HVAC 2020
A showcase of emerging systems

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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
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
Equipment Types

- Mini split heat pumps
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- Ventilation
Single Zone Ductless Mini Split Heat Pumps
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
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
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
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
Multi Zone Ductless Mini Split Heat Pumps
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
Multi zone ductless mini split

- Up to HSPF 12.5, SEER 19,
- 208 systems on NEEP list
- Up to about 60 K BTU at 5F
- Over 100% rated heating capacity at 5F
- Up to 4:1 turndown
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
Some thoughts about load calculations and sizing heat pumps...
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
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

90 degree rotation in orientation added 22,985 Btu to cooling load, or 28% net gain
How to oversize a heat pump

Screw it up or...

- 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

Get it right

- 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
One more thing about mini split heat pumps... they need to be cleaned.
Equipment Types

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Compact Ducted
Mini Split Heat Pumps
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
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.
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
# Static Pressure Calculator

## Static Pressure Calculator Table

<table>
<thead>
<tr>
<th>TO FIND DUCT DIAMETER AND FRICTION LOSS</th>
<th>TO FIND DUCT DIAMETER AND DUCT VELOCITY</th>
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http://bry-air.com/resources/utilities/static-pressure-calculator/
Compact Ducted vs Multi Split

Images courtesy of Mike Duclos, DEAP Energy Group
# Multi Zone vs Compact Ducted

## Performance Specs

<table>
<thead>
<tr>
<th>Heating / Cooling</th>
<th>Outdoor Dry Bulb</th>
<th>Indoor Dry Bulb</th>
<th>Unit</th>
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## Performance Specs

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</table>

**MXZ-3C24NAHZ2**
Multi Zone Ductless

**SUZ-KA18NA2 / SEZ-KD18NA**
Compact Duct
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
Compact Ducted systems in the real world...
Compact Duct Installation
Compact Duct Installation
Compact Duct Installation
Compact Duct Installation
Equipment Types

- Mini split heat pumps
- Ducted heat pumps
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- Ground Source heat pumps
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- Distribution systems
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Centrally Ducted Heat Pumps

“whole house heat pump”
Centrally Ducted Heat Pumps
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
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
Balance Point, Capacity

<table>
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<tr>
<th>Heat Pump Make Model</th>
<th>York YHM36B22</th>
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<td>York YHM36B22</td>
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<td>21100</td>
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<td>York YHM36B22</td>
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<tr>
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![Graph showing Capacity Balance Point with BTU on the Y-axis and Outdoor Air Temperature on the X-axis.](image)
Balance Point, economic

<table>
<thead>
<tr>
<th>NEEP Rated COP at OAT</th>
<th>Heat Pump make model</th>
<th>Heat Pump $/MMBtu</th>
<th>Fuel</th>
<th>Fuel cost</th>
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**Fuel $/MMBtu**

- **Natural Gas**: $11.11, $11.11, $11.11
- **Propane**: $30.61, $30.61, $30.61
- **Oil**: $24.81, $24.81, $24.81

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**Economic Balance Point**

![Graph showing economic balance point](chart.png)
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
Centrally Ducted Heat pump in the real world...
Recent Installation
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
Equipment Types

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Benefits of ATW

• Comfortable
  ➢ Zonal
  ➢ Fully Distributed
  ➢ Reduced stratification
  ➢ Quiet
Mono-bloc

- Refrigerant to water
  Heat exchange is outside
Split Systems

• Refrigerant to water heat exchange is inside
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
## COP Example

<table>
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<tr>
<th>Supply Water Temp °F</th>
<th>Ambient Temp °F</th>
<th>Capacity BTU/hr</th>
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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
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
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
Glycol

- In Monobloc systems a must

- 2 strategies:
  - Whole system (expensive)
  - Primary loop with heat exchanger

- Slight efficiency reduction
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
ATW heat pump in the real world...
Low temp distribution
Low temp distribution
Utility Room

Outdoors
Measured Performance, COP @ outdoor temperature
Why they installed an Air to Water heat pump
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
Equipment Types

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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
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
Ground Source Heat Pumps

Image stolen from the internet
GSHP in the real world...
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*
Geothermal System Overview

- **Tekmar 260** heating control w/ outdoor temp logic
- **Taco six zone controller w/ DHW priority**
- **Taco six zone controller w/ DHW priority**
- **105 gal Marathon radiant storage tank**
- **Grundfos Alpha 3-speed constant pressure circulator**
- **400’ well 6” bore**
- **Belimo flow control valve 12 GPM**
- **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**
- **Radiant floor & wall heat distribution**
- **1/2 HP VFD pump**
- **Flat plate heat exchanger**
- **1.5 GPM per zone**
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.
Simple Concept Meets Reality
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!
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
### 2018 Measured Performance

*Just the numbers, please*

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

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

<table>
<thead>
<tr>
<th>Name</th>
<th>Company</th>
</tr>
</thead>
<tbody>
<tr>
<td>Andy Shapiro</td>
<td>Energy Balance, LLC</td>
</tr>
<tr>
<td>Matt Sargent</td>
<td>Efficiency Vermont</td>
</tr>
<tr>
<td>Lee Grutchfield</td>
<td>Truex-Cullins</td>
</tr>
<tr>
<td>Josh Walker</td>
<td>Josh Walker Construction</td>
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<tr>
<td>Jeff Gould</td>
<td>Gould Plumbing &amp; Heating</td>
</tr>
<tr>
<td>Chad Wendell</td>
<td>Wendell Electric</td>
</tr>
</tbody>
</table>
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
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
Public Perception of “Biomass Heating”
Pellet Boiler Benefits

• Replace fossil fuel
• Use local, renewable fuel source
  – Stimulate local economy
• Low particulate 0.032lb/MMBtu
Particulate emissions

Source: EPA Burnwise program
Average Oil, Propane, Wood Pellets, and Woodchips Fuel Price (1991-2016)
($/MMBTU of heat delivered after combustion)
Wood pellet heating system
Space heating and domestic hot water supply with pellets

1. Storage room
2. Pellet boiler
3. Buffer storage
4. Space heating
5. Domestic hot water
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
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
...a brief plug for low temp Hydronic Distribution Systems
Hydronics are a great way to move heat

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

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

Slide stolen from Mike Simons, Abode Energy
Low Temp Distribution
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
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
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
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
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**
Water Heating
Drain Water Heat Recovery

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

CSA B55.1 performance testing

Best Practice when feasible

Not just for new construction projects
Drain Water Heat Recovery in the real world...
Water Heater Replacement
Drain Water Heat Recovery
Drain Water Heat Recovery
Getting that other drain
Equal Flow Plumbing
Combined DWHR and HPWH

Week of Aug 26, 2019
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
Thank You

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