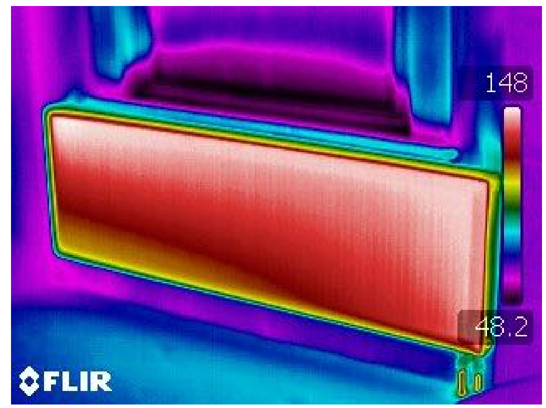
Hydronics for Low-Energy & Net-Zero Homes

Feb 22, 2022
Duluth, MN



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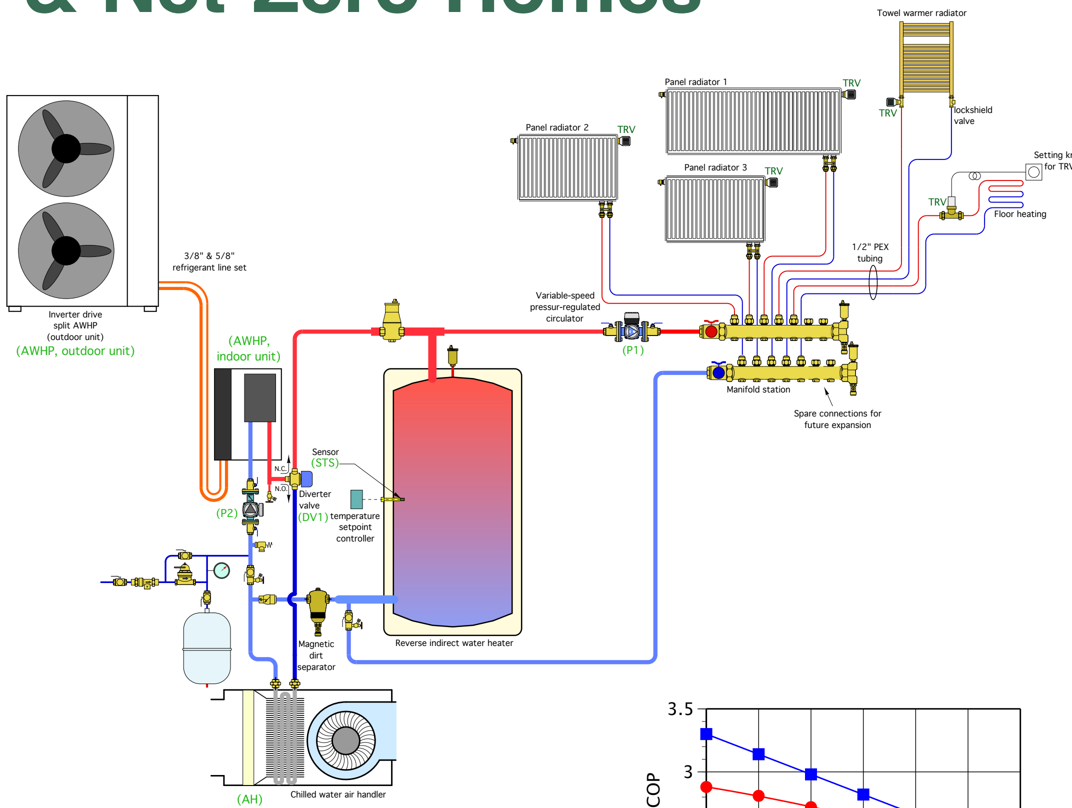
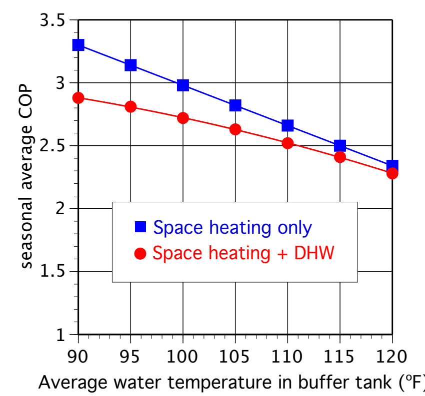
Hydronics for Low-Energy & Net-Zero Homes

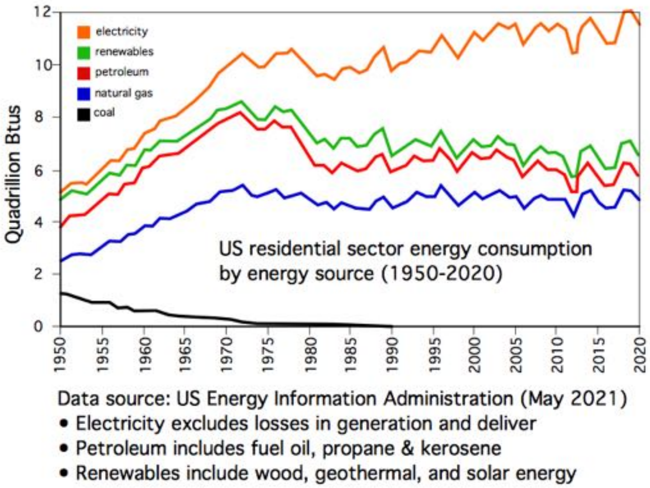
Topics we'll cover…

- Electrification is coming - *and FAST!*
- Poor perceptions of hydronic systems
- What's changing with residential construction?
- Comfort vs. thermodynamics?
- Why hydronics?
- What's an air-to-water heat pump?
- Retrofitting an AWHP to an existing system
- Example systems





Electrification is happening - everywhere…



During 2020, utility-scale solar photovoltaic systems and utility-scale wind turbine systems accounted for more than 75 percent of all new electrical generation in the U.S.

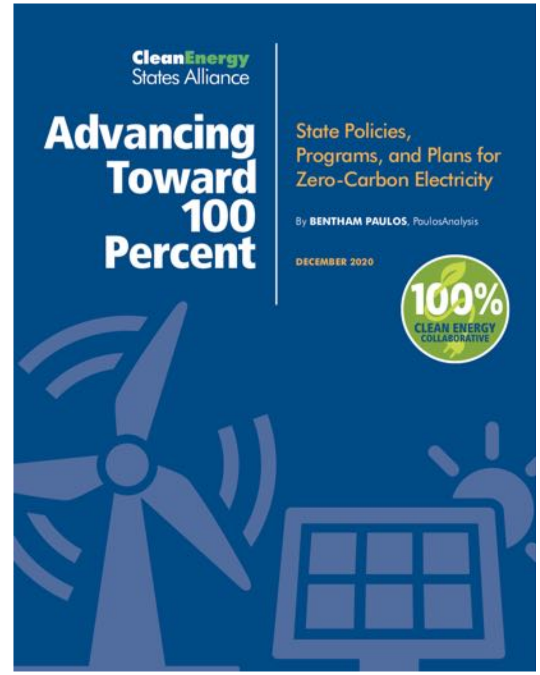
This trend represents a huge opportunity for the North American hydronics industry.

Electrification in North America

States with 100 Percent Clean Energy Goals

State	The Goal	Comments
Arizona	100% carbon-free electricity by 2050	Adopted by order of the Arizona Commerce Commission in November 2020, extending and expanding the existing state RPS. Docket number RU-00000A-18-0284.
California	100% carbon-free electricity by 2045	2018 legislation (SB 100) extended and expanded the existing state RPS. State agencies are required to submit implementation plans by January 1, 2021. Also in 2018, Gov. Jerry Brown's Executive Order B-55-18 set a goal of statewide carbon neutrality by no later than 2045, with net negative GHG emissions thereafter.
Colorado	100% carbon-free electricity by 2050 for Xcel Energy	A 2019 law (SB 19-236) codified a pledge previously made by Xcel, whose service territory covers approximately 60% of the state's load. It is mandatory "so long as it is technically and economically feasible."
Connecticut	100% carbon-free electricity by 2040	Governor Ned Lamont's 2019 Executive Order (Number 3) set a 2040 goal for carbon-free electricity and asked the Department of Energy and Environmental Protection to develop a decarbonization plan for the power sector, in line with previous legislation to cut economy-wide carbon emissions by 80% below 2001 levels by 2050.
District of Columbia	100% renewable electricity by 2032 through the RPS	The *Clean Energy DC Omnibus Amendment Act of 2018* (DC Act 22-583) amended the existing RPS to mandate 100% renewable electricity by the year 2032.
Hawaii	100% renewable energy by 2045 through the RPS	2015 legislation (HB623) made Hawaii the first state to set a 100% RPS for the electricity sector.
Louisiana	Net zero greenhouse gas emissions by 2050	Governor John Bel Edwards' 2020 Executive Order (JBE 2020-18) established a Climate Initiatives Task Force to develop a roadmap and make recommendations.
Maine	100% clean energy by 2050	2019 legislation (LD 1494) increased Maine's RPS to 80% by 2030, and set a goal of 100% by 2050. Also LD1679 sets an economy-wide goal of 80% cuts to greenhouse gases by 2050.
Massachusetts	Net-zero greenhouse gas emissions by 2050	In April 2020, the Executive Office of Energy and Environmental Affairs set a 2050 net-zero goal under the authority of 2008 legislation, and is developing a roadmap by the end of 2020.
Michigan	Economy-wide carbon neutrality by 2050	Governor Gretchen Whitmer's order in 2020 (Executive Directive 2020-10) set a goal "to achieve economy-wide carbon neutrality no later than 2050." It directed the Department of Environment, Great Lakes, and Energy to develop a plan by the end of 2021.
Nevada	100% carbon-free electricity by 2050	2019 legislation (SB 358) raised the RPS to 50% by 2030, and set a goal of a net-zero emission power sector by 2050.
New Jersey	100% carbon-free electricity by 2050	Governor Phil Murphy's Executive Order 28 in 2018 set a carbon free goal for the power sector and directed the BPU to develop an Energy Master Plan, which was released in 2020.
New Mexico	100% carbon-free electricity by 2045	2019 legislation (SB 489) requires a zero-carbon power supply by 2050, with at least 80% from renewables.
New York	100% zero-emission electricity by 2040	2019 legislation (S6599) requires zero-emissions electricity by 2040 and sets a goal of cutting all state GHGs 85% by 2050. A Climate Action Council will develop a plan.
Puerto Rico	100% renewable energy for electricity by 2050	2019 legislation (SB1121), the Public Energy Policy Law of Puerto Rico, set a timeline for reaching 100% renewable electricity by the year 2050.
Rhode Island	100% renewable energy electricity by 2030	Governor Gina Raimondo's 2020 Executive Order (20-01) requires the Office of Energy Resources to "conduct economic and energy market analysis and develop viable policy and programmatic pathways" to meet 100% of statewide electricity deliveries with renewables by 2030.
Virginia	100% carbon-free electricity by 2045 for Dominion Energy and 2050 for Appalachian Power Company	The 2020 *Virginia Clean Economy Act* (House Bill 1526 and Senate Bill 851) requires zero-carbon utilities by 2050 at the latest.
Washington	100% zero-emissions electricity by 2045	2019's *Clean Energy Transformation Act* (SB5116) applies to all utilities. The state Commerce Department started a rulemaking process in August 2019. Utilities must file implementation plans by January 2022.
Wisconsin	100% carbon-free electricity by 2050	Governor Tony Evers' Executive Order (EO38) in 2019 directed a new Office of Sustainability and Clean Energy to "achieve a goal" of all carbon-free power by 2050.

The "operative" word in these energy targets is ELECTRICITY…



https://www.cesa.org/wp-content/uploads/Advancing-Toward-100.pdf

Moritoriums on fossil fuels - happening rapidly

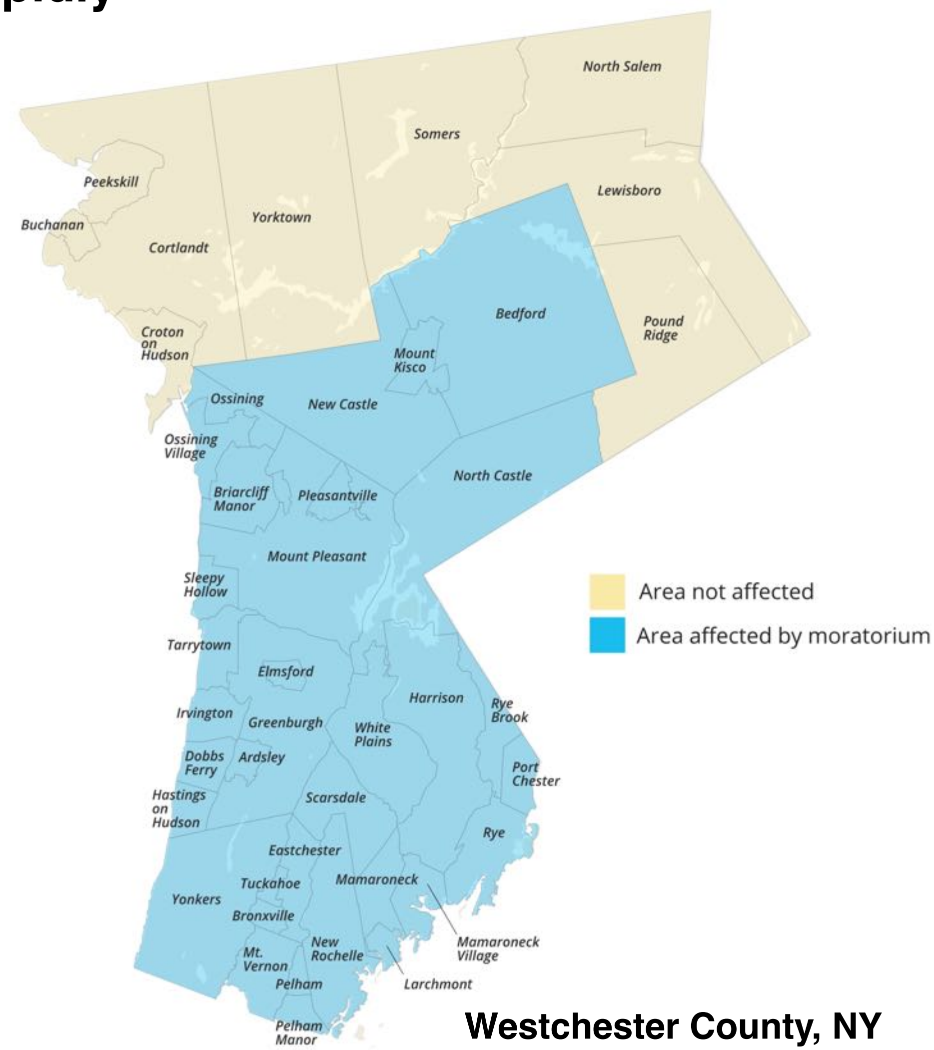
WESTCHESTER COUNTY, NY: National Grid has said it will not approve requests for new or upgraded gas service in its territory in New York City and Long Island until the state approves a $1 billion natural gas pipeline, arguing there will be a lack of adequate gas supply until it's built.

HOLYOKE MA,— Holyoke Gas and Electric (HG&E) has imposed a moratorium on new natural gas connections for residential and business customers, citing no increases in pipeline capacity by Berkshire Gas and Columbia Gas of Massachusetts.

SEATTLE, WA -- As of Jan 1, 2022 multi-family building of 4 stories of less will no longer be permitted to use natural gas for heating or hot water. Gas fireplaces, cooking appliances will still be permitted

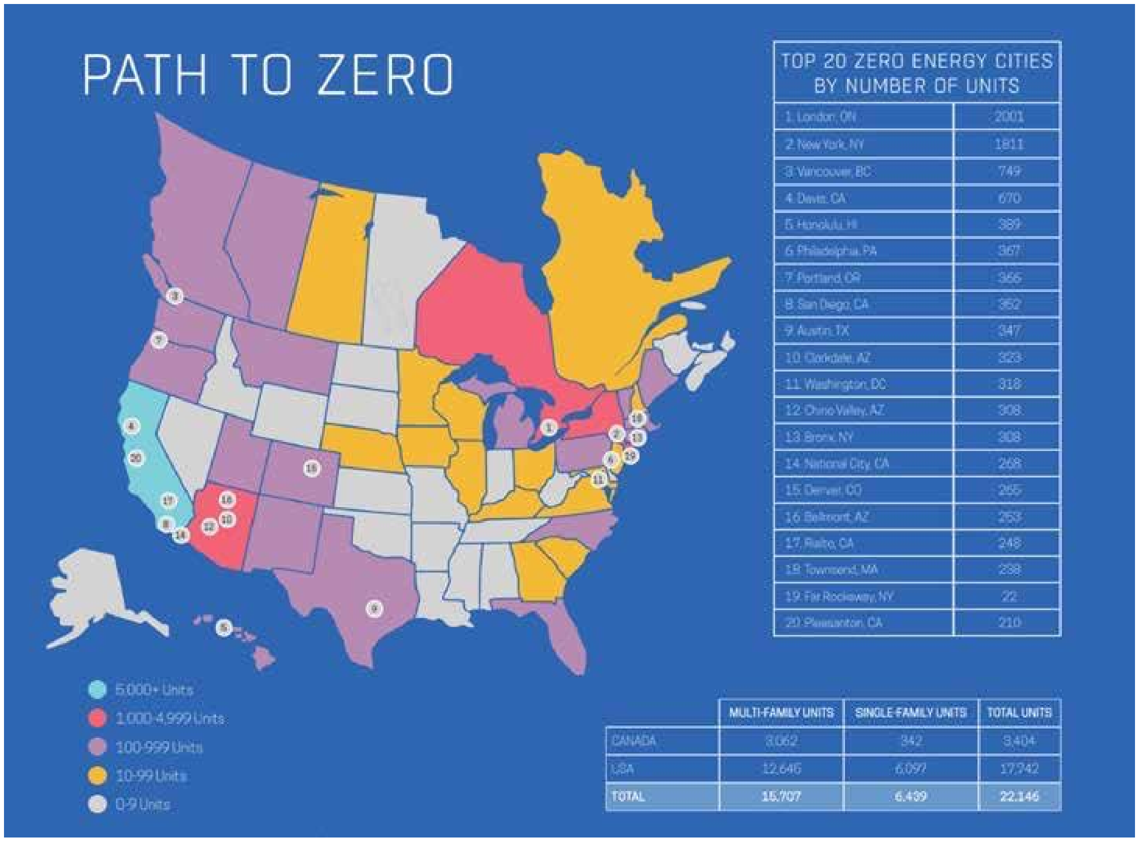
Other locations where natural gas is being restricted (or banned in some instances)

BROOKLINE, MA
SAN FRANSISCO
NEW YORK CITY
SACRAMENTO
OAKLAND
VANCOUVER



Westchester County, NY

Net-zero buildings are one of the fastest growing sectors of the construction market



TOP 20 ZERO ENERGY CITIES BY NUMBER OF UNITS	
1. London, ON	2001
2. New York, NY	1811
3. Vancouver, BC	749
4. Davis, CA	670
5. Honolulu, HI	389
6. Philadelphia, PA	367
7. Portland, OR	366
8. San Diego, CA	362
9. Austin, TX	347
10. Clarkdale, AZ	323
11. Washington, DC	318
12. Chino Valley, AZ	308
13. Bronx, NY	308
14. National City, CA	268
15. Denver, CO	265
16. Bellmont, AZ	253
17. Rialto, CA	248
18. Townsend, MA	238
19. Far Rockaway, NY	22
20. Pleasanton, CA	210

	MULTI-FAMILY UNITS	SINGLE-FAMILY UNITS	TOTAL UNITS
CANADA	3,062	342	3,404
USA	12,646	6,097	17,742
TOTAL	15,707	6,439	22,146

The Global Zero Net Energy Building (NZEB) Market is expected to grow at a significant CAGR of 15% by 2028.

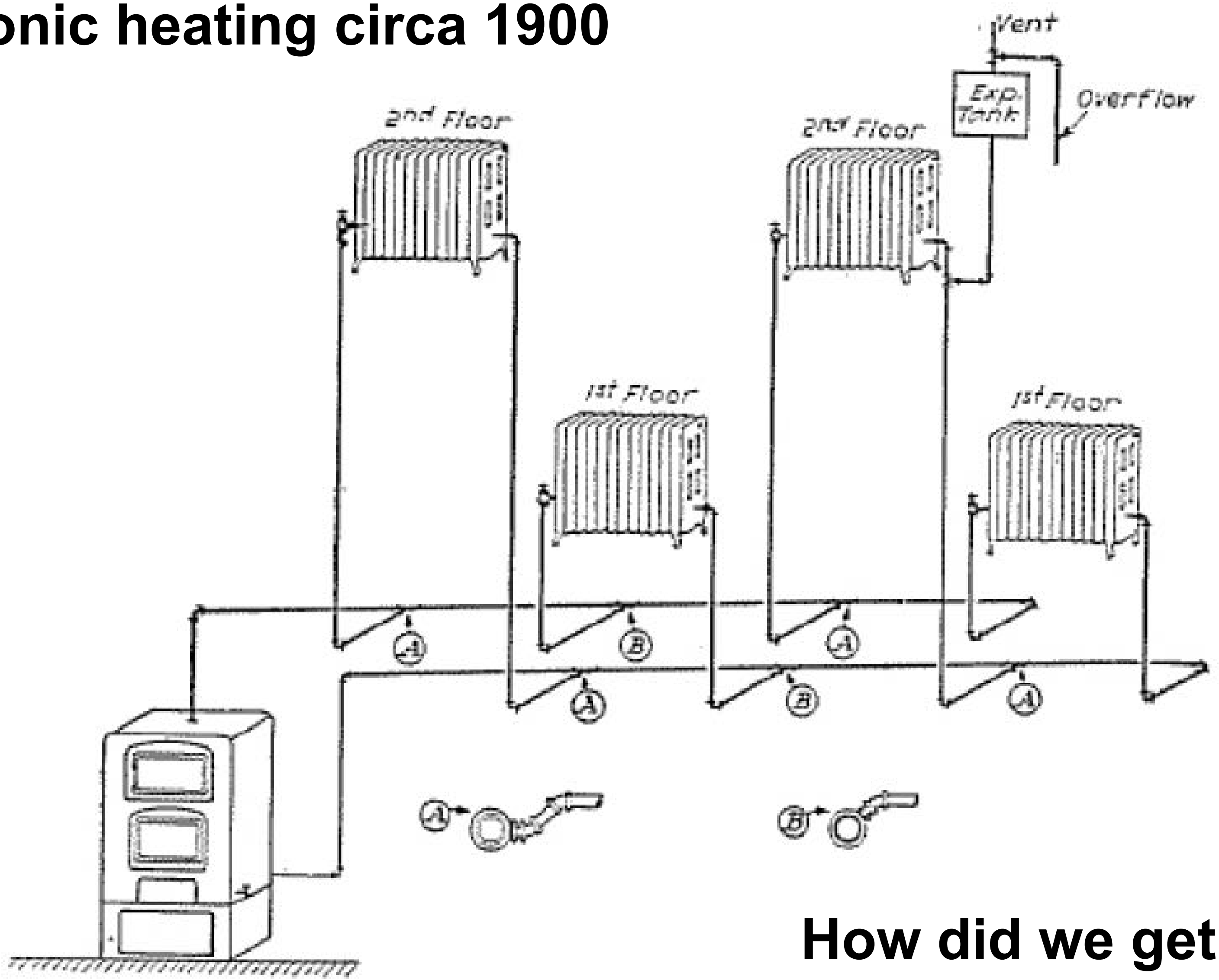
ZERO
ENERGY READY HOME
U.S. DEPARTMENT OF ENERGY

The zero net energy (ZNE) homes market is just beginning to emerge, according to a recent report from Navigant Research called ZNE, Near-ZNE, and ZNE-Ready Homes: Market Drivers, Case Studies, and Forecast Data. Growth is expected to reach 27,000 total units by 2025.

The Net-Zero Energy Coalition estimates the U.S. has only 5,000 net-zero energy single-family homes and over 7,000 net-zero multi-family homes. That number could expand in 2020 to over 100,000 net-zero energy homes, based on the average annual new home constructions in California.

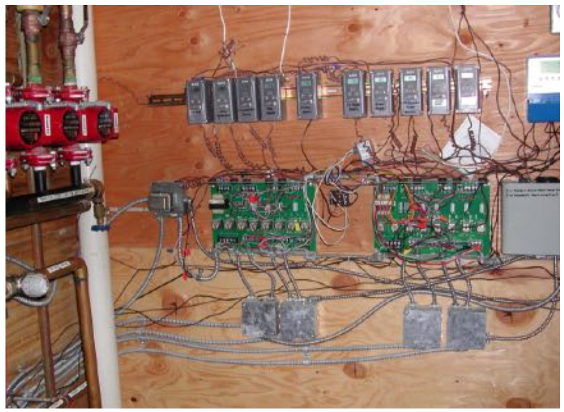
Poor perception of hydronic systems in low-energy residential applications

Hydronic heating circa 1900



How did we get from this...

To this??



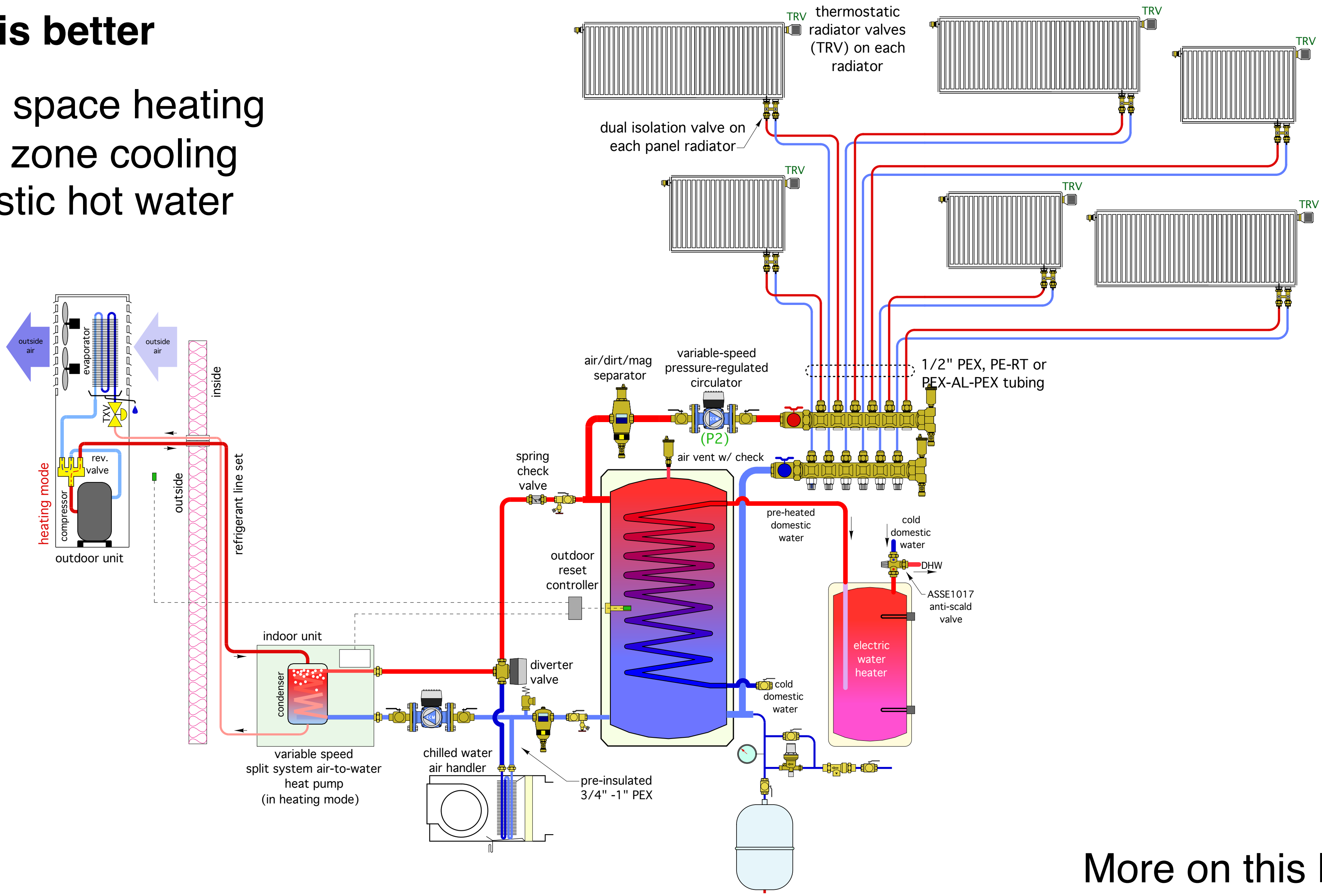
To this??

Is this what it takes to operate a hydronic heating system???

This is not the future of hydronics!

