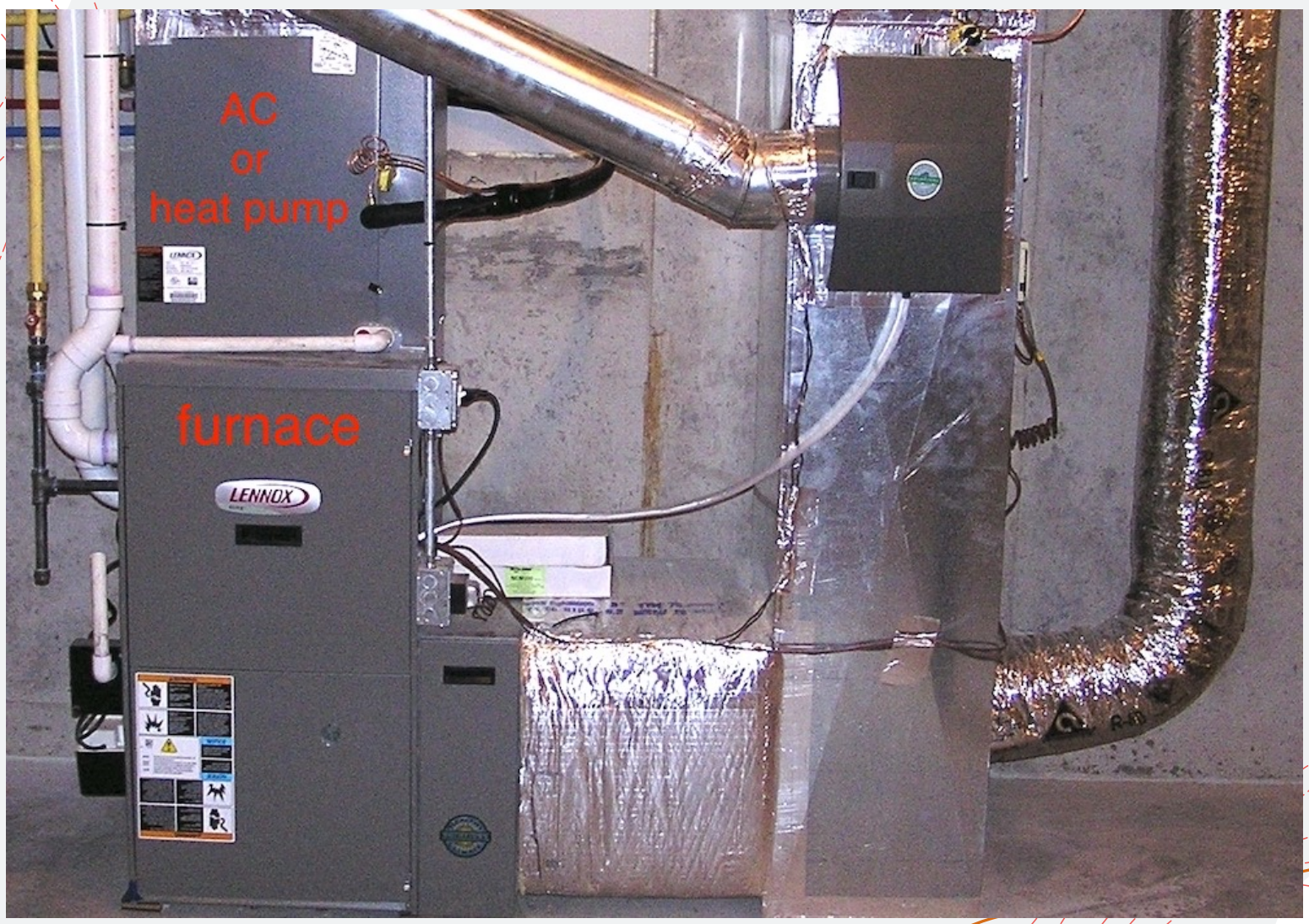
- Multiple indoor units with individual temperature controls

Fully Ducted

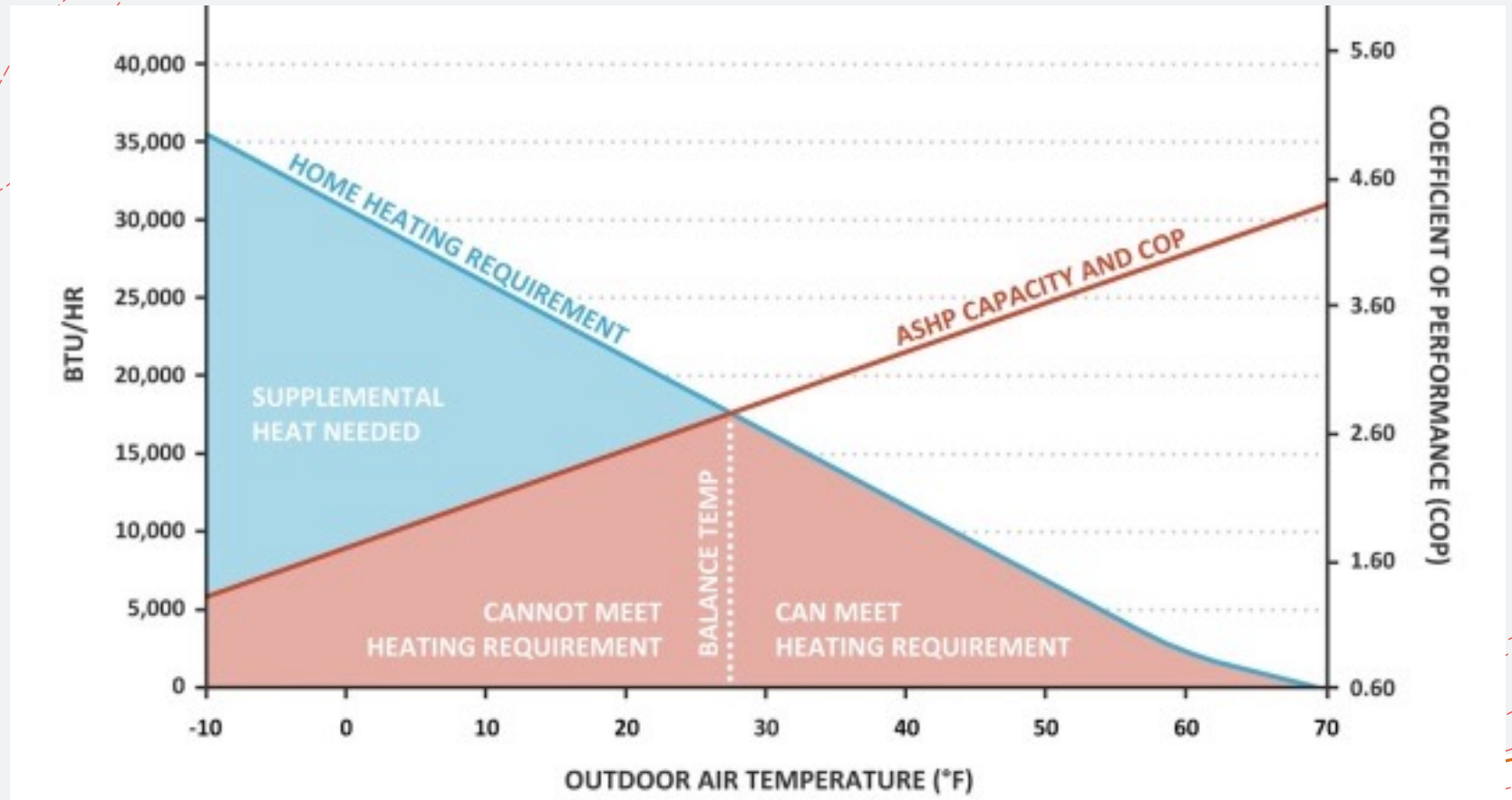
- Central indoor unit with central control

