Beyond HFCs: Refrigerant Management in Design, Construction, and Operations

Since 1972, Steven Winter Associates, Inc. has been providing research, consulting, and advisory services to improve the built environment for private and public sector clients.

Our services include:

- Energy Conservation and Management
- Sustainability Consulting
- Green Building Certification
- Accessibility Consulting

We have over 125 staff across three office locations:
New York, NY | Washington, DC | Norwalk, CT

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Upon Completion of Module

You will receive the following items via email:

- AIA Certificate of completion-can also be used for:
  - PHI Credits
  - NYS PE CEUs
- PDF of final presentation
- Link to the webinar recording


Steven Winter Associates, Inc.
Improving the Built Environment Since 1972
Provider #: J827

CERTIFICATE OF COMPLETION

THIS CERTIFICATE IS TO CERTIFY THAT
Katie Zoppo

PARTICIPATED IN
Module 1: Overview of PH/Net Zero Building Concepts, Techniques and Benefits

COURSE NUMBER
M1OOPHNZBCTAB

ON
February 11th, 2020

LOCATION
New Paltz, NY

EARNING
4 AIA CES Learning Unit/HSW

Lois B. Arena, PE
Director, Passive House Services
Steven Winter Associates, Inc.

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61 Washington Street
Norwalk, CT 06854
203.857.0200

Learning Objectives

Understand history of refrigerants and refrigerant protocols, and their global warming potential.

Learn the importance of preventing refrigerant leaks and methods of prevention.

Learn where the industry is going and importance of future-proofing with regulations to reduce environmental impact of refrigerants.

Understand common VRF issues identified during Cx such as refrigerant leaks, charging and controls.

Overview of Presentation

10 min break
~9:30 AM

10 min break
~10:30 AM

1. History of refrigerant management
2. Refrigerant Leaks
3. Refrigerant management considerations in design
4. Refrigerant based heating and cooling systems, packaged and field piped
5. Refrigerant in VRF systems
6. Refrigerant management considerations during install and Cx
7. Where is industry going?
8. VRF and WSHP Issues Identified During Cx

10 min break
~11:30 AM

Coykendall Science Building

Why we are here: **Directive 1B-2**

- 2018 Chancellor calls for all new buildings to be zero-net-carbon & deep energy retrofits for existing buildings
- 2018 SUCF issued Directive 1B-2
  - Purpose: define and identify goals for Net Zero Carbon (NZC) new buildings and Deep Energy Retrofits (DER) of existing buildings.
  - Function: outlines the project target goals and provides direction for project designs.
  - Metrics: Site Energy as the measure of performance and energy consumption.

Why we are here: **Directive 1B-2**

- Design and construct highly energy efficient buildings which significantly reduce energy consumed below an energy code standard for new buildings or energy usage for an existing building.
- In the case of insufficient project funding, the design goal will be to design the building as NZC “capable” where: the design achieves the energy use intensity (EUI) limit using HVAC equipment and systems that can be electrically powered from renewable energy sources.

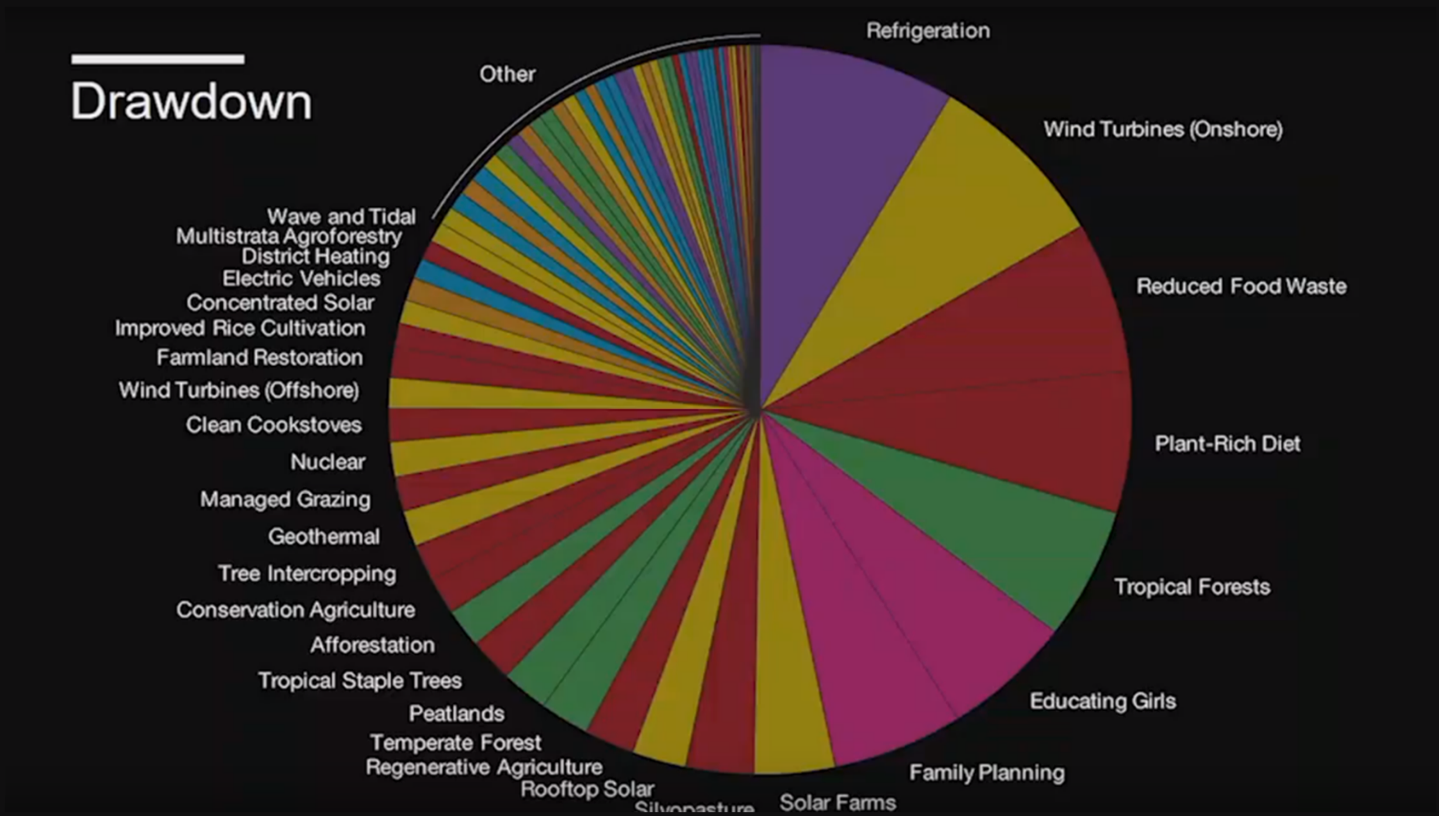
New Building Performance goals:
Site Energy Use Intensity (EUI) limits

Classroom building	50 kBTU/ft2/year
Office building	50 kBTU/ft2/year
Laboratory building	150 kBTU/ft2/year
Residence Hall	32 kBTU/ft2/year

These **Trainings**

- **Module 1:** Overview of PH and Net Zero
- **Module 2:** Construction Methods and High-Performance Products and Details
- **Module 3:** Air Barrier Development & Implementation
- **Module 4:** Net Zero HVAC Strategies and Controls + DHW
- **Module 5**: Construction Documents and Bidding
- **Module 6**: Deep Energy Retrofits
- **Module 7**: Refrigerant Management in Design, Construction, and Operations
- **Module 8**: Construction Manager/Subcontractor/Tradesperson Training

Why talk about refrigerants?

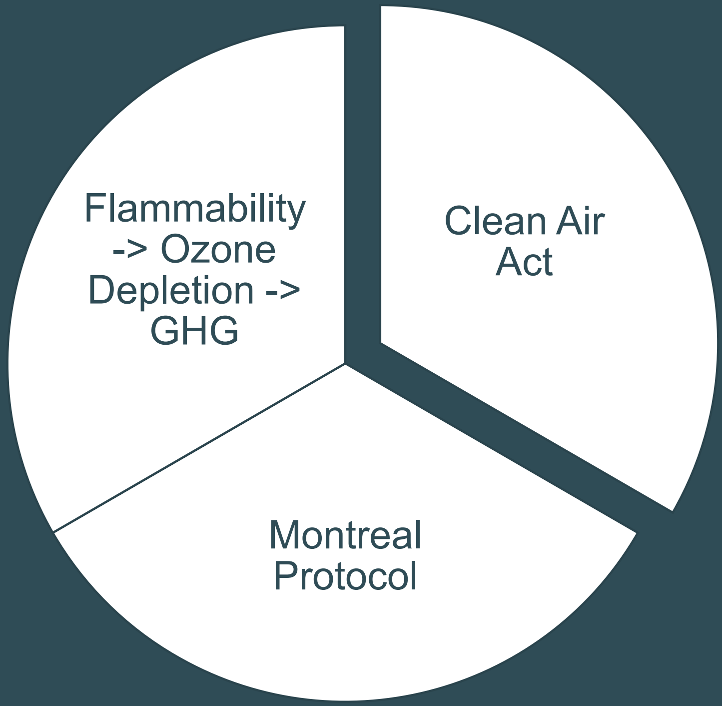


Drawdown – Summary of Solutions, by Rank

Rank	Solution	Sector	TOTAL ATMOSPHERIC CO2-EQ REDUCTION (GT)	NET COST (BILLIONS US $)	SAVINGS (BILLIONS US $)
1	**Refrigerant Management**	Materials	89.74	N/A	$-902.77
2	**Wind Turbines (Onshore)**	Electricity Generation	84.60	$1,225.37	$7,425.00
3	**Reduced Food Waste**	Food	70.53	N/A	N/A
4	**Plant-Rich Diet**	Food	66.11	N/A	N/A
5	**Tropical Forests**	Land Use	61.23	N/A	N/A
6	**Educating Girls**	Women and Girls	51.48	N/A	N/A
7	**Family Planning**	Women and Girls	51.48	N/A	N/A
8	**Solar Farms**	Electricity Generation	36.90	$-80.60	$5,023.84
9	**Silvopasture**	Food	31.19	$41.59	$699.37
10	**Rooftop Solar**	Electricity Generation	24.60	$453.14	$3,457.63

Source: https://www.drawdown.org/solutions/table-of-solutions

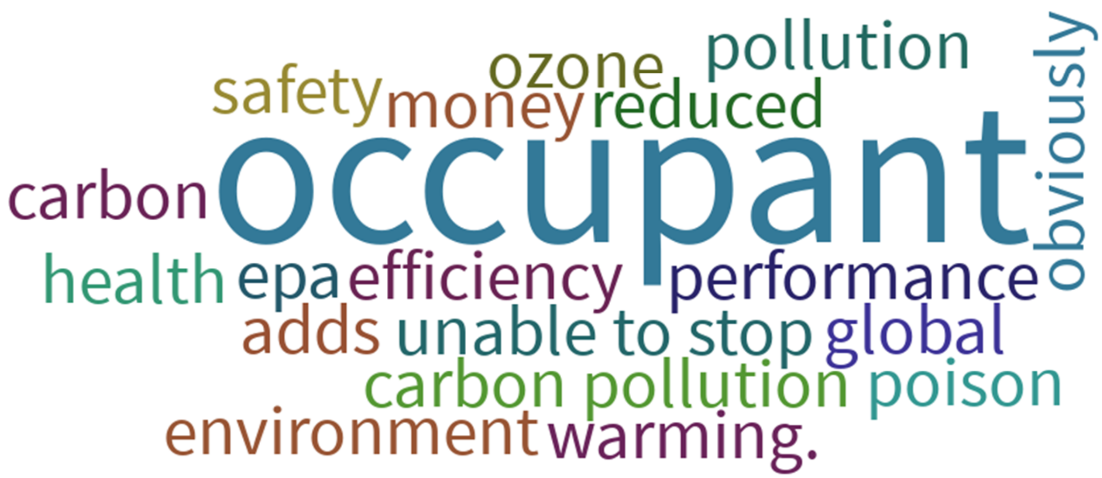
History of Refrigerant Management



When poll is active, respond at **PollEv.com/swa335**

Text **SWA335** to **22333** once to join

What are some concerns when refrigerant leaks?



History of Refrigerant Management

Health and Safety
- Toxicity
- Flammability

Environmental
- Ozone Depletion Potential (ODP)
- Global Warming Potential (GWP)

Economic
- Efficiency
- Performance

Montreal Protocol - 1987

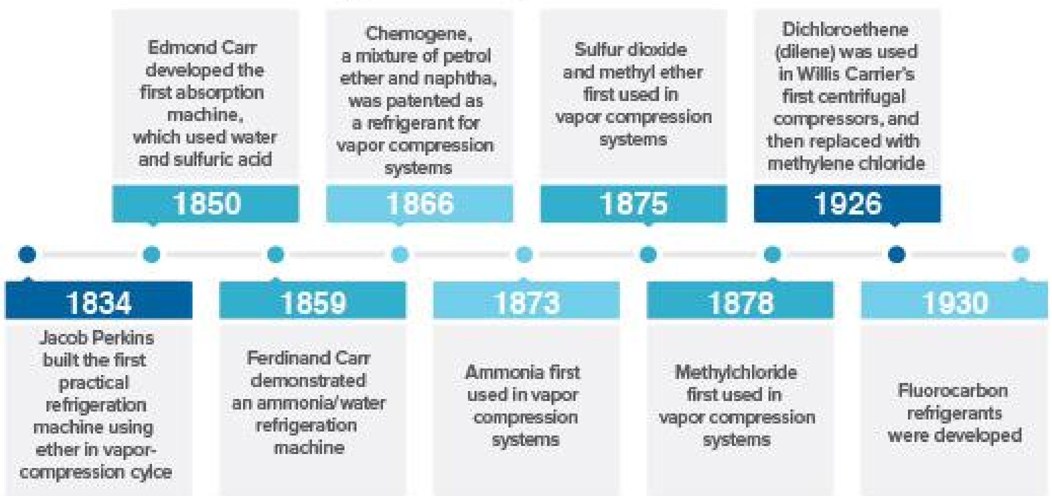
Clean Air Act – 1990 amendment

Kigali Amendment to the Montreal Protocol – 2016

Standards like ASHRAE 15, ASHRAE 34, UL 60335-2-40

History of Refrigerants

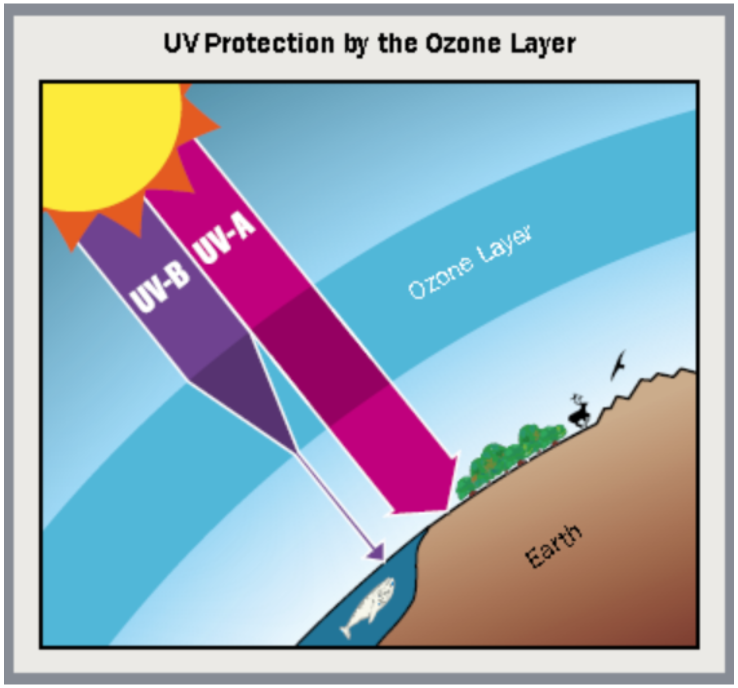
FIGURE 1. Timeline of Refrigerant History.



Source: https://www.epa.gov/snap/refrigerant-safety

- Historically refrigerants were flammable, toxic, or both
- Search for nonflammable, good stability
  - 1926 – A chlorofluorocarbon (CFC), (R-12)
  - 1936 – First hydrochlorofluorocarbon (HCFC) - R-22
- CFCs and HCFCs a Success:
  - Nearly nontoxic
  - Nonflammable
  - Highly stable
  - Good thermodynamic properties

Ozone Layer Depletion



Montreal Protocol - 1987

Year	Ban on	Exceptions
2010	R-22 and R-142b	Existing Equipment Servicing
2015	All HCFCs	Existing Equipment Servicing
2020	R-22 and R-142b	Servicing with recycled or stockpiled R-22
2030	All HCFCs	NA

- Regulation and phase out of CFCs & HCFCs
- 2010 - ban on production, import and use of R-22 and R-142b, except for continuing servicing needs of existing equipment
- 2015 - ban on production, import, and use of all HCFCs, except continuing servicing needs of equipment
- 2020 - ban on remaining production and import of R-22 and R-142b. After 2020, servicing with R-22 will rely on recycled or stockpiled
- 2030 - ban on remaining production and import of all HCFCs

December 31, 1970

Clean Air Act of 1970

December 2, 1970

Official Formation of EPA

UNITED STATES • ENVIRONMENTAL PROTECTION AGENCY •

Clean Air Act (1990) Section 608

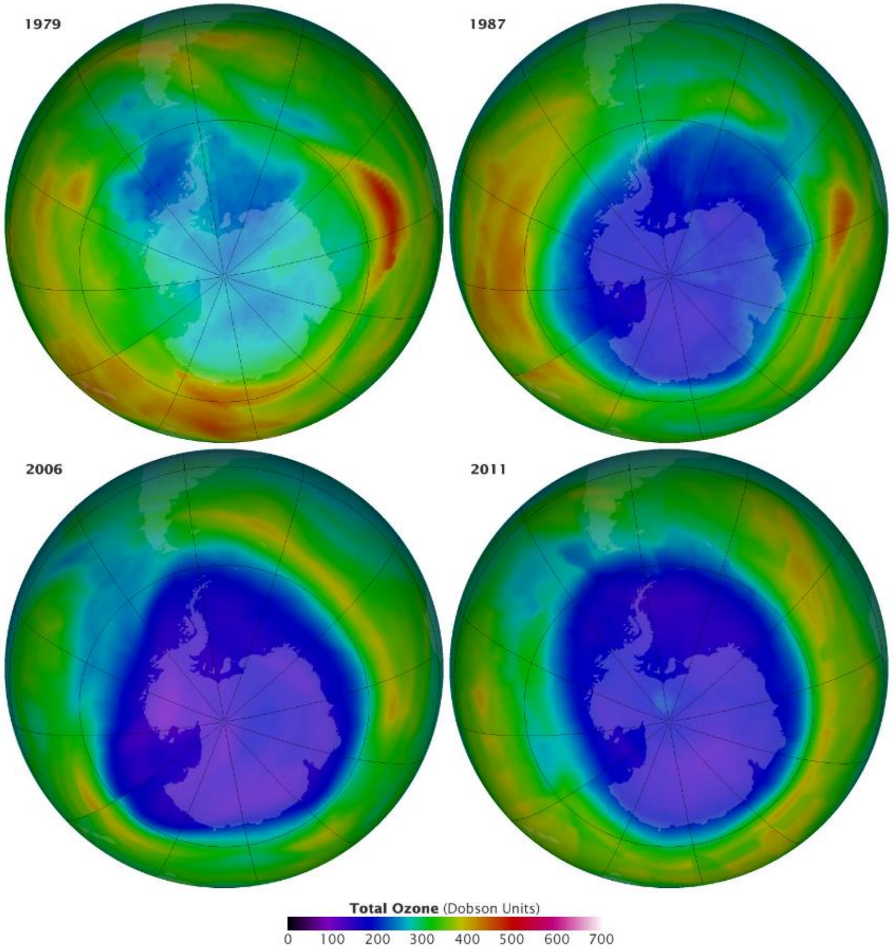
R-410a

- Hydrofluorocarbon (HFC) – no Chlorine
- 1991 – Honeywell
- First Residential AC: 1996
- Recommended alternative in Montreal Protocol
- Widespread use as R-22 phased out (2010+)

R-410a = R-32 + R-125

	R-410a	R-32	R-125
Flammability	none (A1)	low (A2L)	none (A1)
Global Warming Potential (GWP)	~2,000	~700	~3,000

Success!



Earth

Jan. 4, 2018

NASA Study: First Direct Proof of Ozone Hole Recovery Due to Chemicals Ban

For the first time, scientists have shown through direct satellite observations of the ozone hole that levels of ozone-destroying chlorine are declining, resulting in less ozone depletion.

Solve Ozone Issue, Now GHG Issue

- Early 2000s, discovered an issue with HFCs
  - No Chlorine = No thinning of ozone
  - New Problem = Global Warming Potential (GWP)
- GWP: relative measure of how much heat a greenhouse gas can trap in the atmosphere. CO_2 = GWP of 1
- Do not want these systems to leak!

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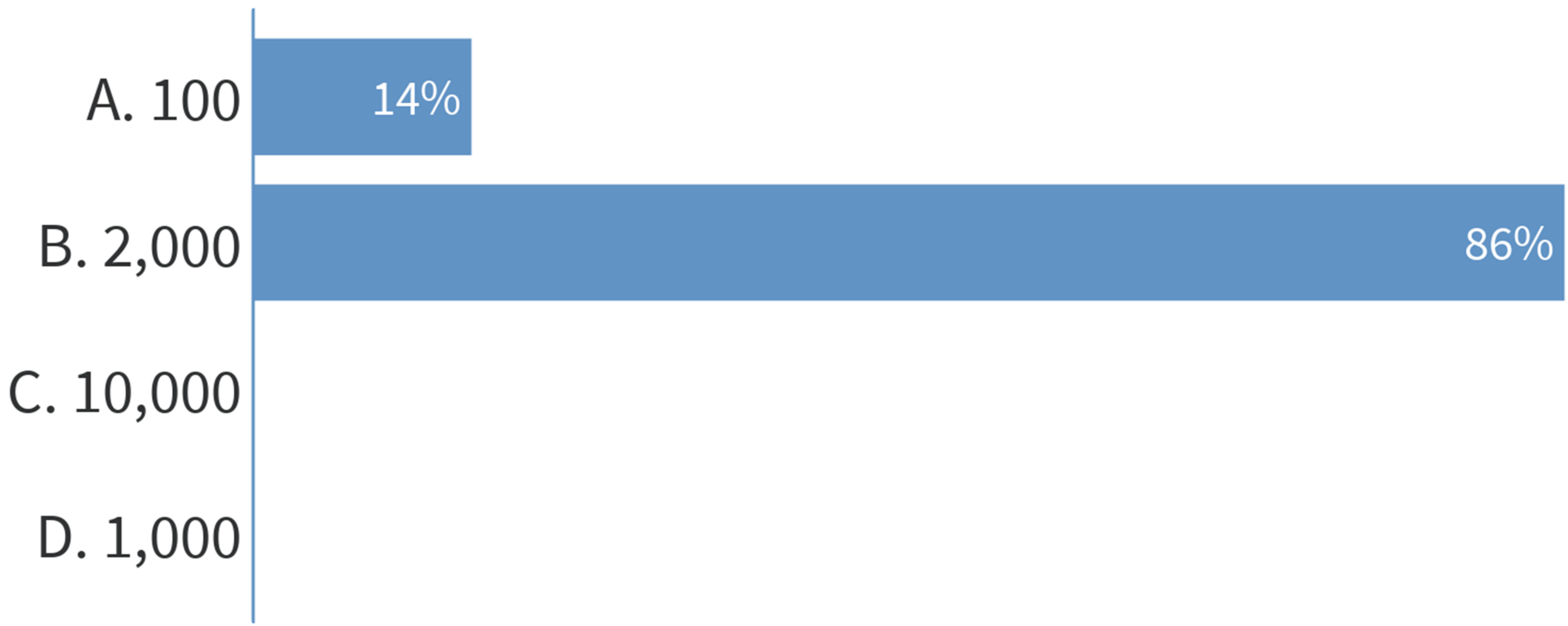
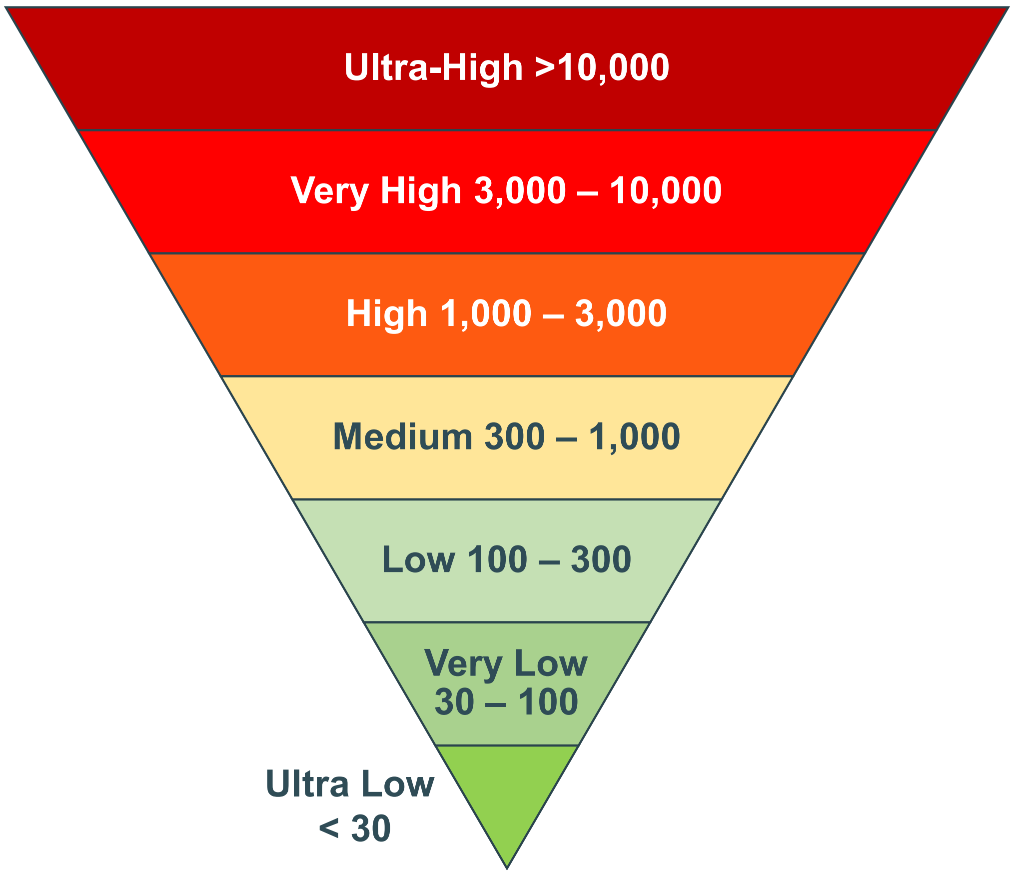
What do you think the GWP of R-410a is?



