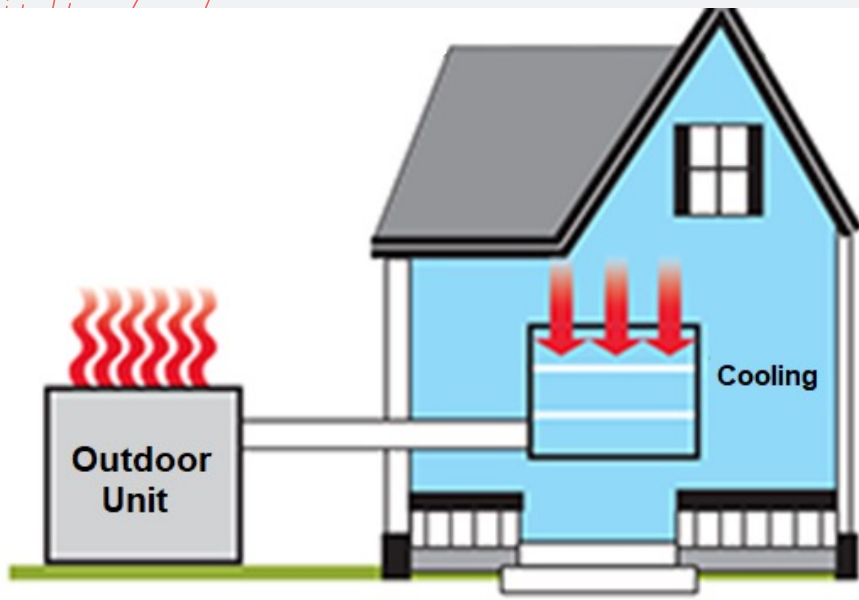


# Heat Pumps

- 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



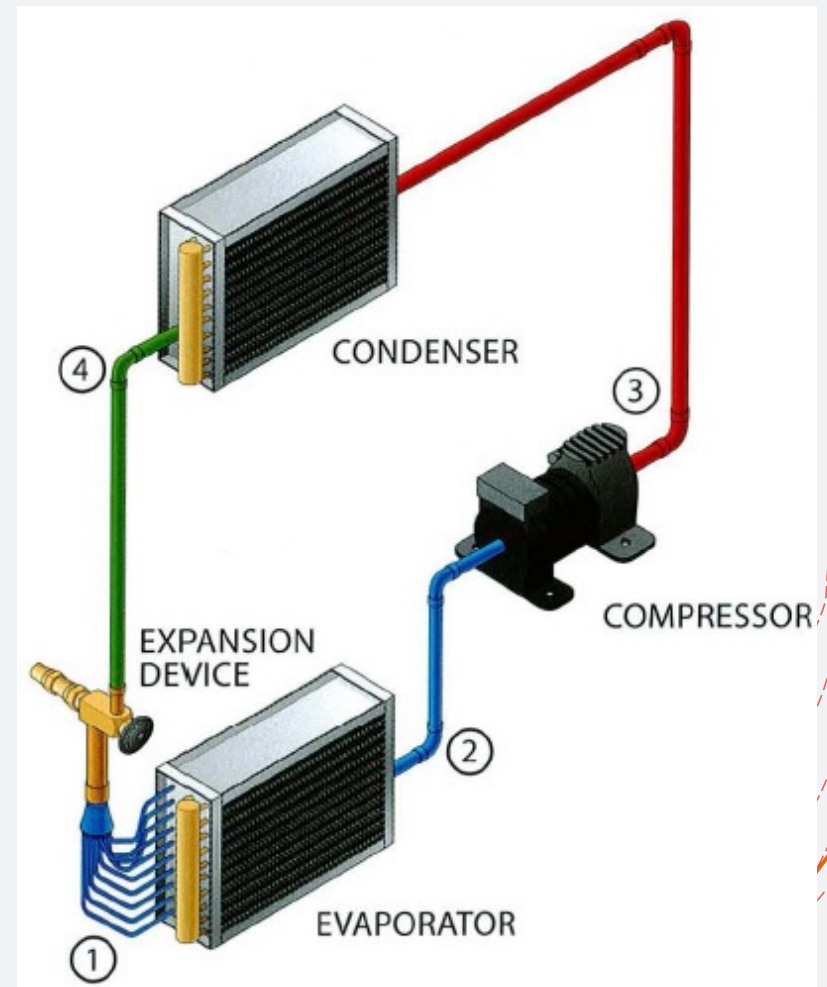
## Winter

Draws heat from outside  
and moves it indoors

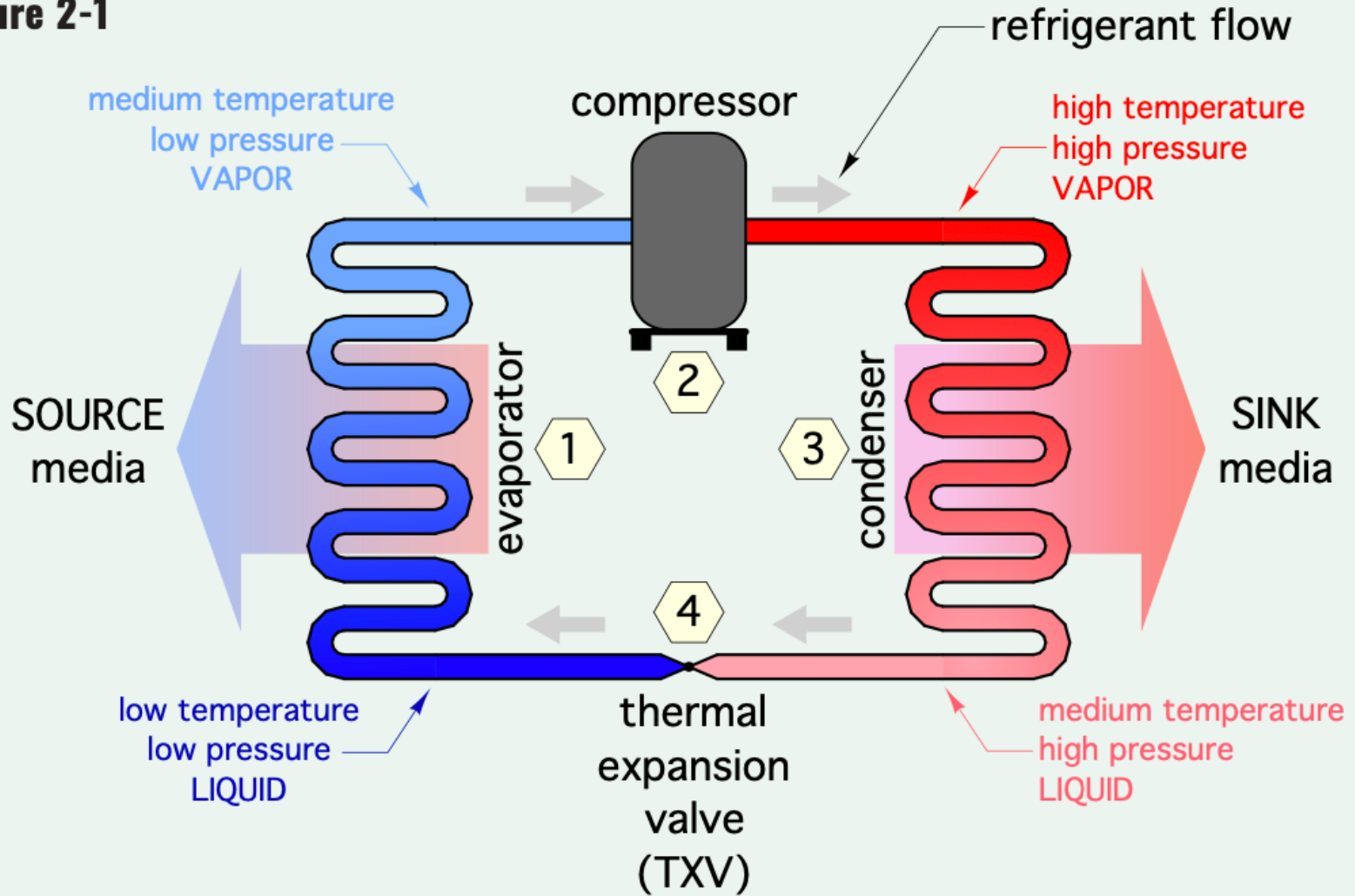
# How Heat Pumps Work

Typical refrigeration system:

- + Compressor
- + Condenser
- + Expansion device
- + Evaporator

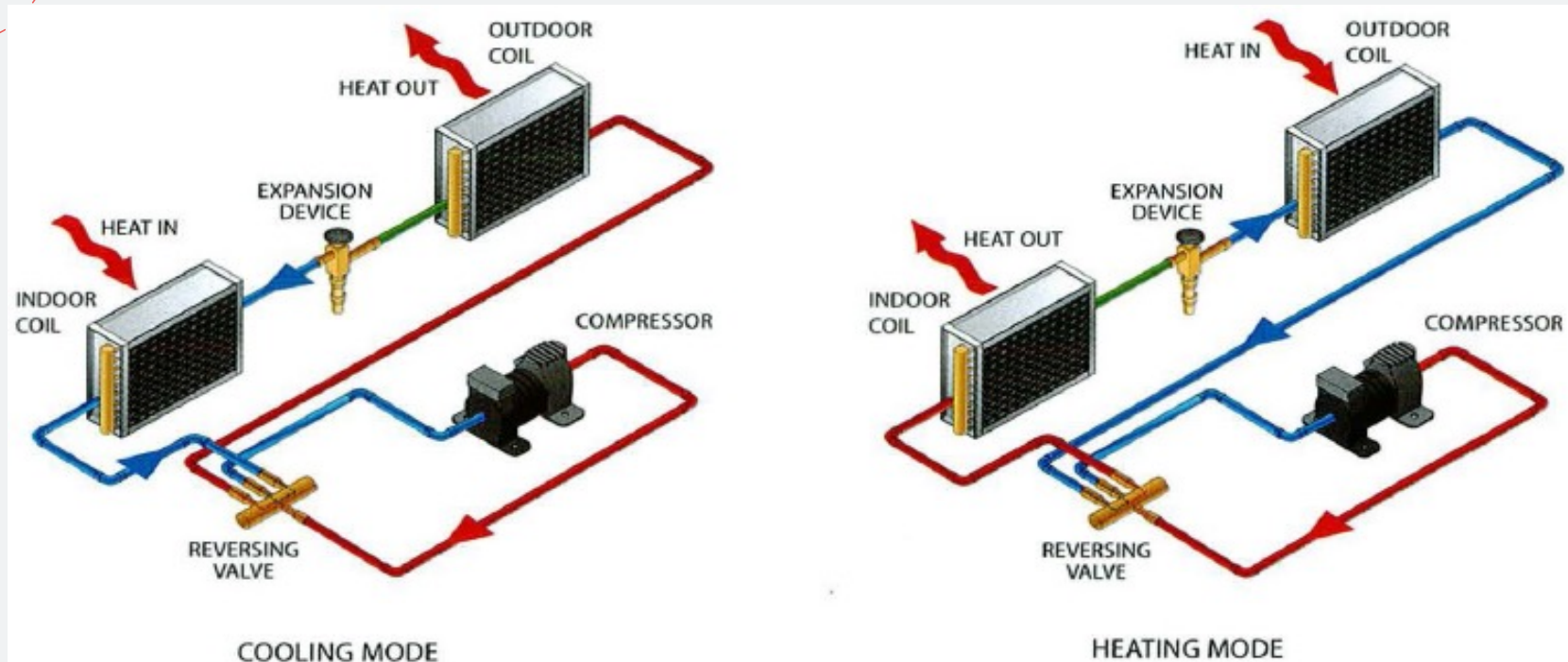


**Figure 2-1**



# How Heat Pumps Work

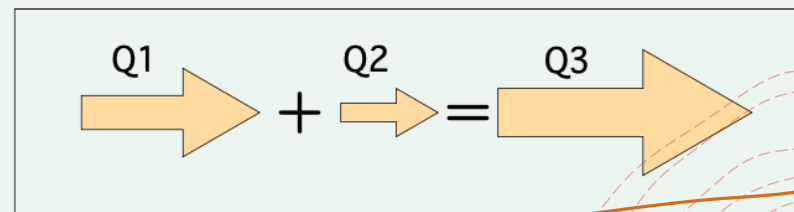
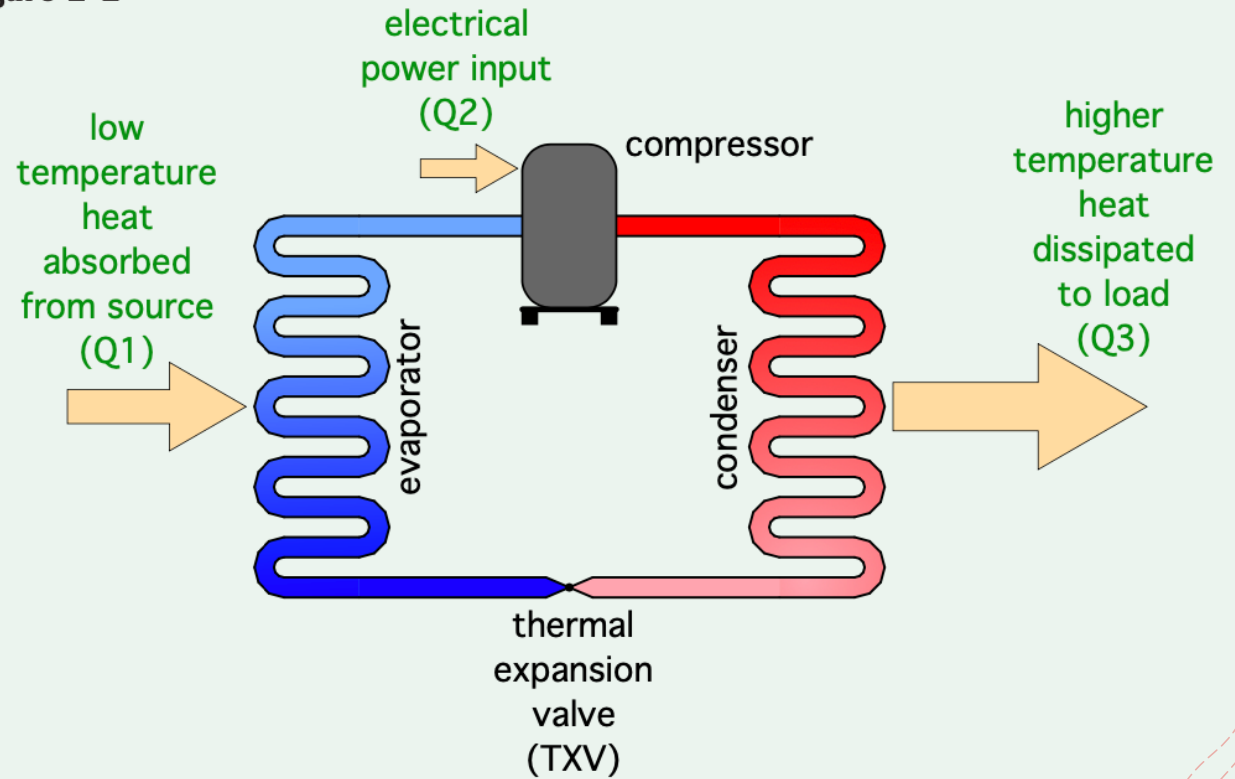
Heat pumps introduce a reversing valve to the refrigeration cycle