Fully ducted heat pump

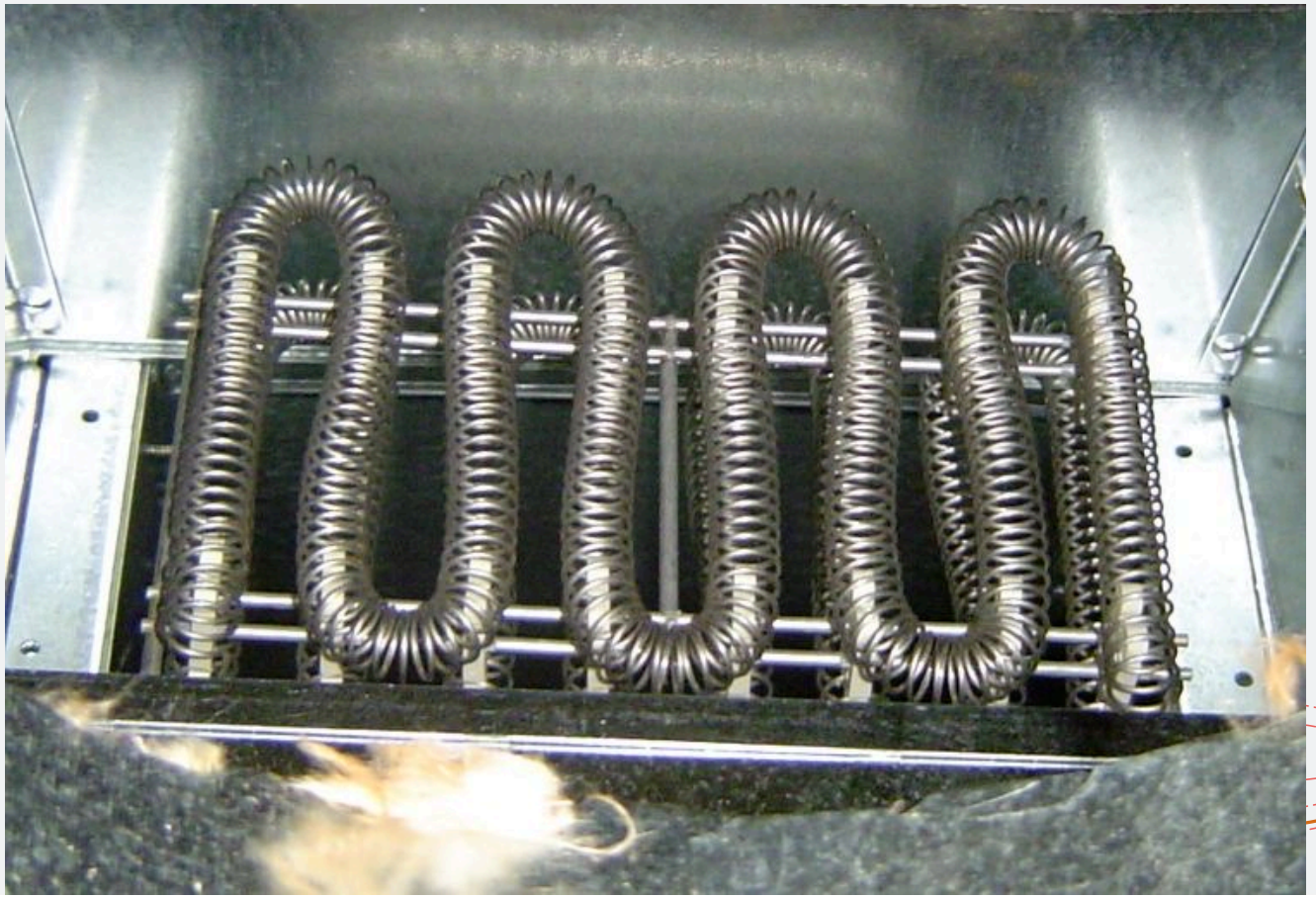



AC
or
heat pump
furnace
LENNOX

Dual fuel system with ASHP sized for cooling



Electric resistance duct heaters. NO!

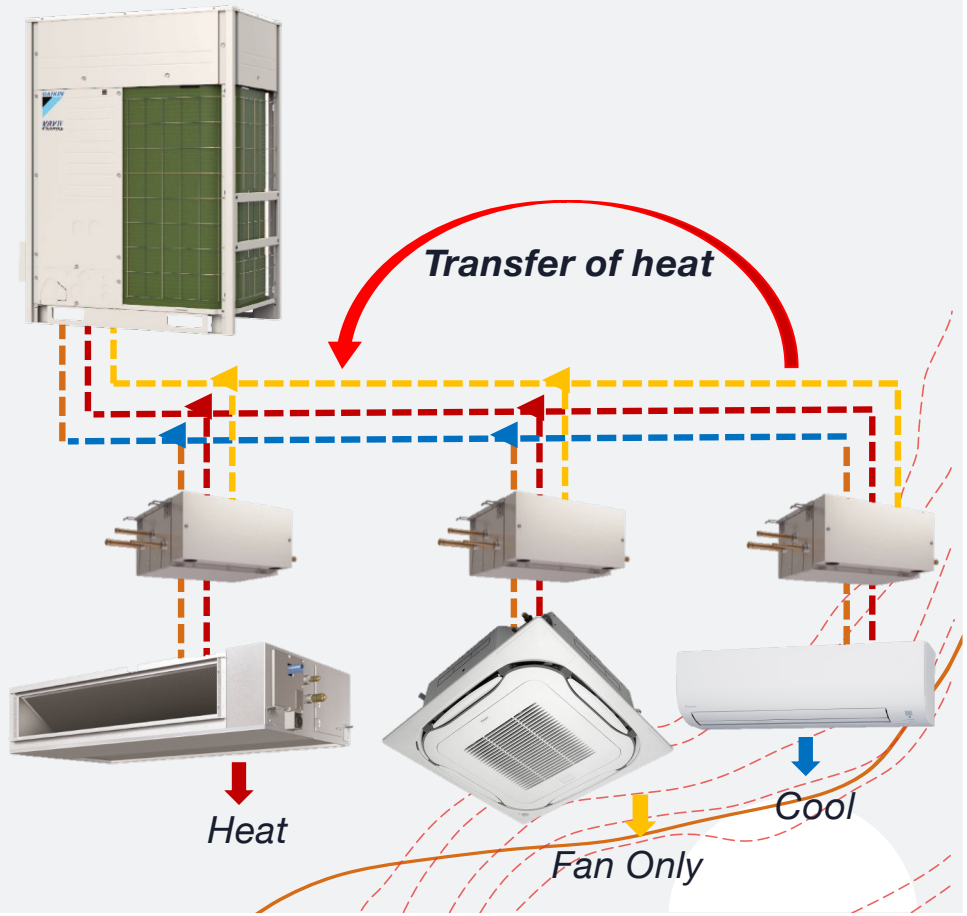


Short ducted mini-splits can replace central furnace if duct system pressure is too high

Types of Heat Pumps

Variable Refrigerant Flow (VRF) with Heat Recovery

- Most VRF systems include heat recovery
- System can provide simultaneous heating and cooling to different zones



VRF Features and Benefits

- High efficiency
  - Variable speed compressor
- Comfort and flexible operation
  - Individual zone control
  - Avoid hot-spot/cold-spot issues with heat recovery
- Quiet operation
  - No compressors in the space
  - Quiet outdoor compressors and fans

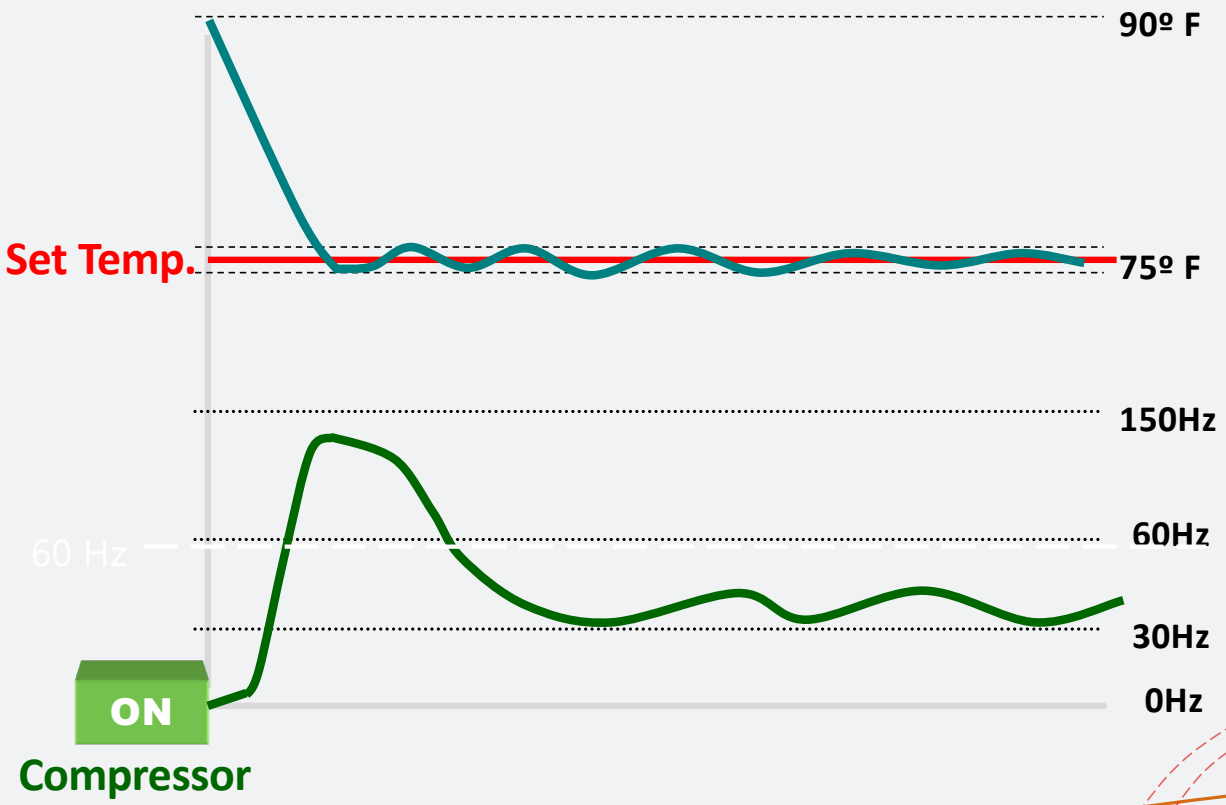
Requirements to insist on for Air Source Heat Pumps

- Inverter driven (minimum turndown ratio 8:1)
- Right size (Manual J)
  - start by sizing for cooling, then check capacity and COP at 5°F and increase if necessary
- True Cold Climate Heat Pump
  - Hyperheat, h2i, EVI
- No electric resistance backup or duct heaters!