GWP of Common Refrigerants

Global Warming Potential (GWP)



R-23 (14,800)	**R-12** (10,900)	
R-404A (3,922)	**R-507A** (3,985)	**R-11** (4,750)
R-410A (2,088)	**R-22** (1,810)	**R-134a** (1,430)
R-32 (675)	**R-466A** (733) *New*	**R-454B** (446)
R-454A (239)	**R-455A** (148)	
R-430A (94)	**R-123** (77)	
R-717 (0) *Ammonia*	**R-744** (1) *CO_2*	**HFO-1234yf** (<1)

Refrigerant Type per Equipment

Equipment Type	Typical Refrigerant Charge (lbs.)	Ultra High	Very High	High	Medium	Low	Very Low	Ultra Low
Industrial Refrigeration	1,340 – 8,110	R-12	R-11 R-404a	R-22 R-134a			R-123	
Commercial Refrigeration	1,320 – 1,980	R-12	R-404a R-507a	R-22				
Chiller	570 – 1,150	R-12	R-11	R-22 R-134a R-407c			R-123	
Unitary AC	3.5 – 9.5			R-22 R-410a				
Window AC	1.1 – 1.3			R-22 R-410a R-407c				
Automobile AC	1.1 – 2.3	R-12		R-134a				R-1234yf

Refrigerant Blends

- Mixture of different chemical compounds
  - Zeotropic (400s)
  - Azeotropic (500s)
- Fractionation is possible
  - Charging the system in vapor phase instead of in liquid phase
  - Tank had a small leak
  - The system has a significant leak.

Questions?

Refrigerant Leaks

- Estimated amount of leakage

When poll is active, respond at **PollEv.com/swa335**

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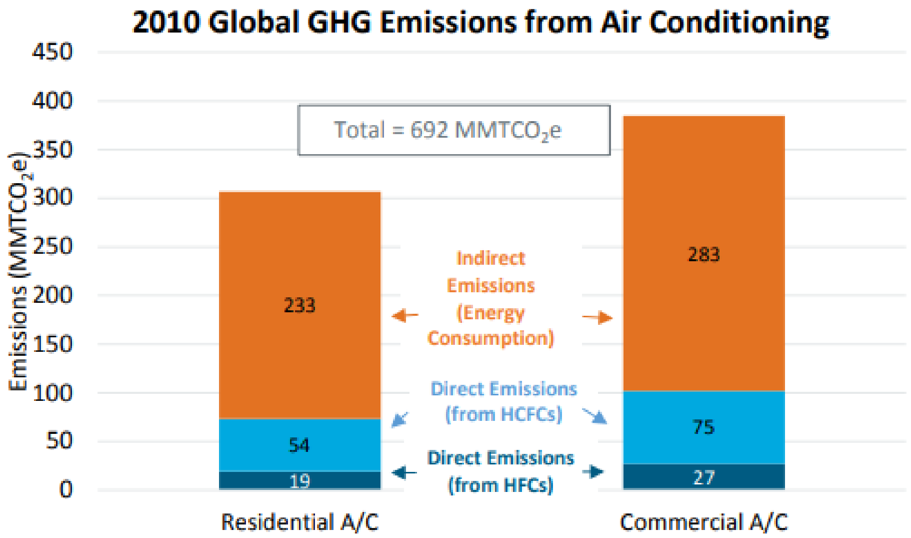
What percentage of equipment experiences a refrigerant leak?

Equipment Refrigerant Leaks

- WSHPs
- Chillers
- Window/Wall AC Units
- RTUs



Sources: IPCC (2014),[32] World Bank (2014),[209] EPA (2012),[210] Xiang, et al. (2014),[211] ICF (2007)[212]

Figure 3-2: Estimated global GHG emissions from A/C systems in 2010

Refrigerant Leakage – Government Perspectives

Empirical Study: Impacts of Leakage from Refrigerants in Heat Pumps

- Mostly Air to Water Heat Pumps and Ground Source Heat Pumps
- 3.5% of refrigerant is leaking
- 8-10% of systems leak per year

Installation Type	Frequency of Leakage	Scenario	Leakage Rate for Systems that Leak	Equivalent Annual Leakage Rate[4]
Non-Domestic	8.97%	Low[1]	20%	1.81%
		Central[2]	42%	3.77%
		High[3]	85%	7.63%
Domestic	10.00%	Low[1]	18%	1.82%
		Central[2]	35%	3.48%
		High[3]	100%	10.00%

Notes:
1. 25th Centile Figure
2. Median Figure
3. 75th Centile Figure
4. Derived from the frequency of leakage multiplied by the leakage rate when leakage occurs.

Table 12: Operational Leakage Rates

"The quality issues regarding this data also raised questions about the nature of log book record keeping in the UK, as our sample indicated very low levels of compliance with the EU F-Gas regulations

www.gov.uk/government/publications/impacts-of-leakage-from-refrigerants-in-heat-pumps

Refrigerant Leakage – Government Perspectives

Department of Defense – Unified Facilities Criteria:
https://wbdg.org/FFC/DOD/UFC/ufc_3_410_01_2013_c4.pdf

- **"(The Services estimate a current annual refrigerant leak rate of 25%.)"**
- "Tracing and repairing a leak on a VRF system is many times more difficult with an additional access requirement of maintenance crews to the workspace environment."

Refrigerant Leakage – Government Perspectives

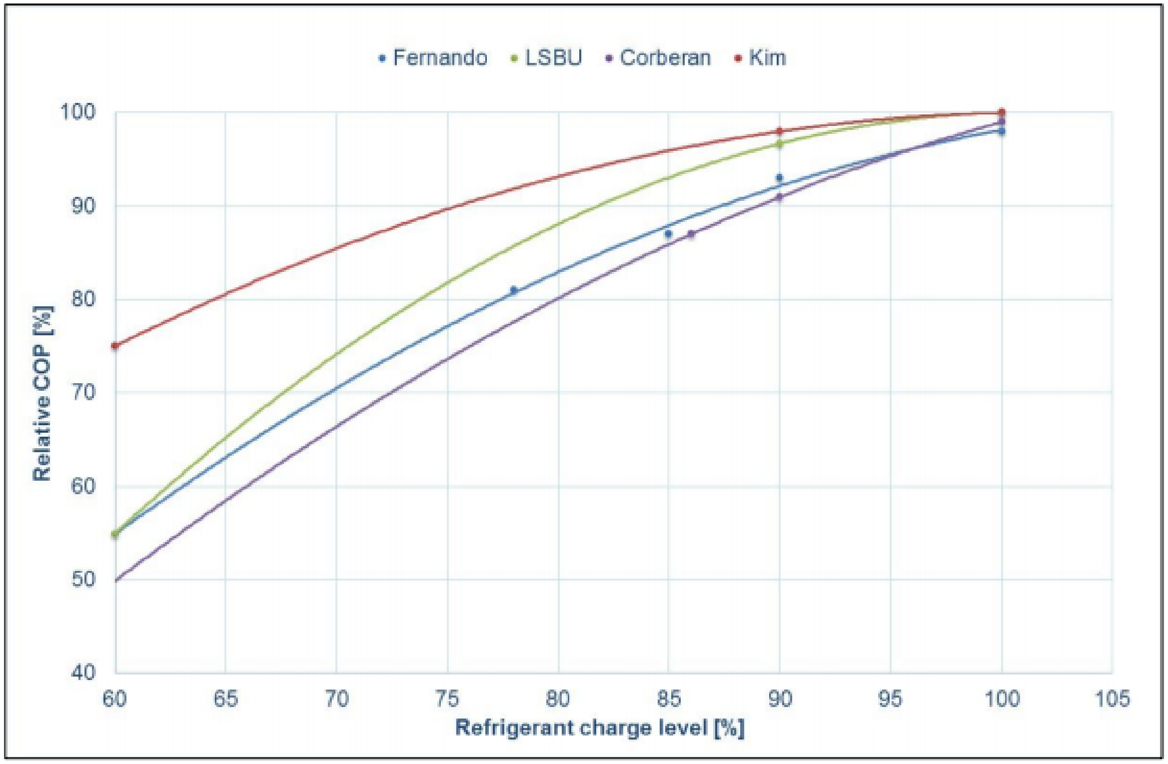
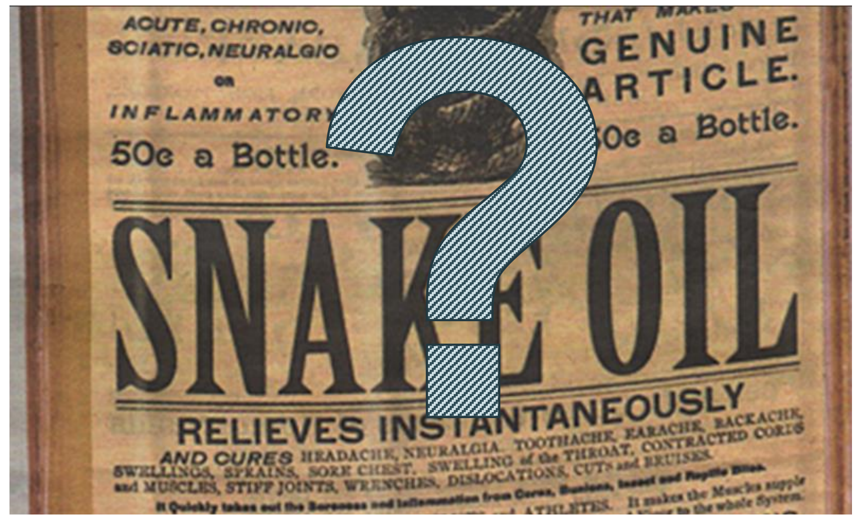


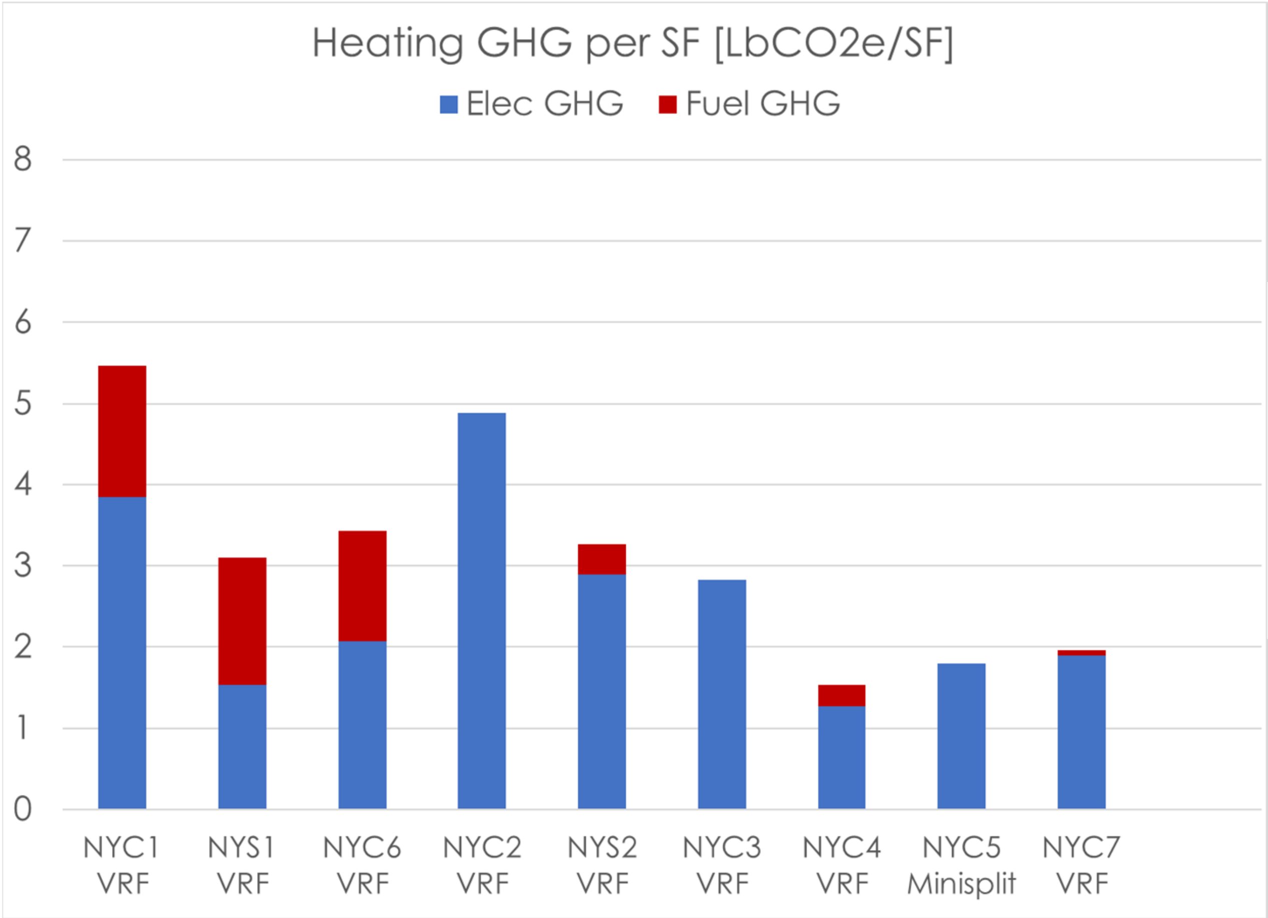
Figure 4: Comparison of Heating Results with Similar Studies

Leak Sealers?

- For the most part:
  - There is a complex chemistry situation going on in your refrigerant system
  - Probably not a good idea unless approved by the manufacturer



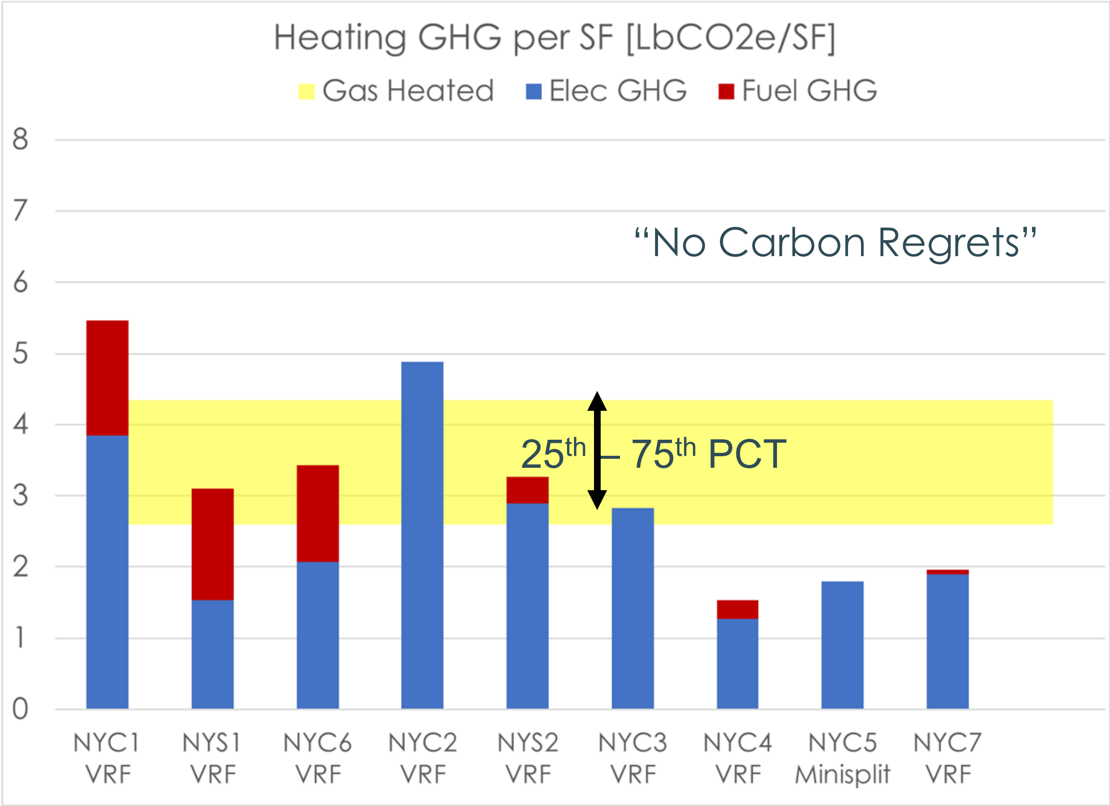
Real World Carbon Performance



Today's Marginal Coefficient

LbCO2e/kBTU
Gas: 0.1173
Elec: 0.3260
(non-baseload)

Real World Carbon Performance



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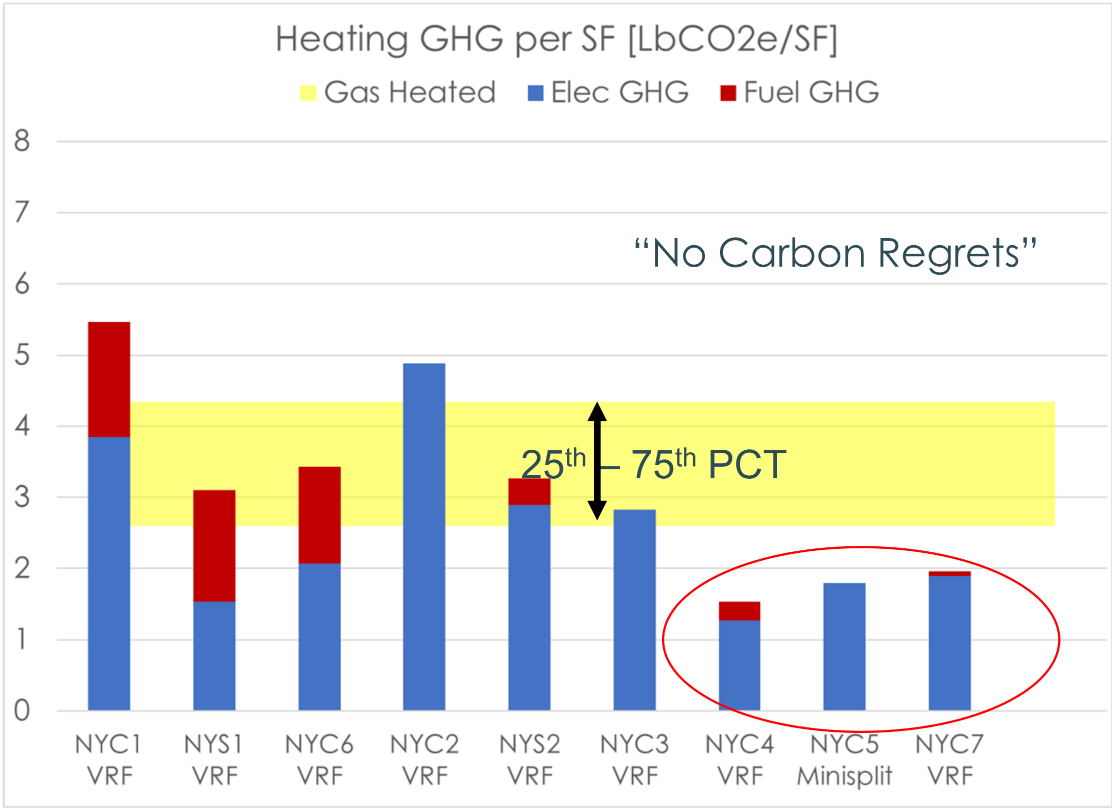
Real World Carbon Performance



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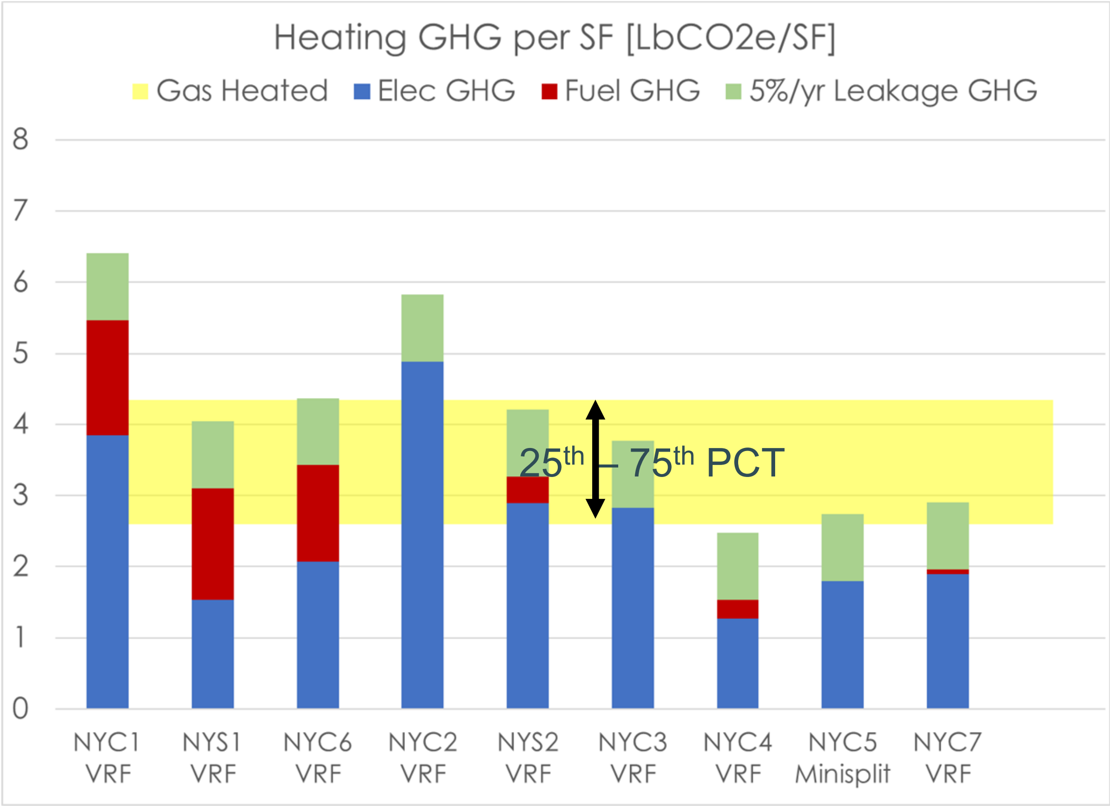

