Introduction to Heat Pumps & VRF

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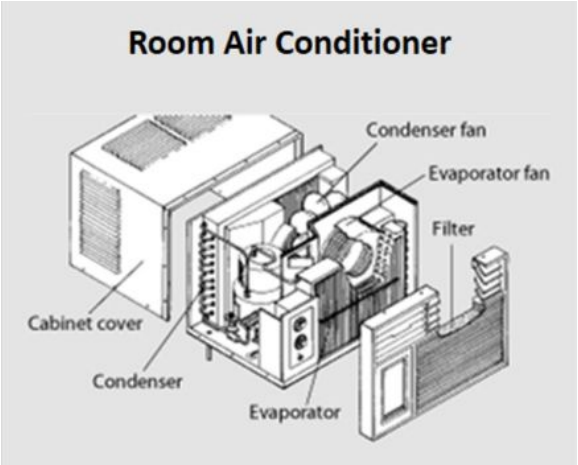
Agenda

- Introduction to heat pumps
- Types of heat pumps
- Refrigerants
- Efficiency
- Cold weather operation
- Maintenance
- Heat pump equipment options
- Ventilation
- Identifying heat pump applications
- Resources
- Mass Save heat pump programs

How Heat Pumps Work

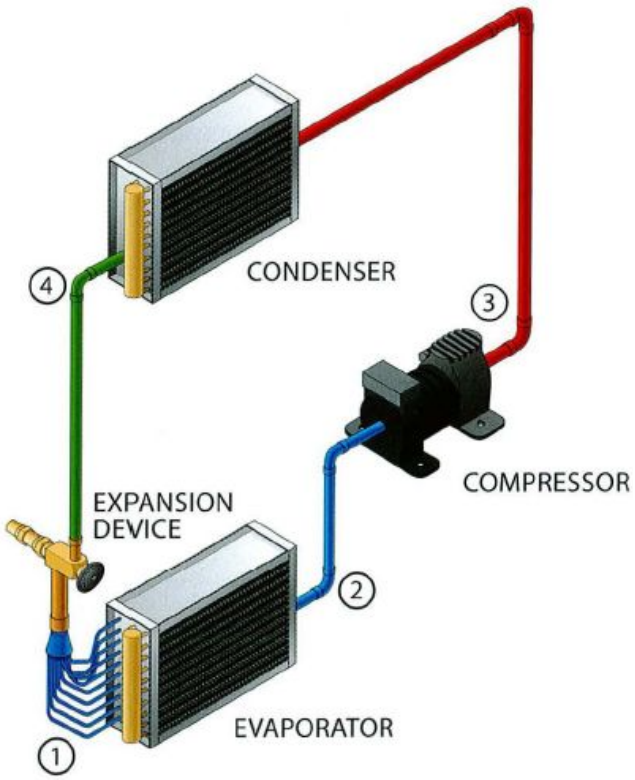
- Powered by electricity
- Similar to any refrigeration system
- Refrigeration cycle allows for the movement of heat across a temperature gradient (rather than generation of heat through combustion of fuels)
- Typical air conditioning system moves heat from indoors to outdoors. Heat pumps reverse the cycle to move heat from outdoors to indoors.



How Heat Pumps Work

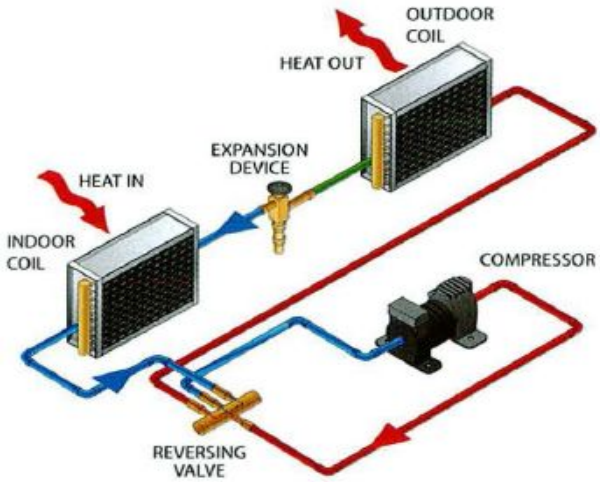
Typical refrigeration system:

- Compressor
- Condenser
- Expansion device
- Evaporator

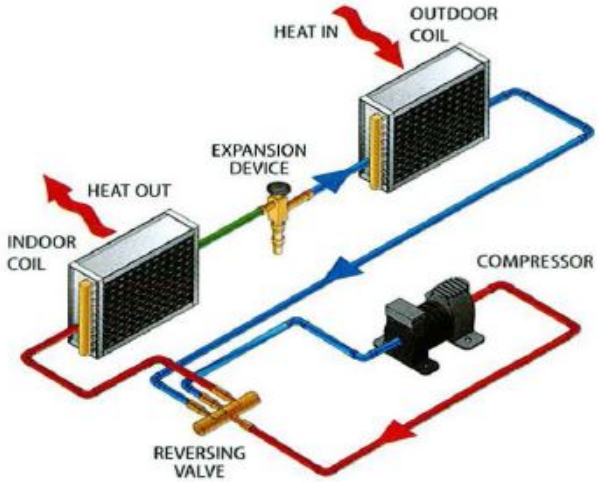


How Heat Pumps Work

Heat pumps introduce a reversing valve to the refrigeration cycle

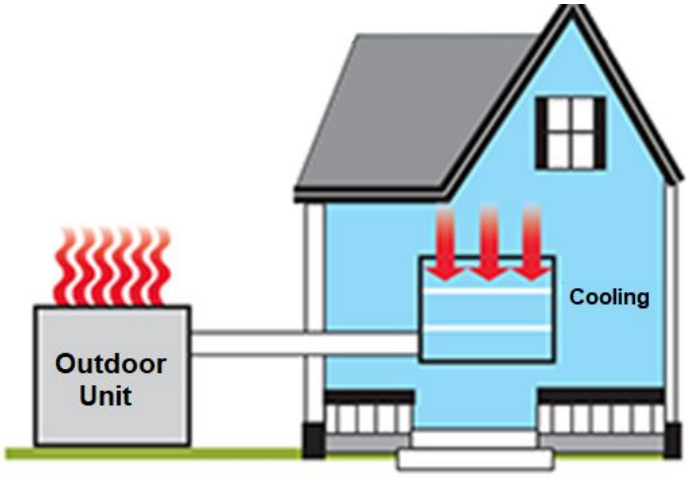


COOLING MODE



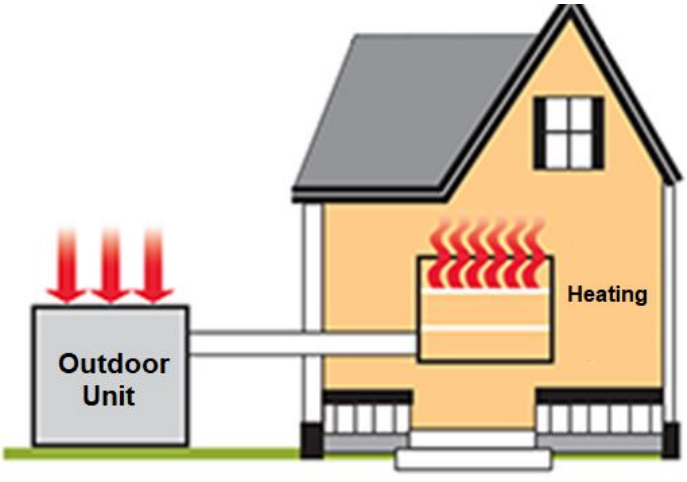
HEATING MODE

How Heat Pumps Work



Summer

Acts as an air conditioner –
draws heat from indoors and moves it outside



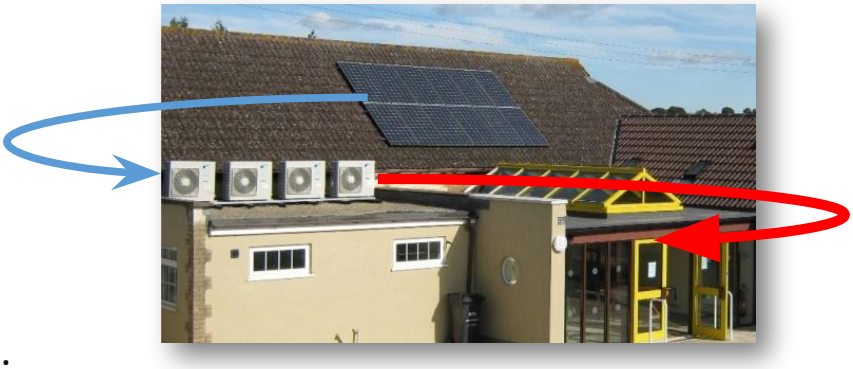
Winter

Draws heat from outside
and moves it indoors

Benefits of Heat Pumps

Electrification of heating:

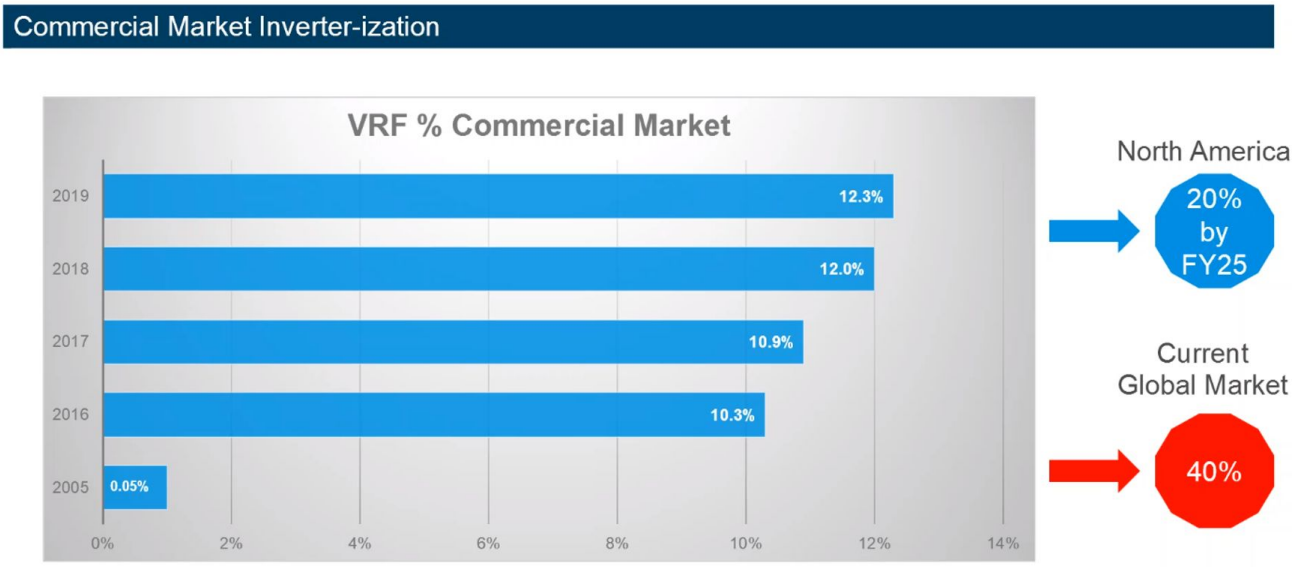
- Transition to efficient electric heating, rather than fossil fuels, will reduce environmental impact as we increase generation of electricity with renewable sources



Cooling:

- Reduced electrical consumption vs. traditional system

Heat Pumps are a Proven Technology



Types of Heat Pump Systems

	Air-Source (ASHP)	Water-Source Heat Pump (WSHP)
Power Source	Electricity	
Possible Outputs	Space heating and cooling, Domestic hot water (heat pump water heater)	
Heat Source/Sink	Outside air	Options include body of water **or** underground piping/wells (known as geothermal or ground-source heat pump (GSHP))
Efficiency	Up to 5 times as efficient as conventional heating because heat pump transfers rather than generates heat.	GSHP have higher efficiency than ASHP because of nearly constant temperature underground, but they require additional electricity to pump water
Siting	Space for outdoor units, elevation limitations	Space and geology for geothermal wells
Cost	Generally lower initial cost	Higher initial cost for infrastructure requirements, which may be offset by long term savings

Types of Heat Pump Systems

		Air-Source (ASHP)		Water-Source (WSHP)	
		Air-to-Air	**Air-to-Water**	**Water-to-Air**	**Water-to-Water**
Distribution system options	**Space heating and cooling**	Distributed system with refrigerant lines **or** central forced-air system (ducted)	Hydronic distribution (best with systems designed for hot water under 120°F)	Distributed system with condenser water lines **or** central forced-air system	Hydronic distribution
	Domestic hot water	-	Hydronic distribution (best used in combination with a supplemental heating source)	-	Hydronic distribution

Heat Pump Types & Nomenclature

	Air-to-Air	Air-to-Water	Water-to-Air	Water-to-Water
reversible chiller		X		X
ASHP chiller		X		
heat recovery chiller		X		X
variable refrigerant flow (VRF)	X		X	
mini-split or multi-split	X			
heat pump water heater		X		X

