Efficiency Vermont

FEB 2020

HVAC 2020

A showcase of emerging systems

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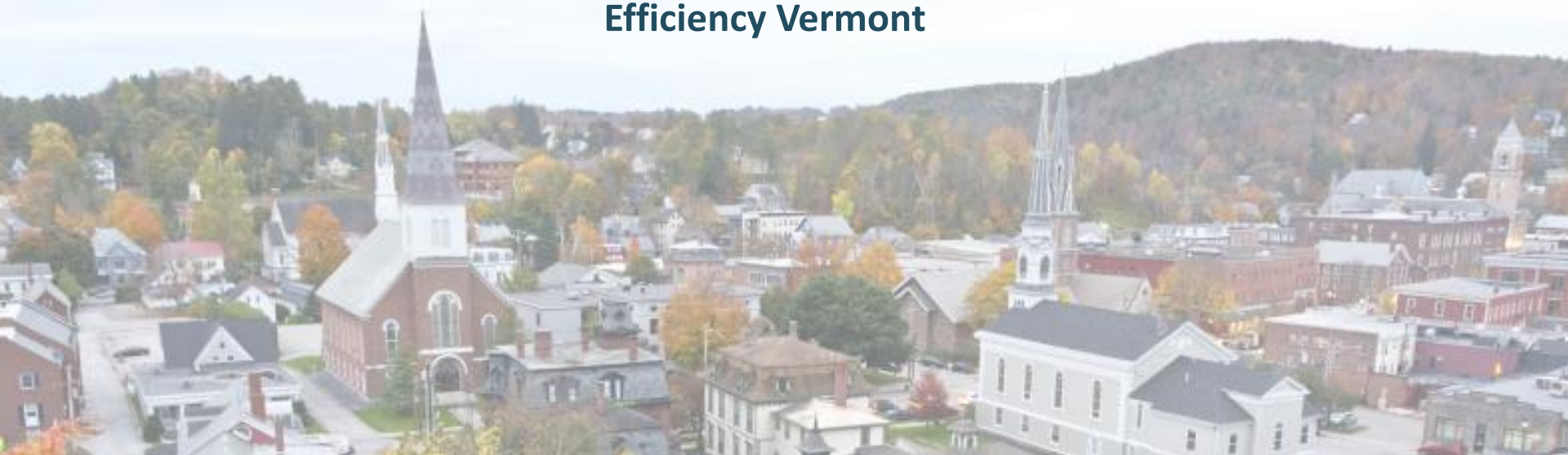
Efficiency Vermont



Agenda

- **Equipment types**
- **Controls**
- **Sizing and Selecting**
- **Installation tips**
- **Case Studies**
- **Code updates**

Understand:

Emerging technologies in HVAC for new and existing construction
Different distribution approaches
Other major loads in the home

Goal:

Enable the design & construction community to fully understand the benefits and successfully implement these technologies as the market grows

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Equipment Types

Mini split heat pumps
Ducted heat pumps
Air To Water heat pumps
Ground Source heat pumps
Advanced Pellet heating
Distribution systems
Domestic Hot Water systems
Ventilation

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Single Zone Ductless Mini Split Heat Pumps

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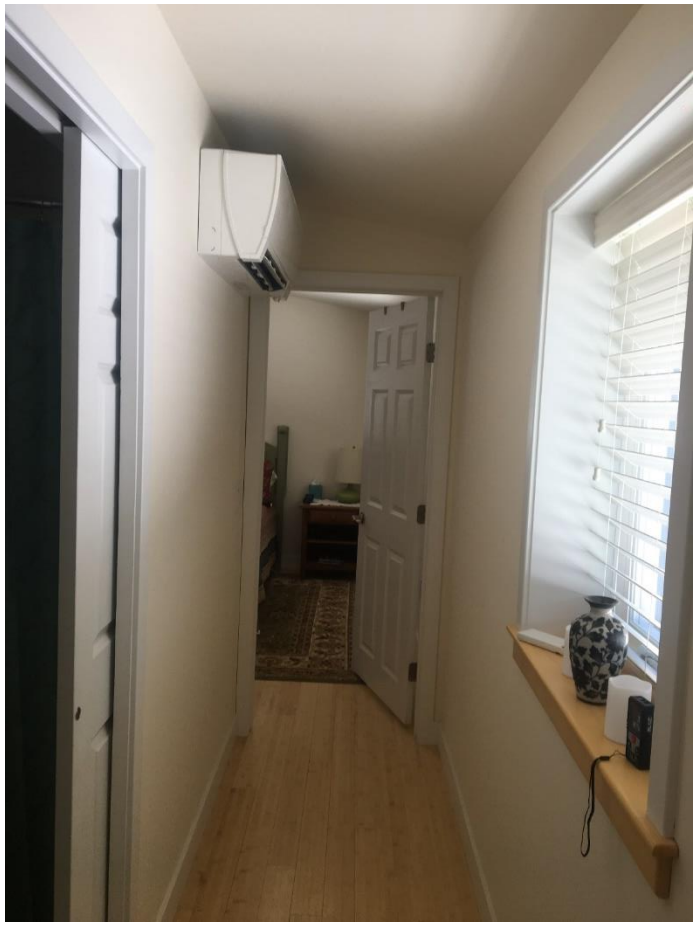
Single zone mini-split



Good news

- Customers love these things
- Cost effective
- Easy retrofit
- Best efficiency of all air sourced heat pumps
- Great low temp capability
- Indoor unit options

Challenges

- Non-distributed
- Comfort
- Sizing and selecting
- Zoning
- Systems integration

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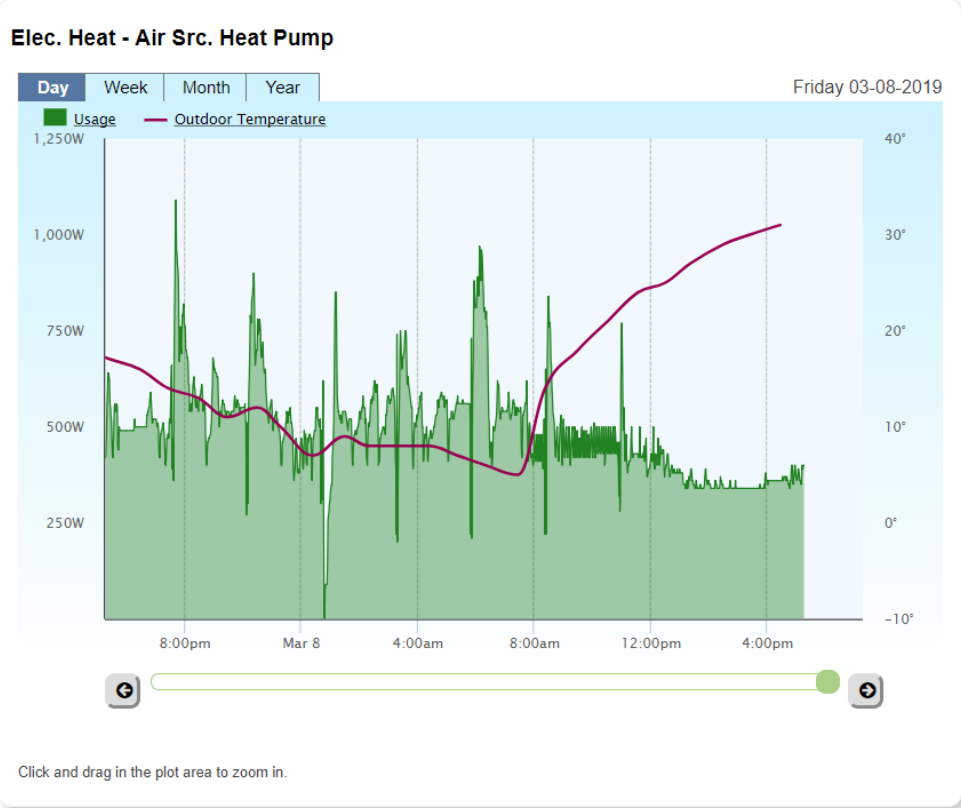
Single zone ductless mini split

- Up to HSPF 15, SEER 42, highest of all air source heat pumps
- Over 800 systems on NEEP list
- Up to about 30 KBtu at 5F
- Over 100% rated heating capacity at 5F
- Up to 8:1 turndown



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Single zone mini split indoor options

- Compact Duct – still considered mini split
- Ductless Floor – looks like space heater
- Ductless Wall - usually best listed performance
- Ceiling Cassettes – variety of styles, don't install in attic

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Equipment Types

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Multi Zone Ductless Mini Split Heat Pumps

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Multi zone ductless heat pumps

Good News
- Single outdoor unit serves multiple indoor units
- Reduced electric infrastructure
- Indoor options

Challenges
- Do not modulate as well as single zones
  - Performance and comfort implications
- Difficulty matching partial loads in small spaces
- Lower listed performance than single zones
- Still need load calcs,
  - block load
  - room by room
  - Sensible and latent

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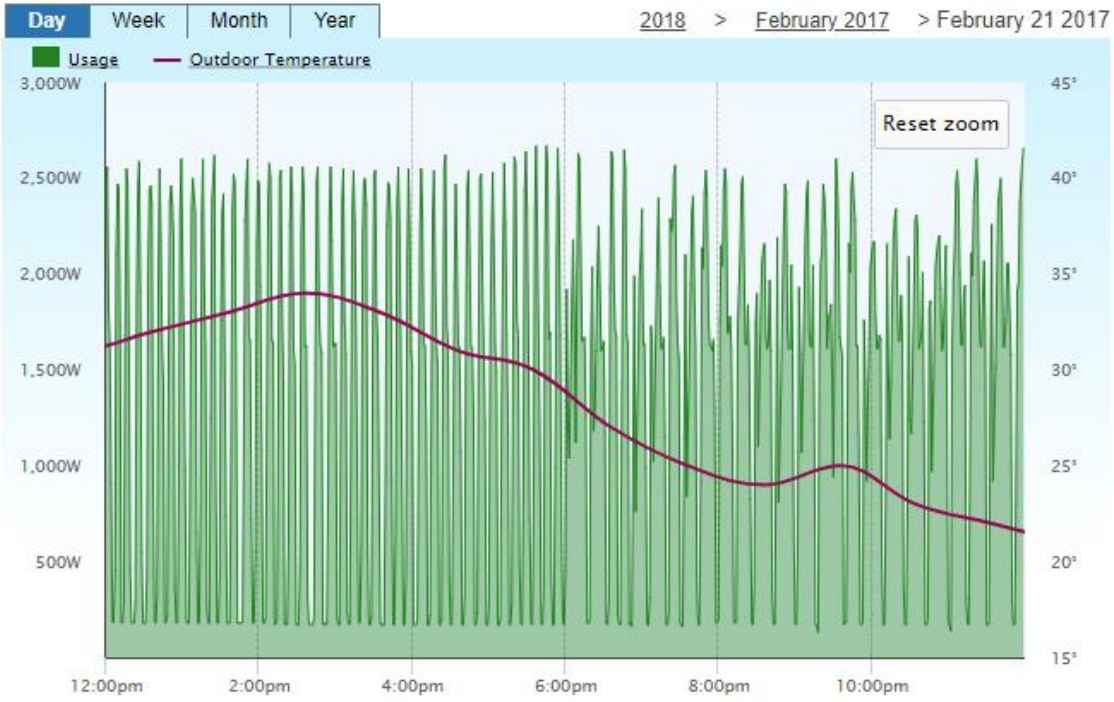
Multi zone ductless mini split

- Up to HSPF 12.5, SEER 19,
- 208 systems on NEEP list
- Up to about 60 KBtu at 5F
- Over 100% rated heating capacity at 5F
- Up to 4:1 turndown



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Special Bulletin:
Multi Split Heat Pumps

- Single zone systems are recommended over multi zone
- Never oversize multi zone heat pumps, size for partial load offset where possible
- Never size multi zone heat pumps based on number of zones

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Some thoughts about load calculations and sizing heat pumps…

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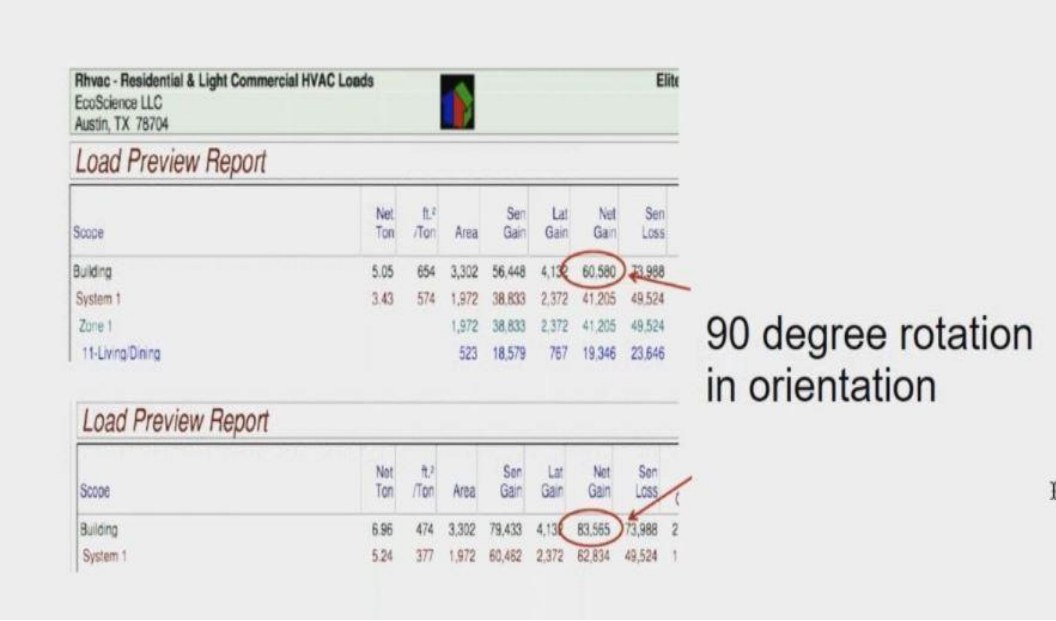
How to screw up load calculations