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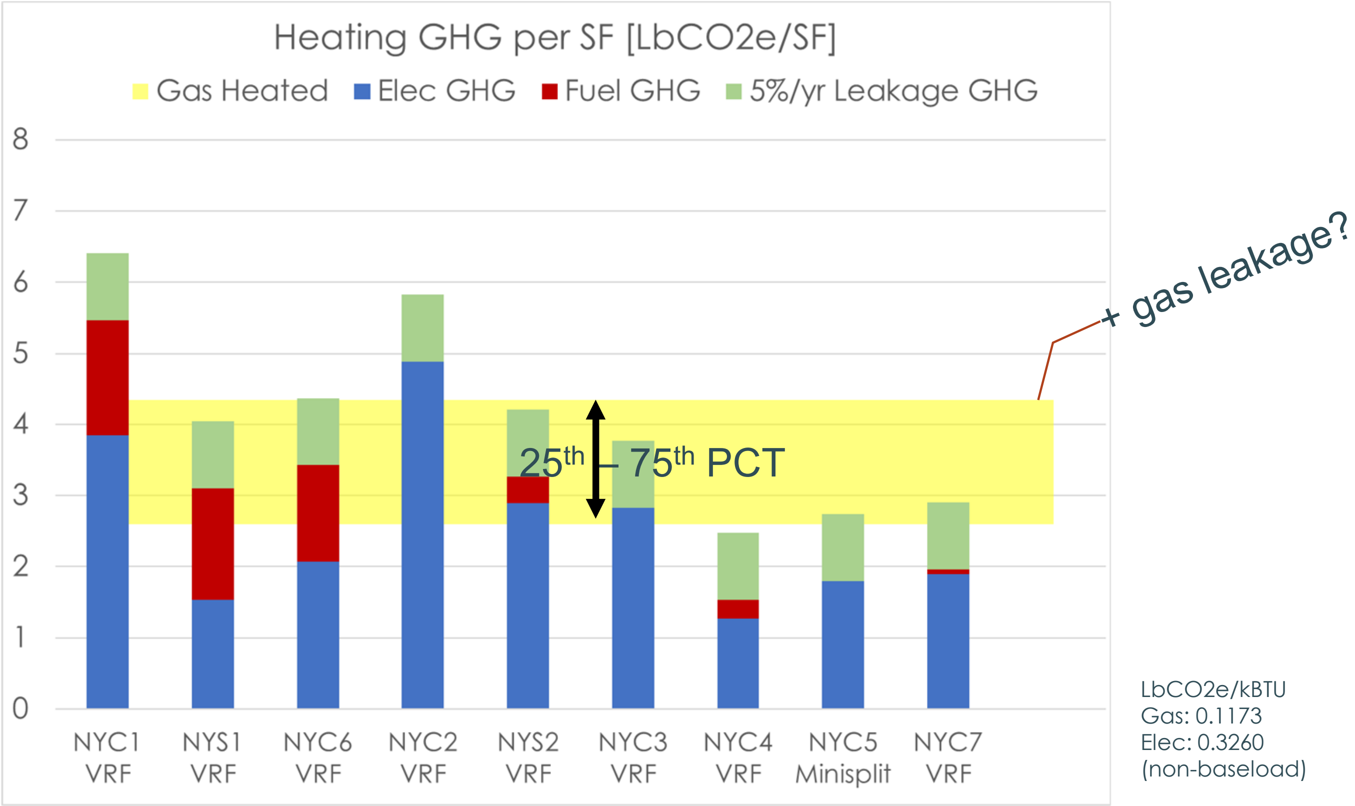
Real World Carbon Performance



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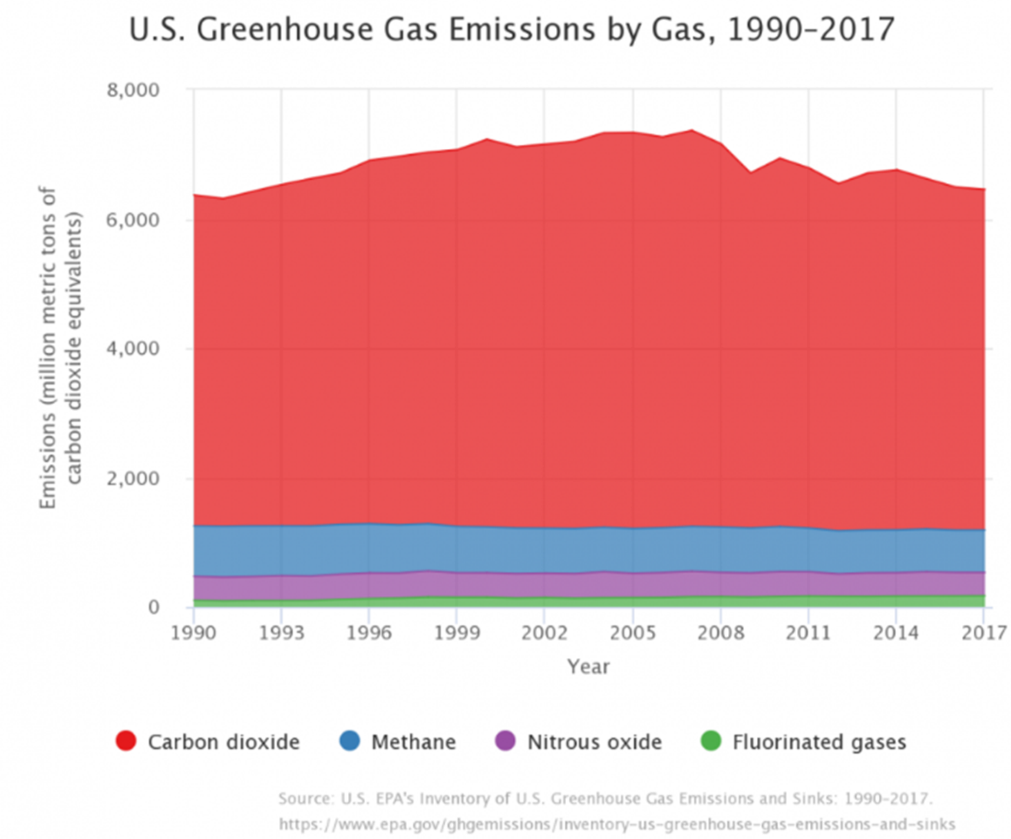
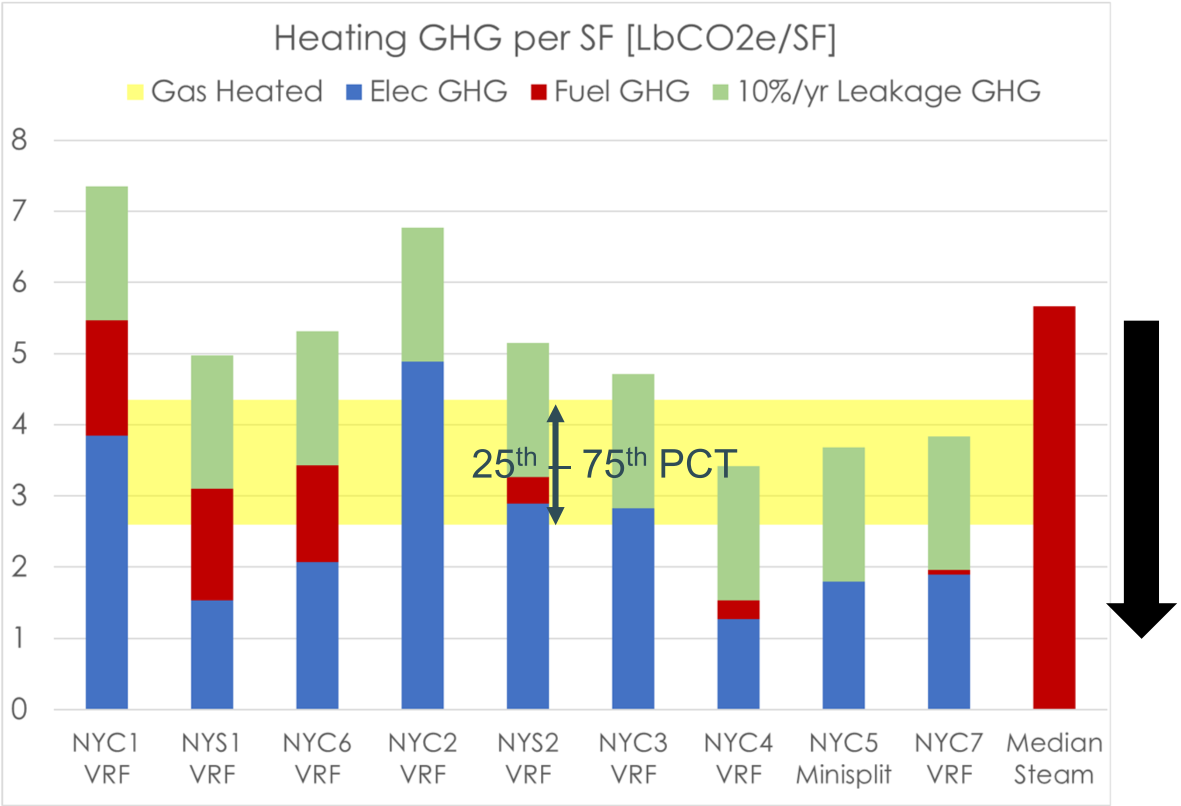


Gas Leakage

AND

- Recent study shows 60% higher methane loss than EPA measured

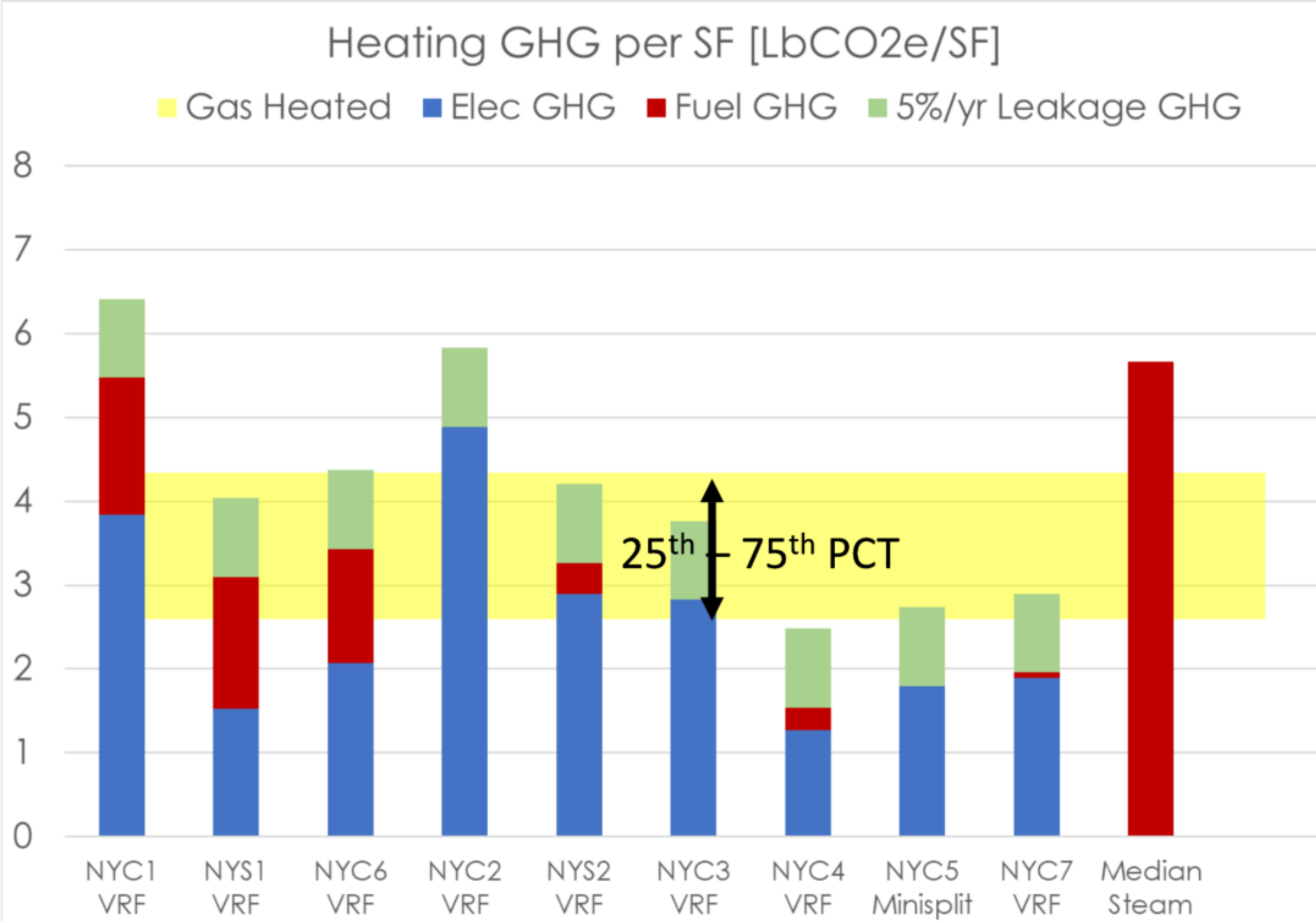
Real World Carbon Performance



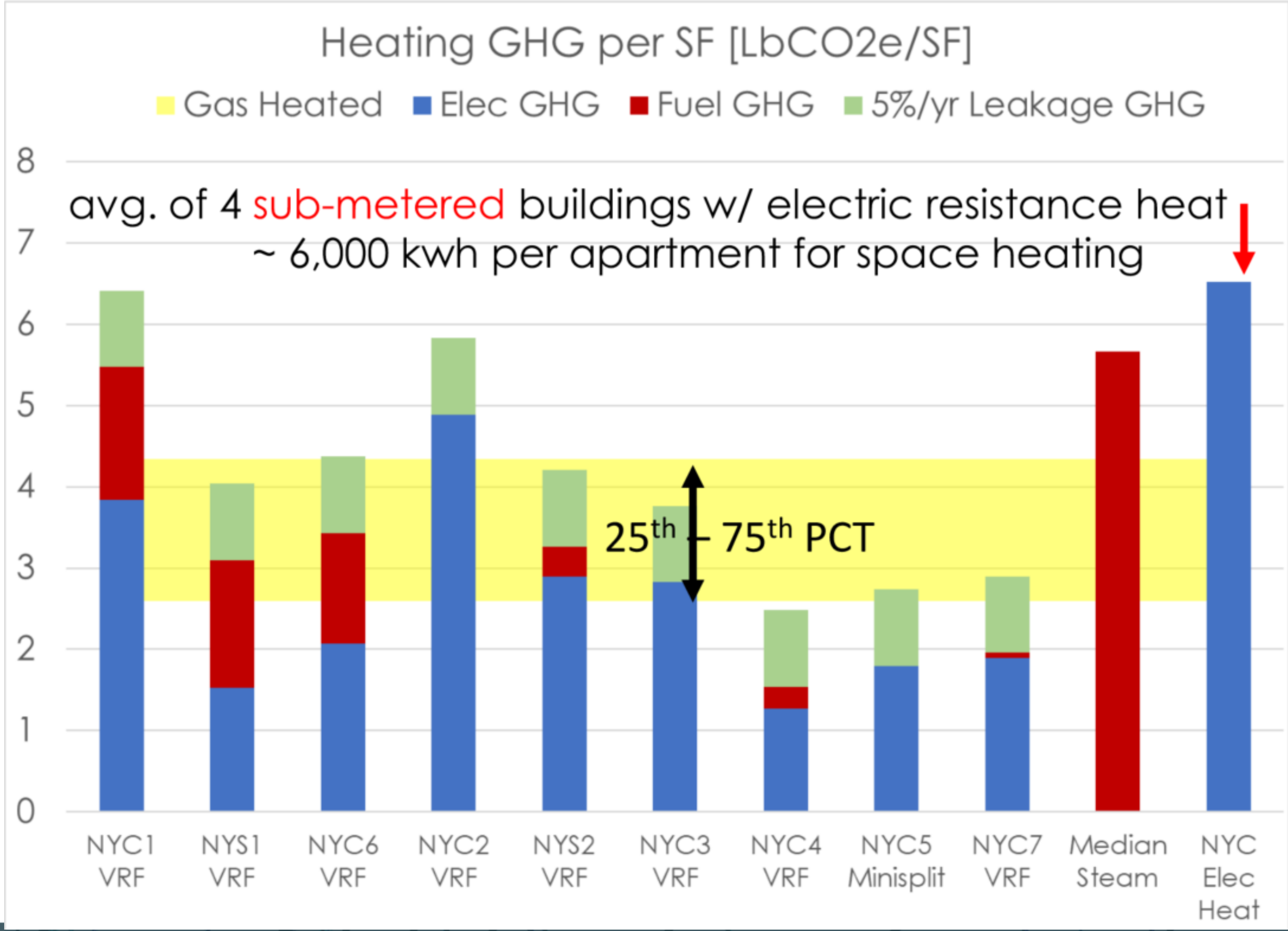
The **Billion+** Dollar Question:

What is the lowest carbon abatement cost path to the goal?

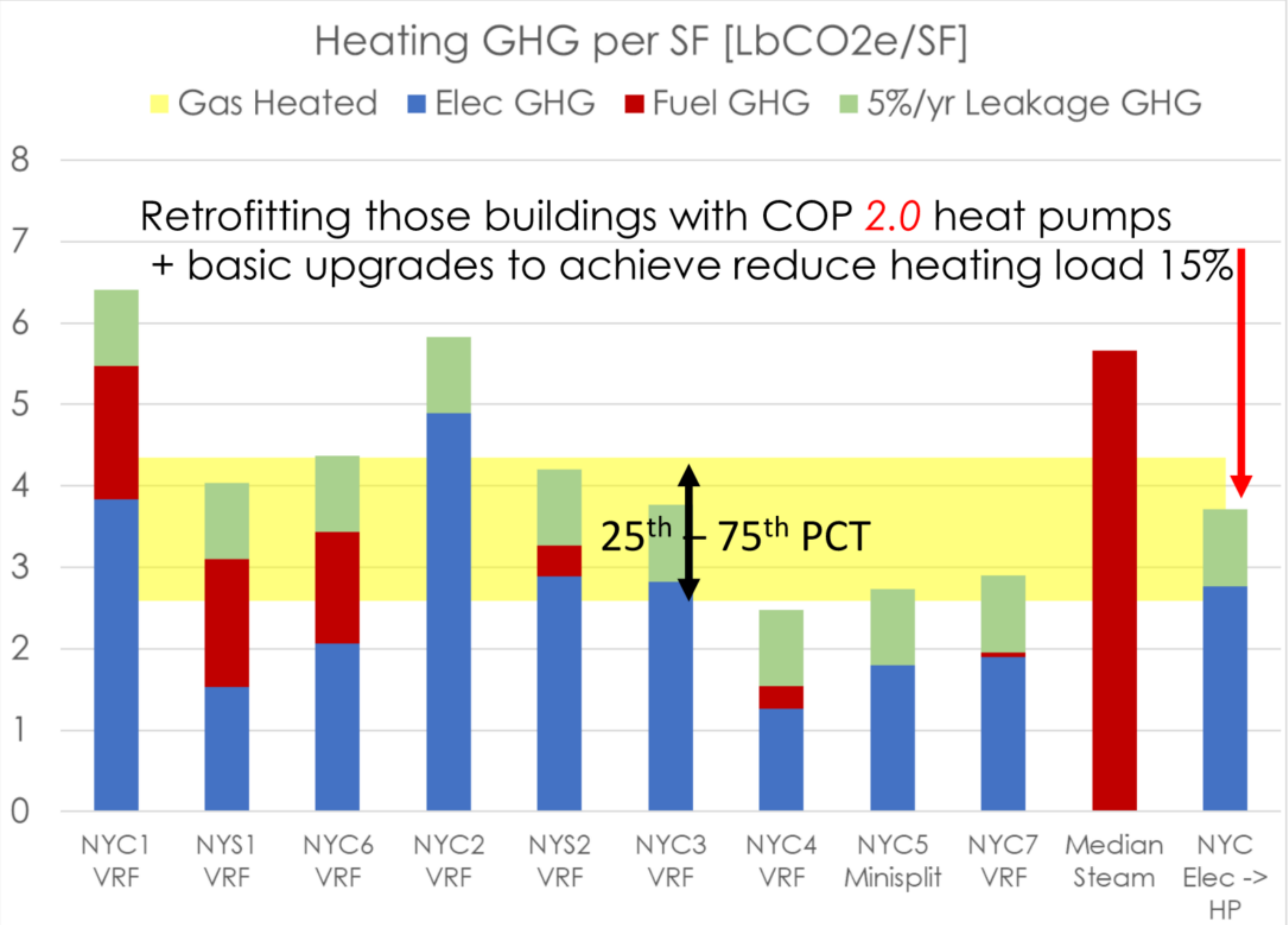
Real World Carbon Performance



Real World Carbon Performance



Real World Carbon Performance



Questions?

10 Minute Break

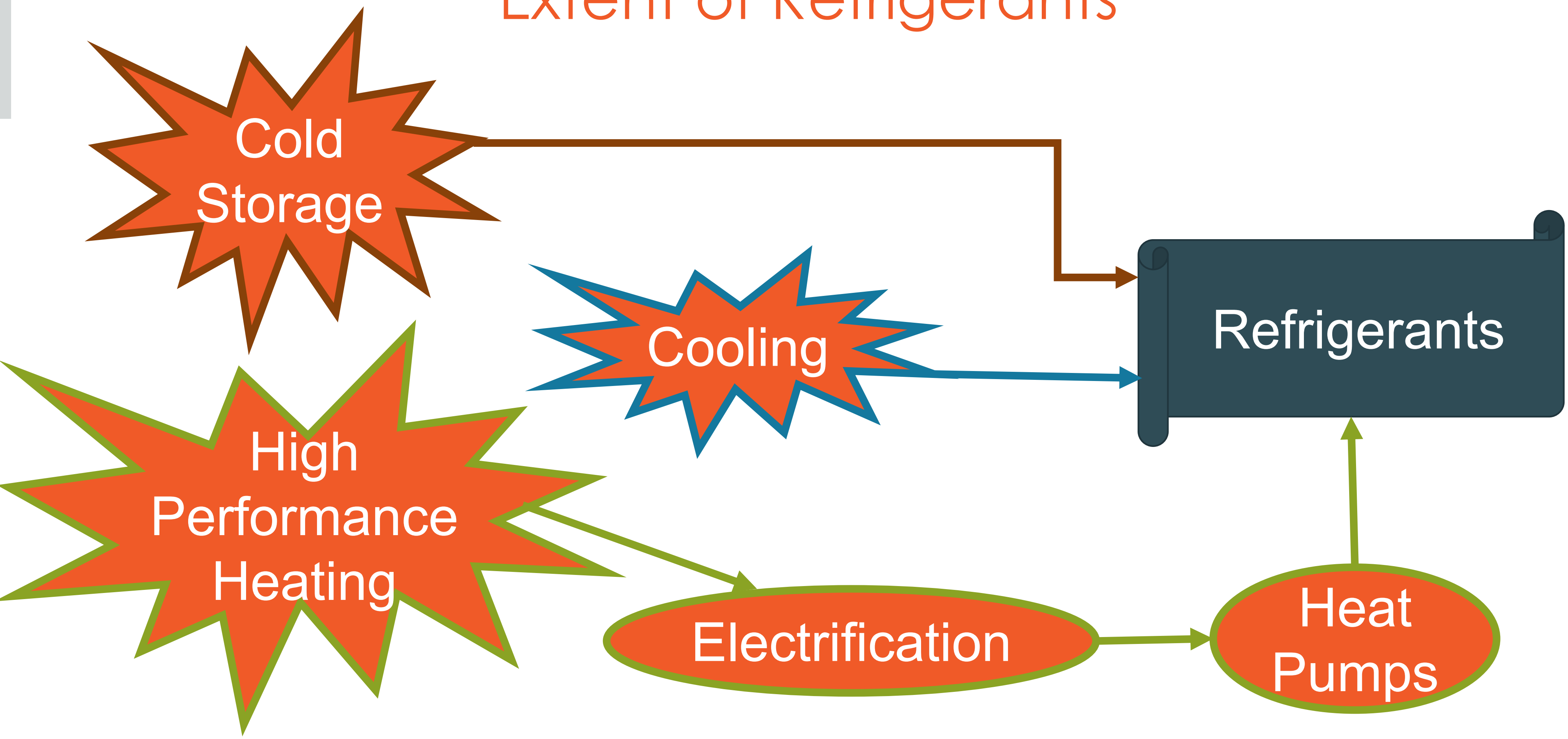
Refrigerant management considerations in design

Extent of refrigerant in high efficiency buildings

Occupant safety

Code requirements

Extent of Refrigerants



Occupant Safety

Global Warming is a major issue **BUT** first we have to deal with the immediate **health and safety** of the **building occupants**

Refrigerant Safety Risks

- Flammability
- Acute toxicity
- Oxygen Depletion Potential

Flammability and Toxicity of Refrigerants

SAFETY GROUP

INCREASING FLAMMABILITY

Higher Flammability	A3	B3
Flammable	A2	B2
Lower Flammability	A2L	B2L
No Flame Propagation	A1	B1
	Lower Toxicity	Higher Toxicity

