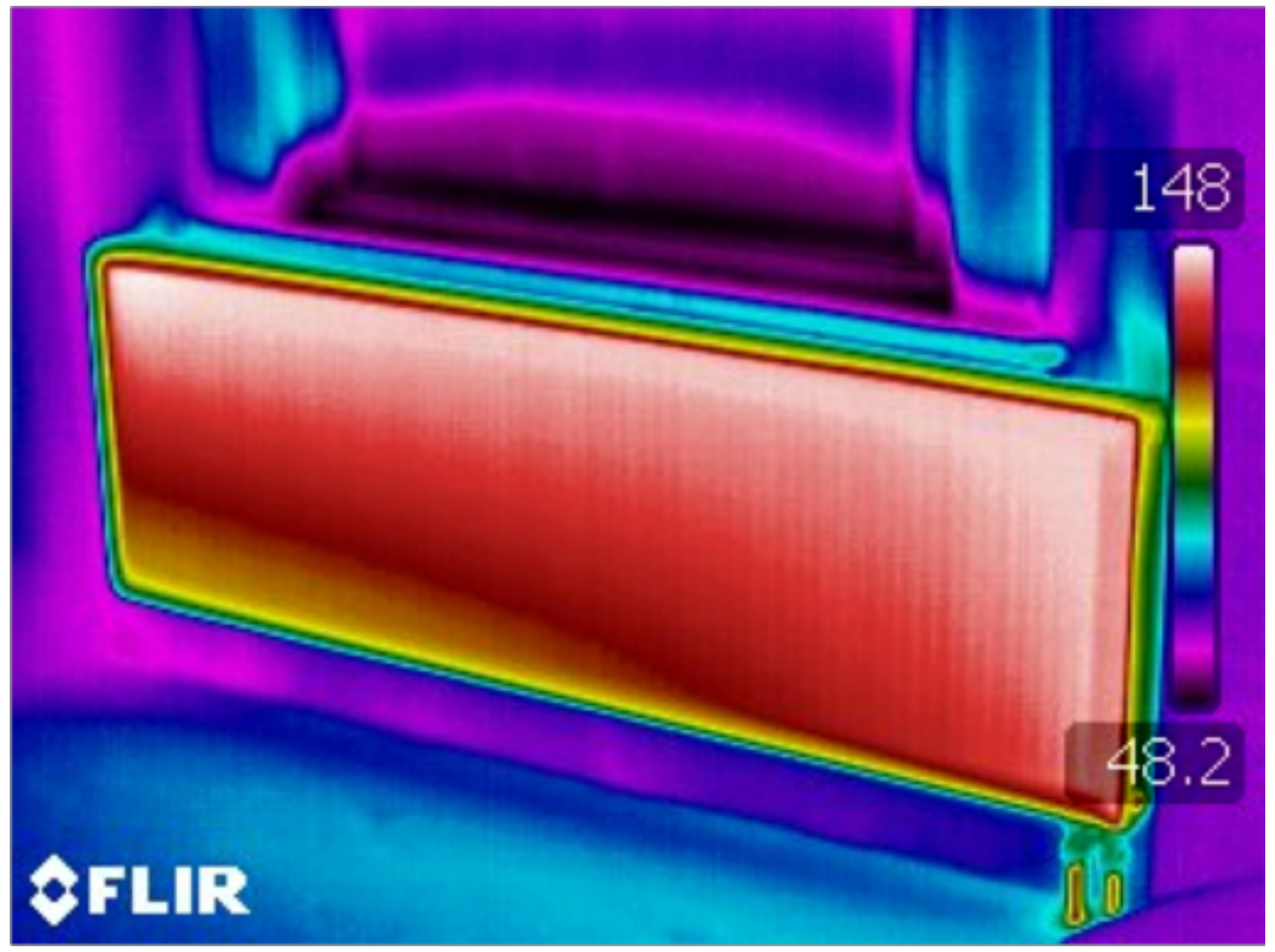
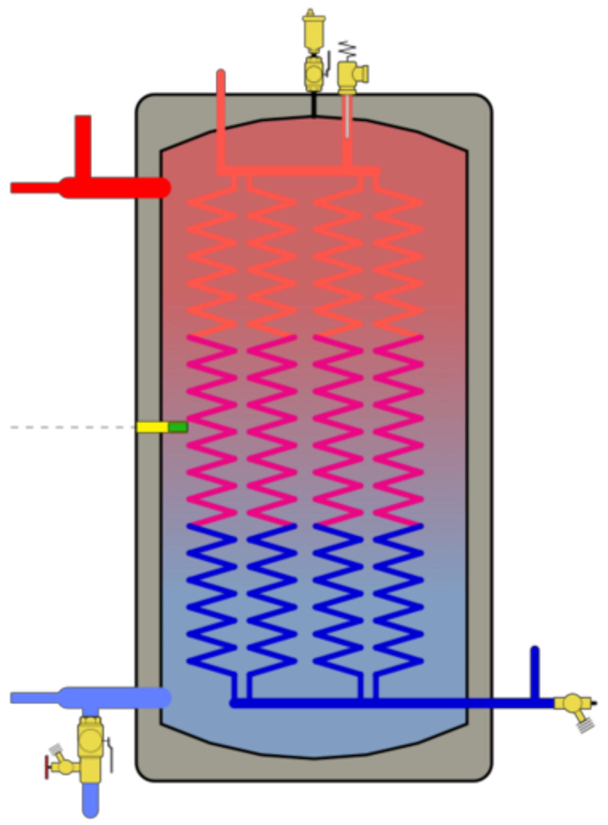
Hydronics for Net-Zero Houses (part 1)





MODERN HYDRONICS
SUMMIT 2022

Sept 15, 2022
Vaughan, Ontario Canada

Presented by:
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After 3 years of “COVID complications “ it’s great to be back in Canada…

Getting here was a bit different this time….

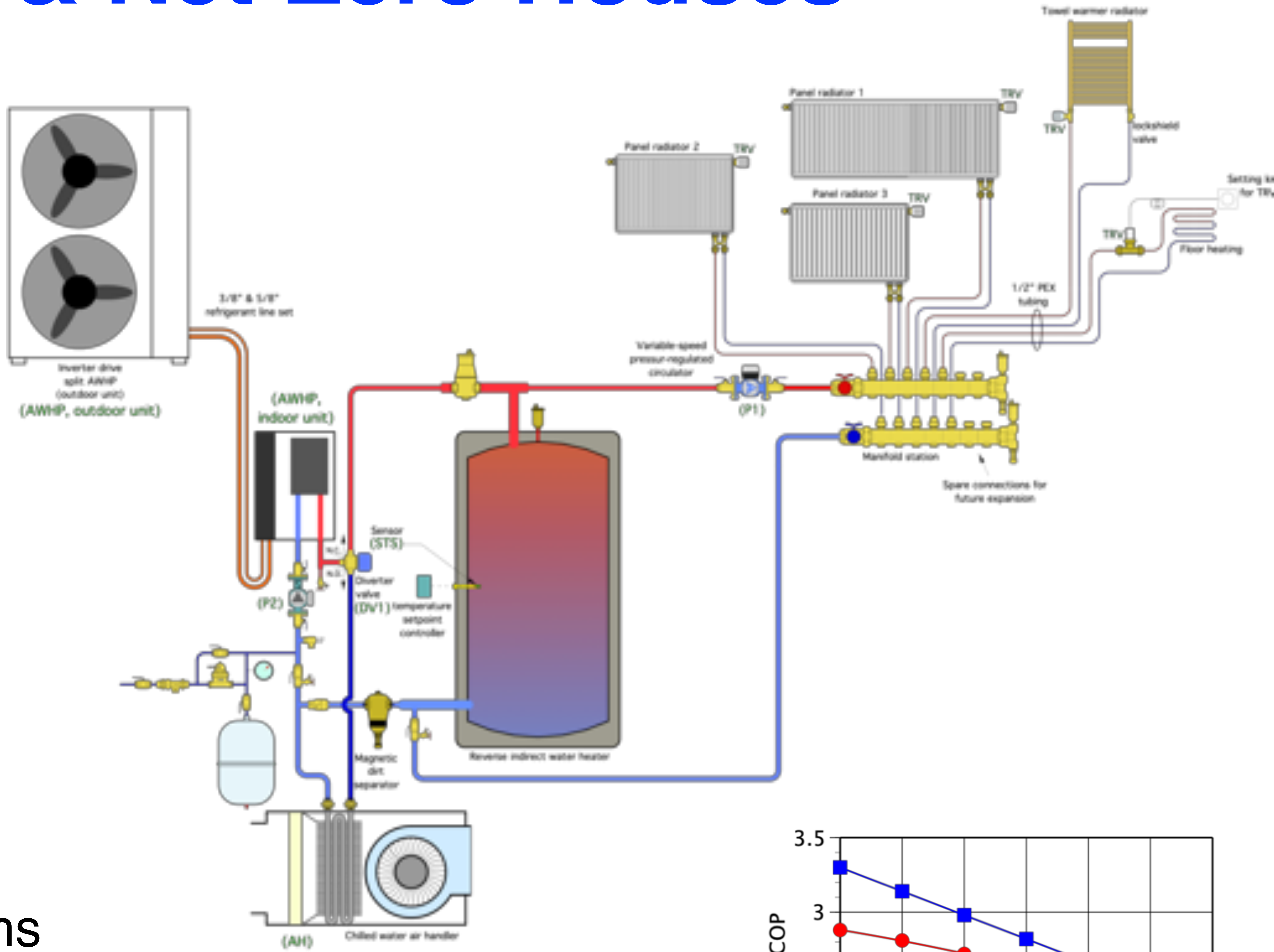
If you happen to see anyone dressed like this at the event please let me know…

Hydronics for Low-Energy & Net-Zero Houses

Topics for today…

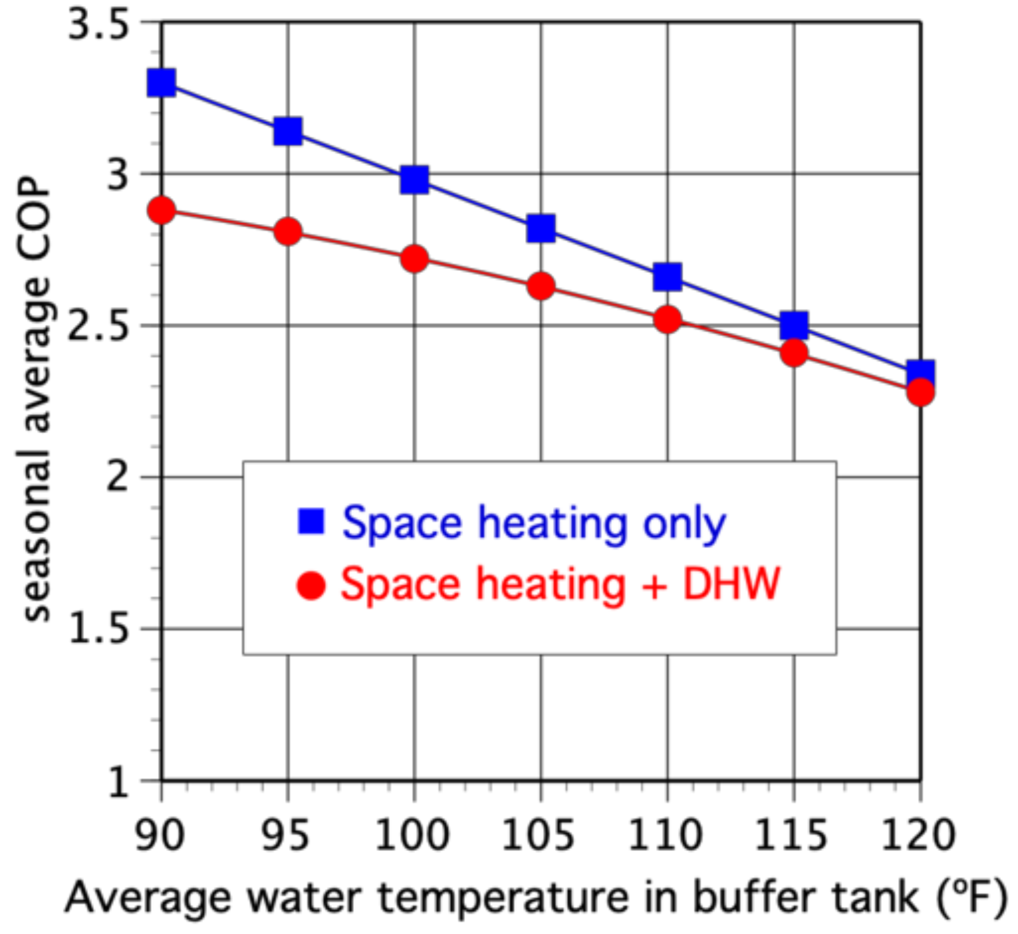
Part 1

- 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?

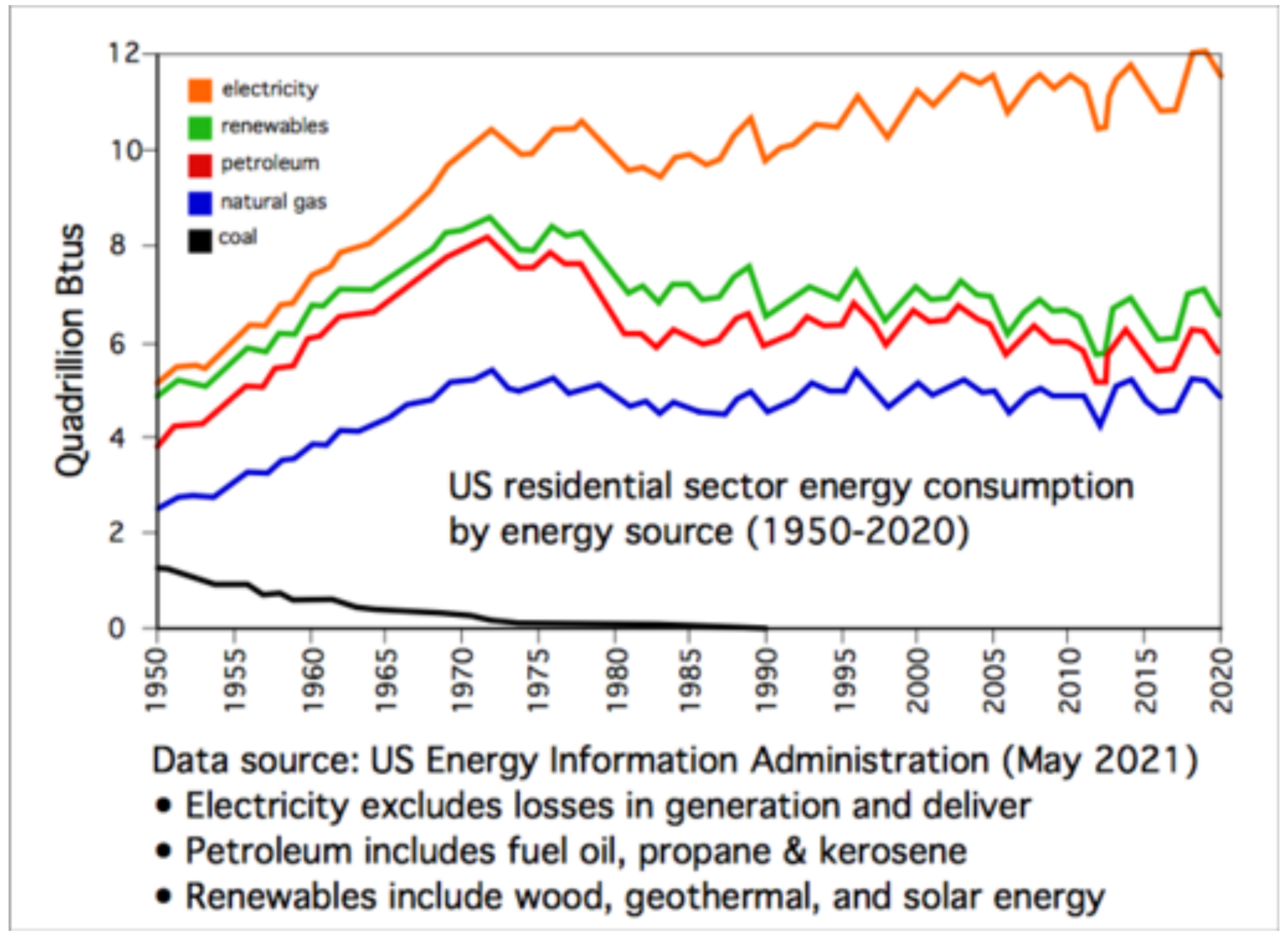


Part 2 (come back at 4:00)

- Importance of low temperature distribution systems
- Retrofitting an AWHP to an existing system
- What about DHW and ventilation ?
- Example systems
- Q&A



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.