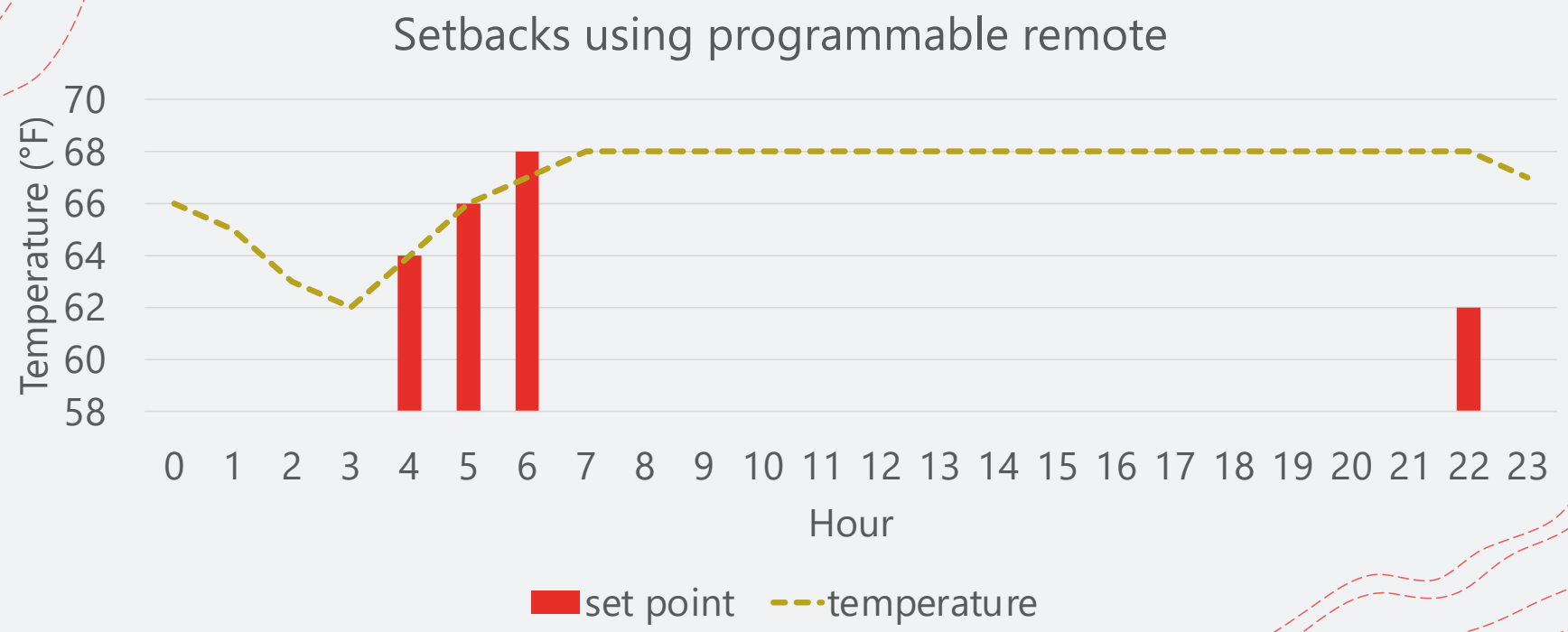
Operating cost comparisons

Fuel	Price	kWh	kBtu	EFF	$/KWH	$/therm	COP to beat
#2 Oil (gal.)	$4.00	40.70	139.60	0.83	$0.12	$ 3.45	2.32
LPG (gal.)	$4.00	26.80	91.30	0.92	$0.16	$ 4.76	1.70
Electr. (kWh)	$0.28	1.00	3.41	3.20	$0.09	$ 2.52	N/A
Pellet (lb)	$0.25	2.49	8.50	0.83	$0.12	$ 3.54	2.27
Nat Gas (therm)	$2.38	29.31	100.00	0.92	$0.09	$ 2.59	3.11

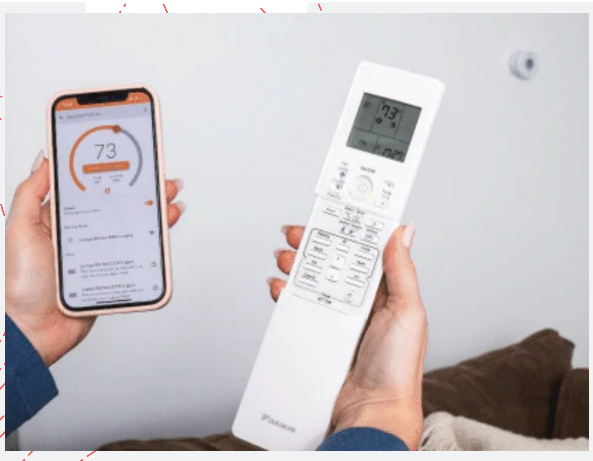
Key Insight: *Inverter efficiency depends on not ramping up and down!*

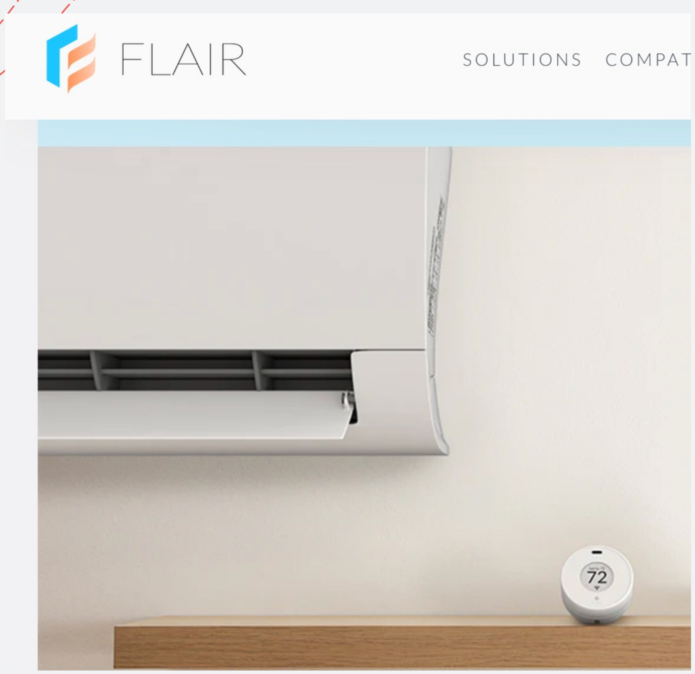


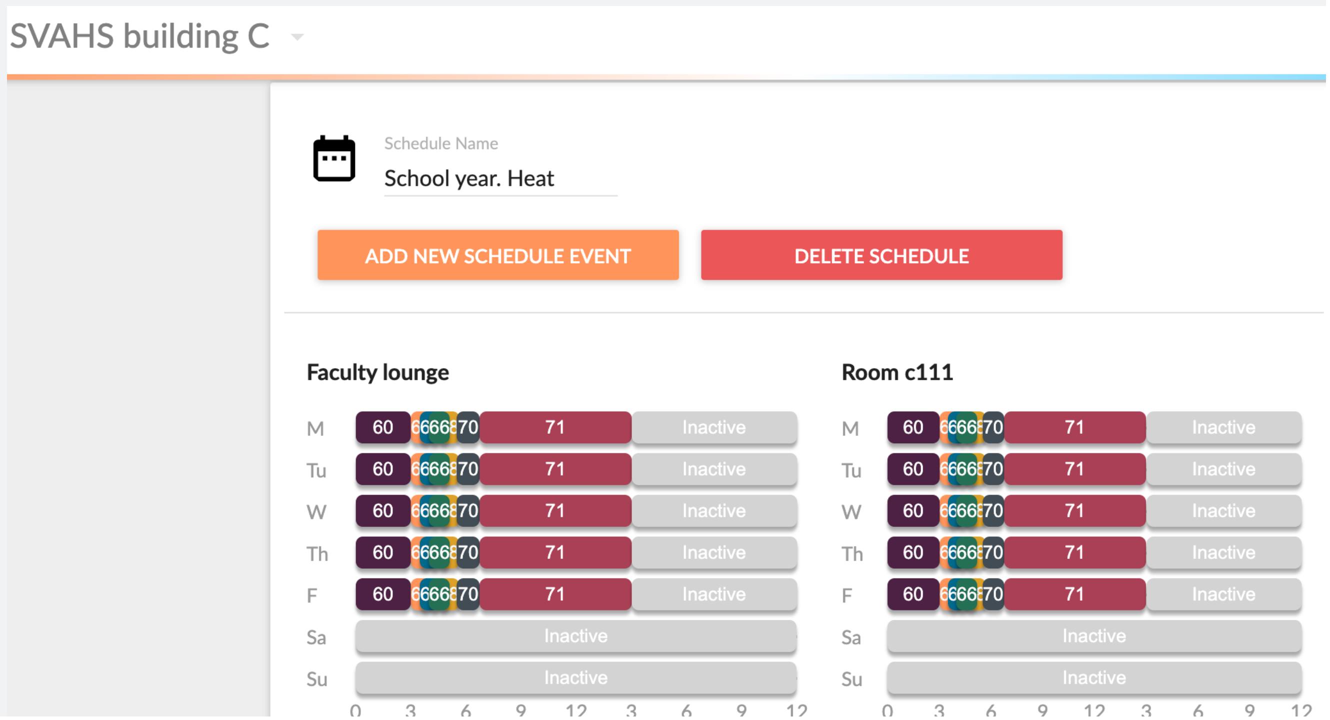
You can use setbacks but avoid big changes



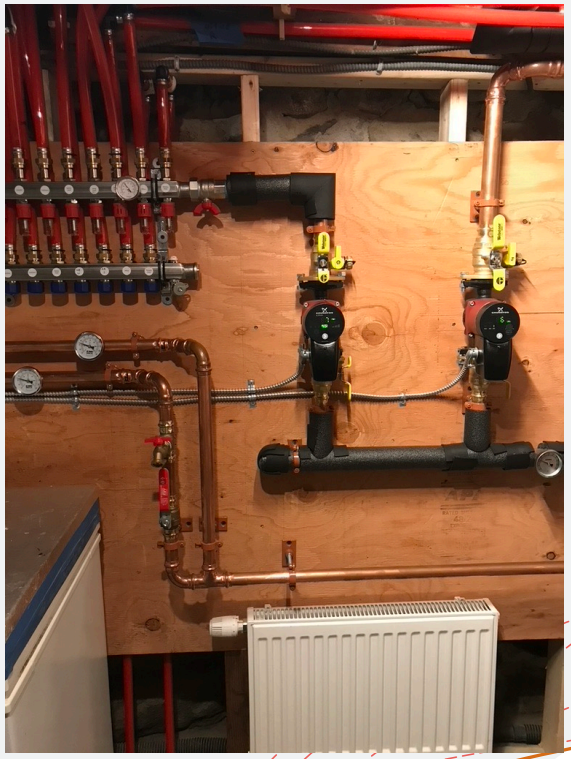
Using WIFI-connected remote replacement to control mini-splits