INCREASING TOXICITY

Refrigerant Safety

- ASHRAE Standard 15 - 2019
  - Refrigeration system personal safety
  - Limits max charge so a complete discharge into a small, enclosed, occupied room can not exceed the allowable limit
- ASHRAE Standard 34 - 2019
  - Refrigerant Naming Conventions
  - Toxicity and Flammability Assignments

NEW YORK STATE OF OPPORTUNITY. | Building Standards and Codes | ICC INTERNATIONAL CODE COUNCIL®

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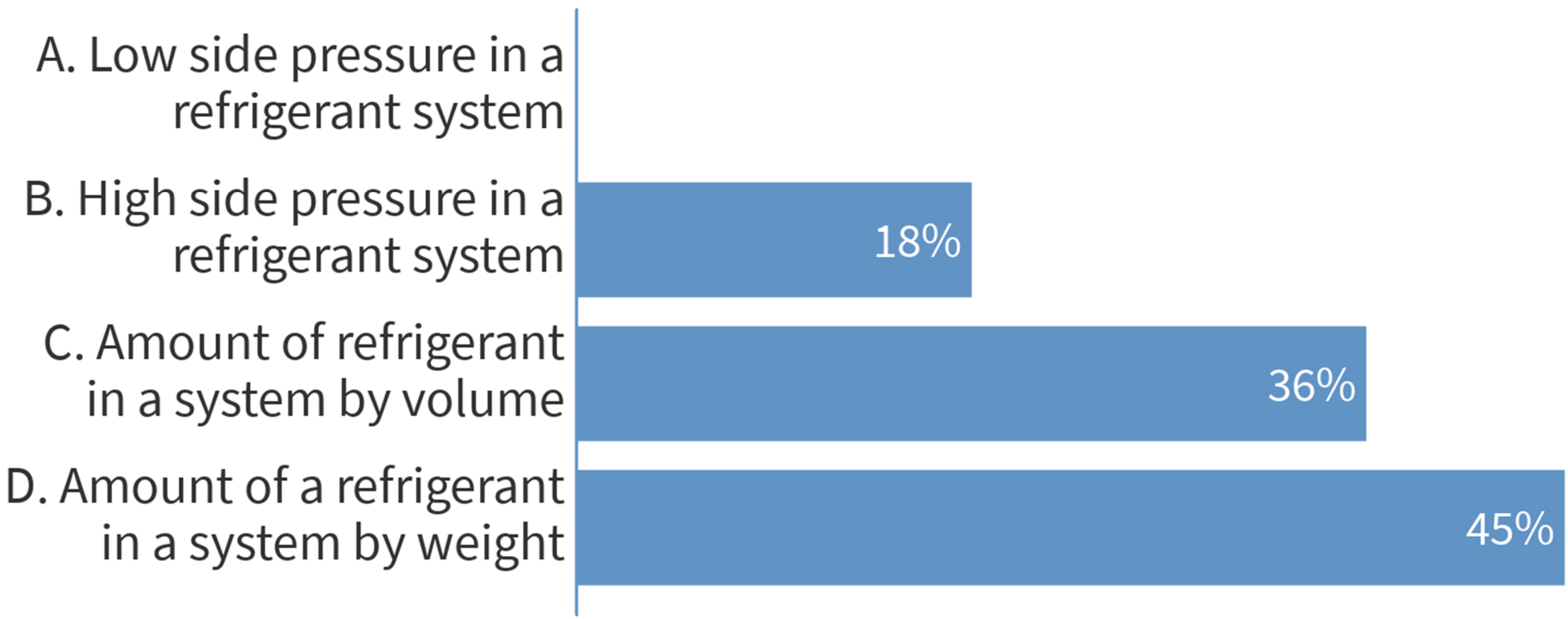
What is refrigerant charge?



ASHRAE 15-2019

Space Types

- Institutional Occupancies
- Industrial Occupancies
- Refrigerated Rooms
- Machinery Rooms

Acronyms

IDLH	*immediately dangerous to life or health*
LFL	*lower flammability limit*
OEL	*occupational exposure limit*
RCL	*refrigerant concentration limit*

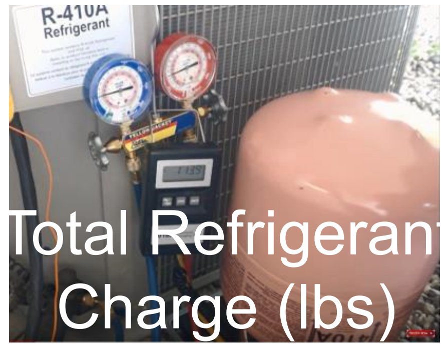
https://www.youtube.com/watch?v=ncgLDYrvN6w

ASHRAE 15-2019 Requirements

Oxygen Depletion Potential

Minimum allowed floor area (sf)

=



× 1,000

RCL (lbs/1,000 ft3)

×

https://www.youtube.com/watch?v=ncgLDYrvN6w

ASHRAE 15 Refrigerant Detection Requirements

- 8.11.5
- Machinery rooms shall contain a detector
  - Alarm @ OEL
  - Audible and Visual
  - Inside and outside the room
  - Manual Reset
- Refrigerated rooms that exceed the RCL (7.2.2)
- Additional Requirements for Flammable Refrigerants

Credit to Tom Burniston and Bacharach generally for content on refrigerant leak detection

Refrigerant Leak Detection – Not just for safety

- Refrigerant leaks
  - Reduce performance and efficiency
  - Refrigerant isn't cheap
  - Bad for the environment

Equipment Type	Charge Sizes (lb)
Chillers	570 – 1,150

ASHRAE 15-2019 Requirements

- <6.6 lbs refrigerant:
- Exempt from most requirements

Equipment Type	Charge Sizes (lb)
Chillers	570 – 1,150
Cold Storage	0.017 - 0.019/ft²
Commercial Refrigeration	1,320 – 1,980
Dehumidifiers	0.4 - 0.5
Domestic Refrigerators & Freezers	0.51
Ice Makers	5.5 – 6.6
Industrial Refrigeration	1,340 – 8,110
PTAC/PTHP	1.3 – 1.5
Unitary AC	7.5 – 9.5
Window AC	1.1 – 1.3

Refrigerant Recovery and Reuse

- Reuse
  - Properly evacuate
  - Reuse in the same system/Same Owner
- Recovery & Reclaiming

Box 2. Why Shouldn't I Just Vent Refrigerant?

1. It's illegal;
2. It's harmful to the environment and human health; and
3. You can earn money by selling recovered refrigerant to an EPA-certified refrigerant reclaimer.

Example Equipment from Tru Tech Tools

When poll is active, respond at **PollEv.com/swa335**

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What else is in your refrigeration system besides refrigerant?

What else is in there?

OIL!

…and sometimes other things that probably shouldn't be there

Why Oil?

- Ensure mechanical components in the compressor are properly lubricated

Oil Management

Issues with Oil

- Refrigerant Migration
  (Liquid in Compressor)
  - Refrigerant not Evaporating completely
    - Dirty evaporator air filters
    - Failed evaporator fan
  - Excess refrigerant charge

- Moisture in the system
- Oil trapping
  - Contaminants clogging system components
  - Piping configuration issue

Acid?

Oil Management System

Potential components

- Oil separator
- Oil reservoir
- Oil accumulator
- Oil Filter
- Oil Regulator

Oil Management System

General Strategies for Chillers

Magnetic Bearing Chillers

- Quiet operation
- Light weight: faster installation
- Low startup draw
- Reduced maintenance costs (no oil use)

https://www.energy.gov/eere/femp/magnetic-bearing-chiller-compressors

AIR-COOLED CHILLERS

TAG	SERVICE	LOCATION	MINIMUM COOLING CAPACITY (TONS)	EVAPORATOR					COP	REFRIG. TYPE	REFRIG. CHARGE (LBS)	COMPRESSOR			AMBIENT (F)		CONDENSER FANS			SPL (dBA)	ELECTRICAL DATA (SINGLE POINT)			DIMENSIONS			OPER. WEIGHT (LBS)	MFR	MODEL
				GPM	MIN FLOW (GPM)	EWT (F)	LWT (F)	MAX P.D. (FT)				QTY	TYPE	NO. STAGES	MAX	MIN	QTY	KW EACH	SPEED CONTROL		MCA	MOCP	V-Φ-HZ	L (IN)	W (IN)	H (IN)			
CH-1	AHU-1	ROOF	80	154	96	57	45	9.75	2.85	R-410A	47	4	SCROLL	4	95	40	4	10 1/3	VFD		160	175	480-3-60	95	89	90	5,200	CARRIER	30RB020

REVOLUTIONARY ENERGY SAVINGS

Air-cooled oil-free centrifugal chillers from Smardt Chiller Group

SMARDT

TD - 0081B
16 Dec 2011

Oil free centrifugal technology - Smardt Chiller

Oil-free centrifugal compressor technology boosts energy efficiency, cuts operating costs and is now well-proven worldwide. ... The totally **oil-free** Turbocor technology achieves the highest part-load efficiencies for **chillers** and chilled water systems (including water-, **air**- and evaporatively-**cooled** applications).

www.mcquay.com.hk › my-product › magnetic-bearing-oil-free-air-c...

Magnetic Bearing Oil-free Air-cooled Chiller - McQuay

Magnetic bearing centrifugal compressor eliminates the efficiency-robbing friction inherent in traditional **chiller**. The positive pressure, **oil-free** design eliminates ...

www.daikin-ce.com › en_us › press-releases › centrifugal-oilfree-chiller

Daikin introduces innovative new oil-free chiller | Daikin

Jul 24, 2018 - The new DZ Series Water-**Cooled Oil Free** Centrifugal **chiller** is fitted with centrifugal compressors which utilize frictionless magnetic bearings ...

www.lg.com › global › business › oil-free-centrifugal-chiller

Oil Free Centrifugal Chiller | Air Solution | Business | LG Global

LG's **oil free chiller** has simplified the piping structure by eliminating oil-related parts. There is no need to replace oil or filters. Learn more now.

www.multistack.com › products › maglev-oil-free-centrifugal-chillers

Maglev oil free centrifugal chillers - Multistack

Multistack's MagLev product lines utilize **oil-free** compressor technology to provide solutions that ... Packaged **Air Cooled** MagLev Centrifugal **Chiller** (ASP_F).

Oil Management System

General Strategies for VRF Systems

- General Strategies for VRF Systems
  - Design of Compressor
  - Oil level monitoring
  - Compressor Oil Sharing
  - “Oil Recovery Mode”

Questions?

Refrigerant based high-performance heating and cooling systems, packaged and field piped

- VRF
- Mini-splits
- Air-to-water heat pumps
- Water-to-water heat pumps

Definitions

VRF (Variable Refrigerant Flow)

Outdoor Units / Indoor Units

Inverter, inverter-driven

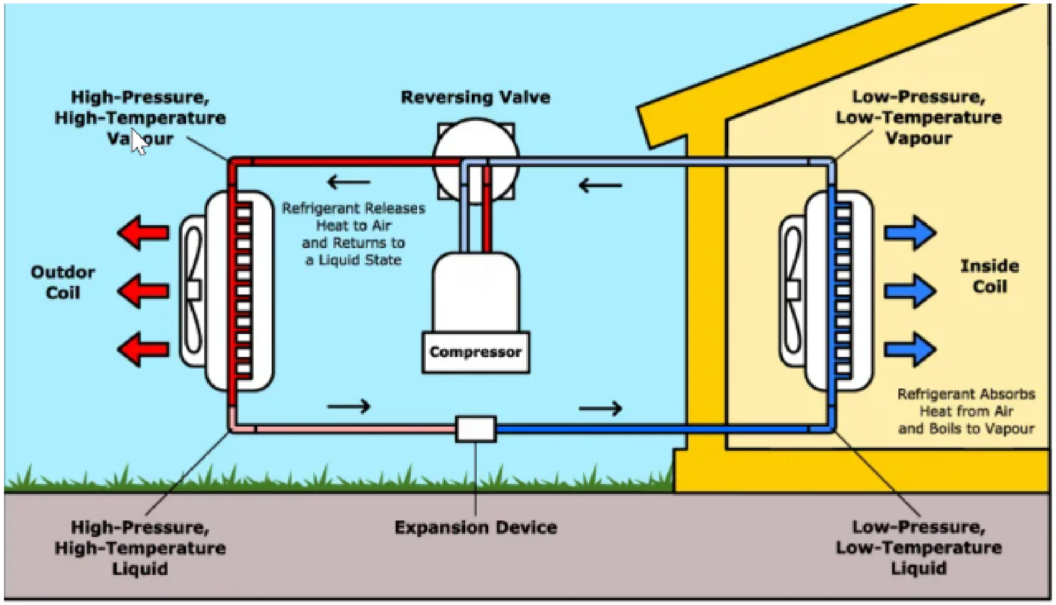
Variable-speed (compressors)

Air-Source

Takes heat from (and rejects heat to) outdoor air

Heat Pump

- An AC unit with a reversing valve to change direction of refrigerant flow
- By reversing direction, heat pump changes from cooling to heating
- Heat is rejected/absorbed through an outdoor unit or condenser water loop
- Heating and cooling

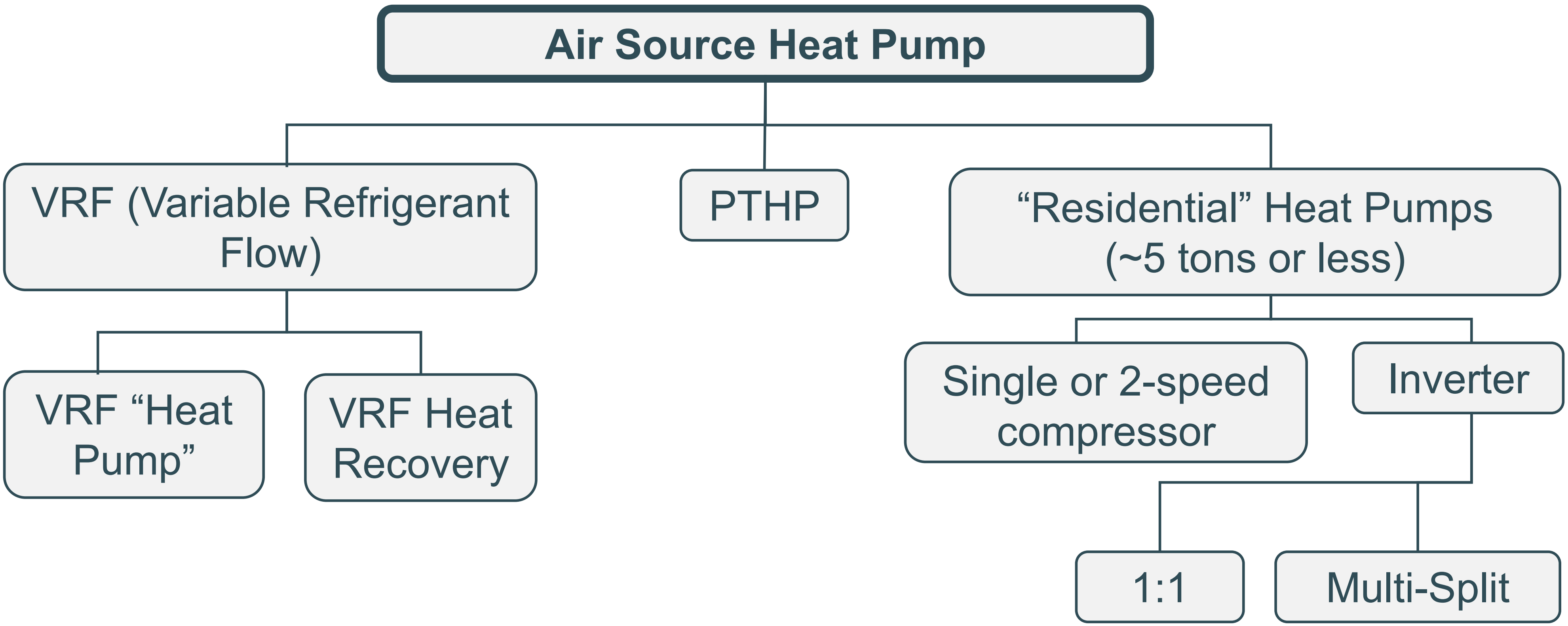


Air Source vs Water Source

- **Air Source**
  - Heat is rejected/absorbed directly from the outdoor unit to outside air
  - Does not require a condenser water loop with heat rejection/injection

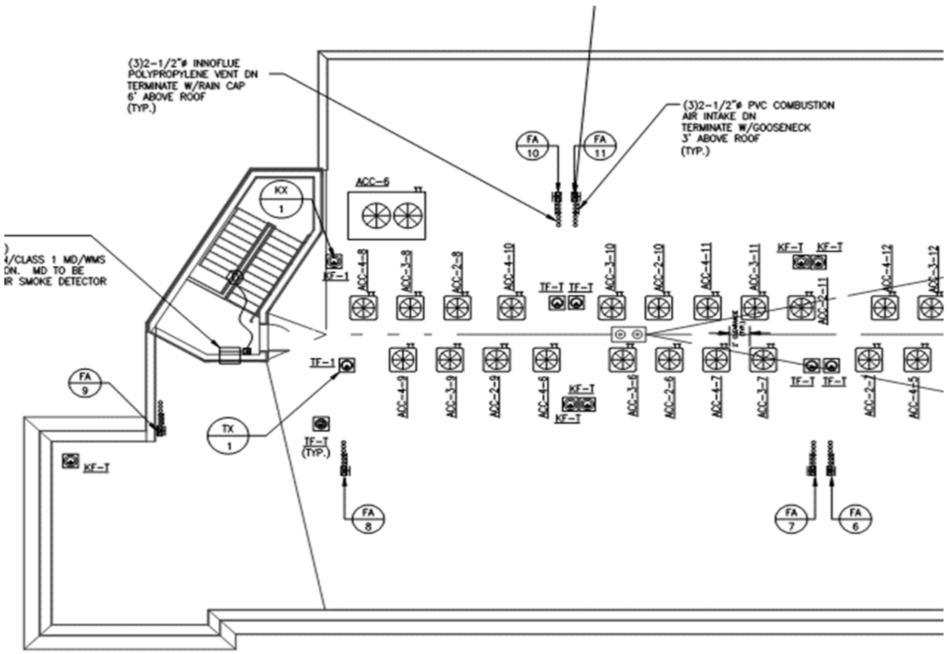
- **Water Source**
  - Makes use of a condenser water loop and condenser water pumps to take the heat from the condenser to the cooling tower
  - For heating mode to occur for VRFs and heat pumps, the condenser needs to absorb heat from the condenser water. Therefore, the condenser water loop also has a method of heat injection typically from boilers.

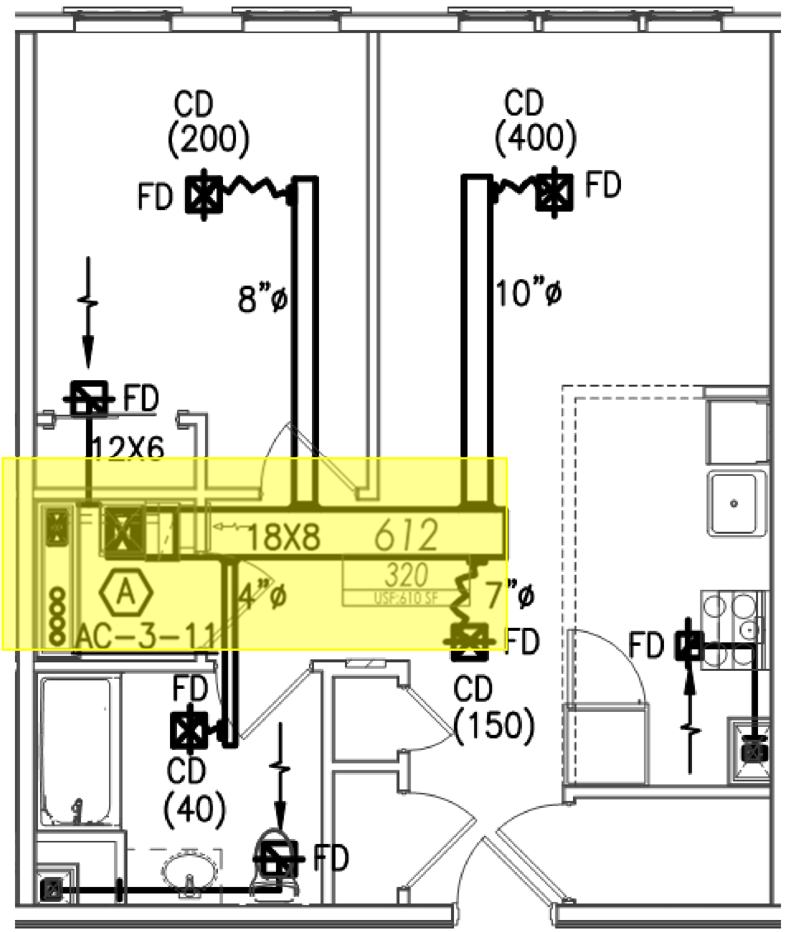
ASHP Tree

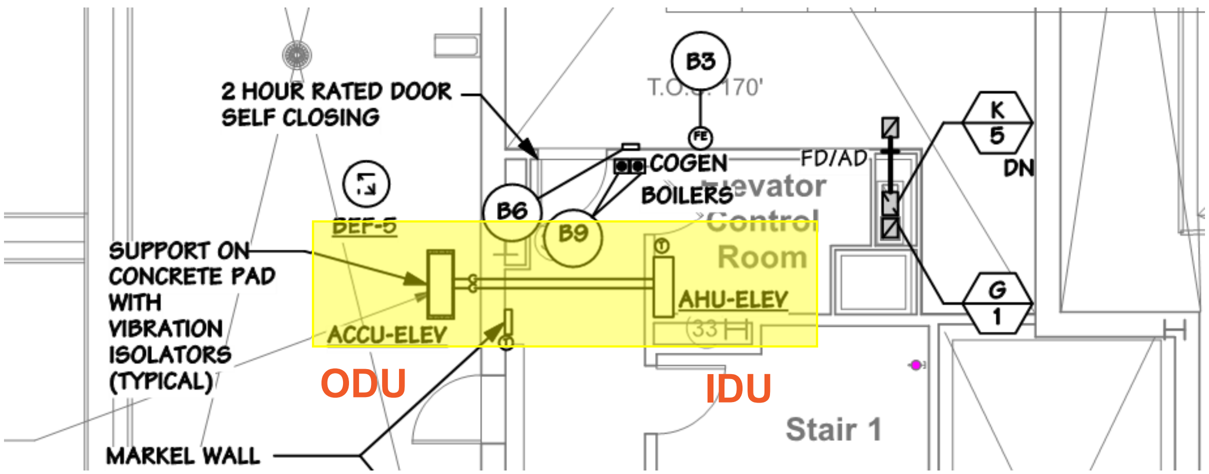

Air Source Heat Pump
VRF (Variable Refrigerant Flow)
PTHP
"Residential" Heat Pumps (~5 tons or less)
VRF "Heat Pump"
VRF Heat Recovery
Single or 2-speed compressor
Inverter
1:1
Multi-Split