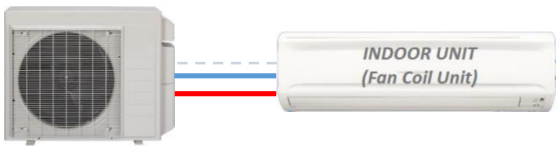
Types of Air-Source Heat Pumps

Packaged

- PTAC (packaged terminal AC) with added heat pump function
- Rooftop Unit

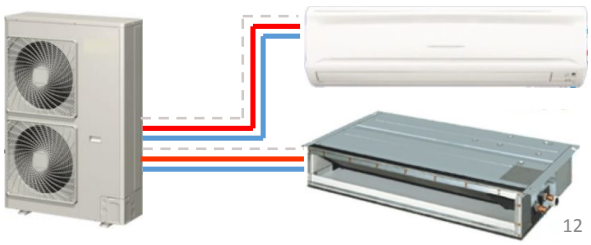
Mini-Split or Single-Split

- One indoor unit and one outdoor unit



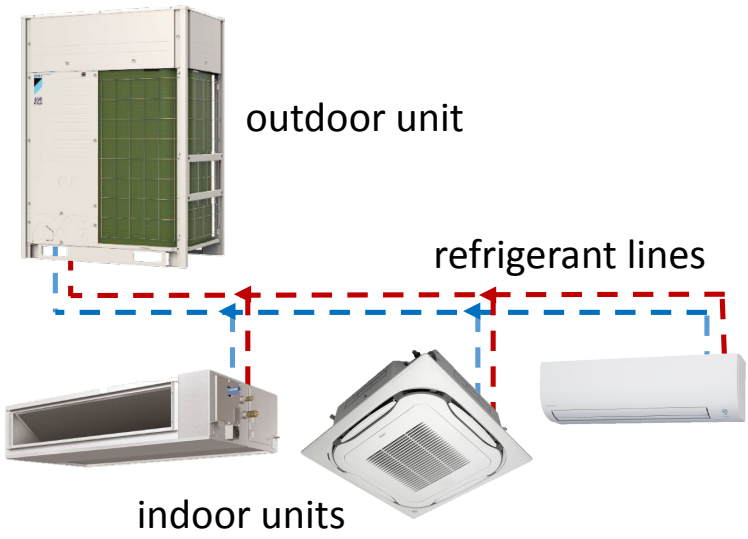
Multi-Split

- Multiple indoor units with individual temperature controls
- System is in either heating or cooling mode



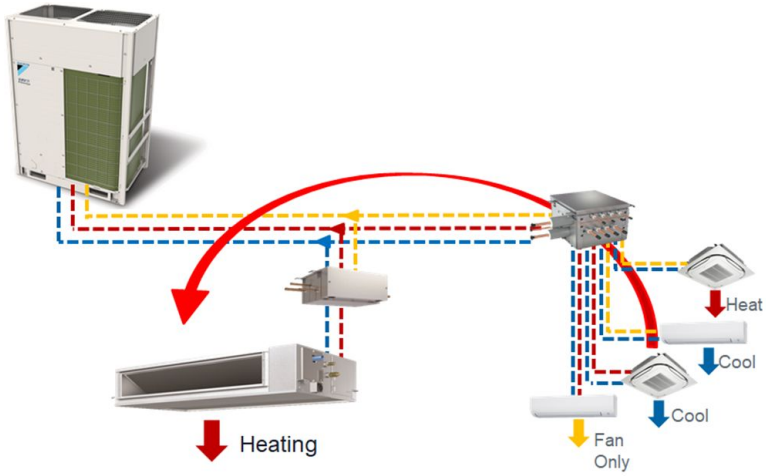
Variable Refrigerant Flow (VRF)

- Typically air-source
- Each indoor unit has an expansion valve to adjust refrigerant flow based on load
- Central controller monitors indoor units and adjusts compressor operation to vary refrigerant flow



VRF with Heat Recovery

- Most VRF systems include heat recovery
- System can provide simultaneous heating and cooling to different zones



Water-Source VRF

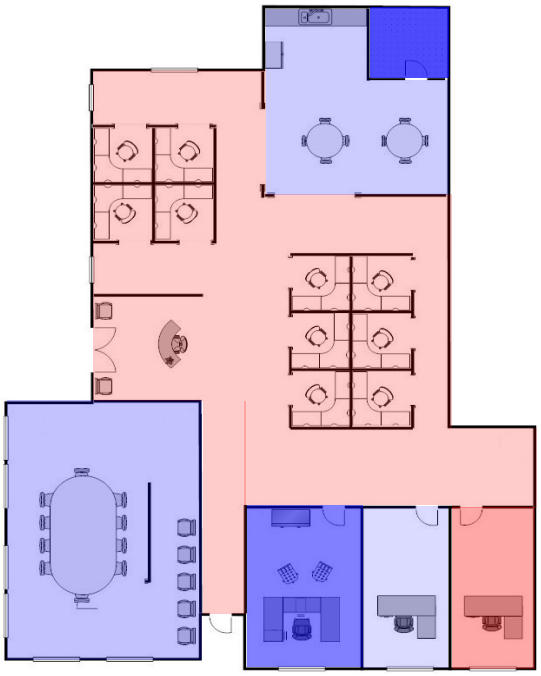
- Fundamentally same technology - but with a different heat source/ sink
- Distribution to the occupied spaces is still with refrigerant

VRF Features and Benefits

- Central control system included
  - Can integrate with third-party components or existing building management system
  - Peak load shedding options
- Flexible system design and minimal physical footprint
  - Energy distributed by refrigerant in copper piping – smaller and more flexible than ductwork or larger water piping
  - Variety of indoor unit options

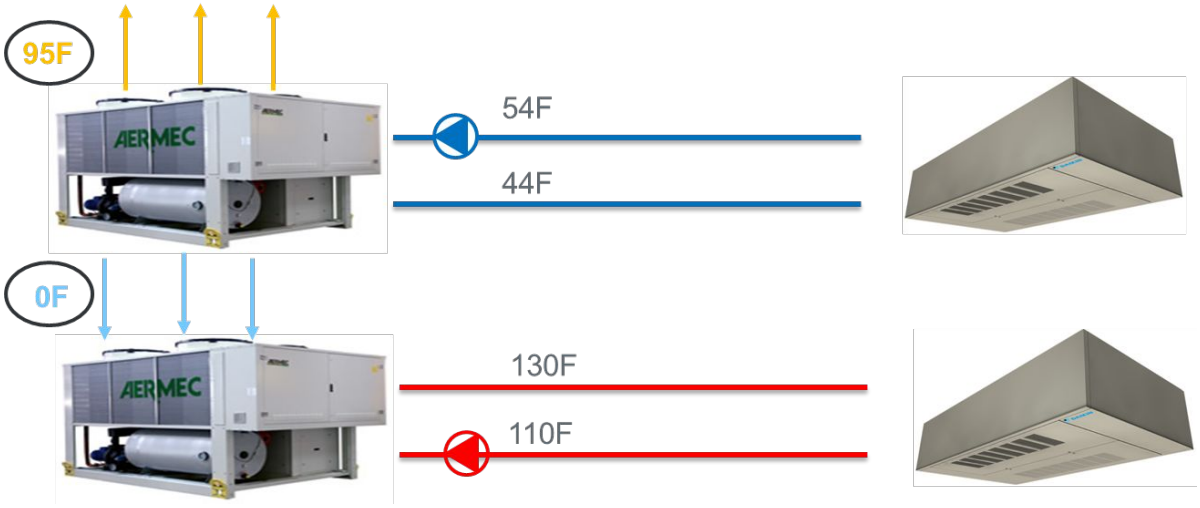
VRF Features and Benefits

- High efficiency
  - Variable speed compressor
- Comfort and flexible operation
  - Individual zone control
  - Avoid hot-spot/cold-spot issues with heat recovery
- Quiet operation
  - No compressors in the space
  - Quiet outdoor compressors and fans