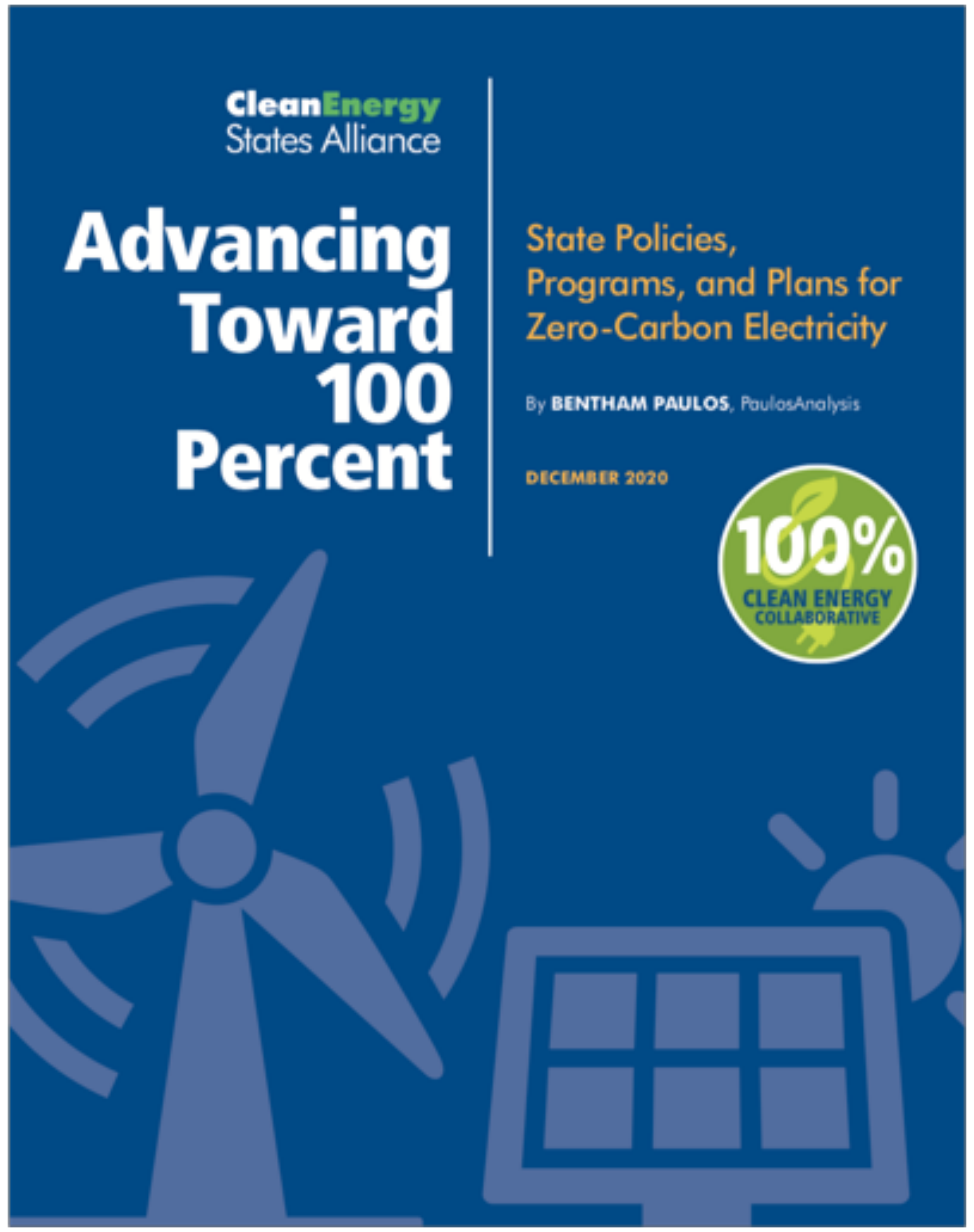
Electrification in the USA

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.

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

State	The Goal	Comments
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.



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

Moritoriums & phaseouts on fossil fuels - happening rapidly

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

NEW YORK CITY: The New York City Council voted to pass legislation banning the use of natural gas in most new construction. This law goes into effect at the end of 2023 for some buildings under seven stories, and in 2027 for taller buildings. Hospitals, commercial kitchens and laundromats are exempt from the ban.

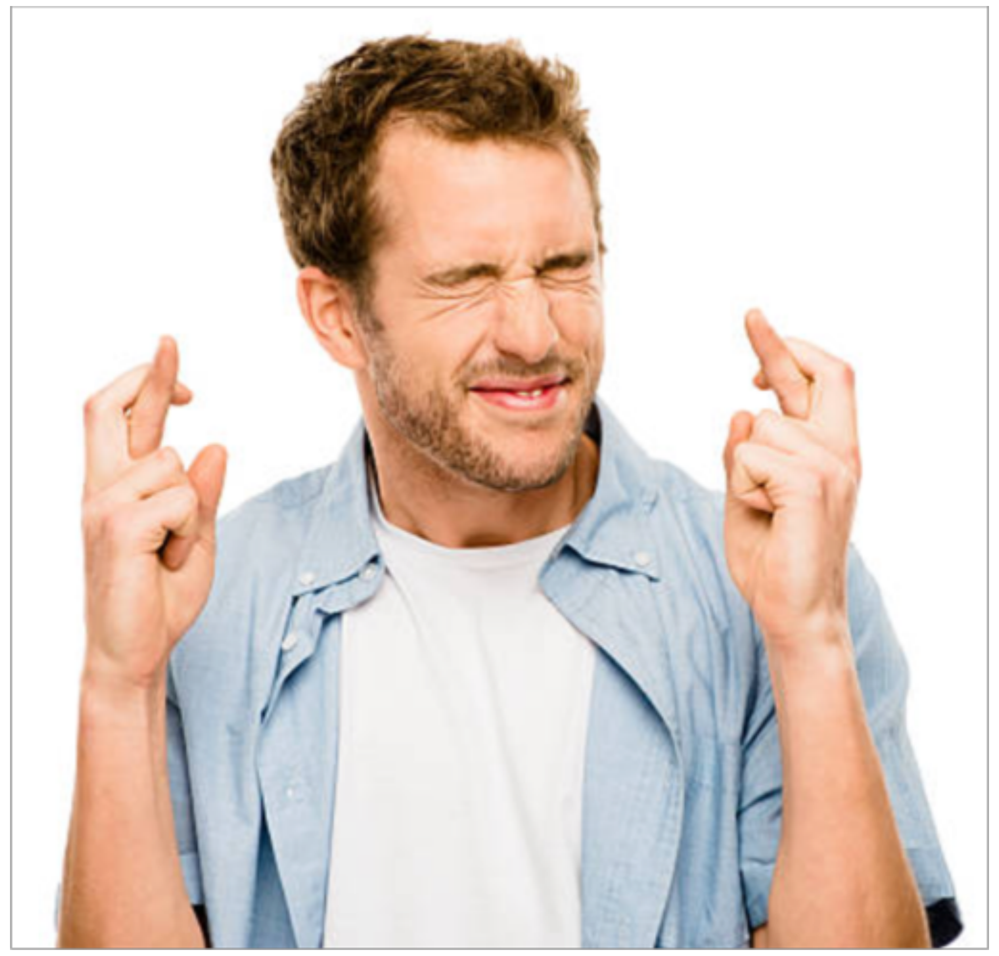
VANCOUVER: Starting Jan. 1, 2022, **equipment for space and hot water heating in new low-rise residential buildings must be zero emissions**. By 2025, all new and replacement heating and hot water systems must be zero emissions.

QUEBEC: Starting Dec. 31, 2021, oil-powered heating has been banned in new construction projects. After Dec. 31, 2023, it will be illegal to replace existing furnaces with any sort of heating system powered by fossil fuels.

TORONTO: In July of 2021 Toronto added it’s endorsement of the Fossil Fuel Non-proliferation Treaty.

SORRY

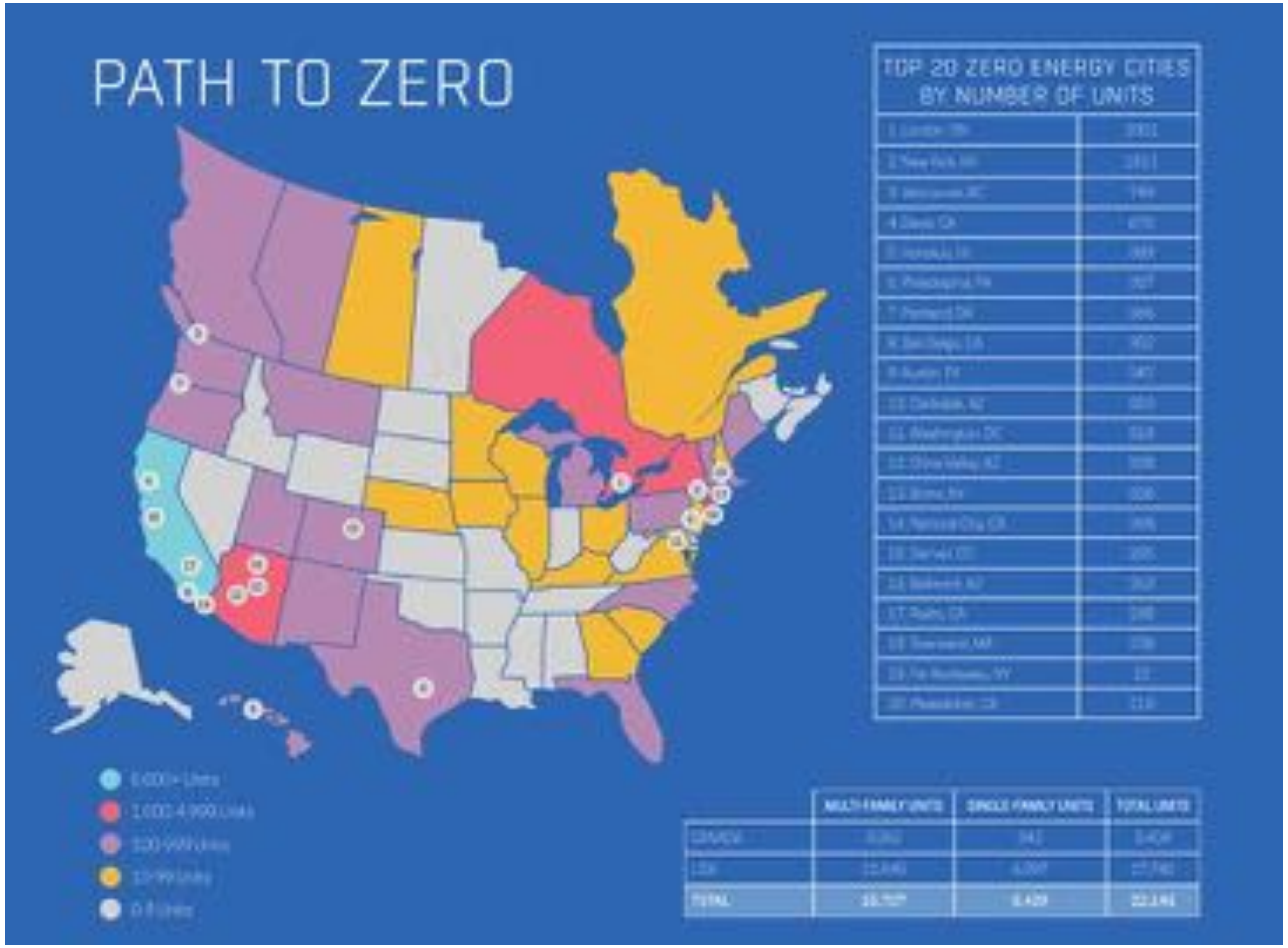
NO PROBLEM!
(we think…)



