MODERN HYDRONICS SUMMIT 2019

# Future proofing hydronic systems

Designing systems today that are relevant for 50+ years

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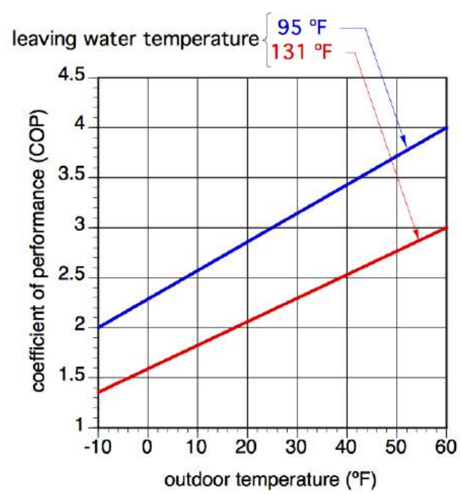
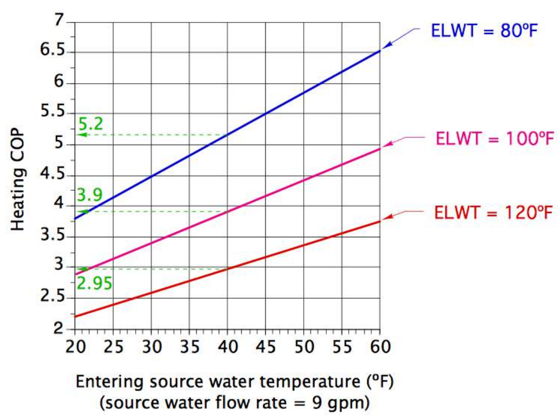
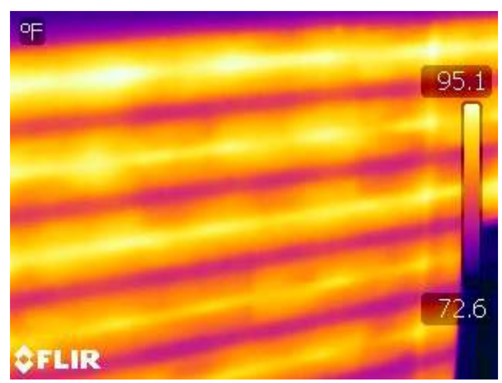
Appropriate Designs

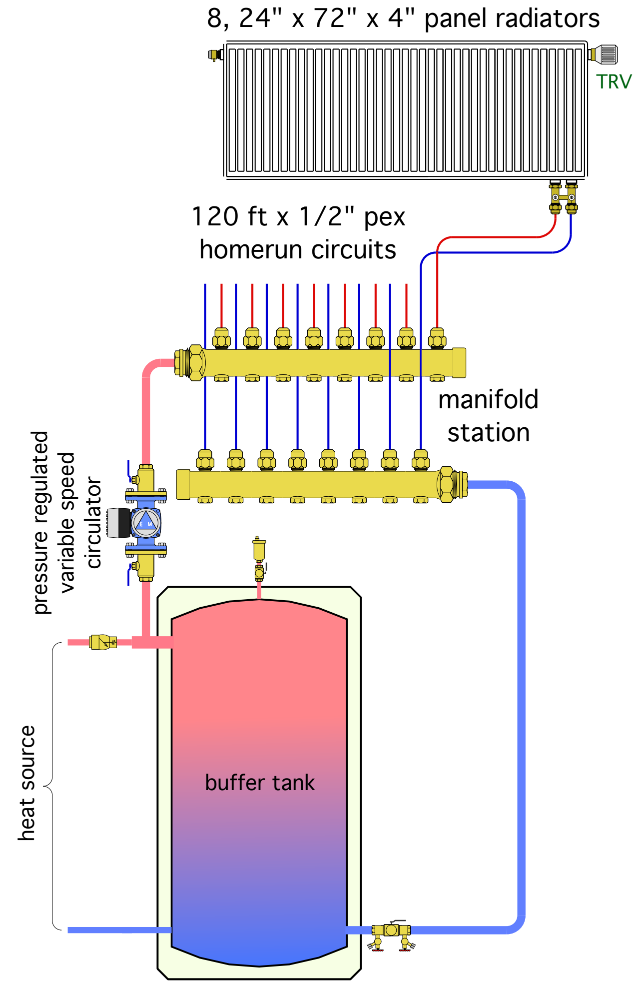




# Future proofing hydronic systems

- *How are the energy needs of future houses changing?*
- *What are the energy "tea leaves" telling us?*
- *Why hydronic system should be considered.*
- *Why is low water temperature so important?*
- *What are some options for  low temperature distribution systems?*
- *What can you do today to help future-proof your hydronic systems?*



# Residential construction trends

1. Heating loads (Btu/hr/ft$^2$) continue to drop
2. Increasing emphasis on net-zero construction

Image: Revision Energy

**• Small design heating loads in the range of 10 to 15 Btu/hr/ft$^2$.**
(A 2000 ft$^2$ house at 10 Btu/hr/ft$^2$ is only 20,000 Btu/hr DESIGN load)

**• Internal heat gains can have more significant impact on internal temperature.**
(room-by-room zoning is important to control overheating)

**• Internal heat flow through open doors and uninsulated partitions helps equalize internal temperature differences.** (hard to maintain significant temperature differences b/w zones)

**• Any large surface area radiant panel will operate at low surface temperatures (71-75ºF).**
(Heated floors don't get as warm as they used to - they don't need to...)

Image: SolarToday magazine

**• Difficult to find a combustion type heat source with capacity well matched to load.**
(will need thermal mass to prevent short cycling)

**• DHW load may exceed space heating load,**
(and thus set the output requirement of the heat source).

**• Monthly service charge associated with gas meter may be hard to justify based on fuel cost difference and usage.** (consider "all electric" house)

**• All "net-zero" houses will use solar PV system,** (and thus favor an "all electric" HVAC system).

**• Heat Recovery Ventilation will be required due to low natural air leakage.**

# Housing's Next Frontier

There's a potentially huge market for Net Zero homes, but you have to know how to sell them.