- Site location
- Orientation
- Area and sq ft / ton
- Mech system location
- Ventilation and dehumidification loads
- Envelope details, roof, glass, insulation, infiltration



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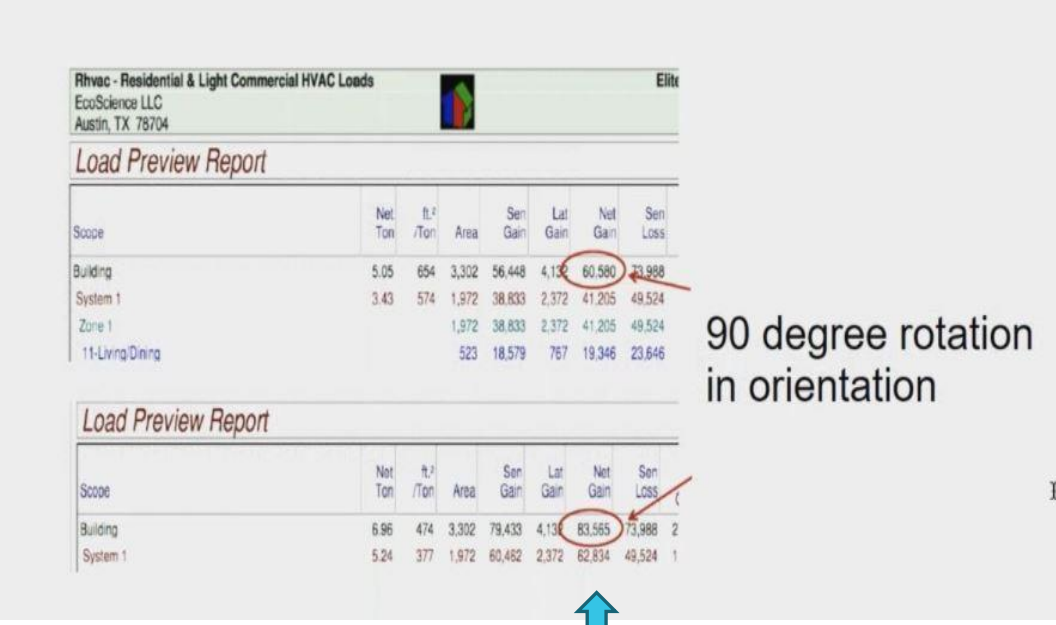

90 degree rotation in orientation added 22,985 Btu to cooling load, or 28% net gain

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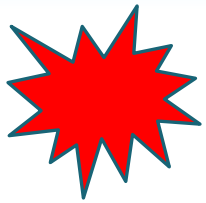
How to oversize a heat pump

Screw it up  or... Get it right 

- Start with # of zones
- Don't worry about partial loads
- Only look at max capacity
- Use extreme design conditions (oversizing)
- Do all of the above

- Start with load calcs
- Consider partial loads
  temps 50-80F = 40% hours
  ASHRAE design temp = 1% hours
- Consider max AND min capacity
- Use cold climate optimized equipment
- Use balance point control and back up system to meet design temp

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One more thing about mini split heat pumps… they need to be cleaned.

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Compact Ducted Mini Split Heat Pumps

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Compact Ducted AKA "ducted mini split"

- Minimal ducting, low static pressure systems
- Good for adjacent rooms
- Slightly lower performance vs single zone mini split
- Connect to HRV? Yes or no?
- 30 Single Zone mini-split compact ducted systems currently on EVT QPL
- EVT rebates found on Mini Split QPL

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Static pressure in a duct system

- Manuf. sells you the heating appliance, not the distribution system. Manuf. is not responsible for the design of the distribution system.

- Engineer designs the system, and the HVAC contractor installs the ducts according to engineer's design.

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Rules of Thumb for Static pressure in a duct system

- As a rule of thumb, it's not a good idea to use rules of thumb for HVAC design. -John Semmelhack
- Ducts and fittings may need to be larger than you'd think.
- Duct runs should be short, with minimal fittings.
- ACCA Manual D is a good place to start.
- Compact ducted systems range in allowable static pressure from 0.2"-0.6" wg

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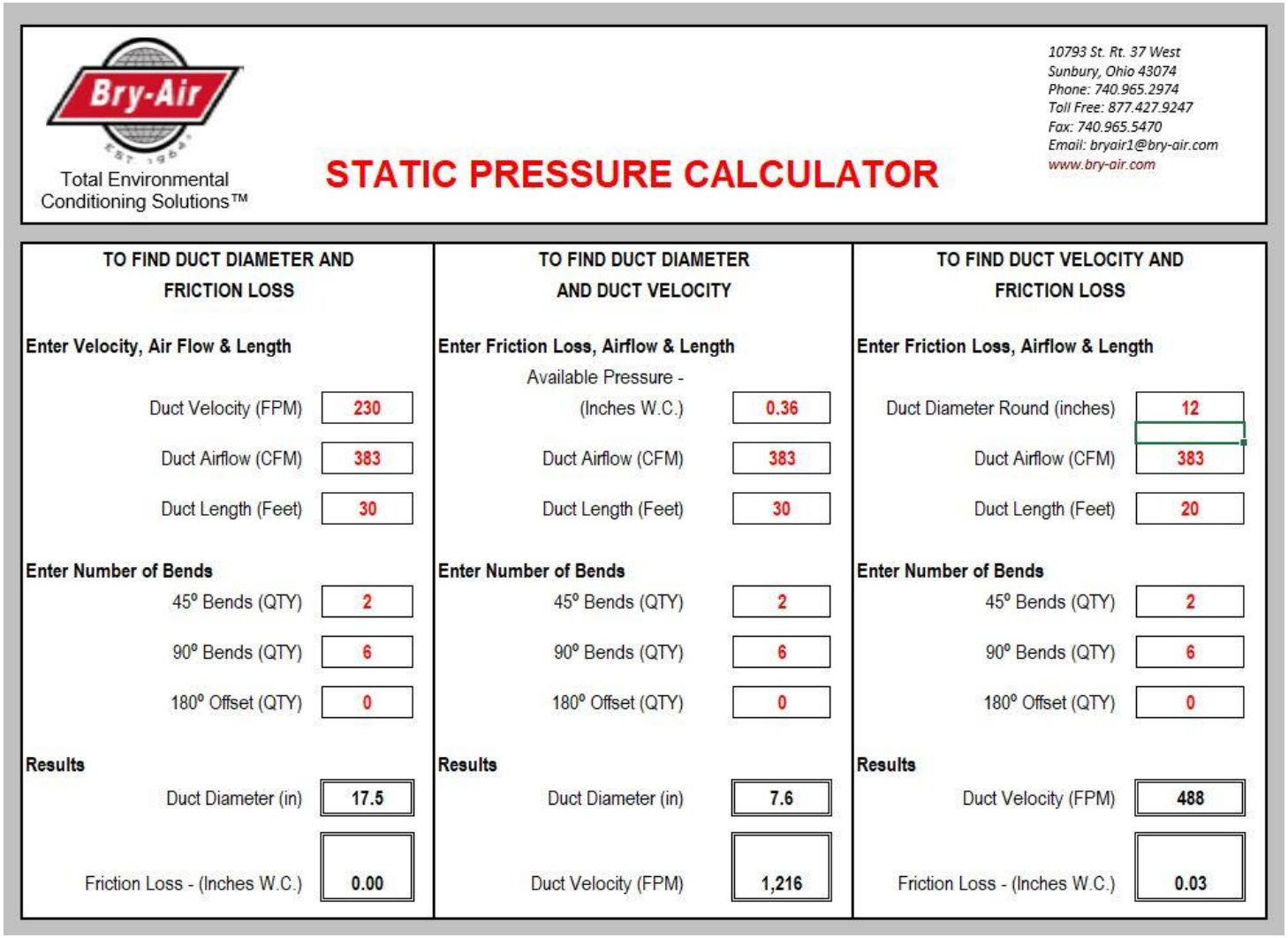
Static Pressure Calculator



Bry-Air
Total Environmental Conditioning Solutions™

STATIC PRESSURE CALCULATOR

10793 St. Rt. 37 West
Sunbury, Ohio 43074
Phone: 740.965.2974
Toll Free: 877.427.9247
Fax: 740.965.5470
Email: bryair1@bry-air.com
www.bry-air.com

TO FIND DUCT DIAMETER AND FRICTION LOSS		TO FIND DUCT DIAMETER AND DUCT VELOCITY		TO FIND DUCT VELOCITY AND FRICTION LOSS	
Enter Velocity, Air Flow & Length		**Enter Friction Loss, Airflow & Length**		**Enter Friction Loss, Airflow & Length**	
Duct Velocity (FPM)	230	Available Pressure - (Inches W.C.)	0.36	Duct Diameter Round (inches)	12
Duct Airflow (CFM)	383	Duct Airflow (CFM)	383	Duct Airflow (CFM)	383
Duct Length (Feet)	30	Duct Length (Feet)	30	Duct Length (Feet)	20
Enter Number of Bends		**Enter Number of Bends**		**Enter Number of Bends**	
45° Bends (QTY)	2	45° Bends (QTY)	2	45° Bends (QTY)	2
90° Bends (QTY)	6	90° Bends (QTY)	6	90° Bends (QTY)	6
180° Offset (QTY)	0	180° Offset (QTY)	0	180° Offset (QTY)	0
Results		**Results**		**Results**	
Duct Diameter (in)	17.5	Duct Diameter (in)	7.6	Duct Velocity (FPM)	488
Friction Loss - (Inches W.C.)	0.00	Duct Velocity (FPM)	1,216	Friction Loss - (Inches W.C.)	0.03

http://bry-air.com/resources/utilities/static-pressure-calculator/

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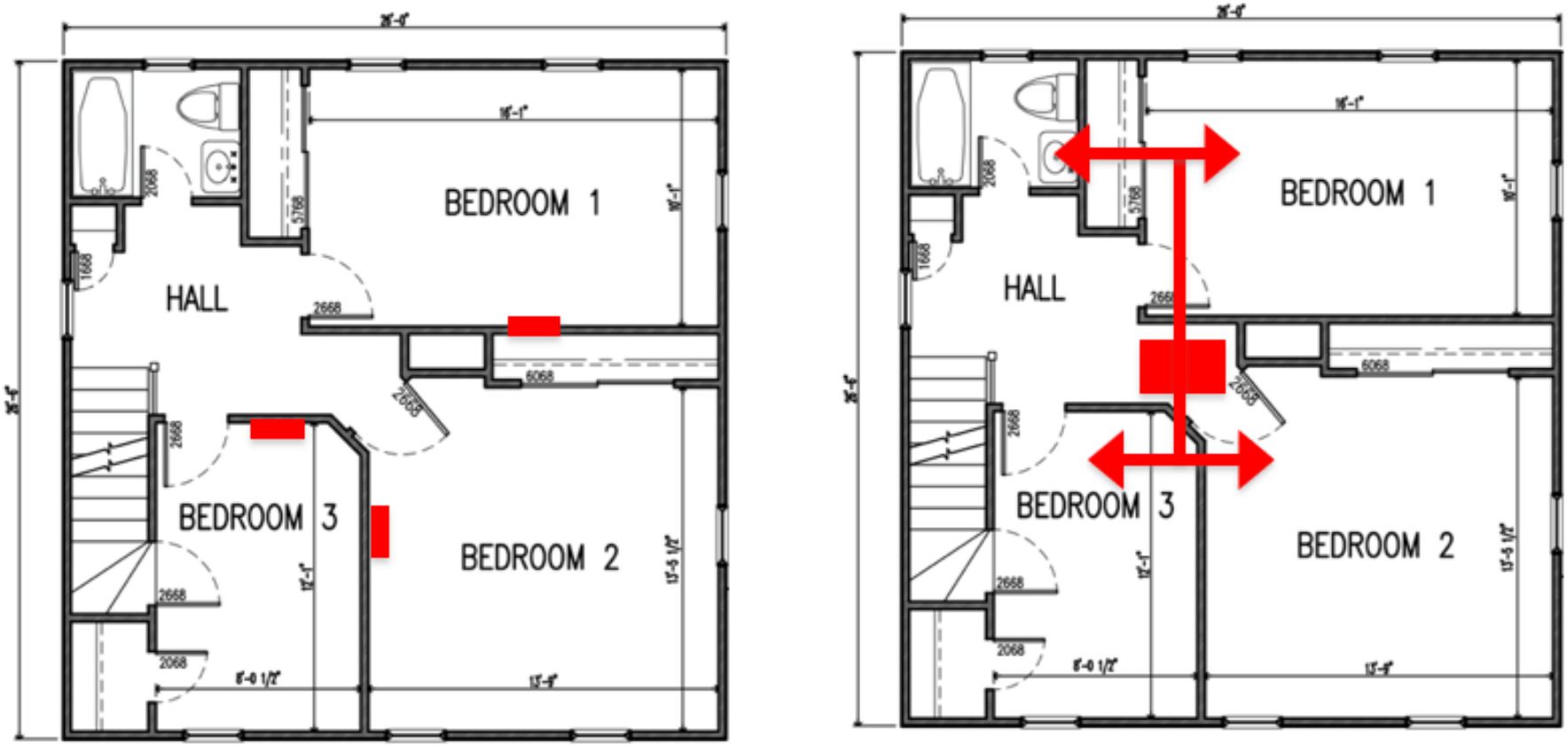
Compact Ducted vs Multi Split