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

BROOKLINE, MA
SAN FRANSISCO
SACRAMENTO
OAKLAND

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



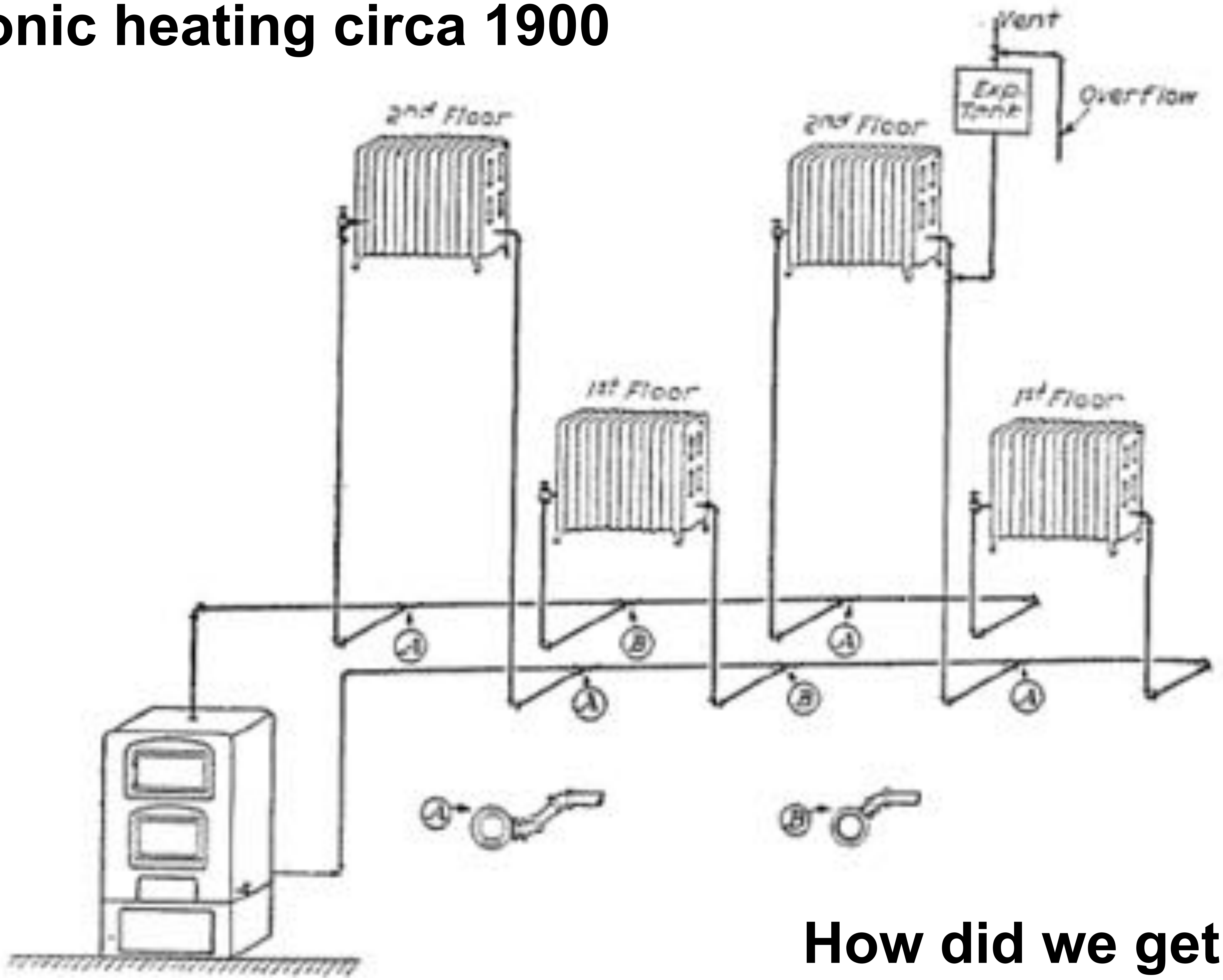
The Global Zero Net Energy Building (NZEB) Market is expected to grow at a significant CAGR of 15% by 2028.

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.

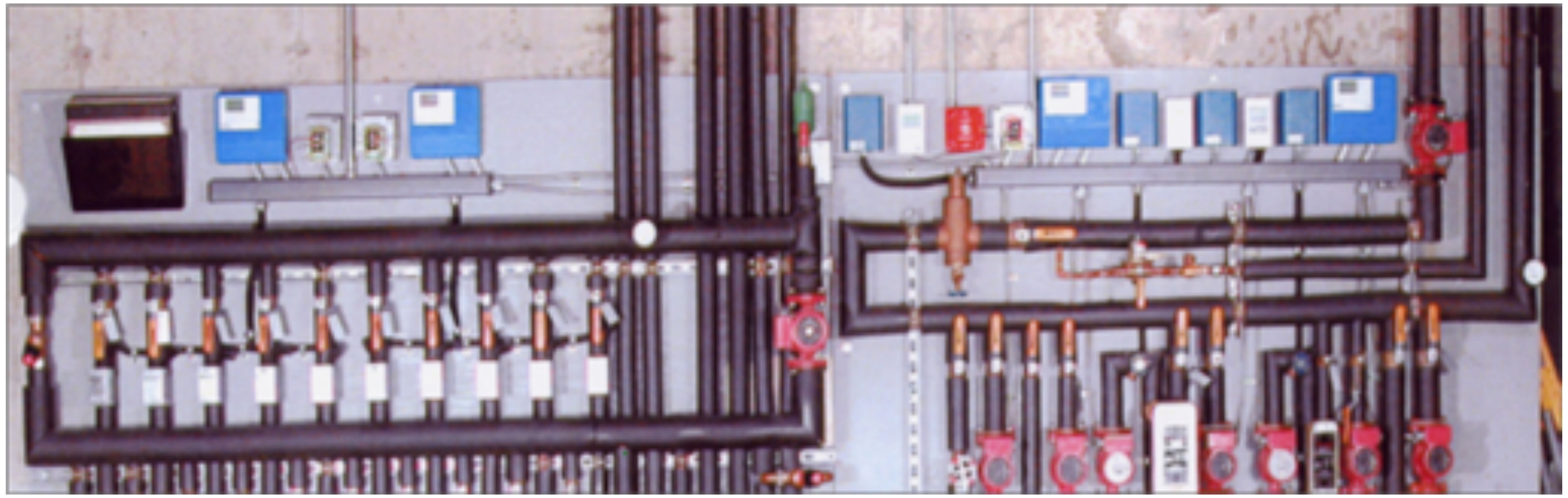
Poor perceptions of hydronic heating

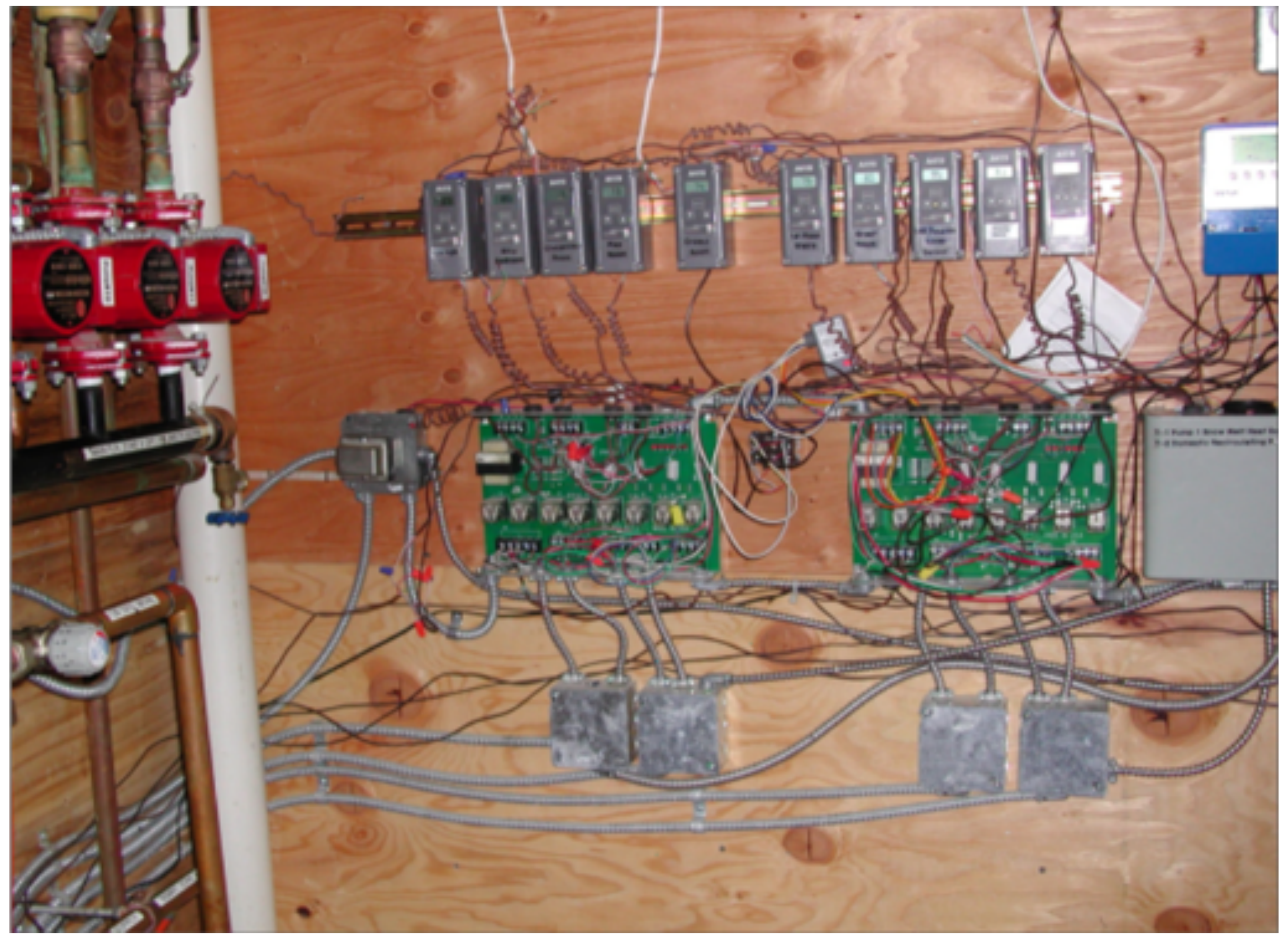
Hydronic heating circa 1900



How did we get from this...

To this??





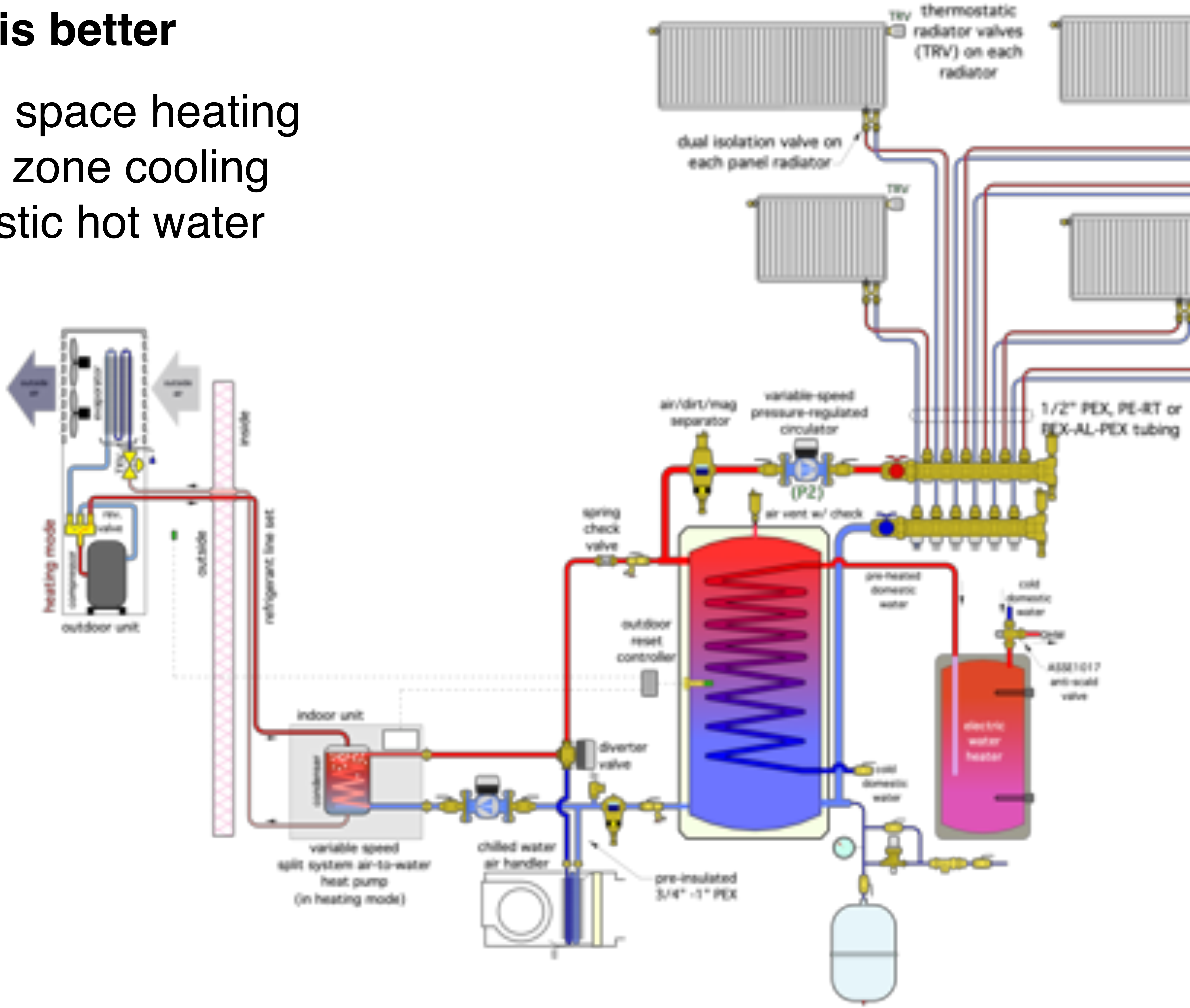
This is not the future of hydronics!

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 (71-75ºF) 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?


Pro Trade CRAFT
For Residential Construction Pros

9 Ways to Hide a Minisplit

December 20, 2019

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.