# Efficiency: Coefficient of Performance (COP)

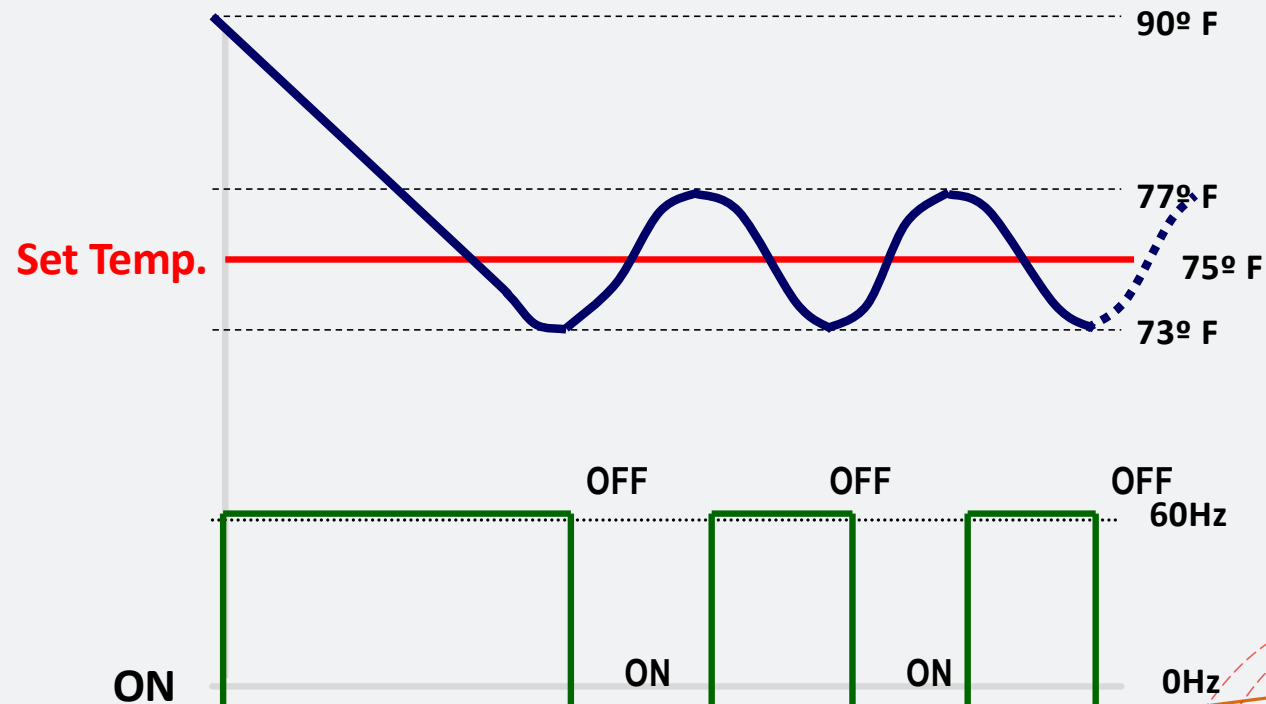
- + Heating COP =  $Q_3/Q_2$
- + Cooling COP =  $Q_1/Q_2$
- +  $Q_2$  = heat of compression

Figure 2-2



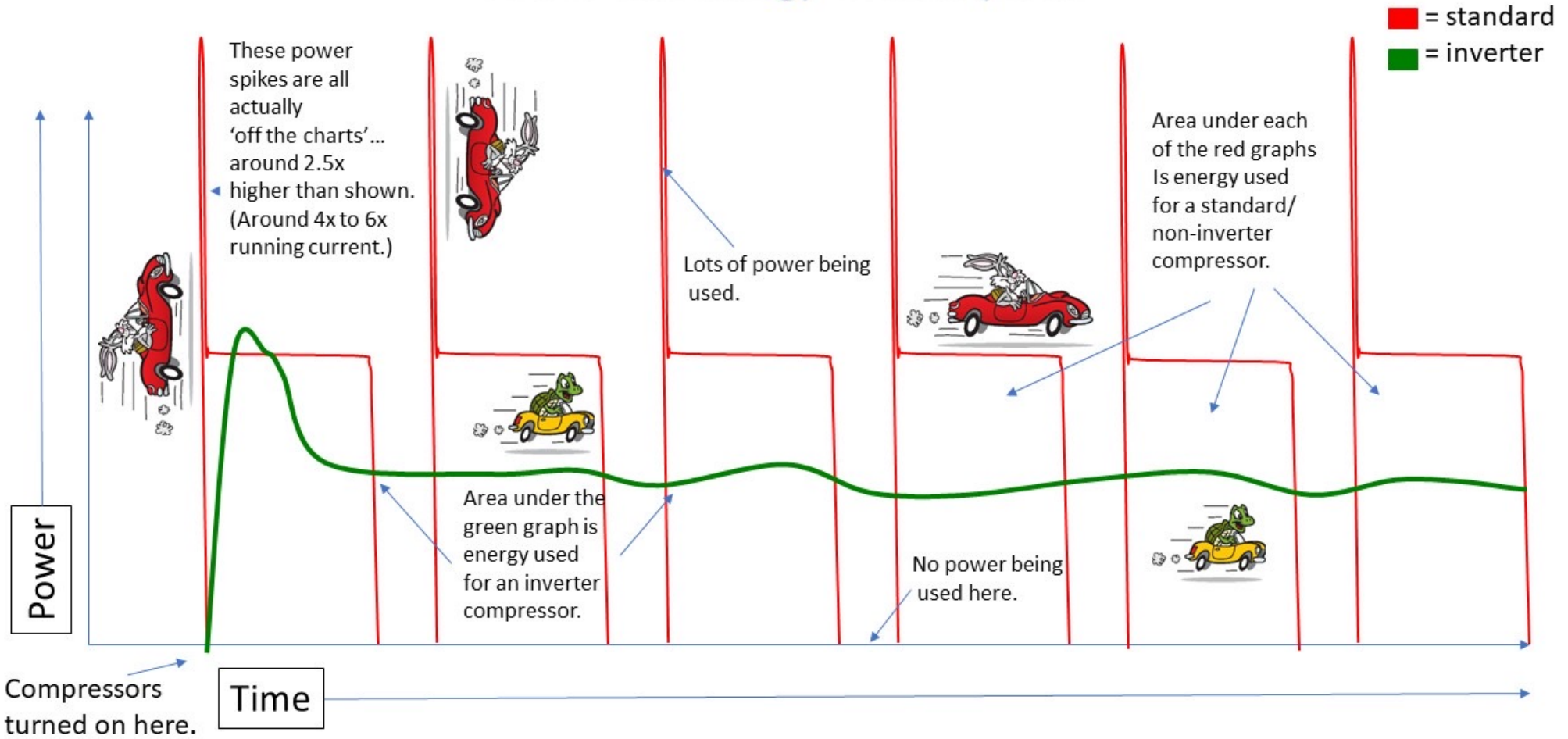
# Efficiency – Traditional Systems

Constant speed ON/OFF compressors

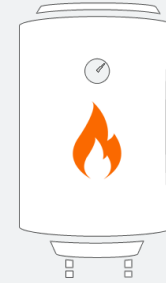
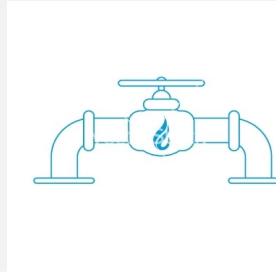




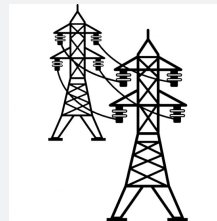
# Standard vs. Inverter Compressor Air Conditioner/Heat Pump Power and Energy Consumption



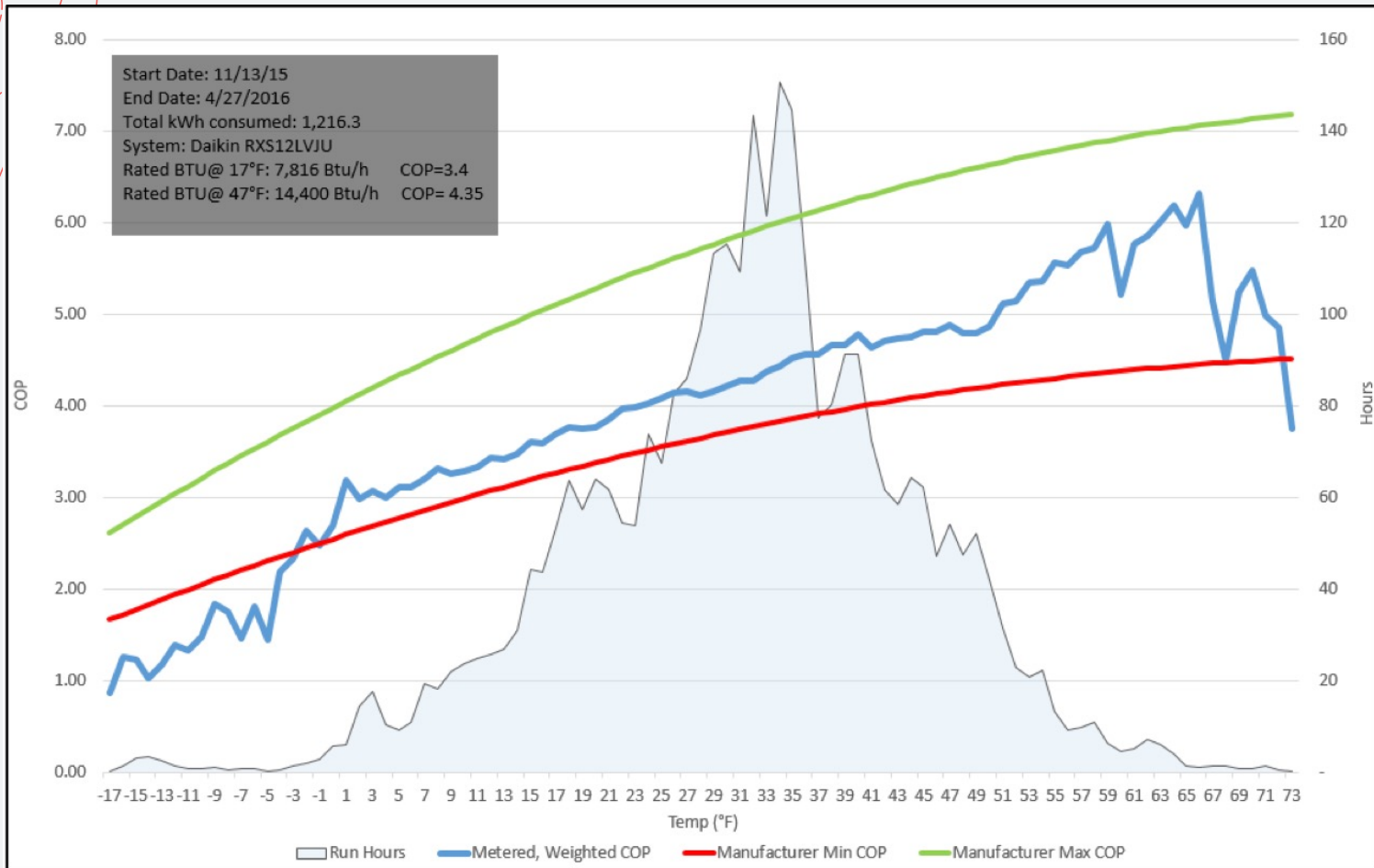
## Efficiency of heaters depending on source