Types of Air-to-Water Heat Pumps

Air Cooled Heat Pump Chiller (2 pipe)



Types of Air-to-Water Heat Pumps

Air Cooled Heat Pump Chiller (4 pipe)

Types of Water-to-Air Heat Pumps

Water-Source Heat Pump

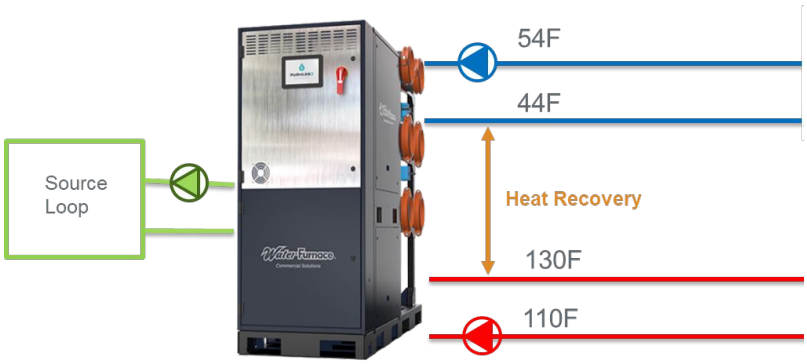
- Horizontal: Offices, condo amenity areas etc.
- Vertical: multi-family
- Typically also uses condenser water loop which also needs heat addition from a boiler or geothermal loop (ground source he pump)

Types of Water-to-Water Heat Pumps

Water-Source Heat Pump Chiller (2 pipe)

Types of Water-to-Water Heat Pumps

Water-Source Heat Pump Chiller (6-pipe)



Types of Air-to-Water Heat Pumps (DHW)

Heat Pump Domestic Hot Water (Residential)

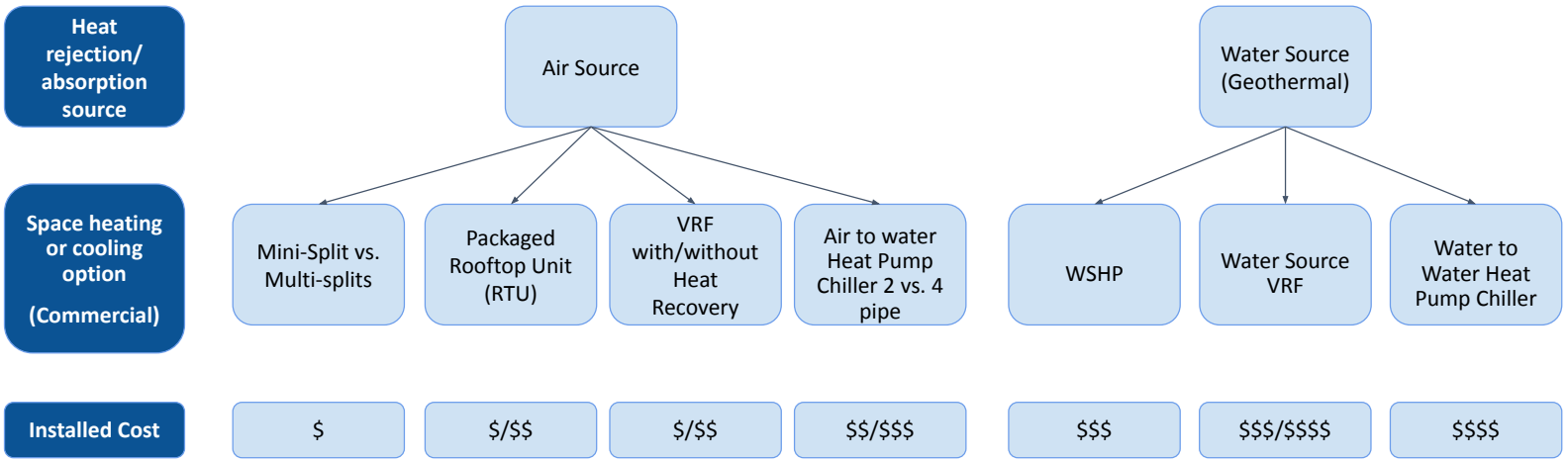
- Indoor
- Indoor and outdoor (CO_2)

Heat Pump DHW (Commercial)

Currently emerging technology:

- ASHP chiller manufacturer
- VRF manufacturers

Types of Heat Pumps - Comparison



Refrigerants

- All air conditioning and heat pumps use refrigerant
- Many refrigerants are greenhouse gases (GHGs) that can contribute to global warming (if they leak)
  - Global warming potential (GWP) is a rating of different GHGs
- R-410a currently used in all new ASHP/VRF in U.S.
  - Does not contribute to ozone depletion
  - High GWP due to flame retardant additives (R410A)
  - Some efforts underway to transition to refrigerant with lower GWP

Refrigerants

- Transitioning to lower GWP refrigerants:
  - American Innovation and Manufacturing (AIM) Act
    - Directs the U.S. Environmental Protection Agency (EPA) to address HFCs
    - Phase down production and consumption of HFCs in the United States by 85 percent by 2036
    - Manufacturers have allowance limits or need to use recycled refrigerants.
  - Building codes still do not allow some alternative (lower GWP) refrigerants from being used inside of buildings (varies by states). ASHRAE 15-2022 needs to be adopted to allow next generation refrigerants (R32/R454B) to be used.
  - R32/R454B are the future refrigerants of choice for high pressure applications
  - R410A outlook
    - Supported and available for the next few decades