Images courtesy of Mike Duclos, DEAP Energy Group

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Multi Zone vs Compact Ducted

Performance Specs

Heating / Cooling	Outdoor Dry Bulb	Indoor Dry Bulb	Unit	Min	Rated	Max
Heating	5°F	70°F	Btu/h	12,500	-	25,000
			kW	1.6	-	3.82
			COP	2.29	-	1.92
Heating	17°F	70°F	Btu/h	13,100	14,000	25,000
			kW	1.5	1.62	3.56
			COP	2.56	2.53	2.06
Heating	47°F	70°F	Btu/h	11,400	25,000	25,000
			kW	0.93	1.72	1.72
			COP	3.59	4.26	4.26
Cooling	82°F	80°F	Btu/h	15,060	-	23,600
			kW	0.68	-	3.77
			COP	6.49	-	1.83
Cooling	95°F	80°F	Btu/h	12,600	22,000	23,600
			kW	0.53	1.63	3.77
			COP	6.97	3.96	1.83

MXZ-3C24NAHZ2
Multi Zone Ductless

Performance Specs

Heating / Cooling	Outdoor Dry Bulb	Indoor Dry Bulb	Unit	Min	Rated	Max
Heating	5°F	70°F	Btu/h	3,800	-	12,000
			kW	0.25	-	1.22
			COP	4.45	-	2.88
Heating	17°F	70°F	Btu/h	4,900	13,900	13,900
			kW	0.31	1.42	1.42
			COP	4.63	2.87	2.87
Heating	47°F	70°F	Btu/h	8,100	21,600	25,600
			kW	0.43	1.58	2.12
			COP	5.52	4.01	3.54
Cooling	82°F	80°F	Btu/h	6,700	-	18,900
			kW	0.25	-	1.1
			COP	7.85	-	5.04
Cooling	95°F	80°F	Btu/h	6,100	18,000	18,000
			kW	0.32	1.31	1.31
			COP	5.59	4.03	4.03

SUZ-KA18NA2 / SEZ-KD18NA
Compact Duct

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Other Ductwork Considerations

- Conditioned attic
- Dropped ceiling and soffits
- Closets
- Easier for new construction/remodel
- Condensate line, must have a plan
  - Assume it will be used for AC at some point even if customer states they won't. Insulate ducts?
- Return air, must have a plan
  - Undercut doors/louvers
  - Open return in hallway
- Limited duct length, low static pressure capability

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Compact Ducted systems in the real world…

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Compact Duct Installation

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Compact Duct Installation

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Compact Duct Installation

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Compact Duct Installation

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Centrally Ducted Heat Pumps

“whole house heat pump”

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Centrally Ducted Heat Pumps

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Centrally Ducted Heat Pumps

- Whole house option, using ducted distribution
- Provide heating and AC
- Replace central AC unit w/Heat Pump
- Keep existing furnace in place
  - Offset dirty and expensive heating fuels used by the furnace
- New construction option

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Control Strategy

- Capacity Balance Point:
  - outdoor temperature at which the capacity of a heat pump equals the heating load in the house.
- Economic Balance Point:
  - Outdoor temperature at which cost to operate heat pump equals cost to operate backup heat

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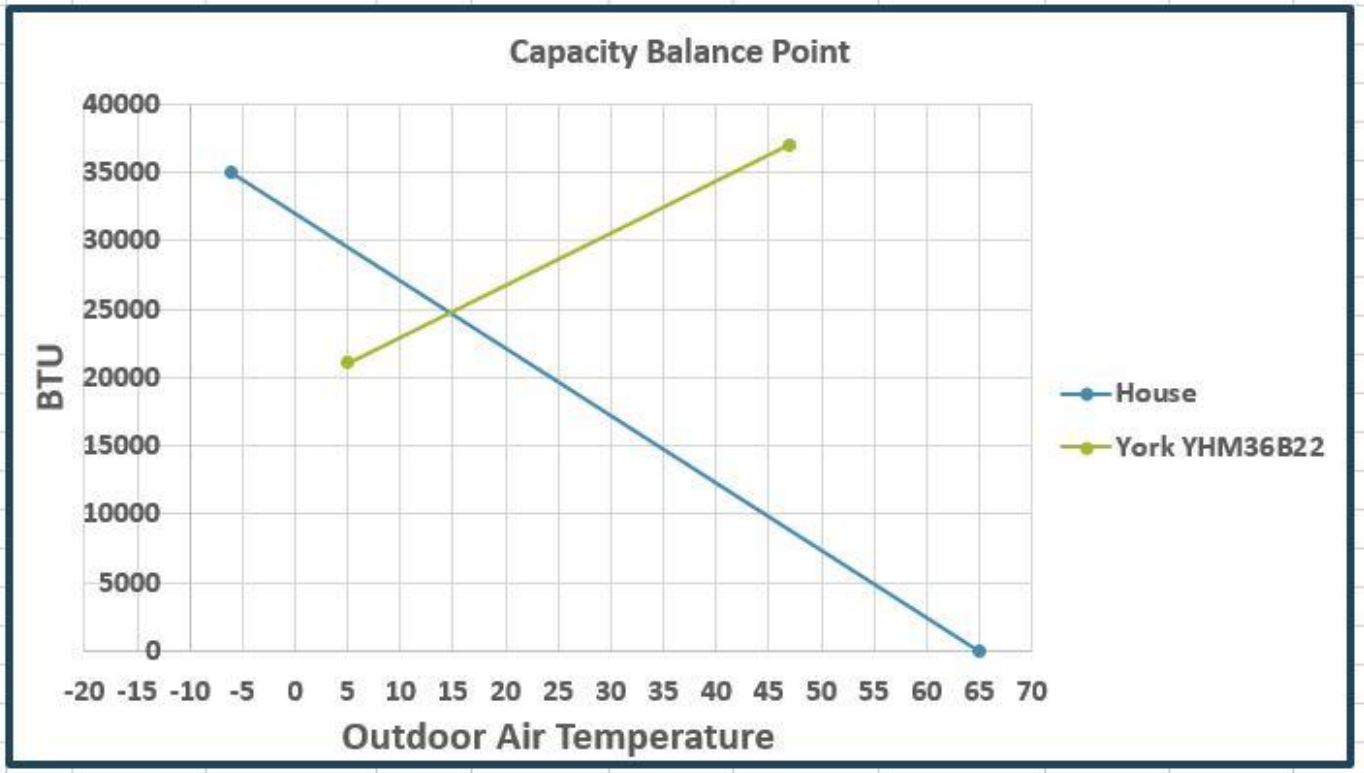
Balance Point, Capacity

Heat Pump Make Model		
York YHM36B22		
Building Design		
Heat Load	35000	
	Temp	Btu
House	-6	35000
House	65	0
York YHM36B22	5	21100
York YHM36B22	47	37000



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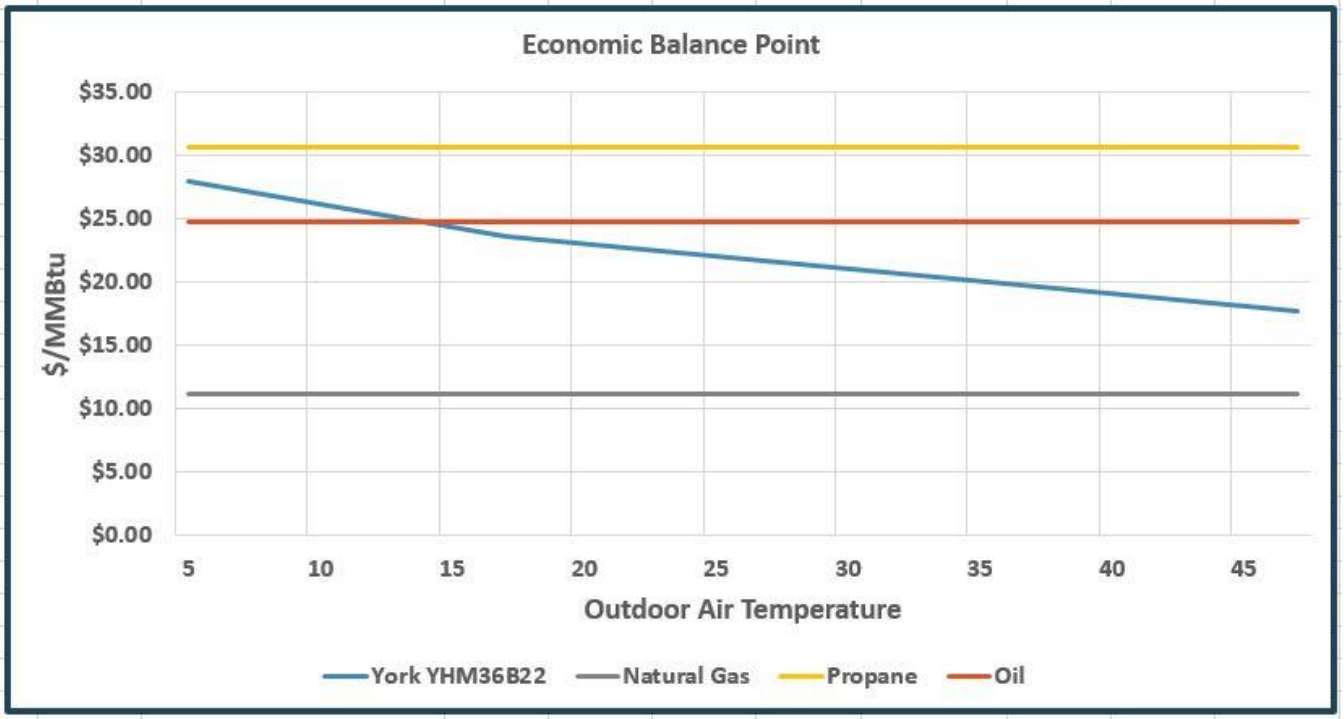
Balance Point, economic

NEEP Rated COP at OAT		
5 F	17 F	47 F
1.78	2.11	2.82

Heat Pump make model	Heat Pump $/MMBtu		
	5	17	47
York YHM36B22	$27.98	$23.61	$17.66

	Fuel $/MMBtu		
Natural Gas	$11.11	$11.11	$11.11
Propane	$30.61	$30.61	$30.61
Oil	$24.81	$24.81	$24.81

Fuel	Fuel cost	Unit	Fuel system Efficiency
Natural Gas	$1.14	/CCF	90.0%
Propane	$2.65	/Gallon	90.0%
Oil	$2.84	/Gallon	82.0%
Electric	$0.17		



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Control Strategy Goals

- Reduce emissions
  - Reduce Loads, Weatherize the Building
  - Install unit sized close to design heating load
  - Use capacity balance point
- Save money
  - Use economic balance point to operate system
  - Caution this will change with fuel prices
- Have this conversation with customer and show them how to set the balance point
- Use Dual Fuel capable thermostat

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Centrally Ducted Heat pump in the real world…

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Recent Installation

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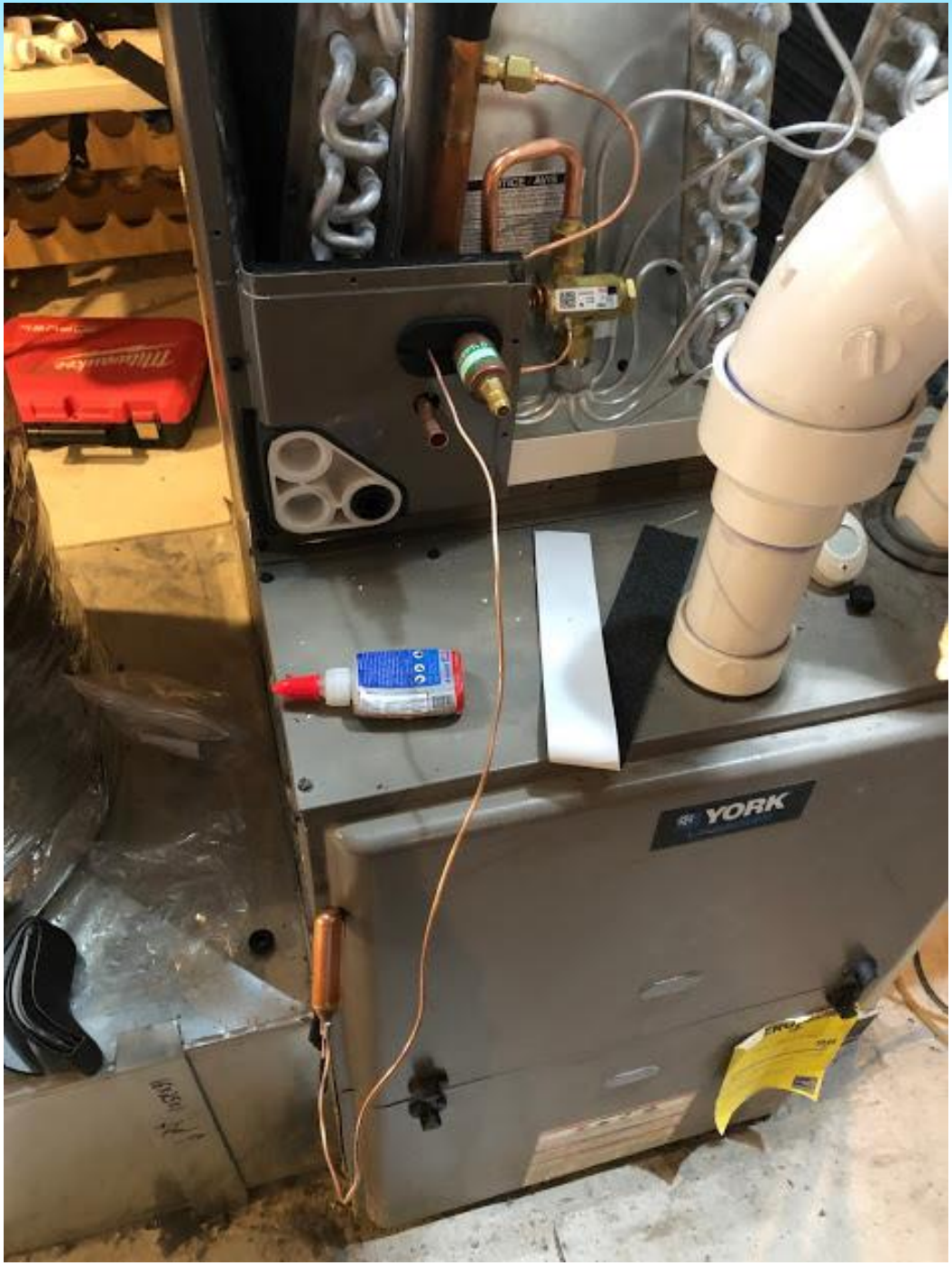