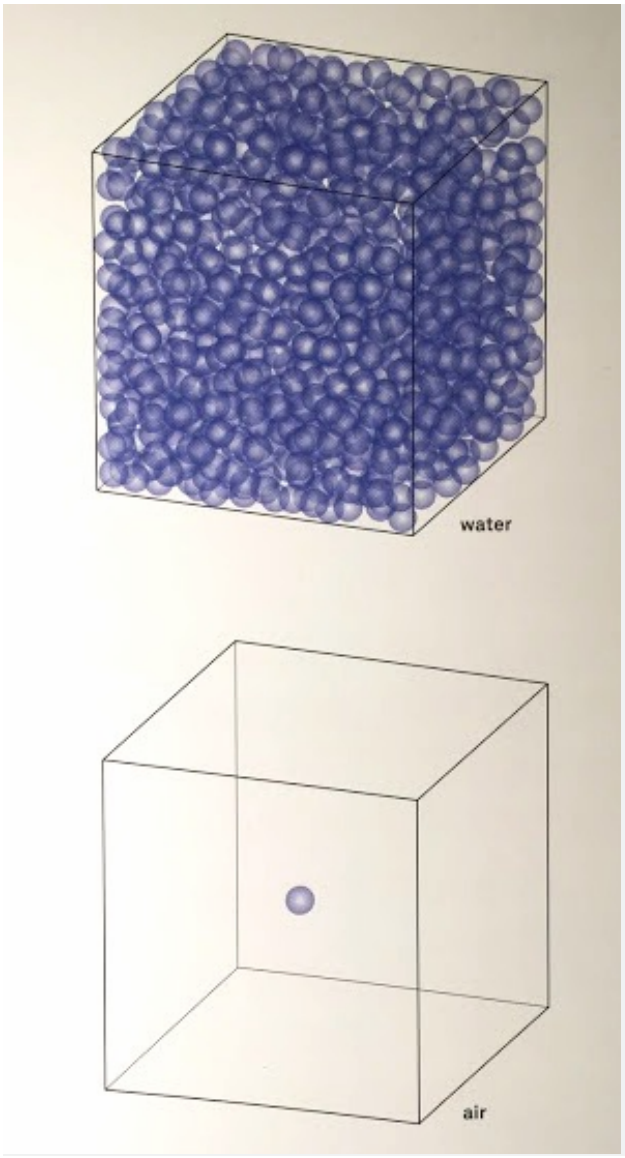




Air to water heat pumps



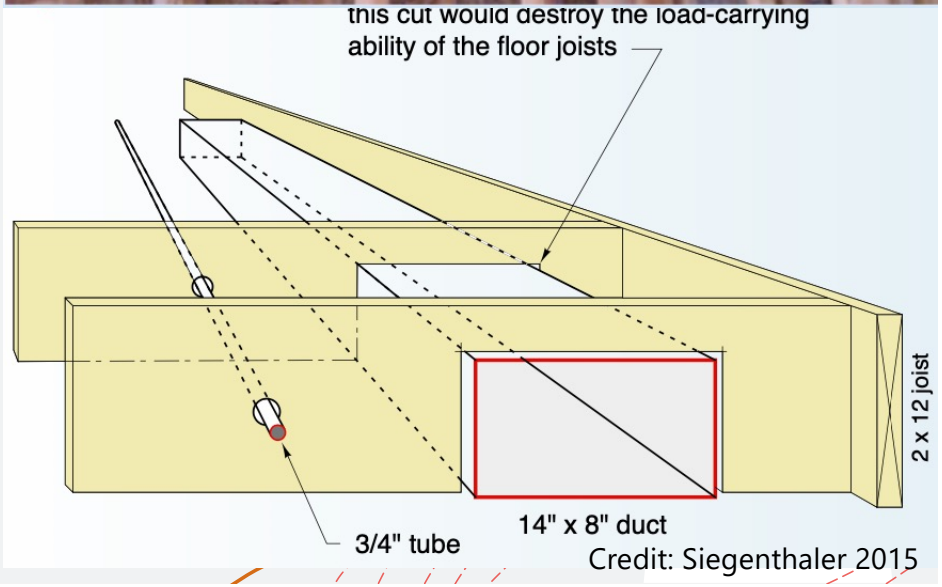

SONY



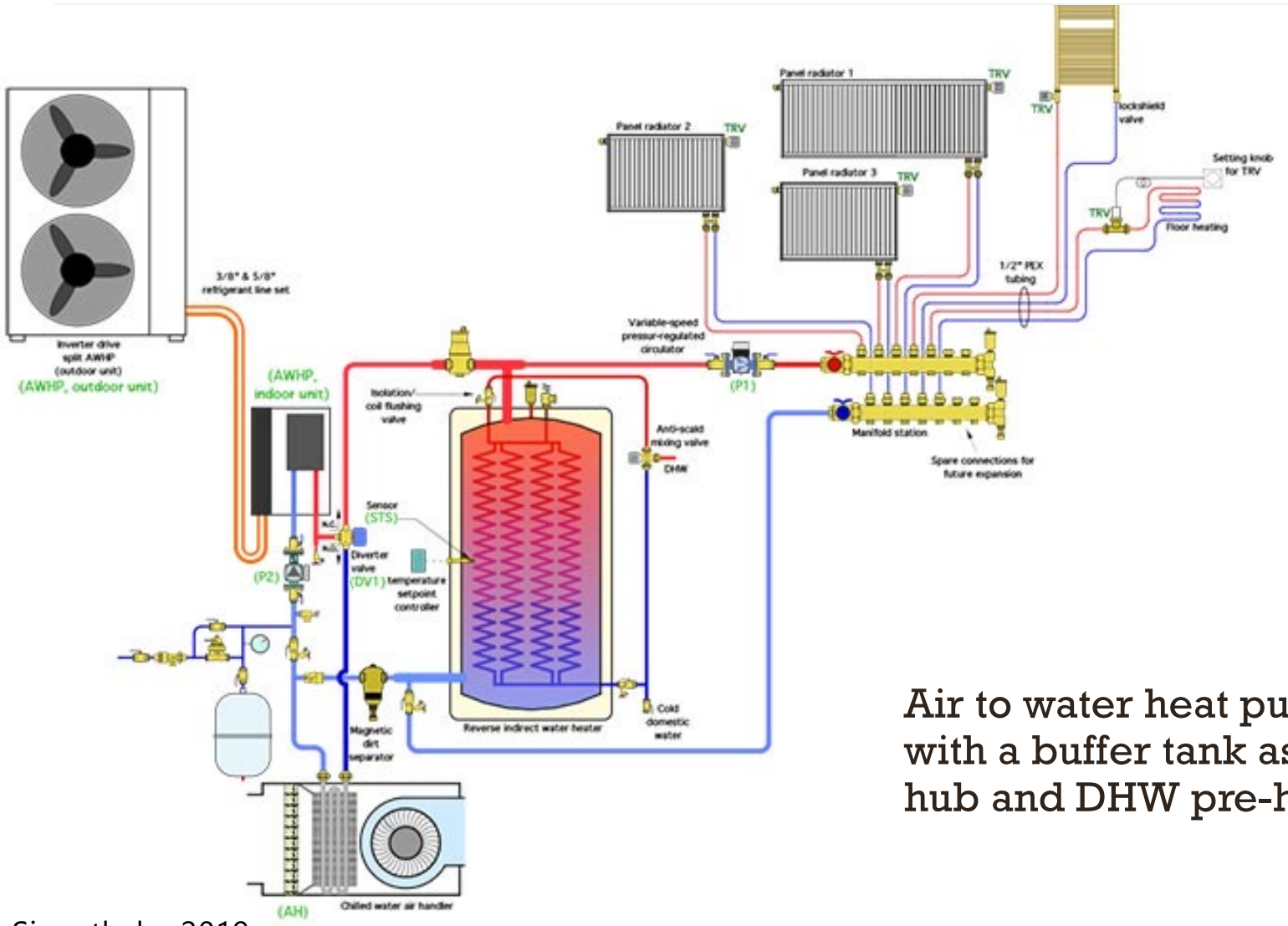
Volumetric Heat Capacity

water: 62.4 Btu/ft^3°F.

air: 0.018 Btu/ft^3°F



Credit: Siegenthaler 2015



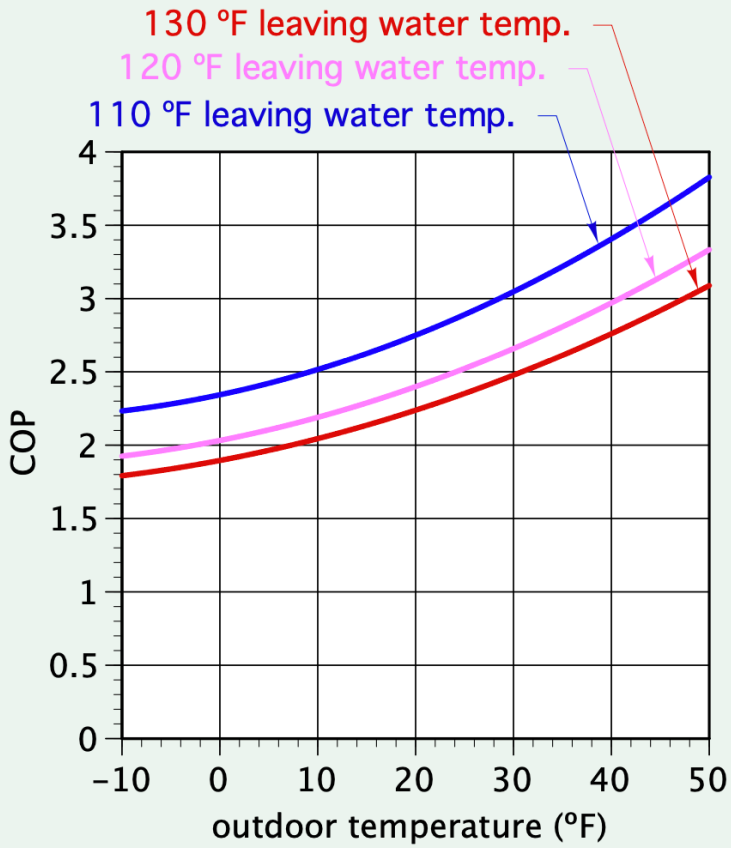
Air to water heat pump with a buffer tank as the hub and DHW pre-heater