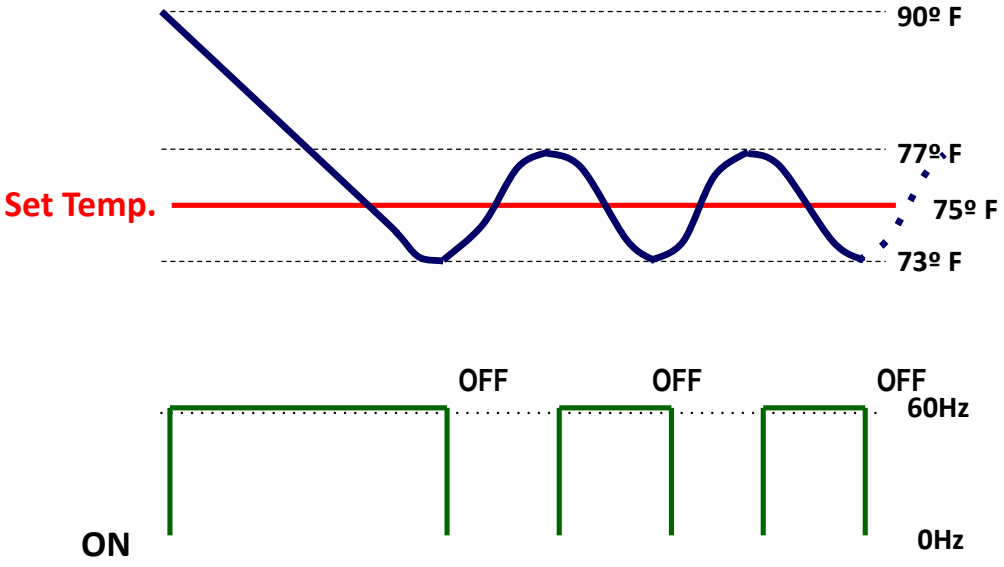
https://www.epa.gov/climate-hfcs-reduction

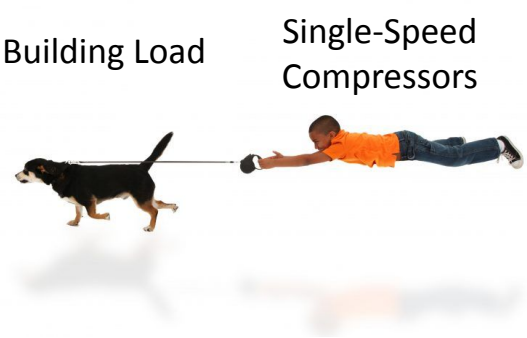
Refrigerants

- No global warming impact if the refrigerant stays in system
  - Refrigerant leakage and risk of leakage can be minimized with proper installation and maintenance
  - Refrigerant needs to be properly recycled when systems are removed
- Studies show that environmental benefits of heat pumps outweigh the impact of potential refrigerant leak

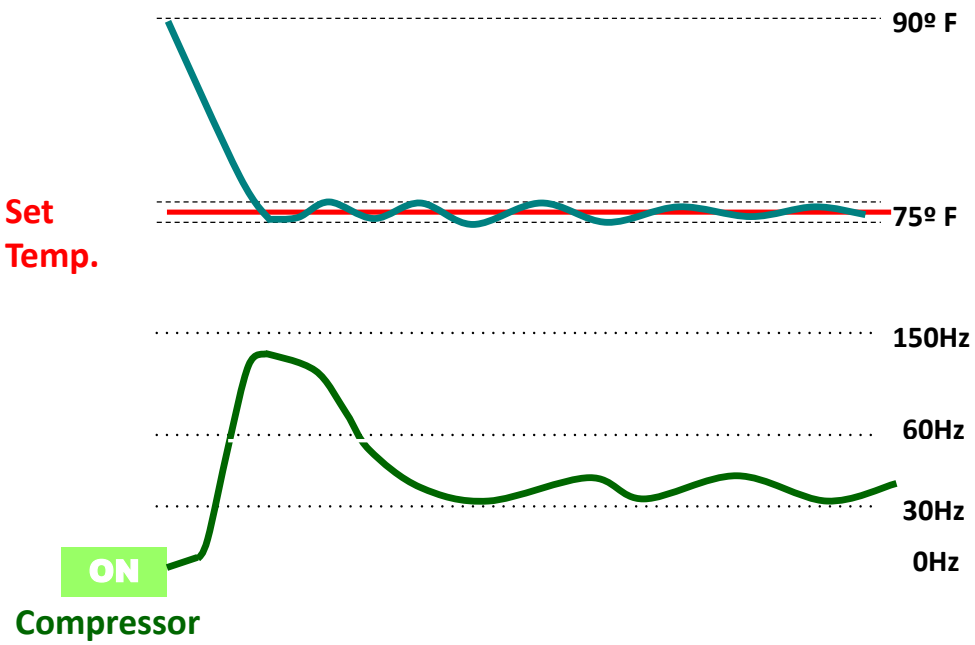
Efficiency – Conventional Systems

Constant speed ON/OFF compressors (WSHP, Rooftop, AC)





Efficiency – Variable Speed Systems



Variable-Speed Compressors

Building Load

Heat Pump Efficiency – Cooling

- Almost all methods of cooling use a compressor and a refrigeration cycle (chillers, packaged rooftop units, PTACs, window units, etc.)
- Heat pumps also cool using a refrigeration cycle, so aside from compressor efficiency, the cooling efficiency is similar

Heat Pump Efficiency – Cooling

- EER/EER2 (Energy Efficiency Ratio) often used to measure efficiency
  - EER = cooling output [Btu] / electricity input [Watt-hours]
  - Measures efficiency at PEAK LOAD, which occurs < 1% of the time
- IEER (Integrated Energy Efficiency Rating)
  - Weighted average of EER values at different temperatures to represent performance over the course of a year

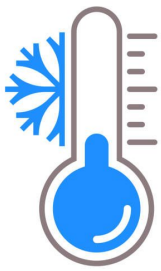
Heat Pump Efficiency – Heating

- Commercial heat pump efficiency measured by COP (Coefficient of Performance) = energy out / energy in
- COP values are published for performance at both 47°F and 17°F
- Smaller units use HSPF (Heating Seasonal Performance Factor)

Heat Pump Efficiency – Heating

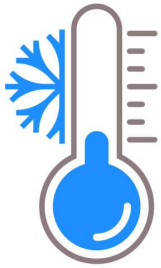
Technology	Typical COP	Notes
Furnace or boiler	0.85 - 0.99	The cost difference between fossil fuel and electricity is what makes electric resistance more expensive
Electric resistance heat	1	
Heat pump	2+	Heat pumps are more efficient because they transfer rather than generate heat

Operation in Cold Weather



- Efficiency / capacity decrease in cold weather, but ASHP technology has significantly improved in the past decade
  - Ability to extract heat from outside air even below -10F
  - Ability to maintain COP around 2 even below 0F
- Backup heat no longer needed, but functional and fairly efficient legacy systems may be cost-effective for supplemental heat
- GSHP avoid de-rates due to steady temperatures underground