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

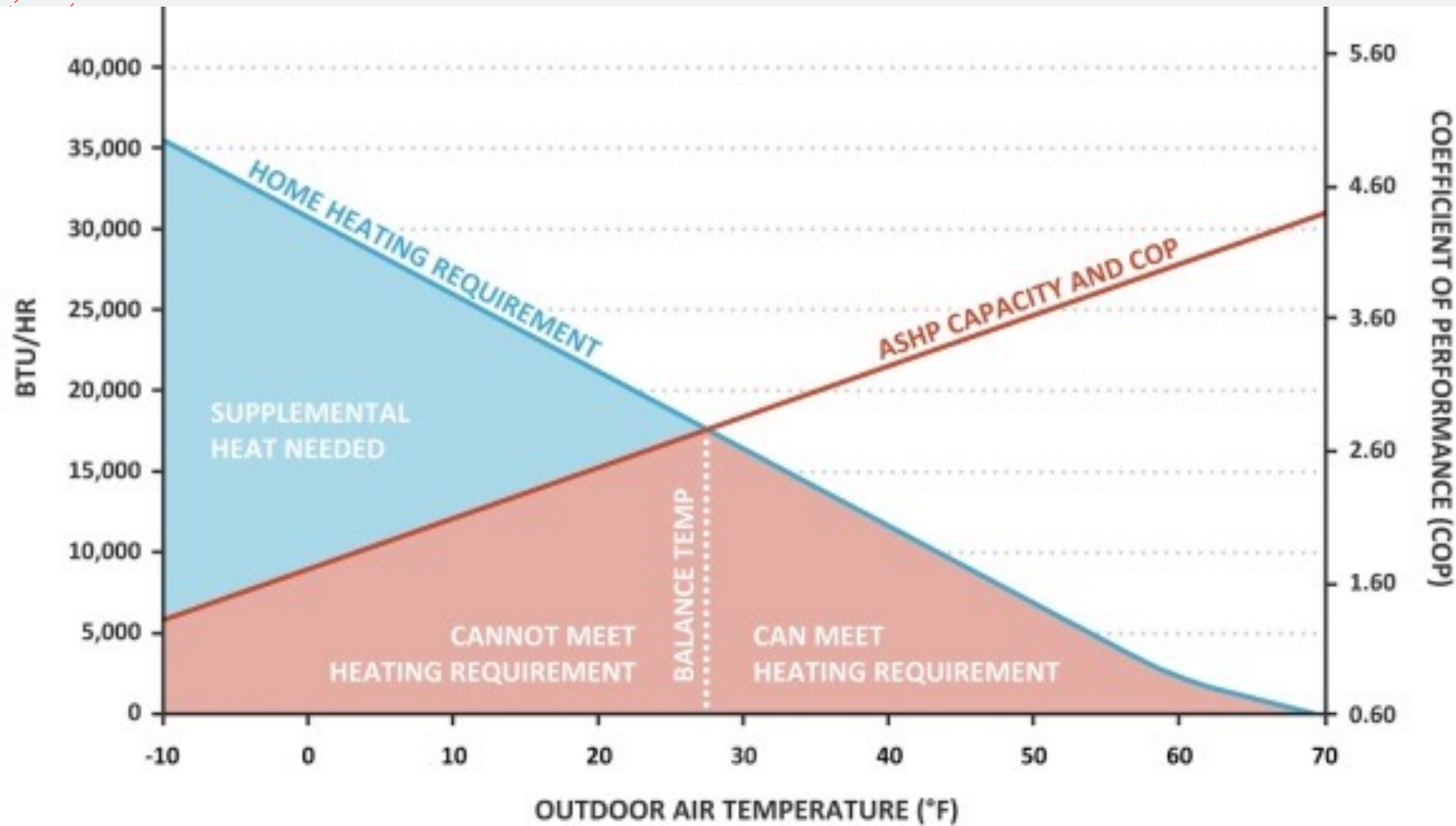


## Air source heat pump efficiency declines with outdoor air temp



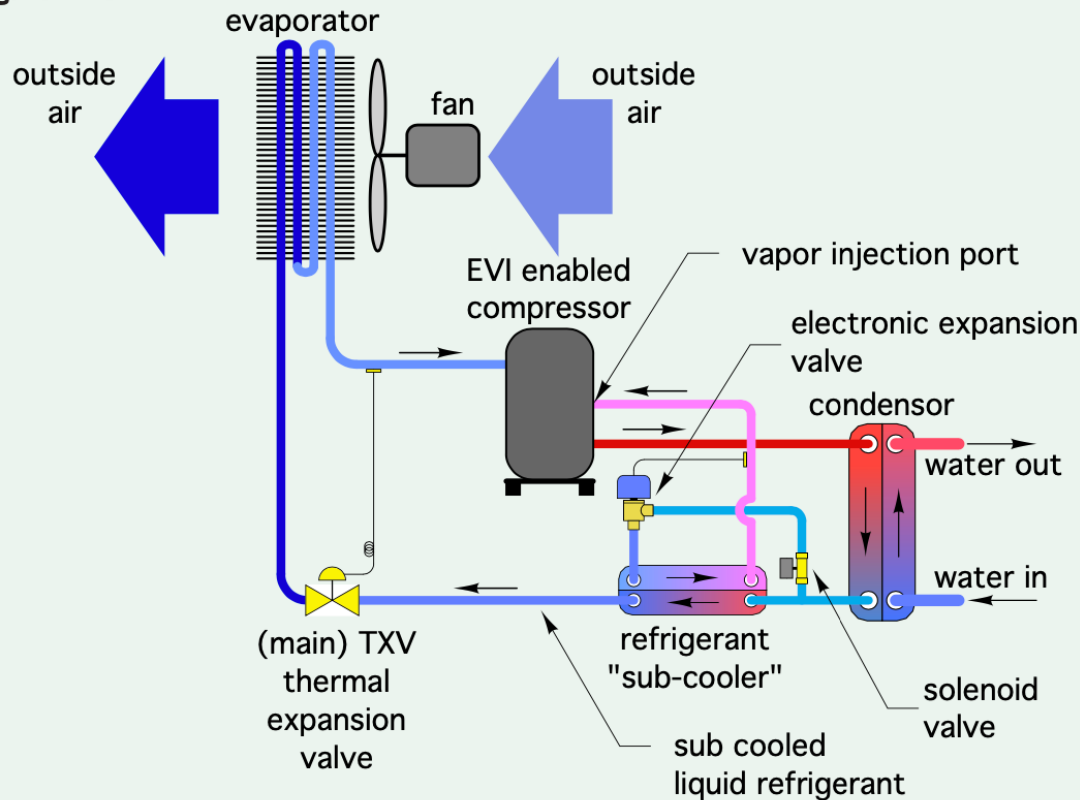
Walczyk & Larson, Ductless Mini-Split Heat Pump Systems: The Answers to Questions about Efficiency You Didn't Know You Had  
 2016 ACEEE Summer Study on Energy Efficiency in Buildings [https://www.aceee.org/files/proceedings/2016/data/papers/1\\_836.pdf](https://www.aceee.org/files/proceedings/2016/data/papers/1_836.pdf)

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



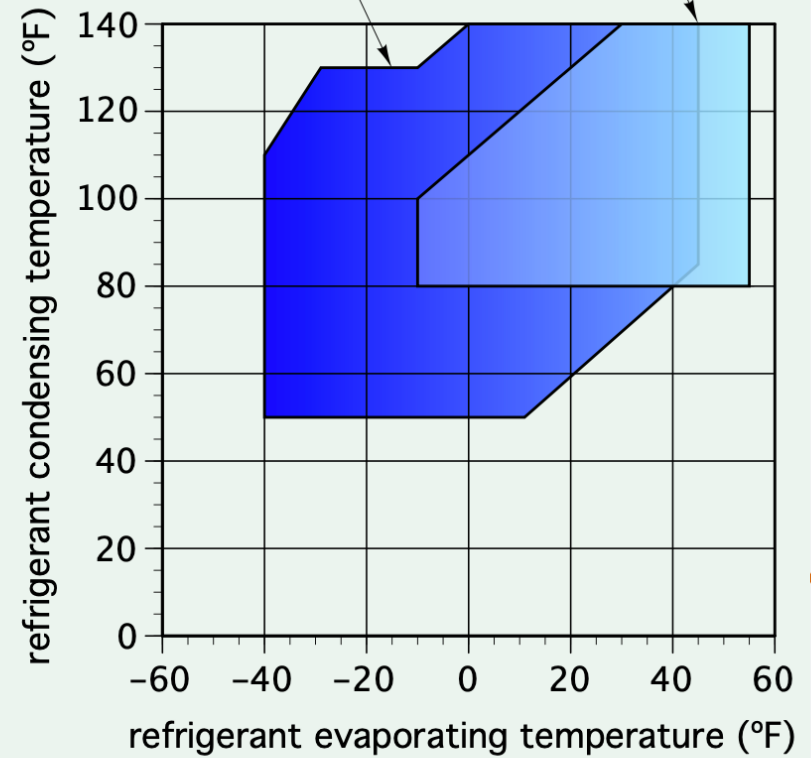
# Newer News: Enhanced Vapor Injection (EVI)

Figure 2-13



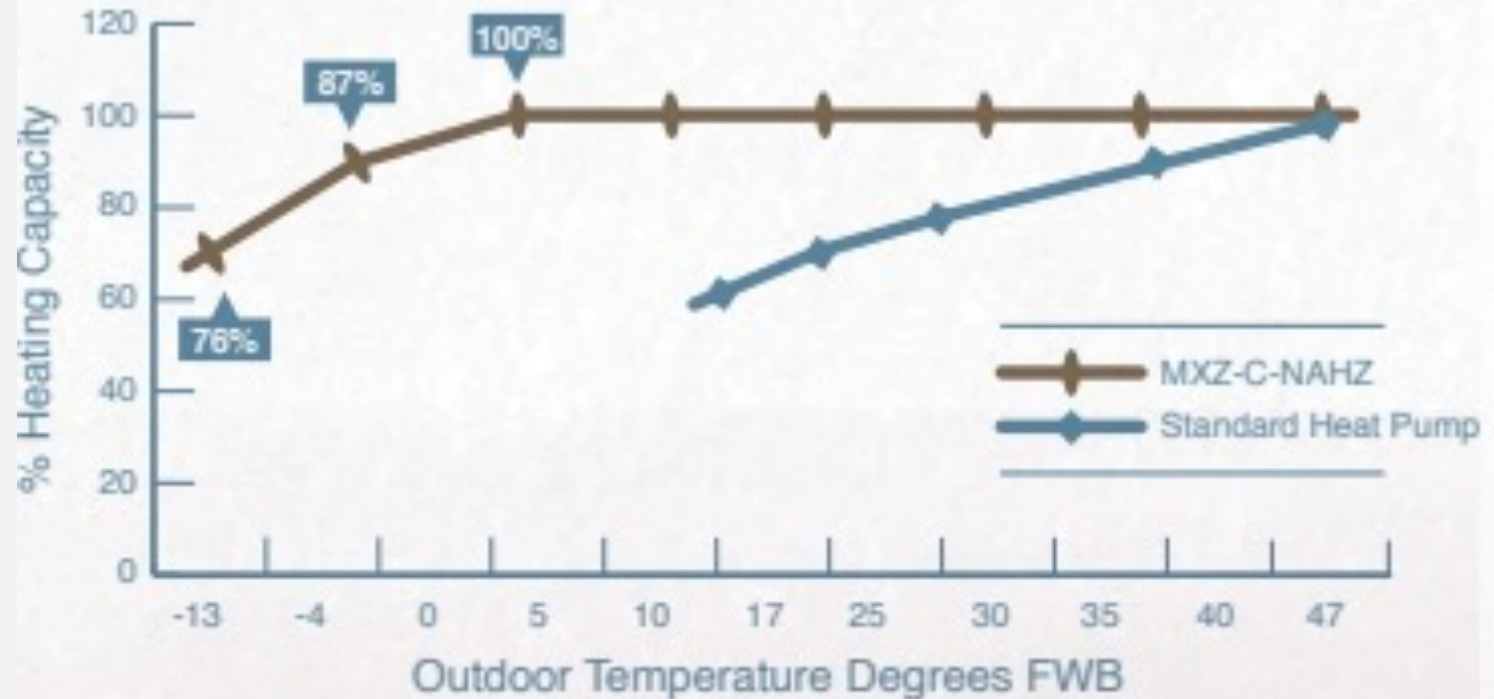
operating range of a typical 2-stage scroll compressor

operating range of a vapor injection compressor



## H2i® TECHNOLOGY

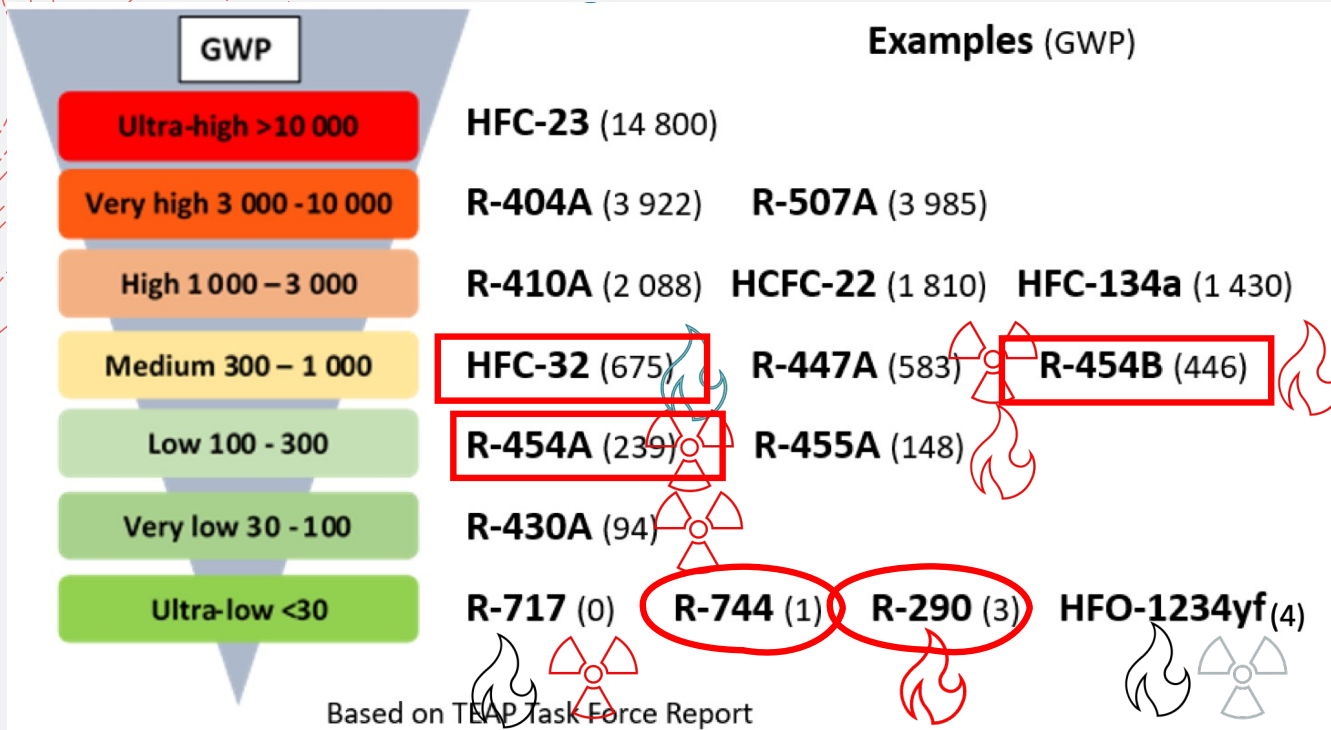
### MXZ H2i HEATING CAPACITY AT LOW TEMPERATURES\*



\* Includes correction for defrost.

“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

HVAC School  
For Technicians

## HFC (R-410A)

PHASEOUT TIMELINE

**2020**

The American Innovation and Manufacturing (AIM) Act is enacted by Congress. The AIM Act directs the EPA's focus to the phasedown, substitution, and management of HFC refrigerants, including R-410A.

**2021**

EPA Administrator Michael S. Regan signs the official final rule for the phasedown of HFC refrigerants. The final rule puts forth a plan to reduce HFC refrigerant production by 85% over 15 years.

**2022**

HFC production will decrease by 10%.

**2024**

HFC production will decrease by 40%.

**2029**

HFC production will decrease by 70%.

**2036**

HFC production will decrease by 85%.

**2034**

HFC production will decrease by 80%.