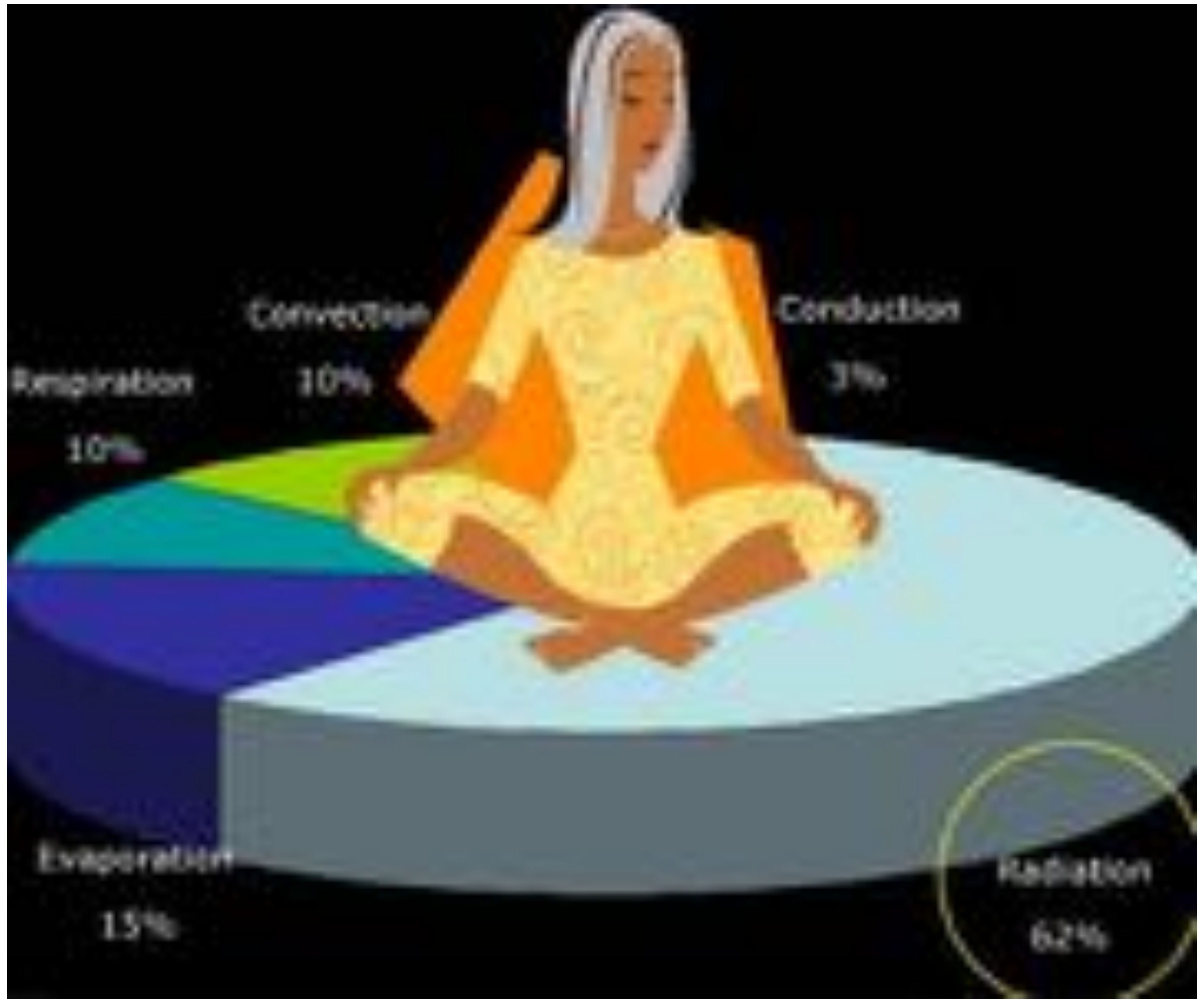
The "sub 0°F" COPs of cold climate ductless mini-split heat pumps with inverter compressors, are not publicized.

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

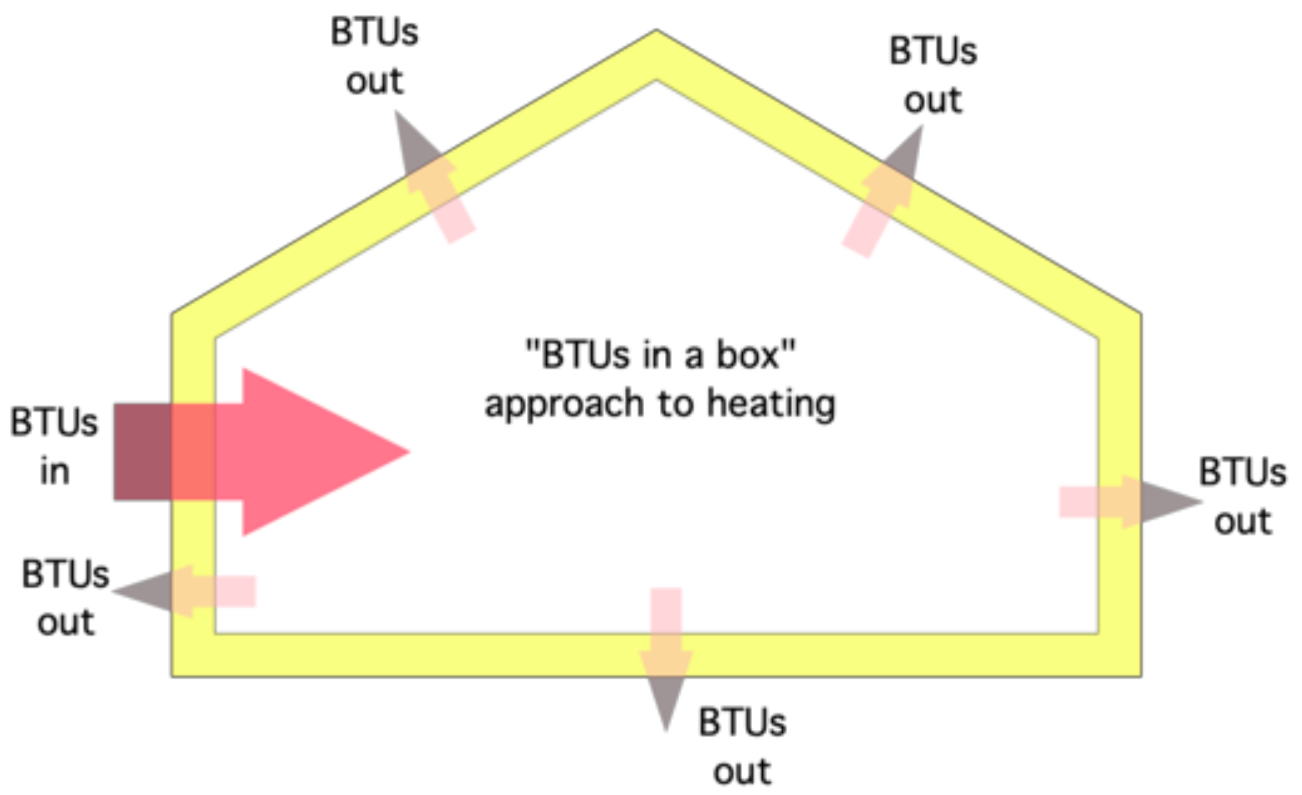
Why is this import?

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 **COMFORT**

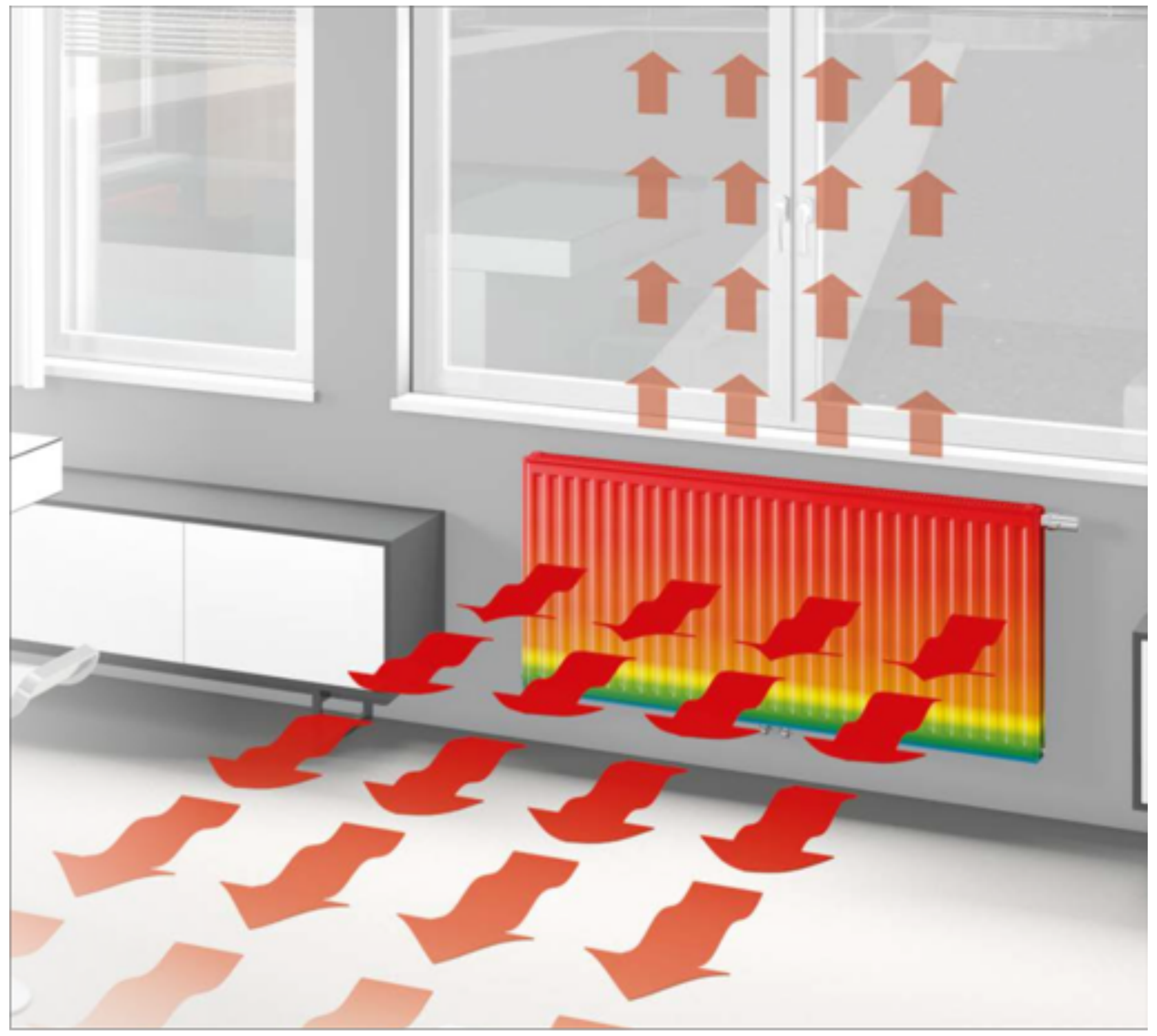
The "**Btus in a box**" approach to comfort is very incomplete…

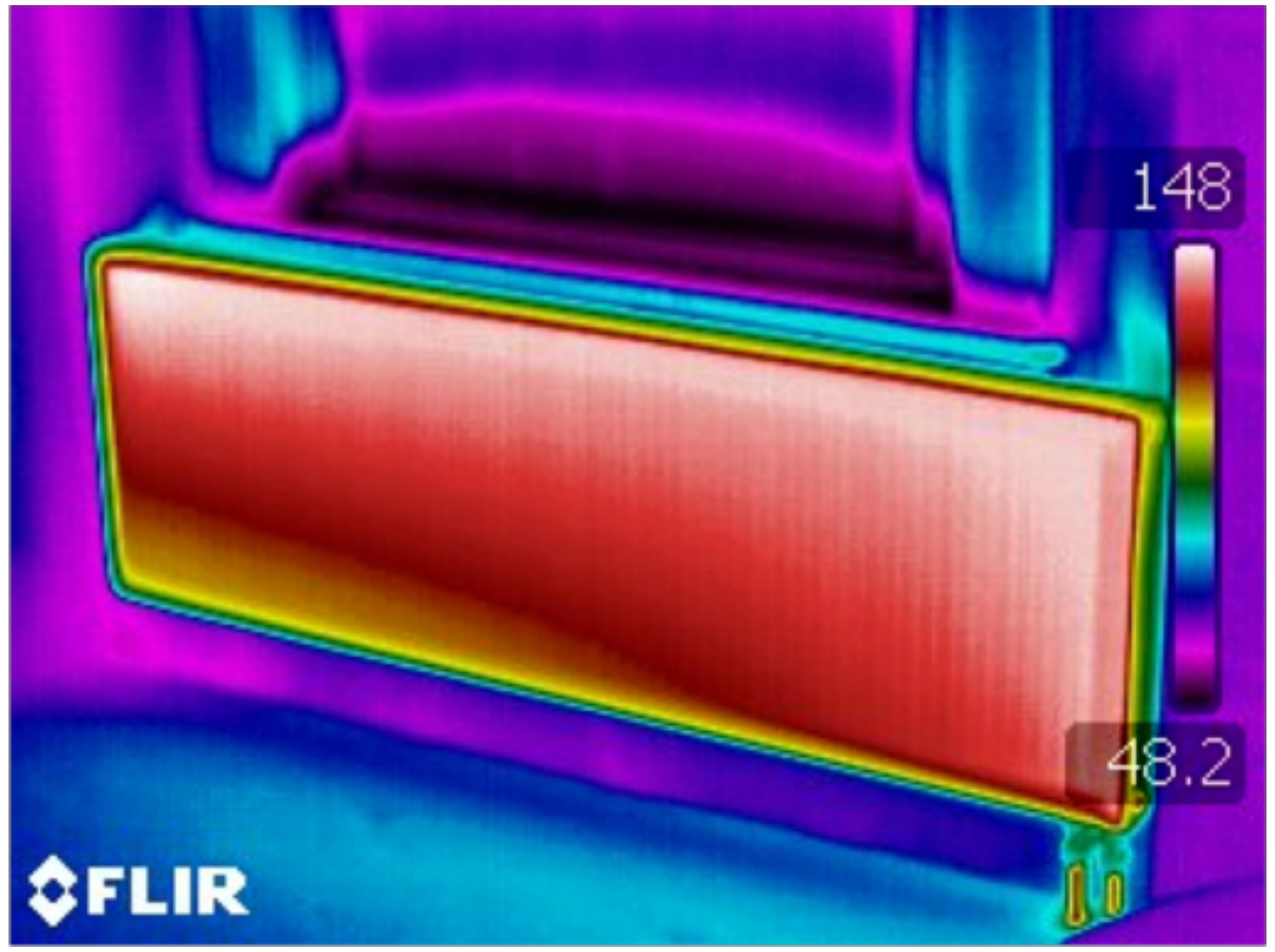


When heat supply rate = heat loss rate, the *thermodynamics* necessary for stable interior temperature are satisfied…