Simple is better

- Zoned space heating
- Single zone cooling
- Domestic hot water



More on this later…

Adapting hydronics technology to evolving building requirements

Factors affecting residential building

- Energy codes (and energy prices) are forcing lower design heating loads

(Pre-1990 houses design load where typically 25-40 Btu/hr/ft^{2})
(Modern low energy houses have typical design loads of 10-15 Btu/hr/ft^{2})

- Strong interest in “net zero” homes - all electric w/ solar PV electric systems

(Strong incentive for use of heat pumps)

- Strong consumer interest in sustainability, resiliency, and recyclable materials

(Well constructed hydronic systems can last for decades. Steel is highly recyclable)

- More consumers want **cooling** in their home

(This has been a “missing piece of the hydronics puzzle” for decades - but it’s changing…)

- Large surface area radiant panels operate at low surface temperatures (71-75°F) in low-energy homes.

(Heated floors don’t get as warm as they used to - they don’t need to...)

- Internal heat gains can have more significant impact on internal temperature

(Room-by-room zoning is important to control overheating)

- Increasing interest in good interior environmental quality

(Limiting spread of interior odors, dust, microbes)

- Discriminating interest in achieving superior comfort

(Significant % of homeowners dissatisfied with the comfort of their current HVAC system)

It's about *COMFORT*…

Not **just** matching BTU delivery to load…

Why is the "net zero" housing market seemingly defaulting to mini-split heat pumps rather than hydronics?

Common suggestion for net zero houses….
Install a ductless mini-split air-to-air heat pump, with 1 or 2 indoor wall cassettes, and leave the interior doors open for heat distribution.

from www.greenbuildingadvisor.com

"Leave bedroom doors open during the day
If you want to heat your house with a ductless minisplit located in a living room or hallway, you'll need to leave your bedroom doors open during the day. ***When the bedroom doors are closed at night, bedroom temperatures may drop 5 F° between bedtime and morning."***

"If family members don't want to abide by this approach, or don't want to accept occasional low bedroom temperatures during the winter, ***then supplemental electric resistance heaters should be installed in the bedrooms."***

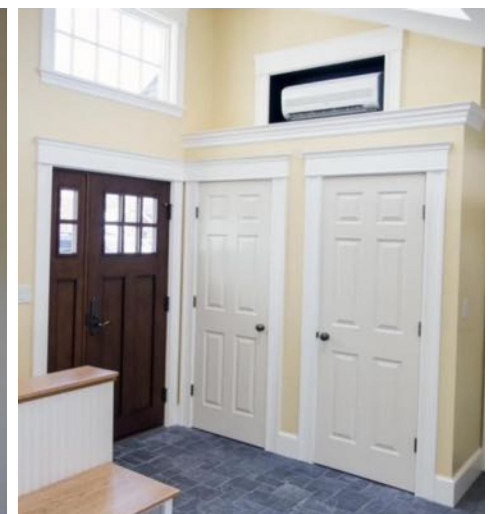
This is certainly a compromise in comfort.

The "sub 0ºF" COPs of cold climate ductless mini-split heat pumps with inverter compressors, are not publicized.

Pro Trade CRAFT
For Residential Construction Pros

9 Ways to Hide a Minisplit

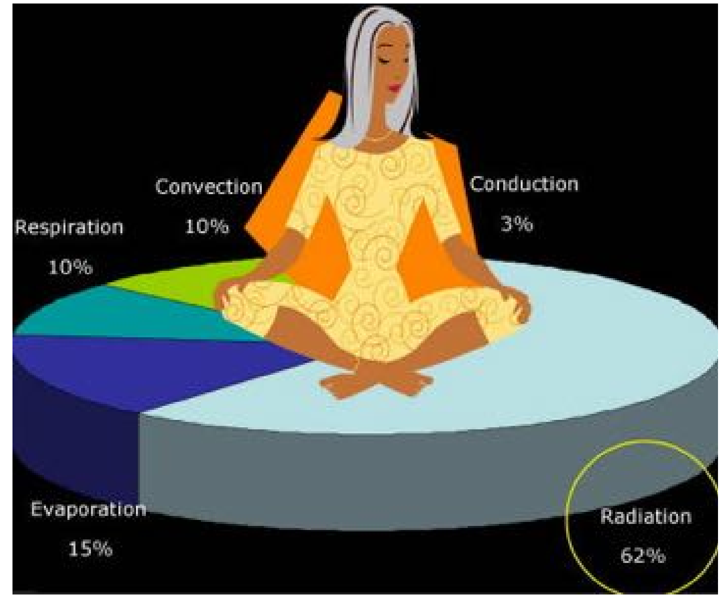
December 20, 2019



Indoor Environmental Quality (IEQ) is affected by many factors, including:

- *Air temperature*
- *Temperature of surrounding surfaces (mean radiant temperature)*
- *Air temperature stratification (variations from floor to ceiling)*
- *Relative humidity*
- *Air movement (drafts, or higher velocity air movement)*
- *Air cleanliness (dust & microbes suspended in air)*
- *Undesirable noises*

courtesy of www.healthyheating.com



Thermal comfort is achieved when the surrounding environment allows heat loss from the body to balance metabolic heat production

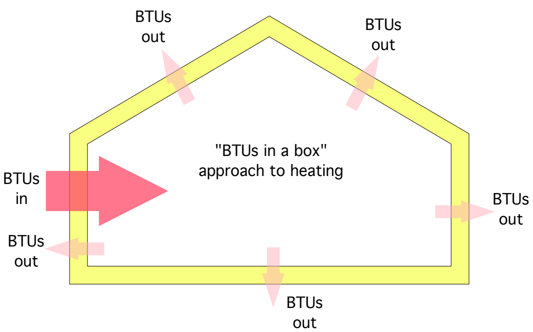
Why is this import?

Many (most?) people believe that air temperature is the sole "proxy" for human thermal comfort.

Many people don't understand what is possible regarding the comfort delivered by their heating system, and assume that they must accept what they have.

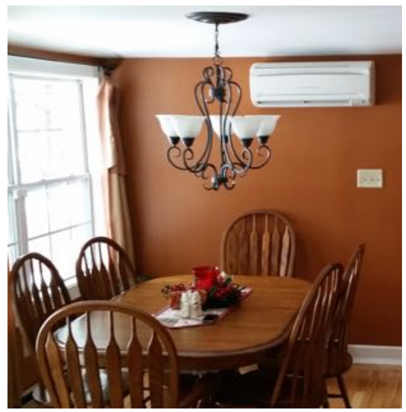
It's not **just** about delivering BTUs… It's about delivering **<u>COMFORT</u>**

The "**Btus in a box**" approach to comfort is very incomplete…

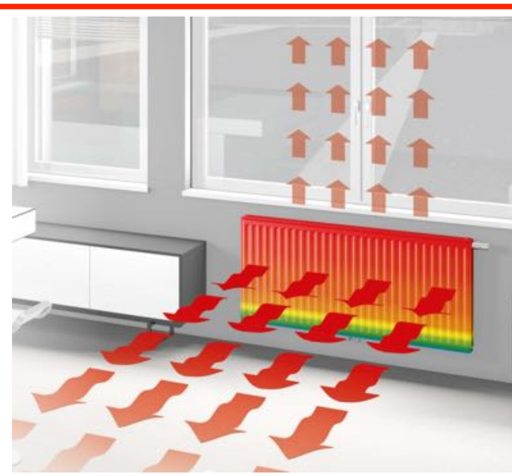


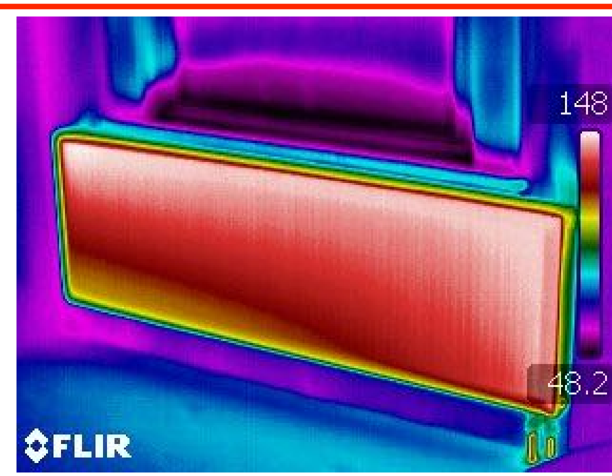
When heat supply rate = heat loss rate, the *thermodynamics* necessary for stable interior temperature are satisfied…

BTUs delivered - except during defrost…



Comfort delivered





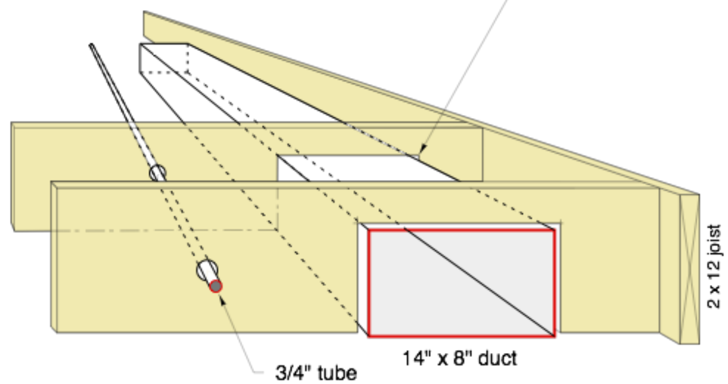
Why hydronics?

Water vs. air: Use the advantage nature has provided...

Material	Specific heat (Btu/lb/°F)	Density* (lb/ft³)	Heat capacity (Btu/ft³/°F)
Water	1.00	62.4	62.4
Concrete	0.21	140	29.4
Steel	0.12	489	58.7
Wood (fir)	0.65	27	17.6
Ice	0.49	57.5	28.2
Air	0.24	0.074	0.018
Gypsum	0.26	78	20.3
Sand	0.1	94.6	9.5
Alcohol	0.68	49.3	33.5

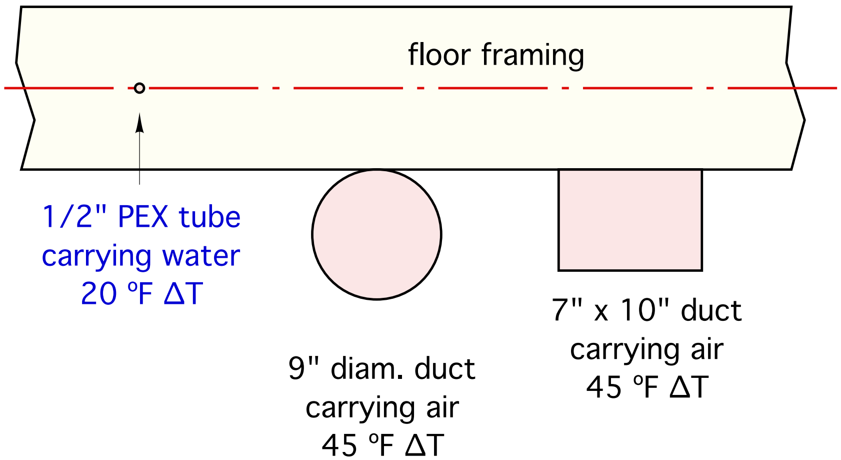
$$\frac{62.4}{0.018} = 3467 \approx 3500$$

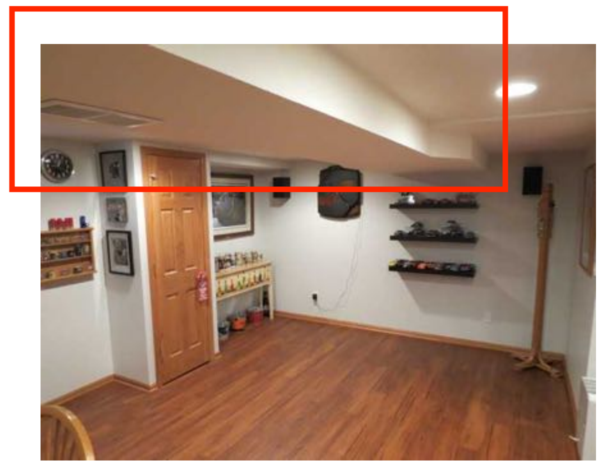
A given volume of water can absorb almost 3500 times as much heat as the same volume of air, when both undergo the same temperature change



Hydronics allows for minimally invasive installation

"Conduit" size required for
12,000 Btu/hr heat transfer rate





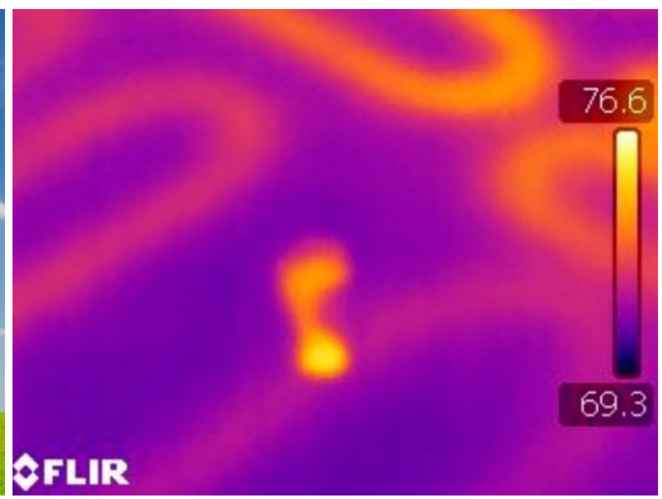
Hydronics & Renewable Energy

Modern hydronics is the "glue" holding together many thermally-based renewable energy systems.

Regardless of what solar collector, geothermal heat pump, or wood-fired boiler is selected, if the distribution system, controls, and heat emitters are not properly matched, that system will not perform well.

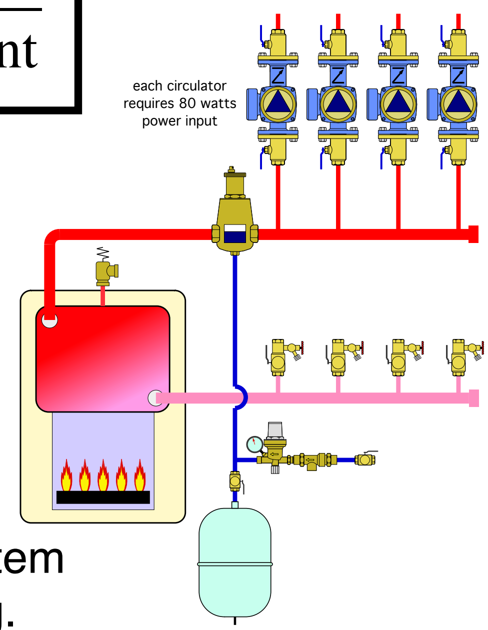
Why hydronics enhances renewable heat sources

- **Unsurpassed comfort**
- Easy to adapt to wide range of renewable heat sources
- Low temp. operation (high heat source efficiency)
- Very high *distribution efficiency*
- Thermal storage potential
- No building filled with refrigerant tubing (e.g., no VRF)
- Easy integration with existing (now “auxiliary”) heat sources
- Very easy to zone to reduce loads
- Potential for thermal metering (ASTM E3137 now in place)



Hydronics provide superior DISTRIBUTION EFFICIENCY

$$\text{distribution efficiency} = \frac{\text{rate of heat delivery}}{\text{rate of energy use by distribution equipment}}$$



Example: Consider a system that delivers 120,000 Btu/hr at design load conditions using four circulators operating at 85 watts each. The distribution efficiency of that system is:

$$\text{distribution efficiency} = \frac{120{,}000\ \text{Btu/hr}}{340\ \text{watts}} = 353\ \frac{\text{Btu/hr}}{\text{watt}}$$

Interpretation: Each watt of electrical power supplied to the distribution system delivers 353 Btu/hr from the heat source to where it's needed in the building.

Why is this import?

High efficiency hydronic heating systems should minimize fuel usage ***as well as the electrical energy needed for heat distribution.***

So is a distribution efficiency of 353 Btu/hr/watt good or bad?

To answer this you need something to compare it to.

Suppose a furnace blower operates at 850 watts while delivering 80,000 Btu/hr through a duct system. It delivery efficiency would be:

$$\text{distribution efficiency} = \frac{80{,}000 \text{ Btu/hr}}{850 \text{ watts}} = 94 \frac{\text{Btu/hr}}{\text{watt}}$$

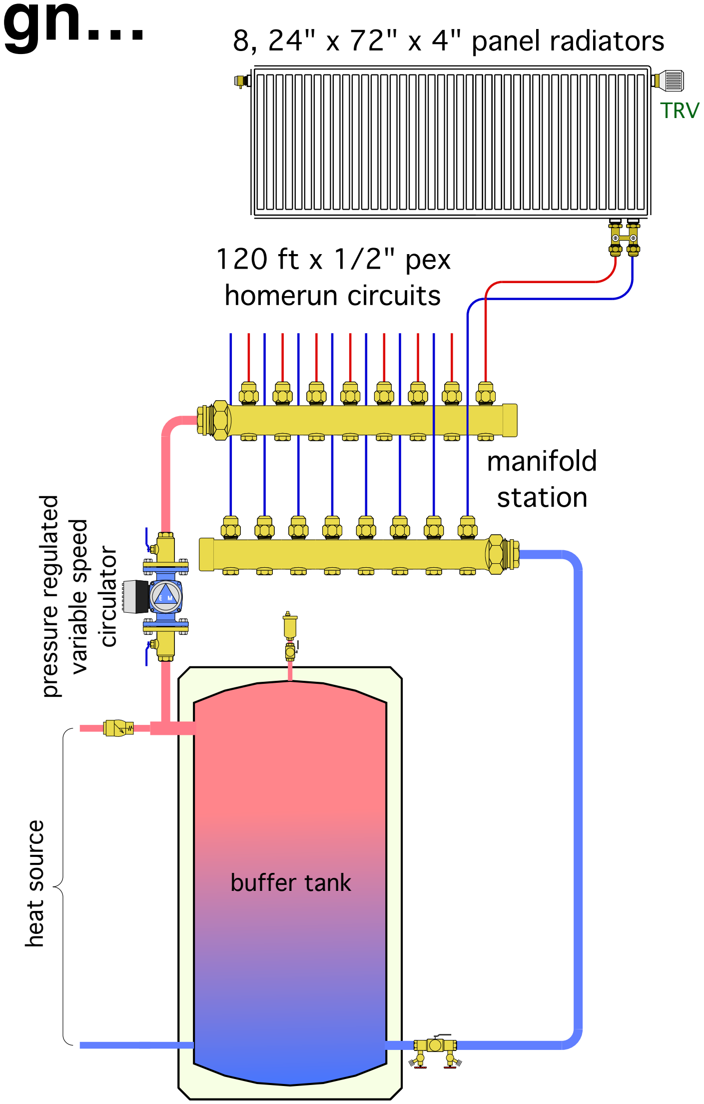
The previously assumed hydronic system had a distribution efficiency almost four times higher than the forced air system.

Water is vastly superior to air as a conveyor belt for heat.

With modern hydronic hardware and design methods (panel radiators, variable speed ECM circulator, homerun distribution system) the distribution efficiency has the potential to be **MUCH** higher…

What’s possible with modern hydronic design…

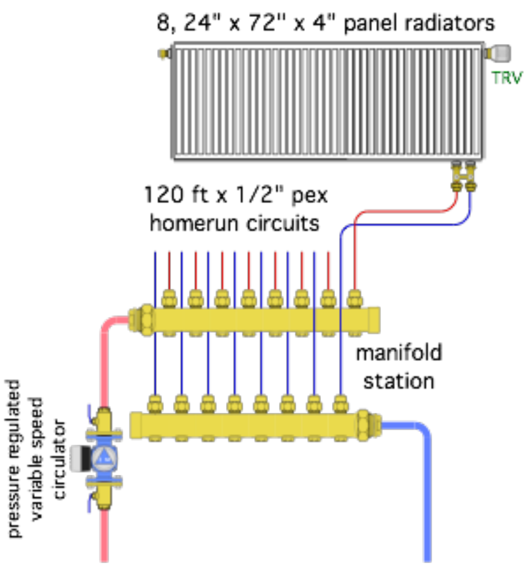
With good design and modern hardware it’s possible to design a homerun distribution system for panel radiators that can supply 30,800 Btu/hr design load using only 8.6 watts of electrical power input to circulator!



$$\text{distribution efficiency} = \frac{30,800\frac{Btu}{hr}}{8.6watt} = 3581\frac{Btu/hr}{watt}$$

The distribution efficiency possible with a well-designed hydronic system far exceeds that attainable with forced air systems

$$\text{distribution efficiency} = \frac{80{,}000\ \text{Btu/hr}}{850\ \text{watts}} = 94\ \frac{\text{Btu/hr}}{\text{watt}}$$



$$\text{distribution efficiency} = \frac{30{,}800\frac{Btu}{hr}}{8.6 watt} = 3581\frac{Btu/hr}{watt}$$

$$\frac{94}{3581} = 2.6\%$$

In this comparison the hydronic system uses only 2.6% of the electrical energy required by the forced air system for equal heat transport (source to load).

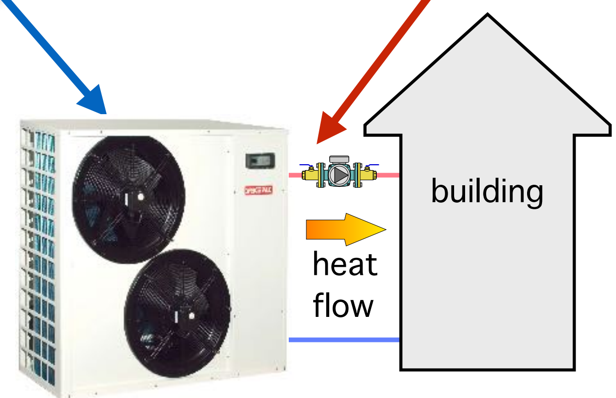
What is an air-to-water heat pump?

Heat pump “flavors”

“Ductless”, “mini-split”
air-to-air heat pump

water-to-water
heat pump

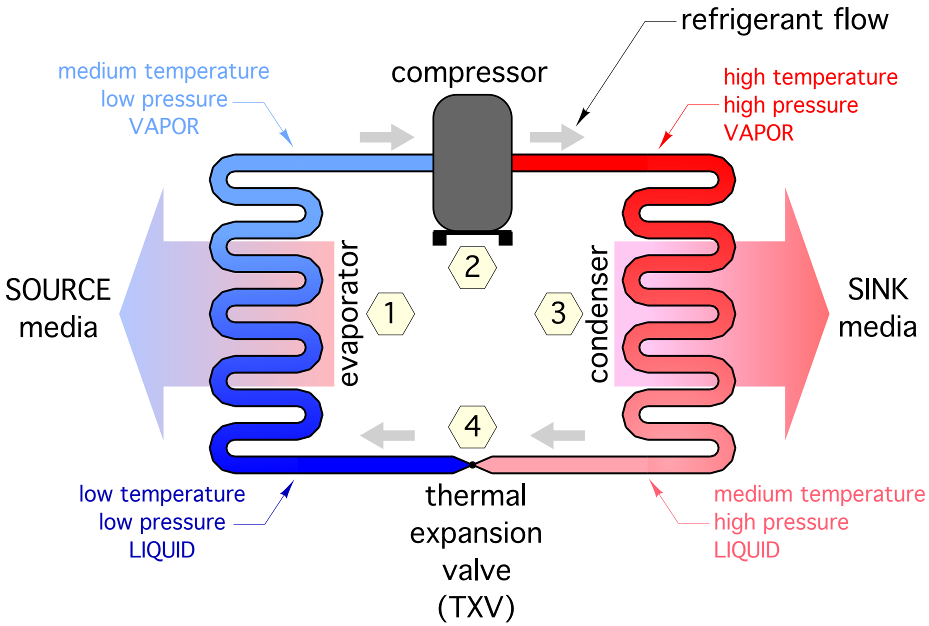
air is the source of the heat



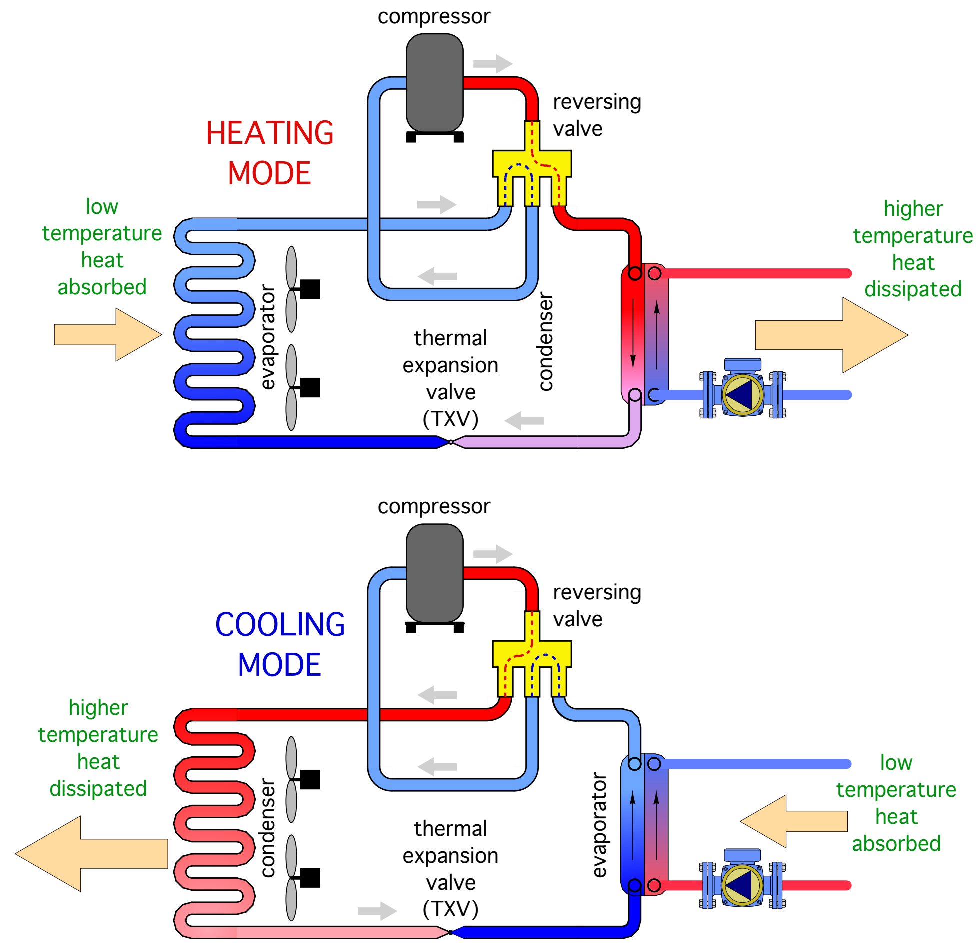
air-to-water
heat pump

water is the “conveyor belt” moving heat to the building

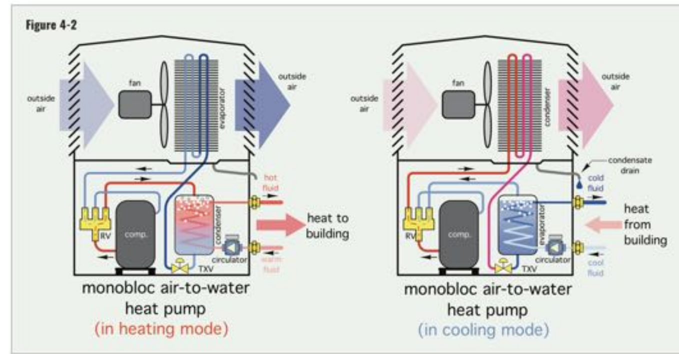
A non-reversible heat pump refrigeration cycle



A reversible air-to-water heat pump refrigeration cycle



A recent issue of ***idronics*** dealt with air-to-water heat pumps

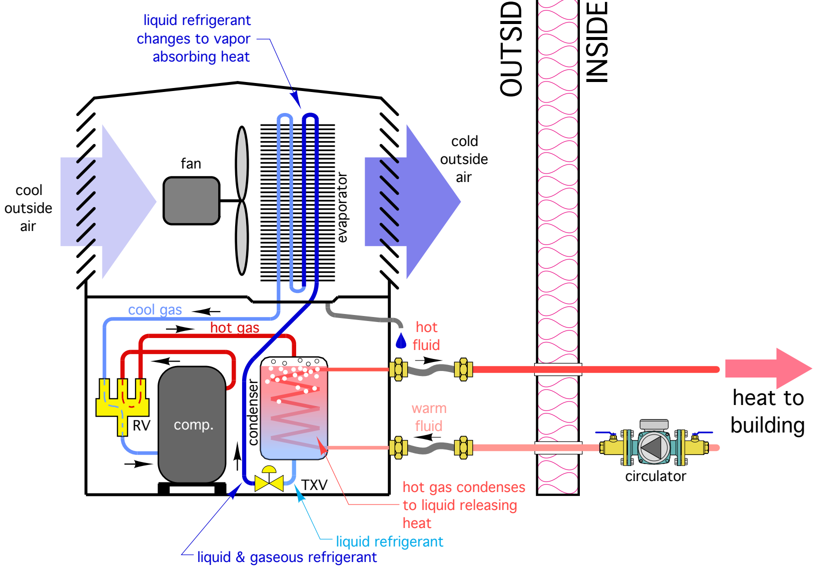


https://idronics.caleffi.com

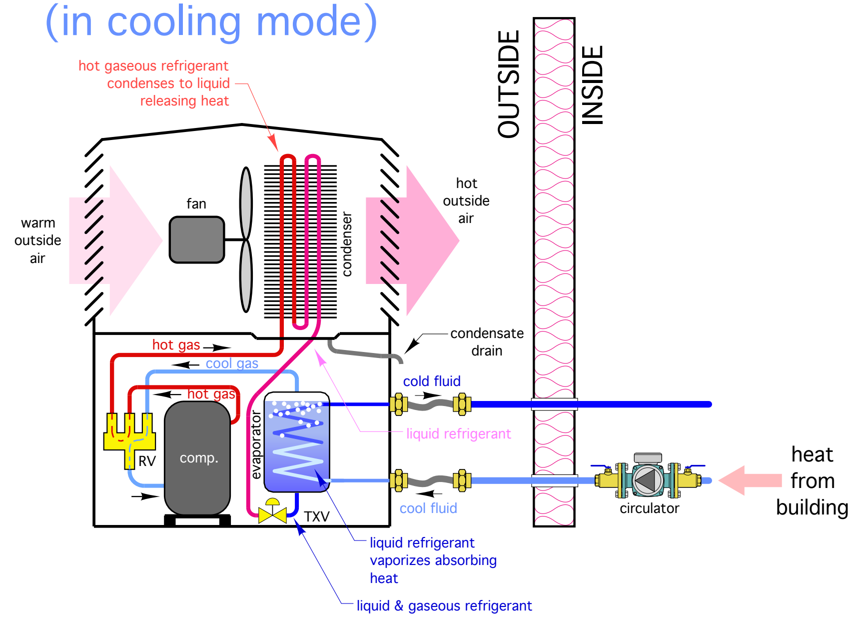
Self-contained (“monobloc”) air-to-water heat pumps

Internals of a monobloc air-to-water heat pump

air-to-water heat pump
(in heating mode)



air-to-water heat pump
(in cooling mode)

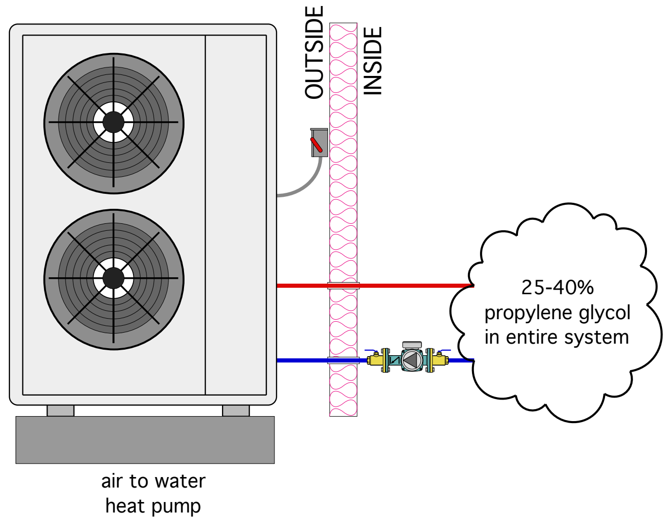


In heating mode: The heat pump extracts low temperature heat from outside air, and transfers it to a fluid stream (water or water & antifreeze) to be used by a hydronic distribution system.