Net Zero has been the topic of countless magazine articles in recent years and has even spawned a government agency: the U.S. Department of Energy's Zero Energy Ready Home program. GreenBuildingAdvisor.com estimates a 33% growth in the program from 2015 to 2016 alone, and some forward-thinking production builders are building entire communities of these homes.

**Thirty-nine Percent Growth Rate Expected by 2021**

According to a report for Technavio, the global zero-energy buildings market is expected to grow at a compound annual growth rate (CAGR) of about 39 percent by 2021.


https://www.energy.gov/eere/buildings/zero-energy-ready-home

https://www.greenbuildingadvisor.com/article/insights-from-successful-net-zero-builders

https://www.erase40.org/

https://www.erase40.org/the-meeting-map

# Net Zero house in Seattle


KEY FEATURES

- Walls: R-29, 6" SIP taped at all interior and exterior joints, fiber cement siding.
- Roof: R-42, 10" SIP taped at all interior and exterior joints. Ice-and-water shield, asphalt shingles.
- Foundation: R-23 ICF stem walls, R-20 rigid foam under slab.
- Windows: Triple-pane, vinyl-framed, low-e windows, U=0.21.
- Air Sealing: 0.60 ACH 50
- Ventilation: Timered exhaust fans.
- HVAC: 4.5 COP air-to-water heat pump for in-floor radiant hydronic heat.
- Hot Water: Air-to-water heat pump, 4.5 COP.
- Lighting: 100% LED
- Solar: 9.5-kW PV, evacuated tube solar hot water.
- Water Conservation: Low-flow fixtures; centrally located water heater.
- Electric car charging station.

PROJECT DATA

- Layout: 4 bdrm, 2.5 bath, 2 fl, 2,463 ft2
- Climate: IECC 4C, marine
- Completed: May 2016
- Category: custom for buyer

MODELED PERFORMANCE DATA

- HERS Index: without PV 44, with PV -2
- Projected Annual Energy Costs: without PV $1,053, with PV $25
- Projected Annual Energy Cost Savings: (vs home built to 2012 IECC) without PV $811, with PV $1,889
- Annual Energy Savings: without PV 9,453 kWh, with PV 20,993 kWh

# Energy Trends

## Reading the "tea leaves" about future energy sources.

Global social/political trends (*in many cases buttressed by regulations*) are moving away from fossil fuels and toward renewably-sourced electricity as the "preferred" energy generation / delivery method.

### Heat pumps overtake gas in Germany

23 APR 2018 0

GERMANY: Heat pumps are said to have overtaken gas for the first time in 2017 to became the most popular form of domestic heating in Germany.

Based on figures released by the Federal Statistical Office, the German heat pump association BWP reveals that heat pumps were installed in 43% of residential buildings in 2017. This was just ahead of gas heaters, which represented 42% of installations.

Air-source and water-source units accounted for around 35%, with geothermal taking 8%.

"The heat pump is increasingly being recognised by builders, planners and specialist contractors as the standard heating system for new buildings," commented Martin Sabel, managing director of BWP. "The big advances in device efficiency, usability and design are driving demand. We expect that share to continue to rise significantly."

In the overall market, heat pumps' share at 41% is still just behind gas at 42%.


### California Plan to go Totally Green by 2045 Passes Senate

Senate President Pro Tem Kevin de Leon (D-Los Angeles)

IF A BILL PASSED BY THE STATE SENATE CAN MAKE IT THROUGH THE ASSEMBLY, CALIFORNIA WILL DRAW ALL ITS POWER FROM RENEWABLE ENERGY SOURCES BY 2045; SPECIFICALLY WIND, SOLAR AND HYDRO.

Global social/political trends (*in many cases buttressed by regulations*) are moving away from fossil fuels and toward renewably-sourced electricity as the “preferred” energy generation / delivery method.

## What does this mean for hydronics technology?

1. There will be increased demand for heat pumps for all types of heating (and cooling) applications (since they are significantly more efficient than electric resistance heating).

2. Hydronic systems can use water-to-water, or air-to-water heat pumps

3. Virtually all currently available heat pumps work better when operating at lower condensing temperature.

**The future of hydronic heating is low water temperature!**

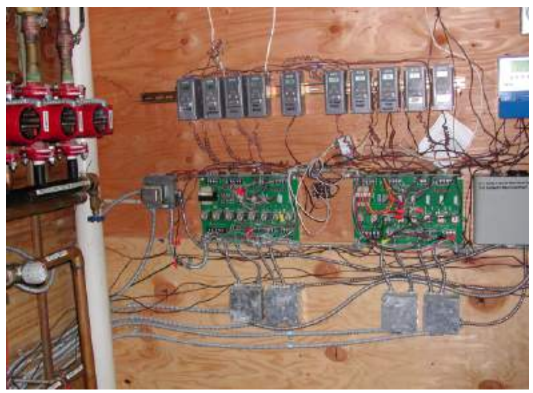
Given these trends it seems “*irrational*” to design “*high water temperature*” systems in the present that will likely require major modification in 15-20 years for compatibility with their next heat source.

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

Training programs for "net zero" houses often promote mini-split heat pumps as the ***only necessary heating & cooling system.***

They often discourage the ***"complication"*** and ***cost*** of hydronic systems.


## Based on this - who can blame them ??



# Why is the “net zero” housing market 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.”

**The COPs of cold climate ductless mini-split heat pumps with inverter compressors is not discussed in detail.**


# It's not **just** about matching BTU delivery to load…

# It's about providing <u>**COMFORT**</u>

Ductless mini-split heat pumps rely on forced air delivery.

While generally acceptable for cooling, forced air delivery doesn't provide optimal comfort for heating.

• There will be some temperature stratification from floor to ceiling.

**• Mini-splits blow cool air into spaces while defrosting outdoor unit.**

**• Cold floors are a common complaint with forced air heating.**

• High wall cassettes do little to counteract natural downdraft from large window surfaces.