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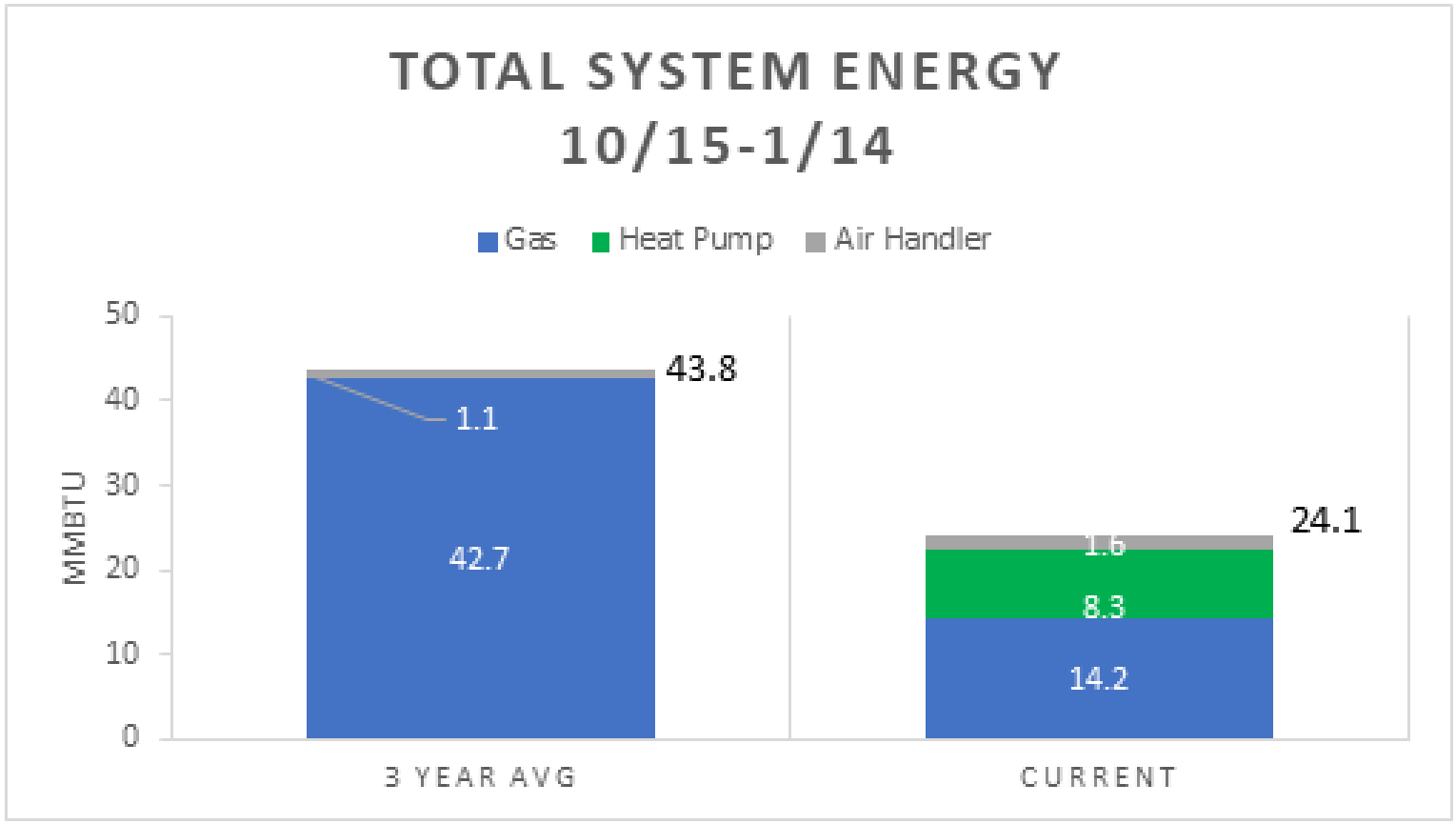
TOTAL SYSTEM ENERGY
10/15-1/14
Gas
Heat Pump
Air Handler
MMBTU
50
40
30
20
10
0
43.8
1.1
42.7
24.1
1.6
8.3
14.2
3 YEAR AVG
CURRENT

About this installation

- Controls are a big deal and are not necessarily easy to configure
  - Ecobee thermostat
  - Fan speed is still unresolved
- Coil is one size bigger, 4 ton heat pump with 5 ton coil
  - Allows better heat transfer

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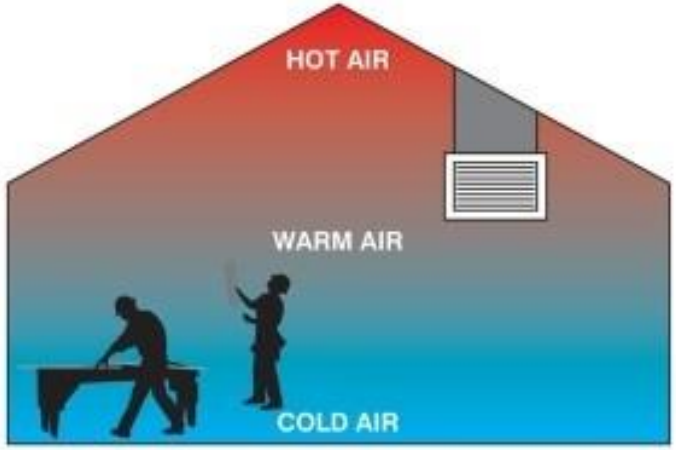
Benefits of ATW

- Comfortable
  - Zonal
  - Fully Distributed
  - Reduced stratification
  - Quiet



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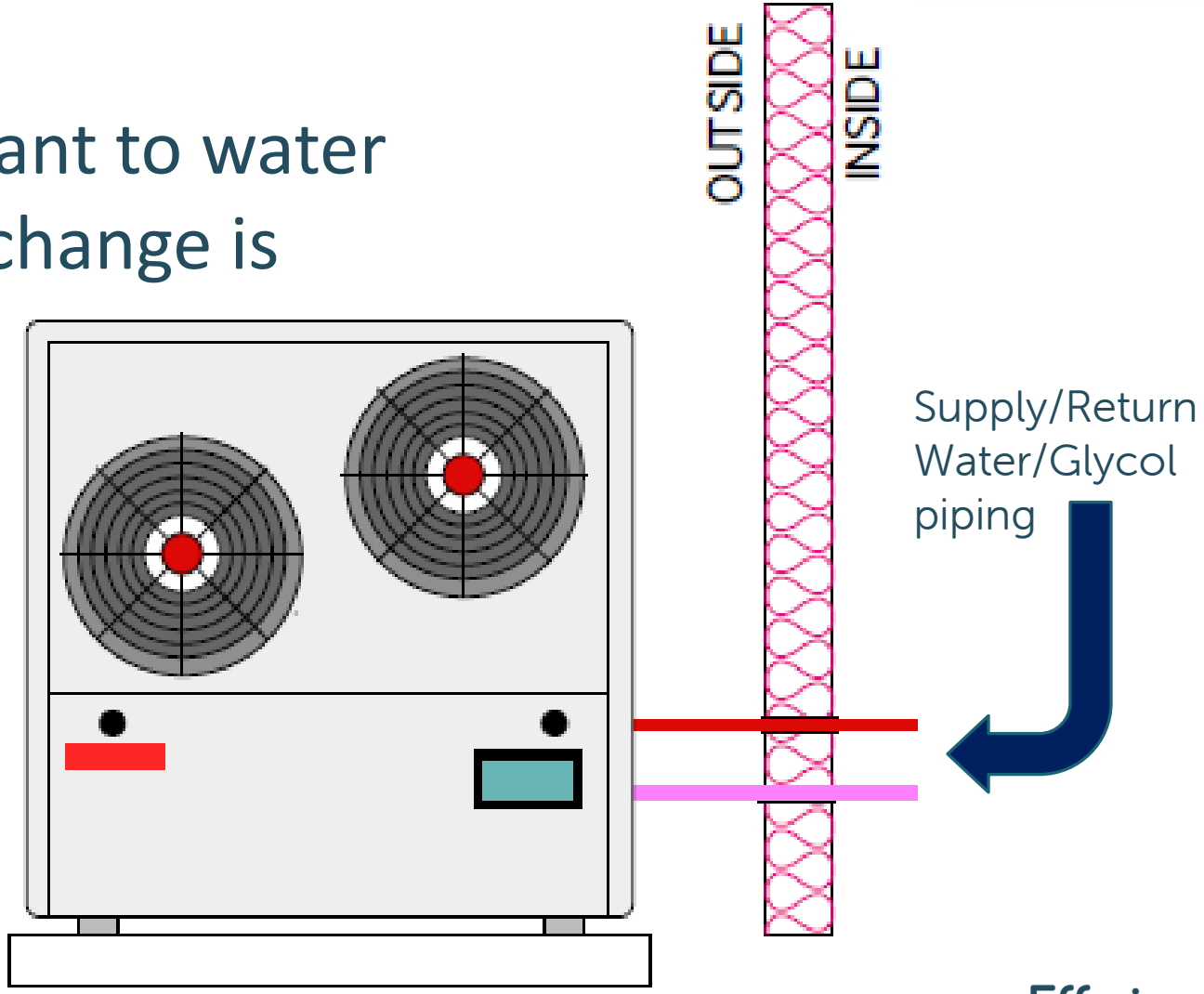
Mono-bloc

- Refrigerant to water Heat exchange is <u>outside</u>



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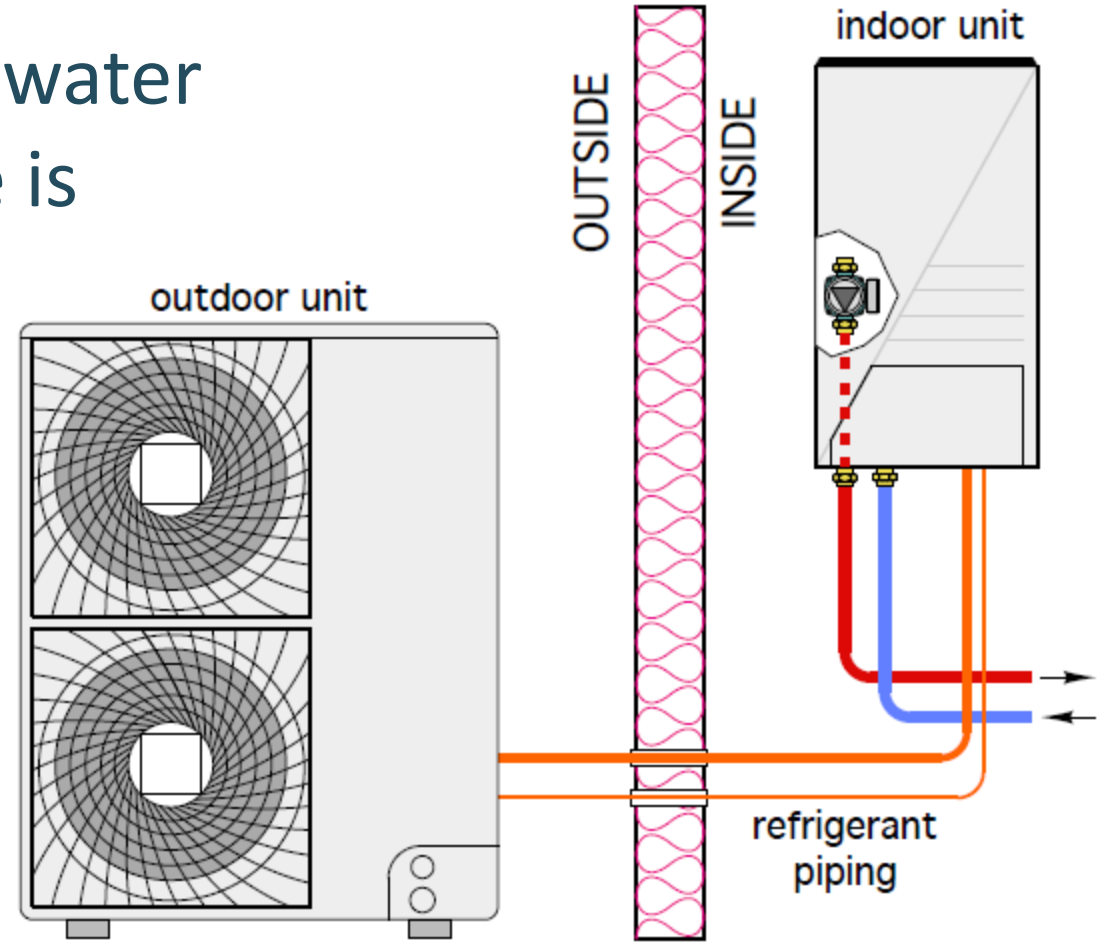
Split Systems