BTUs delivered - except during defrost…

Comfort delivered





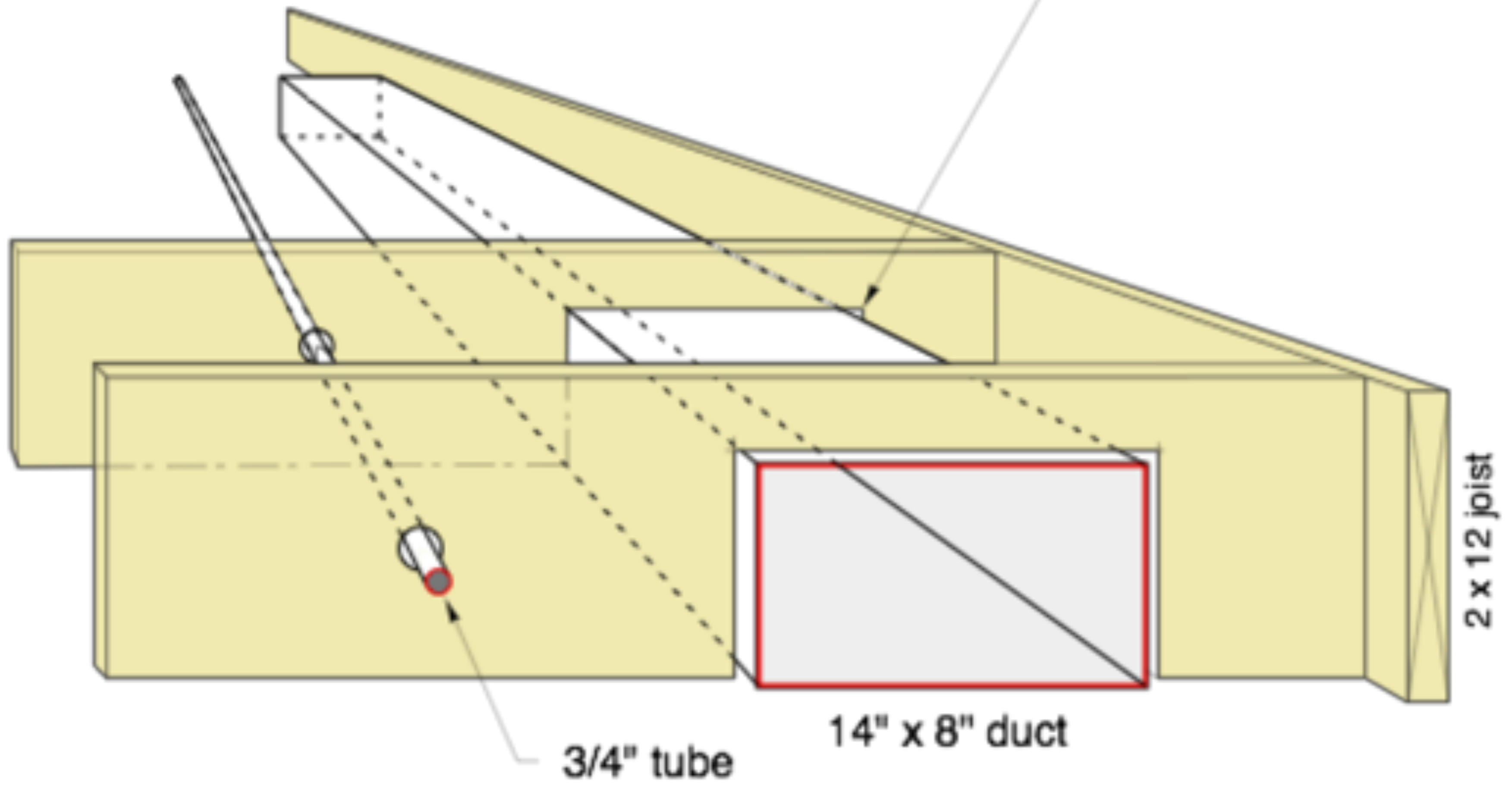
Why hydronics?

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

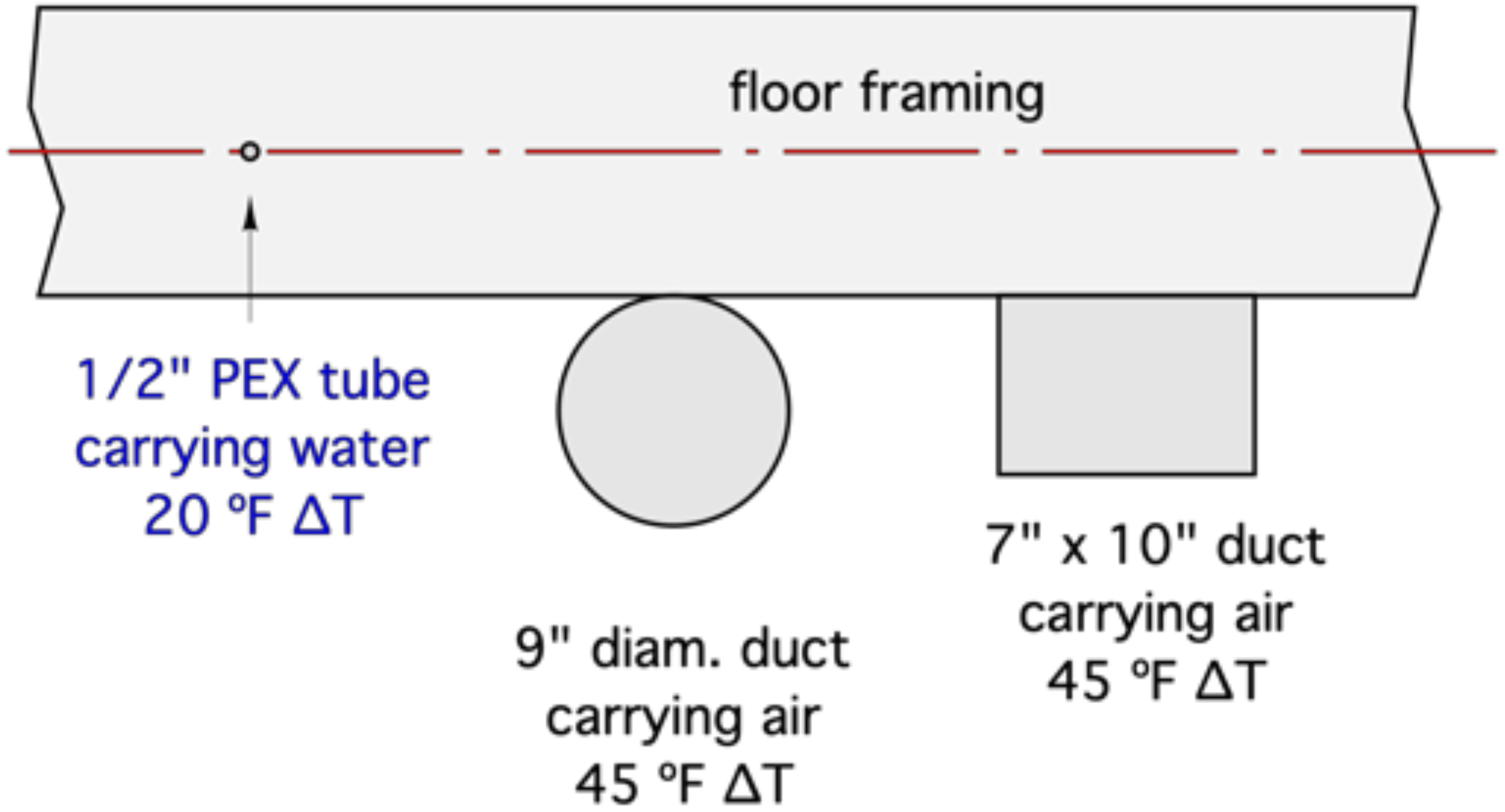
$$\frac{62.4}{0.018} = 3467 \approx 3500$$

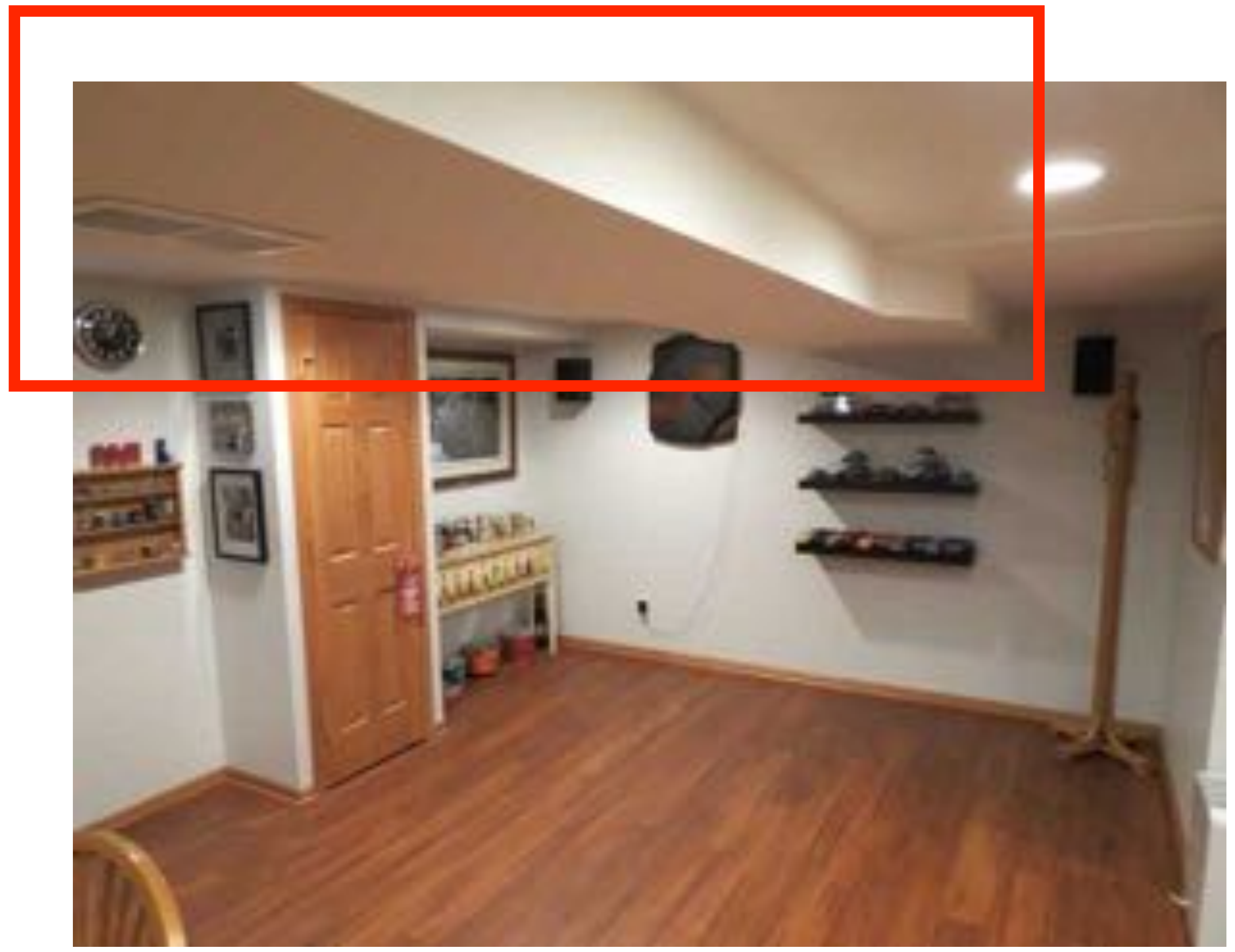
A given volume of water can absorb almost 3500 times as much heat as the same volume of air, when both undergo the same temperature change



Hydronics allows for minimally invasive installation

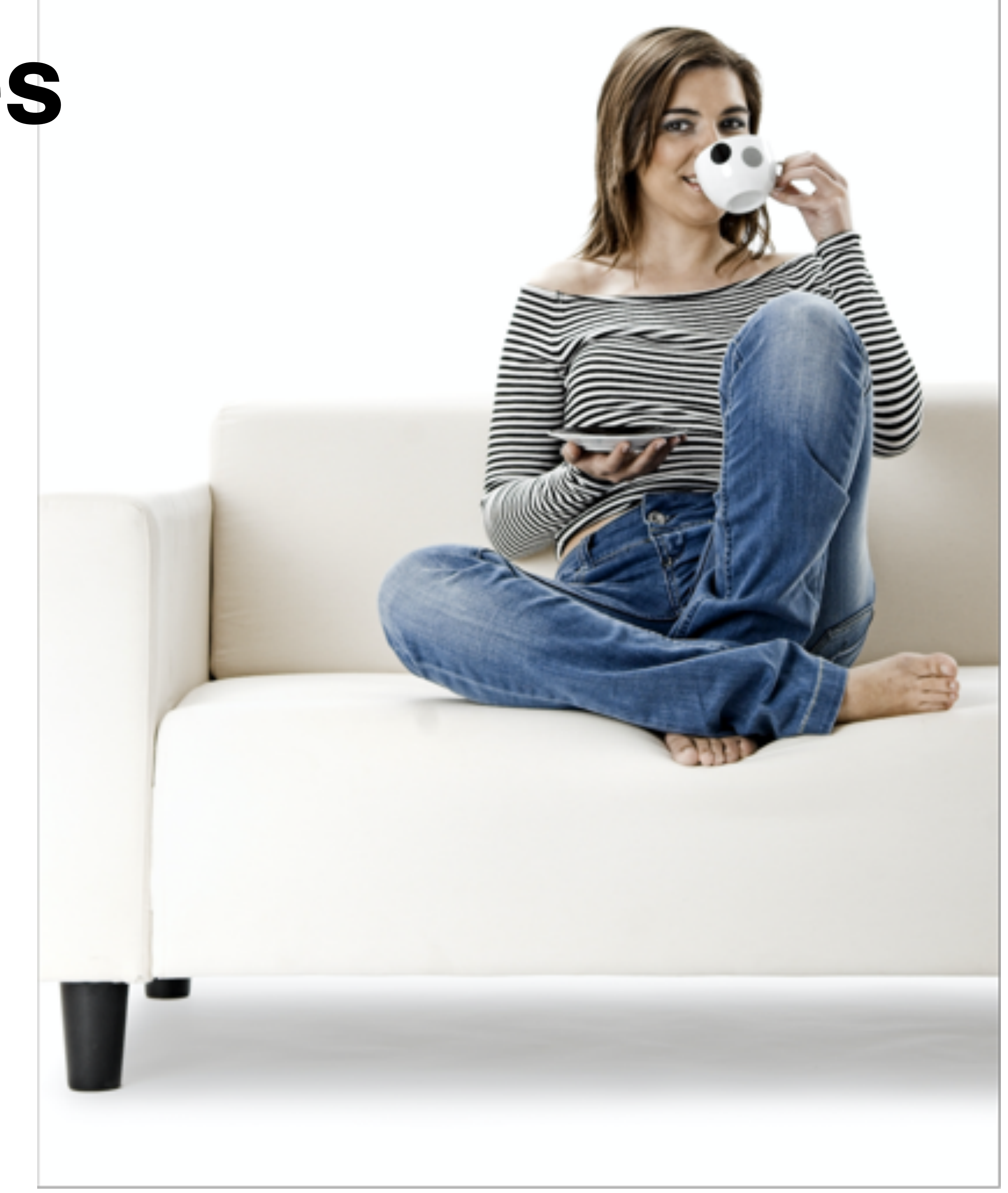
"Conduit" size required for
12,000 Btu/hr heat transfer rate