• Forced air heating may aggravate allergies or other respiratory symptoms.

• There will be some sound from forced air terminal units. Properly designed radiant floor, wall, and ceiling panels can operate with virtually no detectible sound.


# Why should hydronics be considered?

Hydronic heating and cooling systems have a lot to offer.

• **Can be combined with a wide variety of current and future energy sources**
(Almost anything that generates heat can be adopted to hydronic distribution)

• Much higher **distribution efficiency** in comparison to forced air heating / cooling delivery systems. (It's not just about the energy use of the heat/cool source!)

• Can be designed to be minimally dependent on future regulations regarding energy sources, and refrigerant regulations. (What's the global warming potential of water?)

• With proper design, installation, and maintenance can last for many decades.
(Is the word "sustainable" applicable here?)

• Ideal for "district energy" systems in combination with heat meters.
(Pay for what you use generally encourages energy conservation)

# Defining DISTRIBUTION EFFICIENCY

$$\text{Efficiency} = \frac{\text{desired OUTPUT quantity}}{\text{necessary INPUT quantity}}$$

**Distribution efficiency for a space heating system.**

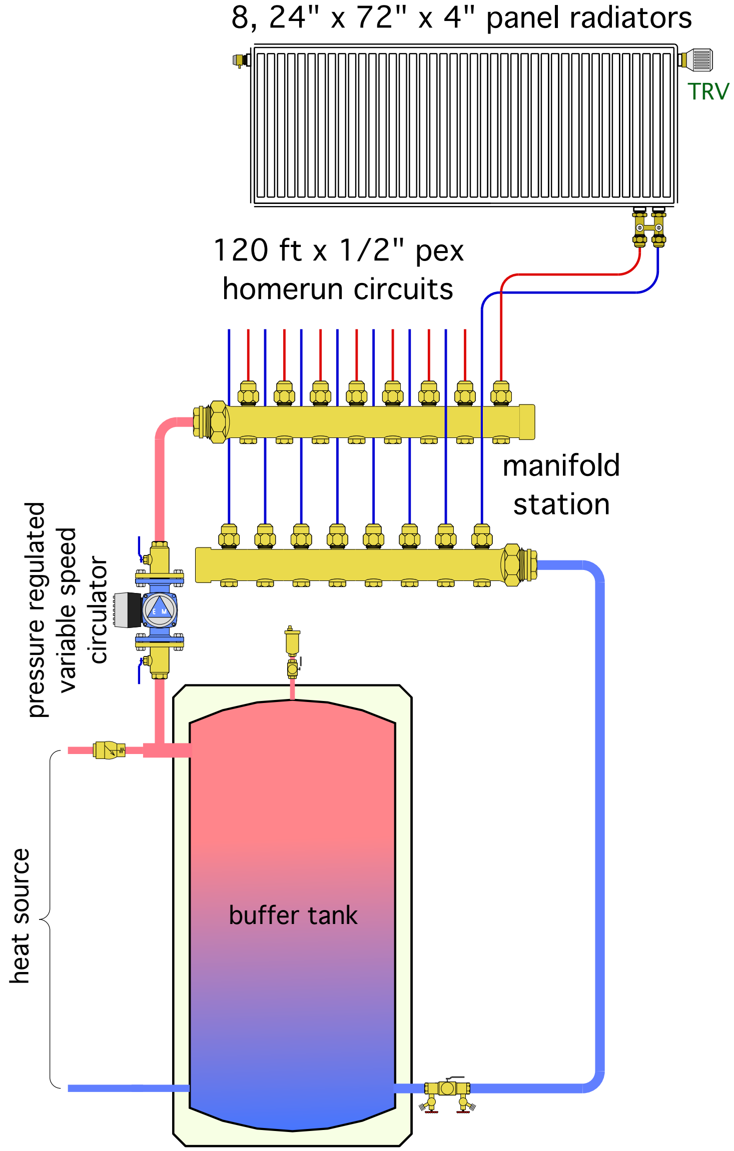
$$\text{distribution efficiency} = \frac{\text{rate of heat delivery}}{\text{rate of energy use by distribution equipment}}$$

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:

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

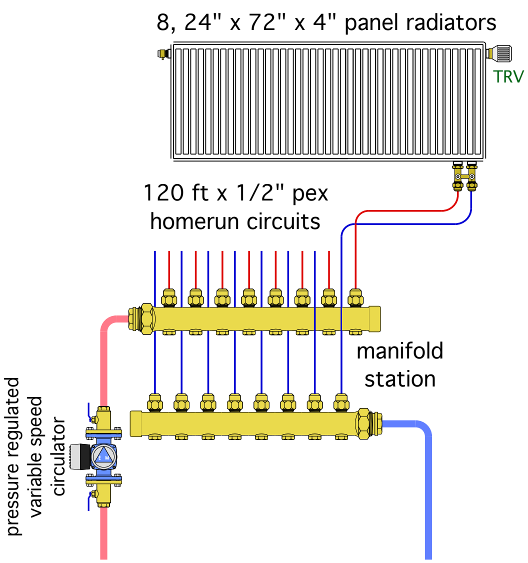
With good design and current hardware it's possible to design a homerun distribution system for panel radiators that can supply 30,000 Btu/hr design load using only 8.6 watts of electrical power input to circulator!