- Refrigerant to water heat exchange is <u>inside</u>



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Performance of ATW

- HSPF? SEER? NOPE!
- AHRI does not list/test
- No ENERGY STAR®
- IPLV – Integrated Part Load Value
- COP – Static points for varying outdoor and delivered water temperatures

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COP Example

Supply Water Temp ˚F	Ambient Temp ˚F	Capacity BTU/hr	Watts	COP
110	-5	37,500	3880	2.30
	17	44,800	3970	2.70
	47	60,580	4263	3.75
120	-5	38,500	4513	2.00
	17	46,440	5790	2.35
	47	66,480	5963	3.26
130	-5	40,425	5249	1.86
	17	48,762	5371	2.18
	47	69,804	6768	3.04

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Performance of ATW

- Overall – Very Good!
- Better with low supply water temperatures
- Similar to ductless, but does not account for distribution energy
- Good cold weather performance, but…
- We need a good metric and cold climate specification

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Product Availability

- **Aermec ANK**
  - 2.5, 3 and 4 ton
- **Arctic EVI**
  - 2.5, 4 and 5 ton
- **Chiltrix CX34**
  - 3 ton
- **Nordic ATW**
  - 3, 4, 5, and 6 ton
- **SpacePak Solstice**
  - 4 ton

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Buffer Tanks

- Small, not thermal storage (25-40 gal common)
- Prevents short-cycling
- Optimizes operation
- Not always needed (modulating systems)
- Adds cost/complexity
- Some DR opportunity

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Glycol

- In Monobloc systems a must
- 2 strategies:
  - Whole system (expensive)
  - Primary loop with heat exchanger
- Slight efficiency reduction

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Heat Exchangers

- Add flexibility to system design
- Reduces need for glycol, but adds a circulator
- Plate heat exchanger most common
- Sizing is important
- Some efficiency loss

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ATW heat pump in the real world…

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Low temp distribution

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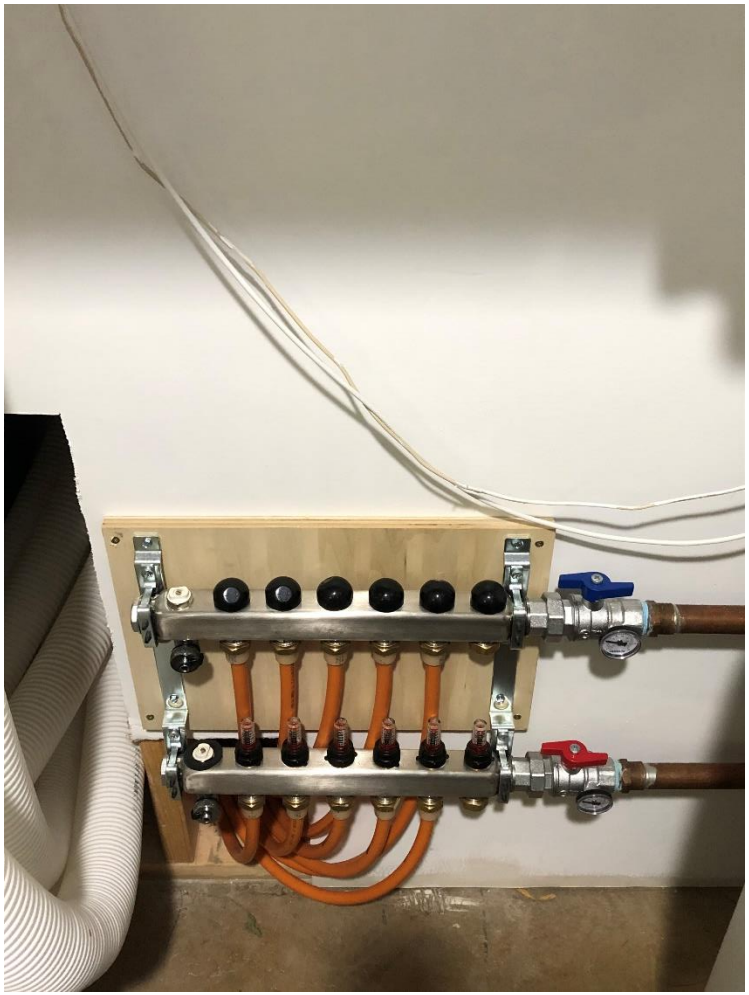
Low temp distribution



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Utility Room

Outdoors

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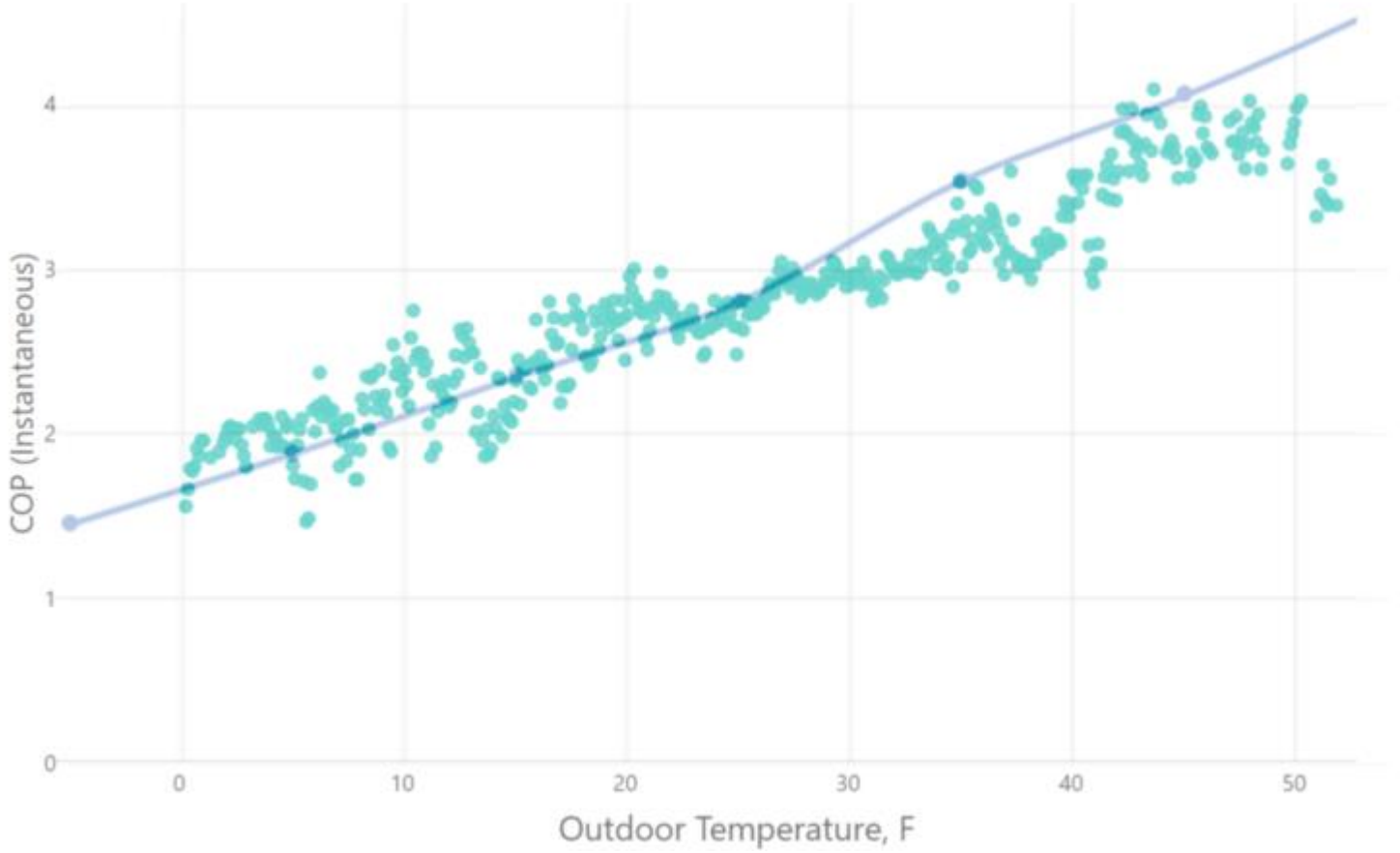
Measured Performance, COP @ outdoor temperature



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Why they installed an Air to Water heat pump

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Homeowner reflections

- Very happy with system, 1st heating season coming up
- Needed new $1000+ electric panel (bummer)
- The whole project took longer and cost more than original estimates
- Need a fair bit of utility room space for split system, buffer tank and HP water heater
- Really glad they went with HP water heater

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Ground Source Heat Pumps

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Ground Source Heat Pumps

- **Benefits:**
  - Can be sized to meet load, no back up needed
  - Good COPs, efficient systems
  - Performance not dependent on outdoor temps
  - Can heat DHW
  - Hydronic or Air distribution
  - Tax Credits

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Ground Source Heat Pumps

Three Part Systems

1. **Earth Connection Subsystem**
   - Heat source in winter, Heat sink in summer
2. **Heat Pump Subsystem**
   - Removes heat/cool from ground, concentrates it
3. **Heat Distribution System**
   - Distribute concentrated heat/cool throughout building

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Ground Source Heat Pumps

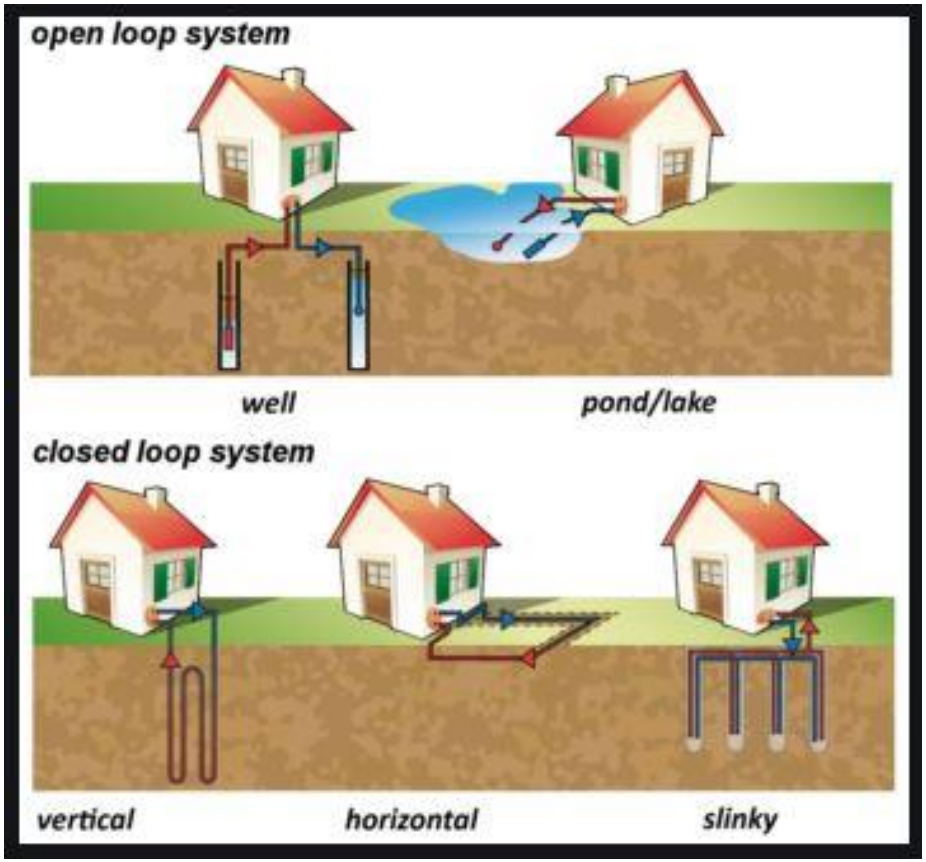

Image stolen from the internet

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GSHP in the real world…

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VT Solar Net Zero Home

Residence & Office
4,300 sq ft heated
Built in 2016

9.5 kW PV Array
11,000 kWh/YR

Geothermal Heating
5 ton unit
Single well, 400' deep

Thin mass radiant floor
& radiant walls

Design: L.W. Seddon
Builder: Josh Walker

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Geothermal System Overview

Tekmar 260 heating control w/ outdoor temp logic

Taco six zone controller w/ DHW priority

105 gal Marathon radiant storage tank

Grundfos Alpha 3-speed constant pressure circulator

1.5 GPM per zone

Radiant floor & wall heat distribution

Flat plate heat exchanger

Belimo flow control valve 12 GPM

400' well 6" bore

½ HP VFD pump

Return flow to top of well 40 F typical

Supply temp 48 F typical

Trane 5-ton heat pump with ni-cu coil

105 gal Marathon DHW tank with electric backup

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Simple Concept Meets Reality

VFD well pump changes pressure and water flow depending on demand

Using a single well for both domestic water and heating (dual mode) requires a flow control valve for HP

Geo heat pumps can get very unhappy – and freeze - if well flow goes just 2 GPM below normal

A freeze protection valve is required to dump about 15% of return flow (2 GPM) when temp falls to 34 degrees F – this allows fresh warmer water to enter well