1:1 ASHPs

- One indoor unit to one outdoor unit
- Cooling and Heating



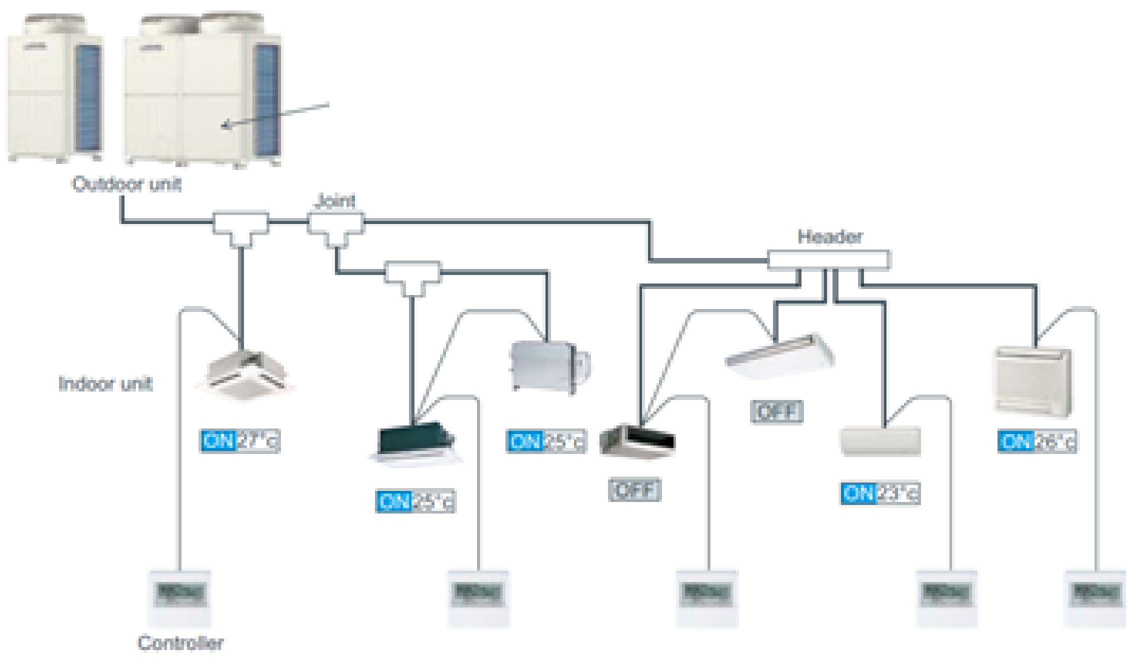




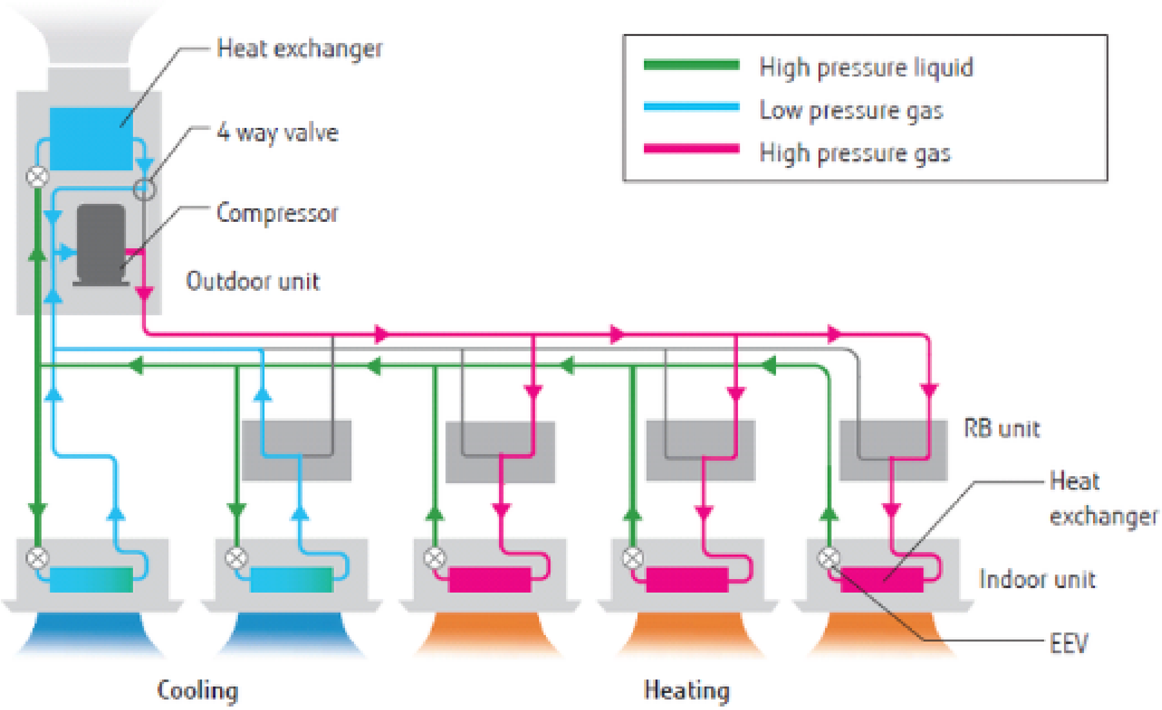
1:1 Split ACs

- Typically wall mounted indoor unit
  - EMRs and mech rooms
- Exterior air-cooled condensing unit
- One indoor unit to one outdoor unit
- Cooling Only

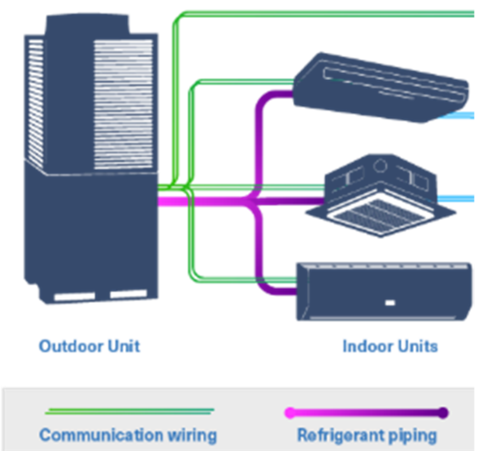
VRFs – Heat Pump VRF



VRFs – Heat Recovery

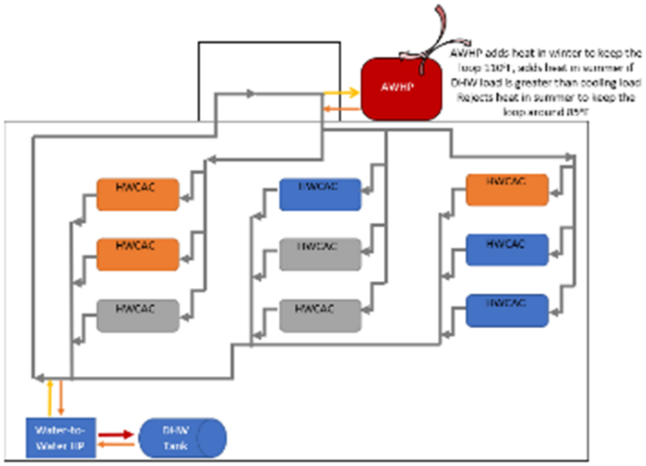


Heating and Cooling Systems Employing Heat Pumps

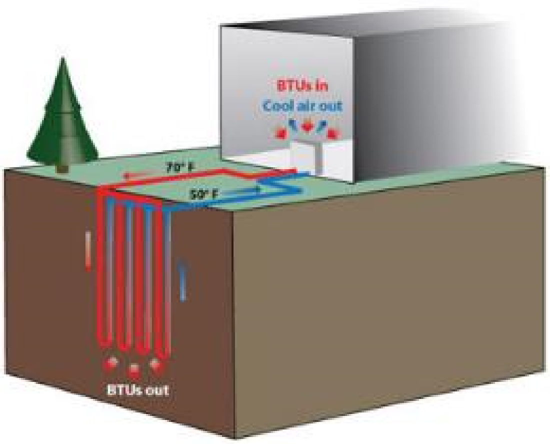


Source: Cool Automation

Air-Source Heat Pump

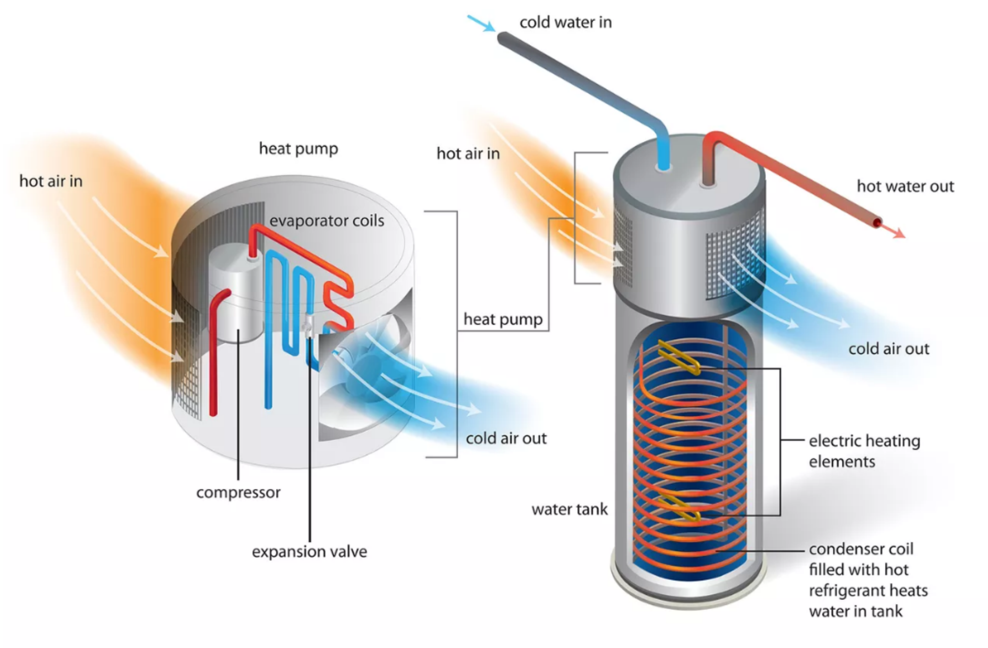


Low Temp Hydronic



Water/Ground Source Heat Pump

Heat Pump Water Heaters – Residential



Heat Pump Water Heaters Large Scale

Ambient Temp
Refrigerant
Max H_2O Supply

Down to -4F
R-410A
Up to 150F

Down to 40F
R-410A
Up to 150F

Down to 10F
R-410A
Up to 150F

Down to 14F
R-744
Up to 194F

Questions?

10 Minute Break

Refrigerant in VRF systems

VRFs have a lot of refrigerant piping

Applying Standard 15

When poll is active, respond at **PollEv.com/swa335**

Text **SWA335** to **22333** once to join

Why are we concerned about the volume of spaces that contain components of a refrigerant based system?

"need_enough_free_air"

"Exhaust"

"Low oxygen levels"

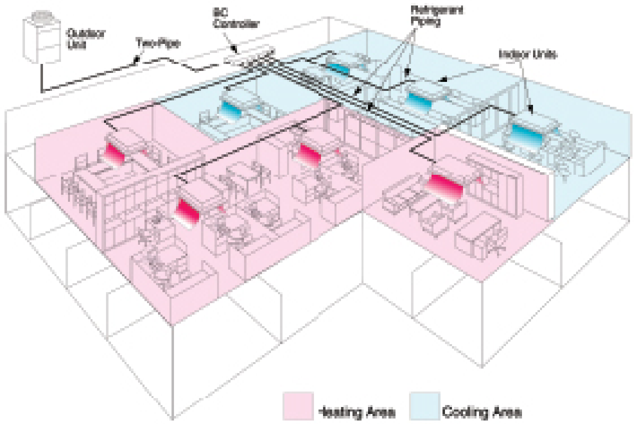
"Oxygen level"

"Oxygen_depletion"

"Exhaust"

"Keep refrigerant levels at save level during leakage"

Applying Standard 15 in VRF System Design



1. Layout of system
2. Calculate amount of R-410a
   - Many VRF manufacturers have calculation software
3. Verification of Standard 15 compliance
   - Occupancy classification
   - Room volumes
   - Confirm no room is too small
   - Review refrigerant piping requirements

Paragraph	Designation	Cooling or Heating Source	Air or Substance to be Cooled or Heated
5.1.1	Direct system		
5.1.2.1	Indirect open spray system		
5.1.2.2	Double indirect open spray system		
5.1.2.3	Indirect closed system		
5.1.2.4	Indirect vented closed system		

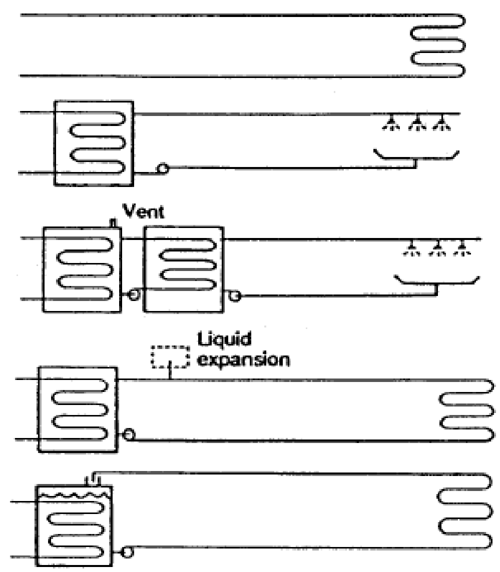
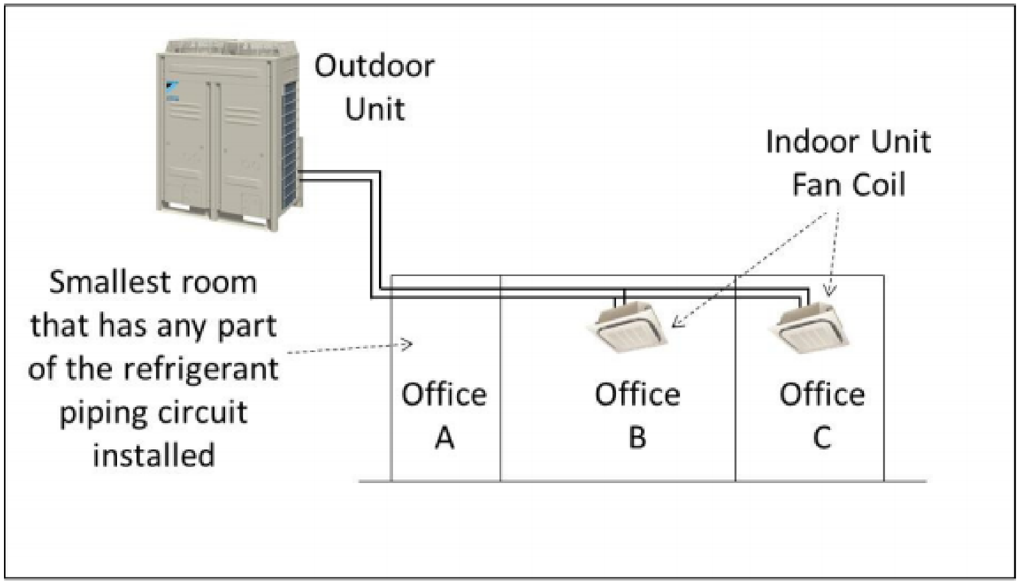


Figure 5-1 ***Refrigerating system*** **designation.**

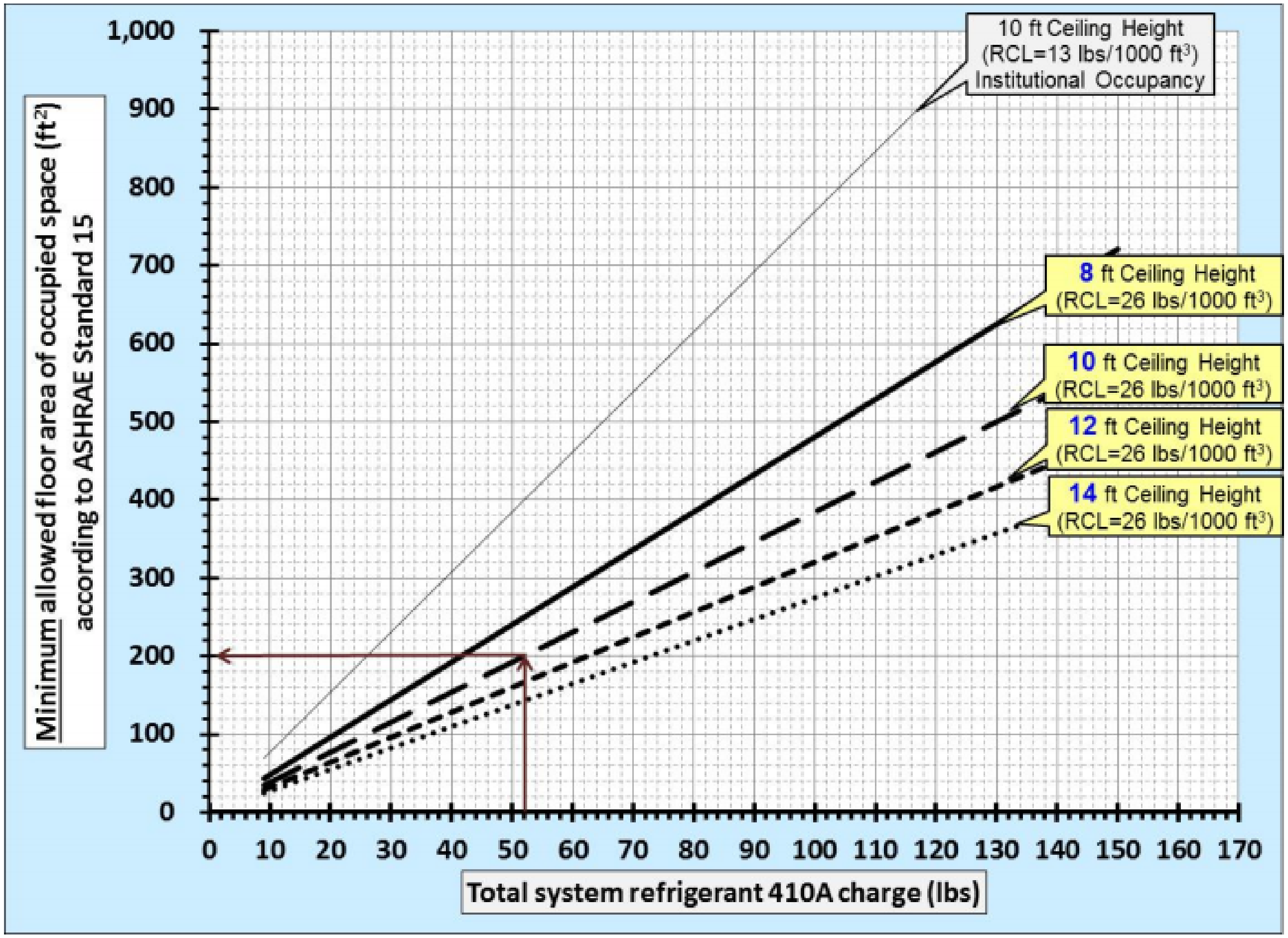
VRFs = Direct System

Direct System = High Probability System

Determine Room Volumes



- Calculate room volume of **smallest** occupied room
- **Based on the volume of space refrigerant disperses in case of a leak**
- The plenum space above a suspended ceiling can be part of the room if it is a part of the air supply or return system



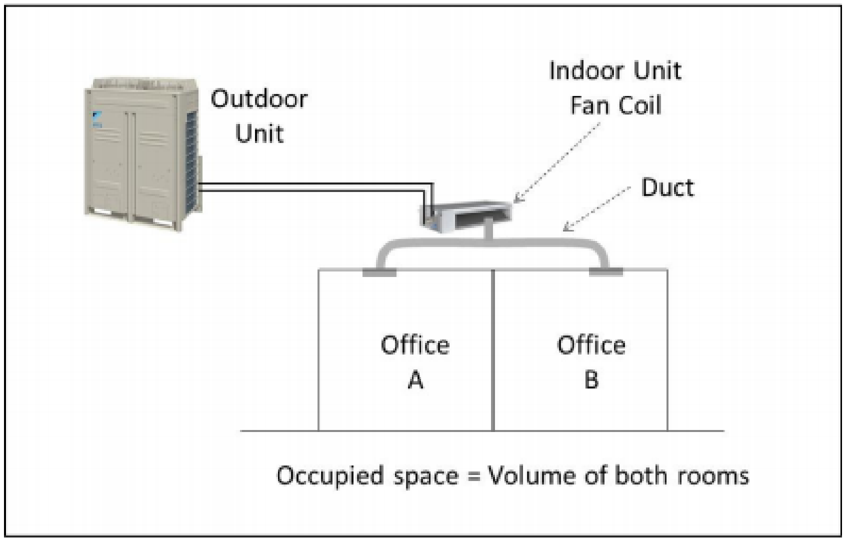
Confirm No Room is Too Small

If Room is Too Small – Increase Room Volume

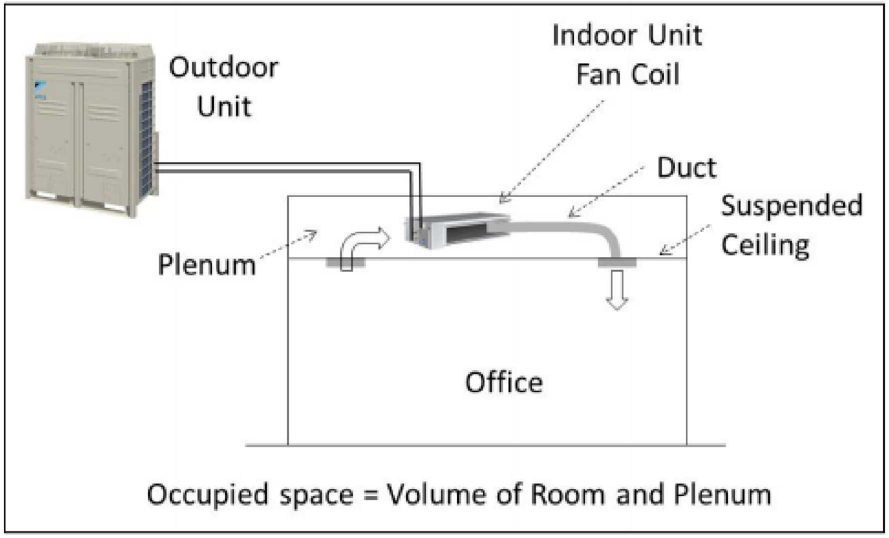
- Use louvers, transfer grilles, etc. to “connect” space to other rooms
- Raise ceiling height

If Room is Too Small - Relocate indoor unit

Duct to several rooms

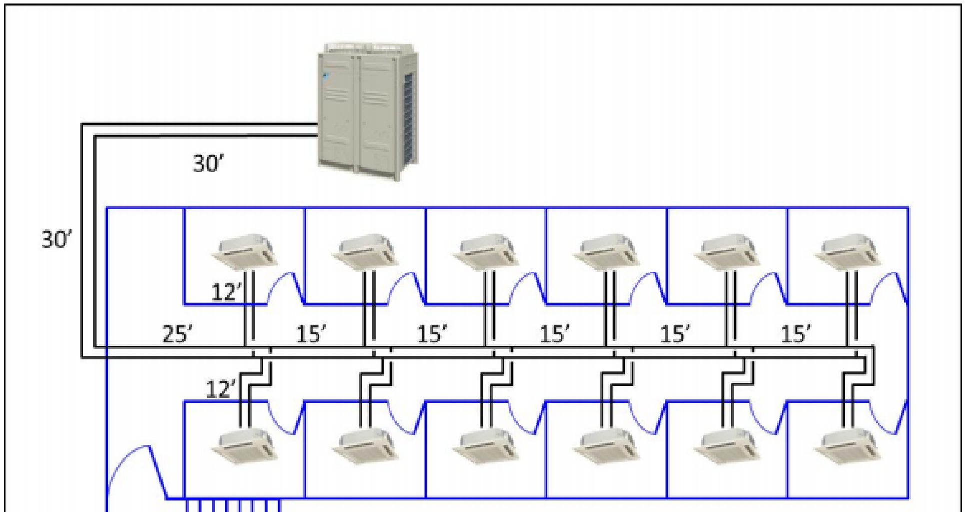


Move to Plenum

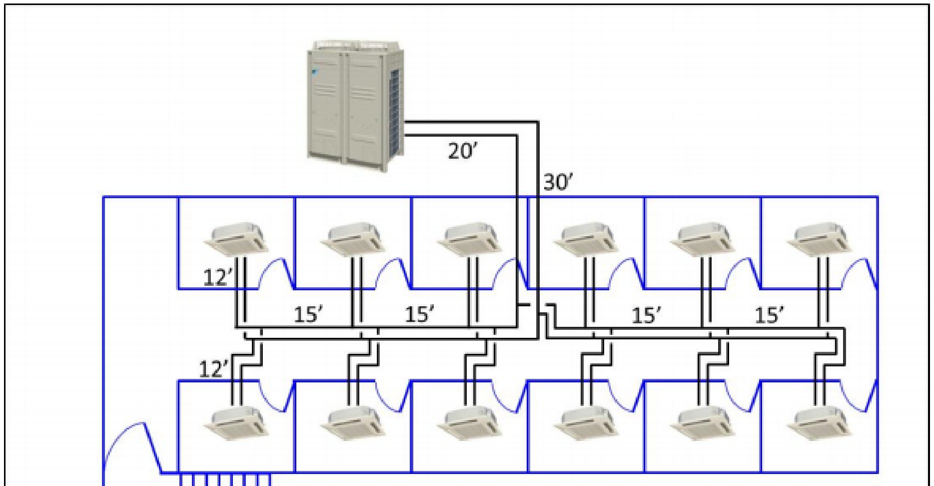


If Room is Too Small – Optimize Piping

- Reduced lengths of the main distribution piping can decrease the refrigerant charge in the circuit