Sources: "Final Rule - Phasedown of Hydrofluorocarbons: Establishing the Allowance Allocation and Trading Program under the AIM Act." Environmental Protection Agency.  
[https://www.epa.gov/climate/Mcs\\_reduction/final\\_rule\\_phasedown\\_hydrofluorocarbons\\_establishing\\_allowance\\_allocation](https://www.epa.gov/climate/Mcs_reduction/final_rule_phasedown_hydrofluorocarbons_establishing_allowance_allocation)  
[https://www.epa.gov/system/files/documents/2021/09/Mc\\_allocation\\_rule\\_nprm\\_fact\\_sheet\\_finalrule.pdf](https://www.epa.gov/system/files/documents/2021/09/Mc_allocation_rule_nprm_fact_sheet_finalrule.pdf)

## GWP comparison of R410A & R32



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

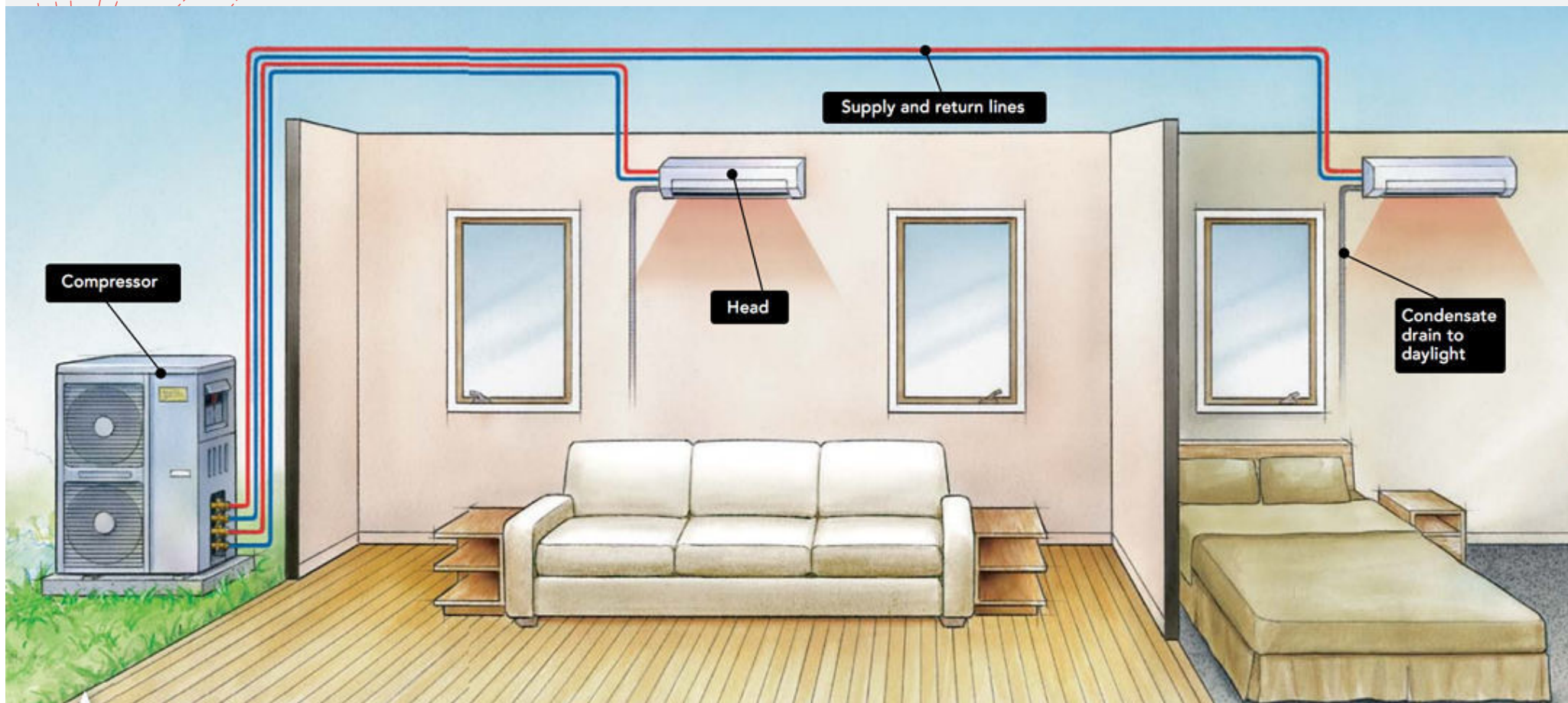
GWP Values according to IPCC 4th Assessment Report  
 For the EU F gas regulation the GWP values of IPCC 3rd report are valid  
 (R410A = 1975, R32 = 650)

# 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



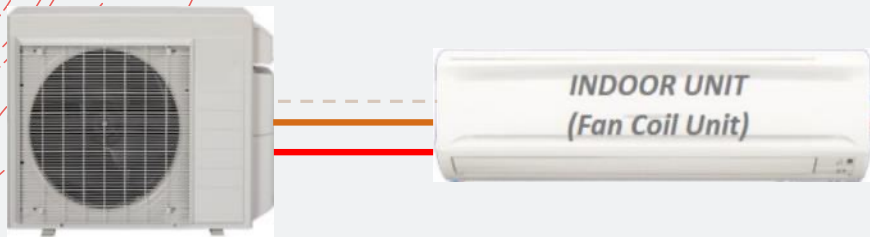
# Mini-and-multi-split ASHPs



# Typical Air-Source Heat Pumps

## Mini-Split or Single-Split

- One indoor unit and one outdoor unit



## Multi-Split

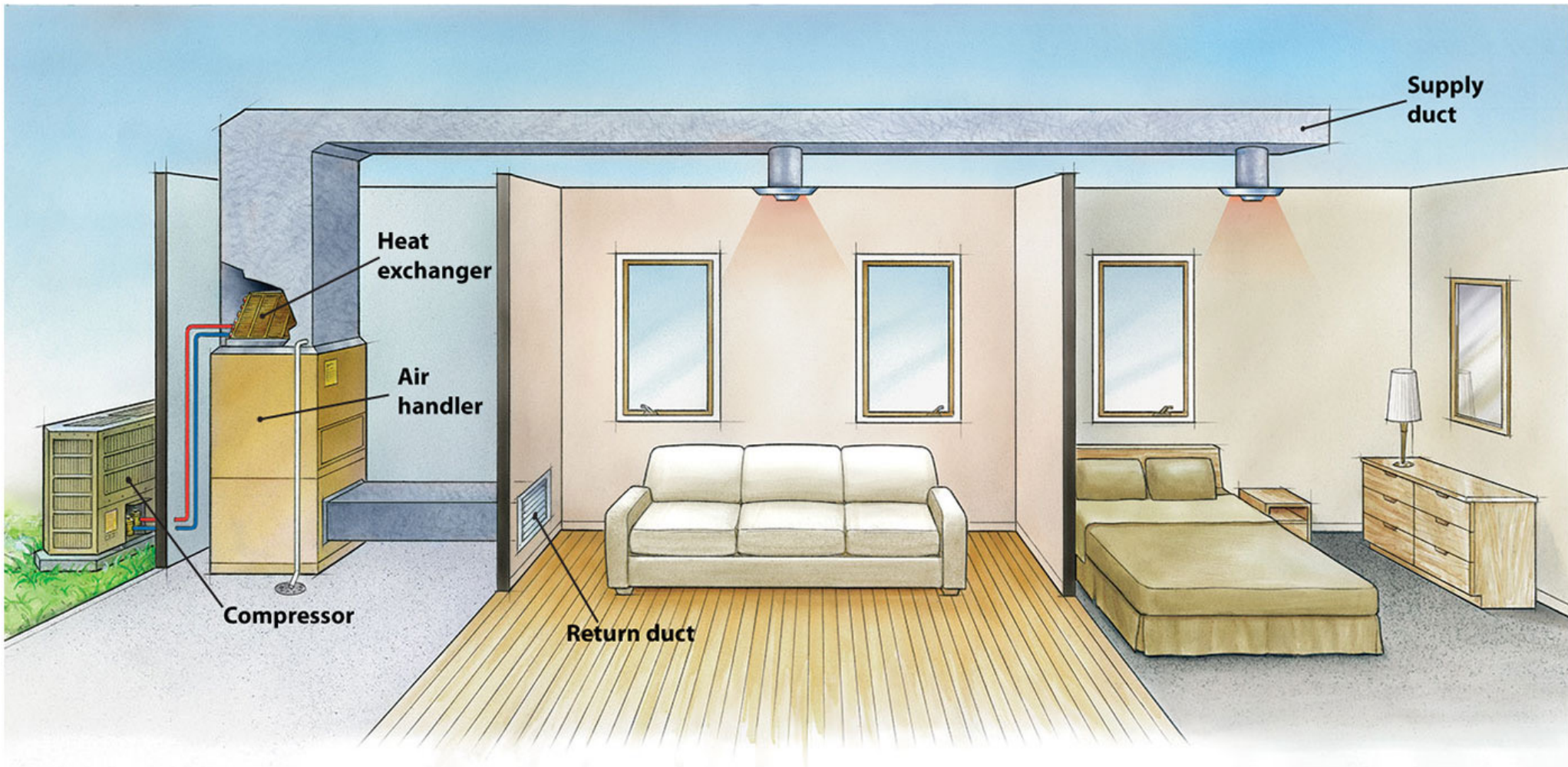
- Multiple indoor units with individual temperature controls

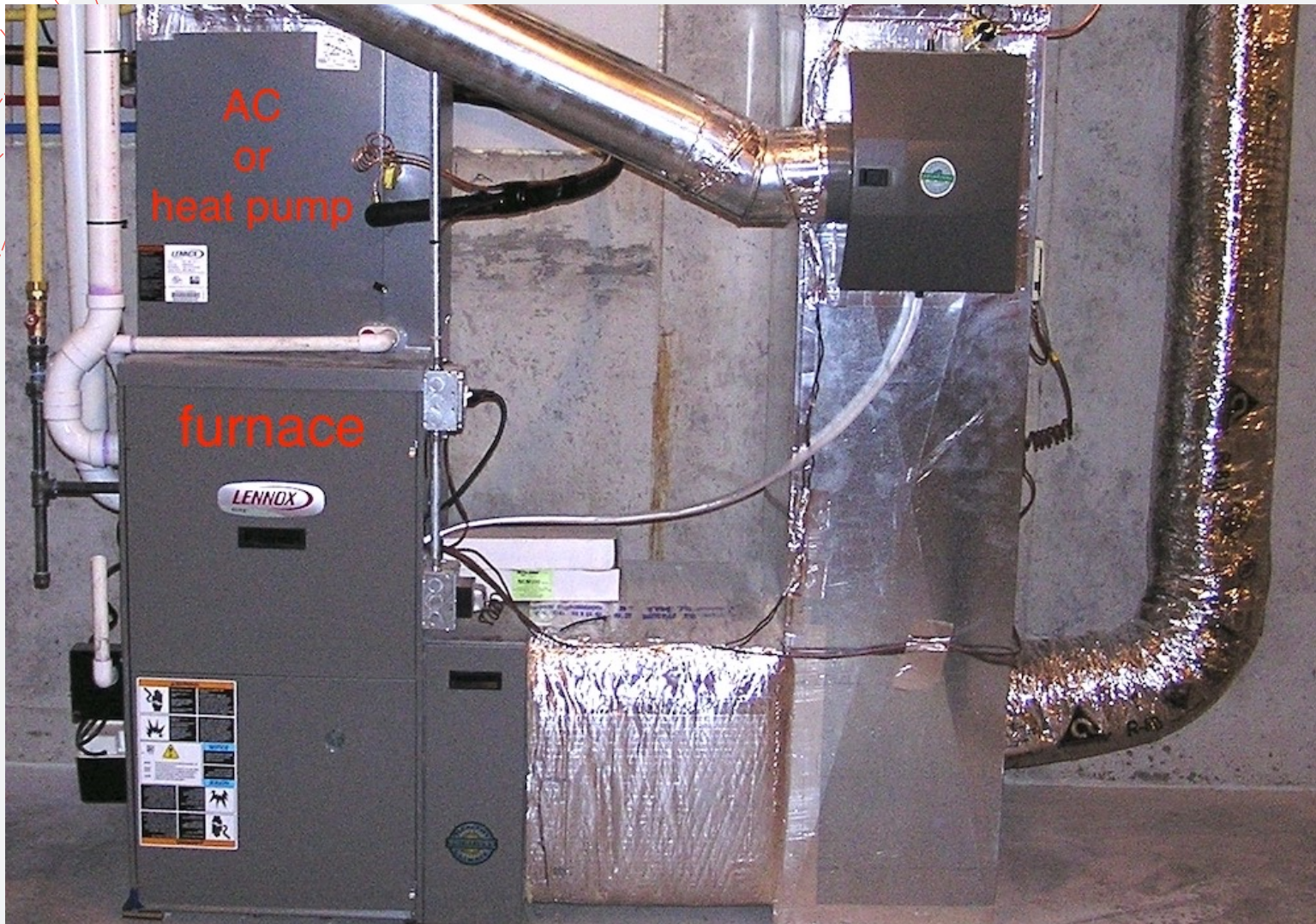


## Fully Ducted

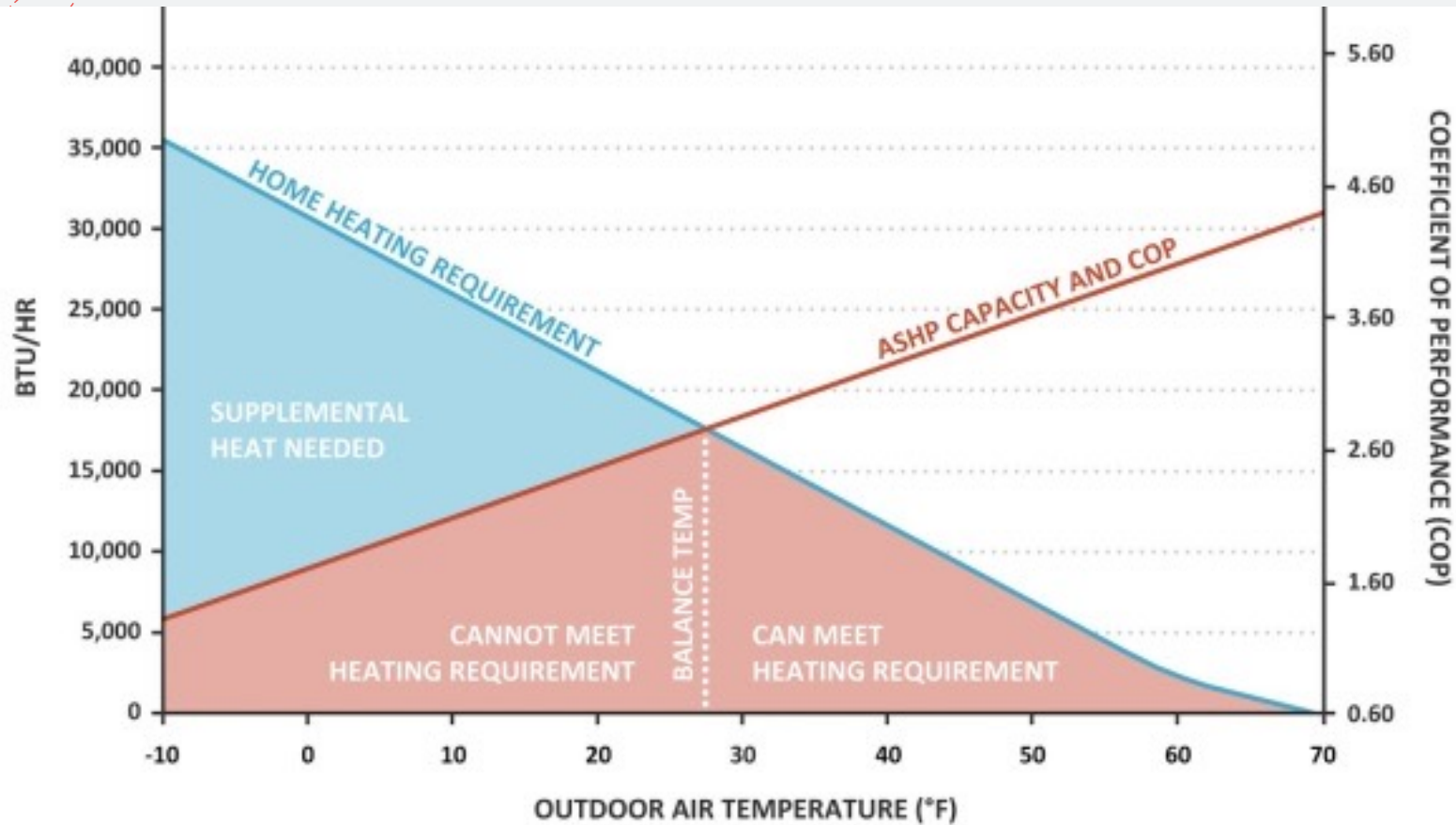
- Central indoor unit with central control