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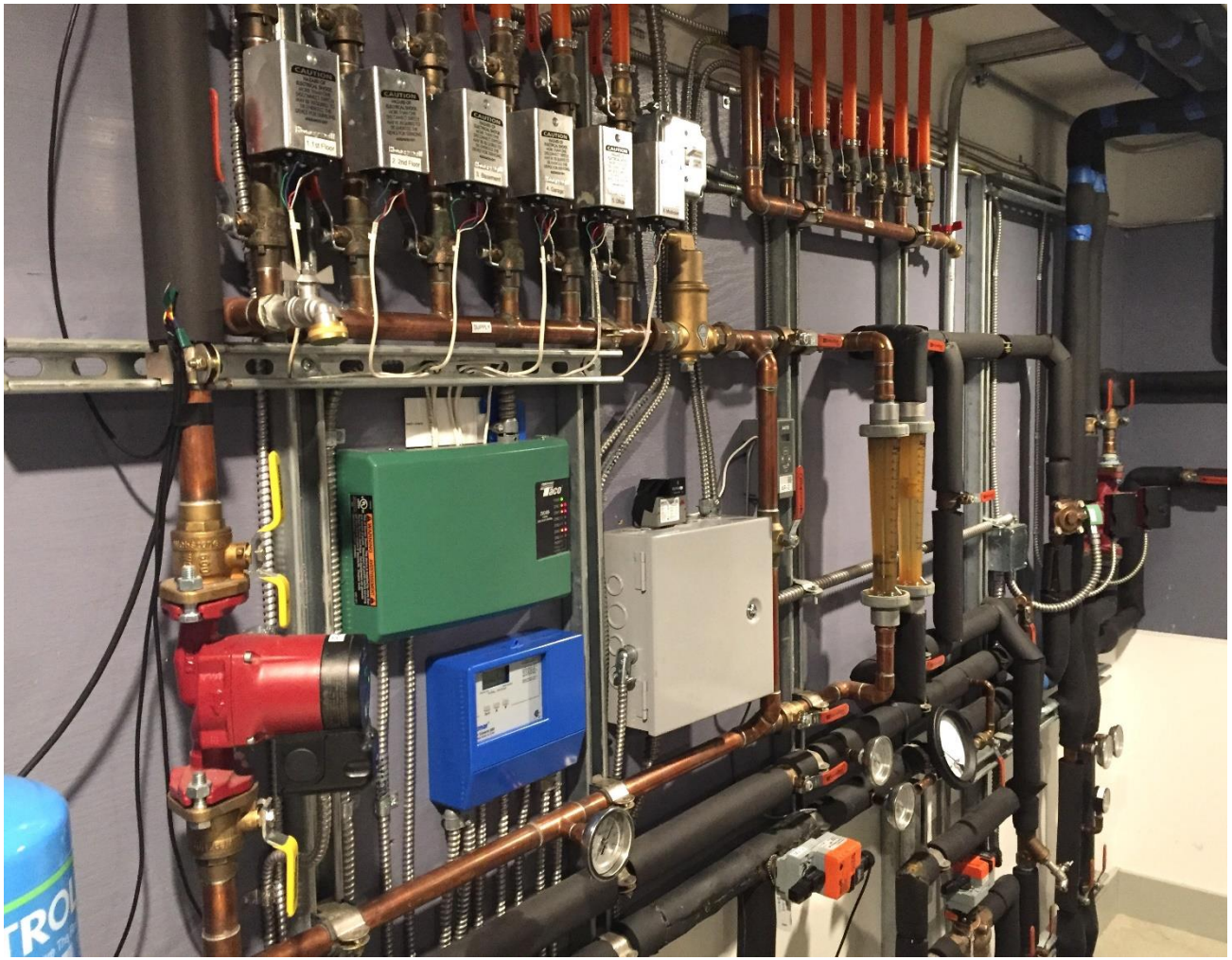
Simple Concept Meets Reality



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Radiant Wall Design

½" PEX with standard aluminum emission plates, ½" drywall finish

Large area required if radiant loop temp is to be kept low (90 F) for max HP efficiency

Use 3/8" drywall strips when studs can't be notched

Use interior walls when possible and install "back to back" radiant areas on room dividing walls

Document placement with pictures and dimensioned drawings!

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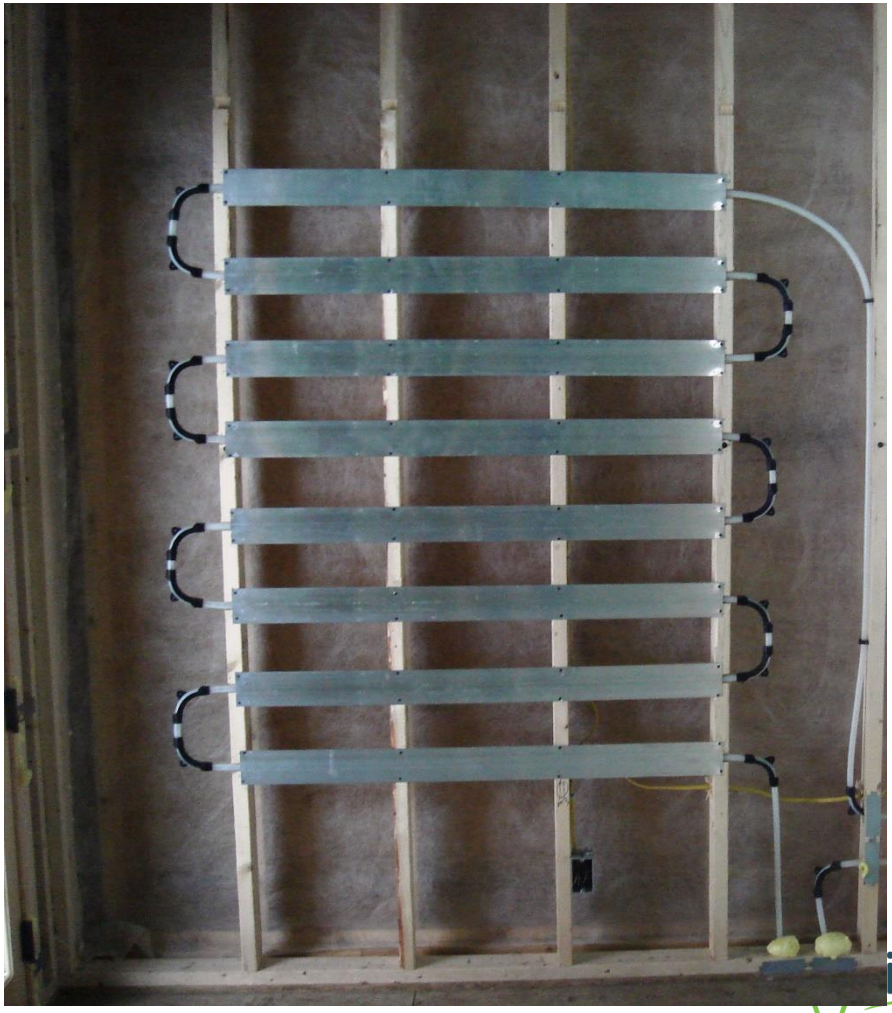
Tubing installed into studs

Standard aluminum emission plates are 4" x 48".

8" on center vertical spacing minimum for ½" PEX bending radius

90 degree snap on elbows help form and protect end PEX bends

At 90 F water temperature, 20 SF wall area shown delivers 260 BTU/HR to room



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2018 Measured Performance

Just the numbers, please

Heating Total kWh Consumed	6,353	kWh
DHW Total kWh Consumed	1,944	kWh
Heating Season Solar Gain (est)	3,042	kWh
Estimated Passive Solar Fraction	0.14	%
Total Geo Heat Delivered to Building	18,765	kWh
Total Heat per Sq Ft of heated area	4.36	kWh/SF
2018 Heating Degree Days (Montpelier)	8,295	HDD
Heat Energy per Degree Day per Sq Ft	0.53	Watts
Heating Cost (@ $.15/kWh, actual cost $0)	953	$
DHW Cost (@ $.15/kWh, actual cost $0)	292	$

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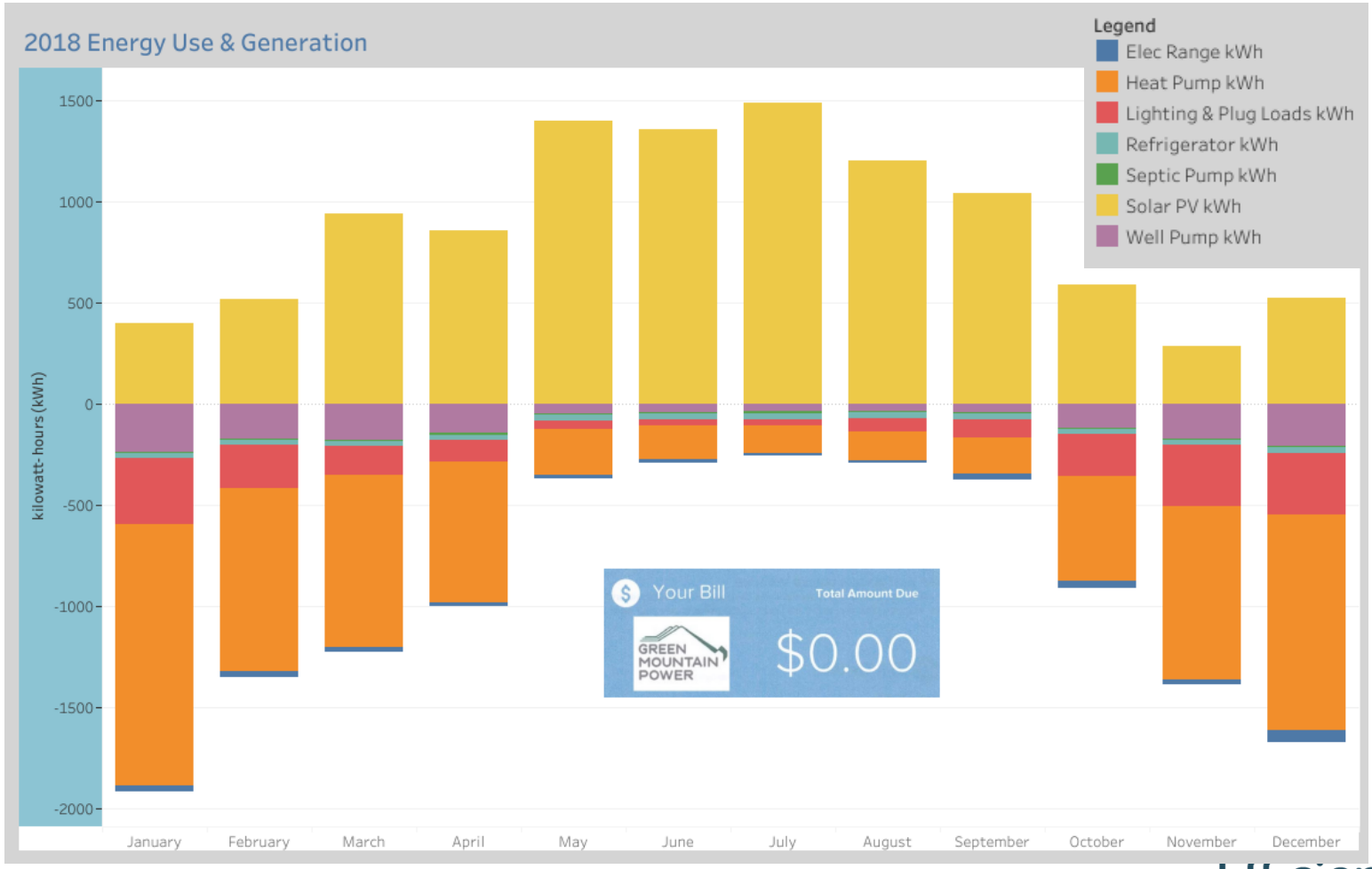
Energy Use & Generation Balance



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Key Takeaways

- Geothermal heating is really efficient – COP of 3.5 or greater compared to COP of 2.5 for air source heat pumps (ASHPs).
- But Geo HPs are more expensive than ASHPs to install and require more attention to design details.
- Using a single well system that provides both domestic water and heat, the extra well cost is 200’ of extra bore hole, about $2,500.
- But the cost of piping and controls make geothermal about twice as expensive as ASHPs to install.
- The comfort level provided by Geo HPs and a radiant distribution system is much greater than ASHPs. No fans, air flow, and noise.
- If the goal is greatest comfort and lowest life cycle cost for heating a net zero home – geothermal systems make a lot of sense.

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It Takes a Village….