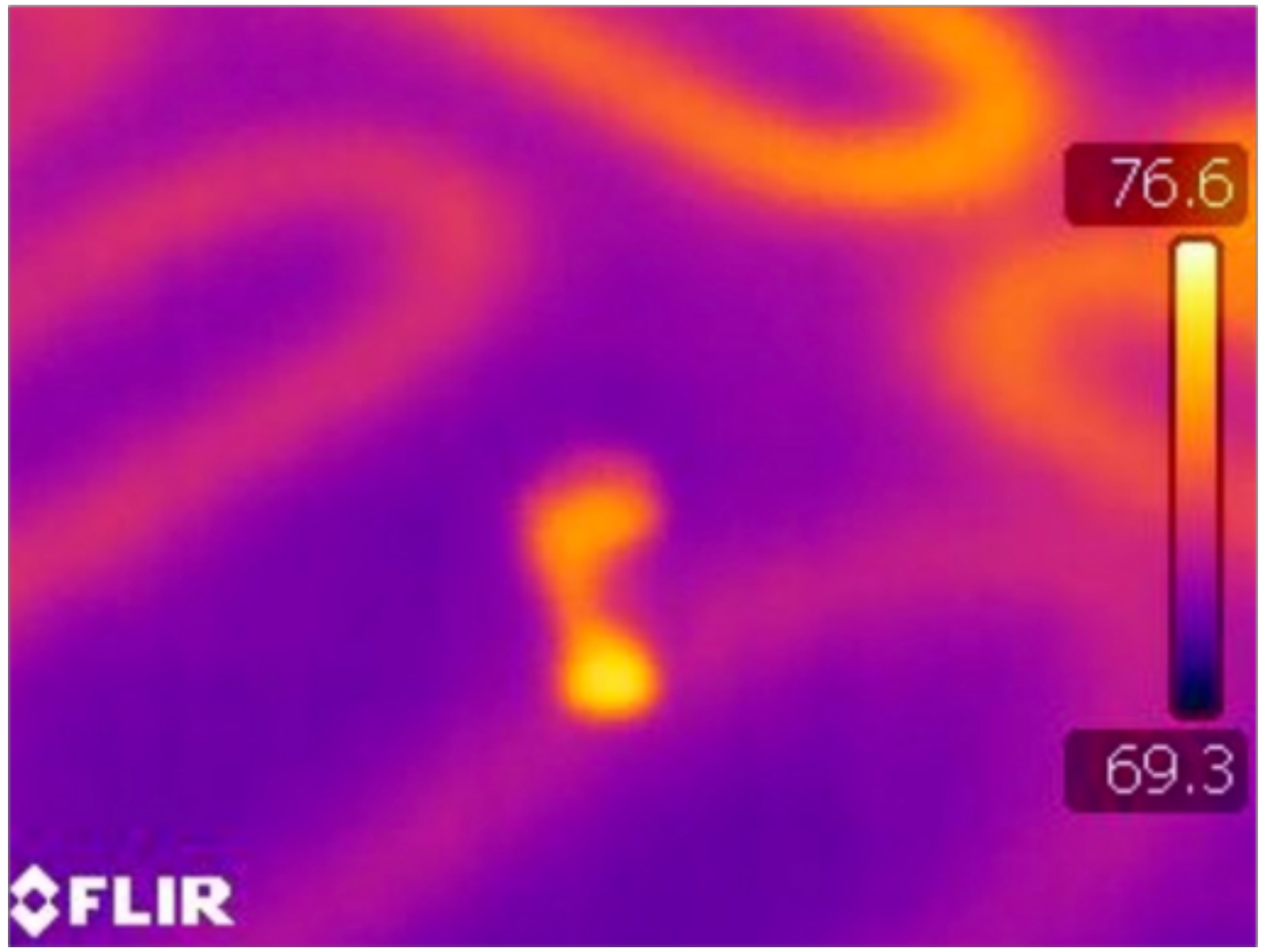




Why hydronics enhances renewable heat sources

- **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)

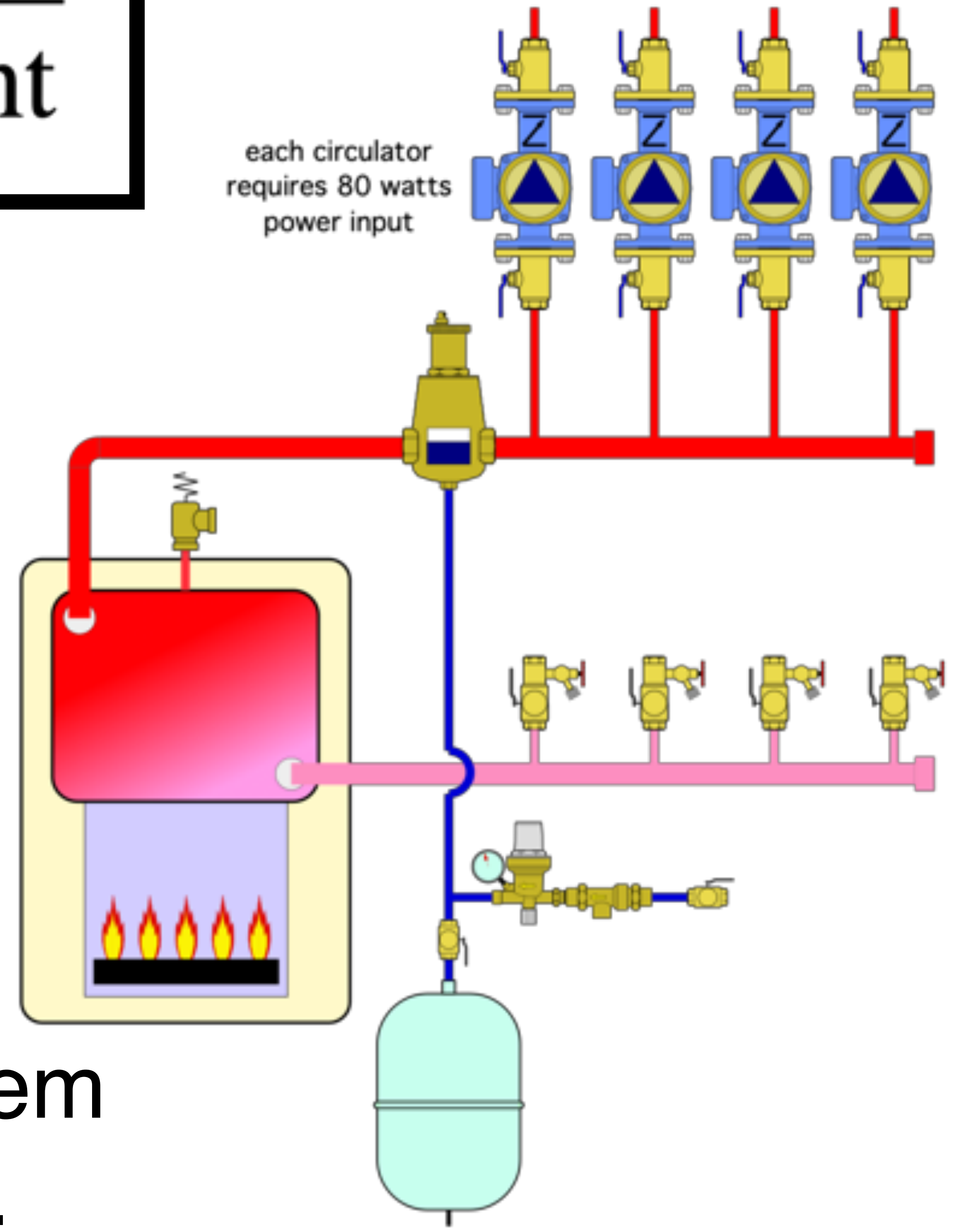




Hydronics provide superior DISTRIBUTION EFFICIENCY

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

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.

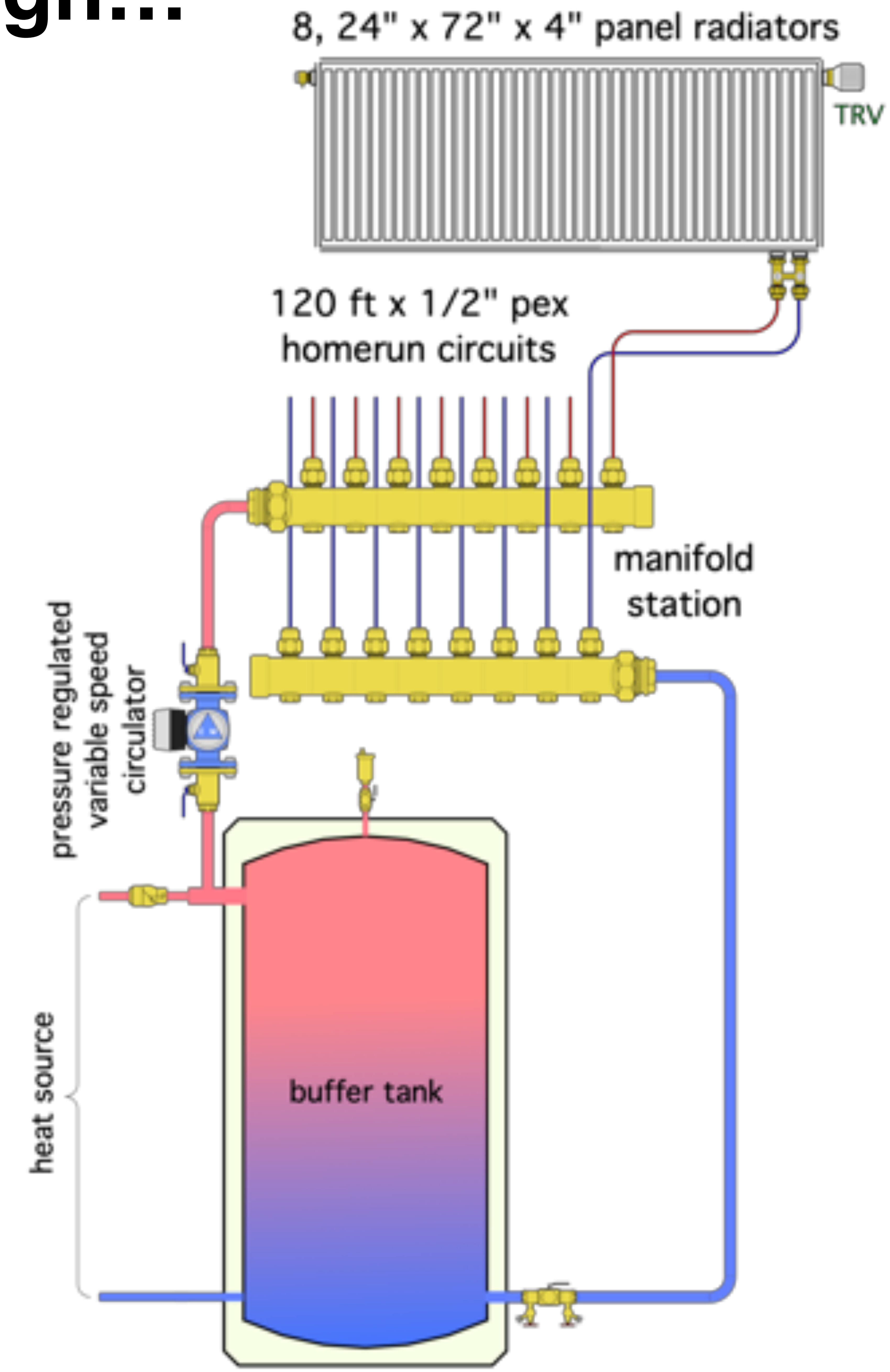
Water is vastly superior to air as a conveyor belt for heat.

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!

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



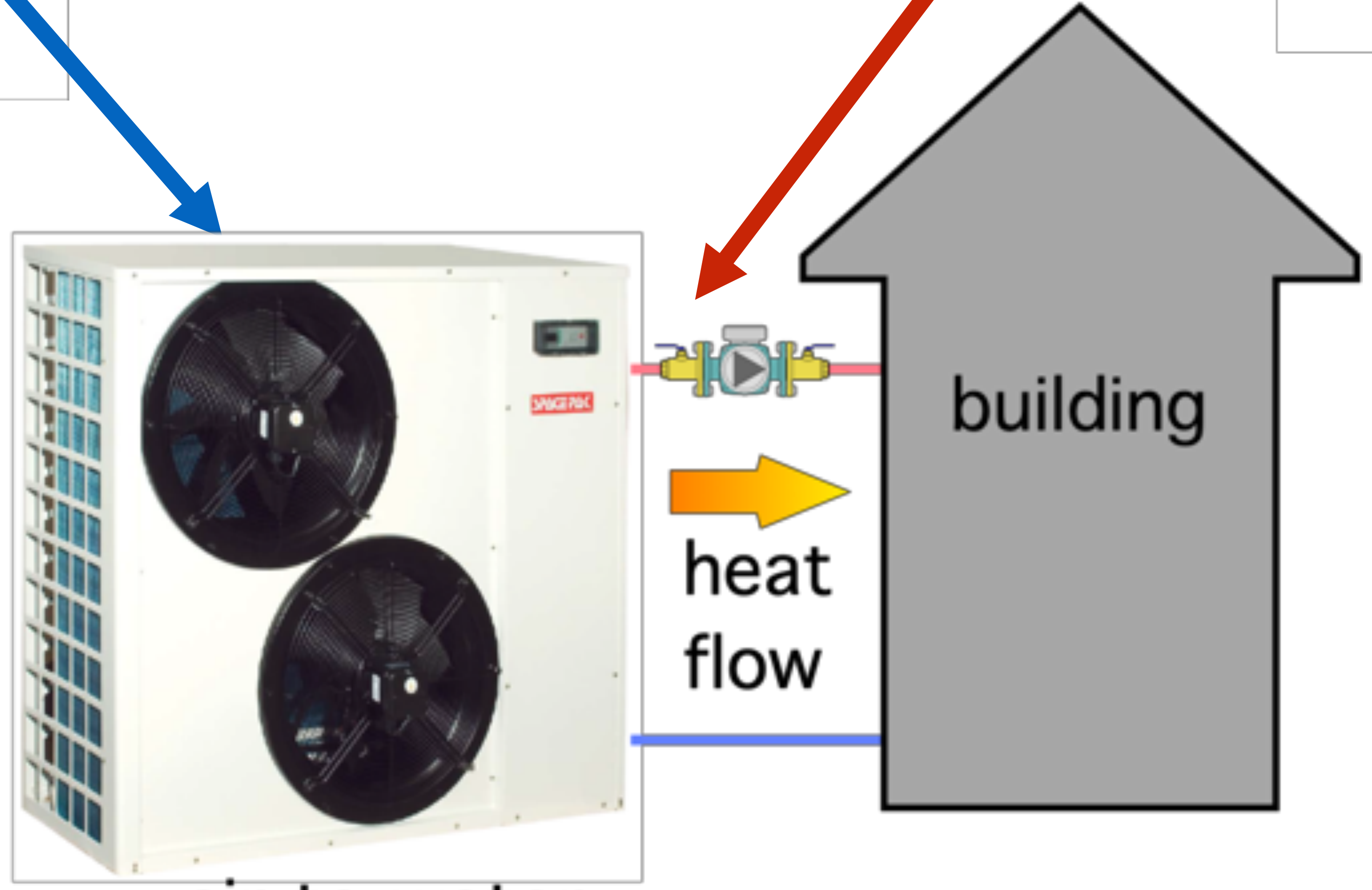
What is an air-to-water heat pump?