# Fully ducted heat pump

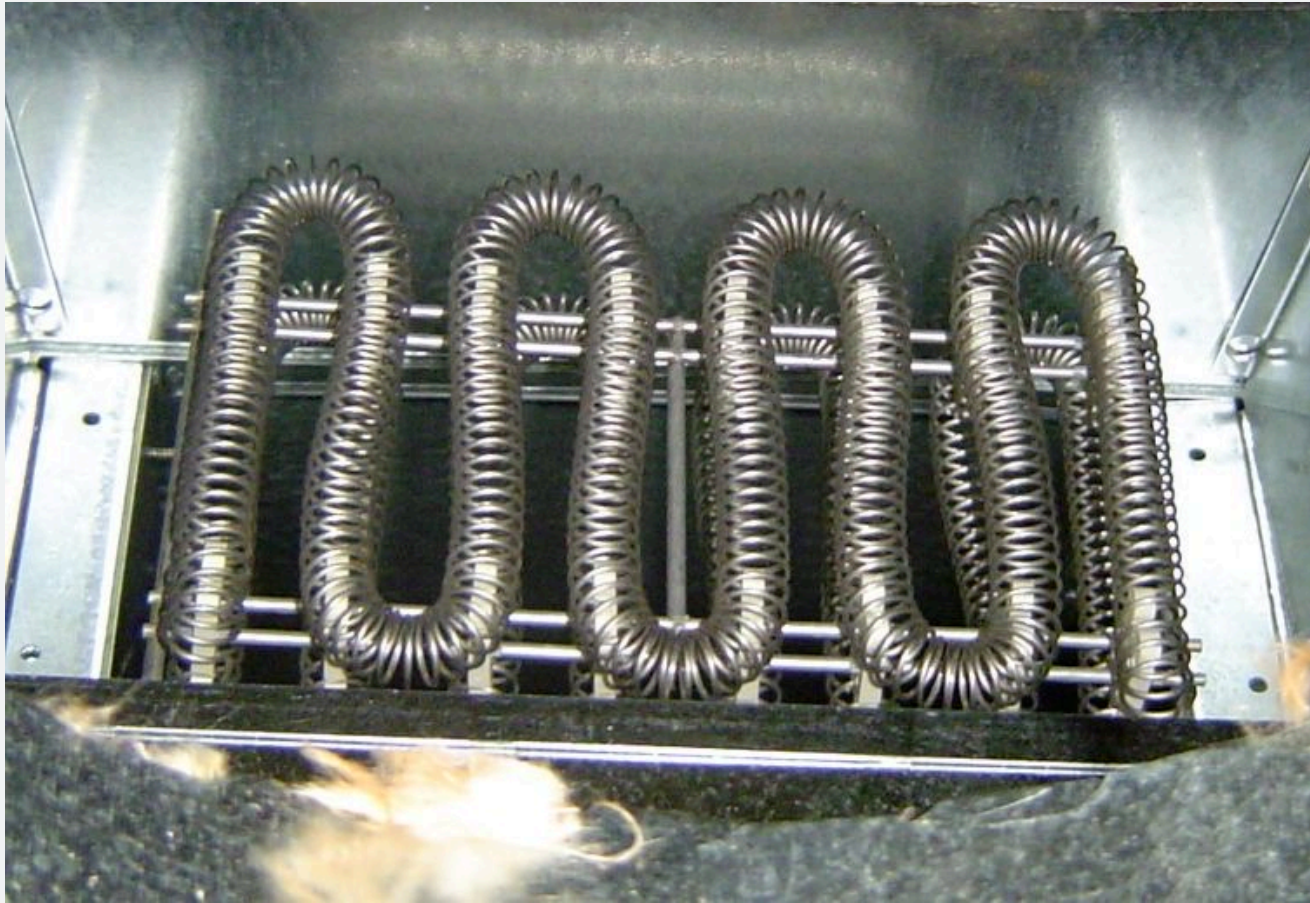




# Dual fuel system with ASHP sized for cooling



**Electric resistance duct heaters. NO!**



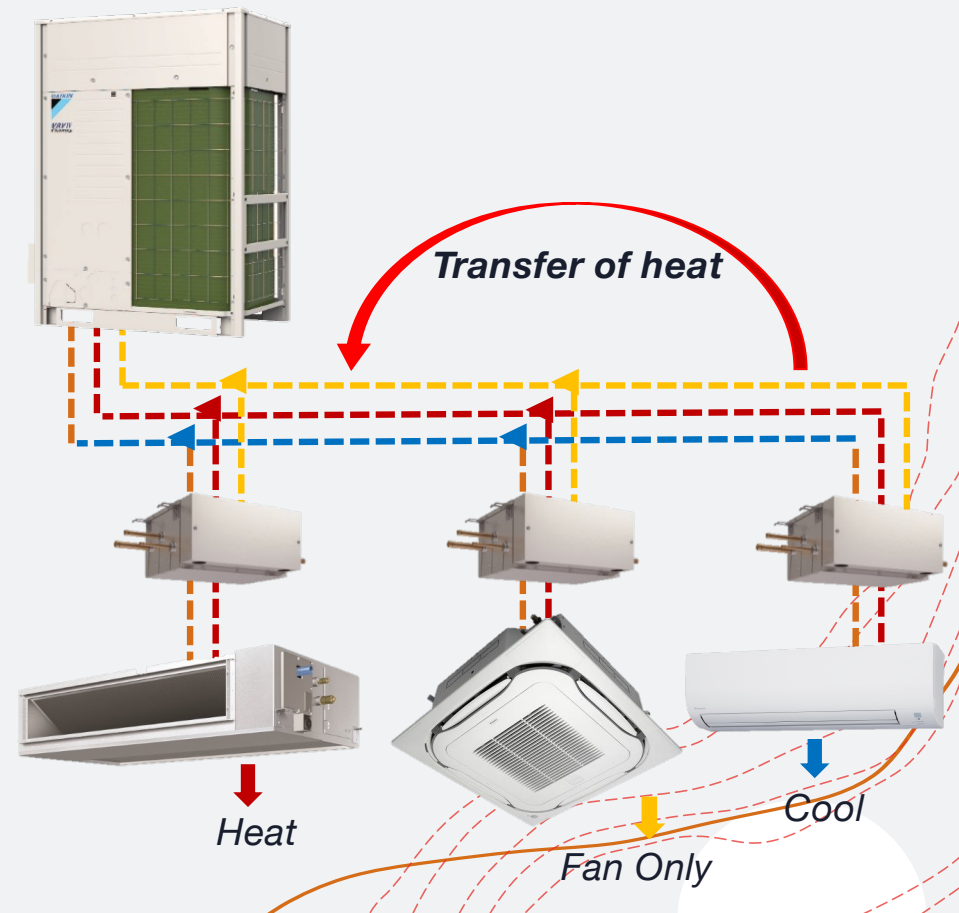
**Short ducted mini-splits can replace central furnace if duct system pressure is too high**



# 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



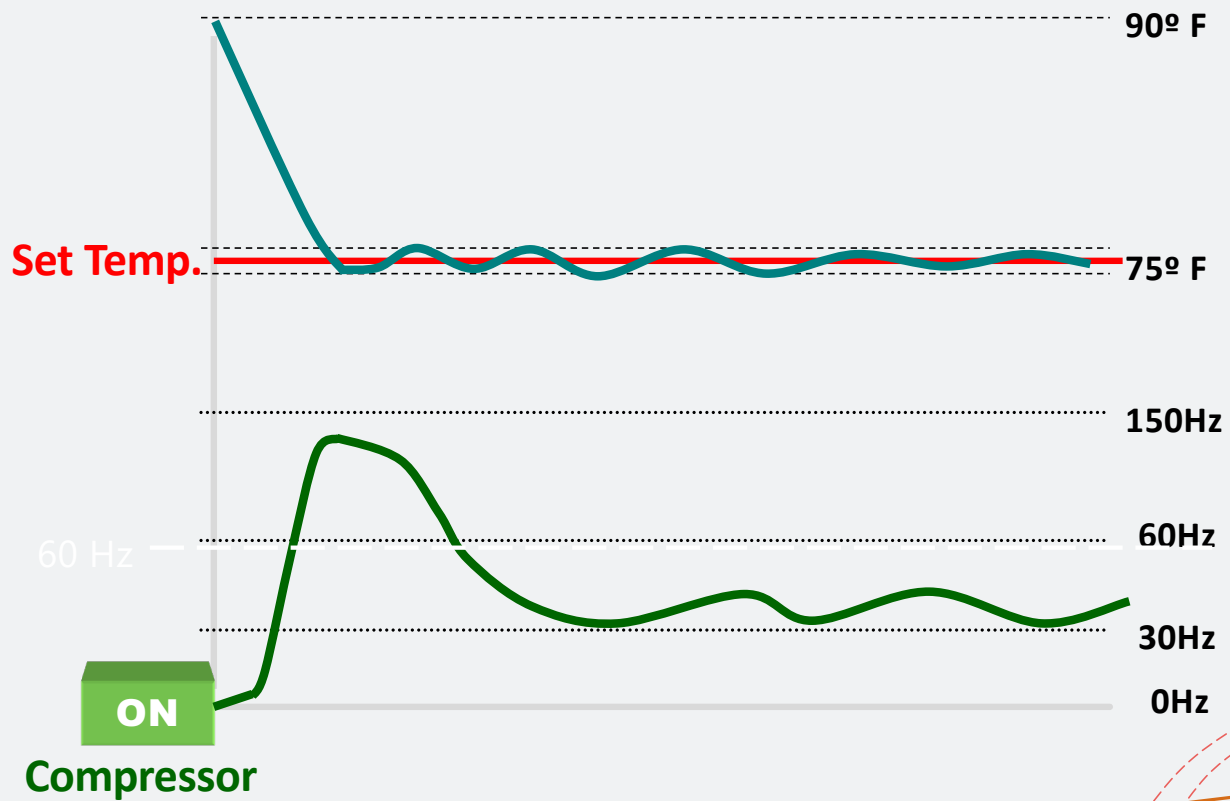
# Requirements to insist on for Air Source Heat Pumps

- + 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

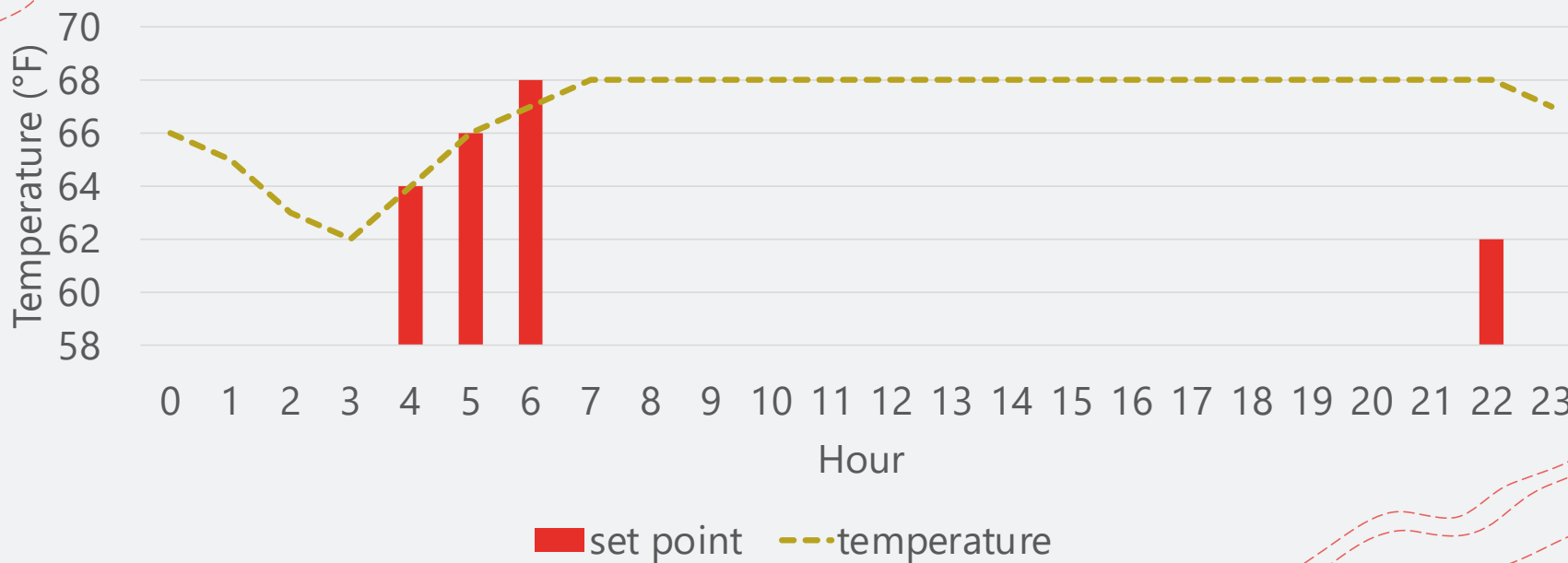
Fuel	Price	kWh	kBtu	EFF	\$/KWH	\$/therm	COP to beat
#2 Oil (gal.)	\$4.00	40.70	139.60	0.83	\$0.12	\$ 3.45	2.32
LPG (gal.)	\$4.00	26.80	91.30	0.92	\$0.16	\$ 4.76	1.70
Electr. (kWh)	\$0.28	1.00	3.41	3.20	\$0.09	\$ 2.52	N/A
Pellet (lb)	\$0.25	2.49	8.50	0.83	\$0.12	\$ 3.54	2.27
Nat Gas (therm)	\$2.38	29.31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

Setbacks using programmable remote



# Using WIFI-connected remote replacement to control mini-splits



SOLUTIONS COMPAT



SVAHS building C



Schedule Name

School year. Heat

ADD NEW SCHEDULE EVENT

DELETE SCHEDULE

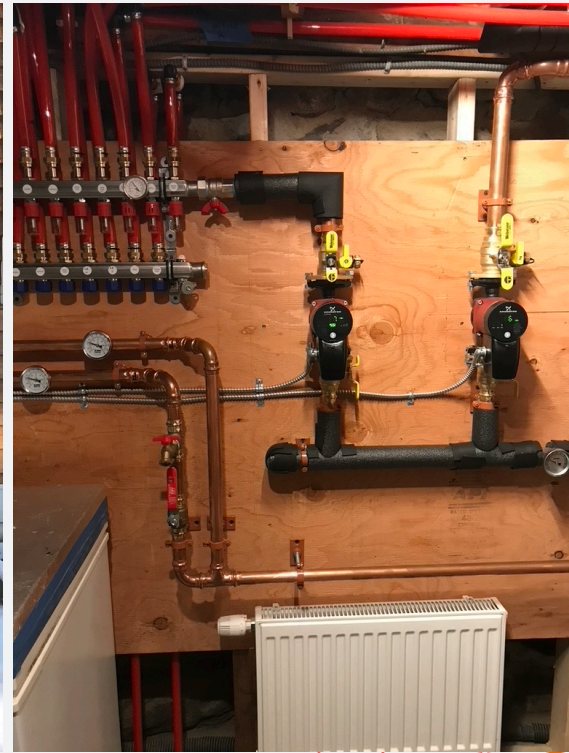
## Faculty lounge

M	60	666670	71	Inactive
Tu	60	666670	71	Inactive
W	60	666670	71	Inactive
Th	60	666670	71	Inactive
F	60	666670	71	Inactive
Sa	Inactive			
Su	Inactive			