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

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

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




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

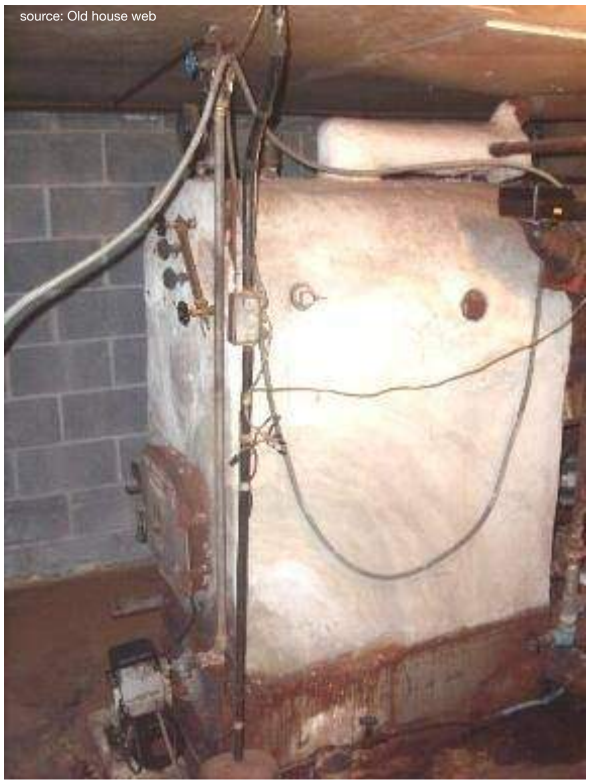
$$\frac{94}{3581} = 2.6\%$$

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).

# Hydronic Heat Source Trends

**All technologies evolve with time.**

That’s certainly been the case with boilers




It's also true about other heat sources such as heat pumps

Old Carrier "Round" heat pump

ductless mini-split

variable speed water-to-water

## **Estimated** life span of hydronic heat sources:

*Assuming proper installation and basic servicing*

Modern mod-con boiler (10-15 years)

Geothermal heat pump (20-25 years)

Exterior air-source heat pump (10-15 years)

Pellet boiler (20–25 years)

Flat plate solar collectors (20-25+ years)

Cast-iron boiler (25-40+ years)


Virtually all likely future heat sources for hydronic systems operate with higher efficiency at **lower supply water temperatures**.

mod/con boilers

solar thermal collectors

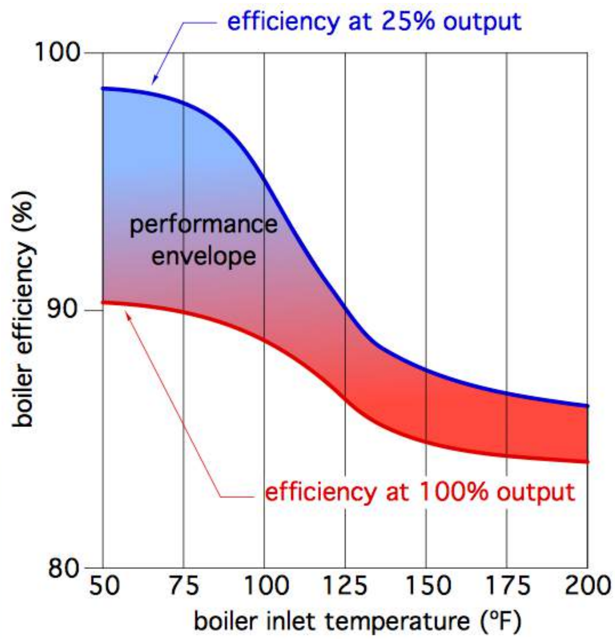

biomass boilers

water-to-water
heat pumps

air-to-water heat pumps

# Modern heat sources all yield higher efficiency at lower water temperatures

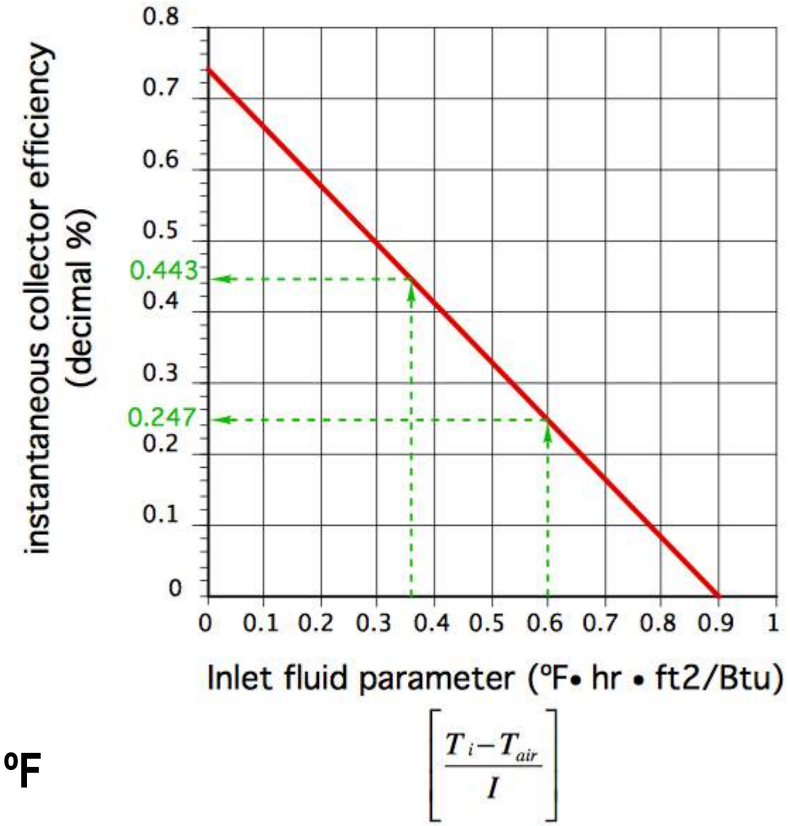
## modulating / condensing boilers:




- Low inlet water temperature is necessary for high (90+%) efficiency
- Connecting a mod/con boiler to a legacy high temperature distribution system will produce some efficiency gain over a "conventional" boiler, but only based on outdoor reset control