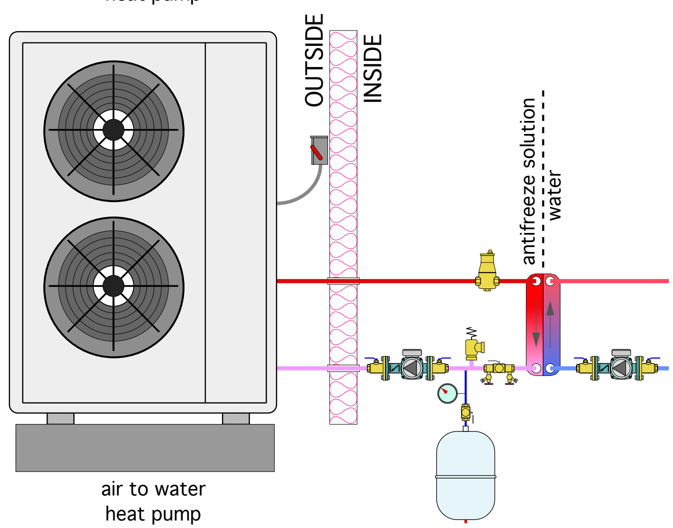
In cooling mode: The heat pump extracts low temperature heat from a fluid stream (chilling it), and dissipates that heat to outside air.

Self-contained ("monobloc") air-to-water heat pumps

- Pre-charged refrigeration system
- Some have internal circulator, others don't
- Should have freeze protection in North American applications



Use 25-40% propylene glycol in the entire system



Use 25-40% propylene glycol in the heat pump loop, with water in remainder of system.

The use of a heat exchanger forces the HP to operate at higher condensing temperatures, and thus lower COP.

Requires 2 circulators & additional hardware / installation labor.

Split system air-to-water heat pump

Outdoor unit

Heating mode:
1. compressor
2. evaporator
3. expansion device

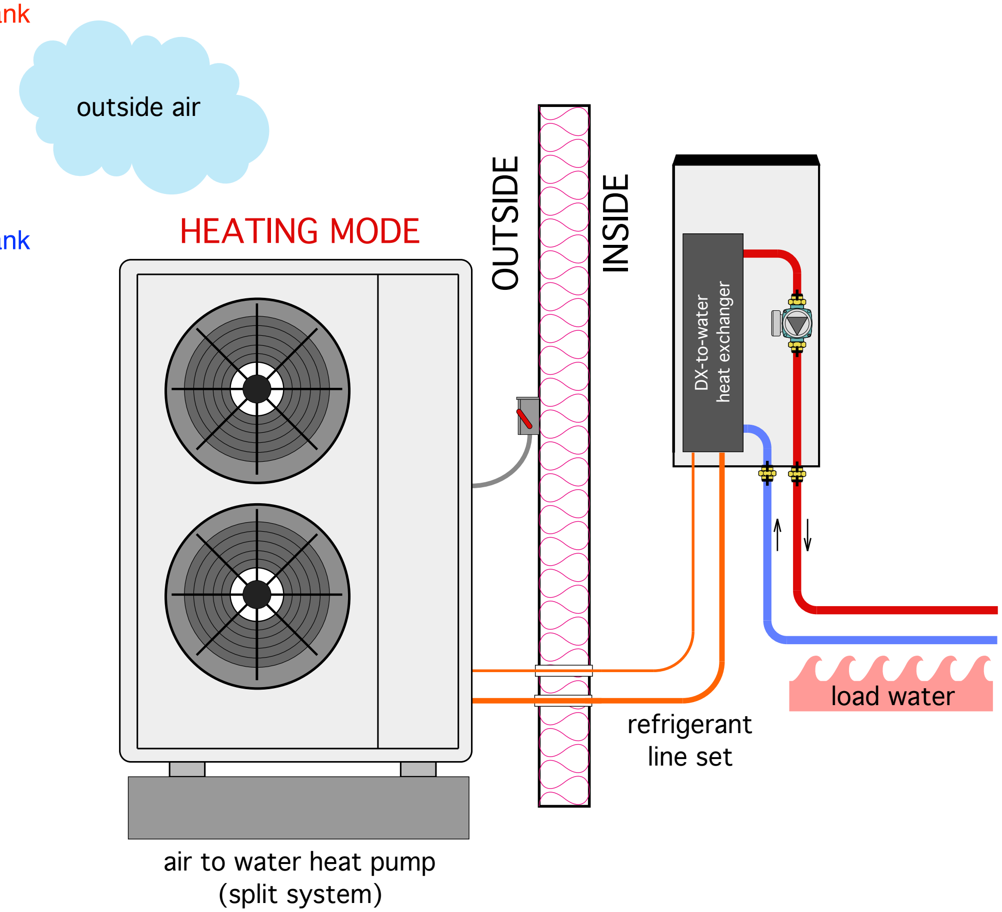
Cooling mode:
1. compressor
2. condenser
3. expansion device

Indoor unit

Heating mode:
1. condenser
2. circulator
3. expansion tank
4. aux element
5. controls

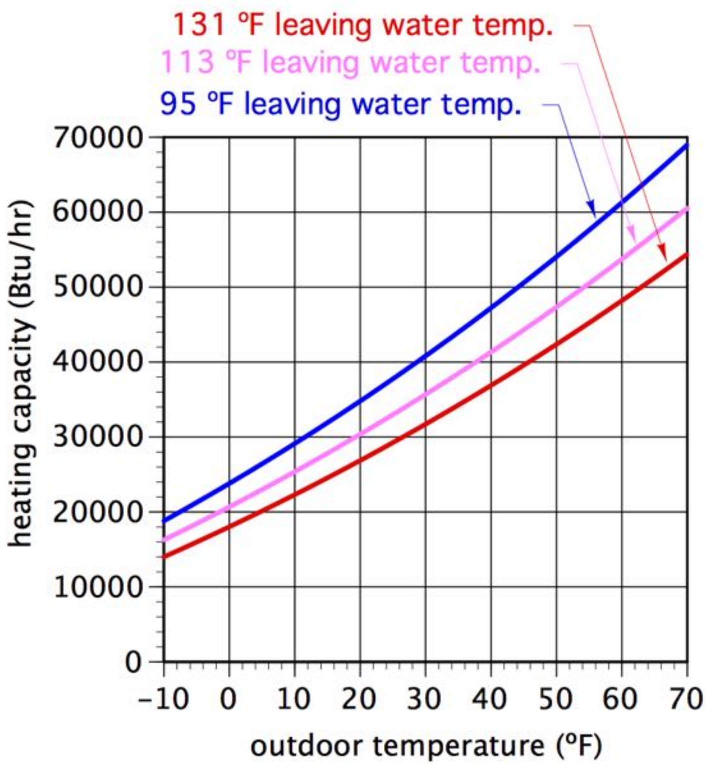
Cooling mode:
1. evaporator
2. circulator
3. expansion tank
4. controls

refrigerant line set

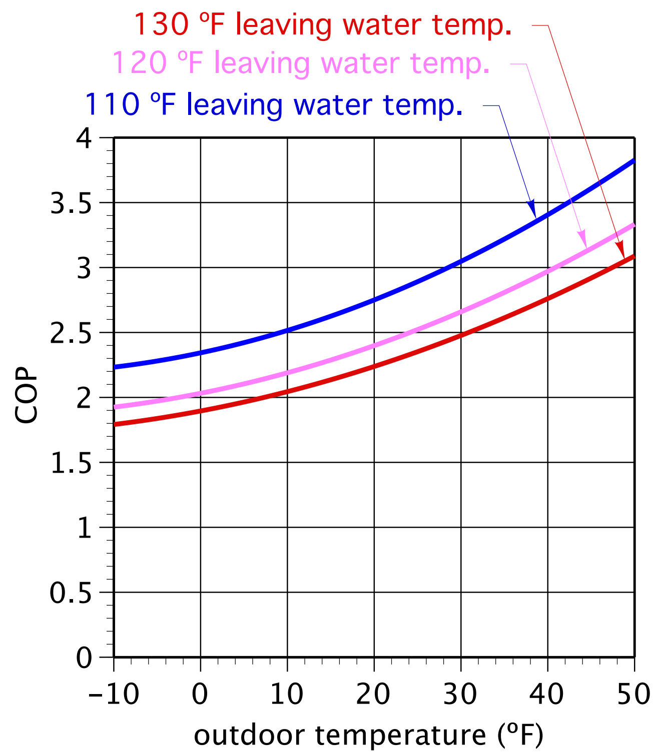


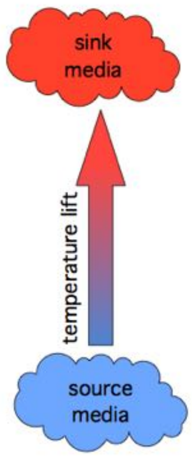
Heating Performance

The heating capacity of most AWHPs decreases with increasing condenser temperature.



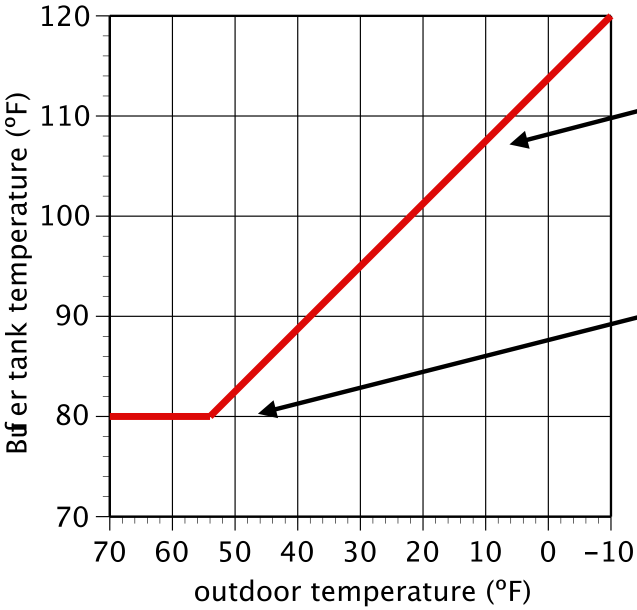
The COP also decreases with increasing condenser temperature.





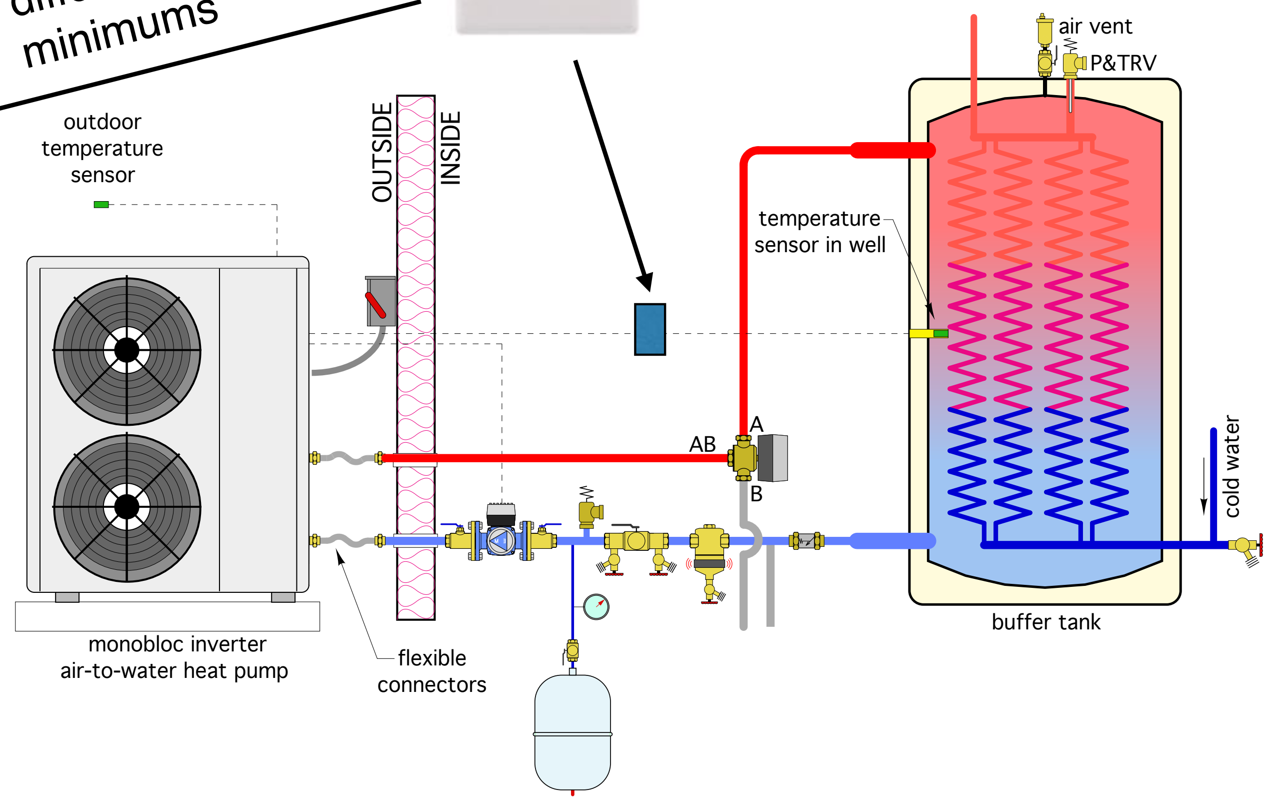
The smaller the "temperature lift" between evaporator and condenser, the higher the heating capacity and COP.

Use outdoor reset control for buffer tank temp. during heating season



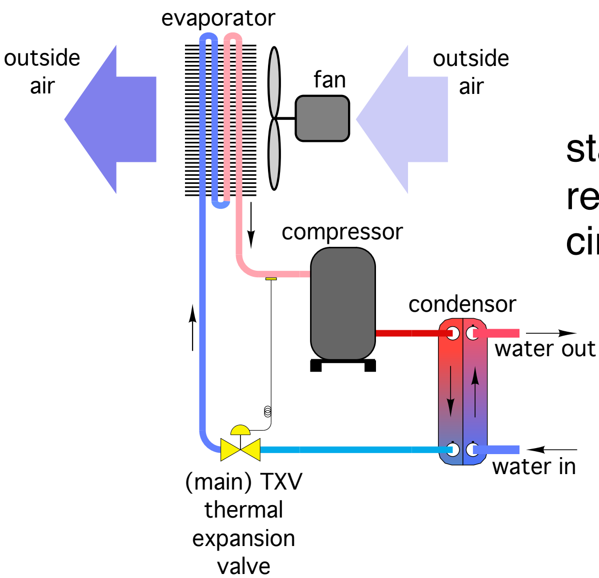
adjustable slopes,
differentials,
minimums

tekmar 256 controller ($169)

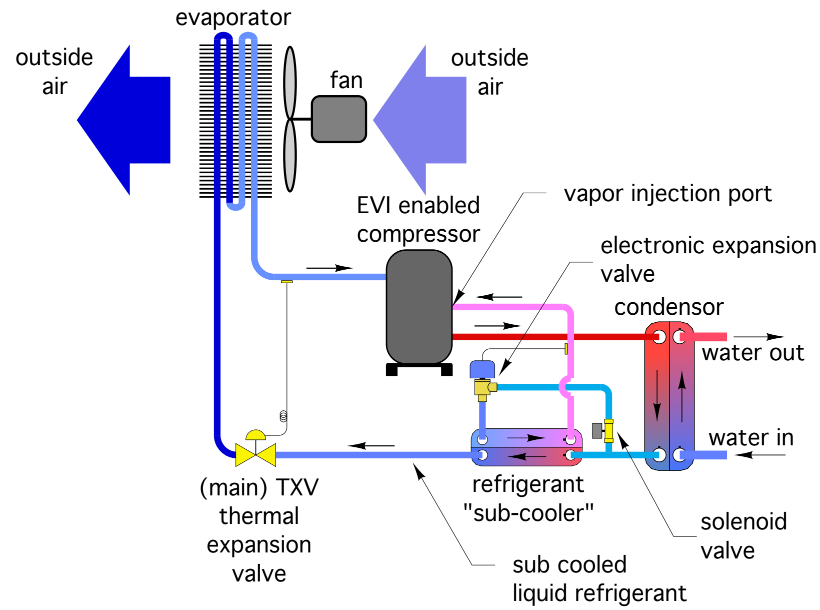


some modern air-to-water heat pumps have built-in outdoor reset control

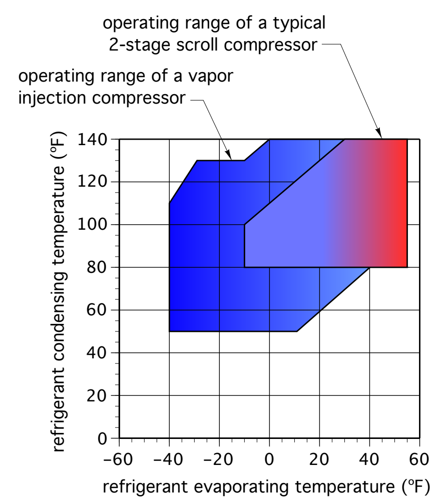
Enhanced Vapor Injection (EVI) Systems



standard refrigeration circuit



EVI refrigeration circuit



- EVI cools the liquid refrigerant to lower temperature prior to Evaporator (during heating mode)

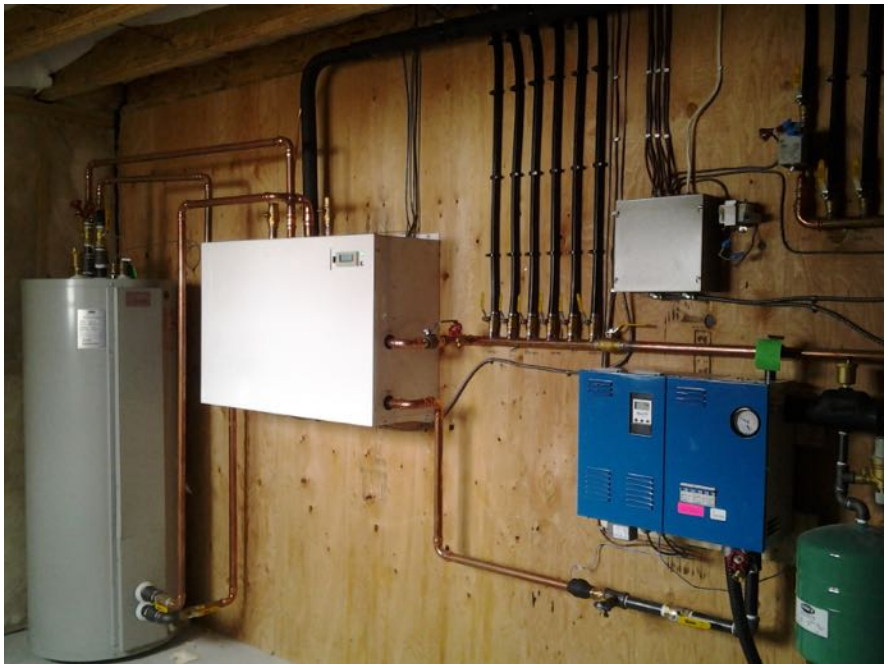
- EVI increase refrigerant mass flow under lower temperature operation

- Some air to water heat pumps with EVI can operate at outdoor temperature down to -22 °F

New Concepts for air-to-water heat pumps

Bring your own condenser...

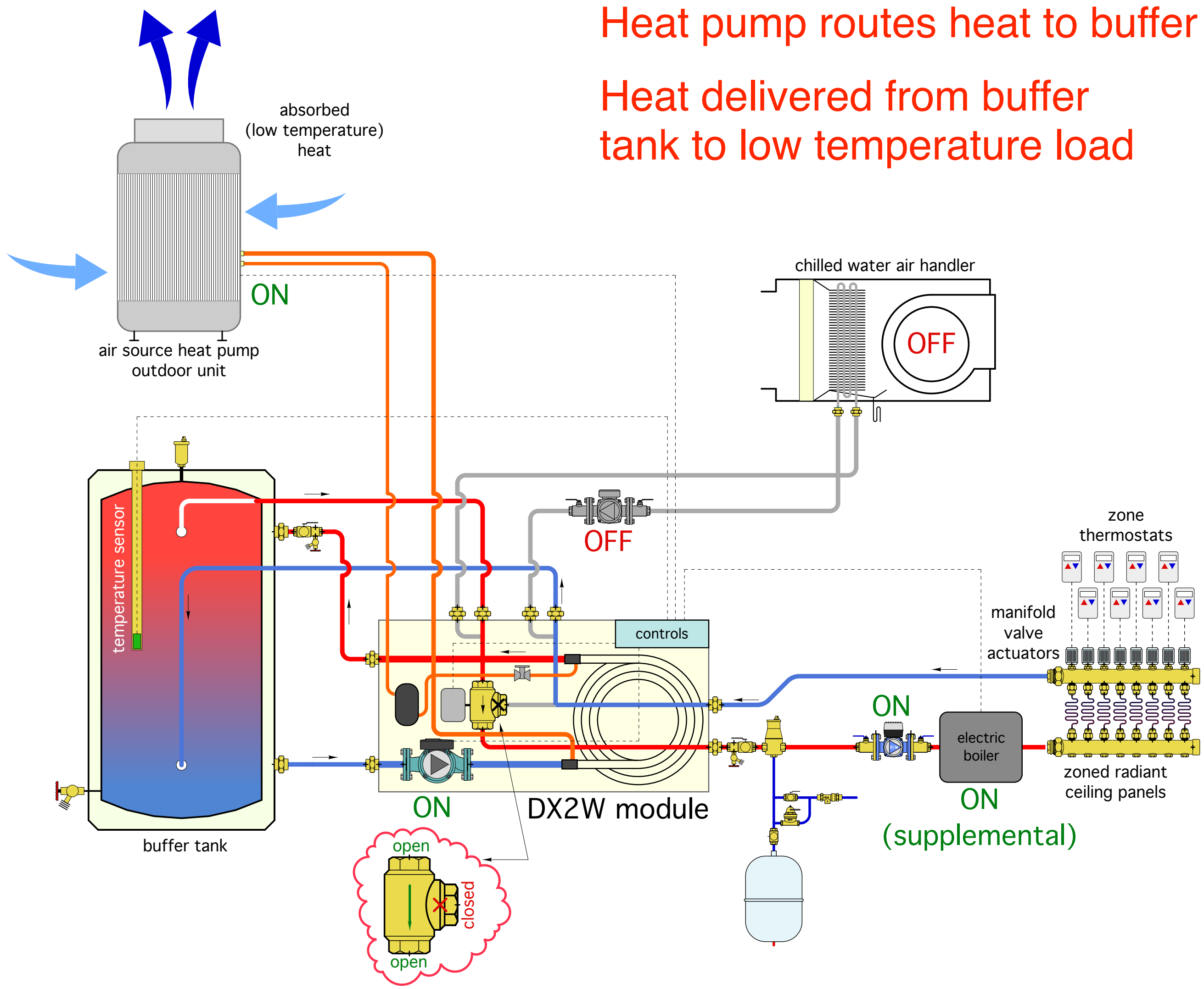
ThermAtlantic Energy Products, Inc.



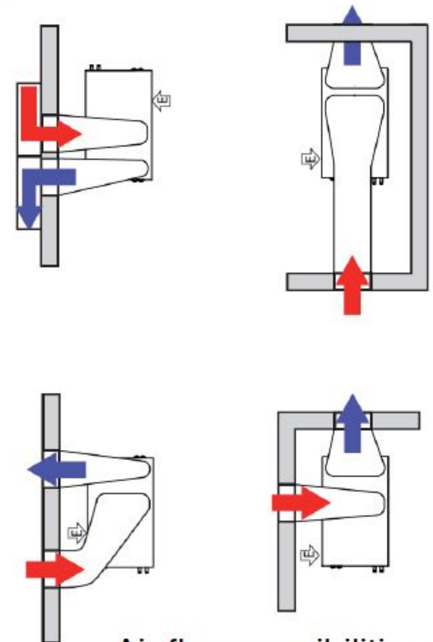
Bring your own condenser... **Heating mode**

Heat pump routes heat to buffer tank

Heat delivered from buffer tank to low temperature load



Interior air-to-water heat pump



Air flow possibilities

Advantages:

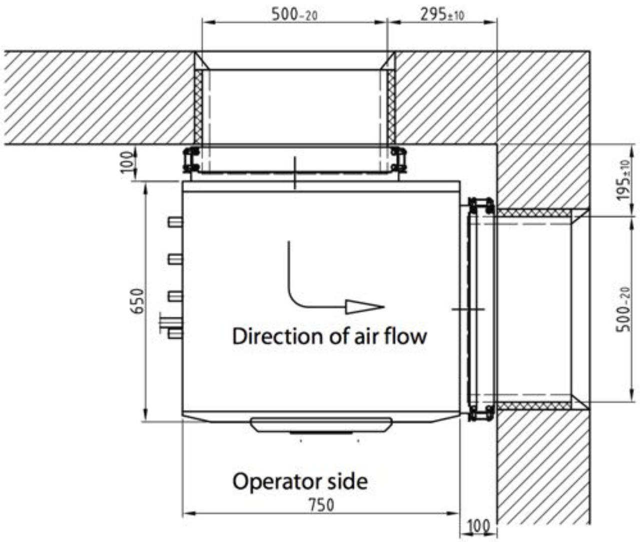
- No outdoor equipment beyond air intake and discharge grills
- Less potential to freeze water containing within the heat pump
- Less environmental weathering effect on equipment
- Reduced potential for debris on heat transfer coil surfaces

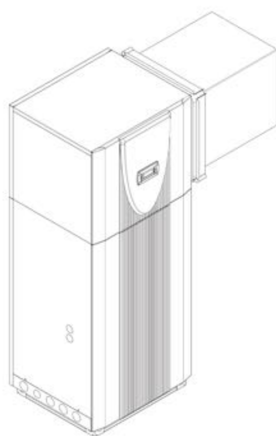
Disadvantages:

- Require more interior space
- Brings compressor sound within the structure
- Requires careful coordination with building design to ensure that adequately sized ducting can be accommodated, and terminated above snow level.