## Room c111

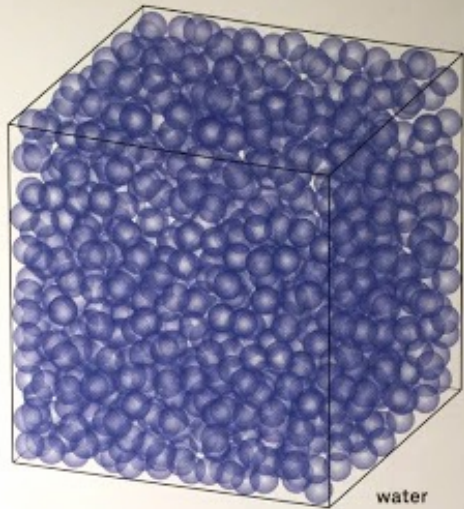
M	60	666670	71	Inactive
Tu	60	666670	71	Inactive
W	60	666670	71	Inactive
Th	60	666670	71	Inactive
F	60	666670	71	Inactive
Sa	Inactive			
Su	Inactive			

# Air to water heat pumps







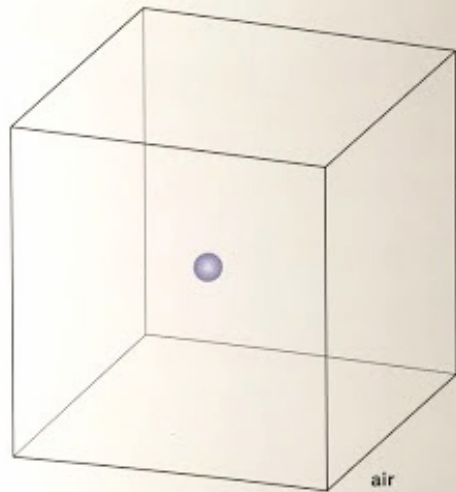


## Volumetric Heat Capacity

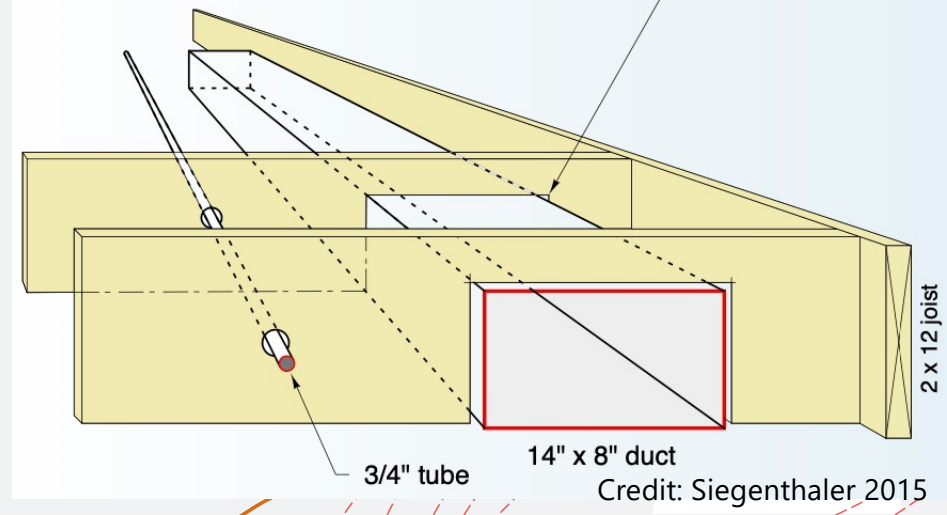
water: 62.4 Btu/ft<sup>3</sup>°F.



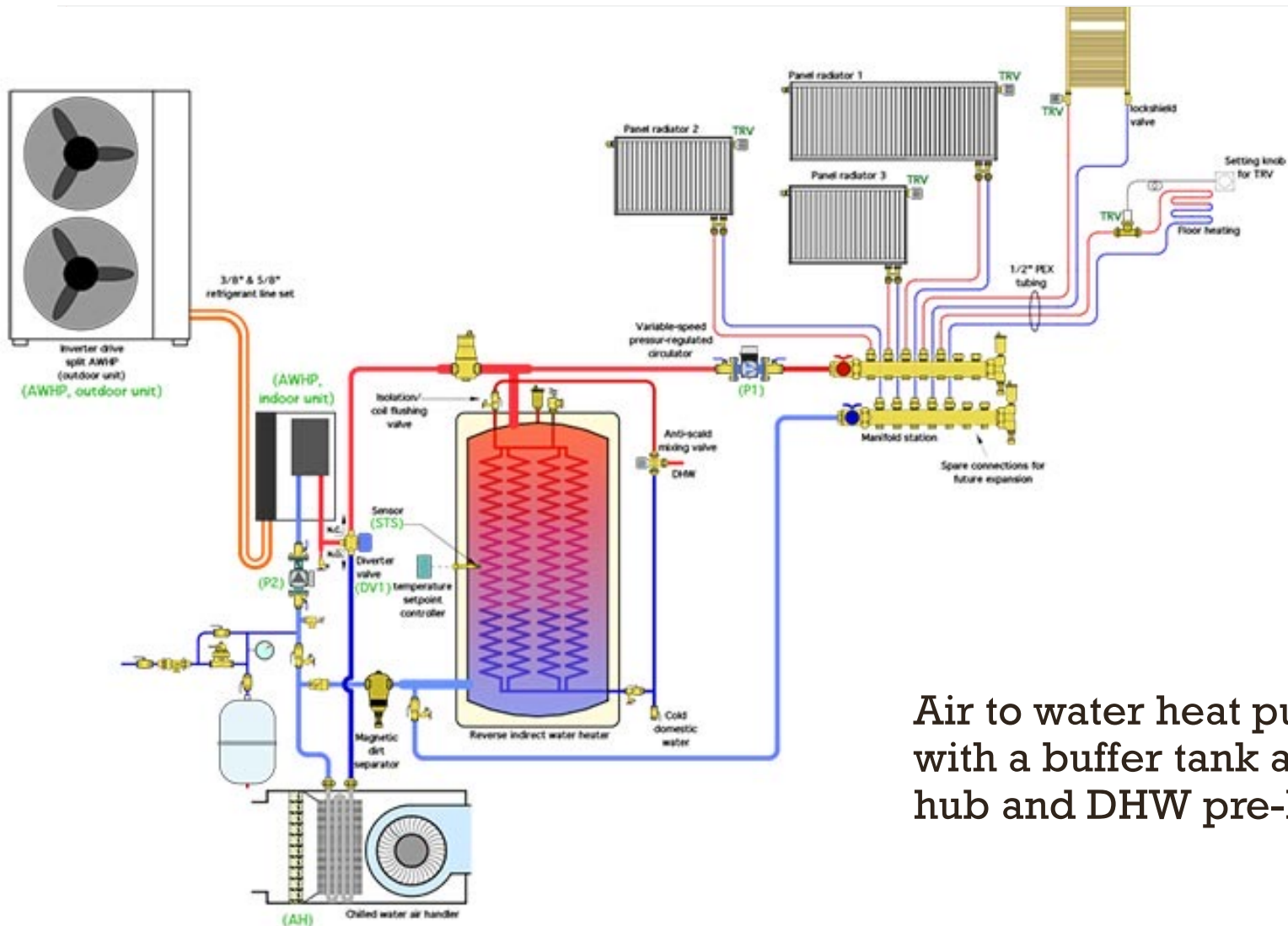
this cut would destroy the load-carrying ability of the floor joists



air: 0.018 Btu/ft<sup>3</sup>°F



Credit: Siegenthaler 2015



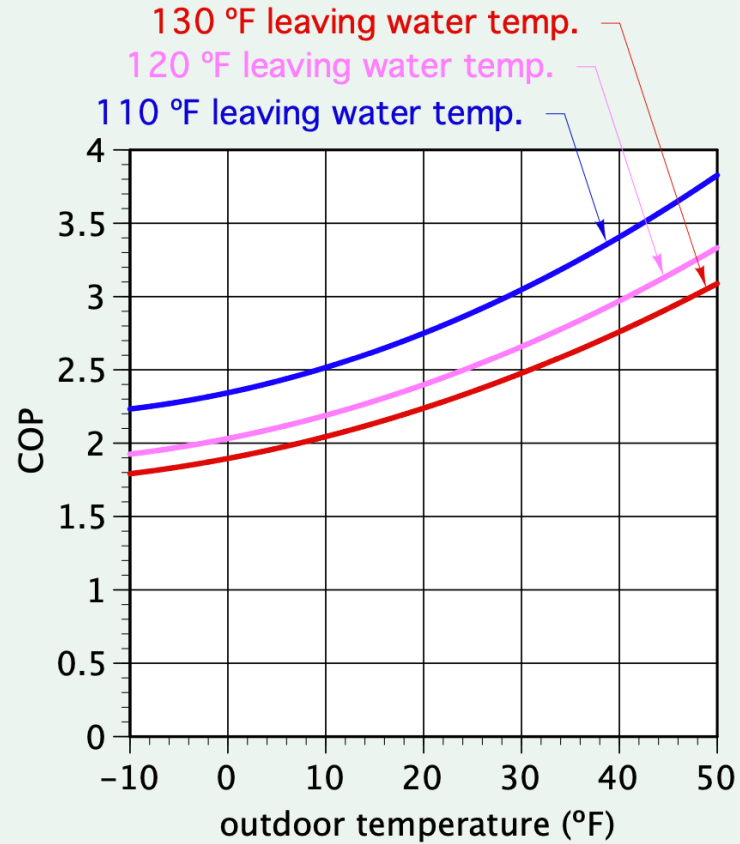
Air to water heat pump with a buffer tank as the hub and DHW pre-heater

Credit: John Siegnthaler 2019

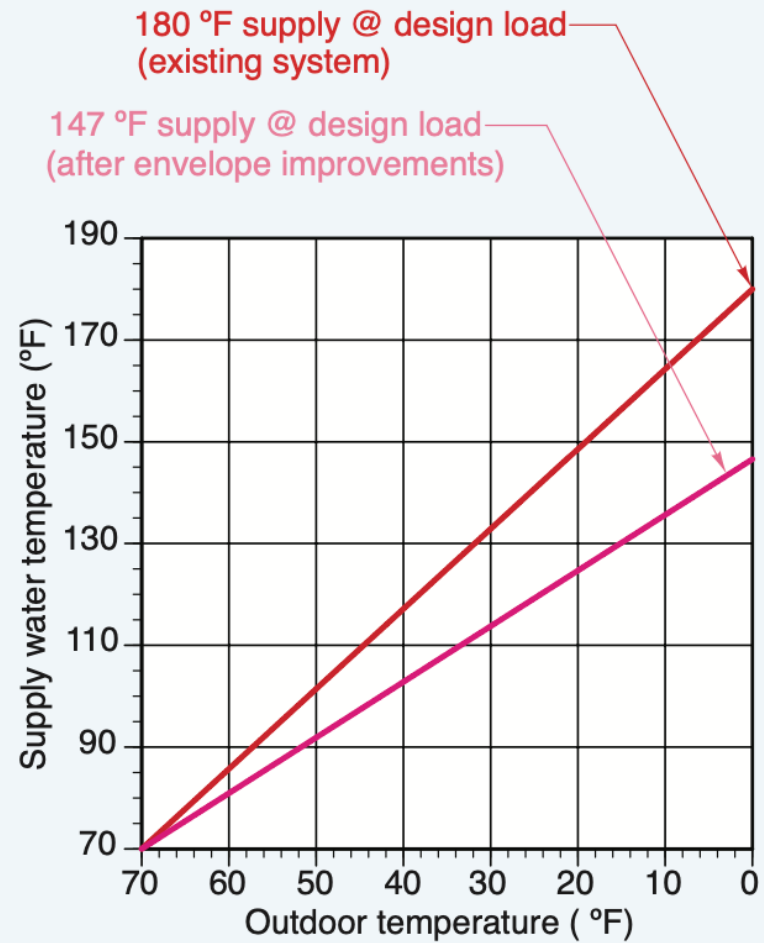
Efficiency declines with decreasing **outdoor** temperatures and increasing **water** temperatures

**Decrease water temperatures!**

Figure 2-9



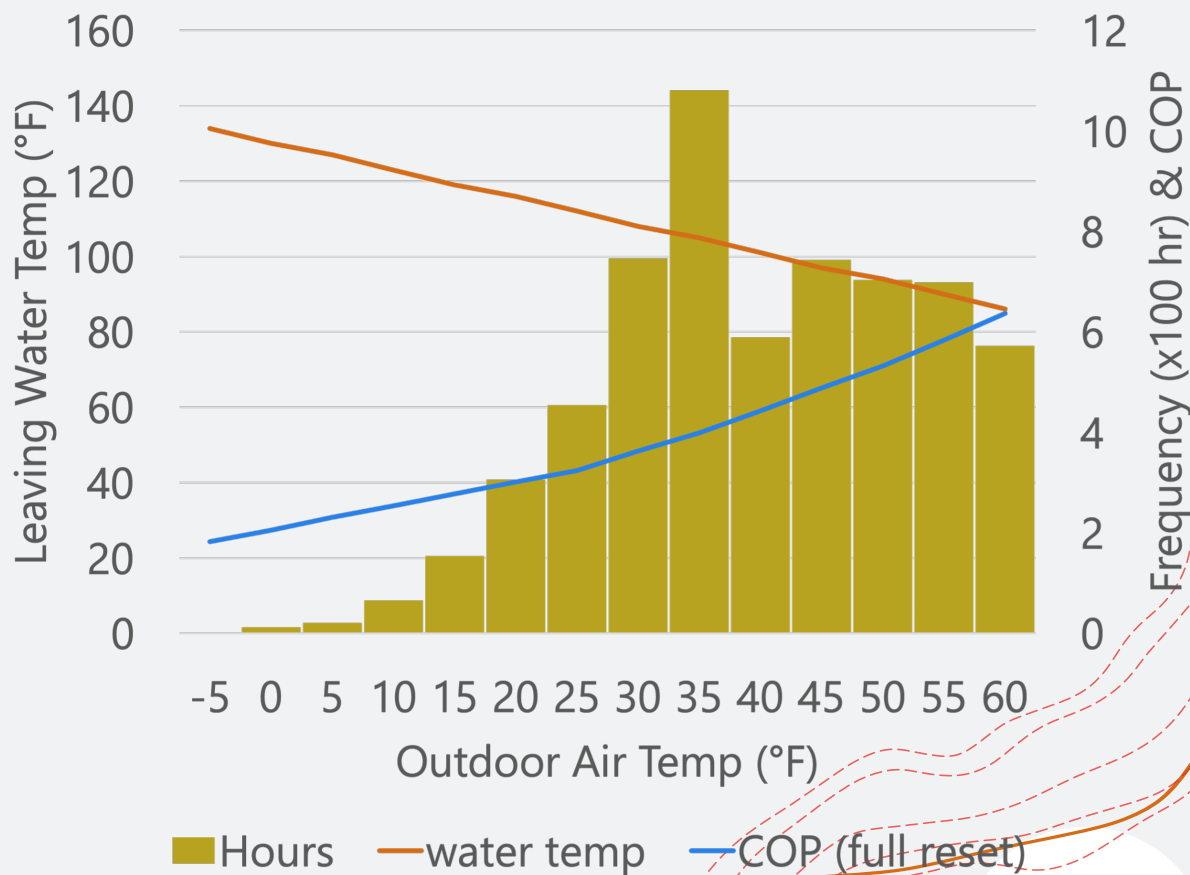
Outdoor temperature reset controls allow low temperatures for most of the time on existing systems