# Modern heat sources all yield higher efficiency at lower water temperatures

## Solar thermal collectors:



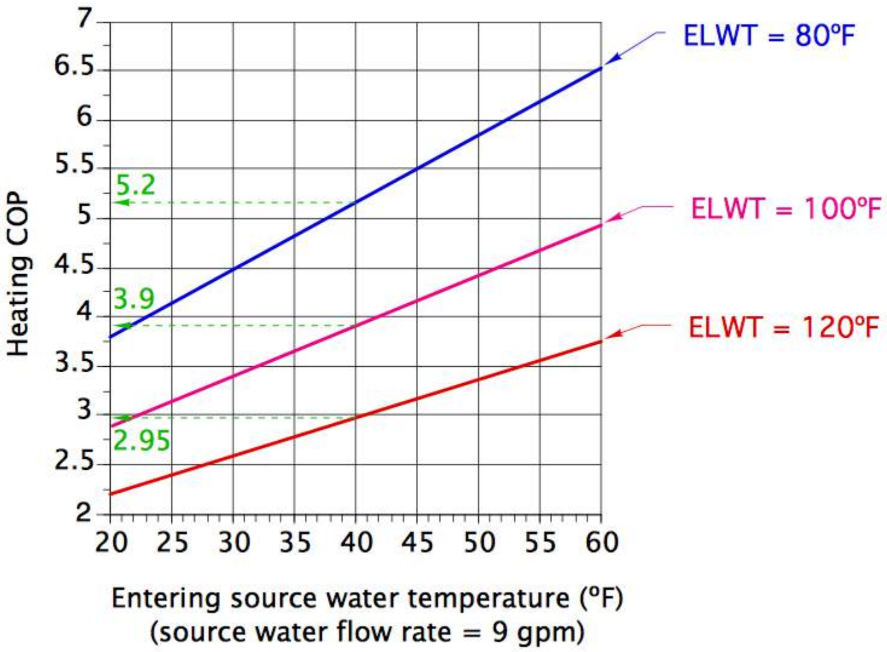

• Sunny winter day: I = 250 Btu/hr/ft2, ambient air temp. = 20 ºF

If Ti = 170 ºF, (Ti-Ta)/I = 0.6, efficiency = 24.7%

If Ti = 110 ºF, (Ti-Ta)/I = 0.36, efficiency = 44.3%

# Modern heat sources all yield higher efficiency at lower water temperatures

## Geothermal water-to-water heat pumps




- **Assume entering temperature of loop fluid = 40 ºF**

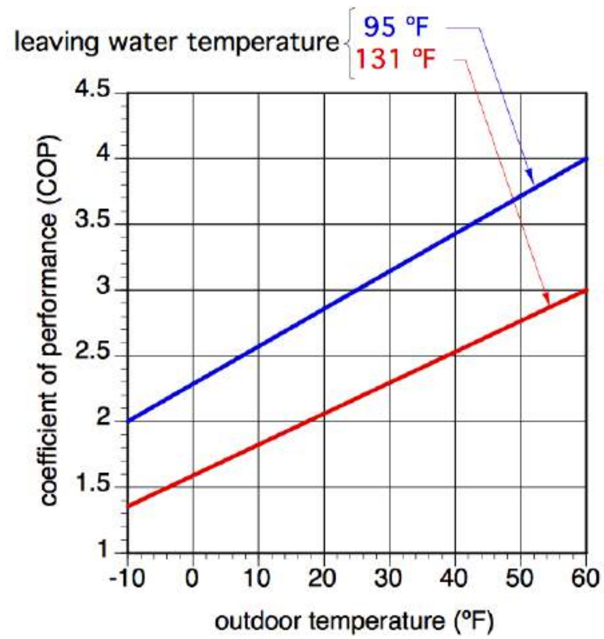
**If Entering load water temperature = 120 ºF, COP =2.95**

**If Entering load water temperature = 100 ºF, COP =3.9**

**If Entering load water temperature = 80 ºF, COP =5.2**

# Modern heat sources all yield higher efficiency at lower water temperatures

## Air-to-water heat pumps



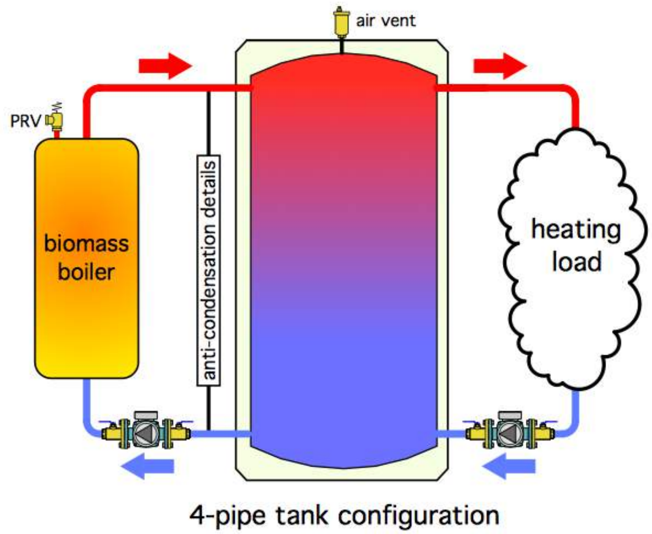

- **Assume outdoor temperature = 40 ºF**

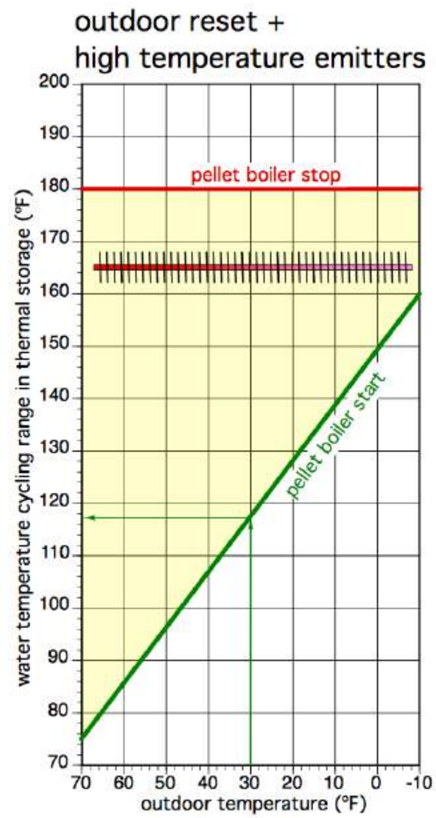
**If Entering load water temperature = 131 ºF, COP =2.55**