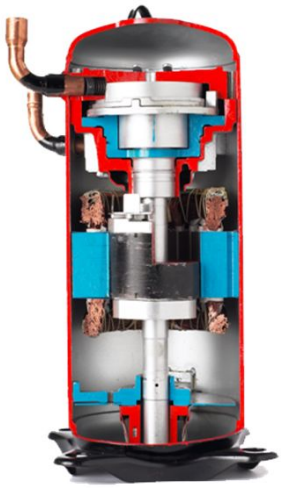
Operation in Cold Weather



- Options for beating the heating de-rates
  1. Flash / vapor-injection technology
  2. Auxiliary heat integration
  3. Sole-source sizing based on heating
  4. Install ODUs inside
  5. Water-source VRF

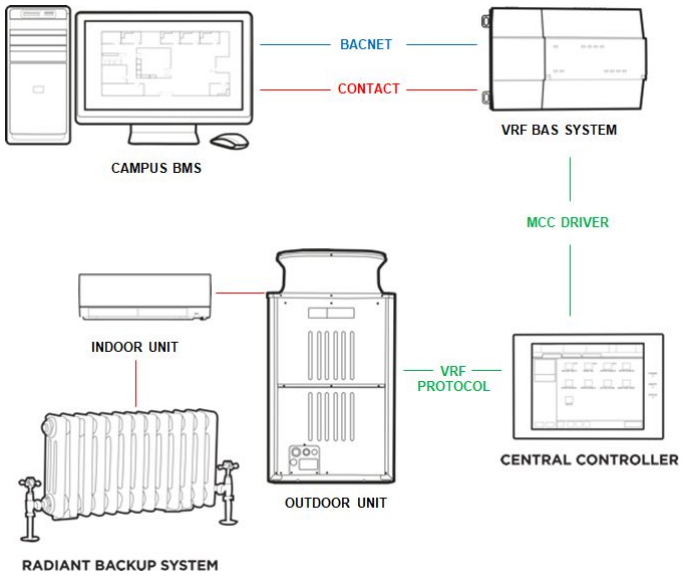
Operation in Cold Weather

- Flash / vapor-injection technology
  - Keeps compressor cool by adding refrigerant to allow for higher speeds and heating capacity
    - Allows system to perform at temperatures below -22F
    - Up to 100% of heating capacity down to 0F
    - Up to 85% of heating capacity down to -13F

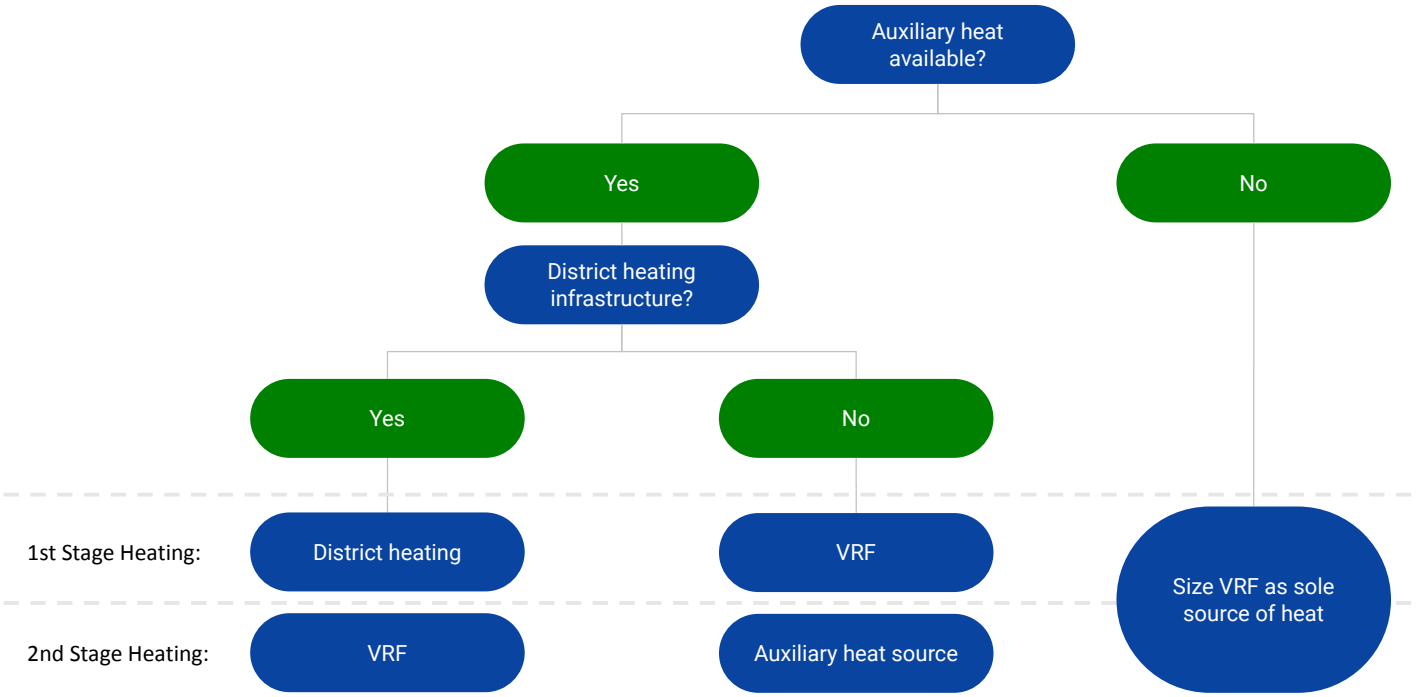


Operation in Cold Weather

- Auxiliary heat integration
  - Determine primary and second stages
  - Energizing methods:
    - Space temperature drop
    - Outdoor temperature
  - Adequately sized VRF system limits need for auxiliary heat