A special thanks to all those that helped with advice, support, and helping hands:

Andy Shapiro	Energy Balance, LLC
Matt Sargent	Efficiency Vermont
Lee Grutchfield	Truex-Cullins
Josh Walker	Josh Walker Construction
Jeff Gould	Gould Plumbing & Heating
Chad Wendell	Wendell Electric

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Ground Source Heat Pumps and Domestic Hot Water

- **Desuperheater**
  - Transfer excess heat from compressor to DHW tank
  - Only works when GSHP is running, may not meet DHW loads at all times
- **Full Demand**
  - Manufacturer installs separate heat exchanger
  - Meets all household DWH needs
- **Separate DHW system**
  - HPWH

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Equipment Types

Mini split heat pumps
Ducted heat pumps
Air To Water heat pumps
Ground Source heat pumps
Advanced Pellet heating
Distribution systems
Ventilation
Domestic Hot Water systems

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Public Perception of "Biomass Heating"

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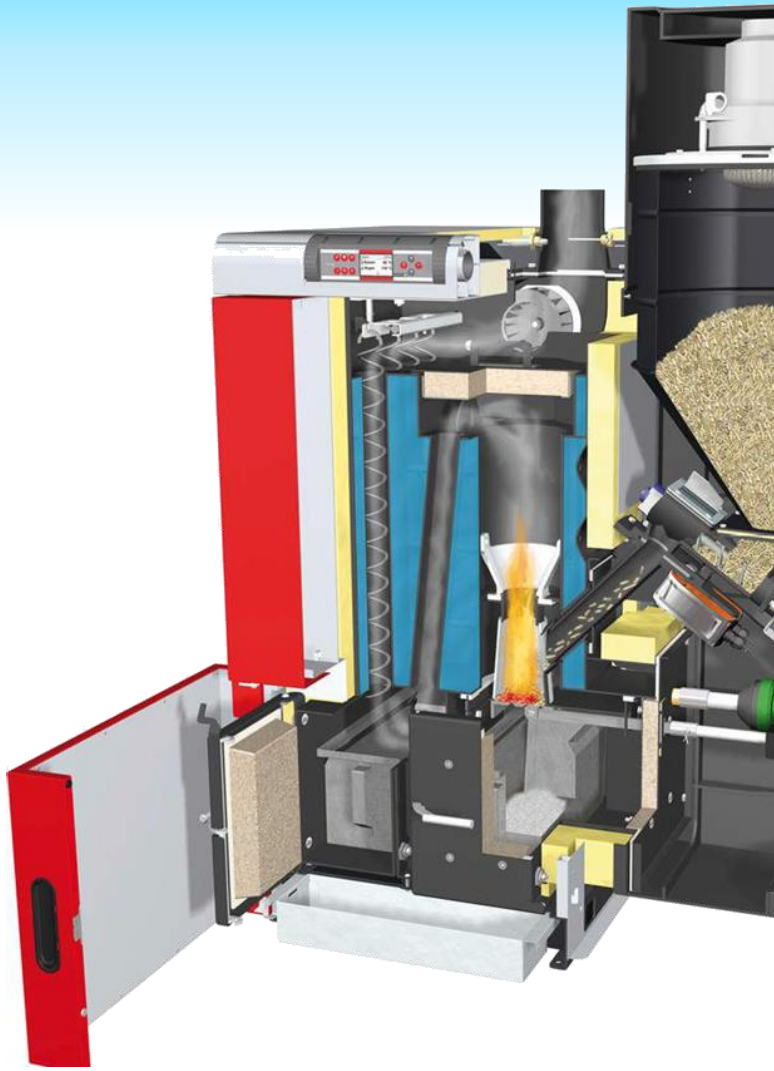
Pellet Boiler Benefits

- Replace fossil fuel
- Use local, renewable fuel source
  - Stimulate local economy
- Low particulate 0.032lb/MMBtu



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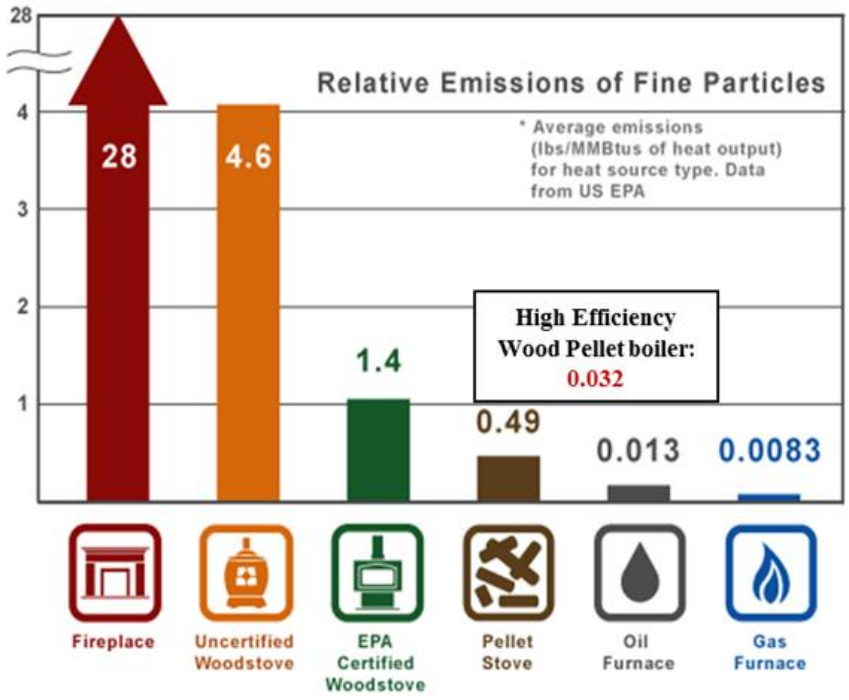
Particulate emissions



Source: EPA Burnwise program

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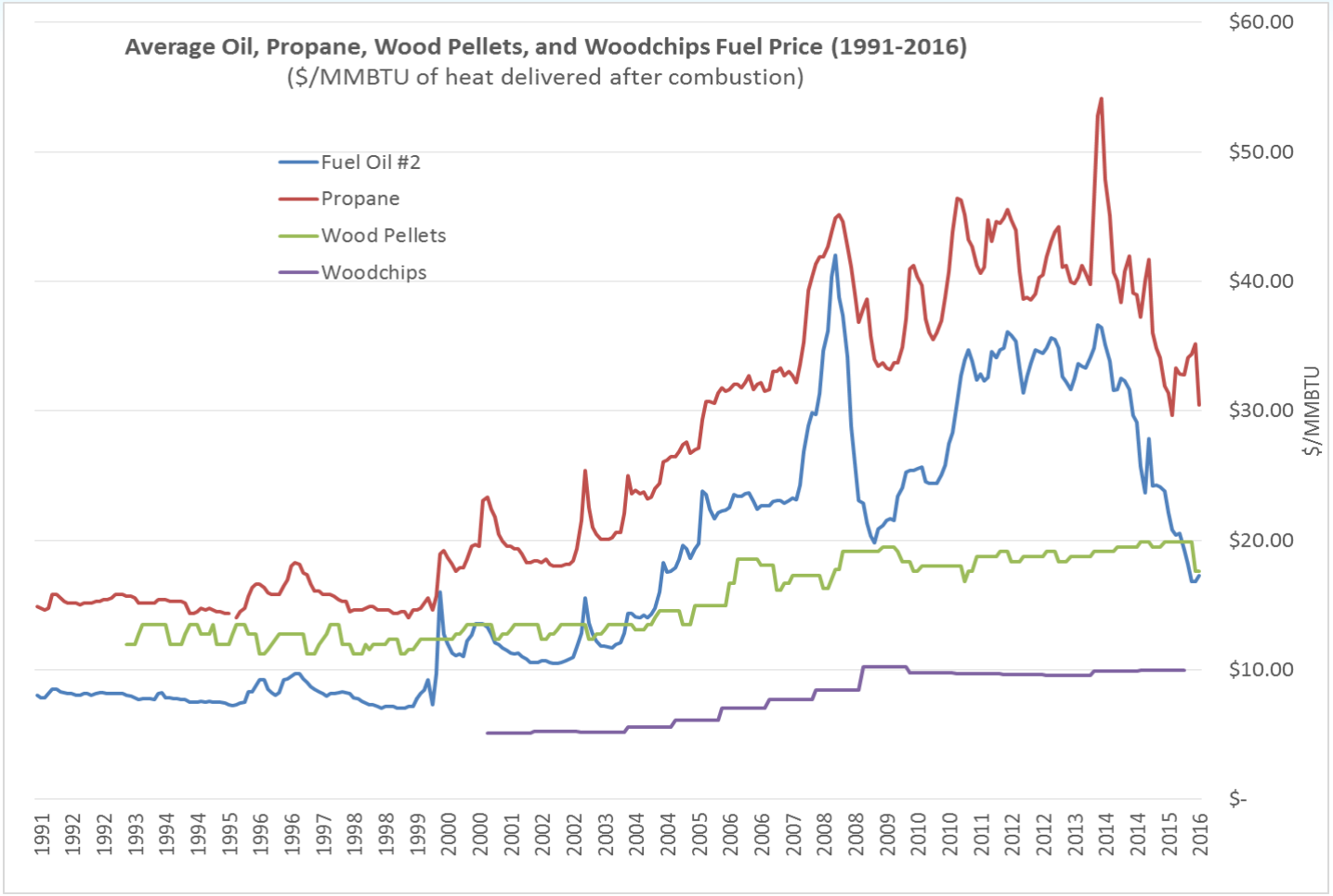

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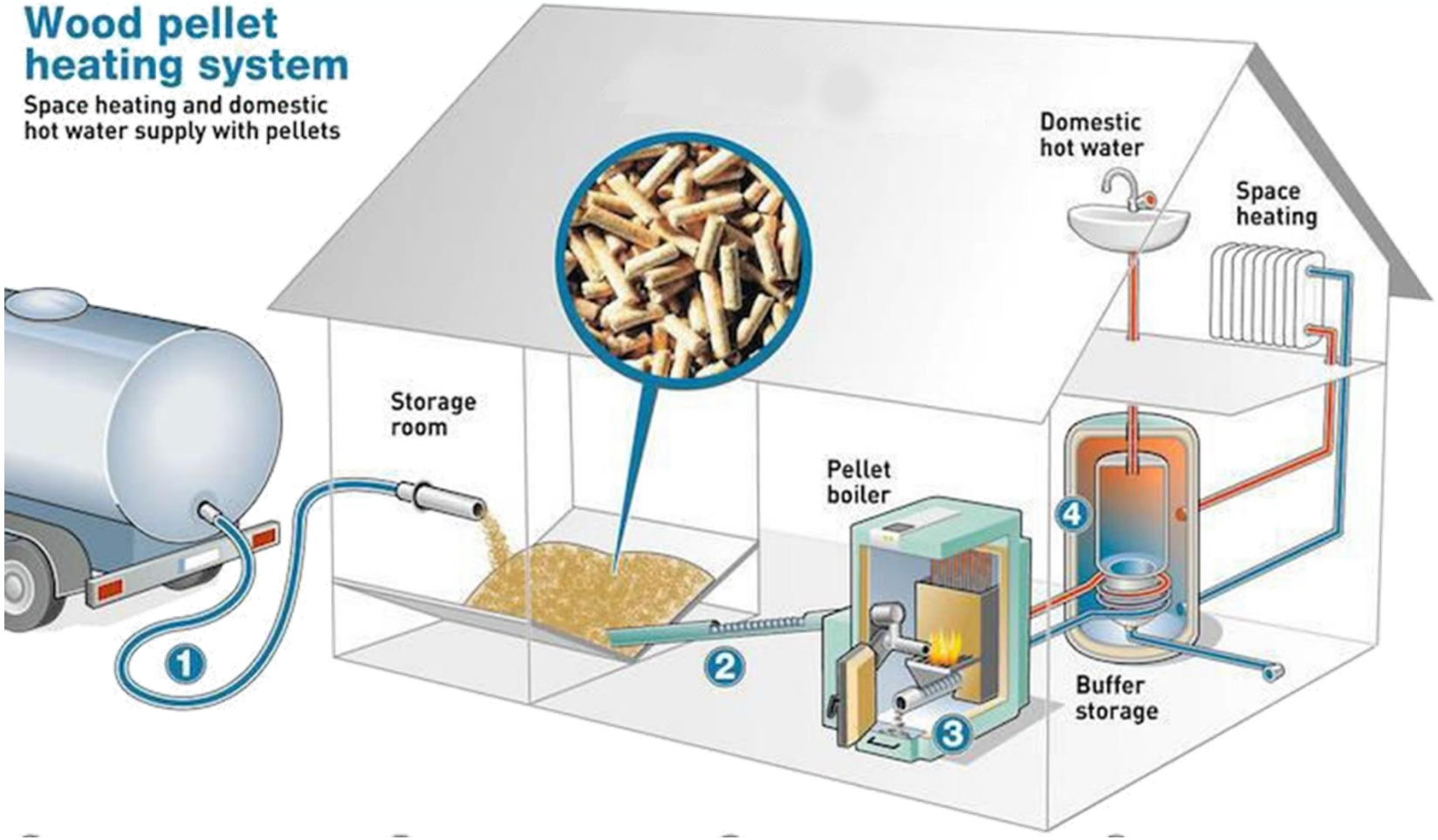

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Thermal Storage for Heating

- Output from boiler is often higher than current heating load
- Allows the heating system to meet intermittent loads without firing the boiler, improving performance and longevity
- Prevents boiler short cycling during partial load conditions
- Able to capture residual heat at boiler shut-down
- Can also provide mass to stabilize domestic hot water production

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Equipment Types

Mini split heat pumps
Ducted heat pumps
Air To Water heat pumps
Ground Source heat pumps
Advanced Pellet heating
Distribution systems
Ventilation
Domestic Hot Water systems

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…a brief plug for low temp Hydronic Distribution Systems

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Hydronics are a great way to move heat

- Water over 30X more efficient than air
- Negligible distribution loss compared to ducts

Slide stolen from Mike Simons, Abode Energy

Hydronics are:

- Comfortable
- Fully distributed
- Easily zoned
- Steady temperatures
- No blowing air
- Quiet
- Less dust
- Warm surfaces

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Low Temp Distribution

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Keeping the costs down

- Limit zoning to the basics
- Use panel rads w/TRVs
  - Fewer, larger panel rads w/TRVs
- Site built manifolds w/PEX fittings
  - Home run piping
- Design for low temp hydronics up front
  - Retrofits are expensive, future proof your building

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Equipment Types

Mini split heat pumps
Ducted heat pumps
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Domestic Hot Water systems