Heat pump "flavors"

"Ductless", "mini-split"
air-to-air heat pump

water-to-water
heat pump

air is the source of the heat

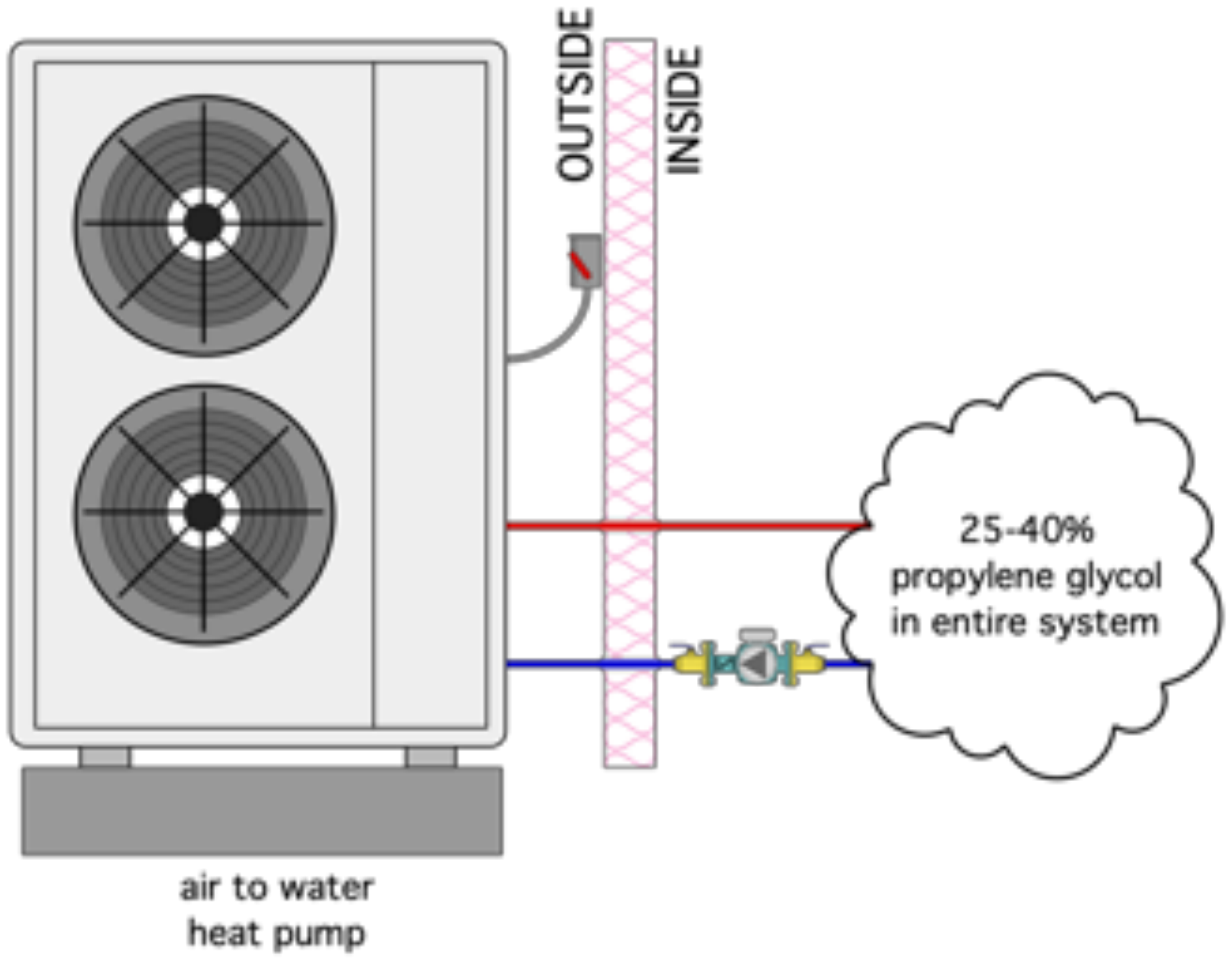


air-to-water
heat pump

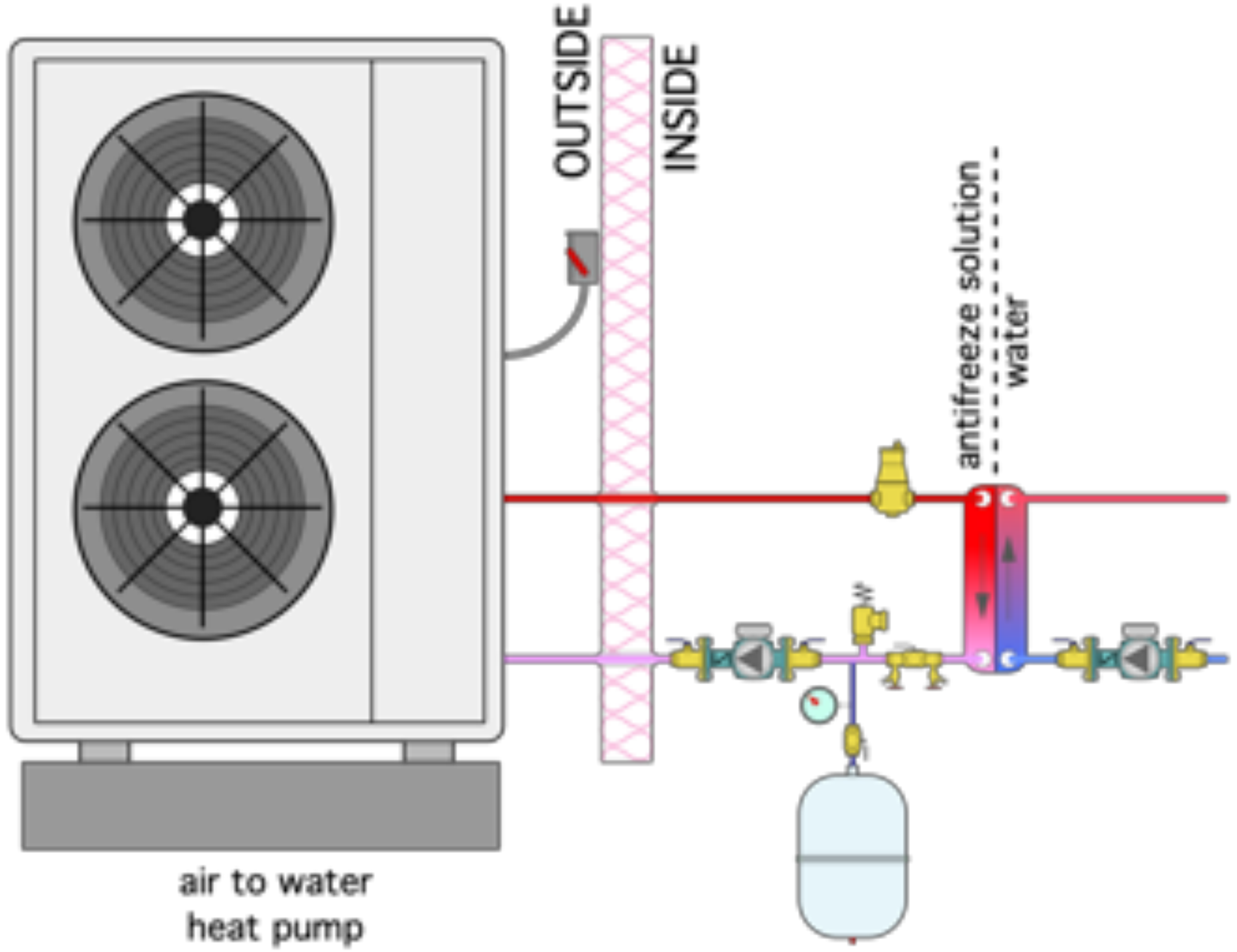
water is the "conveyor belt" moving heat to the building

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

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



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.

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

Split system air-to-water heat pump

Outdoor unit

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

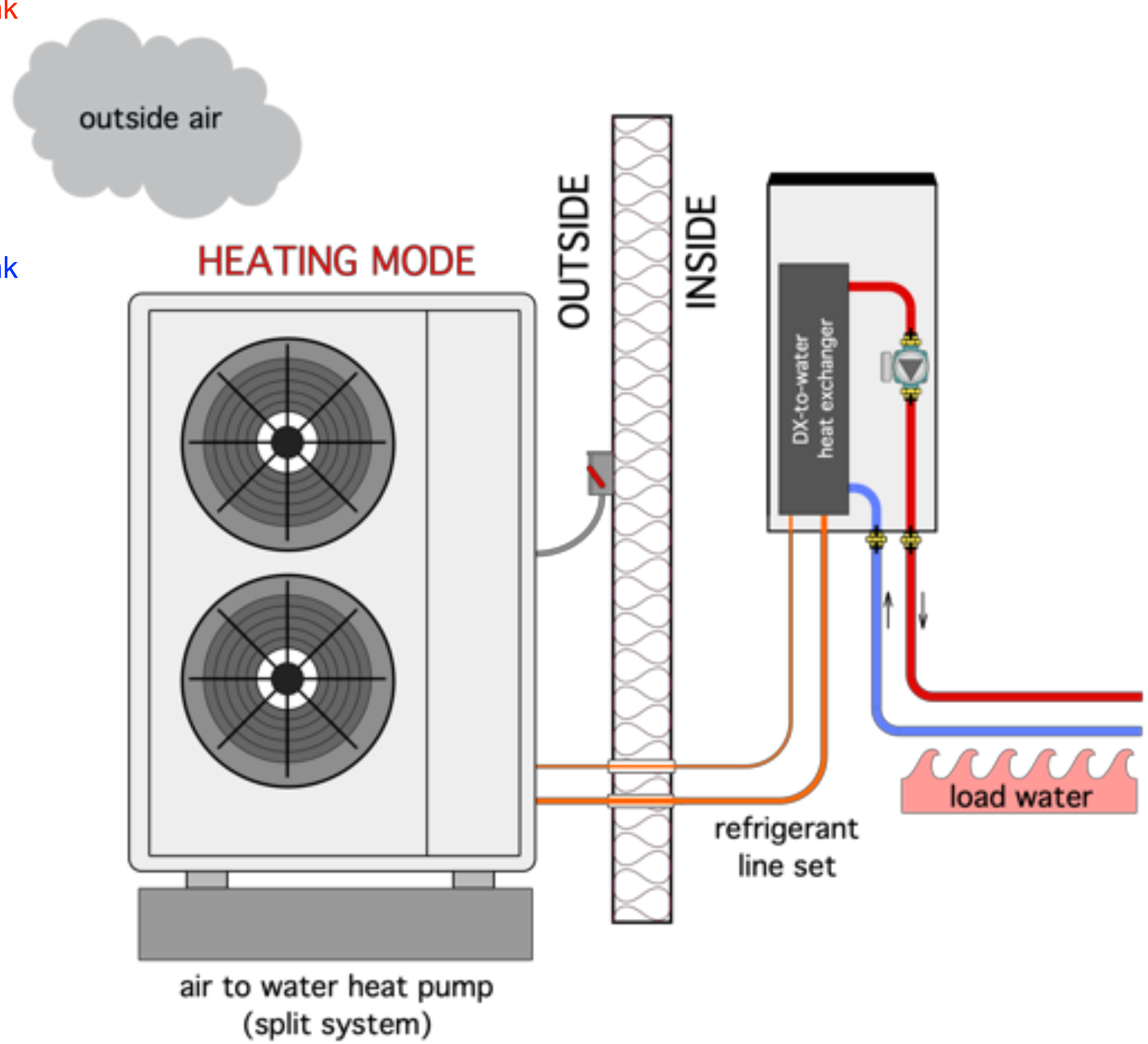
Cooling mode:
1. compressor
2. condenser
3. expansion device

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



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)

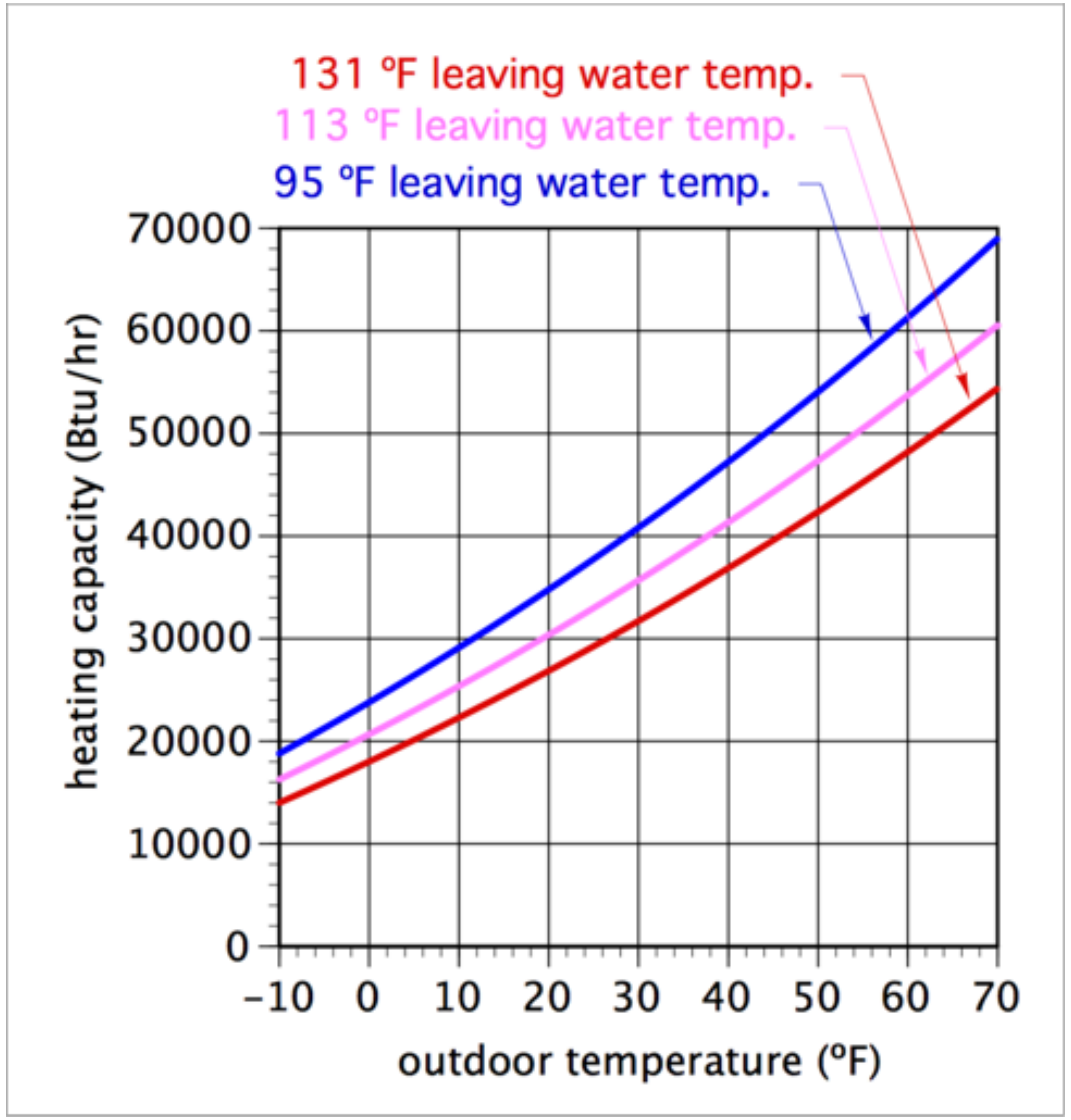
Mitsubishi
(Residential & **Commercial** AWHPs)