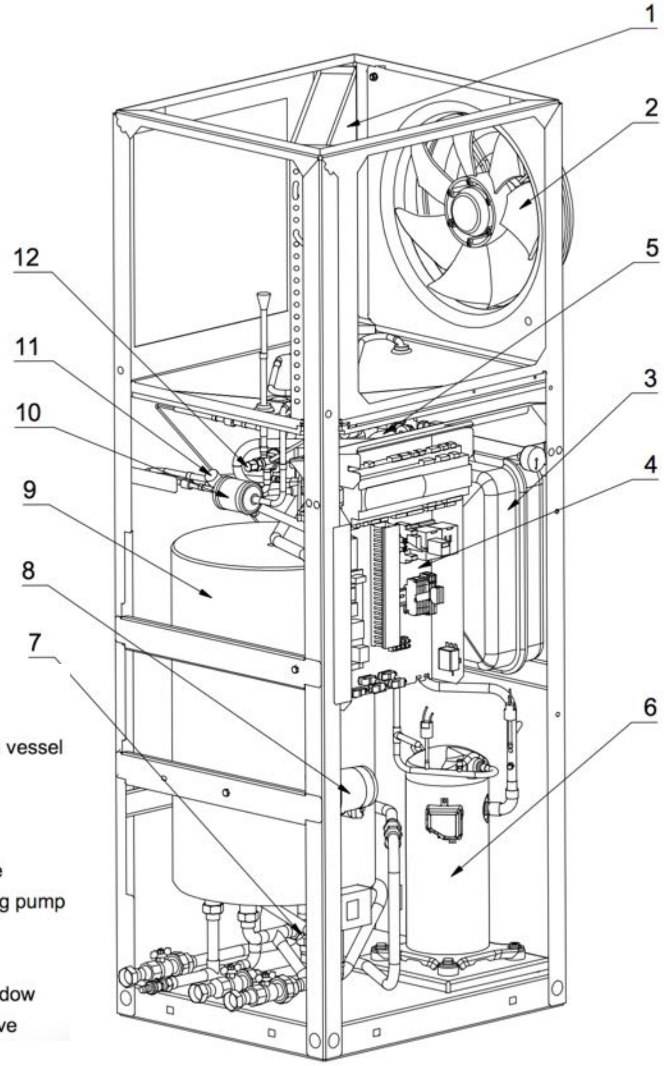
image courtesy of HotJet.cz

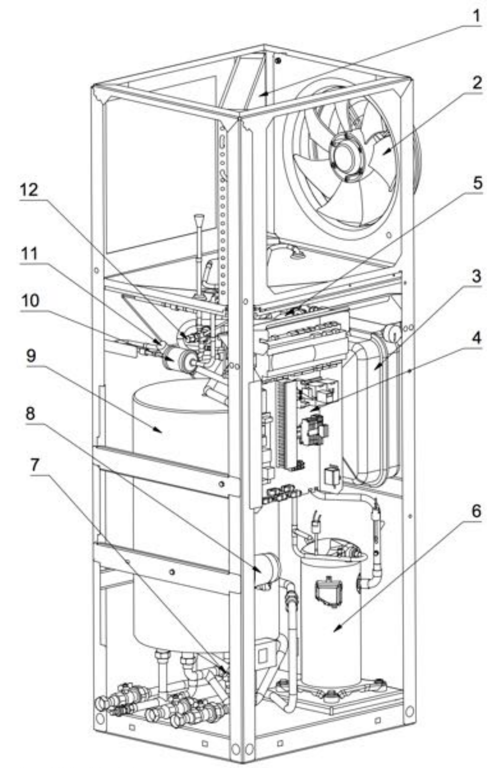
Interior air-to-water heat pump (corner)





1) Evaporator
2) Ventilator
3) 24 l expansion vessel
4) Switch box
5) Liquifier
6) Compressor
7) Overflow valve
8) Heat circulating pump
9) Buffer tank
10) Filter dryer
11) Inspection window
12) Expansion valve





1) Evaporator
2) Ventilator
3) 24 l expansion vessel
4) Switch box
5) Liquifier
6) Compressor
7) Overflow valve
8) Heat circulating pump
9) Buffer tank
10) Filter dryer

Currently available air-to-water heat pumps:

Aermec
(Residential & **Commercial** AWHPs)

Arctic heat pump
(Residential / light commercial AWHPs)

Chiltrix
(Residential / light commercial AWHPs)

Electro Industries
(Residential / light commercial AWHPs)

Enertech Global
(Residential / light commercial AWHPs)

Multiaqua
(Residential / light commercial AWHPs)

Nordic
(Residential / light commercial AWHPs)

SpacePak
(Residential / light commercial AWHPs)

ThermAtlantic
(Residential / light commercial AWHPs)

Anticipated products:

Emmeti
(Residential / light commercial AWHPs)

GREE
(Residential / light commercial AWHPs)

Group Atlantic
(Residential / light commercial AWHPs)

Mitsubishi
(Residential & **Commercial** AWHPs)

Stiebel Eltron
(Residential / light commercial AWHPs)

Taco
(Residential / light commercial AWHPs)

Why the *North American* air-to-water heat pump market will grow

Global air-to-water heat pump market:

In July 2020, the Japanese HVAC publication JARN reported the pace of air-to-water heat pump adoption, globally, in 2019, increased at an annualized rate of **25.8%**, reaching a demand of **3.42 million units**.

China accounted for just over 2 million of these units. Around 600,000 units were attributed to the European market, lead by France, Germany and Italy.

Many of these heat pumps were installed as part of phase out plans for oil-fired boilers and low efficiency gas-fired boilers.

Asian manufacturers [Daikin, Mitsubishi, Fujitsu, Hitachi, Samsung, LG, Gree, Toshiba]
German manufacturers [Dimplex, Wolf, Viessmanm, Bosch,Vaillant]
Canadian manufacturers [ThermAtlantic, Nordic, Arctic, Aermec]

* Source: JARN July 2020,

Trends supporting an emerging market for air-to-water heat pumps in North America

1. Rapidly growing interest in Net Zero houses:

• Typical net zero house has a low loss thermal envelope, and a sizable solar photovoltaic array.

• Net metering laws - where they exist - allow owners of photovoltaic systems to sell surplus electrical power back to the utility at full retail rate.

• North America held the largest market share for net-zero construction accounting for 79.1% in 2018. The North American market is projected to grow at a CAGR of 16.0% during the period 2019-2024.

Trends supporting an emerging market for air-to-water heat pumps in North America

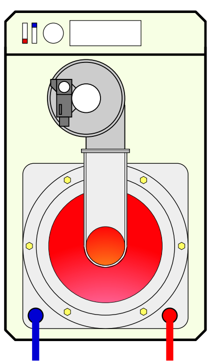
2. Decreasing heating loads:

- ***Pre-1990 houses design load where typically 25-40 Btu/hr/ft^2***
- ***Modern low energy houses have typical design loads of 10-15 Btu/hr/ft^2***

Consider a 1800 ft^2 house at 10 Btu/hr/ft^2 design load = 18,000 Btu/hr (5.3kw) (at design!)

Often difficult to find a boiler small enough to avoid oversizing, and short cycling under partial loads.

gas-fired modulating / condensing boiler



boiler model	MAXIMUM HEAT OUTPUT (Btu/hr)	MINIMUM HEAT OUTPUT (Btu/hr)
model 55	51,000	7,700
model 85	79,000	7,900
model 110	102,000	10,200
model 155	144,000	14,400
model 200	185,000	18,400
model 285	264,000	26,400
model 399	377,000	75,600

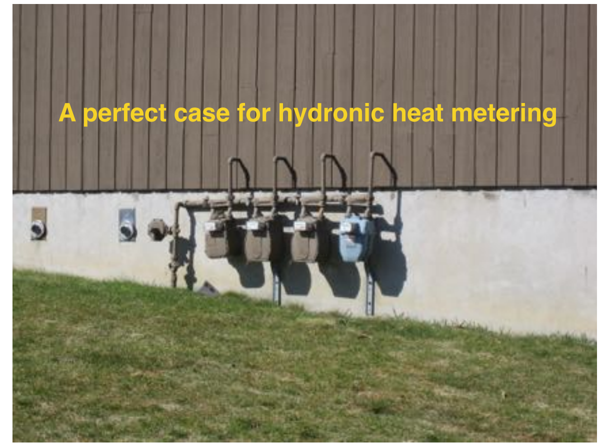
Trends supporting an emerging market for air-to-water heat pumps in North America

3. Eliminating gas eliminates the basic service charge for a gas meter

GAS RESIDENTIAL

Meter Number: [redacted]

Dec 19 reading (Actual)		9524	
Nov 17 reading (Actual)		-9349	
Total Usage CCF 32 days		175	
Delivery Charges			
Basic Service Charge			$20.00
Includes	3CCF	@ 0.000¢ each	$00.00
Next	47 CCF	@ 65.285¢ each	$30.68
Next	125 CCF	@ 62.835¢ each	$78.54
Month Gas Adj		@ 12.22455¢ each	$21.39
NY Assessment	175 CCF	@ 0.96528¢	$1.69
RDM Adjustment	175 CCF	@ 0.72803¢	$1.27
SBC Charge	175 CCF	@ 0.51500¢	$0.90
Government surcharges - Delivery			$5.22
Total Delivery Charges			**$159.69**
Merchant Function Chg	175 CCF @ 2.9453¢		$5.15
Government surcharges - Delivery			$0.17
Merchant Function Charges			**$5.32**
Gas Supply Chg	**175 CCF @ 33.00655¢**		**$57.75**
Government surcharges - Commodity			$0.75
Total Supply Charges			$58.51
CURRENT GAS CHARGES			**$223.52**

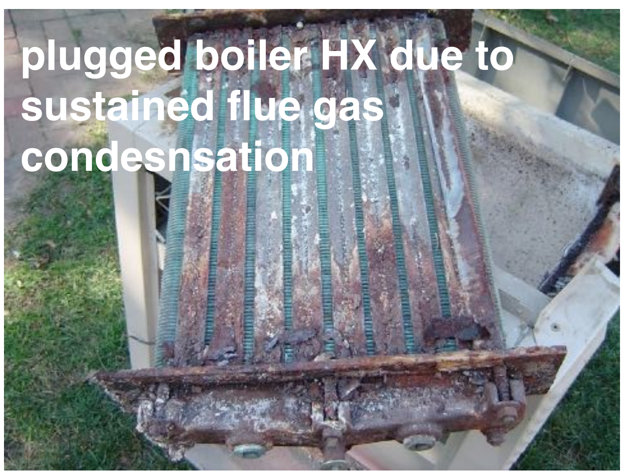


In some low energy houses the basic service charge could exceed the cost of purchased natural gas.

Trends supporting an emerging market for air-to-water heat pumps in North America

4. *Safety / liability issues associated with fossil fuels*

CO leaks inside bldg.



plugged boiler HX due to sustained flue gas condesnsation

fuel leaking from buried tanks

corroded vent piping

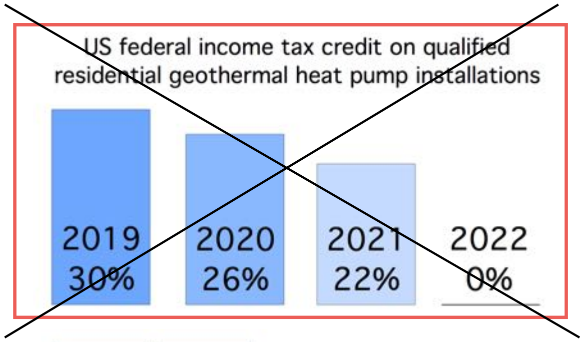
Trends supporting an emerging market for air-to-water heat pumps in North America

5. The geothermal heat pump industry is highly dependent on subsidies:

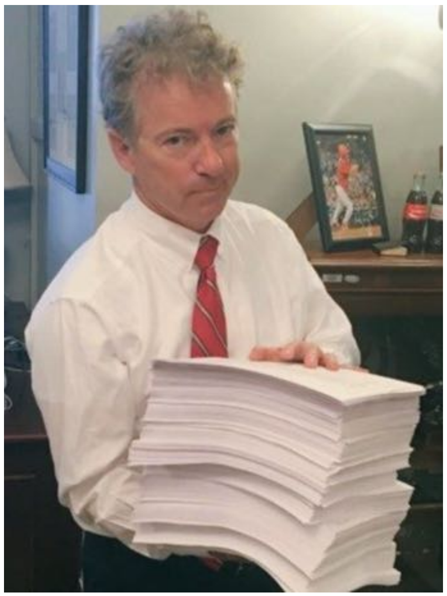
https://www.geoexchange.org/news/

50% decline in US residential GHP shipments during 2017, after original federal tax credit expired 12/31/16.

This tax credit was reinstated in Feb 2018, retroactive to its 12/13/16 expiration.



current credits



Do you want to build your business model on the assumption that subsidies will always be there?

Trends supporting an emerging market for air-to-water heat pumps in North America

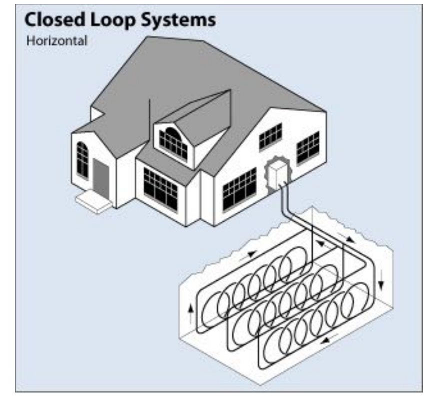
6. Air-to-water heat pumps are <u>significantly less expensive</u> to install compared to geothermal heat pumps:

This is especially true if vertical boreholes are required for the earth loop.

In my area, these holes cost about $3,000+ per ton for drilling, pipe insertion, and grouting. Additional cost is incurred for connecting multiple vertical piping loops, and routing piping back to the location of the heat pump.

In simplest terms: Air-to-water heat pumps eliminate the geothermal loop

geothermal heat pump
typical installed cost = $X



air-to-water heat pump
typical installed cost
= $(30% to 50%)X

Trends supporting an emerging market for air-to-water heat pumps in North America

7. Air-to-water heat pumps are <u>significantly less disruptive to install</u> compared to geothermal heat pumps:

Horizontal earth loops require large land areas and major excavation.

In my area, vertical earth loops cost about $3,000+ per ton for drilling, pipe insertion, and grouting. Additional cost is incurred for connecting multiple vertical piping loops, and routing piping back to the location of the heat pump. The drill "tailings" usually have to be removed from the site.

Replacement of any affected pavements or landscaping also needs to be factored into the cost of installing a geothermal heat pump system.

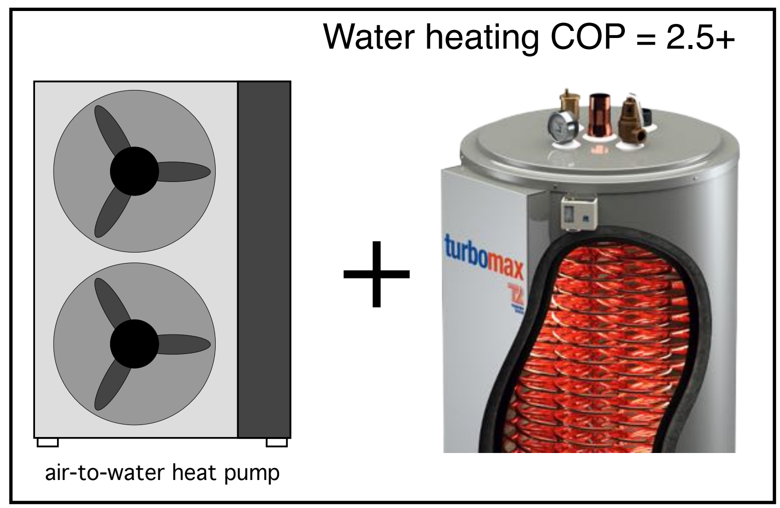
Trends supporting an emerging market for air-to-water heat pumps in North America

8. As home space heating loads get smaller, the domestic water heating load becomes an increasingly higher percentage of the total annual heating energy requirement.

Some estimates put the DHW load at 25-30 percent of the total annual energy requirement in a well insulated modern home.

Most ductless mini-split heat pumps cannot provide domestic water heating, but a properly configured air-to-water heat pump can.

A standard electric water heater providing domestic water heating in a situation where the heat pump cannot, delivers heat at a COP of 1.0. If that energy was instead attained through an air-to-water heat pump, it could be delivered at a COP averaging perhaps 2.5 over the year. For a family of 4, needing 60 gallons per day of water heated from 50 to 120 ºF, and assuming electrical energy priced at $0.12 per KWHR, **the *difference* in annual domestic water heating cost between these options is $270.**



Several trends suggest that a growing market will emerge for air-to-water heat pumps.

9. The high COP cited for some geothermal heat pumps doesn't include the power required to move flow through the earth loop.

Example of a commercially available earth loop flow center.
4, UP26-150 circulators (370 watts each) = 1,480 watts pumping power input.

The ANSI 13256-2 standard for geo heat pump COP includes an estimate for the power required to move flow through the heat pump - BUT DOESN'T INCLUDE ANY ALLOWANCE FOR THE EARTH LOOP PUMPING POWER.

The high flow and head required in some geothermal earth loops requires substantial circulator power.

Example: A specific water-to-water geothermal heat pump has the follow listed performance information:
Earth loop entering temperature = 30ºF
Entering load water temperature = 100 ºF
Flow rate (both evaporator and condenser) = 9 gpm
Heating capacity = 27,700 Btu/hr
Electrical power input = 2370 watts

Based on a typical earth loop, the pumping requirement is 10.5 gpm at 35.5 feet of head. This equates to an estimated pump input of 287 watts.

$$COP_{\text{HP only}} = \frac{27700\frac{Btu}{hr}}{(2.37kw)\left(\frac{3413\frac{Btu}{hr}}{kw}\right)} = 3.42 \qquad COP_{\text{HP +loop pump}} = \frac{27700\frac{Btu}{hr}}{(2.37kw + 0.287kw)\left(\frac{3413\frac{Btu}{hr}}{kw}\right)} = 3.05$$

Nominal 11% drop in "net" COP

Trends supporting an emerging market for air-to-water heat pumps in North America

10. The "COP gap" between geothermal and low ambient air source heat pumps is closing.

You don't pay for COP! (you pay for kilowatt•hours)

Example: A house has a design heating load of 36,000 Btu/hr when the outdoor temperature is 0 ºF, and the indoor temperature is 70 ºF. The house is located in Syracuse, NY with 6,720 annual heating ºF•days. The estimated annual space heating energy use is 49.7 MMBtu. Assume that one heat pump option has a seasonal average COP of 3.28. The other heat pump has a seasonal COP of 2.8.

$$S = load\left[\frac{1}{COP_L} - \frac{1}{COP_H}\right] = 49.7\left[\frac{1}{2.8} - \frac{1}{3.28}\right] = 2.6\,MMBtu\,/\,year$$

The cost savings associated with an energy savings of 2.6 MMBtu/hr depends on the cost of electricity. For example, if electricity sells at a flat rate of $0.13 / KWHR, the cost savings would be:

$$\text{Cost savings} = \frac{2.6\,MMBtu}{year}\left(\frac{292.997\,KWHR}{1\,MMBtu}\right)\left(\frac{\$0.13}{KWHR}\right) = \$99\,/\,year$$

Can the added cost of the higher COP heat pump be recovered in a reasonable time?

11. Boilers *don't provide cooling*

- ***This has long been an "Achilles heel" for hydronics***

- ***Rather than tell prospective "heating" customers that they need an entirely separate system if the want cooling, heat pumps offer the opportunity to it in a single system.***

- ***Existing hydronic systems can potentially be upgraded to include cooling.***

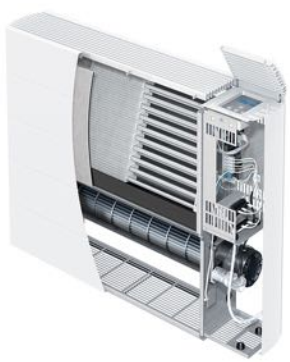
- ***New hydronic systems can be designed to include cooling.***

pre-insulated 3/4" PEX

Several approaches:

- ***single zone cooling / multi-zone heating***
- ***zoned air handlers***
- ***zoned wall consoles / cassettes***
- ***single coil with zoned fans***
- ***radiant panel cooling***

Myson iVector wall console

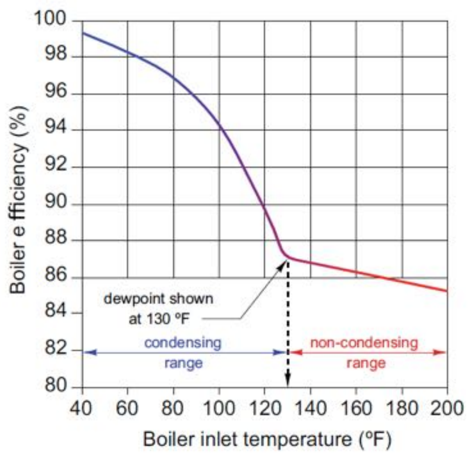


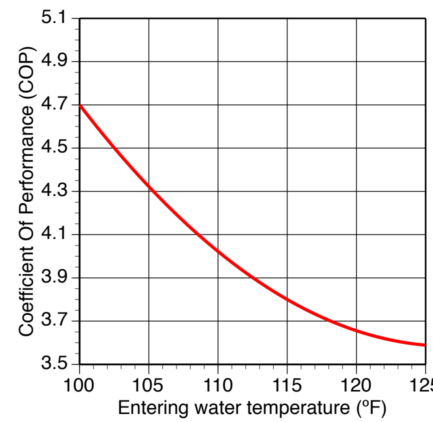
SpacePak high wall cassette

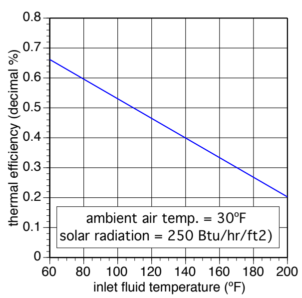
air handler w/ chilled water coil

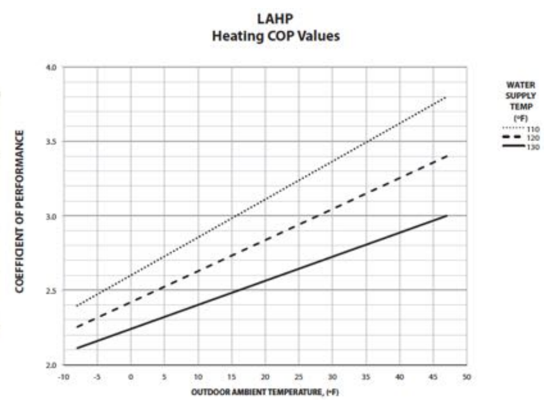
Importance of low temperature distribution systems

Heat sources such as condensing boilers, geothermal & ATW heat pumps, and solar collectors all benefit from low water temperature operation.





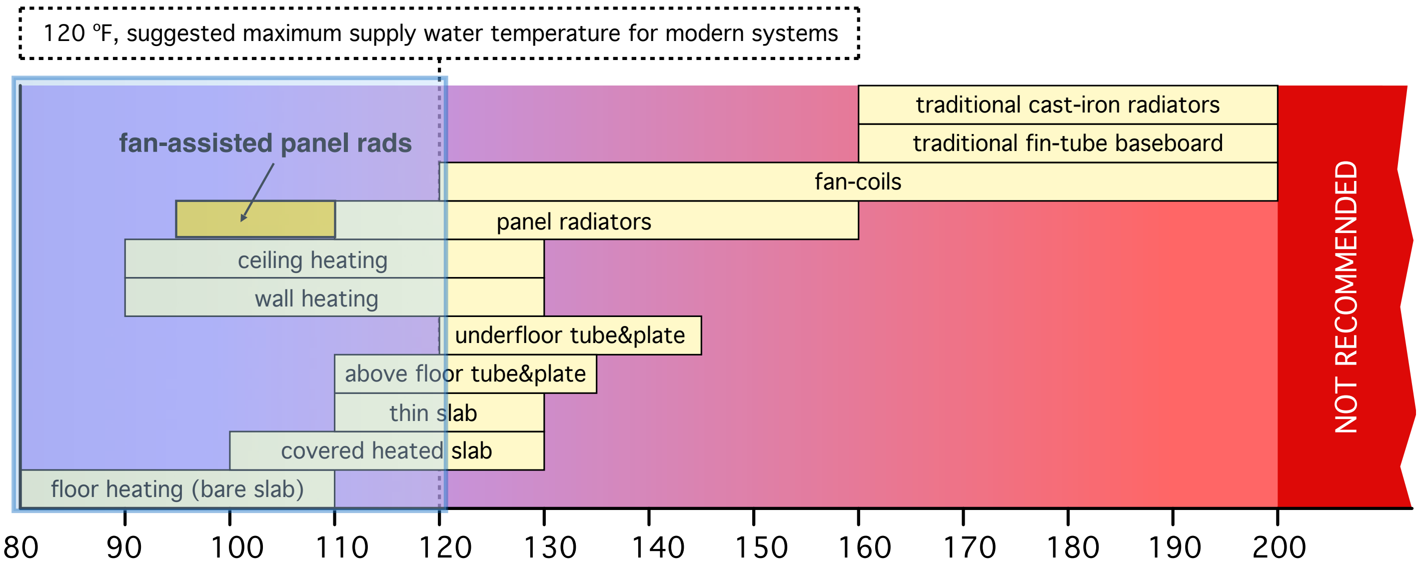


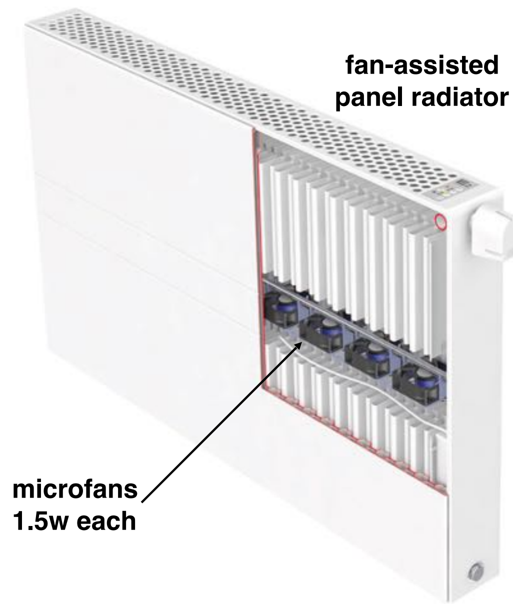


A suggested criteria: ***Design all hydronic space heating systems so that they can deliver design heating load using a water temperature no higher than 120 ºF - even lower when practical.***

This "Future-proofs" your hydronic distribution system

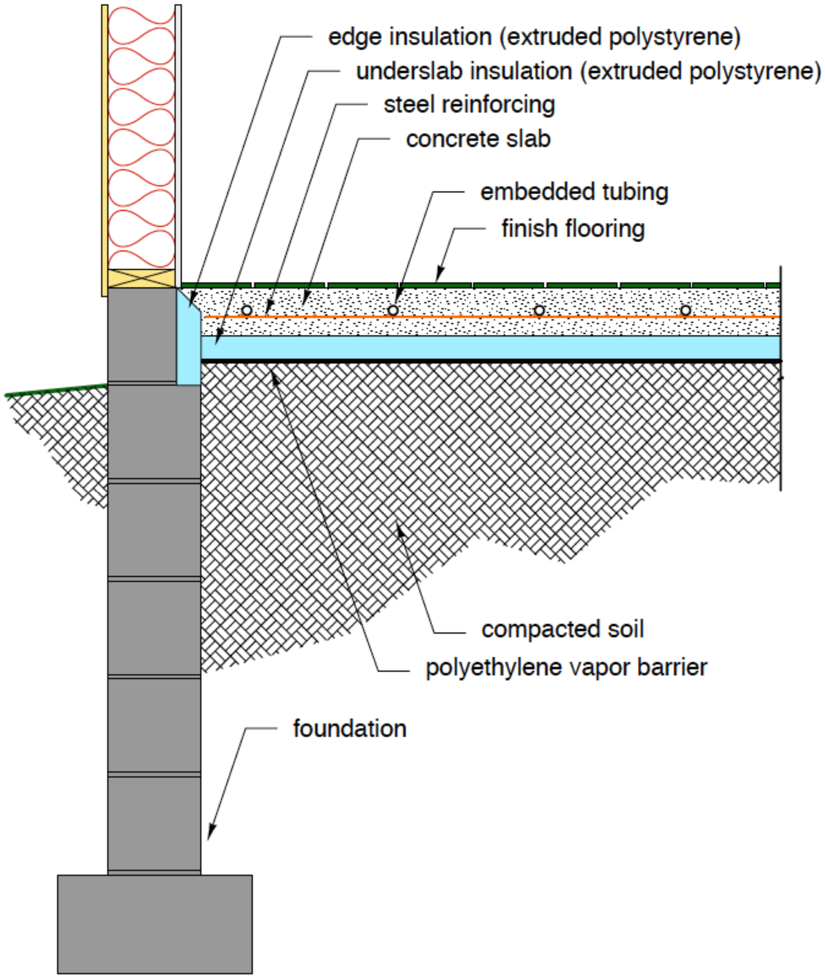
This is well within the reasonable efficiency range of modern hydronic heat sources such as geothermal water-to-water heat pumps, air-to-water heat pumps, biomass boiler systems, and mod/con boilers

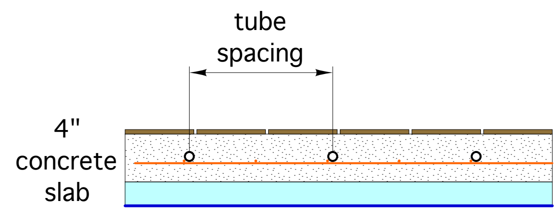


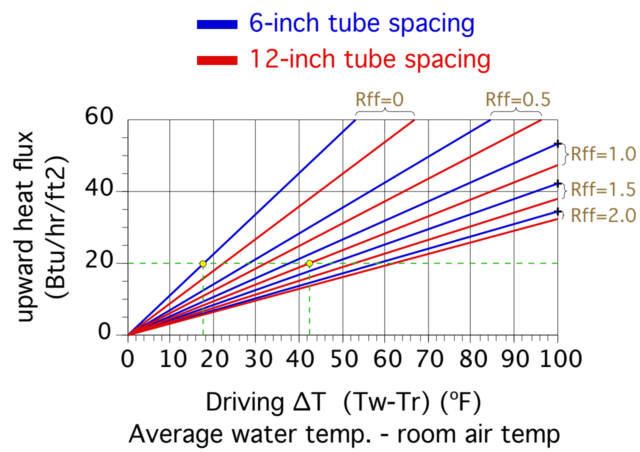


Don't feel constrained to select heat emitters based on "traditional" supply water temperatures…

Slab-on-grade floor heating

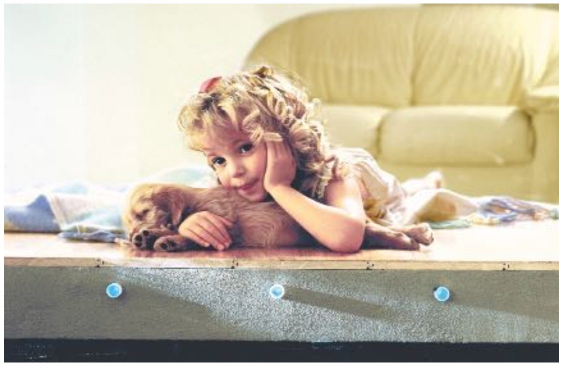






Rff = resistance of finish flooring (°F/hr/ft^2/Btu)

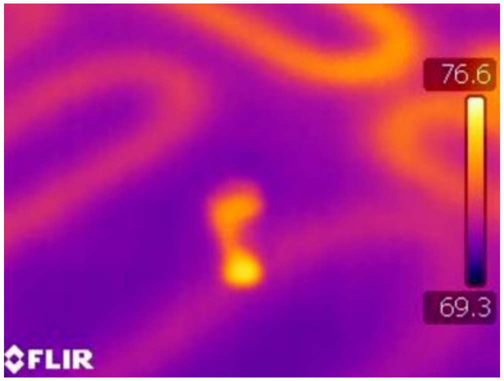
Is radiant floor heating **always** the answer?