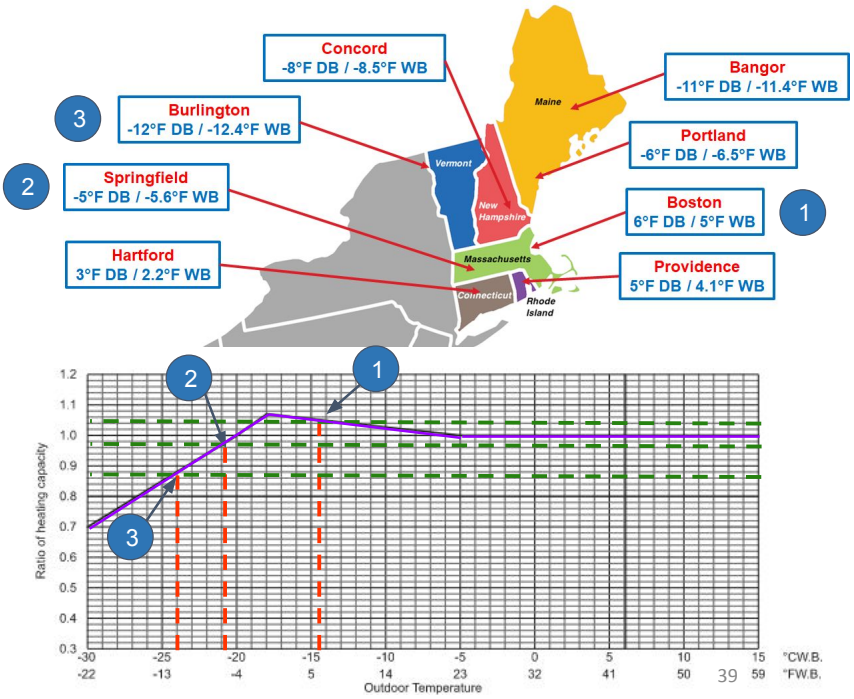


Operation in Cold Weather



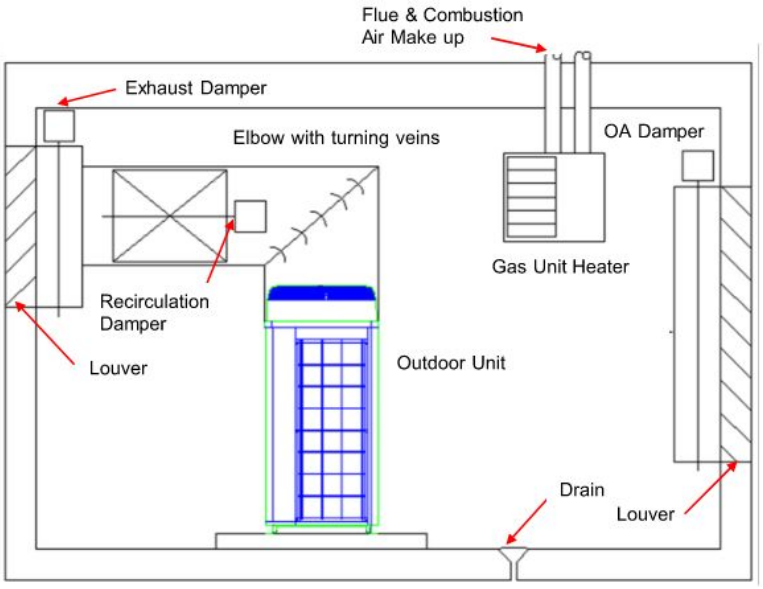
Operation in Cold Weather

- Sole-source sizing based on heating
  - Size system based on ASHRAE design conditions
  - Account for diversified building load (block load vs. peak load)
  - Review heating de-rates to ensure adequate capacity



Operation in Cold Weather

- Install outdoor units inside
  - Limits derating during severe cold
  - Simplifies service and maintenance
  - Useful in dense urban environments with limited rooftop space



Heat Pump Maintenance

- Heat pumps operate well with proper system design, installation, programming, maintenance
- Inverter-driven compressors and high efficiency DC fan motors lead to long equipment life – all components are designed to last the life of entire system
- Basic maintenance is still required!
  - Check/Clean/Replace indoor unit filters regularly
  - Keep Outdoor coils free and clear of debris
  - Maintain condensate removal systems
  - If water sourced, maintain the water side infrastructure as well (pumps, strainers etc.)

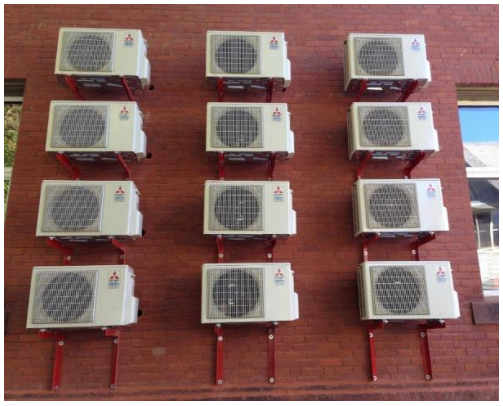
Heat Pump Equipment Options

- Outdoor units
- Indoor units
- Ventilation overview

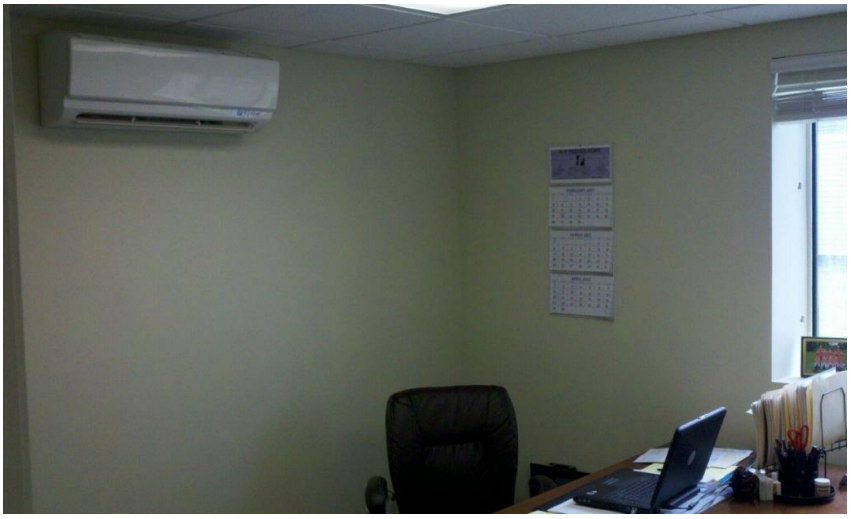
Outdoor Units

VRF/ASHP/GSHP Multi-Split Systems

ASHP Mini-Splits



Indoor Units (VRF/ASHP/GSHP)

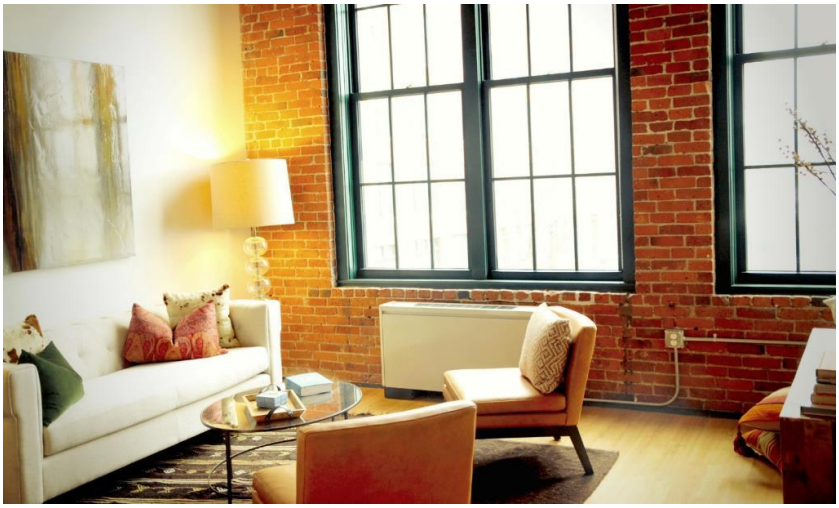


Wall-mounted unit

Indoor Units (VRF/ASHP/GSHP)