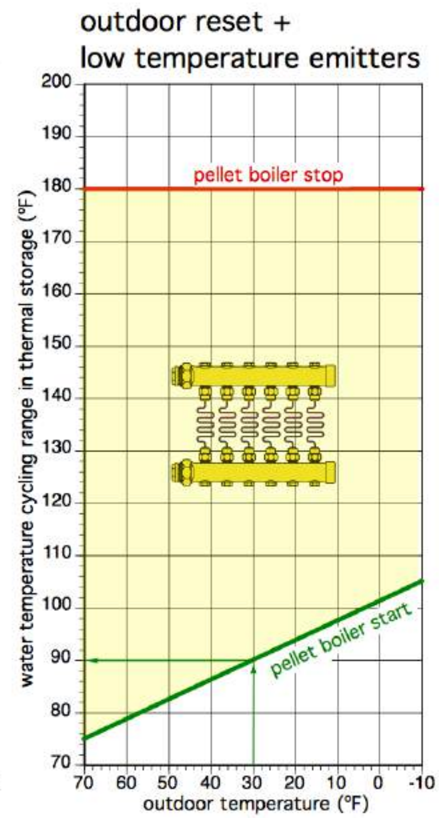
**If Entering load water temperature = 95 ºF, COP =3.4**

## Modern heat sources all yield higher efficiency at lower water temperatures

# Biomass boiler systems w/ thermal storage:


**The lower the "usable" temperature of thermal storage, the longer the boiler on / off cycles.**

**Longer boiler on / off cycles yield higher thermal efficiency & lower emissions.**

Keep you eyes on the developing North American market for air-to-water heat pumps

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



*More coming in 2020*

*Split system* air-to-water heat pump

*More coming in 2020*

- Fan and coil are only exterior major components
- Compressor and electronics inside
- Allows for domestic water heating via desuperheater

What about
hydronic distribution systems?

# How long does a well-designed, properly-installed, and adequately-maintained hydronic distribution system last?

Copper tubing and steel pipe in closed hydronic systems with proper water conditions, and lack of dissolved oxygen can **last for many decades**.

Some sources show the projected life of PEX tubing in certain applications (lower temperature / lower pressure) to be **over 100 years**.

My first slab floor heating using barrier PEX was in 1988 (31 years ago), and the distribution system is still functioning fine.

Many of you can think of one or more functioning hydronic distribution systems that are **at least 50 years old**.

PEX tubing in test lab
(source: Water and Pipes, by T. Lenman

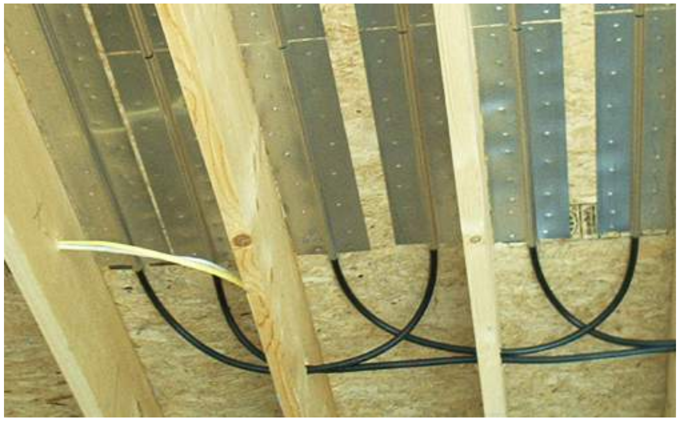
# Of course, there are exceptions…


It’s highly likely that well-designed, properly installed, and adequately maintained hydronic distribution systems will outlast their initial heat source.

This leads to 2 important questions:

1. Will the hydronic systems I’m currently designing be compatible with future heat sources?

2. What can I do **today** to increase the likelihood that the answer to question 1 is YES?



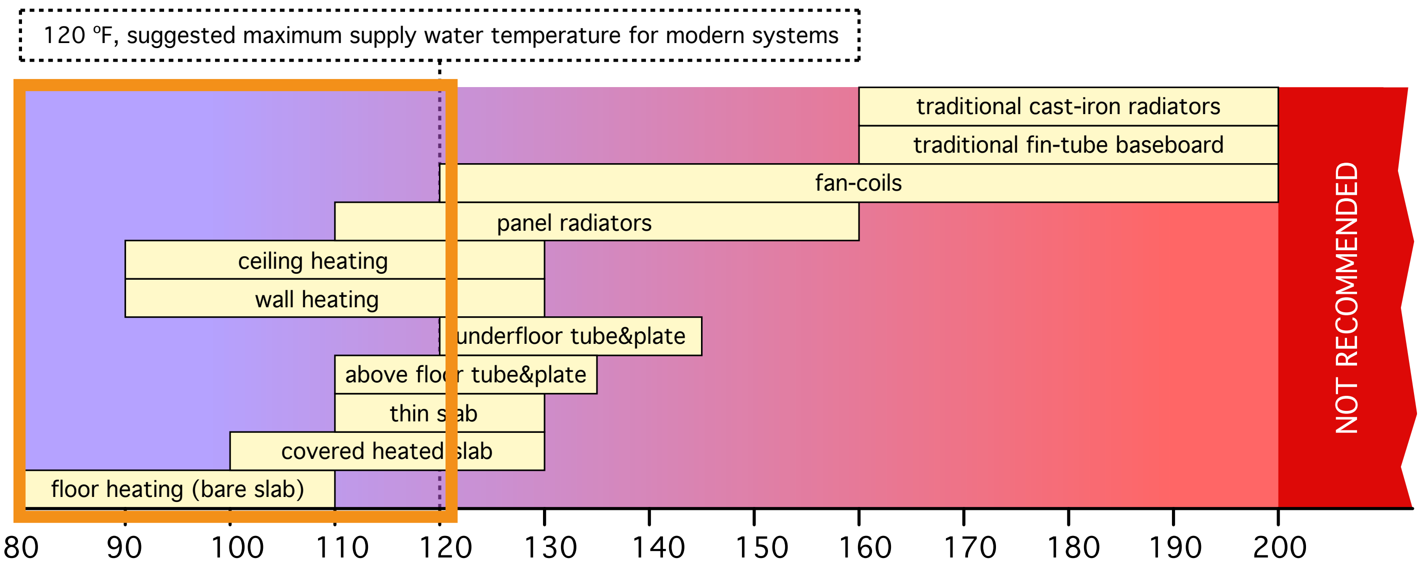
## Heat Emitter Fundamentals

• The heat output of ***any*** heat emitter always drops with decreasing water temperature.