"Barefoot friendly" floors...

Is radiant floor heating **always** the answer?

Consider a 2,000 square foot well insulated home with a design heat loss of 18,000 Btu/hr. Assume that 90 percent of the floor area in this house is heated (1800 square feet). The required upward heat flux from the floor at design load conditions is:



$$\text{heat flux} = \frac{\text{design load}}{\text{floor area}} = \frac{18{,}000\ \text{Btu/hr}}{1{,}800\ \text{square feet}} = 10\,\frac{\text{Btu}}{\text{hr}\bullet\text{ft}^2}$$

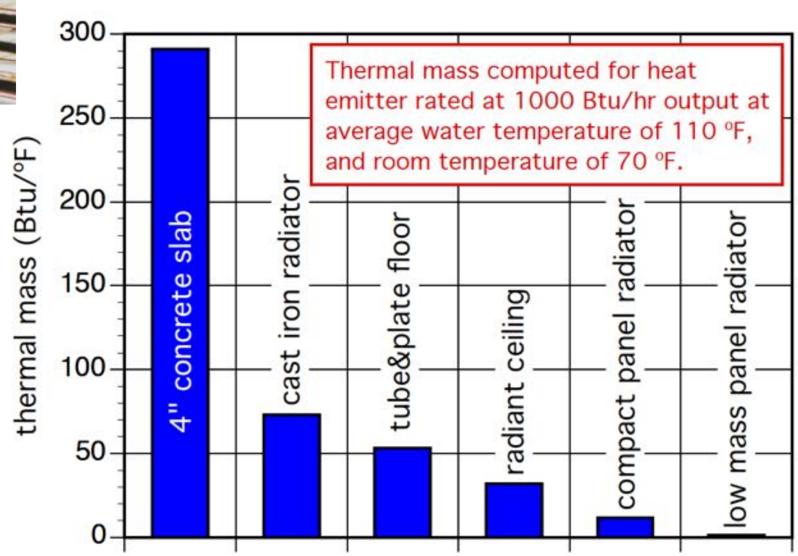
$$T_f = \frac{q}{2} + T_r$$

Tf = average floor surface temperature (°F)
Tr= room air temperature (°F)
q=heat flux (Btu/hr/ft^2)

To deliver 10 Btu/hr/ft^2 the floor only has to exceed the room temperature by 5 degrees F. Thus, for a room at 68 degrees F the average floor surface temperature is only about 73 degrees F.

*This is not going to deliver "**barefoot friendly floors**" - as so many ads for floor heating promote.*

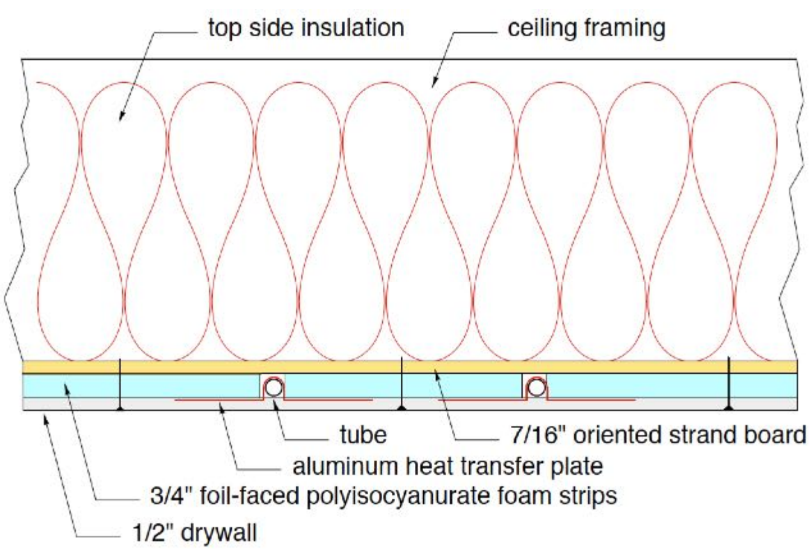
A comparison of THERMAL MASS for several heat emitters: All heat emitters sized to provide 1000 Btu/hr at 110 °F average water temperature, and 70 °F room temperature:

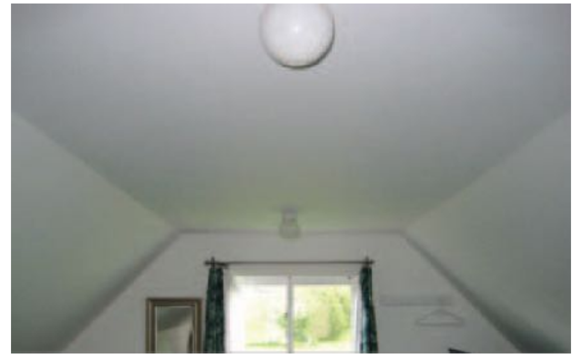


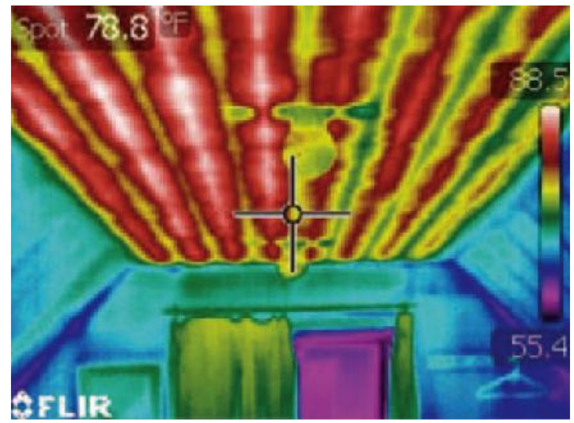
Low thermal mass heat emitters are generally preferred in low load buildings - due to fast response characteristic

fan-assisted panel radiator

Site built radiant CEILINGS...







Thermal image of radiant ceiling in operation

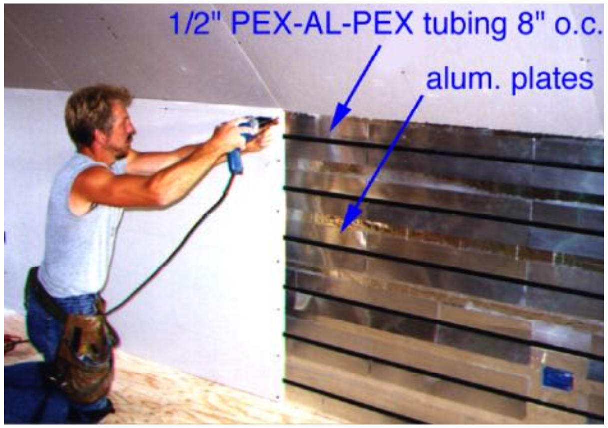
Heat output formula:

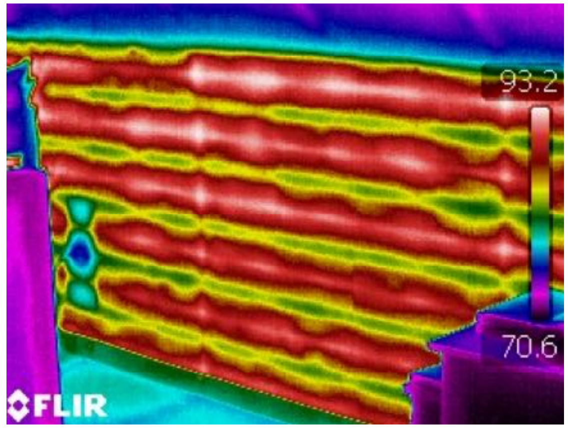
$$q = 0.71 \times (T_{water} - T_{room})$$

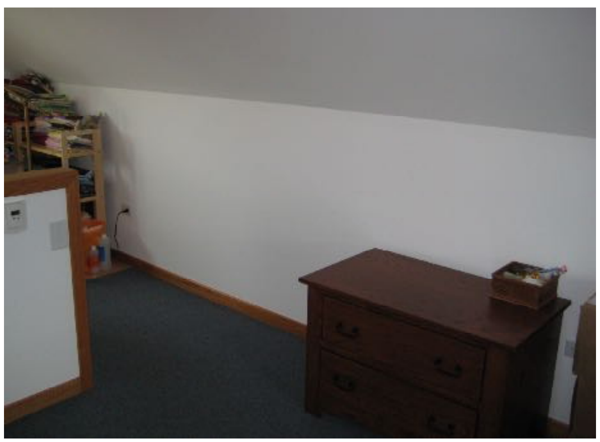
Where:

Q = heat output of ceiling (Btu/hr/ft²)
T_{water} = average water temperature in panel (ºF)
T_{room} = room air temperature (ºF)

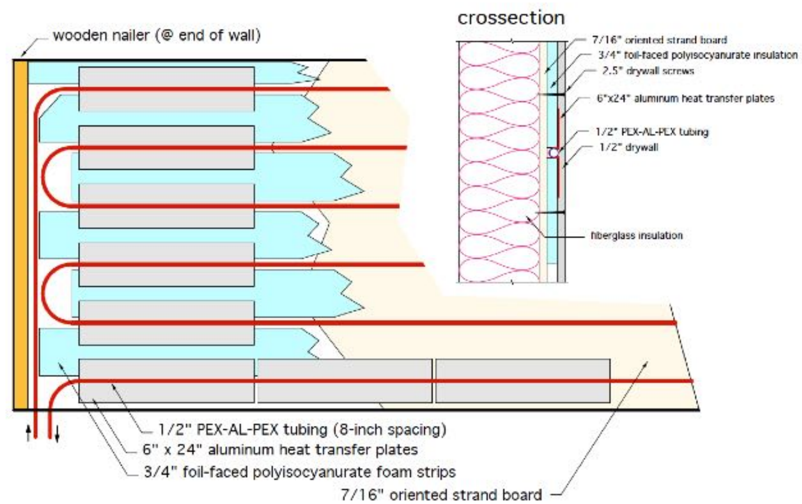
Site built radiant WALLS...







- completely out of sight
- low mass -fast response
- reasonable output at low water temperatures
- stronger than conventional drywall over studs
- don't block with furniture



Heat output formula (for above construction):

$$q = 0.8 \times (T_{water} - T_{room})$$

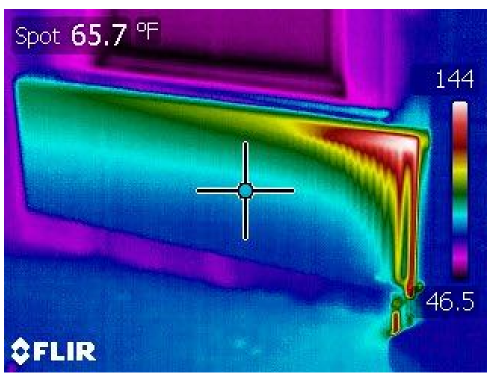
Where:

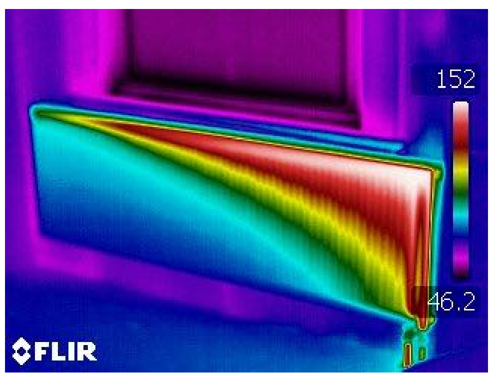
Q = heat output of wall (Btu/hr/ft^2)
T_{water} = average water temperature in panel (ºF)
T_{room} = room air temperature (ºF)

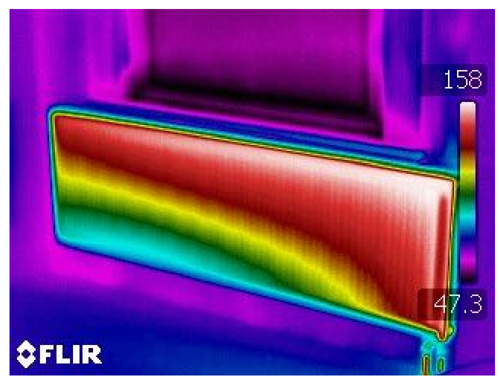
Hydronic heat emitters options for low energy use houses

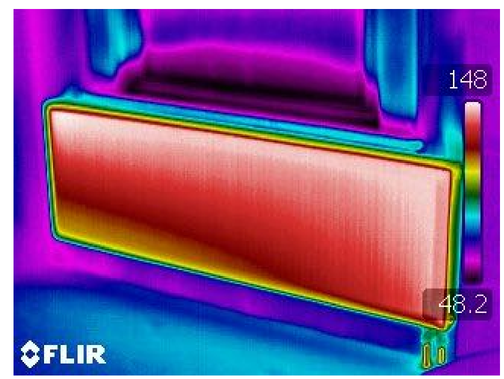
Panel Radiators

Panel Radiators respond quickly…







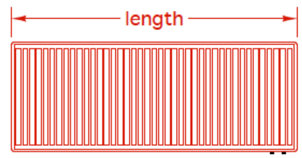


From setback to almost steady state in <u>4 minutes</u>…

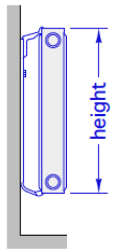
Hydronic heat emitters options for low energy use houses

Panel Radiators

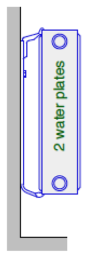
- Adjust heat output for operation at lower water temperatures.



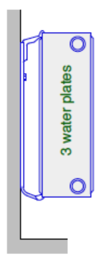
Heat output ratings (Btu/hr)
at reference conditions:
Average water temperature in panel = 180°F
Room temperature = 68°F
temperature drop across panel = 20°F



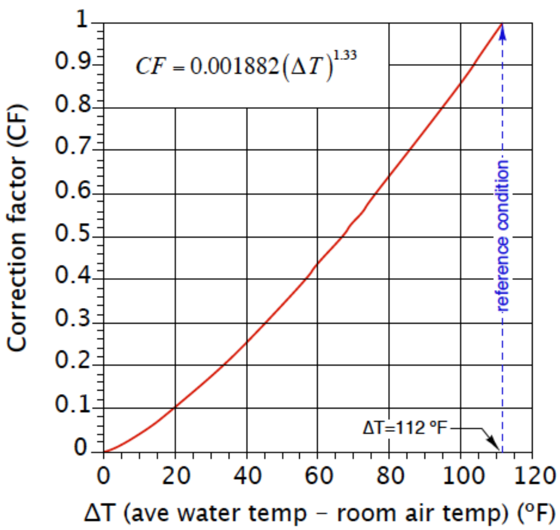
1 water plate panel thickness	16" long	24" long	36" long	48" long	64" long	72" long
24" high	1870	2817	4222	5630	7509	8447
20" high	1607	2421	3632	4842	6455	7260
16" high	1352	2032	3046	4060	5415	6091



2 water plate panel thickness	16" long	24" long	36" long	48" long	64" long	72" long
24" high	3153	4750	7127	9500	12668	14254
20" high	2733	4123	6186	8245	10994	12368
16" high	2301	3455	5180	6907	9212	10363
10" high	1491	2247	3373	4498	5995	6745



3 water plate panel thickness	16" long	24" long	36" long	48" long	64" long	72" long
24" high	4531	6830	10247	13664	18216	20494
20" high	3934	5937	9586	11870	15829	17807
16" high	3320	4978	7469	9957	13277	14938
10" high	2191	3304	4958	6609	8811	9913



Reference condition:
Ave water temp. in panel = 180°F
Room air temperature = 68°F

As an approximation, a panel radiator operating with an average water temperature of 110 °F in a room room maintained at 68 °F, provides approximately 27 percent of the heat output it yields at an average water temperature of 180 °F.

Fan-assisted Panel Radiators

- **Wider availability in Europe**
- **Designed to operate with 104 ºF water**
- **Expect more offerings in North America**

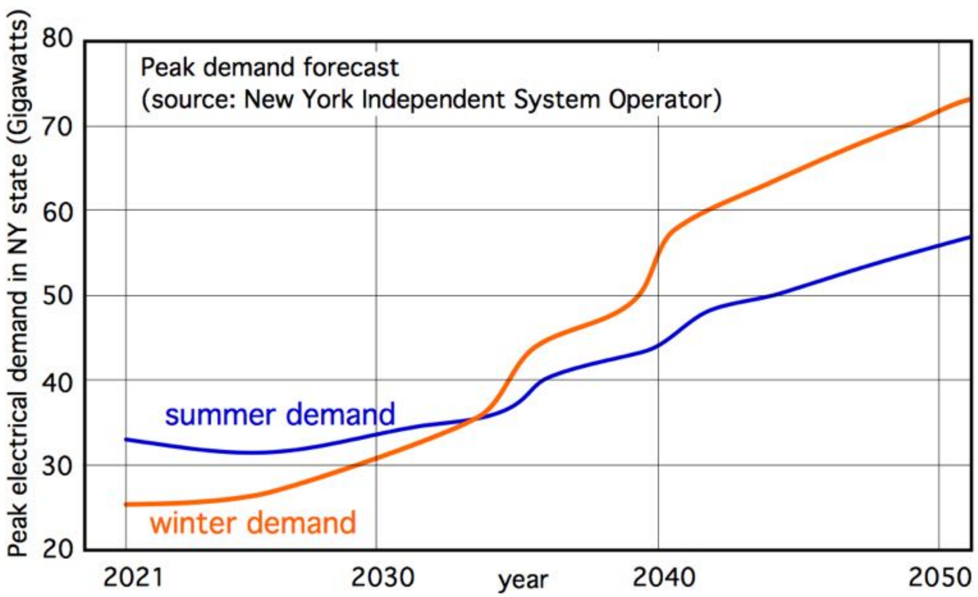
Courtesy of Vogel & Noot

What about retrofitting existing hydronic systems in buildings transitioning to electric HVAC?

A rational path toward electrification

1. Can the utility grids handle rapid and extensive shift from all fossil fuels to electricity?

2. Should all existing hydronic heat sources operating on fossil fuel be immediately scrapped and replaced by heat pump?



Hydronics technology can enable a rational transition…

Don’t write off existing (or new) boilers, in combination with air-to-water heat pumps

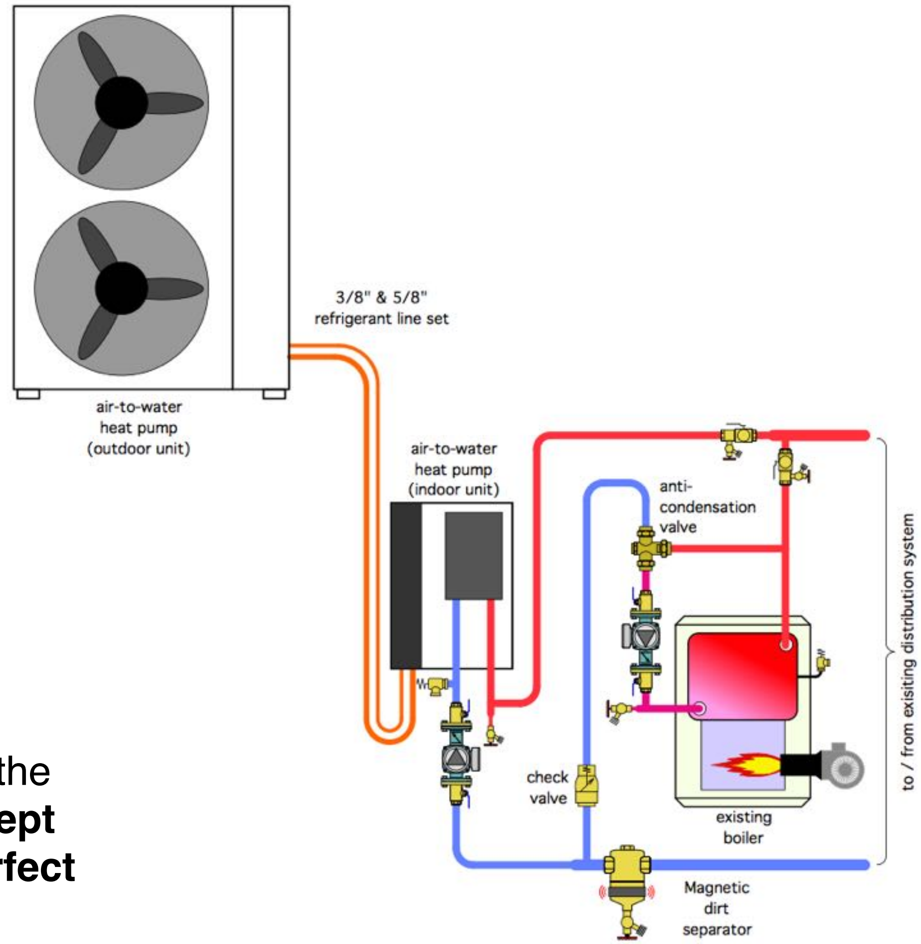
The existing (or new) boiler can provide 4 important functions:

1. Supplemental heat during extreme cold weather.

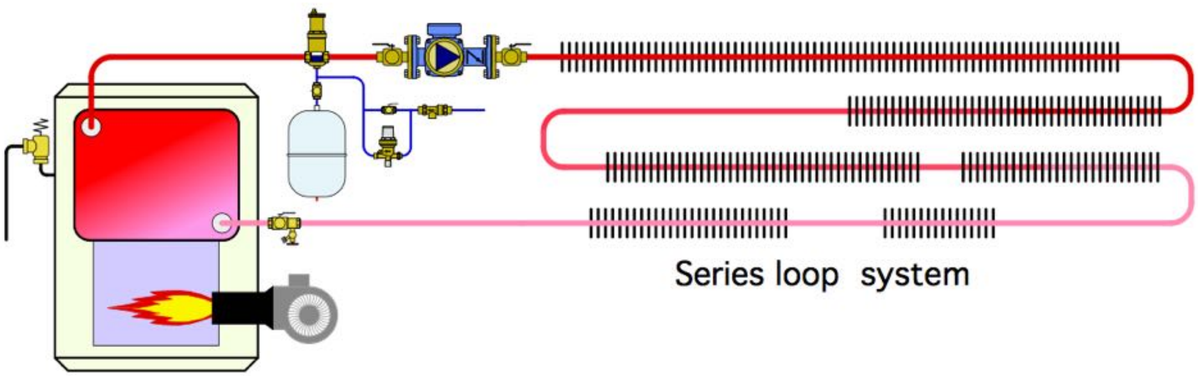
2. Backup heating if heat pump is down for servicing.

3. Backup heat powered from a *small* generator during a utility outage *(400 watts to operate boiler vs. 4000 watts to operate heat pump).*

4. One of the biggest challenges to electric utility planners is how to meet peak winter loads if many buildings have air-source heat pumps with electric resistance backup. Having a non-electric boiler in the system reduces this issue. **This “dual fuel” concept needs to be promoted, and hydronics is the perfect “media” to implement it.**

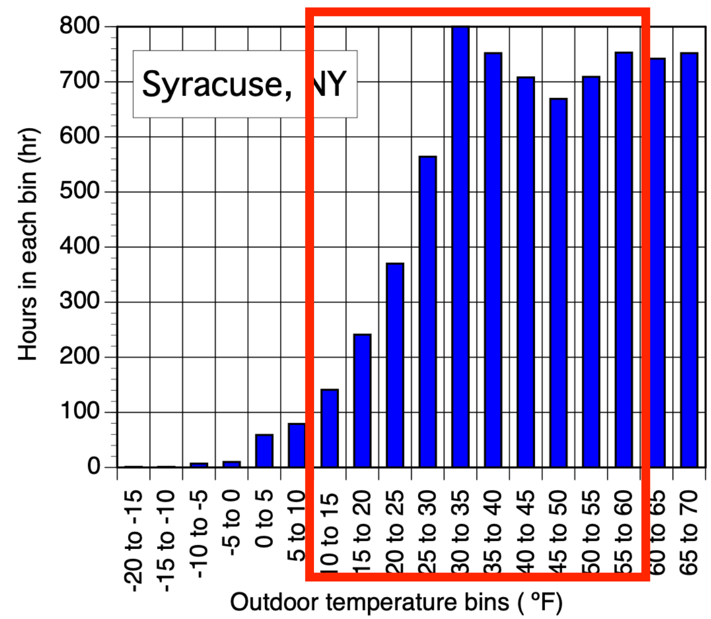


Existing hydronic distribution systems are usually designed for high temperature water (160 to 200 °F **at design load**)



These temperatures cannot be supplied by current generation heat pumps.

However, the vast majority of space heating energy use does NOT occur at or near design load. →



Air to water heat pumps can contribute the majority of space heating energy use during partial load conditions.

75+ % of seasonal load can be met without extensive modification of the higher temperature distribution system.