Credit: John Siegnthaler 2019

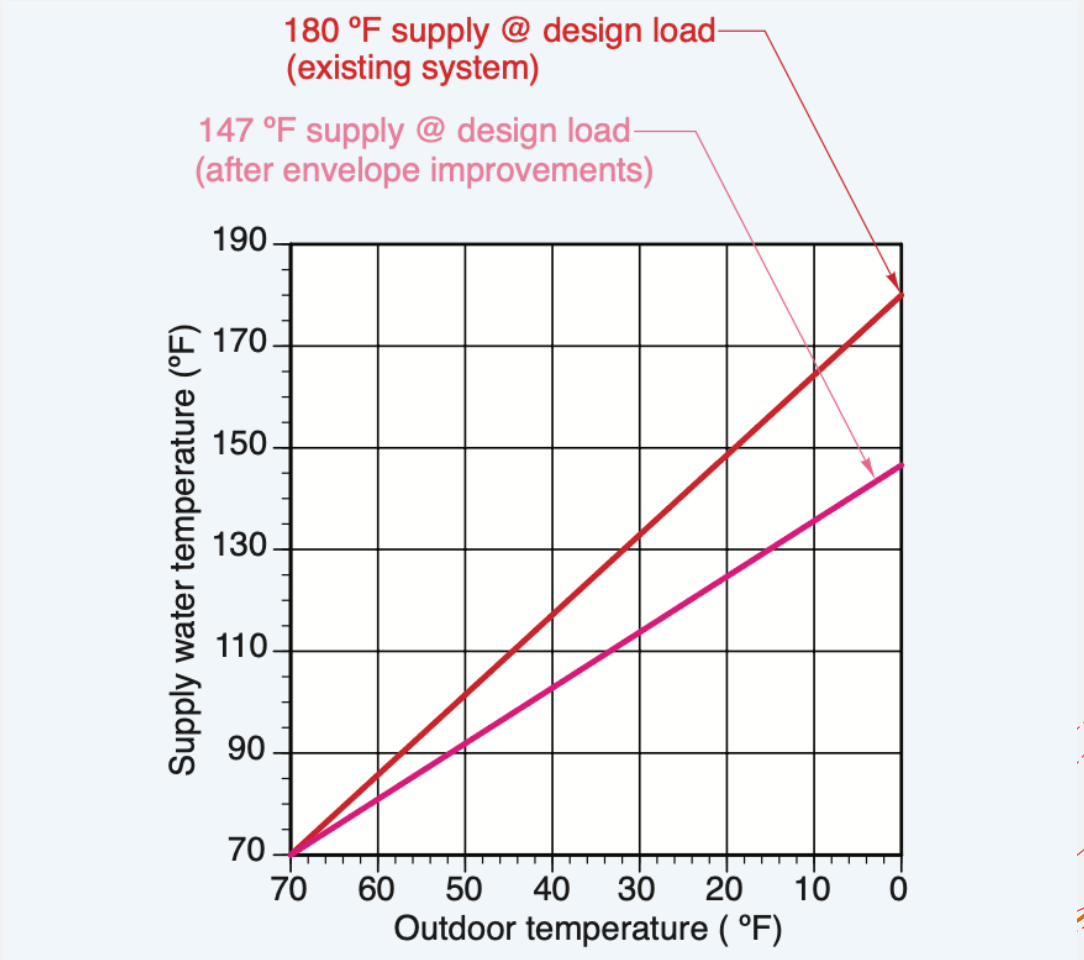
Efficiency declines with decreasing **outdoor** temperatures and increasing **water** temperatures

Decrease water temperatures!

Figure 2-9

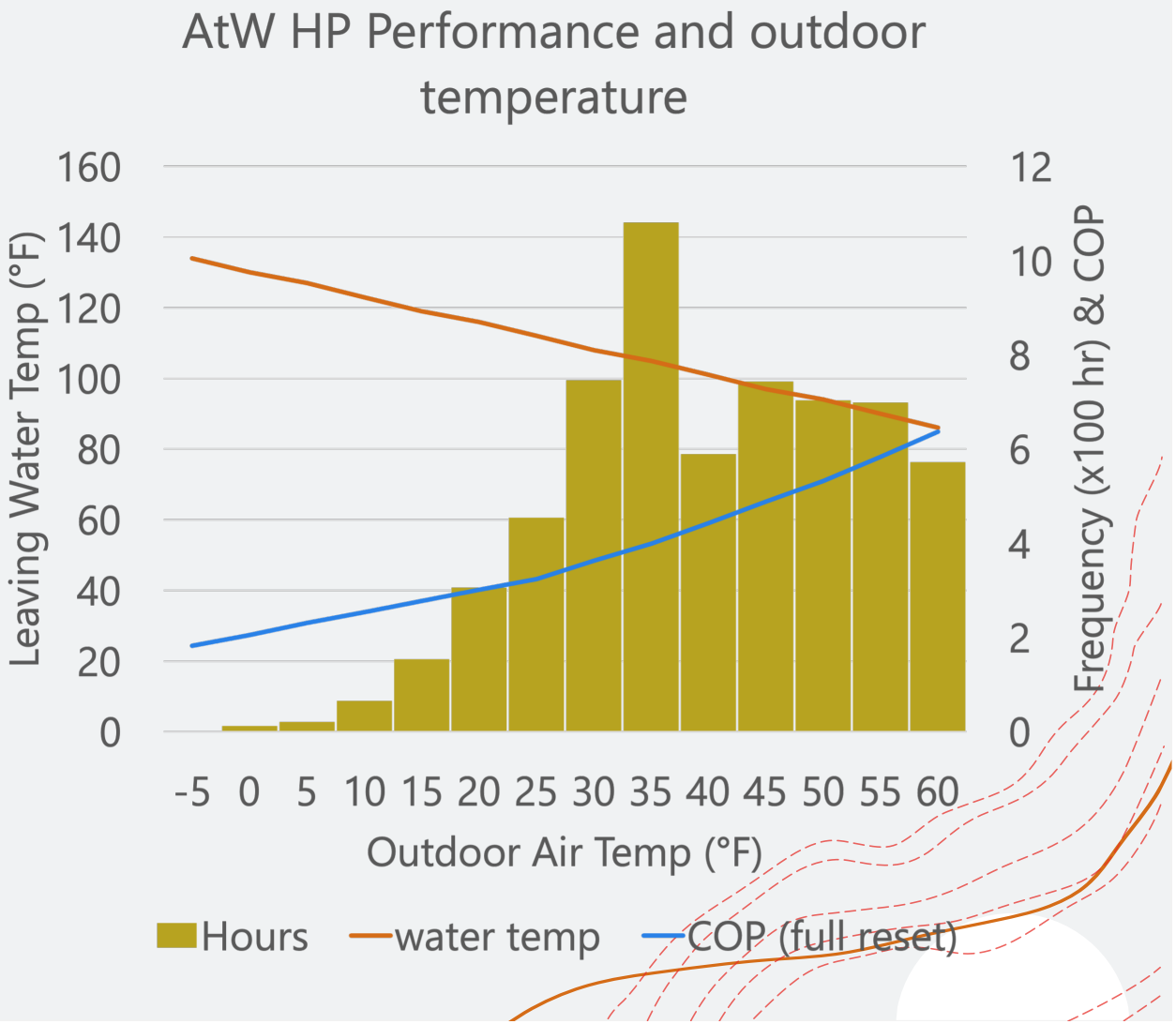


Outdoor temperature reset controls allow low temperatures for most of the time on existing systems