## Heating Season Performance is high even with moderate temperature reduction

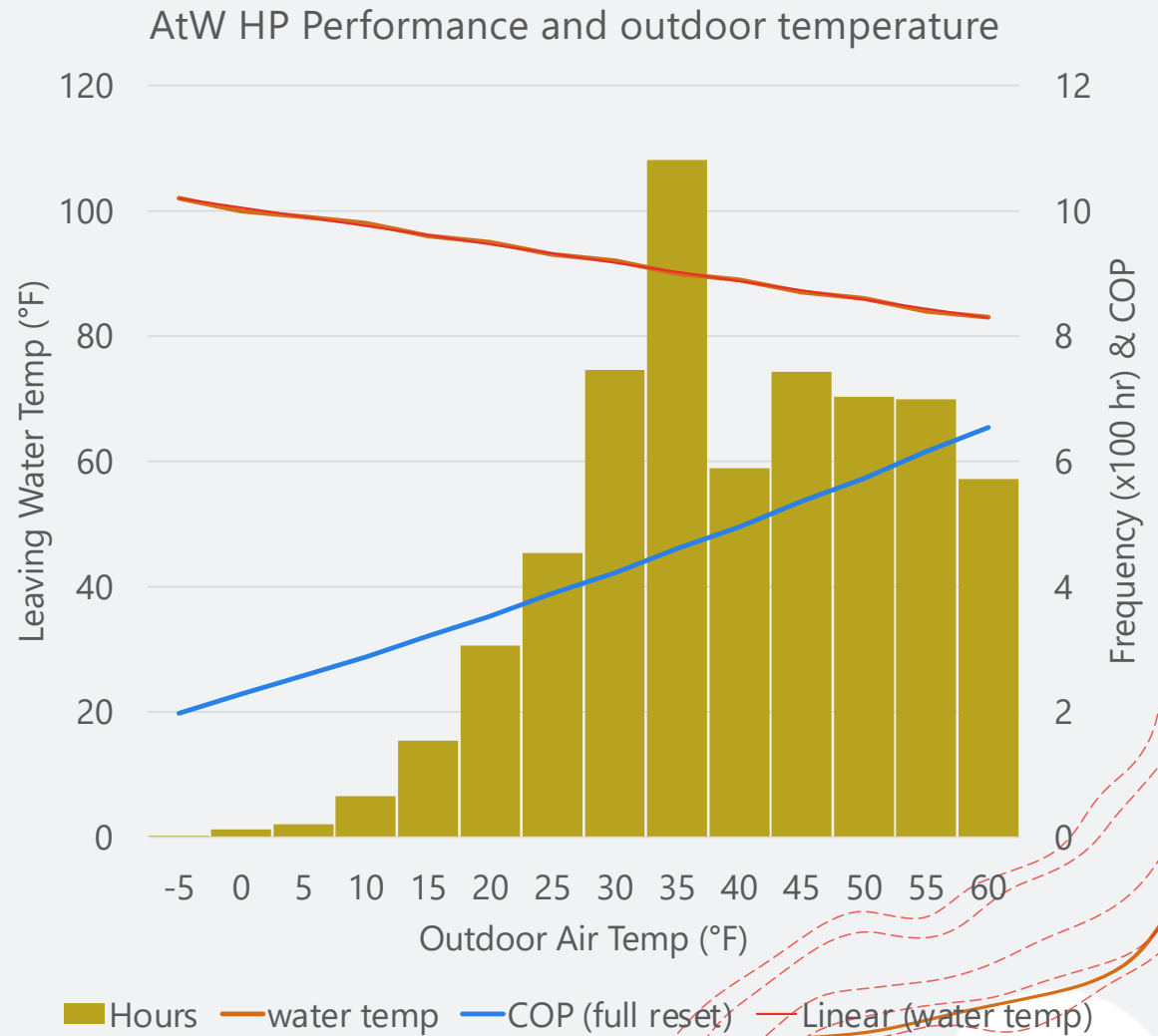
- 130°F design water temp
- 90% of hours COP is above 2.3
- Seasonal COP = 3.8

### AtW HP Performance and outdoor temperature



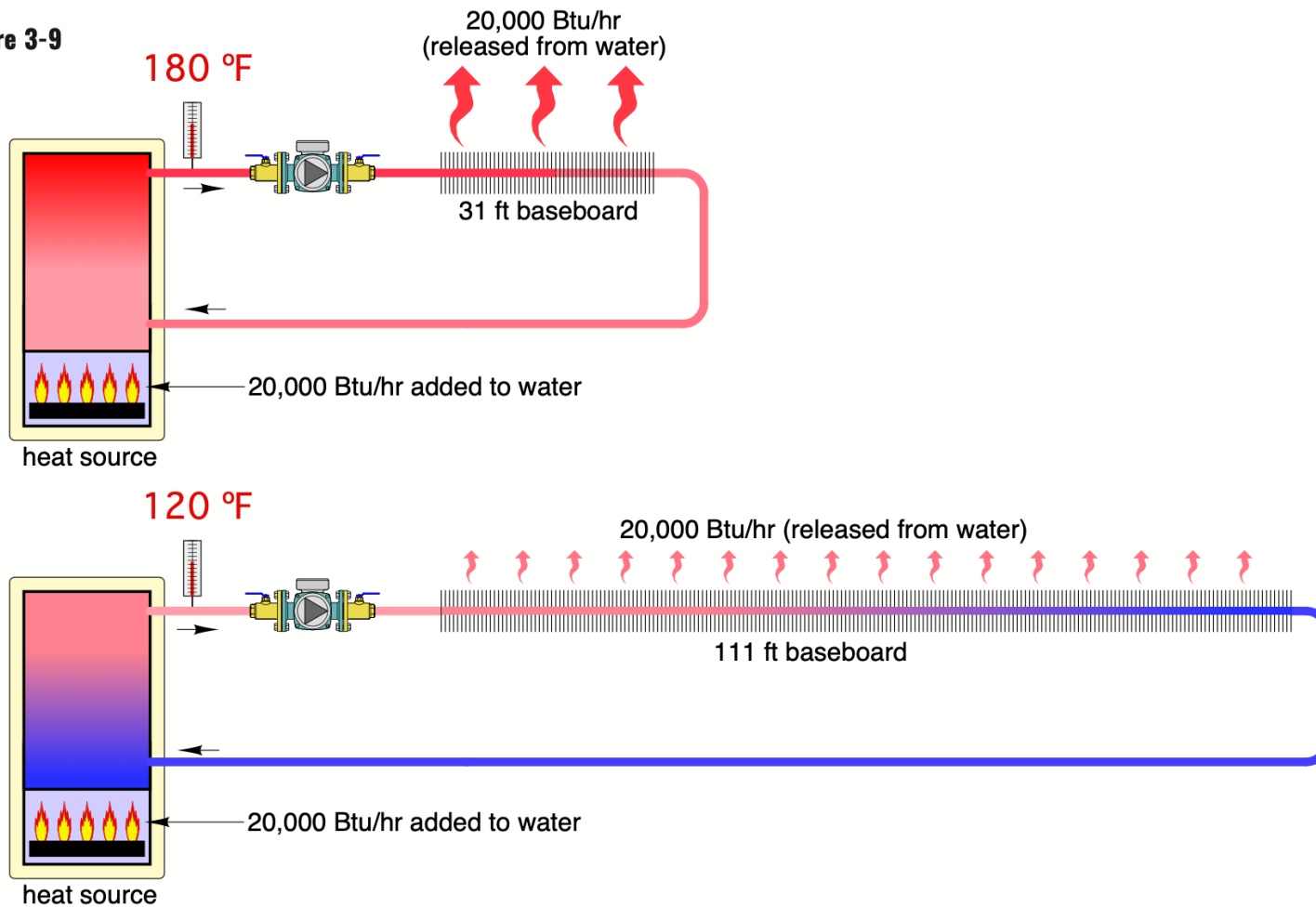
# My system performance

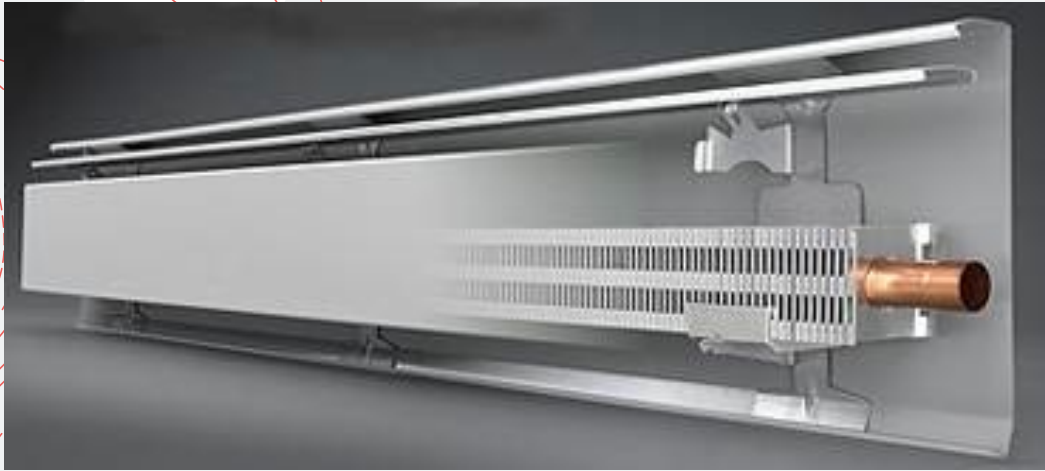
- Design Water Temp = 100°F
- Seasonal COP:
  - 4.3 heating only
  - 3.7 heating and hot water



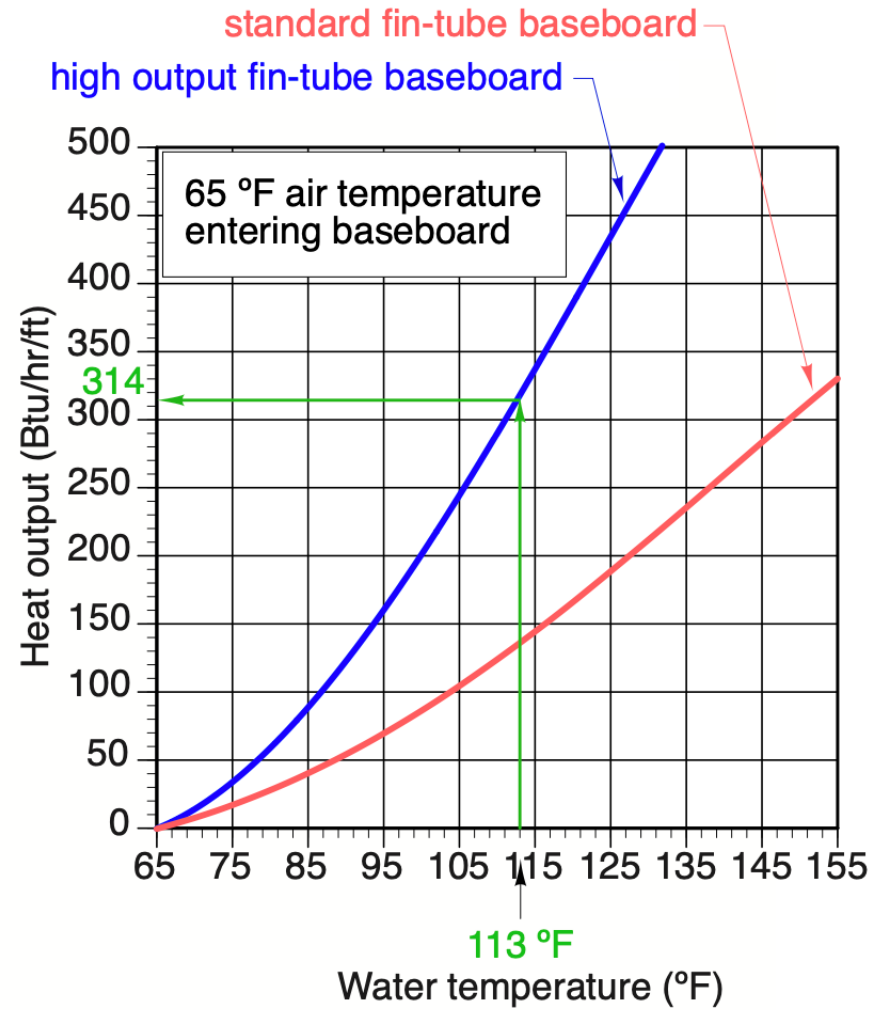
# existing emitters may have too little surface area