• There is always ***some*** output provided the supply water temperature is above the room air temperature.

• There is always a trade off between the *total surface area of the heat emitters* in the system, and the *supply water temperature* required to meet the heating load.

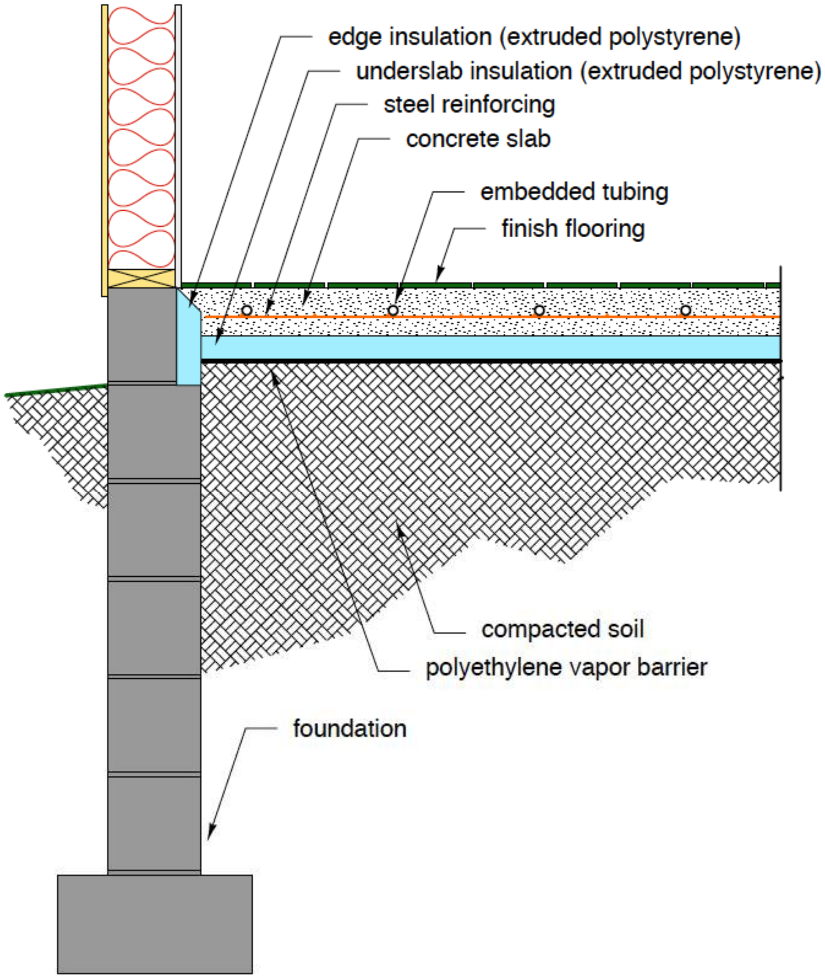
• ***More heat emitter area always lowers the required supply water temperature.***

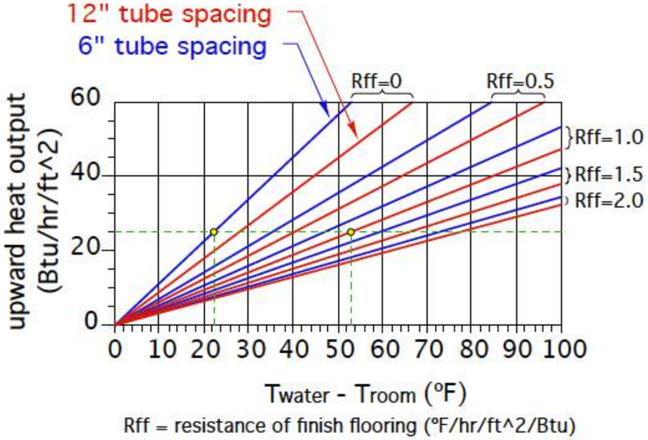



• **Don't feel constrained to select heat emitters based on traditional supply water temperatures…**

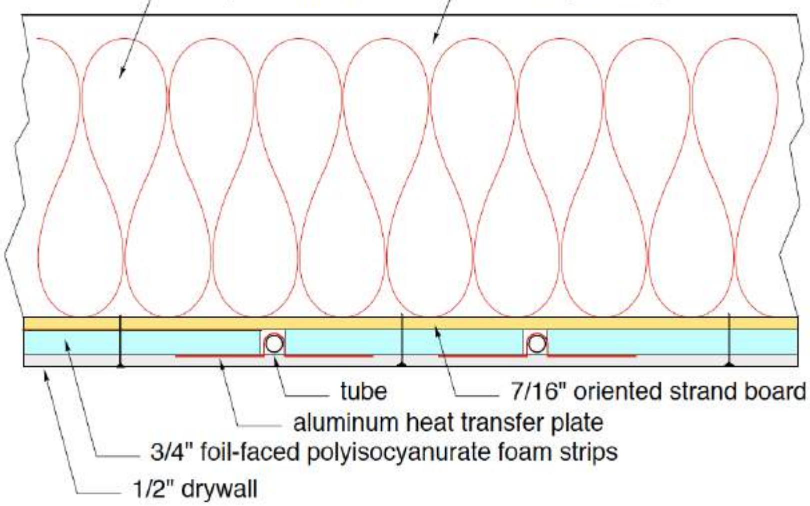
# A small sampling of low temperature heat emitter options