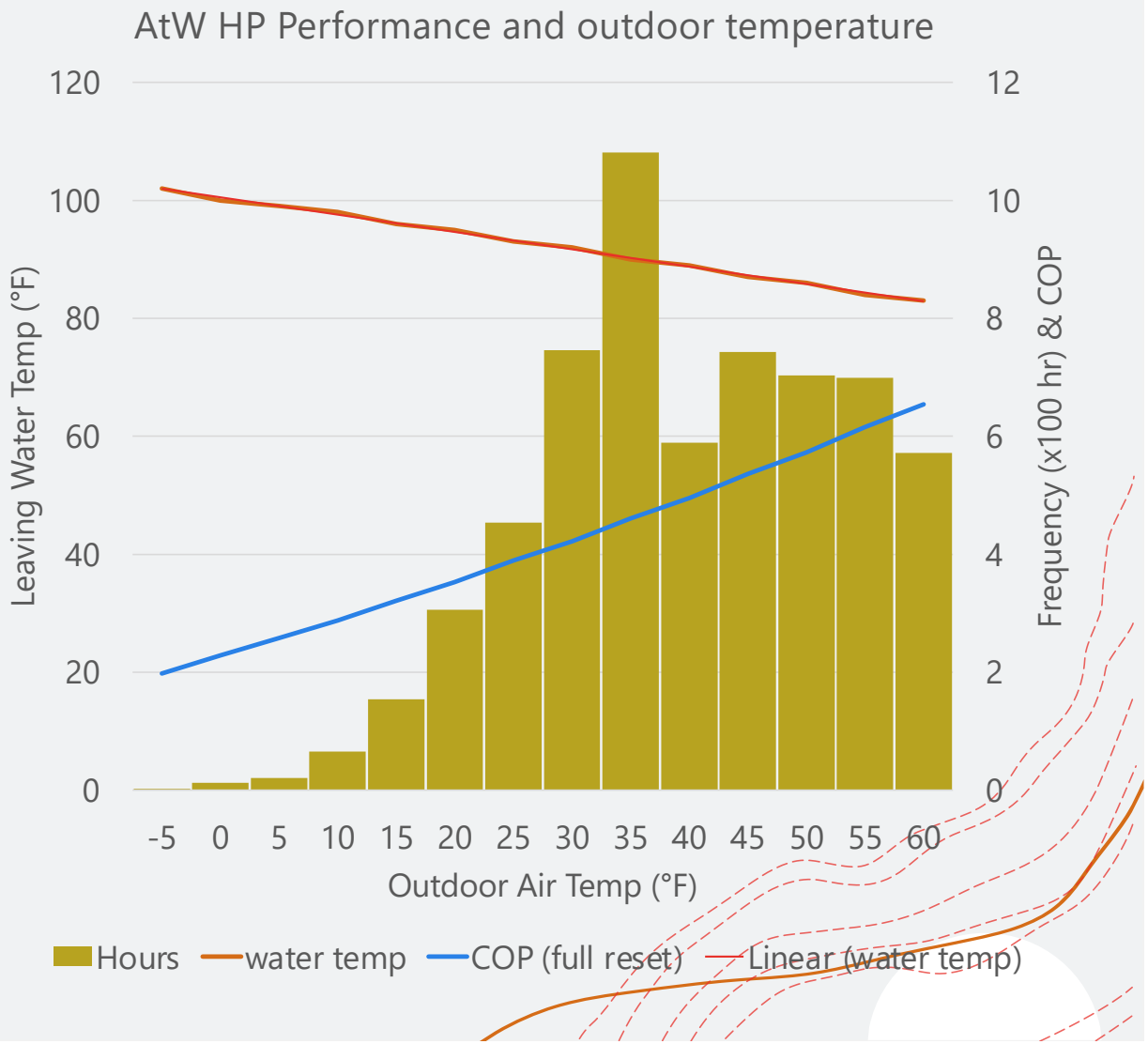
Heating Season Performance is high even with moderate temperature reduction

- **130°F design water temp**
- **90% of hours COP is above 2.3**
- **Seasonal COP = 3.8**

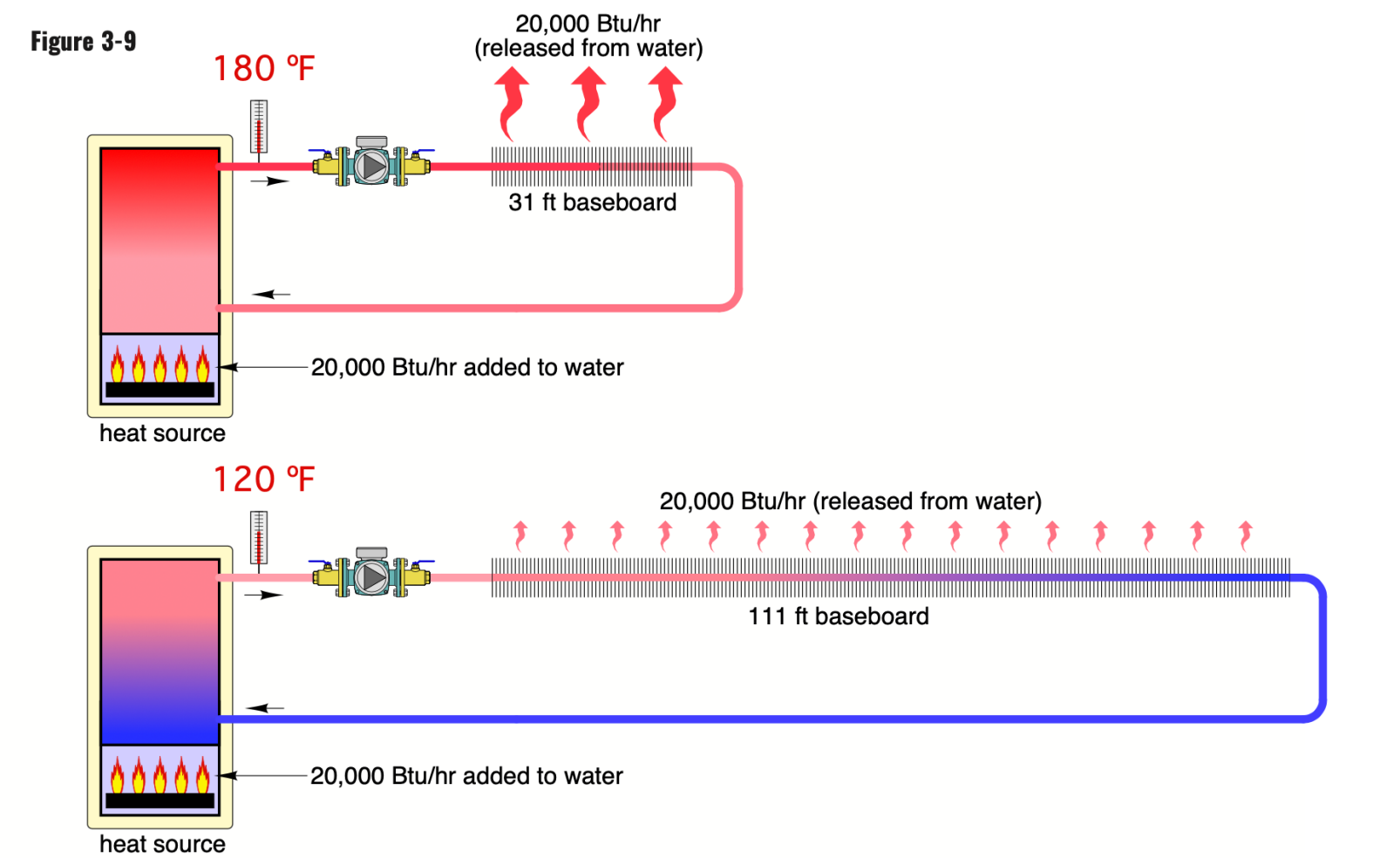


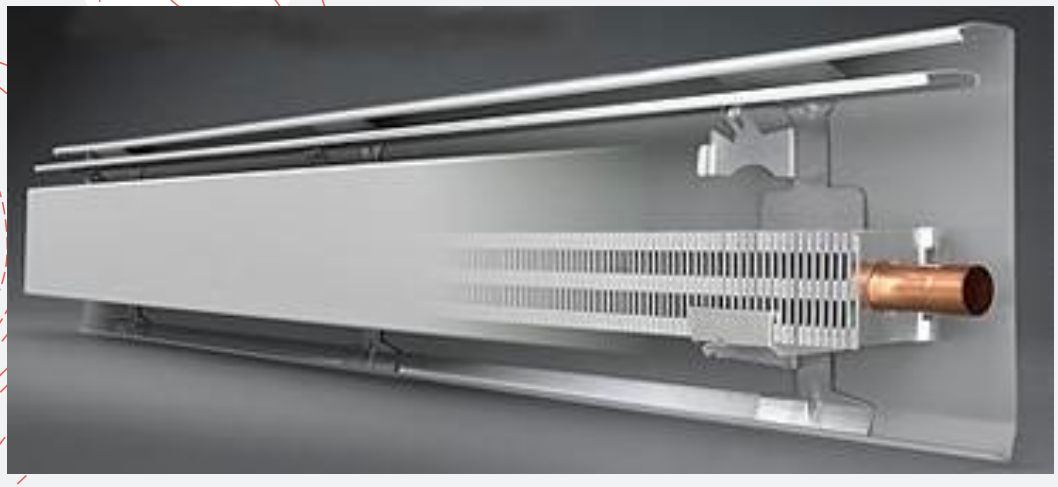
My system performance

- Design Water Temp = 100°F
- Seasonal COP:
  - 4.3 heating only
  - 3.7 heating and hot water