Figure 3-9





Swap out old fin-tube for high output



# Other hydronic heat emitters

Ceiling  
Cassettes



concealed  
fan-coils



fan coil  
convectors



Panel  
Radiators

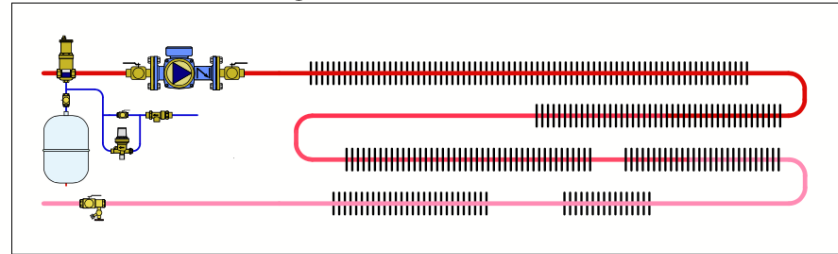


Ducted  
Hydro-air  
units

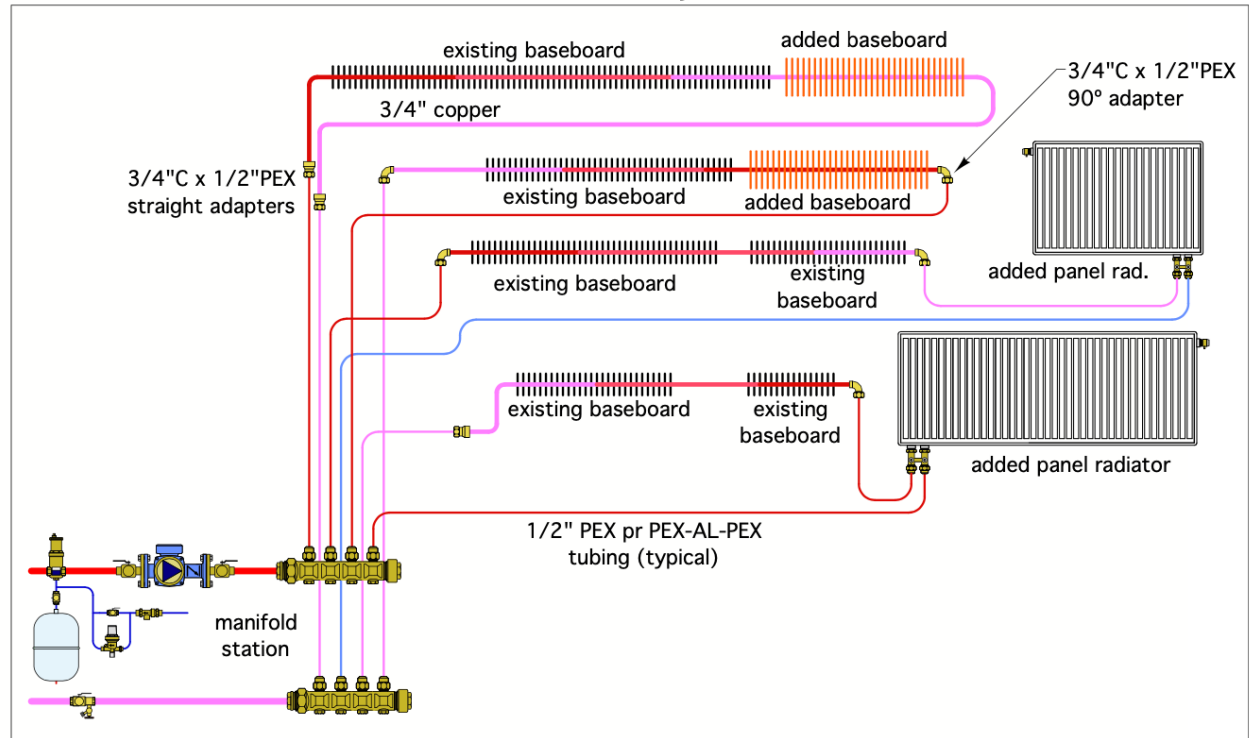


modify  
existing series  
baseboard for  
low temp  
water

Existing series baseboard circuit

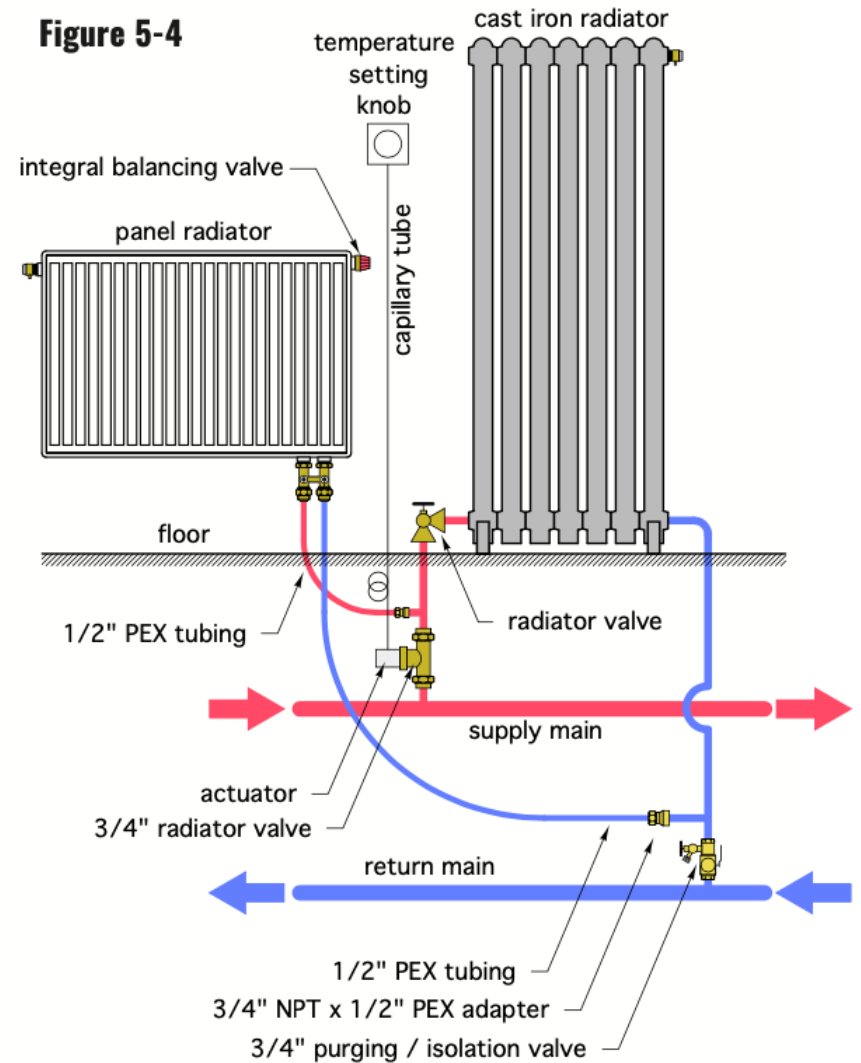


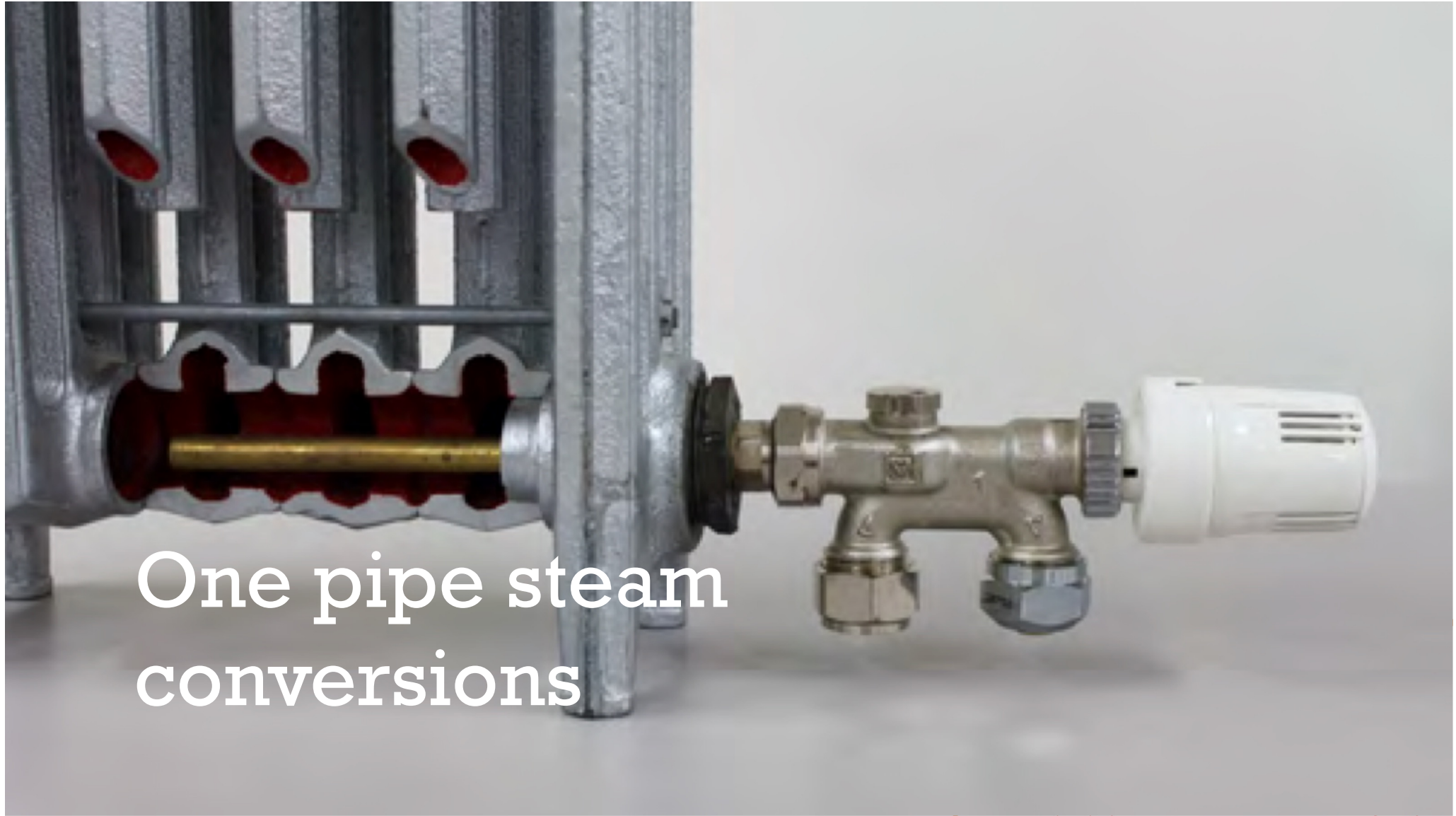
Modified distribution system



# Adding additional radiation to an existing 2-pipe system

**Figure 5-4**

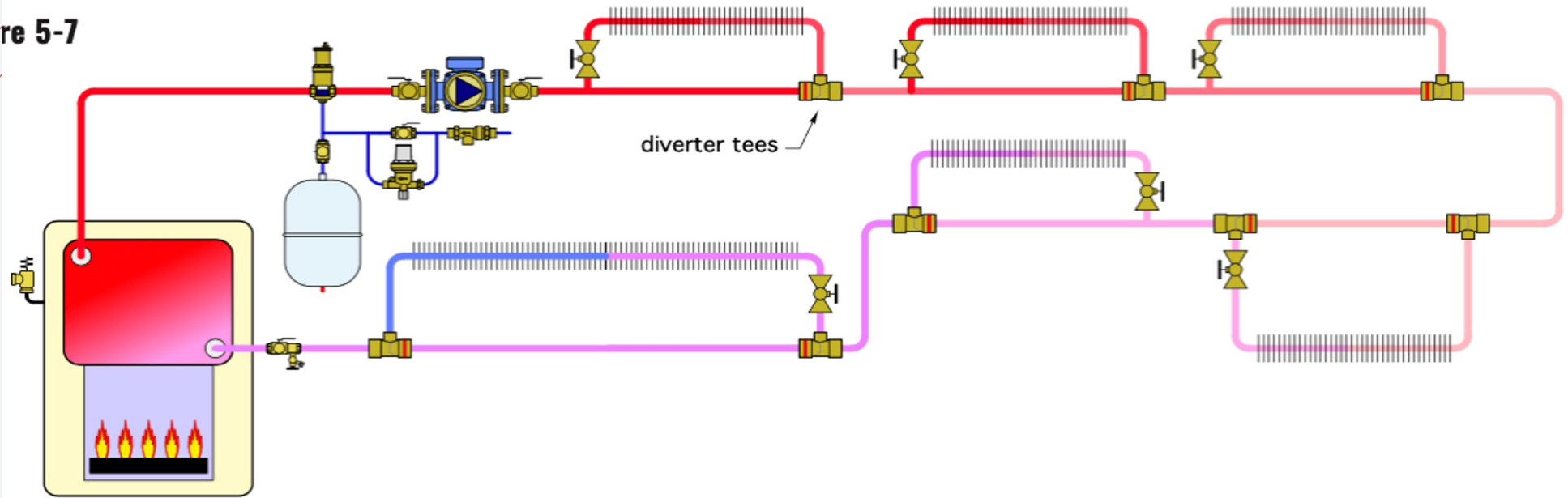


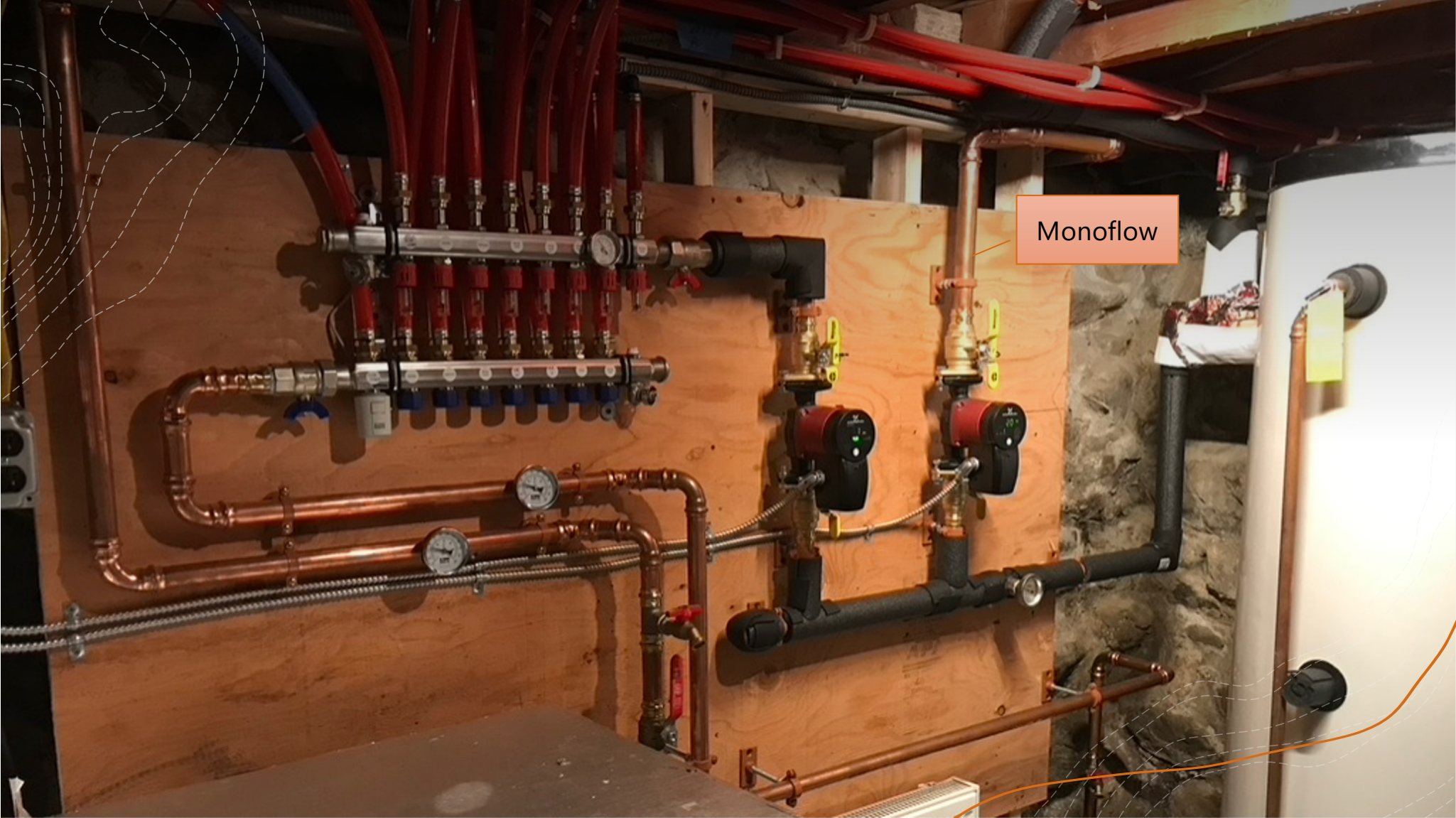


One pipe steam conversions

# Supplementing a mono-flow system

re 5-7





Monoflow