NYSERDA is current funding development of an air-to-water heat pump simulator

NYSERDA Air to Water Heat Pump Simulator Beta 1.01

Automatic Calculations ON Checked

Current Date: 2/4/22

Apply Defrost Data

Use Alternate Heat Pump

Go to Help Sheet

Inputs

BUILDING LOAD INPUTS			Range
Design Heating Load Building	40,000	Btu/hr	10,000 to 200,000
Inside air temperature required	70	°F	60 to 80
Outdoor temperature at design load	2	°F	-10 to 40
Average hourly internal heat gain	3,413	Btu/hr	0 to 17,000
Space heating supply water temperature required at design load	100	°F	100 to 180

HEATPUMP SELECTION	
◉	SpacePak LAHP air to water heat pump
○	Enertech AV060 air to water heat pump
○	Nordic ATW-65 air to water heat pump

LOCATION OF STUDY	
○	Albany
○	Binghamton
○	Brooklyn
○	Buffalo
○	Glens Falls
○	Jamestown
○	Lake Placid
○	Massena
○	Old Forge
○	Plattsburg
○	Rochester
◉	Syracuse
○	Utica
○	Watertown

ENTER HEAT PUMP CIRCULATOR POWER			Range
Electrical power required by heat pump circulator	150	watts	0 to 500

DOMESTIC WATER HEATING INPUTS			Range
Gallons per day domestic hot water required	60	gallons	0 to 120
Required domestic hot water delivery temperature	120	°F	100 to 140
Seasonal average cold water temperature at site	50	°F	40 to 65

BUILDING COOLING LOAD INPUTS			Range
Inside air temperature required for cooling comfort	75	°F	72 to 82
Chilled water temperature required by cooling coil	50	°F	40 to 60
Sensible heat ratio	0.70		0.60 to 0.90
SEER of supplemental cooling source	14.0	Btu/hr/watt	7 to 22

Inputs

FINANCIAL INPUTS			Range
Installed cost of air-to-water heat pump system	$20,000		$5,000 - $60,000
% Downpayment applied installation cost	0	%	% of IC, 0-100%
% Upfront rebate to deduct from installed cost	0	%	0 to 50% of IC
Term of loan (if any) to finance system installation	5	Years	0 to 20 years
Design life of heat pump system	15	Years	10 to 25 years,
Cost of electricity	0.15	$/kwhr	0.03 to 0.50 $/kwhr
Annual % increase in electrical cost	1.0	%	0 to 5 %
Annual % interest earned on capital if downpayment remained invested	1.0	%	0 to 5 %
% Income tax rate of owner	25.0	%	0 to 40 %
% Interest rate for loan	5.0	%	0.5 to 15 %

ALTERNATE HEAT PUMP THERMAL INPUTS			Range
Alternate heat pump seasonal average COP	3.0		1.5 to 4.0
Alternate heat pump seasonal average SEER	14	Btu/hr/watt	10 to 22
Supplemental cooling source SEER	14	Btu/hr/watt	10 to 22
% of space heating load covered by alternate heat pump	95	%	75 to 100
% of cooling load covered by alternate heat pump	100	%	75 to 100

ALTERNATE HEAT SOURCE FINANCIAL INPUTS			Range
Installed cost of alternate heat pump system	$20,000		$5,000-$60,000
% downpayment on alternate heat pump system	50	%	% of IC, 0-100%
Rebate (if any) on alternate heat pump system (% of installed cost)	0.0	%	0 to 50%
Term of loan (if any) to finance alternate heat pump system	5	years	0 to 20
% Interest rate of loan (if any) to finance alternate heat pump system	5	%	1 to 10%
Design life of alternate heat pump system	15	years	10 to 25

Outputs

HEATING OUTPUTS for air-to-water heat pump		
Annual building space heating energy required=	87.26	MMBtu
Heating season space heat & DHW energy supplied by air-to-water heat pump=	96.71	MMBtu
Heating season space heat & DHW energy supplied by auxiliary heat source=	3.324	MMBtu
Annual hours of air-to-water heat pump HEATING operation=	2,208.4	hrs
Heating season average COP of air-to-water heat pump =	3.10	

COOLING OUTPUTS for air-to-water heat pump		
Annual building cooling energy required =	1.056	MMBtu
Annual cooling energy supplied by air-to-water heat pump =	1.056	MMBtu
Annual cooling energy supplied by supplemental cooling source =	0.000	MMBtu
Annual hours of air-to-water heat pump cooling operation =	23.0	hrs
Seasonal average EER of air-to-water heat pump =	11.08	Btu/hr/watt

FINANCIAL OUTPUTS for air-to-water heat pump	
Total building heating cost over system design life =	$24,420.14
Total building cooling cost over system design life =	$230.14
Downpayment =	$0.00
Monthly loan payment =	$377.42
Total owning & operating cost over system design life =	$47,295.75

ALTERNATE HEAT PUMP FINANCIAL OUTPUTS	
Total building heating cost over system design life =	$19,549.34
Total building cooling cost over system design life =	$182.11
Downpayment =	$10,000.00
Monthly loan payment =	$188.71
Total owning & operating cost over system design life =	$36,813.61

Detailed models for heat pumps, hydronic heat emitters, and building loads.

Uses an “aggressive” model for derating capacity and COP based on defrosting.

Simulates specific air-to-water heat pumps in a range of NYS climates.

Allows input for domestic water heating load, as well as space heating and cooling loads.

Allows comparison with other heat pump options.

Here are some results

location	ALBANY	BROOKLYN	PLATTSBURG
design heating load (Btu/hr)	54,000	41,831	59,327
electric cost ($/kwhr)	$0.12	$0.21	$0.05
cost of AWHP	$15,000	$18,000	$15,000
cost of AAHP	$9,500	$11,400	$9,500
assumed ave COP of AAHP	2	2.2	2.0
ave COP of AWHP (180ºF water @ design)	2.64	2.89	2.70
ave COP of AWHP (140 ºF water @ design)	2.8	3.06	2.78
ave COP of AWHP (30% load reduction allowing 147ºF water @ design load)	2.74	3.05	2.75
ave COP of AWHP (30% load reduction & 60 GPD DHW	2.79	3.08	2.76
% of space heat & DHW load covered by AWHP, no modification of hydronic system or load	**84.2%**	**84.0%**	**81.0%**
% of space heat & DHW load covered by AWHP (w/ 30% load reduction & 60 GPD DHW	**96.3%**	**95.8%**	**97%**
15 yr life cycle O&O cost of AWHP assuming 30% load reduction & 60 GPD of DHW	$30,481	$37,356	$20,451
15 yr life cycle O&O cost of AAHP assuming 30% old reduction & 60 GPD of DHW	$33,723	$43,294	$18,488

The house modeled was based on 1970s vintage thermal envelope, 1800 square foot house with design load of 30 Btu/hr/ft^2.

The design heating loads of the house were adjusted based on the outdoor design temperature so that ***the same thermal envelope is being simulated in all three locations***.

The hydronic distribution system was assumed to be fin-tube baseboard with a supply water temperature requirement of 180 °F at design load.

The air-to-water heat pump used was SpacePak LAHP 048

Based on these simulations…

location	ALBANY	BROOKLYN	PLATTSBURG
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15 yr life cycle O&O cost of AAHP assuming 30% old reduction & 60 GPD of DHW	$33,723	$43,294	$18,488

• **The air-to-water heat pump is providing 84 to 97% of the seasonal space heating + DHW energy, even using an unmodified “high temperature” baseboard distribution system.**

• Adding heat emitters to lower design load water temperature from 180 ºF to 140 ºF improves seasonal COP about 6%.

• Reducing the design load by 30% through envelope improvements, which allows design load water temperature to drop from 180 to 147ºF improves seasonal COP 4-6%.

• Reducing the design load by 30%, which allows design load water temperature to drop from 180 to 147ºF **and including 60 GPD of domestic water heating (50-120ºF)** increases seasonal COP 5-7%

• 15 year life cycle total owning and operating cost of the air-to-water heat pump system is competitive with that of an air-to-air heat pump combined with electric resistance domestic water heating.

• **Looking forward - using a low ambient air-to-water heat pump in a low energy building envelope is likely to show seasonal COPs of 3.0 or higher.**

Lowering water temperatures in existing hydronic systems

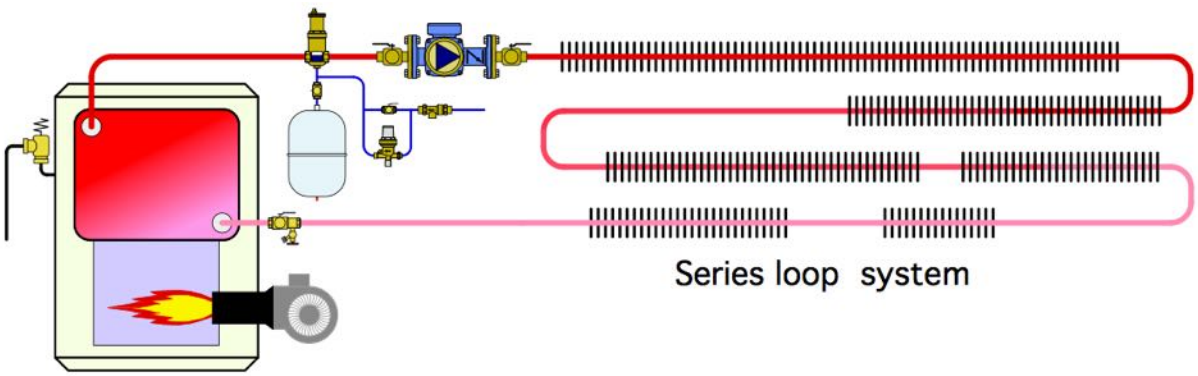
Two ways to reduce the supply water temperature of any hydronic heating system:

1. Reduce the design load of the building envelope through improvements such as added insulation, better windows and reduced air leakage.

2. Add heat emitters to the existing system.

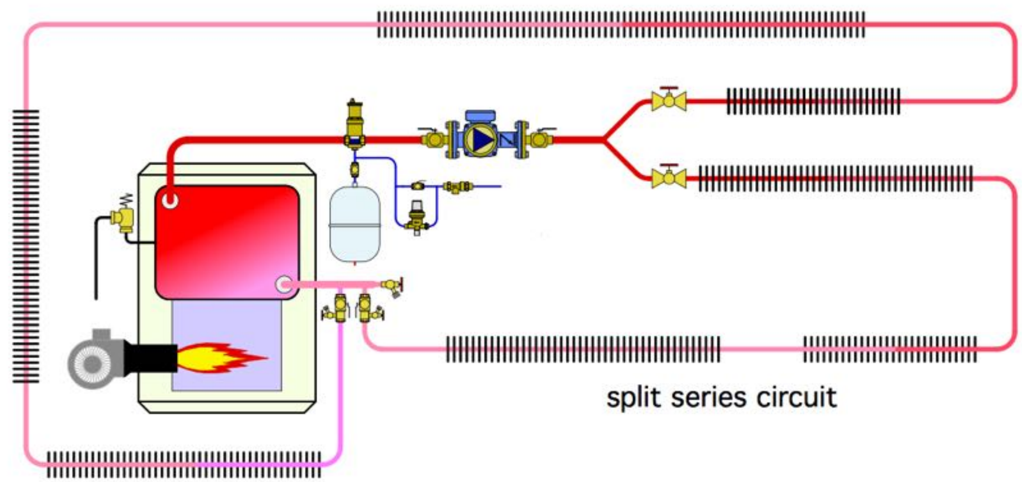
Combinations of these two approaches are also possible.

Retrofitting existing high temperature distribution systems



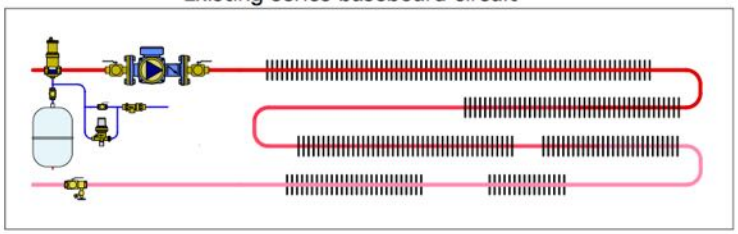
Common piping configurations for residential fin-tube baseboard systems.

Fin-tube typically sized based on supply water temperatures (180-200 °F) at design load conditions.

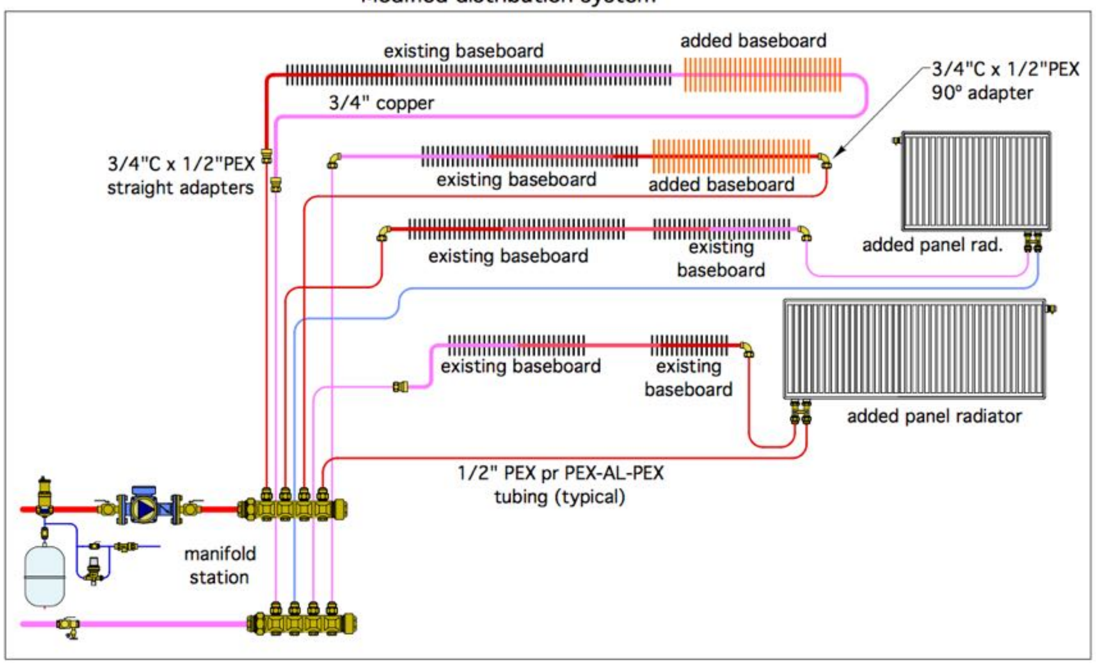


Convert the series system to a parallel system

Existing series baseboard circuit



Modified distribution system

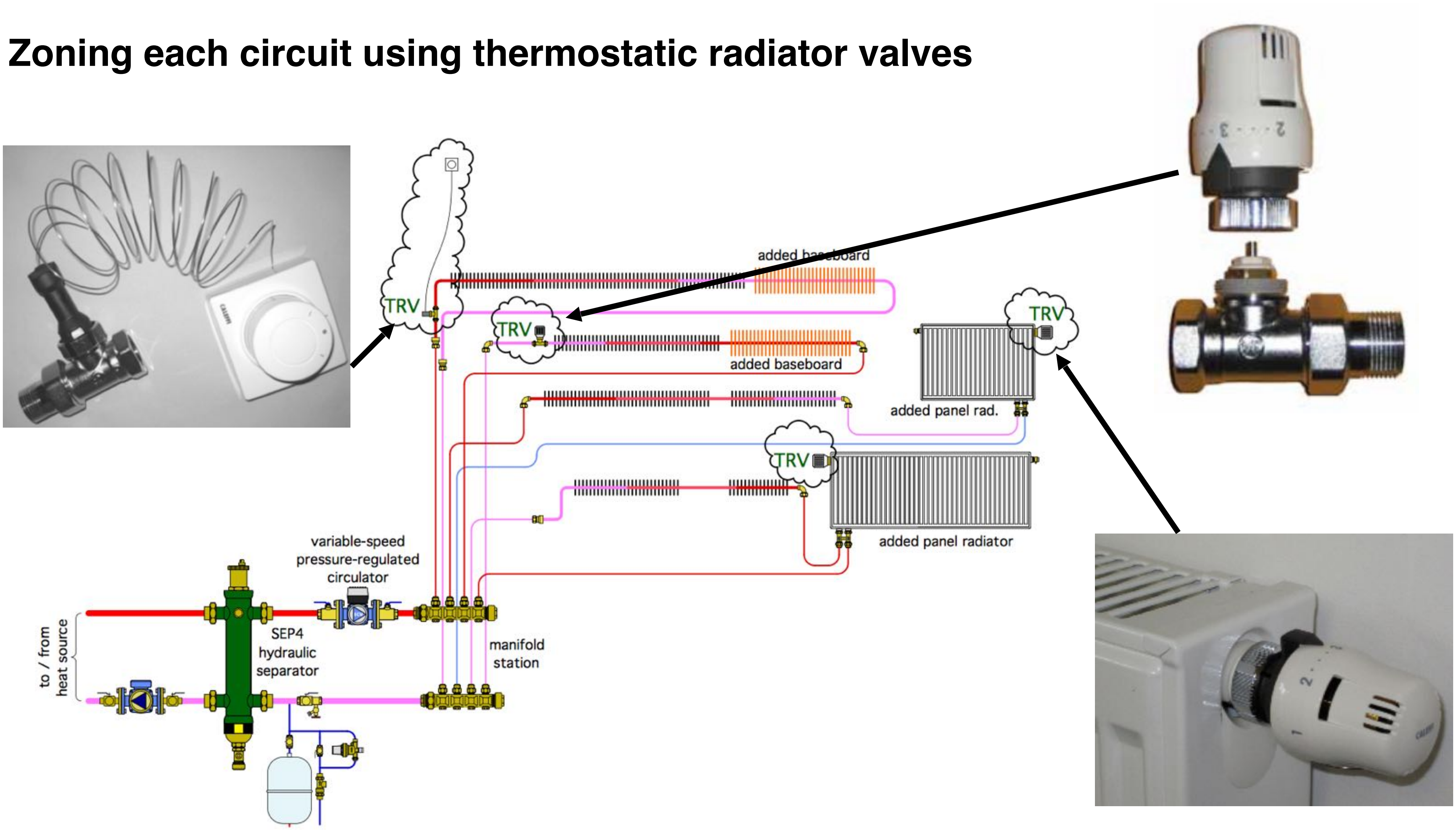


• Parallel piping of heat emitters is preferred over series piping because is ***eliminates sequential temperature drop*** from one heat emitter to another.

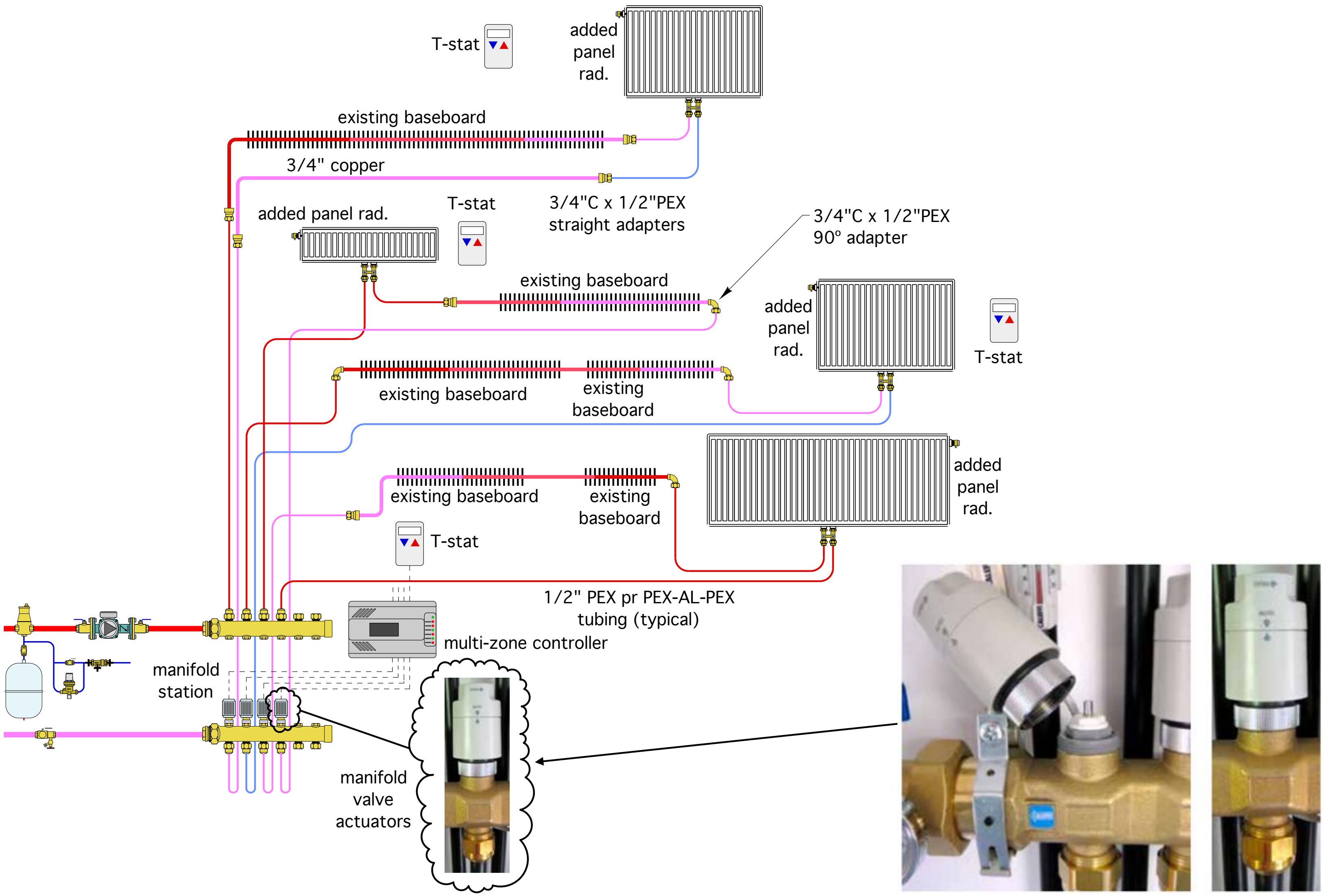
• Parallel piping also allows for ***easier zoning and flow balancing***.

•Likely easier to "morph" distribution system from series to parallel using homerun circuits of 1/2" PEX or PEX-AL-PEX.

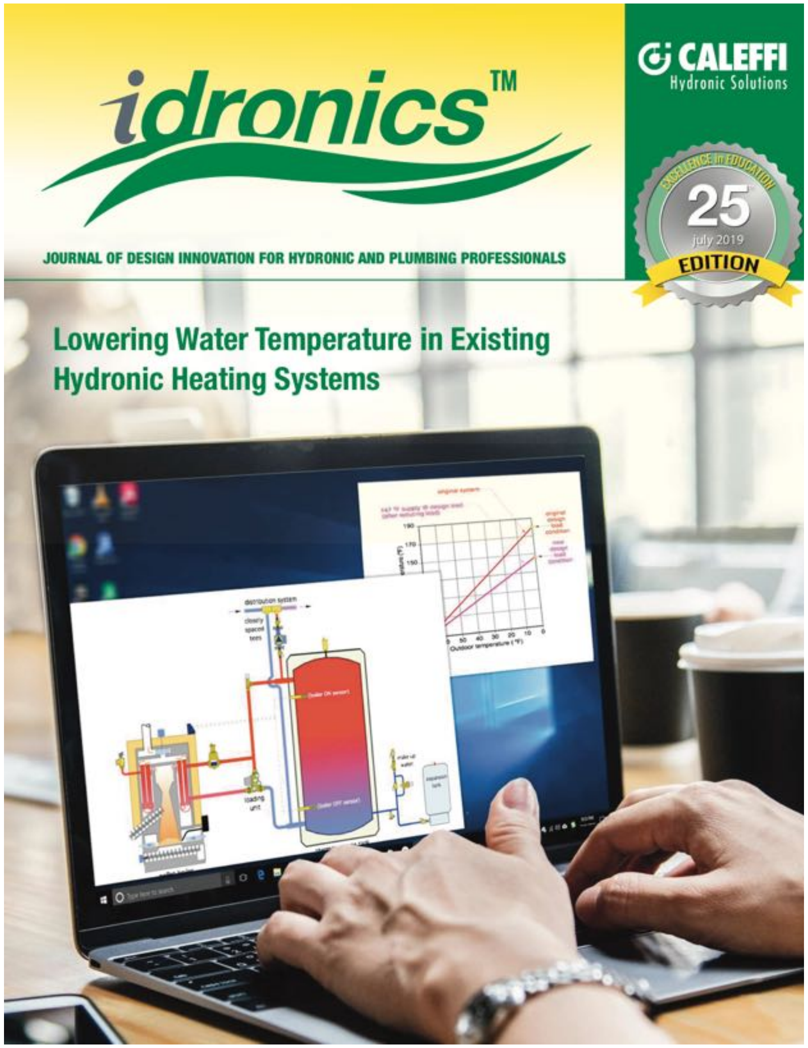
Zoning each circuit using thermostatic radiator valves

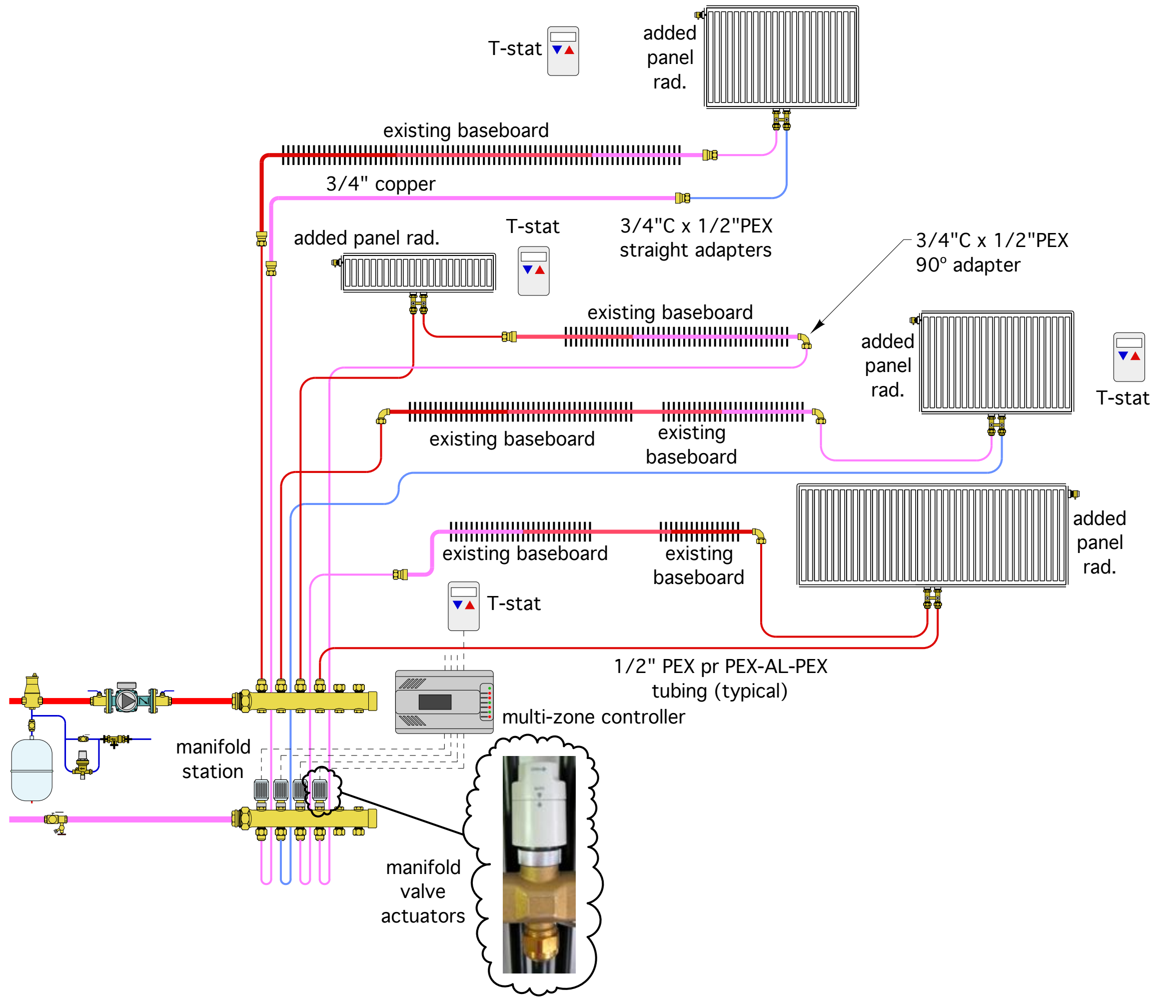


Zoning each circuit using manifold valve actuators



idronics #25 covers water temperature reduction in detail



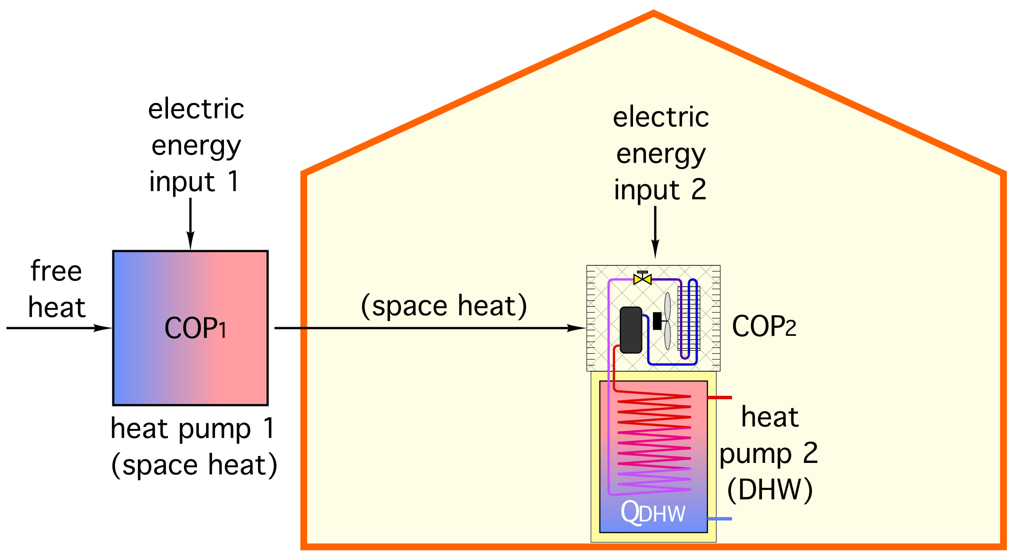


What about domestic hot water?