Stiebel Eltron
(Residential / light commercial AWHPs)

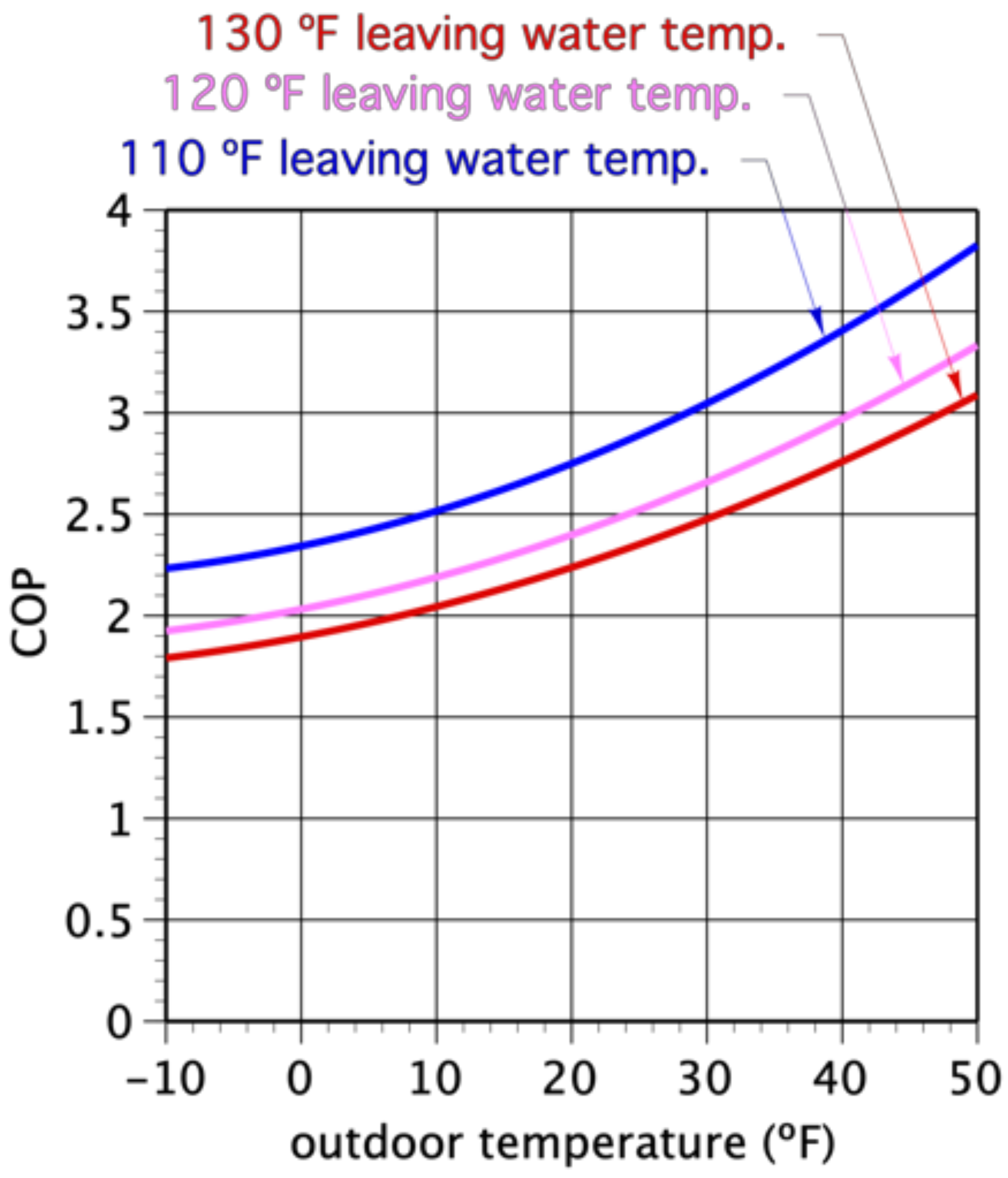
Taco
(Residential / light commercial AWHPs)

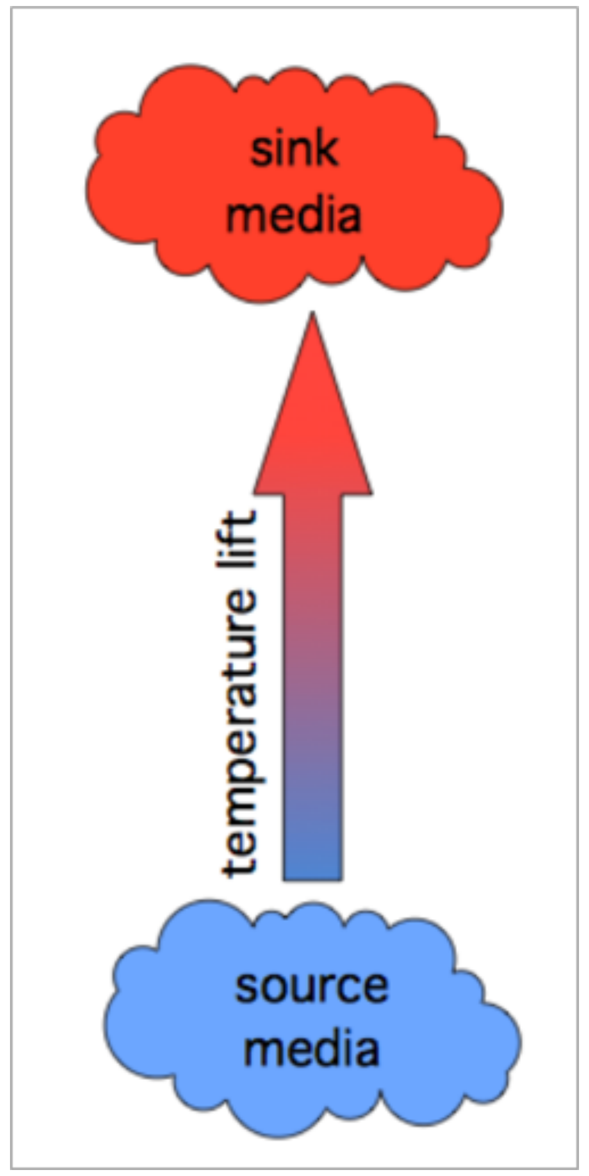
Heating Performance

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



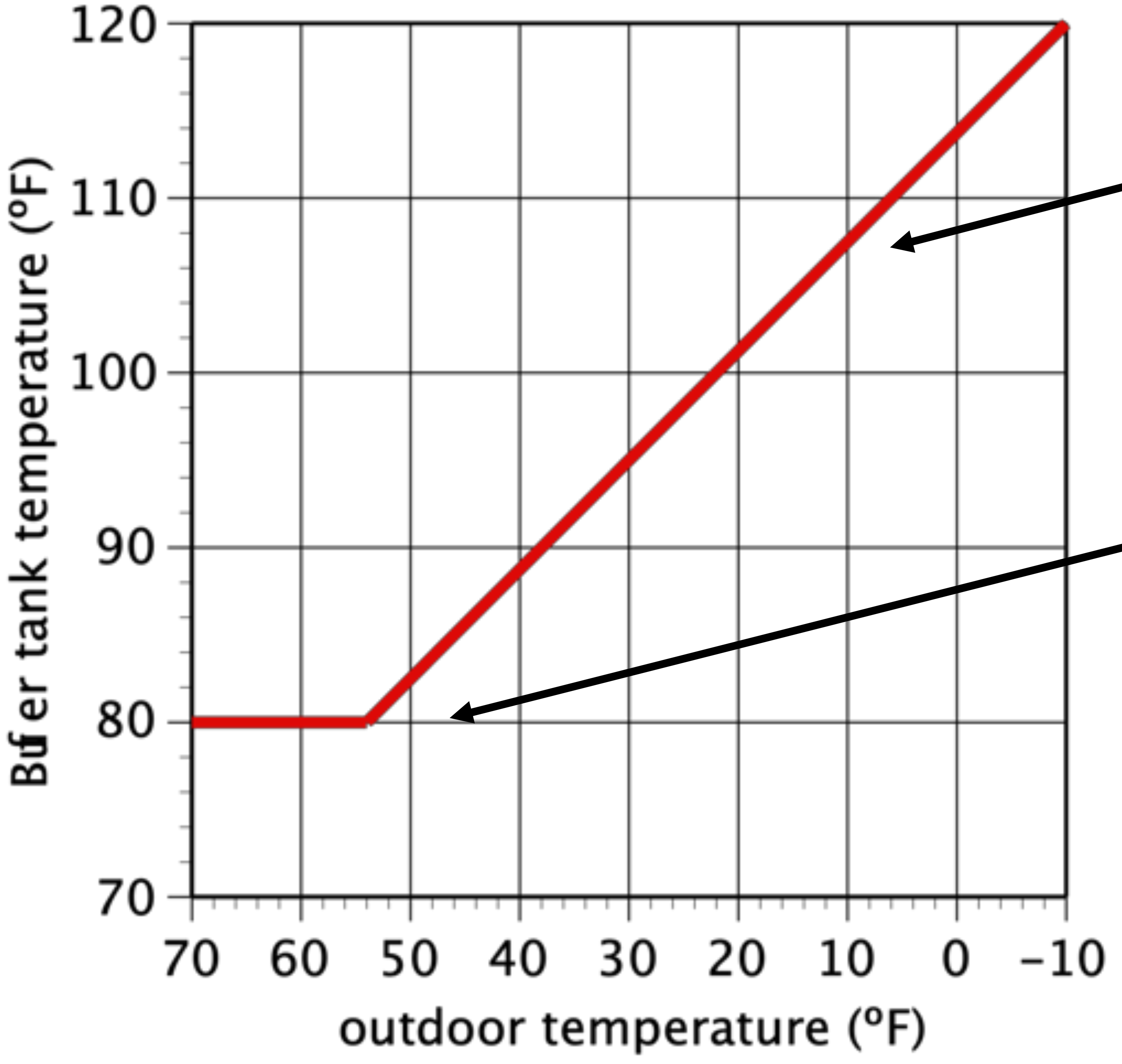
The COP also decreases with increasing condenser temperature.



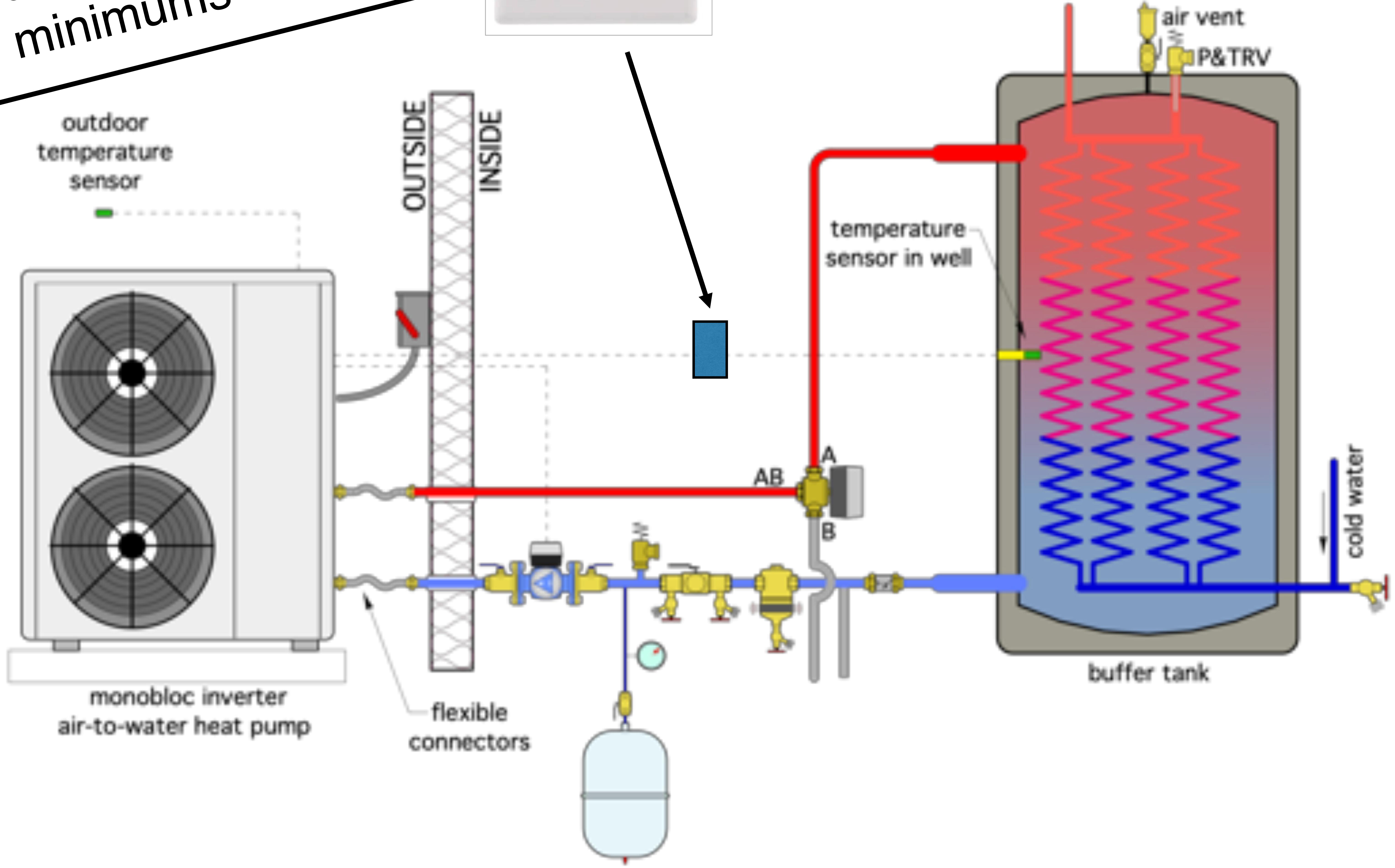


The smaller the "temperature lift" between evaporator and condenser, the higher the heating capacity and COP.

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



adjustable slopes,
differentials,
minimums



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

Come on back at 4:00…

Hydronics for Net-Zero Houses (part 2)

Part 2 topic

- Importance of low temperature distribution systems
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