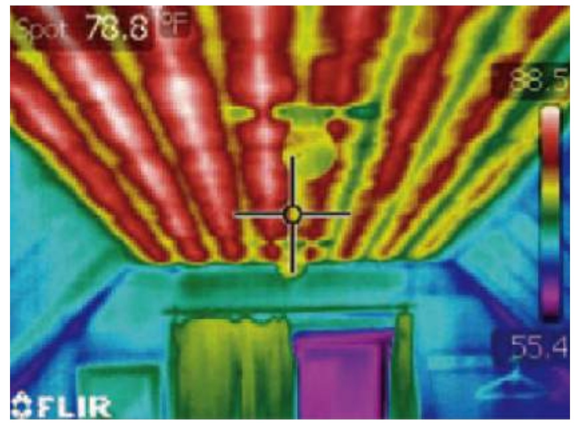
# Slab-on-grade floor heating



# Site built radiant CEILINGS...




Thermal image of radiant ceiling in operation

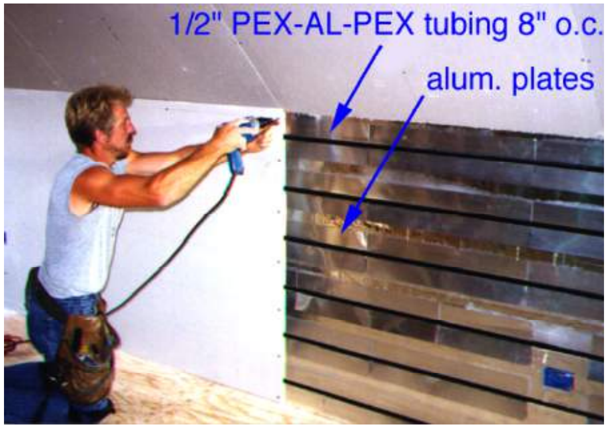
## Heat output formula:

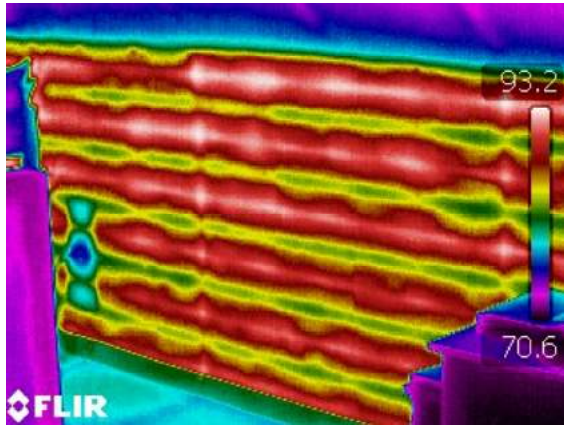
$$q = 0.71 \times (T_{water} - T_{room})$$

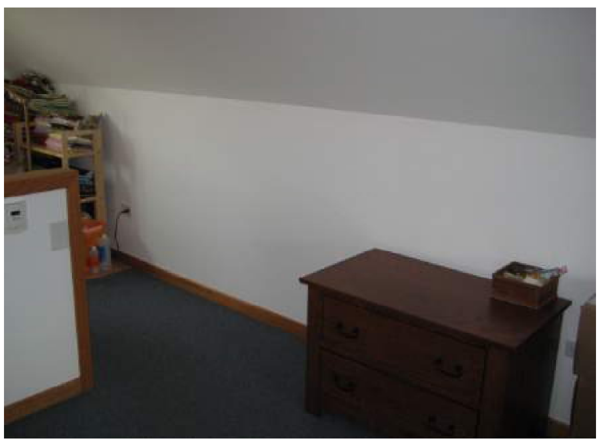
Where:

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

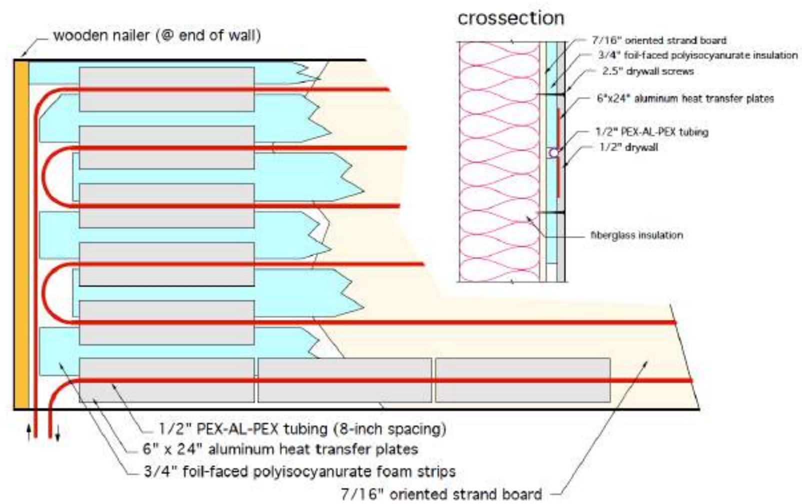
# Site built radiant WALLS...



- 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)

## Fan-assisted Panel Radiators

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


**Courtesy of Vogel & Noot**

# Future proofing hydronic systems

## What can you do now?

**1. Plan for low water temperature in ALL your systems.**
**(I suggest 120 ºF max at design load).**

2. Keep flow velocity in copper tubing ≤ 4 ft/sec.
3. Internally clean the system during commissioning
4. Use demineralized water
5. Use a stabilizing thin-film forming water additive
6. Use a magnetic dirt separator, capture and remove magnetite
7. Do annual checks on antifreeze, maintain pH of 7.5 to 8.0
8. Avoid “open” systems (too many potential issues)
9. Have a “plan B” if currently-specified controllers are not available for future replacement.
10. Create detailed piping and electrical schematics, and description of operation for every system.
11. Protect cast iron, steel,and copper tube boilers against sustained flue gas condensation
12. Lift tubing & welded wire reinforcing during slab pours
13. Install surge suppression for all system wiring
14. Avoid non-barrier PEX tubing in all hydronic systems.

## Thanks for attending

MODERN HYDRONICS SUMMIT 2019

Please visit our website for more information (publications & software) on hydronic systems:

www.hydronicpros.com