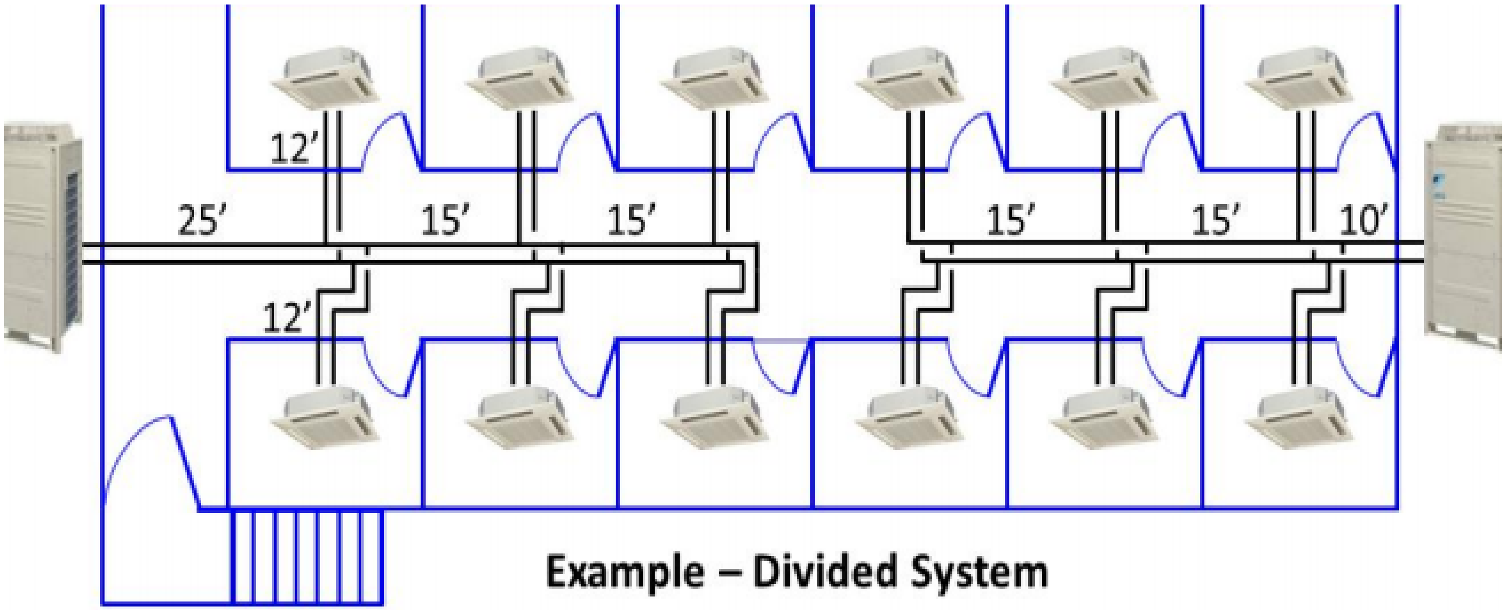
Example – Initial Piping Layout



Example – Revised Piping Layout

(83% of the refrigerant charge for the *Initial Piping Layout)*

If Room is Too Small – Divide System



Example – Divided System

(**40%** of the refrigerant charge for the *Initial Piping Layout)*

Refrigerant Piping Requirements – Standard 15

- Cannot be:
  - <7.25’ above the floor
  - In a shaft with moving object
  - In an enclosed means of egress
- Protect piping or cause obstruction
- Field installed joints to remain exposed for visual inspection before covered or enclosed

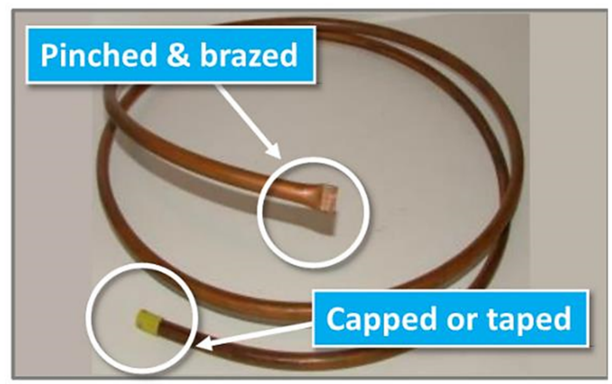
Questions?

Refrigerant management considerations during installation, Start up and Turnover

1. Leak testing of piping
2. Staging of construction to avoid damage to installed piping
3. Challenges and guidelines for proper refrigerant charging

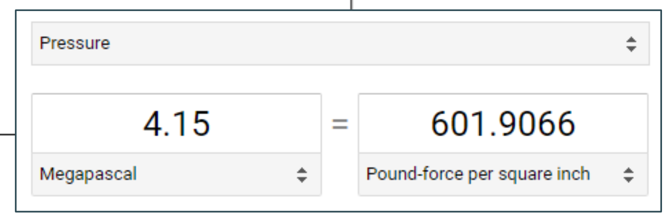
Pipe Installation

- Protection of Piping
- Brazing
  - Flow nitrogen
  - Copper Oxide = bad
- Proper insulation

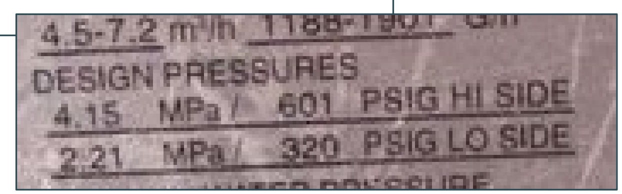


Pipe Testing

Airtight test procedure	Restriction
(1) After obtaining to the design pressure (4.15 MPa) using nitrogen gas, allow the system to stand for about one day. If the pressure does not drop, airtightness is good. However, if the pressure drops, and the leakage area is unknown, the following bubble test may also be performed. (2) After the pressurization described above, spray the flare connection parts, brazed parts, and other potential leakage areas with a bubbling agent (Kyuboflex, etc.) and visually check for bubbles. (3) After the airtight test, wipe off the bubbling agent.	• If a flammable gas or air (oxygen) is used as the pressurization gas, it may catch fire or explode.



1108.1 General. Every refrigerant-containing part of every system that is erected on the premises, except compressors, condensers, vessels, evaporators, safety devices, pressure gauges and control mechanisms that are listed and factory tested, shall be tested and proved tight after complete installation, and before operation. Tests shall include both the high- and low-pressure sides of each system at not less than the lower of the design pressures or the setting of the pressure relief device(s). The design pressures for testing shall be those listed on the condensing unit, compressor or compressor unit name-plate, as required by ASHRAE 15.



Nitrogen Pressure Testing Considerations

Example

Pressure test at 8:00 am @ 600 psi at a ambient temperature of 87° F

Pressure test check the next day at 8:00 am at a ambient of 66° F and a gauge reading of 583 psi.

Since Nitrogen is subject to expansion and contraction due to ambient temperatures, we must use a formula to compensate for temperature changes from one day to the next when performing the 24 hour pressure test. The following formula will help you do this.

Take the temperature when the system is pressurized (Tp) and subtracting the temperature when the pressure is checked (Tc) and multiplying by a factor of 0.80 to get the pressure drop (PD).

$(Tp - Tc) \times 0.80 = PD$

87°- 66° X 0.80 = 16.8 psi pressure drop.

Starting Pressure	600 psi
Pressure drop	-16.8 psi
	583.2 psi

Do you have a leak ?

No Leaks

Pipe Testing

System held pressure for 24 hours

Be careful what you ask for…

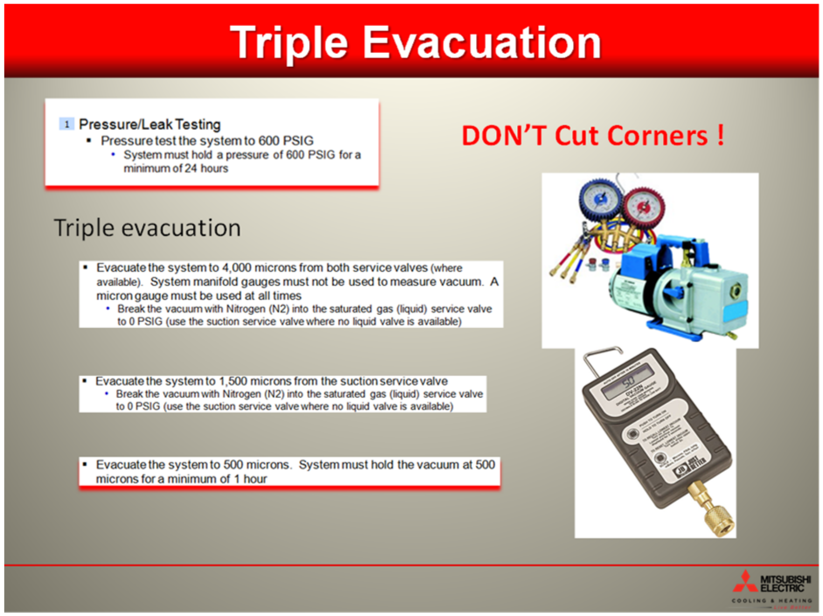
Evacuation

- Micron Scale
- Confirm no leaks
- Confirm no moisture

Evacuate and Charge

LotBlock N-101

	Chk	NA	Iss
Evac and Charge			
Confirm test pressure at 95 -100 PSI	☑	☐	☐
Confirm CU connected to the correct Apt.	☑	☐	☐
Evacuate to 30" hg and Charge by weight.	☑	☐	☐
0-15Ft 0 lbs-0 ozs	☐	☐	☐



Charging

- Measure twice charge once

FW: Pipe Testing

To Kelly Westby

Cc

You replied to this message on 8/19/2015 5:40 PM.

Mitsubishi Submittal.pdf
7 MB

Hi Kelly-

Mechanical Contrcator believes that the calculations regarding the refrigerant charging you are looking for are included within the Mitsubishi condenser/FCU/branch controller submittal attached. Please take a look and let me know if you require further information. Thank you.

K Generation Y Series Charge Caclulation

	Feet	oz/foot	Y/N	Add Oz	Total
Liquid Pipe					
7/8 Pipe (ft)		4.19			0
3/4 Pipe (ft)	215	3.12			670.8
5/8 Pipe (ft)	8	2.16			17.28
1/2 Pipe (ft)	64	1.3			83.2
3/8 Pipe (ft)	341	0.65			221.65
1/4 Pipe (ft)	79	0.26			20.54
Total IU Capacity					
Models ~ 27				71	
Models 28 ~ 54				89	
Models 55 ~ 126				106	
Models 127 ~ 144				124	
Models 145 ~ 180				159	
Models 181 ~ 234				177	
Models 235 ~ 273				212	
Models 274 ~ 307				283	
Models 308 ~ 342				318	
Models 343 ~ 411			y	353	353
Models 412 ~ 480				424	
Models 481 ~				494	
OU Capacity					
P72				0	
P96				71	
P120				283	
P144 (Single)				283	
P144 (Dual Module)				0	
P168				71	
P192				283	
P216				354	
P240				566	
P264				283	
P288				354	
P312				566	
P336				637	
P360			y	849	849

Additional Charge: 2215 oz
138.5 lbs

3D	03/12/12	START UP	
	04/10/13	NO HEAT	LOW REFRIGERANT
	08/27/13	NO COOLING	LOW REFRIGERANT
	01/08/14	NO HEAT	LOW REFRIGERANT
3E	03/12/12	START UP	
	02/04/13	UNIT NOT WORKING	LOW REFRIGERANT
	02/20/13	NO HEAT	DISCHARGE AIR
	12/30/13	NO HEAT	LOW REFRIGERANT
3F	03/12/12	START UP	
	02/12/13		REFRIGERANT LEAK
	07/31/13	NO COOLING	REFRIGERANT LEAK
	01/17/14	NO HEAT	LOW REFRIGERANT

(Re) Charging

- Track it
- Prior to adding additional refrigerant, evacuate refrigerant and check for leaks

Pipe Insulation

TABLE C403.2.10
MINIMUM PIPE INSULATION THICKNESS (in inches)[a, c]

FLUID OPERATING TEMPERATURE RANGE AND USAGE (°F)	INSULATION CONDUCTIVITY		NOMINAL PIPE OR TUBE SIZE (inches)				
	Conductivity Btu · in./(h · ft² · °F)[b]	Mean Rating Temperature, °F	< 1	1 to < 1½	1½ to < 4	4 to < 8	≥ 8
> 350	0.32 – 0.34	250	4.5	5.0	5.0	5.0	5.0
251 – 350	0.29 – 0.32	200	3.0	4.0	4.5	4.5	4.5
201 – 250	0.27 – 0.30	150	2.5	2.5	2.5	3.0	3.0
141 – 200	0.25 – 0.29	125	1.5	1.5	2.0	2.0	2.0
105 – 140	0.21 – 0.28	100	1.0	1.0	1.5	1.5	1.5
40 – 60	0.21 – 0.27	75	0.5	0.5	1.0	1.0	1.0
< 40	0.20 – 0.26	50	0.5	1.0	1.0	1.0	1.5

Questions?

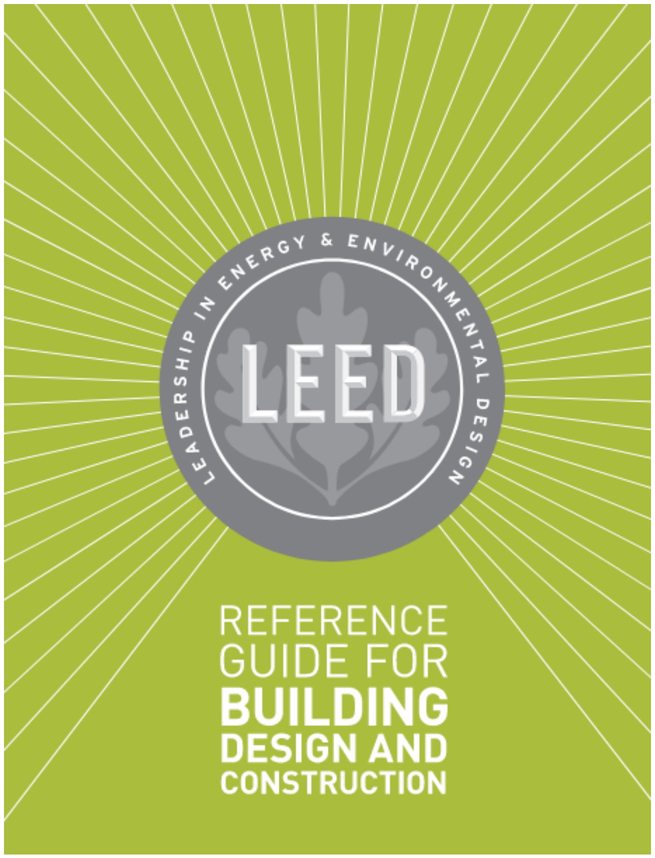
10 Minute Break

Where is industry going?

- Advantages and disadvantages of refrigerants on the horizon
- Future-proofing of designs utilizing refrigerant

Where is Industry Going
What can we do now?

- Improved test procedures and performance criteria/standards for Split systems
- Addressing refrigerant usage and leaks
- Increase workforce training on proper system installation



Refrigerant Management - LEED

- Prerequisite:
  Fundamental Refrigerant Management

> **INTENT**
>
> To reduce stratospheric ozone depletion.

- Credit:
  Enhanced Refrigerant Management
  - Option 1: ODP = 0, GWP<50
  - Option 2: Refrigerant Impact Calculation
  - Separate requirements for commercial refrigeration equipment

Packaged Equipment

ICE AIR
World Class Comfort®

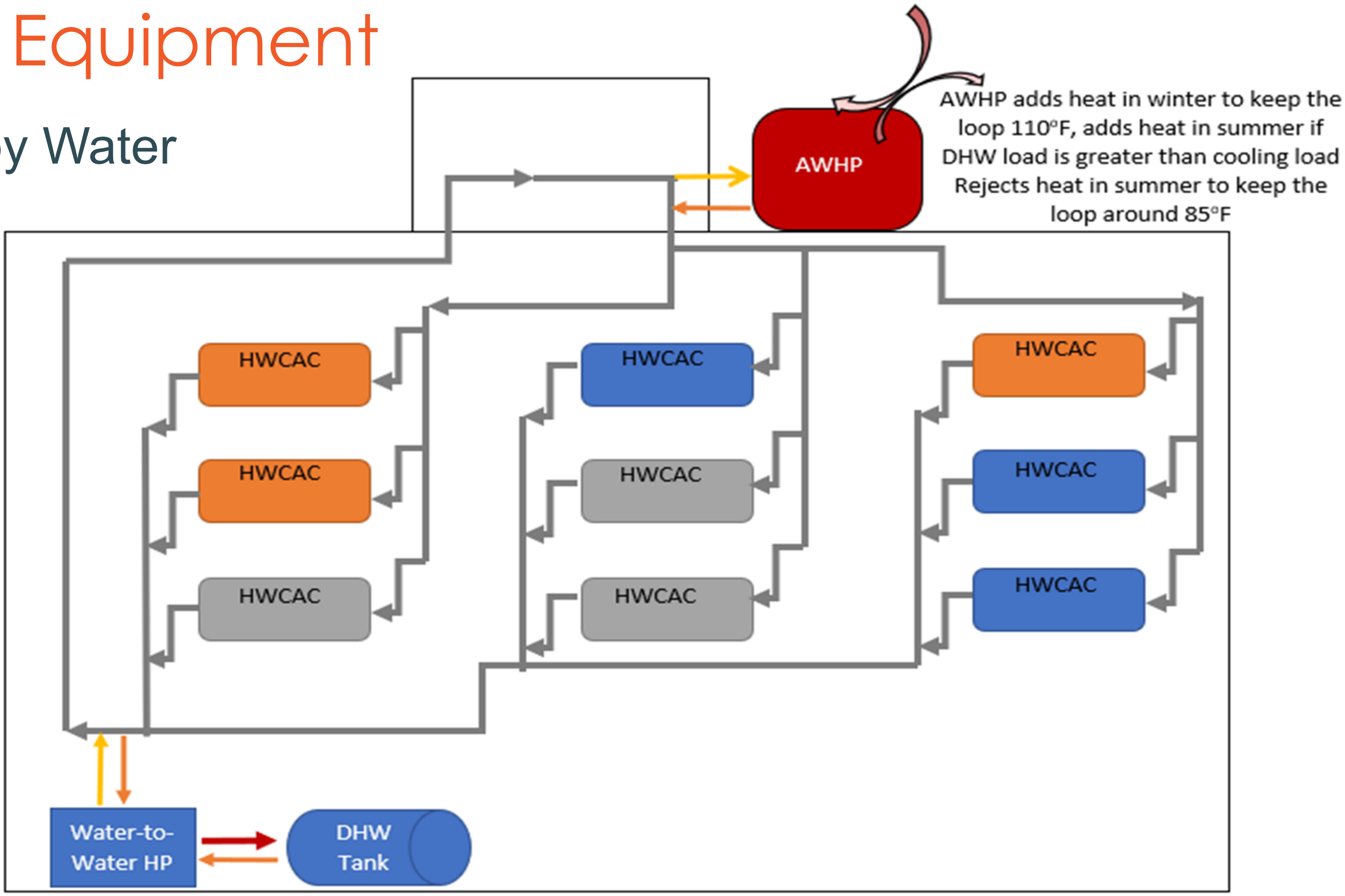
PTHP-XC Family
Packaged Terminal Heat Pumps

Since the 1950s, Packaged Terminal Air Conditioners (PTACs) have been used as a cost-effective means of conditioning hotels, apartments, dormitories and similar properties. Heat pump technology allowed more efficient heating, but was limited by poor low ambient temperature performance. Until now...

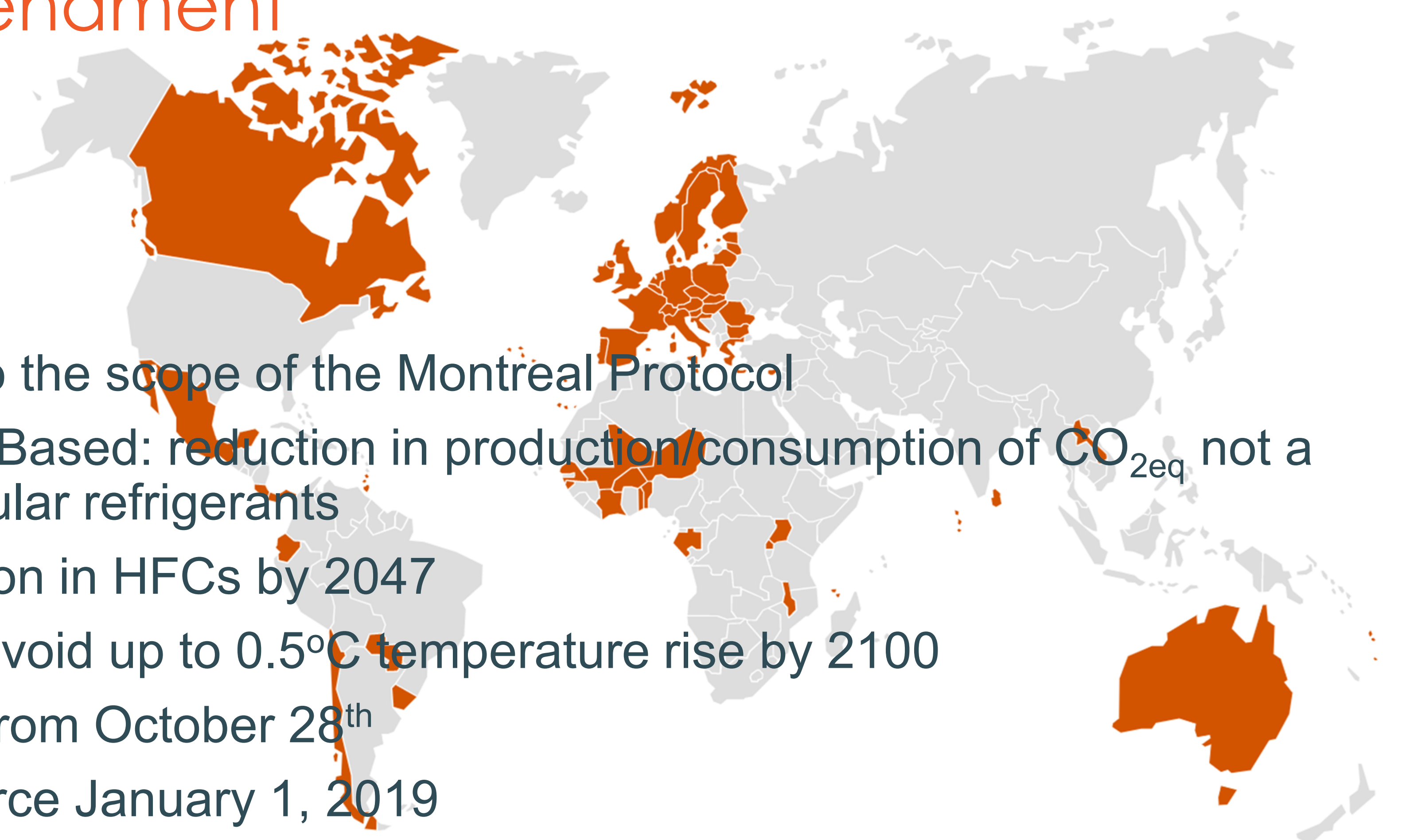
Ice Air's ***Breakthrough Cold Climate Technology*** has changed all that – allowing Packaged Terminal Heat Pumps (PTHPs) and Single Packaged Heat Pumps (SPHPs) units to function efficiently down to -5°F. And our advanced VRF technology ensures that your unit is pinpointing the exact amount of high-efficiency heating or cooling required for the desired room conditions.