Ceiling-suspended unit

Indoor Units (VRF/ASHP/GSHP)

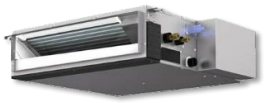


Floor-standing unit

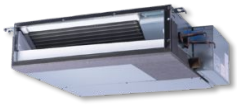
Indoor Units (VRF/ASHP/GSHP)

Concealed floor-standing unit

Indoor Units (VRF/ASHP/GSHP)



Medium static ducted unit



Low profile ducted unit

Indoor Units (VRF/ASHP/GSHP)

High static ducted unit

Indoor Units (VRF/ASHP/GSHP)

Vertical ducted unit

Indoor Units (VRF/ASHP/GSHP)

1-way cassette

Indoor Units (VRF/ASHP/GSHP)

4-way large cassette

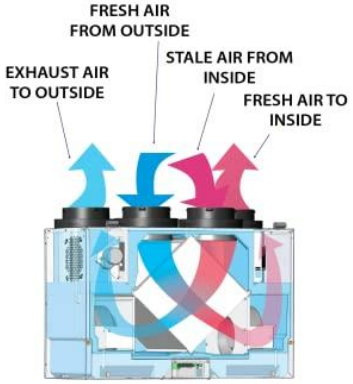
4-way small cassette

Ventilation Overview

- All buildings require fresh air ventilation
- Many buildings depend on windows and passive air leakage for ventilation
  - Doesn't ensure air quality
  - Often wastes energy
- Can integrate accessories to minimize virus transmission
  - Filtration
  - UV lights
  - Bipolar ionization

Ventilation Overview

- Most heat pumps provide only heating and cooling
- Additional equipment generally needed for ventilation – dedicated outdoor air systems (DOAS)
  - Ventilation system dependant on building type, occupancy, existing infrastructure
  - Consider energy recovery for system efficiency
  - May also provide dehumidification that heat pump systems alone are not sized to meet
  - Option - oversize DOAS to offset heating load on VRF



American Aldes Ventilation Corporation.

Identifying Heat Pump Applications

ASHP vs WSHP:

- Does the site have an existing building loop or access to a body of water for water source (geothermal).
- Does the site have appropriate conditions for ground source?
- Does the site have appropriate conditions for air source?
- Do you have the capital to invest in higher installation cost for ground source?

Identifying Heat Pump Applications

Retrofits:

- What type of existing distribution?
  - Hydronic -> Consider water-to-water or air-to-water system
  - Forced air -> Consider water-to-air or air-to-air system
  - Steam or other with no ductwork -> Consider refrigerant-based system

Identifying Heat Pump Applications

Comfort Cooling and Heating:

- Is zoning required? (ASHP packaged rooftop vs. VRF)
- How many zones? (splits vs. VRF)
- Is tenant metering required [MA]? (splits vs. VRF)

Identifying Heat Pump Applications

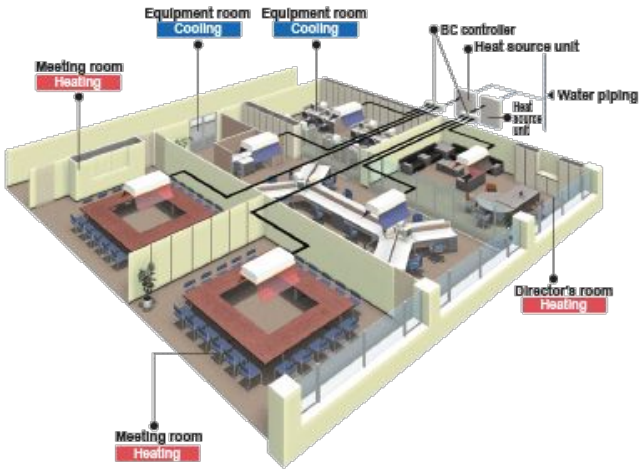
- Always review efficiency opportunities in building envelope before sizing an HVAC system
  - Improving building envelope might allow reduction of HVAC equipment size, reducing the cost of installing a new system
- First Cost Installation, ROI, LCC (5-10 years ago vs. today)
- What are the alternatives? (Cost profile is different)

Multi-Family Application

Design considerations:

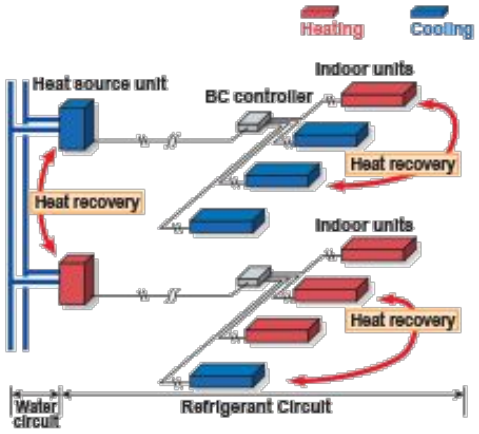
- Who will be paying utilities?
- Single-phase / three-phase power
- Heat pump vs. heat recovery
- Space constraints (ducted / ductless)
- Ownership (condos vs. apartments)
  - Will this ever change?
- Ease of installation (and phasing)
- Footprint minimization
- Controls integration - existing BMS, auxiliary heat, third-party thermostats

Office Application - Water-Source VRF



Office Application - Water-Source VRF

- Advantages:
  - ➢ Eliminate low-ambient ODU de-rates by using water loop for HX
  - ➢ Compact and modular footprint for centralized installations
  - ➢ Heat recovery between systems
  - ➢ Wide water-loop temperature range (23-113 dF)
  - ➢ Geothermal applications available
- Disadvantages
  - ➢ Higher installed cost
  - ➢ More complex controls



Finding a Contractor: Ask the Right Questions

- Why is the proposed technology a good fit for my building?
- Has the proposed equipment been properly sized for my building?
- How do installation and operating costs compare to alternatives?
- Has the designer/contractor/installer completed manufacturer training on the selected equipment?
- When was the contractor's last installation of similar scope?

Resources

- Manufacturer Websites
  - List of contractors who have completed training
  - Schedule of upcoming training
- Incentive & grant programs
  - Alternative Portfolio Standard
    www.mass.gov/alternative-energy-portfolio-standard
  - Mass Save presentation to follow
  - If served by a municipal utility - see nextzero.org or contact your utility

Q&A and Contact Info

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