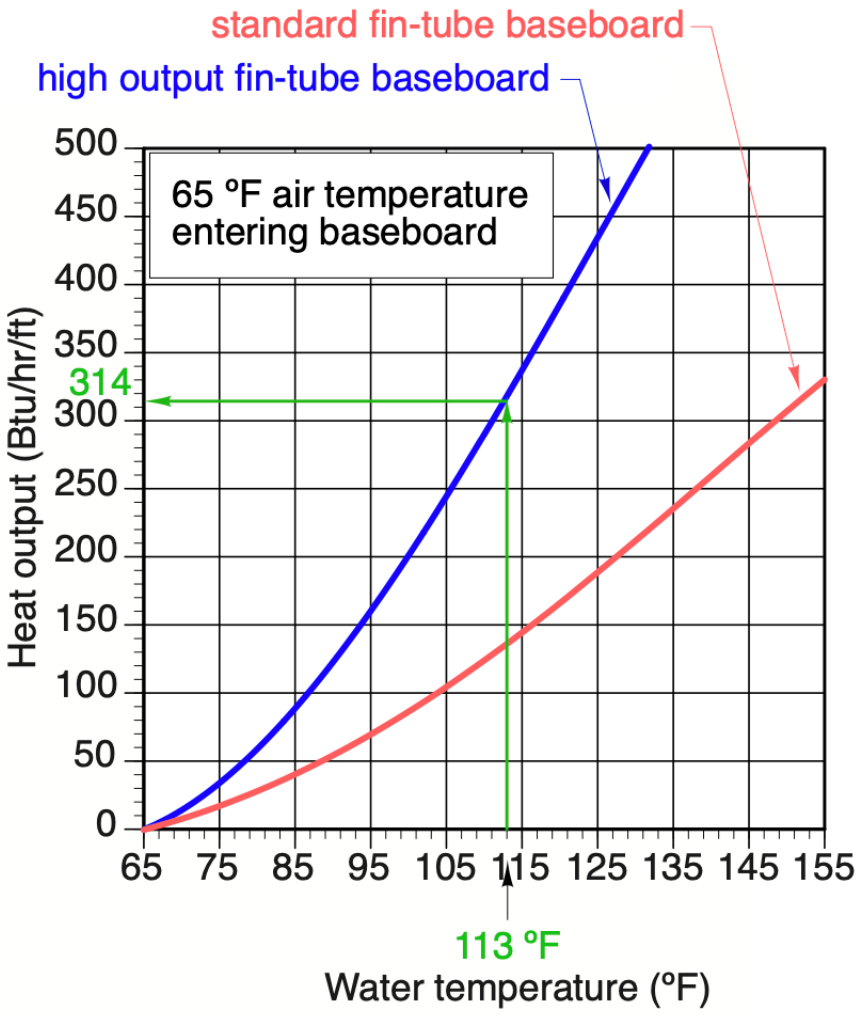


existing emitters may have too little surface area





Swap out old fin-tube for high output



Other hydronic heat emitters

concealed
fan-coils

Ceiling
Cassettes

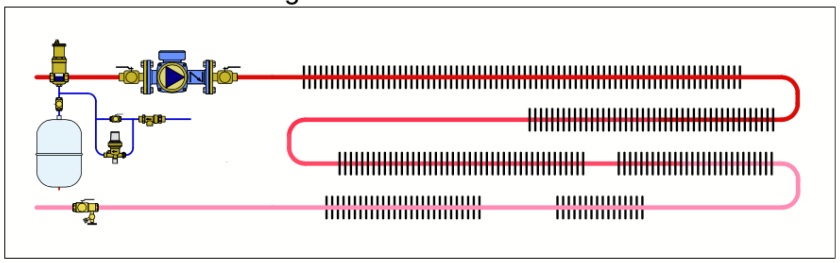
Panel
Radiators

fan coil
convectors

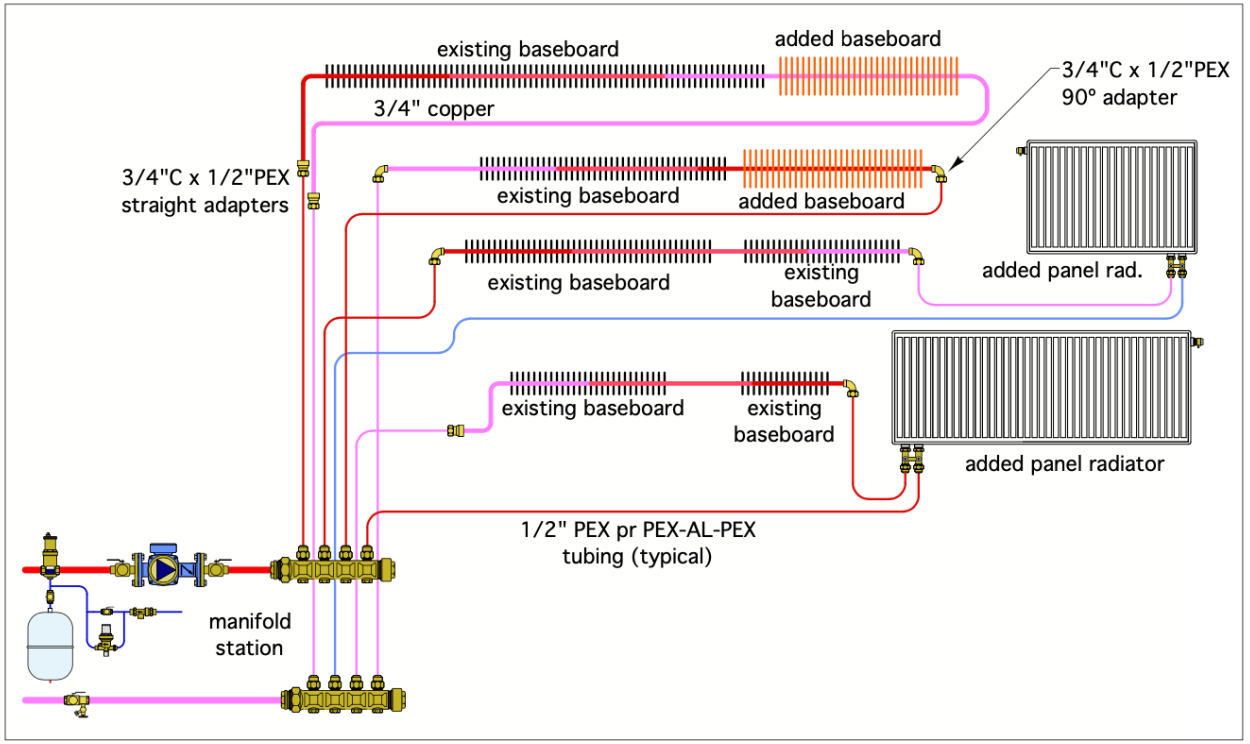
Ducted
Hydro-air
units

modify existing series baseboard for low temp water