Packaged Equipment

…Connected by Water



Kigali Amendment

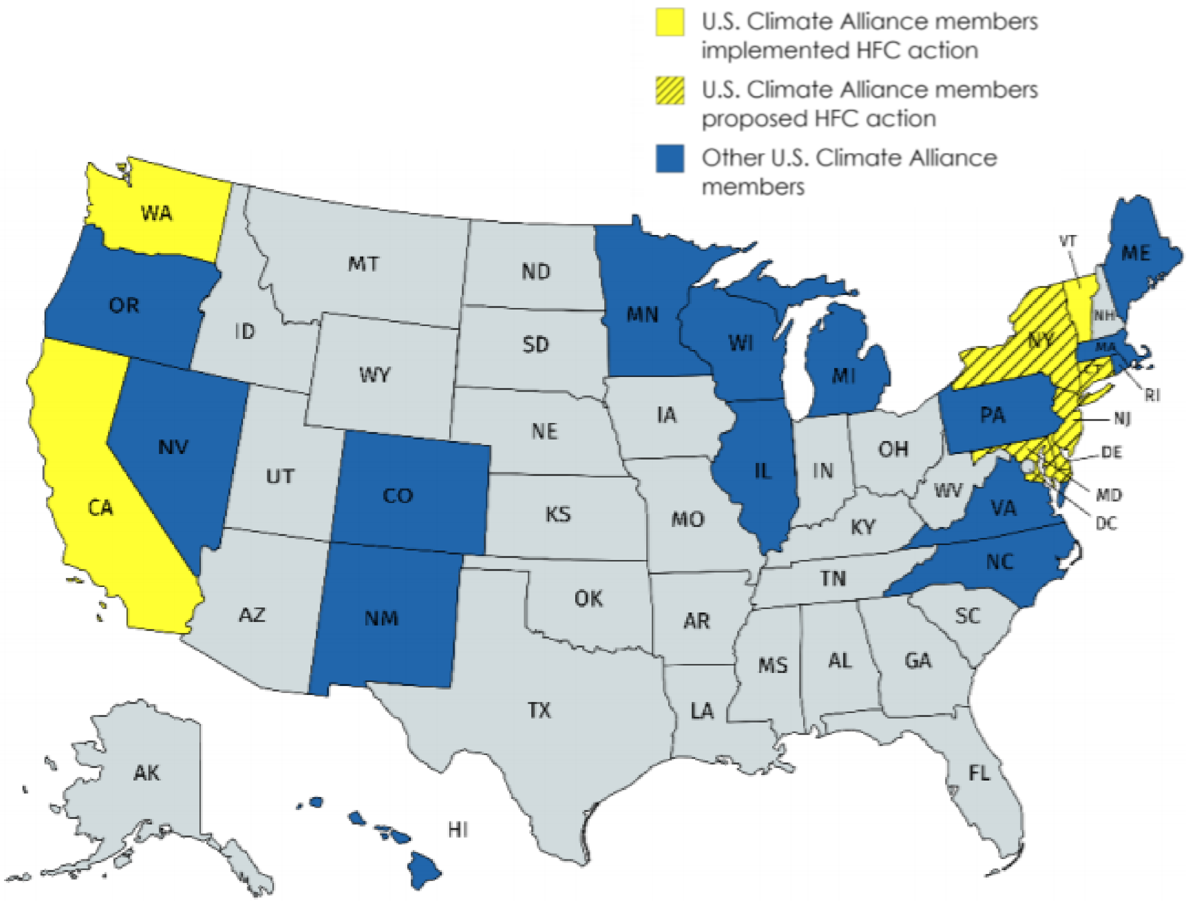


- Adds HFCs to the scope of the Montreal Protocol
- Performance Based: reduction in production/consumption of CO_{2eq} not a ban on particular refrigerants
- <80% reduction in HFCs by 2047
- Expected to avoid up to 0.5^{o}C temperature rise by 2100
- Amendment from October 28th
- Enters into force January 1, 2019

Oh SNAP!

U.S. EPA SNAP Regulations

The U.S. Environmental Protection Agency (EPA) issued Significant New Alternatives Policy (SNAP) regulations in 2015 and 2016 to prohibit certain end uses of HFCs where safer alternatives are available (SNAP Rules 20 and 21). The rules set deadlines for adopting HFC alternatives in commercial refrigeration, vehicle air conditioning, building chillers, foam manufacture, aerosol products, and more. In 2017, a federal court decision limited EPA's authority over HFCs under the "Safe Alternatives" provision of the Clean Air Act. The SNAP rules would have avoided about 68 million metric tons of CO_2-equivalent HFC emissions in 2025. States are now filling the gap left by the court decision.



https://www.nrdc.org/sites/default/files/media-uploads/fact_sheet_on_state_hfc_action_0.pdf

California Air Resources Board (CARB) Regulations

- GOAL: Reduce HFC emissions 40 percent below 2013 levels by 2030
- Current Regulation Covers:
  - Chillers
  - Retail Food Refrigeration
  - Cold Storage Warehouses
  - Vending Machines
  - Residential Refrigeration Appliances
  - Other Non-refrigerant Items (Foams, Aerosols)

CARB Regulations: Proposed

- New residential and commercial air conditioners in buildings (excl. chillers) may use only refrigerants with GWP < 750 starting in 2023.
- New commercial refrigeration systems containing more than 50 pounds of refrigerant and installed and sold starting in 2022 may use only refrigerants with GWP < 150.
- Sales, distribution, or import for use in California of refrigerants with GWP > 1500 is prohibited starting in 2022.

NYS to follow?

NEW YORK STATE

Services News Government Local

Department of Environmental Conservation

Proposed Part 494, Hydrofluorocarbon Standards and Reporting

Home » Regulations and Enforcement » Proposed, Emergency, and Recently Adopted Regulations » Climate Change Regulatory

Part 494, Hydrofluorocarbon Standards and Reporting

Proposed Part 494, Hydrofluorocarbon Standards and Reporting

Written public comments will be accepted through March 16, 2020.

NYS to follow?

NYS to follow?

- HFCs 5% of current emissions in New York State
- Projected to be 10% of 2030 emissions

- GWP typically sets the baseline as CO_2 over a 100-year period
- We can also look at the impact over a 20-year period for more immediate-term impacts
- 100-year ->20-year HFCs become a bigger part of the remaining budget

SECTOR SUMMARY

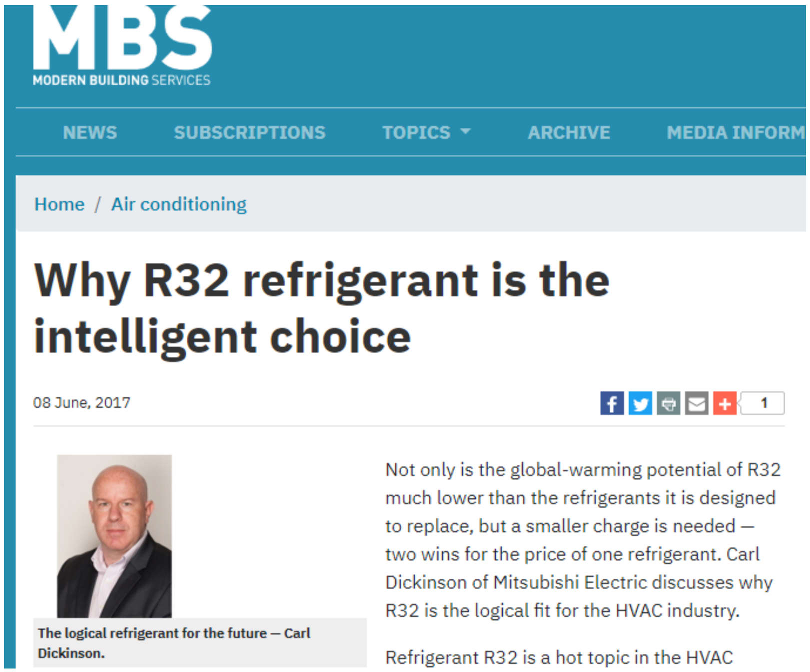
BUILDINGS

- **Enhance Efficiency.** Whether for building retrofits or brand new construction, energy-efficiency solutions are largely the same. Many address the building "envelope" and insulation—means of keeping conditioned air in and unconditioned air out—while others use technology to optimize energy use.
- **Shift Energy Sources.** Clean alternatives can replace more polluting fossil energy sources typically used to heat space, warm water, or prepare meals.
- **Address Refrigerants.** The gases used as refrigerants today are potent greenhouse gases. We can reduce emissions by managing leaks that often happen within buildings, as well as properly disposing of refrigerants (a waste process that falls under industry, above). Ultimately, these fluorinated gases can be replaced with alternatives that are not greenhouse gases.

The Search for Alternatives:

- Safe to use
- No toxicity
- Zero flammability risk
- Compatible with all materials used in constructing cooling appliances
- Readily available
- Cost efficient
- Chemically stable
- Energy efficient

The Search for Alternatives:


MBS
MODERN BUILDING SERVICES

NEWS SUBSCRIPTIONS TOPICS ARCHIVE MEDIA INFORM

Home / Air conditioning

Why R32 refrigerant is the intelligent choice

08 June, 2017

The logical refrigerant for the future – Carl Dickinson.

Not only is the global-warming potential of R32 much lower than the refrigerants it is designed to replace, but a smaller charge is needed — two wins for the price of one refrigerant. Carl Dickinson of Mitsubishi Electric discusses why R32 is the logical fit for the HVAC industry.

Refrigerant R32 is a hot topic in the HVAC

R32 and R454B "mildly flammable" A2L gases, suitable for smaller units but not acceptable for larger-charge VRF systems

…(Remember the 6.6 lbs thing)

The Search for Alternatives:

the NEWS

Magazine News Products Multimedia Refrigeration Service Business 101 Residentia

Home » Refrigerant Choices for Chillers Remain Complex

HVAC Commercial Market | Chillers & Towers | Refrigeration | Refrigerants

Refrigerant Choices for Chillers Remain Complex

Low-GWP alternatives that are nonflammable and efficient still elusive

Advantages and disadvantages of refrigerants on the horizon

Table 4-1: Refrigerant Changes Over Time

Refrigerant Category	Timeline	Example Refrigerants
1st Generation "Whatever Worked"	1830-1930	HCs, NH_3, CO_2
2nd Generation "Safety and Durability"	1931-1990	CFCs, HCFCs (e.g., R-12, R-22)
3rd Generation "Ozone Protection"	1990-2010s	HFCs (e.g., R-410A, R-134a)
4th Generation "Global Warming"	2010-future	Low-GWP HFCs (e.g., R-32), HFOs (e.g., R-1234yf), HCs, others

Source: Calm (2008)[59]

Table 4-2: Summary of Refrigerant Environmental Properties

Refrigerant Type	Ozone Depletion Potential	Global Warming Potential
CFC	High	Very High
HCFC	Very Low	Very High
HFC	Zero	High
HFO	Zero	Lower
HC	Zero	Negligible
CO_2	Zero	Negligible

Source: Adapted from *Refrigerants, Naturally!*[60]

Working with Lower GWP Refrigerants

ENGINEERING TOMORROW Danfoss

Honeywell | Refrigerants

The Danfoss Turbocor® Portfolio of Oil-Free Compressors

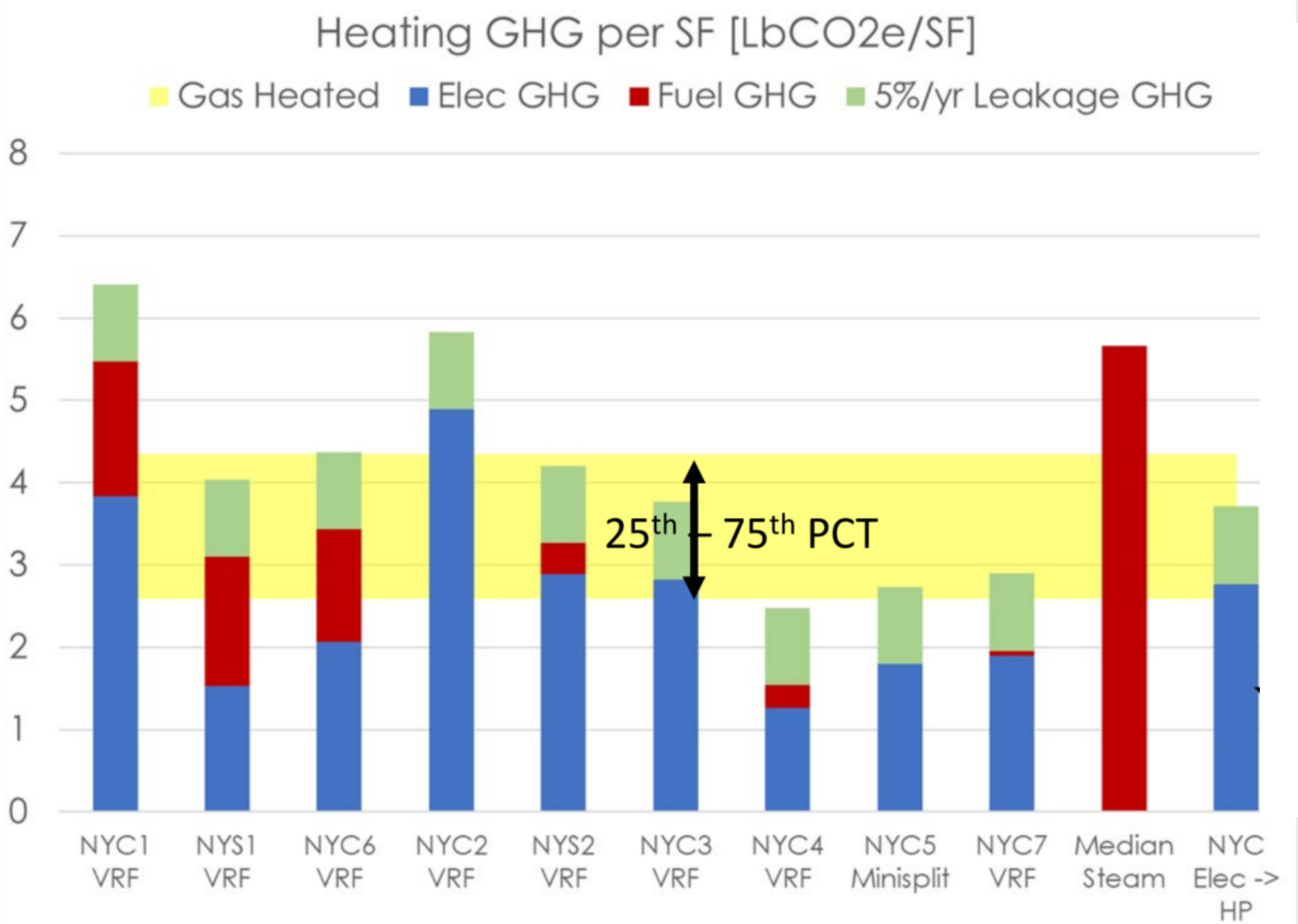
Model TGS490

Environmentally Friendly: The new TGS490 is the world's first oil-free, magnetic bearing centrifugal compressor that offers the flexibility to be used with either ultra low GWP HFO-1234ze or R-515B. R-515B has a GWP of 299 and an ASHRAE A1 safety classification - allowing users to be compliant with applicable refrigerant regulations and safety codes.

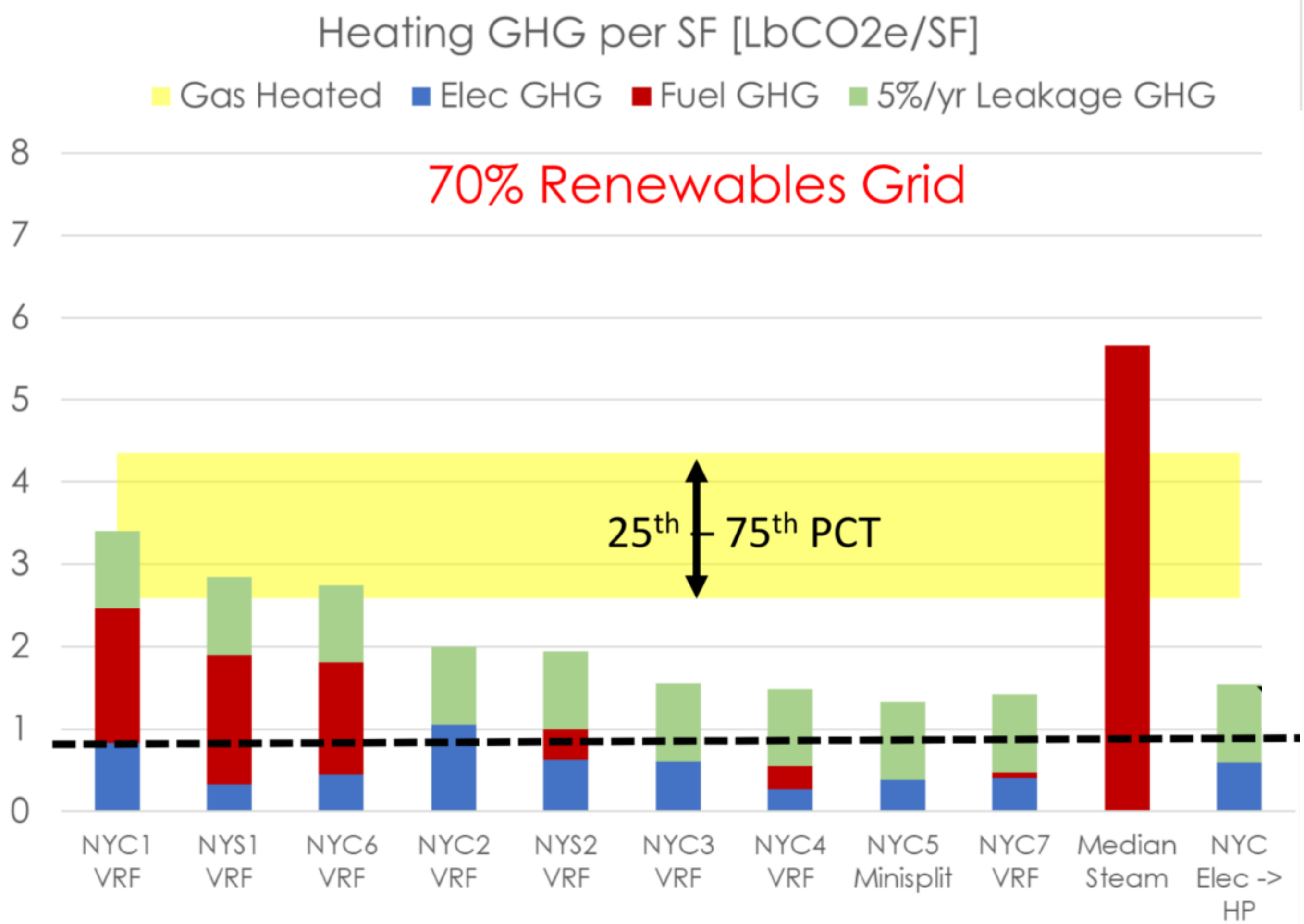
R1234ze(E) and small amounts of the HFC R227ea

Back to Heat Pumps

Real World Carbon Performance



Real World Carbon Performance



Promising results for R466A in VRF air con tests

10 JAN 2019

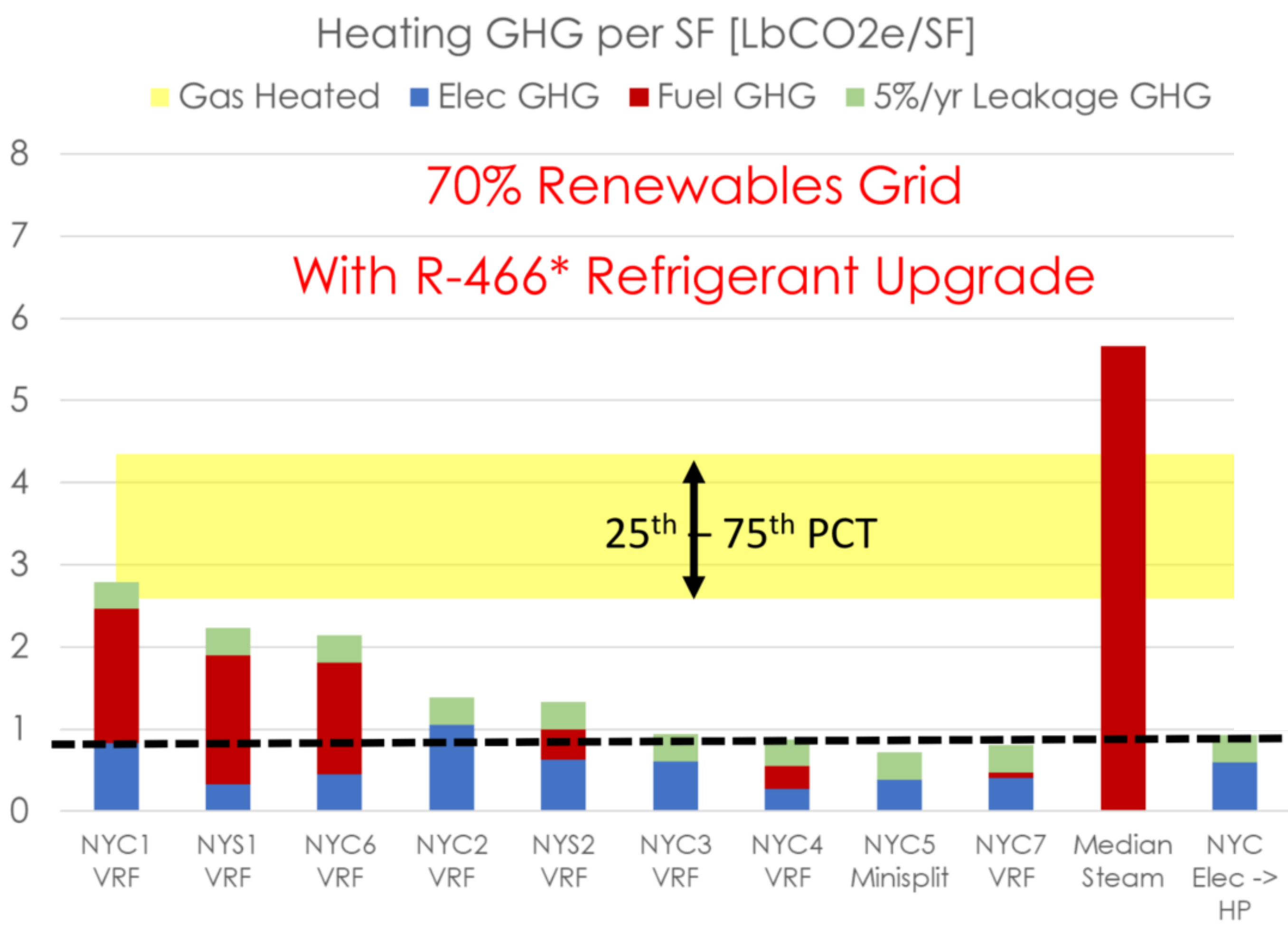
- Appears to offer non-flammable, low GWP (733) alternative for R410A.
- According to Honeywell: efficiency, cooling and heating capacity of VRF systems using R466A is "very similar" to those using R410A.

50% R32 + 50% R125 = R410A,

Add trifluoroiodomethane (CF3I)

Fire suppressant GWP = 0.4

Real World Carbon Performance



The Search for Alternatives:

- Recap

REFRIGERANT CHOICES

		Low Pressure			Medium Pressure				High Pressure					
		R-123	R-1233zd	R-514A	R-134a	R-513A	R-1234ze	R-1234yf	R-22	R-410A	R-466A	R-452B	R-454B	R-32
Flammability	ASHRAE Class	1	1	1	1	1	2L	2L	1	1	1	2L	2L	2L
Toxicity[1]	ASHRAE Class	Higher (B)	Lower (A)	Higher (B)	Lower (A)	Lower (A)	Lower (A)	Lower (A)	Lower (A)	Lower (A)	Lower (A)	Lower (A)	Lower (A)	Lower (A)
	OEL	50	800	320	1000	650	800	500	1000	1000	860	870	850	1000
Efficiency (COP)		8.95	8.85	8.91	8.47	8.28	8.45	8.17	8.48	7.99	8.14	8.14	8.15	8.22
Capacity Change		baseline	~35% gain	~5% loss	baseline	similar	~25% loss	~5% loss		baseline	~1% loss	~2% loss	~3% loss	~9% gain
GWP[2]		79	1	2	1300	573	1	1	1760	1924	703	675	466	677
Atmospheric Life		1.3 years	*26 days*	*22 days*	13.4 years	5.9 years	*16 days*	*11 days*	11.9 years	17 years	5.6 years	5.5 years	3.6 years	5.2 years

[1] None of the refrigerants shown in the table are considered “toxic” or “highly toxic” as defined by the IFC, UFC, NFPA 1 or OSHA regulations.
[2] GWP values reported are per the Fifth Assessment Report (AR5) of the IPCC (Intergovernmental Panel on Climate Change).

https://www.achrnews.com/articles/141178-refrigerant-choices-for-chillers-remain-complex

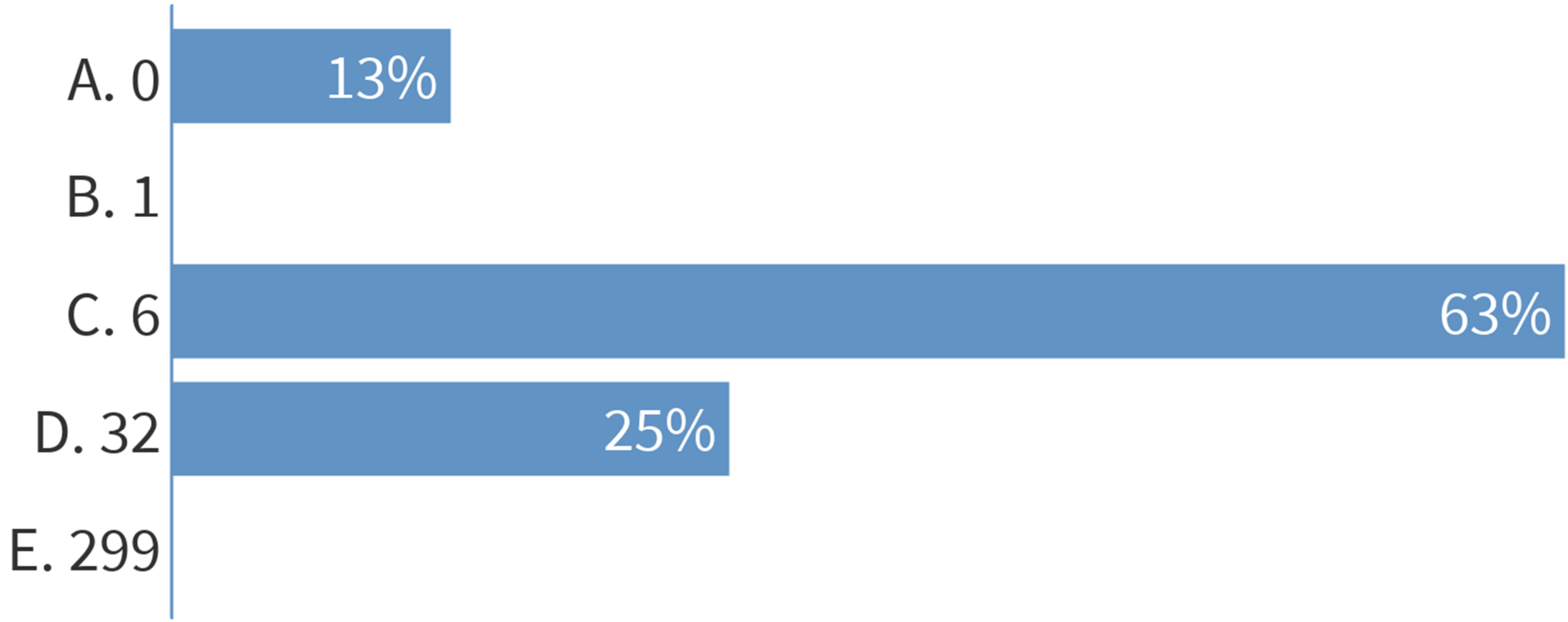
Working with Ultra-Low GWP Refrigerants

https://emersonclimateconversations.com/2015/04/30/co2-as-a-refrigerant-criteria-for-choosing-refrigerants/

When poll is active, respond at **PollEv.com/swa335**

Text **SWA335** to **22333** once to join

What is the GWP of R-744?