It’s natural to think that using an air-source heat pump for space heating, along with a heat pump water heater for domestic hot water is a good solution…

+

Combining an air-to-air heat pump with a heat pump water heater



$$COP_{net} = \frac{\text{outdoor (free) heat delivered to domestic water}}{\text{electrical energy required}}$$

$$COP_{net} = \frac{\left(\frac{COP_1}{COP_1 - 1}\right)\left(\frac{COP_2}{COP_2 - 1}\right)}{\left[\left(\frac{COP_1}{COP_1 - 1}\right)\left(\frac{COP_2}{COP_2 - 1}\right) - 1\right]}$$

Consider an installation where the heat pump that supplies space heating is operating at a COP_1 of 4.0. The heat pump water heater is operating at a COP_2 of 3.0. The net COP based on getting free heat into domestic water would be:

$$COP_{net} = \frac{\left(\frac{COP_1}{COP_1 - 1}\right)\left(\frac{COP_2}{COP_2 - 1}\right)}{\left[\left(\frac{COP_1}{COP_1 - 1}\right)\left(\frac{COP_2}{COP_2 - 1}\right) - 1\right]} = \frac{\left(\frac{4}{4-1}\right)\left(\frac{3}{3-1}\right)}{\left[\left(\frac{4}{4-1}\right)\left(\frac{3}{3-1}\right) - 1\right]} = \frac{2}{2-1} = 2.0$$

Using a low ambient air-to-water heat pump for both space heating & domestic hot water is likely more efficient than combining an air-to-air heat pump with a heat pump water heater.

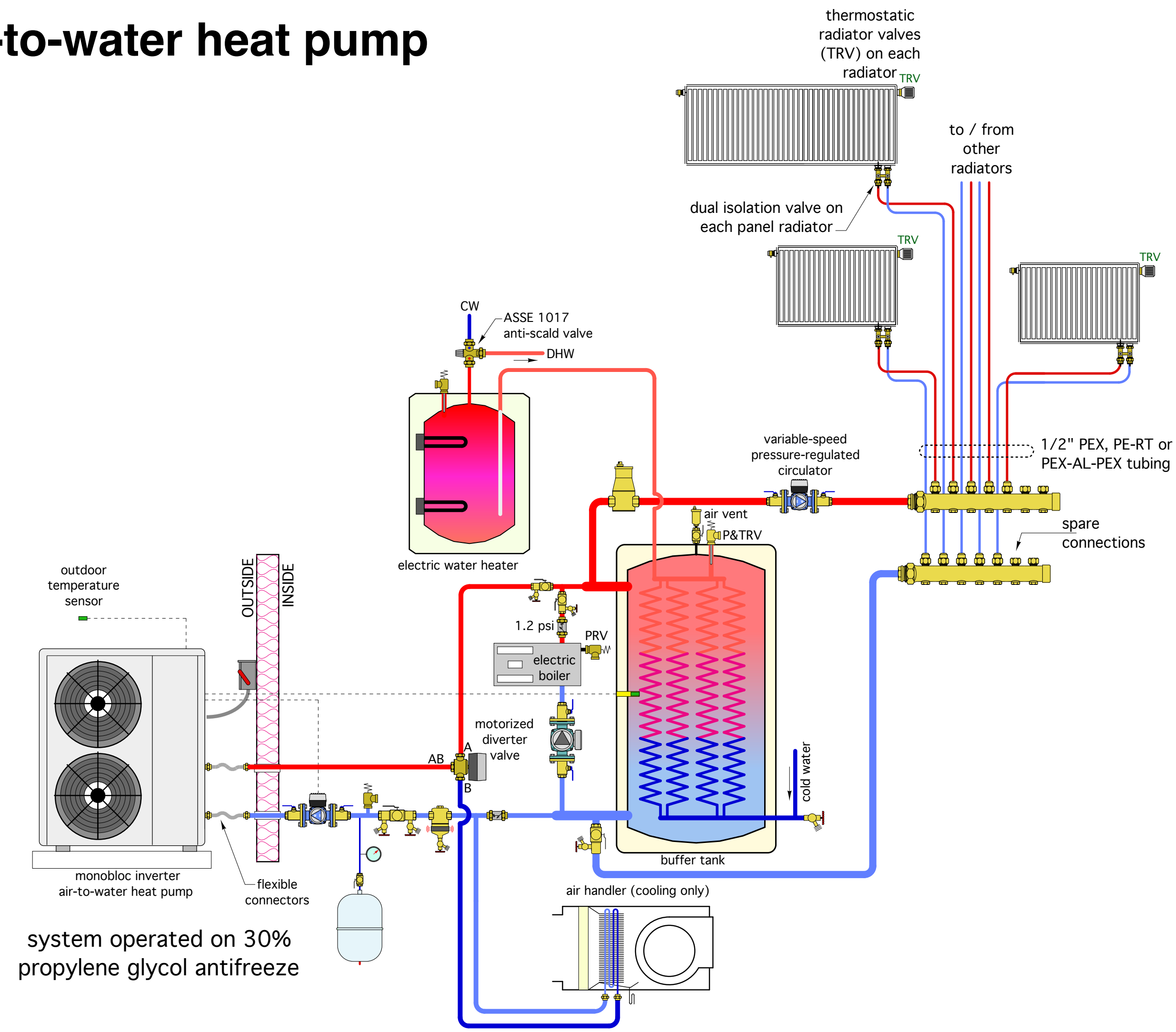
Control strategy for DHW using air-to-water heat pump

1. During heating season the buffer tank temperature is maintained based on outdoor reset control.

2. During "non-heating" season the buffer tank temperature is maintained based on setpoint control (120-130 °F) range. [warm outdoor temperatures = high COP, and high heating capacity]

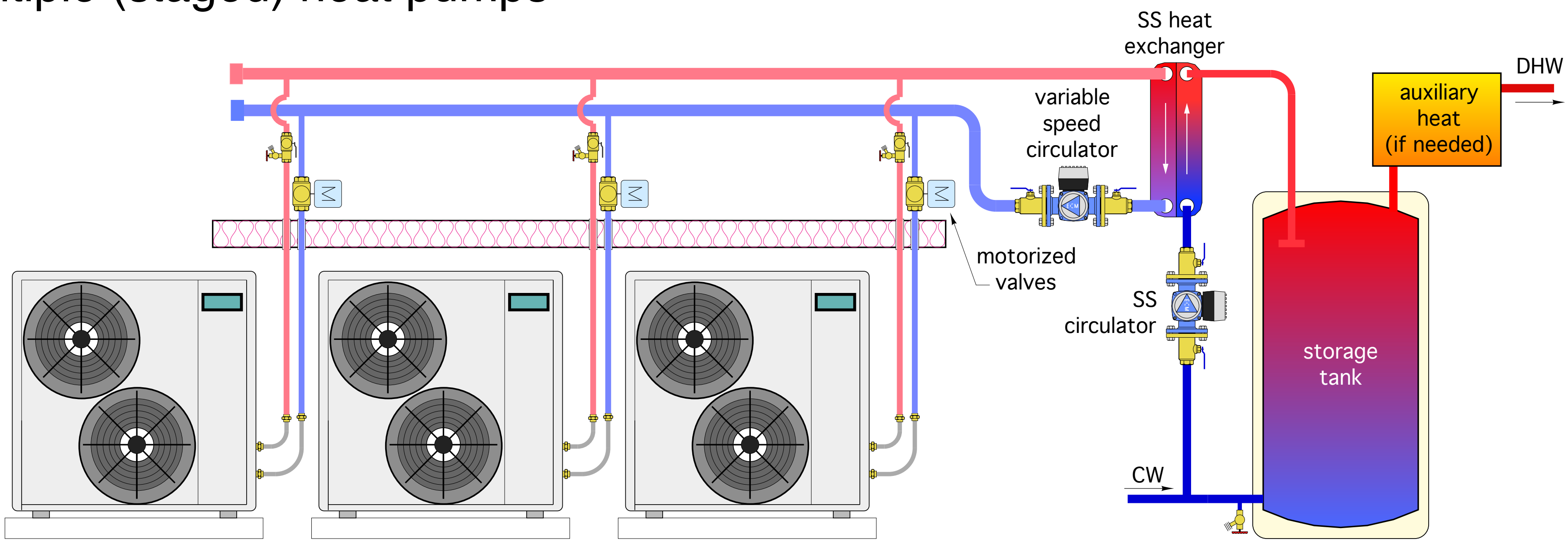
3. During cooling season, a call for cooling takes priority over call for DHW.

4. temperature-based time delay on air handler blower startup to allow fluid to "chill" down to 70 °F prior to air circulation.



Air to water heat pumps can also provide commercial DHW

• Multiple (staged) heat pumps

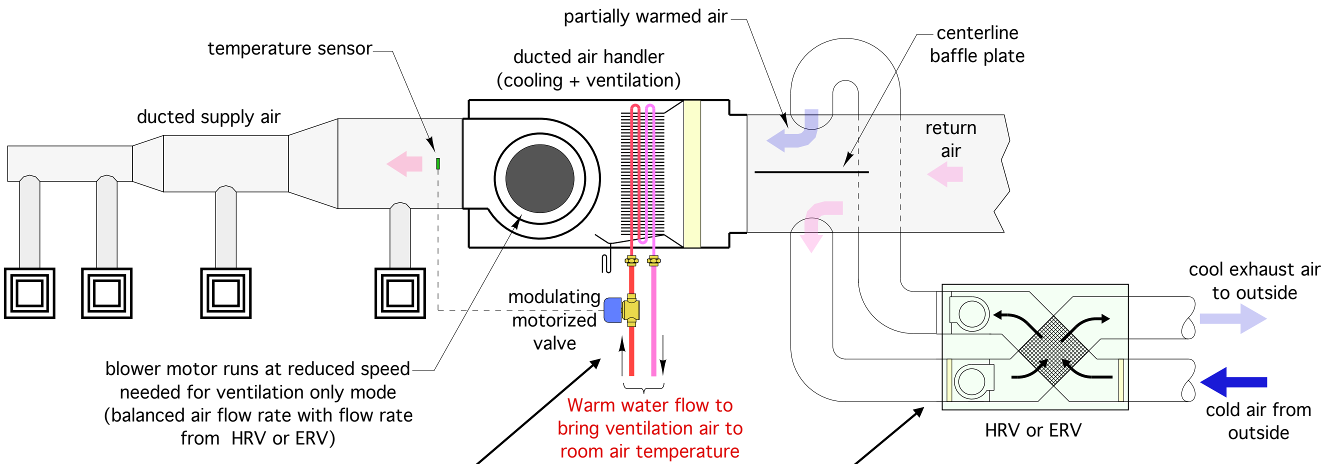


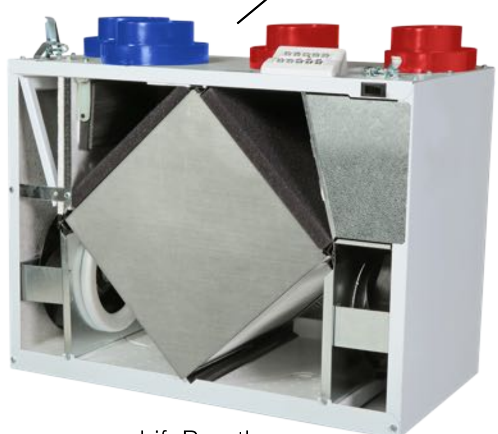
• Variable speed circulator automatically adjusts flow as heat pumps stage on & off

• Each heat pump can be isolated and serviced without system shut down.

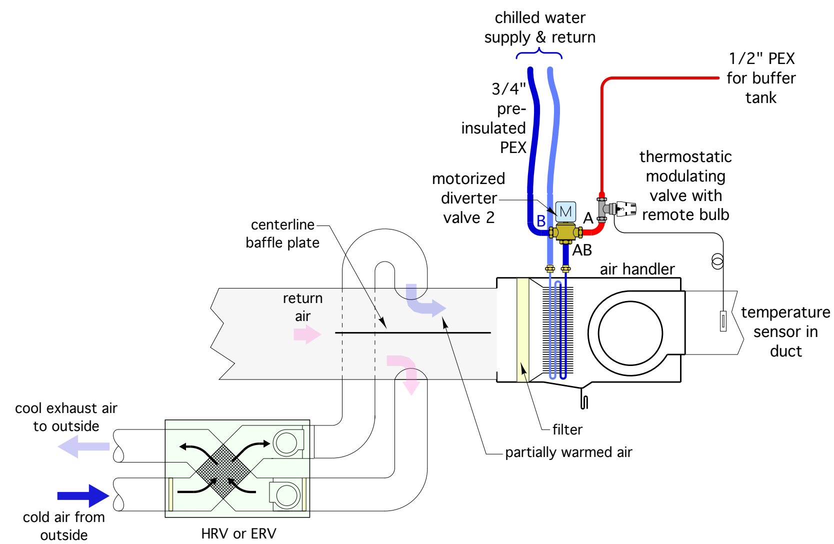
What about ventilation?

Incorporate a heat recovery ventilator with the air handling system





source: LifeBreath



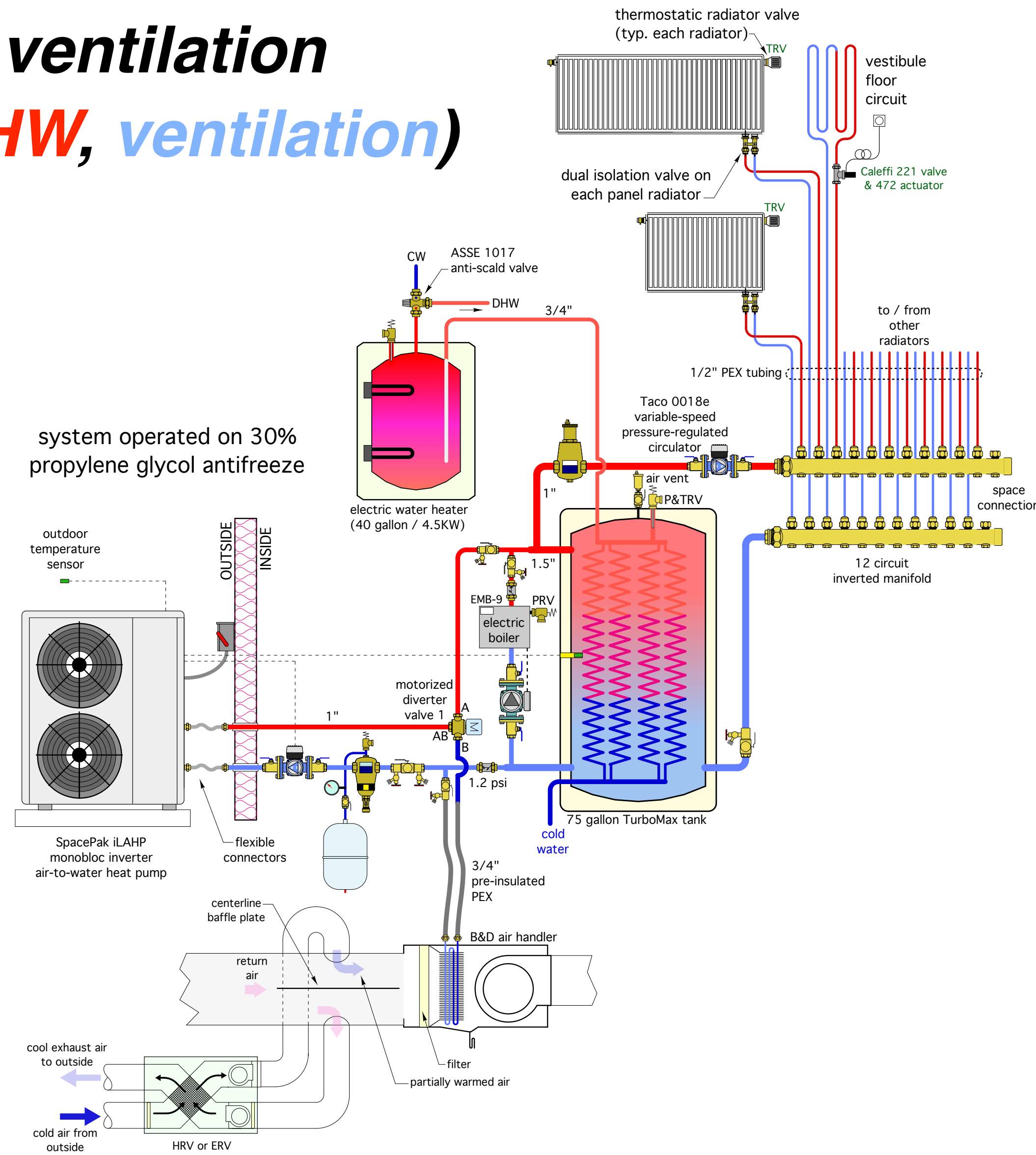
Incorporate heat recovery ventilation
(space heating, cooling,DHW, ventilation)

• A total solution for a low-energy or net-zero project

• Single source for all installation work and service

• Air handler blower can be "programmed" for low speed operation (100-150 CFM)when in ventilation only mode.

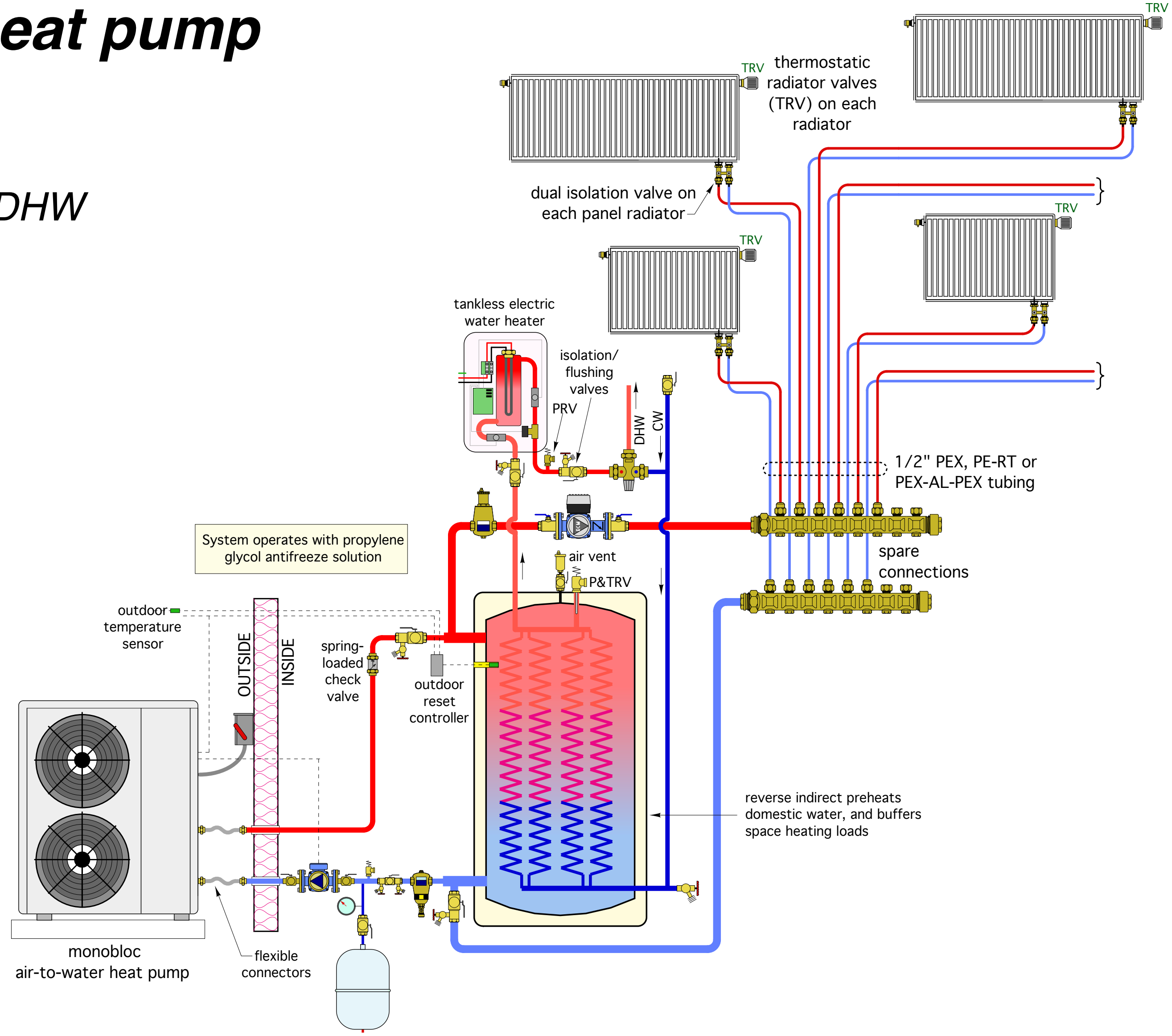
• Air handler blower can go to high speed (400 CFM per ton of capacity) for cooling.



Example systems

Monobloc air-to-water heat pump (space heating & DHW)

- *Reverse indirect provide year round DHW*
- *Tankless water heater provides boost when needed*



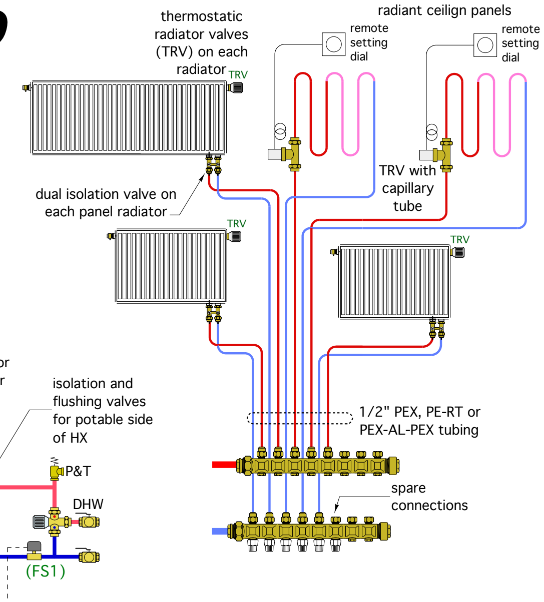
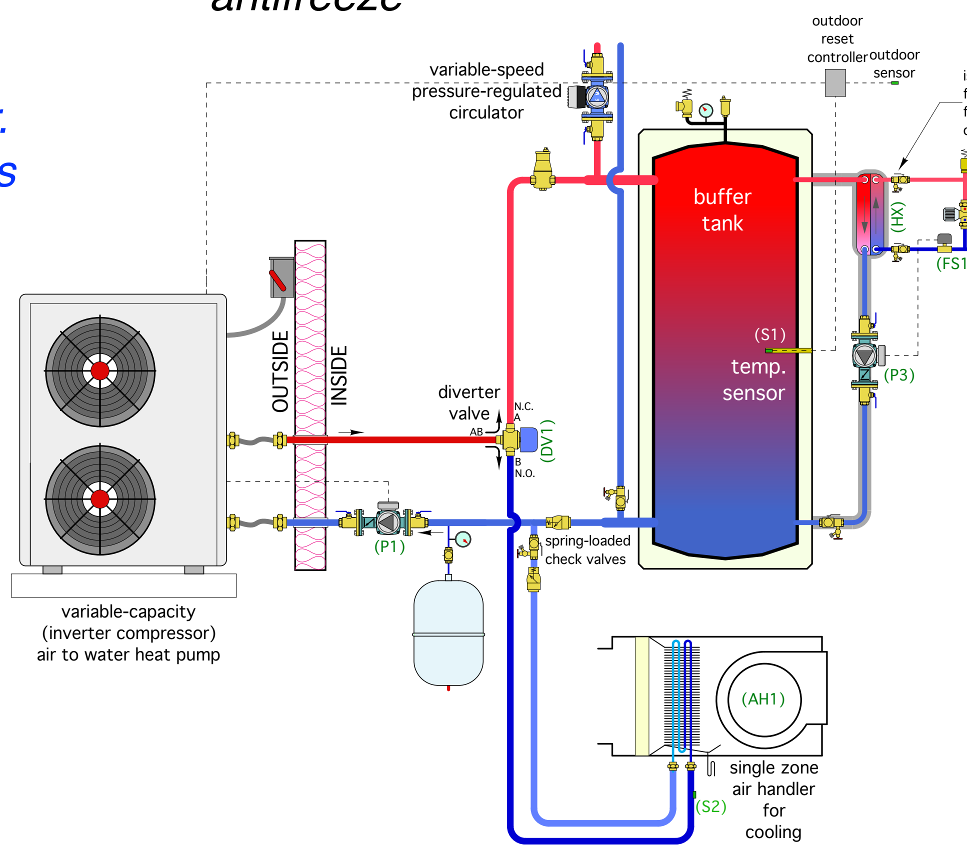
Variable speed monobloc air-to-water heat pump (space heating, cooling & DHW)

- *Buffer tank serves zoned space heating and provides DHW through brazed plate heat exchanger*

- *This system requires antifreeze*

- *Cooling via single air handler. Capacity of heat pump reduces to maintain 45ºF chilled water temperature to air handler.*

- *Homerun distribution system shows a mix of panel radiators and radiant panel circuits, all with individual thermostatic valves for room temperature control.*

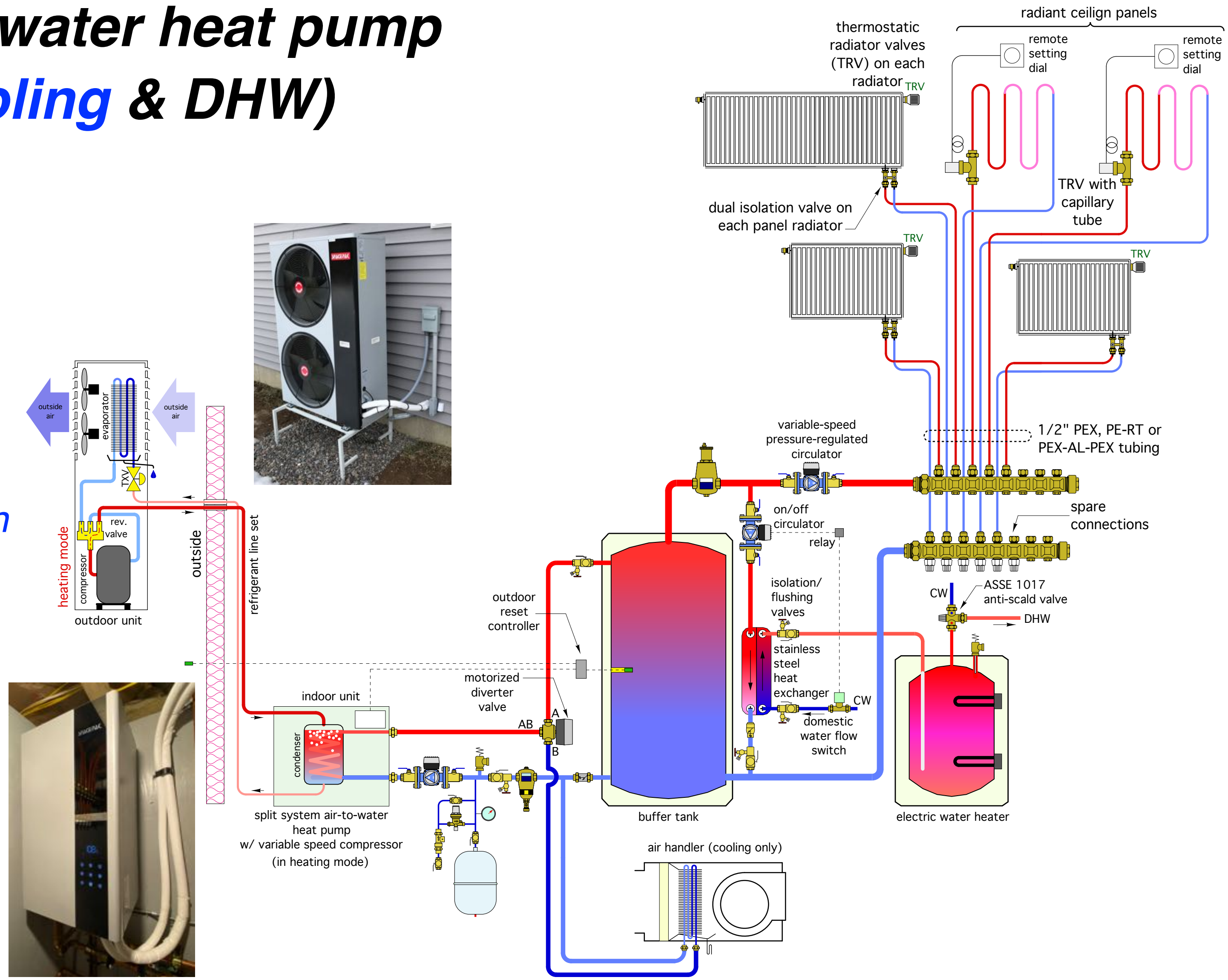
Split-system air-to-water heat pump (space heating, cooling & DHW)