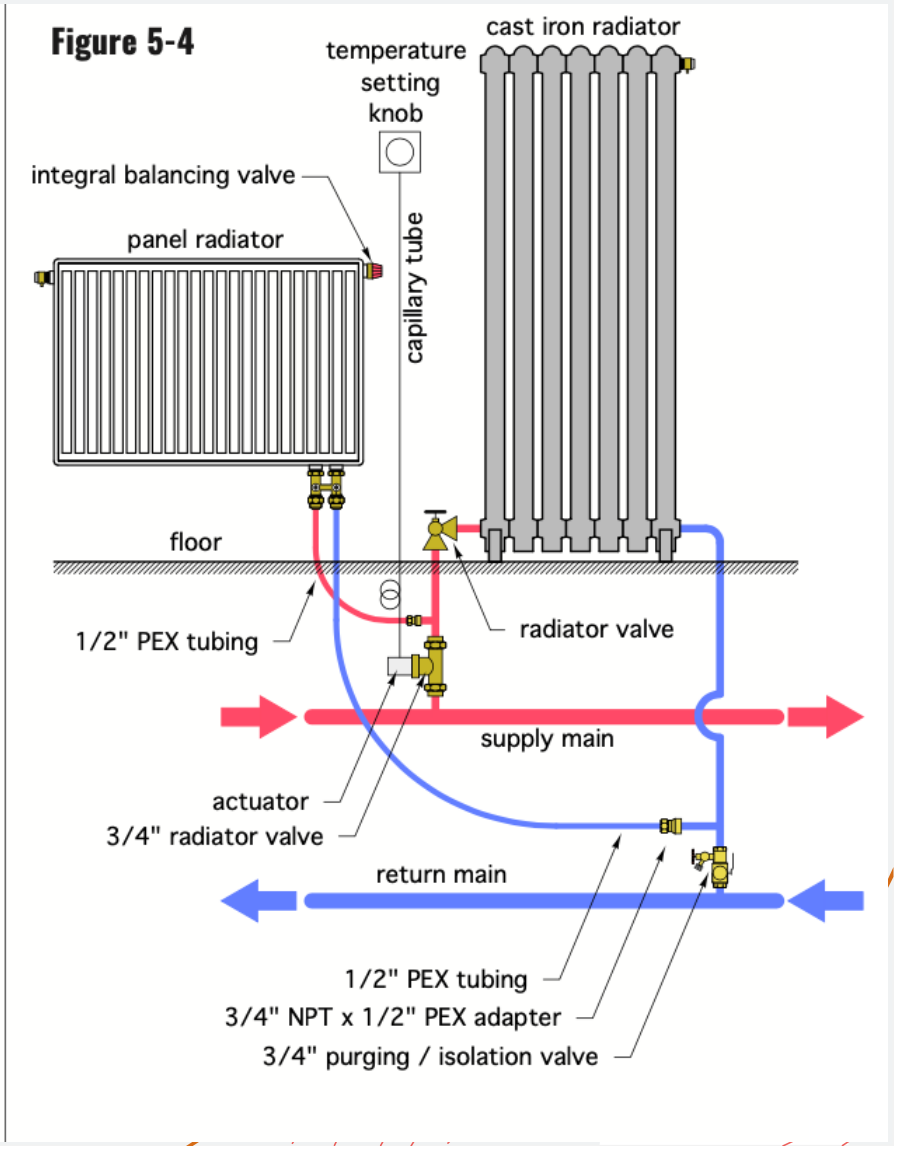
Existing series baseboard circuit

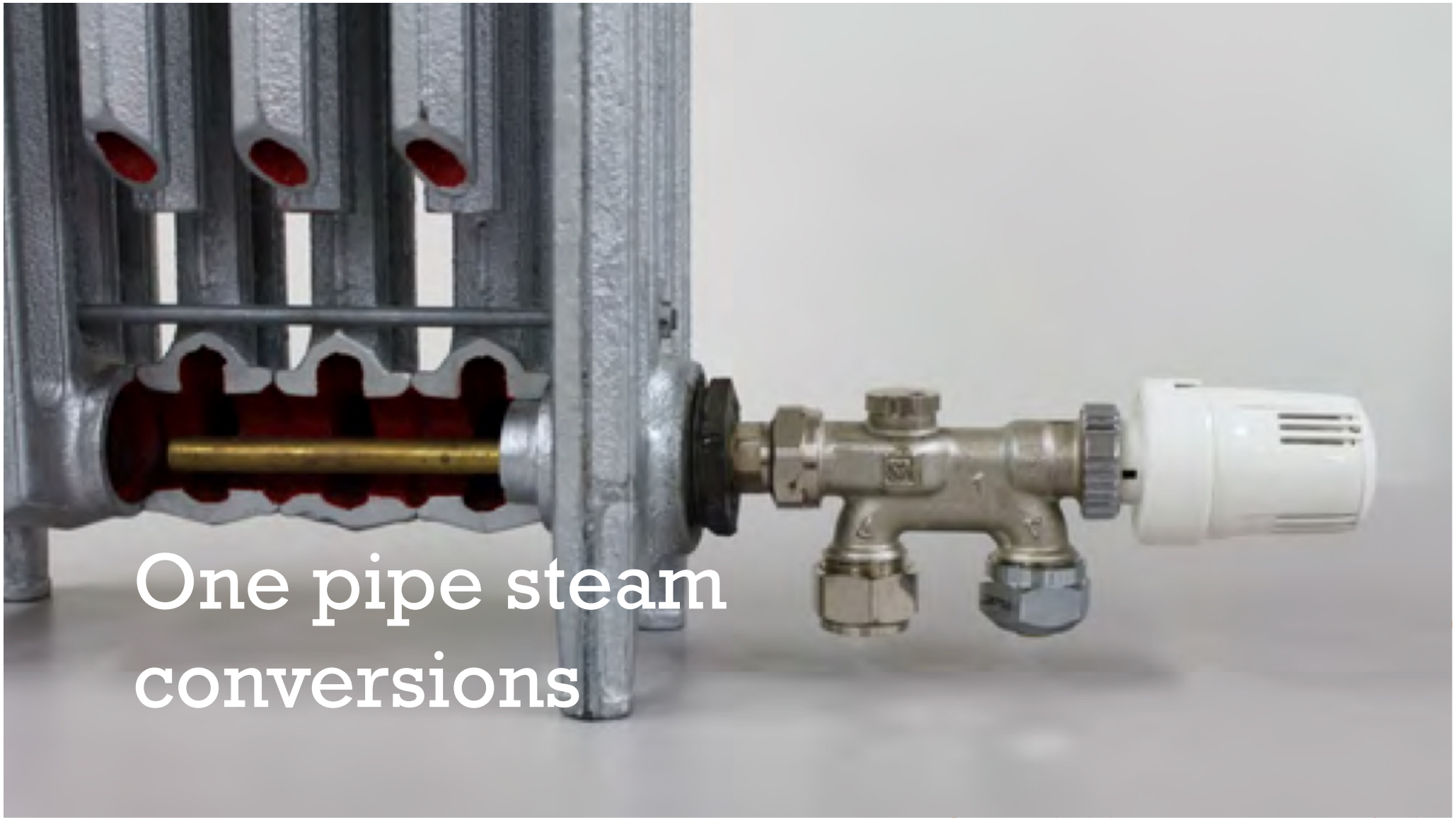


Modified distribution system

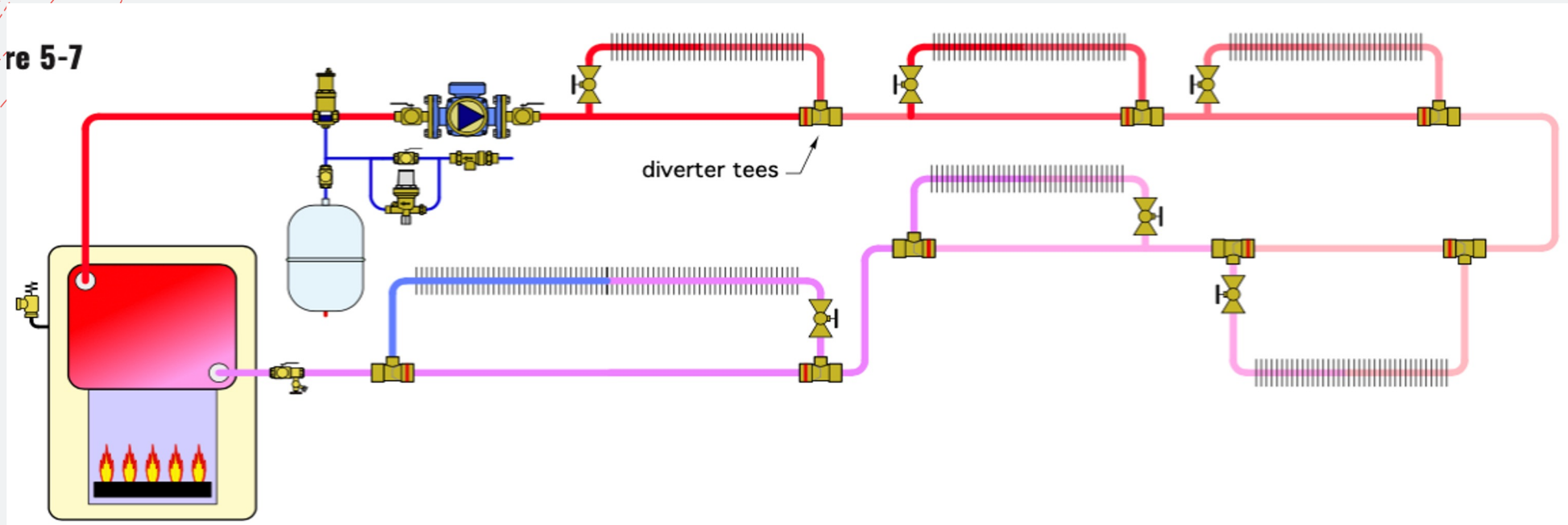


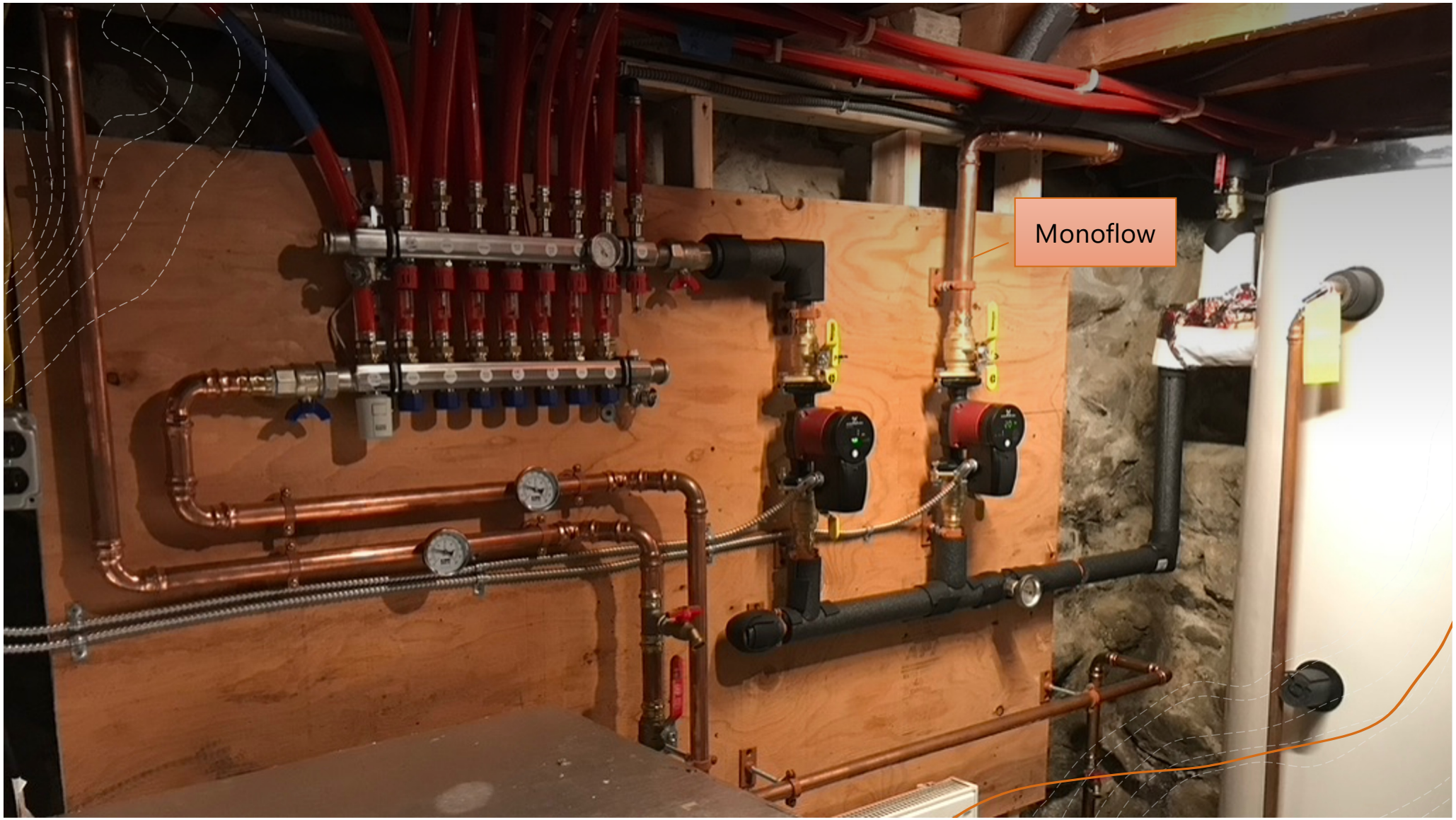
Adding additional radiation to an existing 2-pipe system




One pipe steam
conversions

Supplementing a mono-flow system




Monoflow