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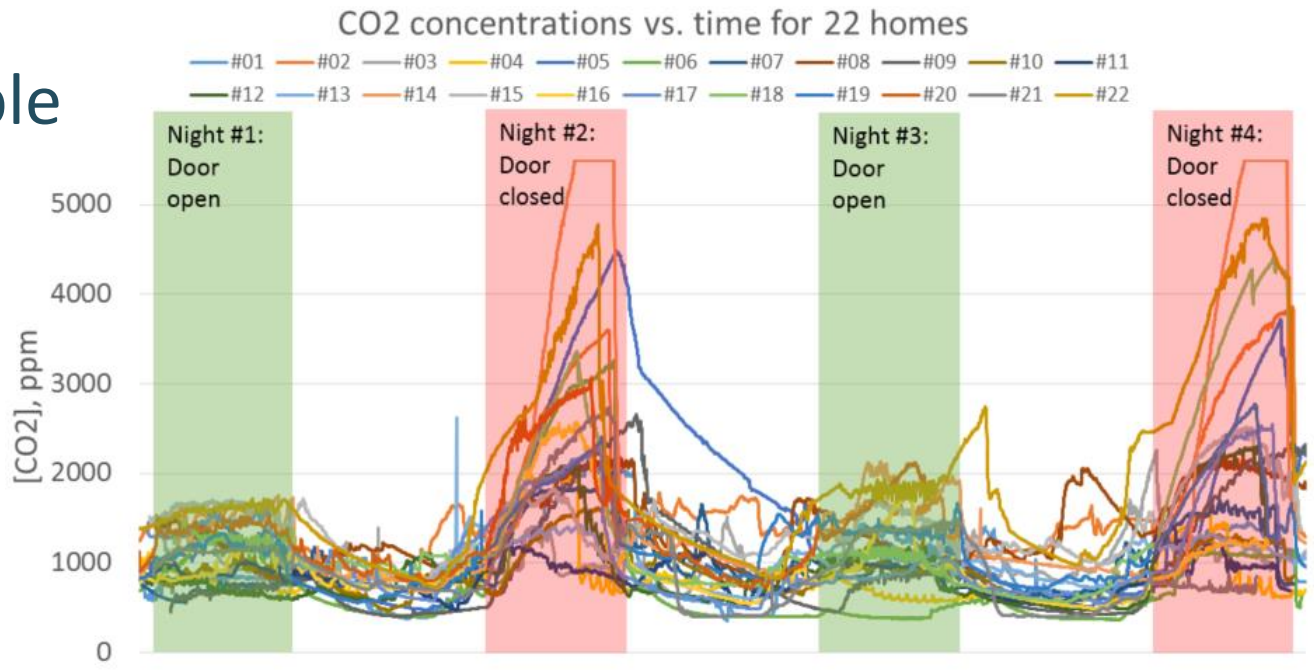
Ventilation

- Always part of a new or rehabbed home
- Fresh air for people
  - Controlled
  - Clean
  - Comfortable



Vermont energy code updates for 2020

- Balanced Ventilation required for Stretch Code (all act 250 developments and towns that have adopted stretch code)
- Earn Points with efficient ventilation systems
  - Tight homes (<2 ACH50) + 70% SRE (HRV) or 65% SRE (ERV) = 3 points
  - Very tight homes + 80% SRE (HRV) or 75% SRE (ERV) = 4 points

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Ventilation Bottom Line

- ALL homes need ventilation
- Match your strategy to your house
- Pick your equipment carefully
- Proper Duct Design
- Continuous operation
- Train the homeowner

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Equipment Types

Mini split heat pumps
Ducted heat pumps
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Distribution systems
Ventilation
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Water Heating

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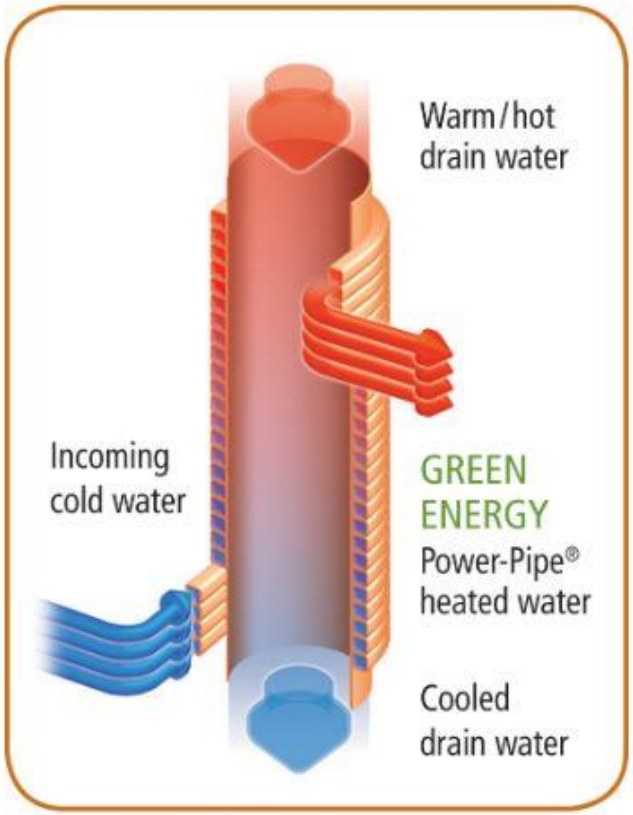
Drain Water Heat Recovery

- Preheat cold water supply to DHW
- 40-60% recovery efficiency
- Reduce energy for DHW
- Improve capacity of water heater



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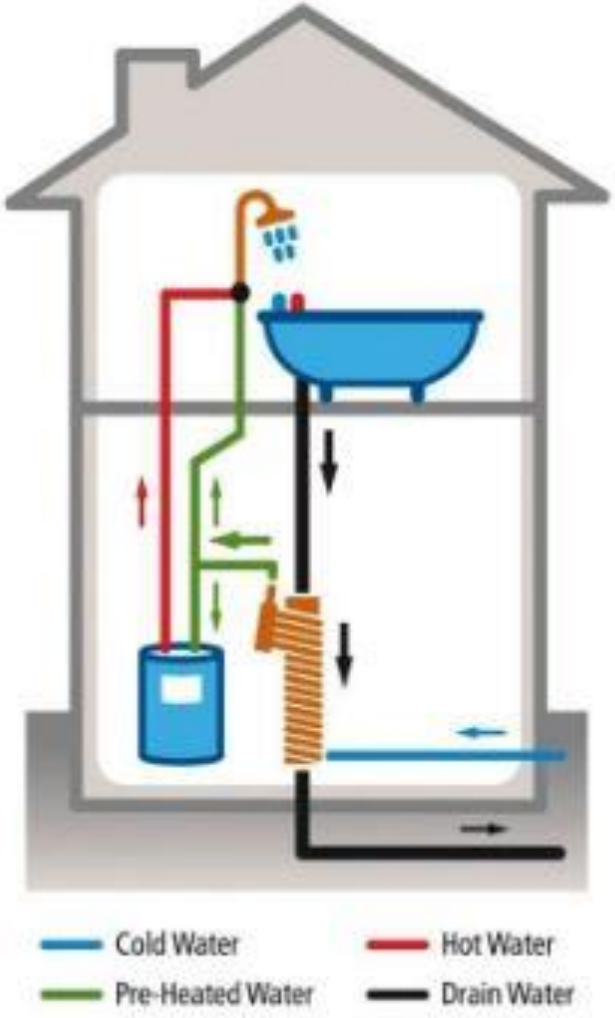
Equal Flow Plumbing



CSA B55.1 performance testing

Best Practice when feasible

Not just for new construction projects

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Drain Water Heat Recovery in the real world…

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Water Heater Replacement

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Water Heater Replacement

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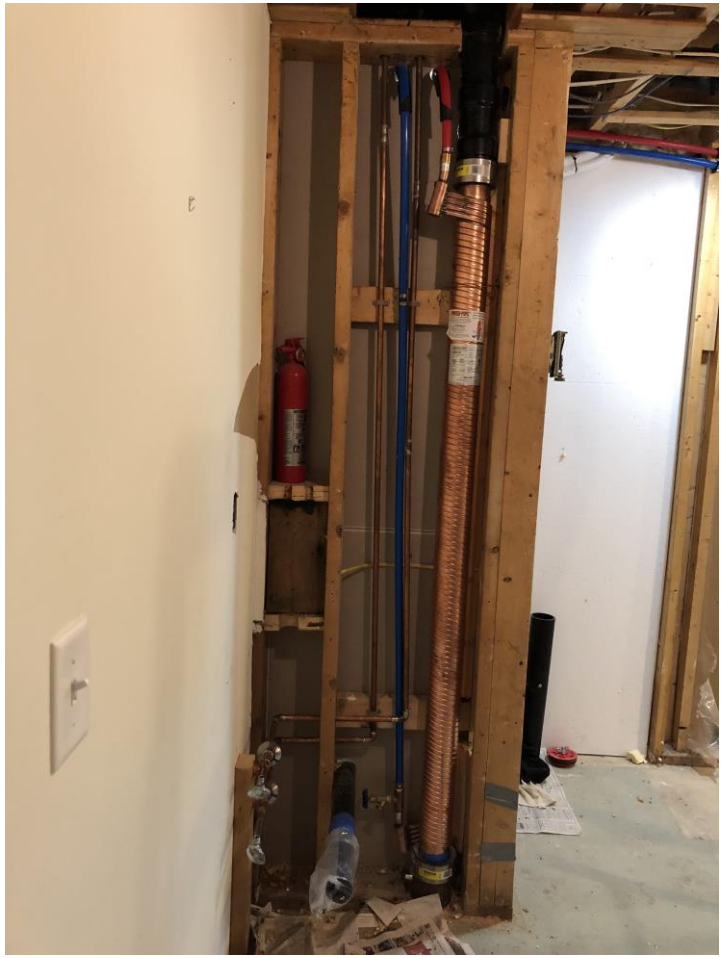
Drain Water Heat Recovery



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Drain Water Heat Recovery

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Getting that other drain

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Equal Flow Plumbing

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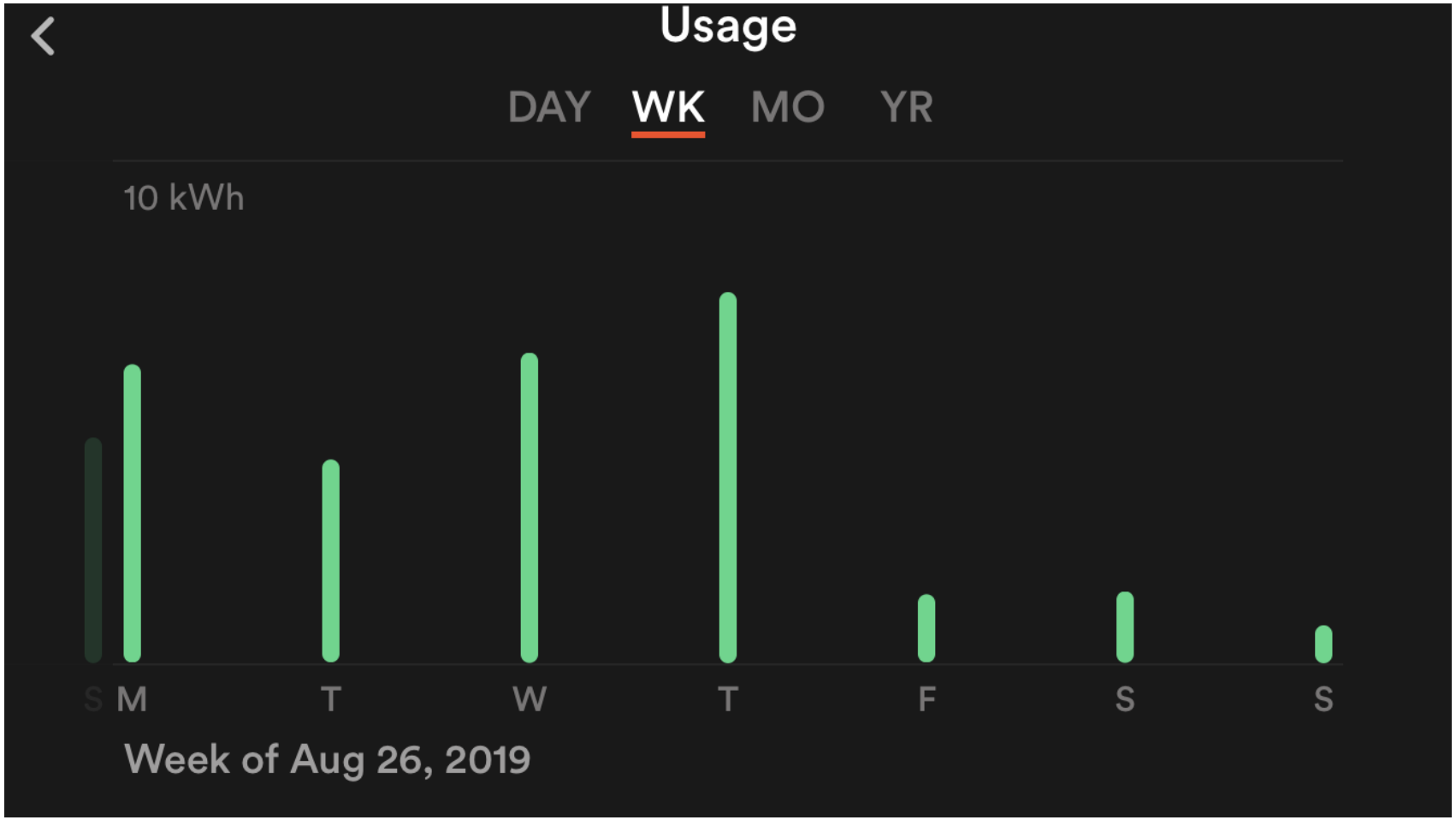
Combined DWHR and HPWH



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Water Heating Bottom Line

- Be deliberate about the water heating strategy
  - It can be the biggest load in the house
- Heat pump water heaters may need cooling and noise mitigation strategies
- Water conservation and heat recovery are just as important as high efficiency water heating
- Reduce plumbing core in new construction

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Thank You

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