- *No antifreeze required with a split system heat pump*

- *DHW preheat through external SS heat exchanger*

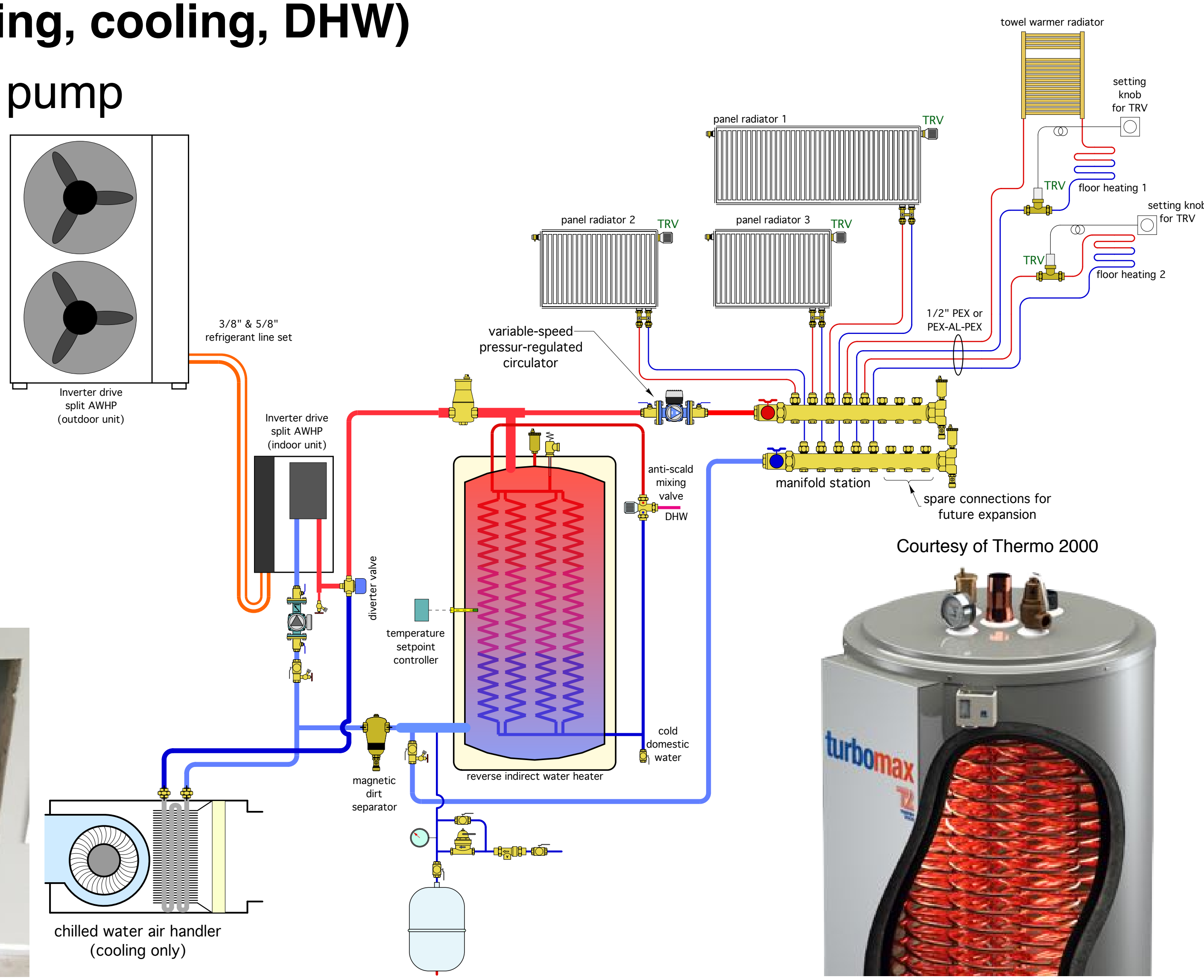
- *Heat pump cooling capacity adapts to air handler based on holding set 45-55ºF chilled water temperature.*

- *If used for cooling all chilled water piping & components would be insulated an vapor sealed.*



A complete system (heating, cooling, DHW)

- Inverter compressor heat pump
- Multi-zone heating
- Single zone cooling
- Domestic water heating
- Single tank system

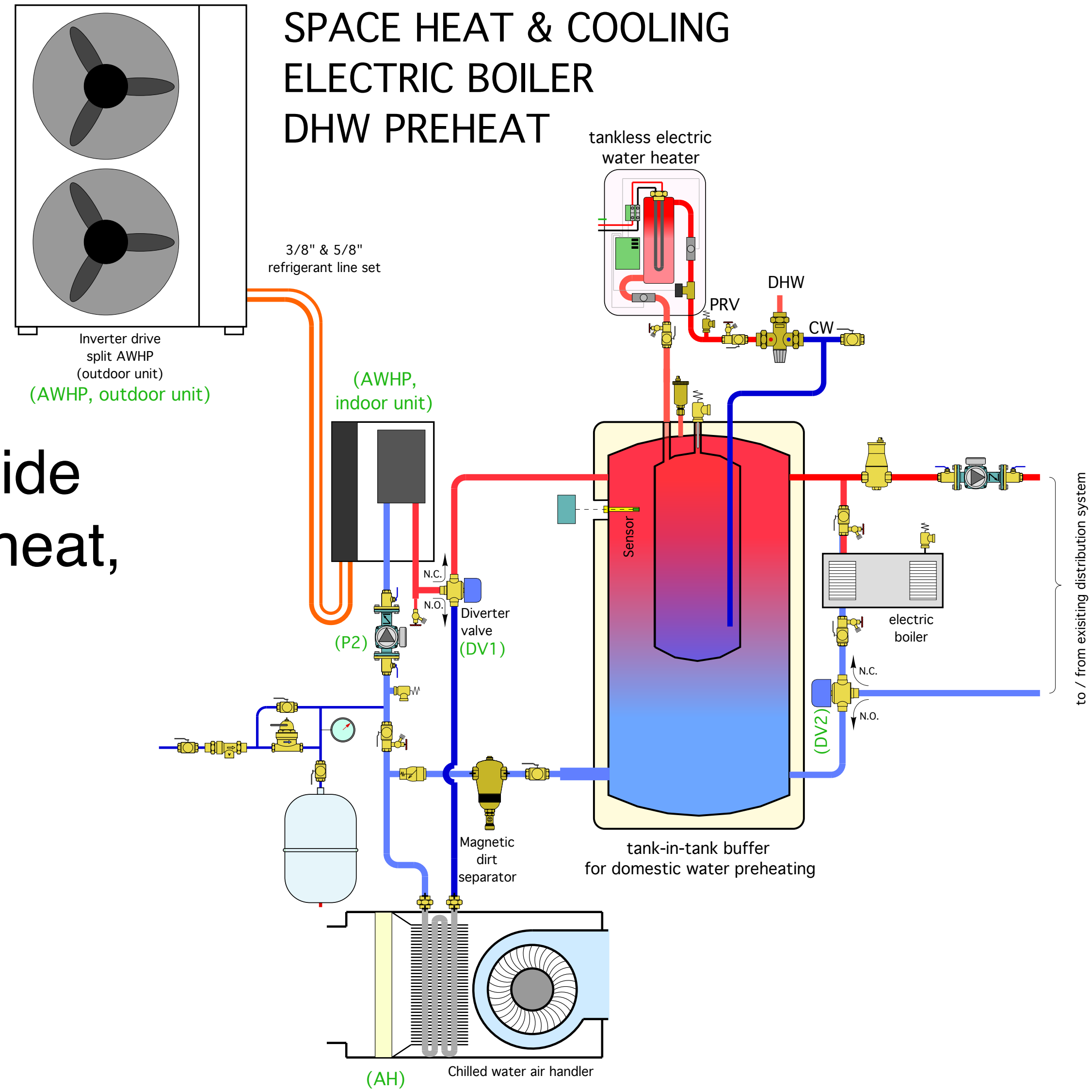


Courtesy of Thermo 2000

Domestic hot water can be preheated with one of two types of “reverse” indirect buffer tanks, then “topped off” with an electric tankless or tank-style heater.

Courtesy of ThermAtlantic

One tank can provide DHW or DHW preheat, and buffer space heating loads.

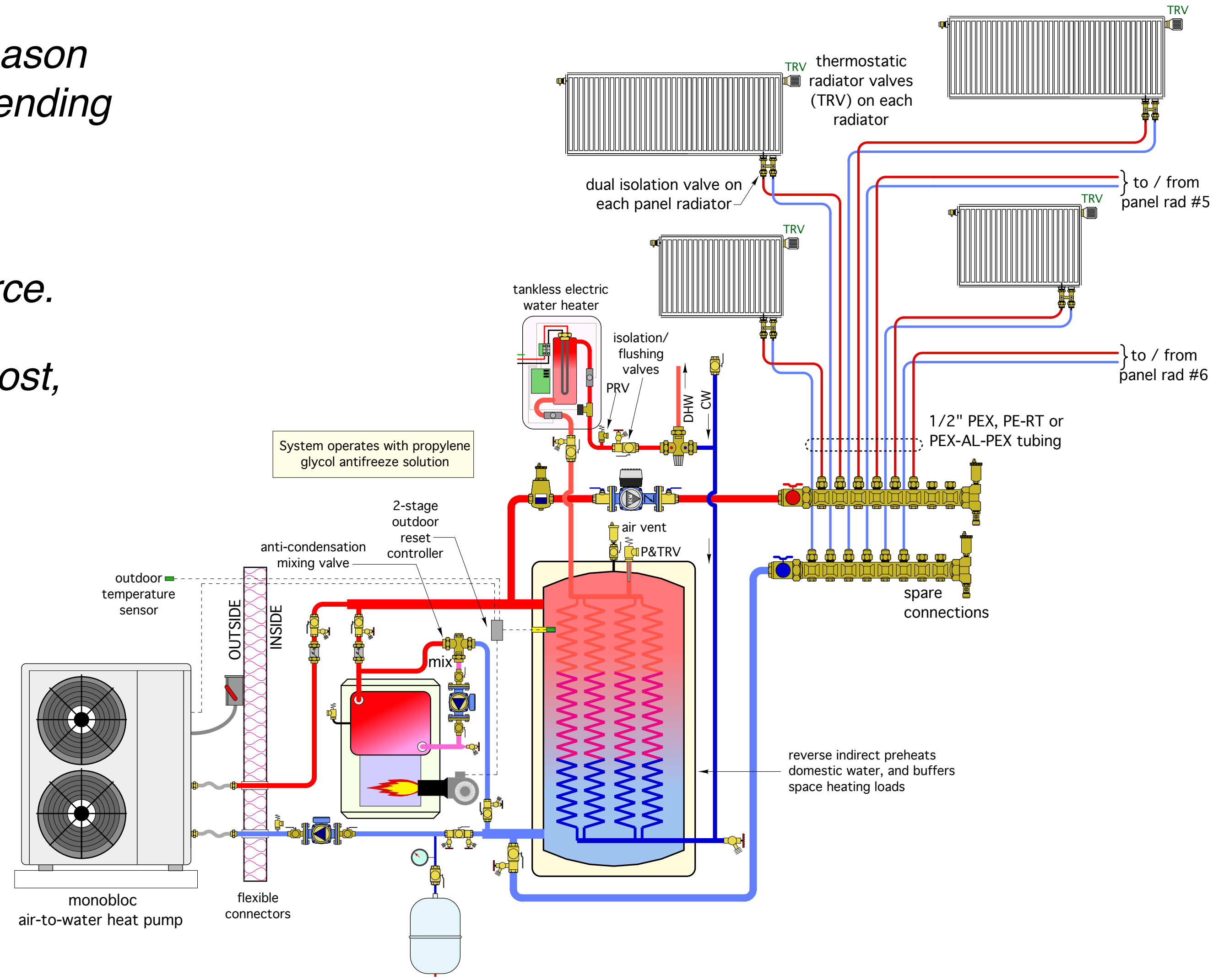


Retain existing boiler as supplemental & backup heat source

- *Heat pump provides majority of season space heating energy (75-95% depending on climate and heat emitters)*

- *Existing boiler serves as a supplemental and backup heat source.*

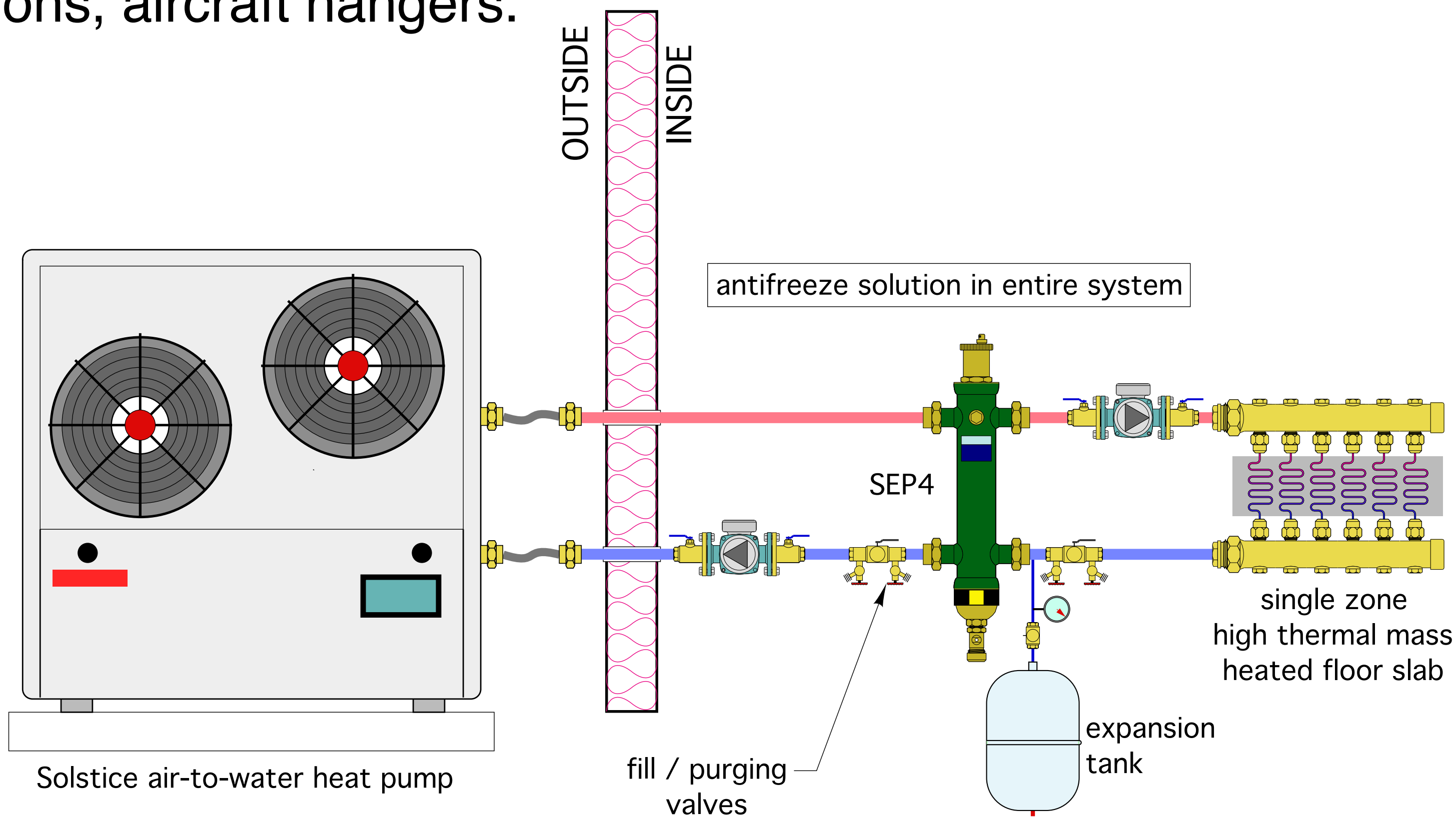
- *Tankless water heat provides a boost, when necessary, to domestic water that's preheated by heat pump .*



Some systems can be designed without a buffer tank.

Example: Single zone high mass radiant floor heating.

Excellent for use in commercial slab-on-grade buildings such as garages, fire stations, aircraft hangers.



New air-to-water system installed in Poestenkill, NY, June 2021

The house

Existing system: propane-fired furnace and water heater

Existing house:

Space heating and domestic water heating supplied by propane-fired furnace and propane-fired water heater. 300 gallon underground propane tank installed for previous owner, and ***owned by propane supplier, with exclusive filling rights***. Spring 2021 cost of propane: $3.62/gallon,(**about $44/MMBtu delivered, assuming 89% combustion efficiency**). House also has propane range and fireplace (latter is used very little). **(September 2021 price was $4.40 / gallon)**

Annual propane cost: approaching $4,000 (Invoices totaling $3585 between mid-Oct 2020 and June 2021). Estimate 90% for space heating & DHW.

Air-to-water heat pump: Enertech “Advantage” air-to-water heat pump system, installed June 2021. This heat pump provides space heating, chilled water cooling, *and close to 100% of domestic hot water*. Heating and cooling supplied through existing forced air duct system. 9 KW (30,700 Btu/hr) electric auxiliary heat contained in indoor unit of heat pump,System includes hydronic manifold station allowing for future addition of panel radiators or areas of radiant floor heating.

Approximate installation cost: $23,000.

Installing Contractor: The Radiant Store, Troy, NY (Terry Moag & Ben Melick)

Estimated annual COP of air-to-water heat pump: 2.5 (conservative estimate)

Average cost of thermal energy provided by heat pump, based on current National Grid rate of $0.125/kwhr, $14.65 / MMBtu delivered).

Estimated saving in heating /DHW cost using heat pump: $2400/year

New air-to-water system installed in Poestenkill, NY, June 2021

Enertech "Advantage" system nominal 5-ton outdoor unit

Installed (unsubsidized) cost
$23,000

Installed by The Radiant Store
(Terry Moag), Troy, NY

System has thermal and electrical
energy monitoring
(Caleffi CONTECA Btu meter)

Indoor portion of system

Enertech indoor unit

future expansion of hydronic heating (Caleffi manifold station)

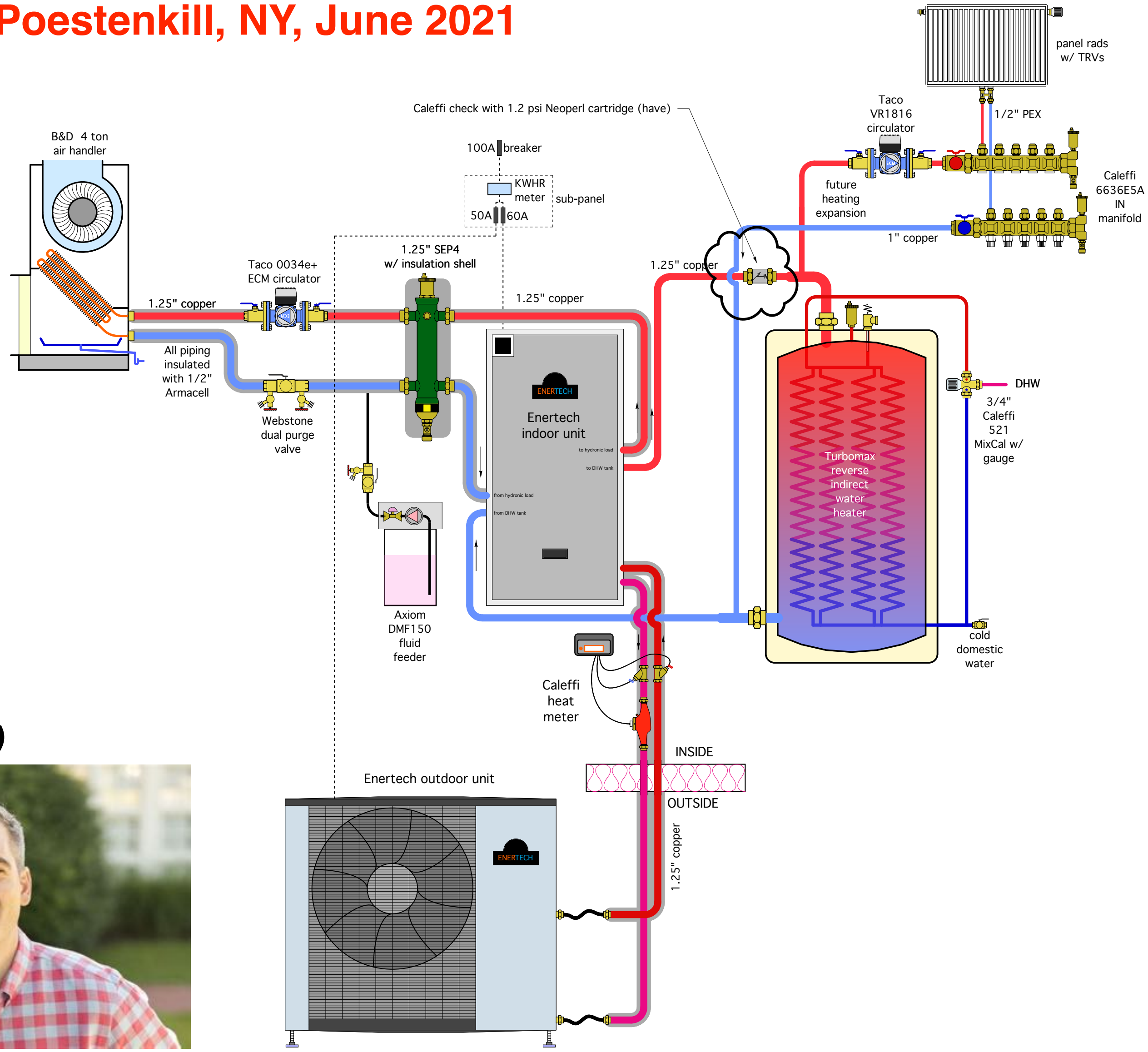
DHW tank (TurboMax)

air handler w/ chilled water coil (B&D manufacturing)

high efficiency ECM circulator (Taco 0034e+)

New air-to-water system installed in Poestenkill, NY, June 2021

Reverse indirect tank allows future hydronic expansion - such as panel radiators or towel warmers



Featured on
"This Old House"
January 2022 (Season 20, episode 13)

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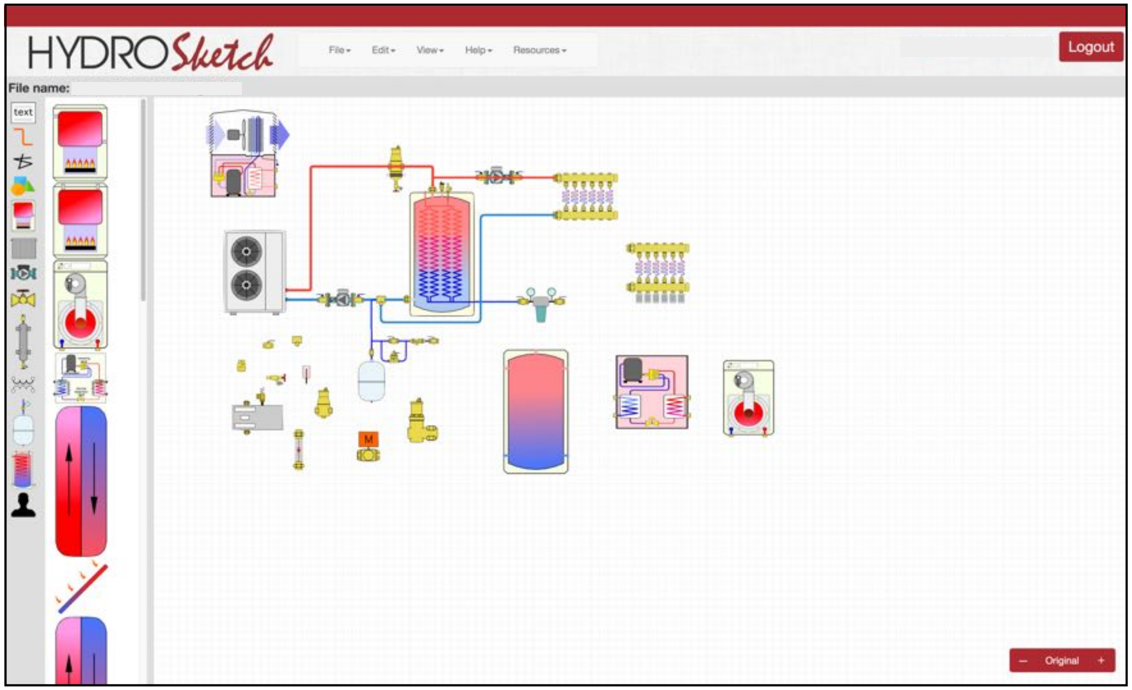
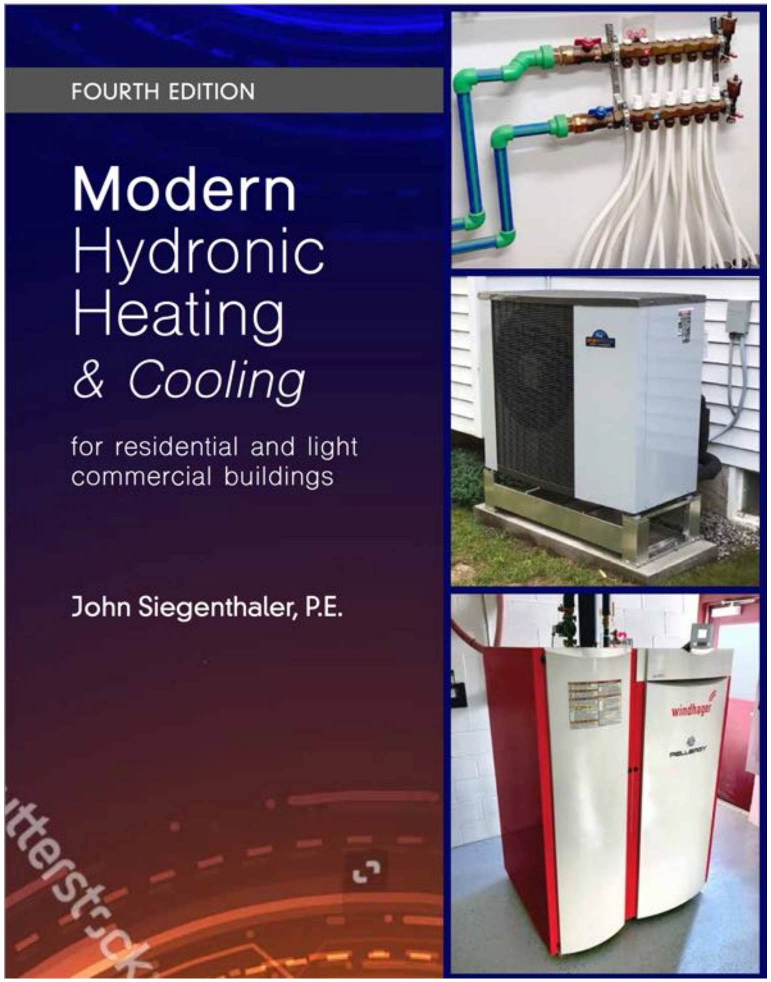


coming in APRIL 2022



QUESTIONS ?