Working with Lower GWP Refrigerants

- What is the GWP of CO2?

Criteria	How well does R744 meet the criteria?
Cooling capacity	Significantly higher volumetric capacity than conventional refrigerants
Efficiency	Varies, depending on system type and ambient temperature
Operating conditions	Operating and standstill pressures significantly higher than for all other common refrigerants
Environmental impact	Global Warming Potential (GWP) = 1, significantly lower than for commonly used HFCs
Availability of refrigerant	Varies globally, but generally available
Availability of system components	Many components differ from those used in HFC retail systems, but all are now generally available
Availability of competent service technicians	Varies globally, but generally low; service technicians must have a good understanding of refrigeration best practices and will require training for R744

https://emersonclimateconversations.com/2015/04/30/co2-as-a-refrigerant-criteria-for-choosing-refrigerants/

Criteria	How well does R744 meet the criteria?
Cost	Refrigerant cost significantly lower than for HFCs, but system costs are generally higher
Safety	Low toxicity and nonflammable; high pressures and associated hazards present challenges
Ease of use	High pressure and low critical point drive the need for more complex systems
Availability of appropriate standards	Europe standards: EN378; ISO 51491 U.S. standards: ASME B31.5; ASHRAE 15; UL 1995/CSA 22.2 No. 236-11; UL 60335-1; UL 60335-2-40; 60335-2-34
Composition	Single molecule, no temperature glide in subcritical operations
Suitability as a retrofit refrigerant	Not suitable because of higher pressures

https://emersonclimateconversations.com/2015/04/30/co2-as-a-refrigerant-criteria-for-choosing-refrigerants/

Where is the Industry Going?

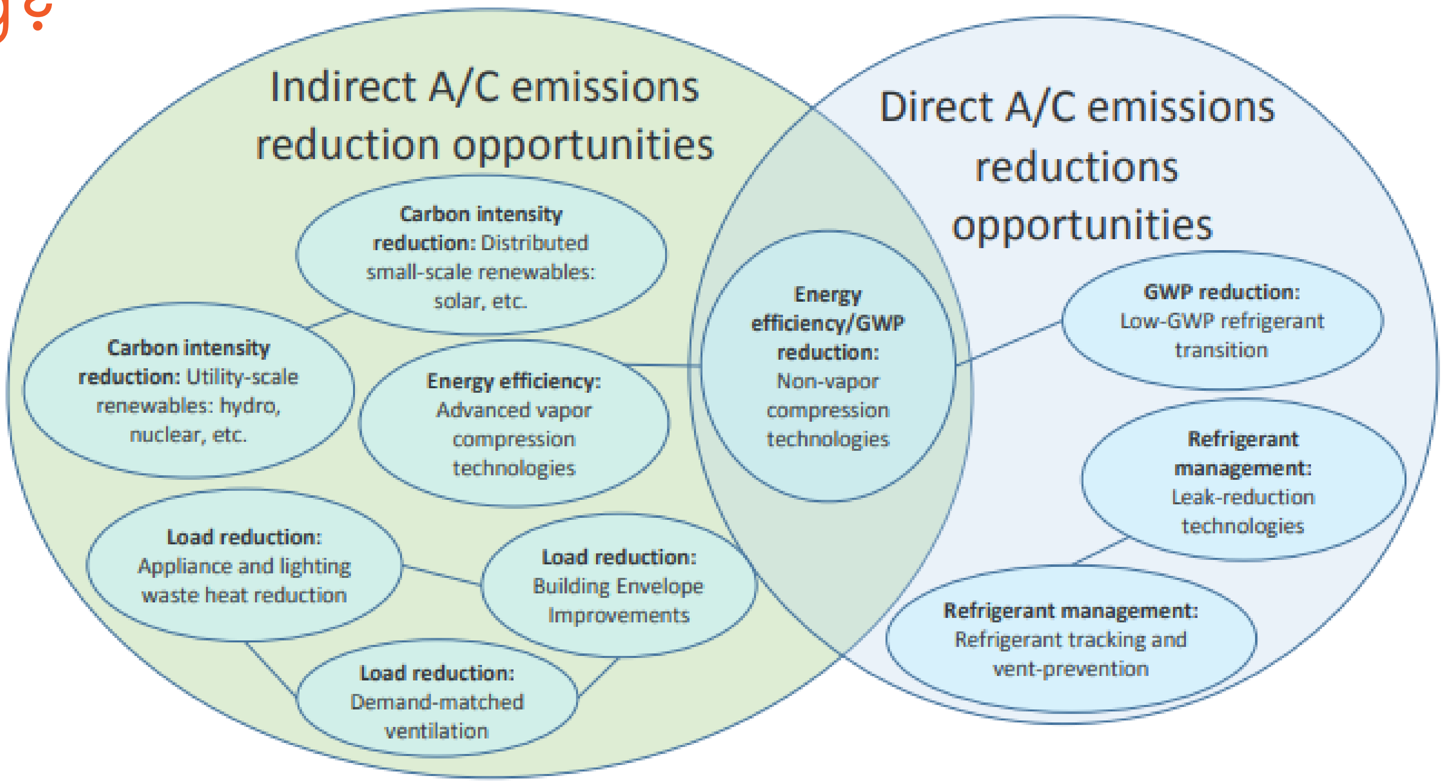


Figure ES-2: Elements of sustainable, low-emissions A/C systems

SUNY New Paltz

- Reducing building loads reduces the amount of refrigerant needed
- Consider packaged equipment
- Reduce refrigerant line lengths make sure piping is protected from damage
- Stay up-to-date with new alternatives
- Manufacturers do not always take the “if you build it they will come approach”: ASK for what you want.

SUNY New Paltz

- For new projects with field installed refrigerant piping:
  - Refrigerant pipe installation inspections
  - Verification of proper system charge
  - Commissioning – design review, install checks, functional testing
  - Future-proof buildings
- For new projects with packaged equipment
  - Confirm charge on site (or sample)
- For existing buildings:
  - Refer to re-charging procedures

Questions?

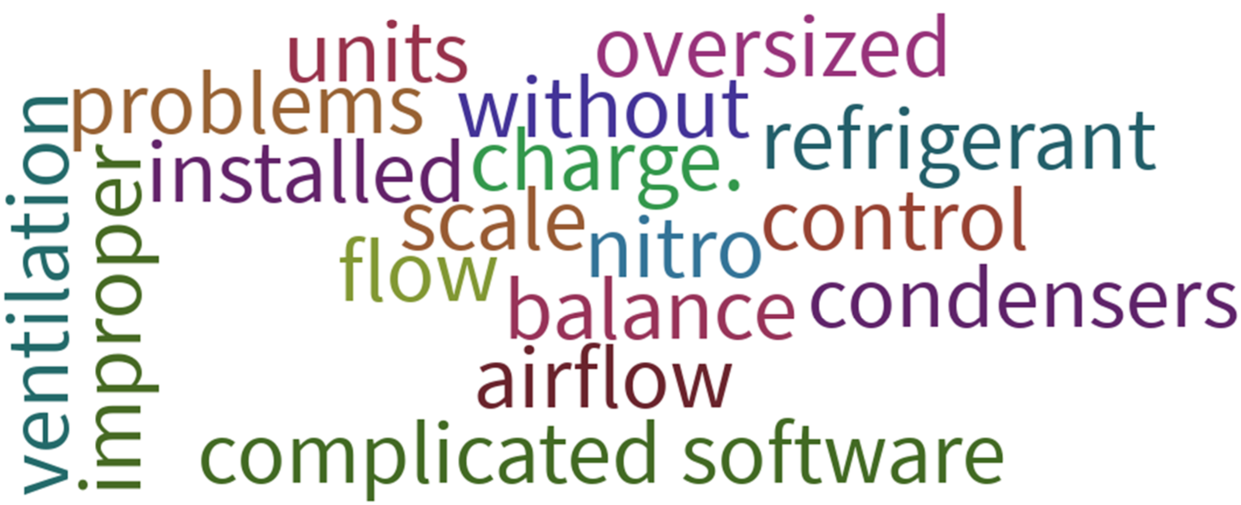
Common VRF Issues

- Heat Pump vs Heat Recovery
- Capacity
- Thermostats and Programming
- Return Air Design

When poll is active, respond at **PollEv.com/swa335**

Text **SWA335** to **22333** once to join

What are some issues you have experienced or heard about VRF systems?



Heat Pumps vs Heat Recovery

Heat Pump

Benefits:

Less pipe runs

Drawbacks:

Less user operability – all indoor units either in heating OR cooling

Heat Recovery

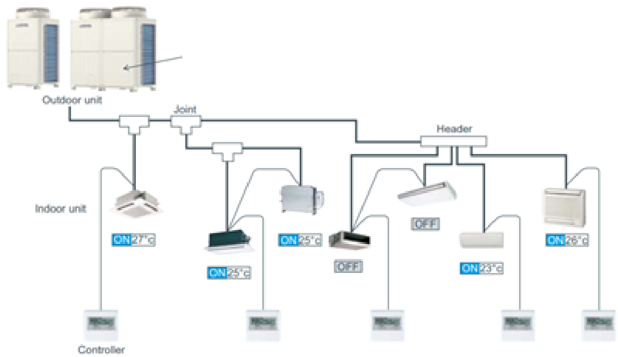
Benefits:

- Greater user operability – each area gets to determine heating/cooling
- In theory, more energy efficient

Drawbacks:

- More pipe runs (therefore more refrigerant -> increased leak potential)
- More equipment (branch controller)

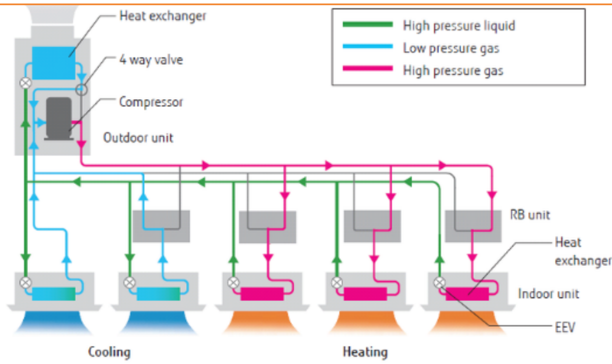
System Type

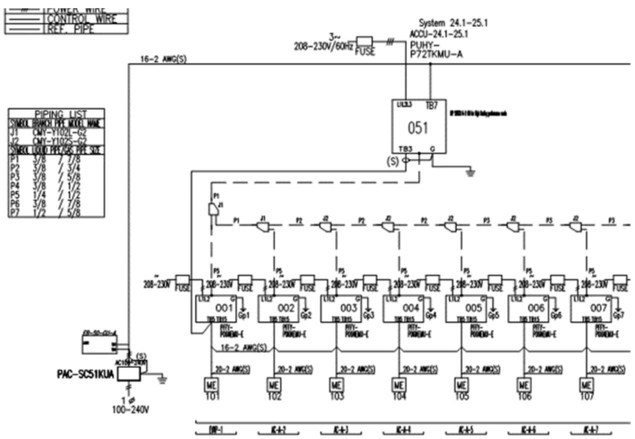


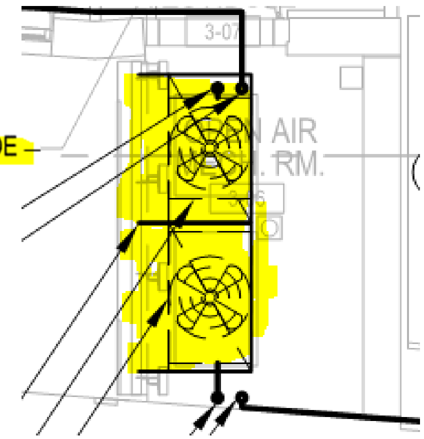
- Heat Pump

  ▪ Do not apply Heat Pumps to any application where individual users MUST have heating or cooling whenever they need it regardless of season. Hotels, Apartment Buildings, Assisted Living etc….

- Heat Recovery







Capacity & Efficiency

Dependent on:

- Line lengths
- Configuration
- Return temperature at indoor unit
- Ambient Temperature at outdoor unit

Capacity & Efficiency

Oversizing **IS** a problem

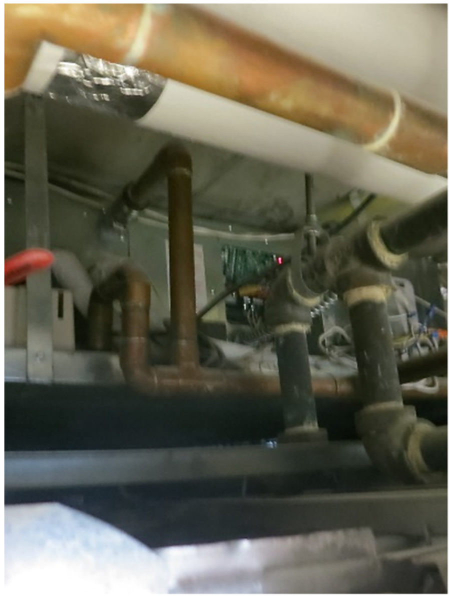
Operation Status Monitor (Trend)

Return Time-Searching Print View Option Window Help

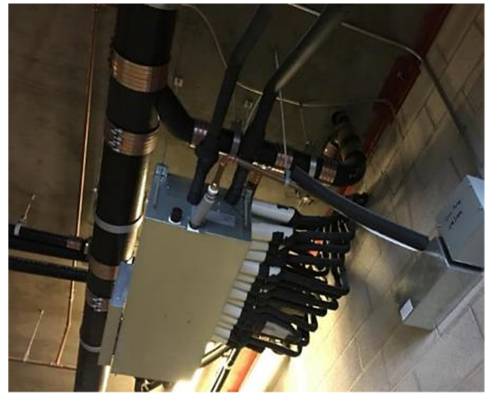
IC

	QJ	G_No	B_No	TH1	TH2	TH3	TH4	SH/SC	Li	TO	Save	O/F
001	4	1	0	70.7	81.0	81.7		1.4	270	75.0	100	Stopping
002	4	2	0	70.7	81.0	81.7		0.7	290	75.0	100	Stopping
003	4	3	0	69.8	81.0	82.6		1.4	290	75.0	100	Stopping
004	4	4	0	69.8	81.0	86.9		5.9	290	75.0	100	Stopping
005	4	5	0	71.6	81.0	94.6		13.5	290	75.0	100	Stopping
006	4	6	0	71.8	81.7	100.4		18.5	290	74.0	100	Stopping
007	4	7	0	69.6	81.0	104.5		23.4	290	75.0	100	Stopping
008	4	8	0	71.1	81.0	108.9		27.9	290	75.0	100	Stopping
009	4	9	0	71.8	81.0	108.9		27.9	290	75.0	100	Stopping
010	4	10	0	72.5	81.0	108.0		27.0	290	75.0	100	Stopping
011	4	11	0	72.5	81.0	104.5		23.4	290	75.0	100	Stopping
012	4	12	0	71.6	81.7	102.9		21.1	290	75.0	100	Stopping
013	4	13	0	72.5	81.0	98.8		17.6	290	75.0	100	Stopping

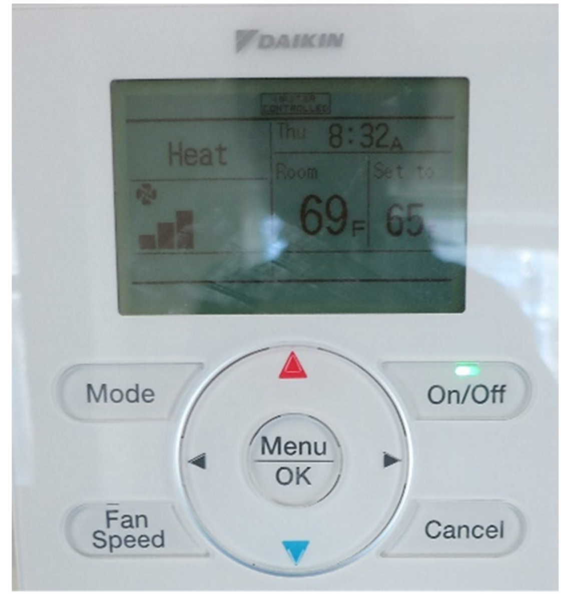
Location, Location, Location



Access



Show All Equipment



Temperature Sensors

Thermostat Location and Programming

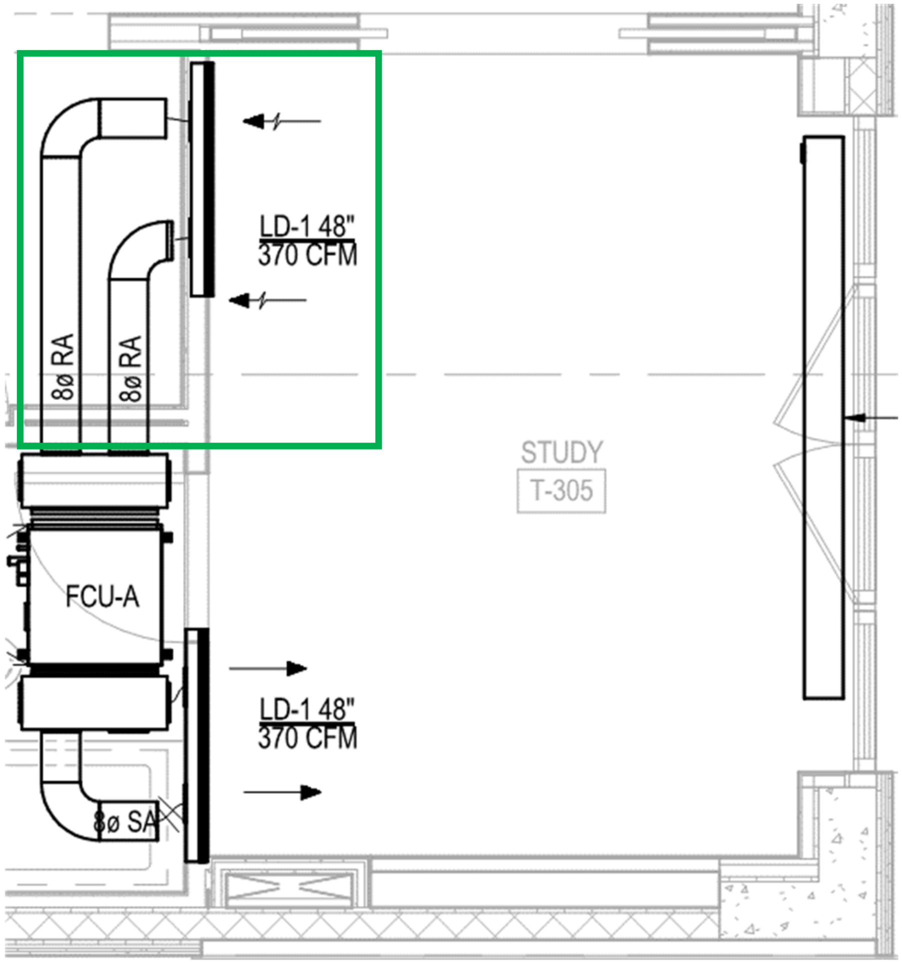
- Don't place it:
  - Near a window
  - Directly under a supply vent
  - On an exterior wall
- Place it in a location representative of the space temperature
- Bad location of thermostat = under/over conditioning of space

Thermostat Location and Programming

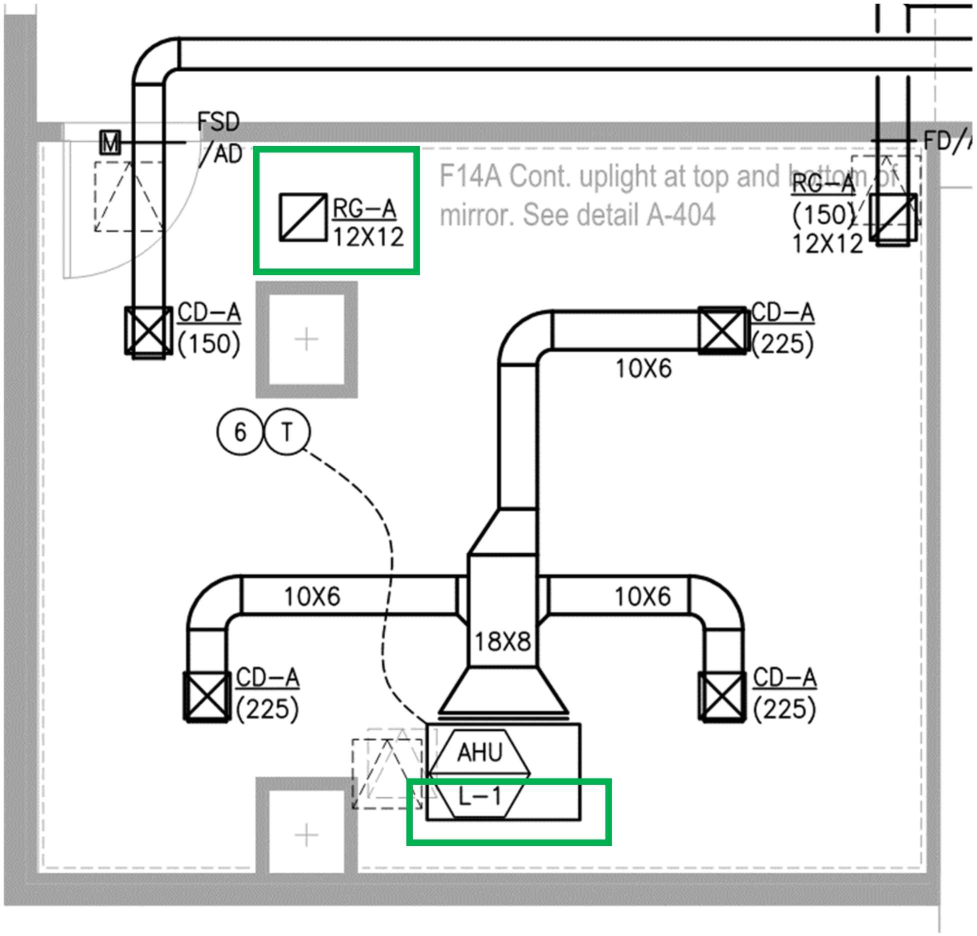
- Most manufacturers have an option of controlling based on space temperature or return temperature and some have a default to measure return temperature.
- Return air temperature sensors might not accurately reflect the space conditions if:
  - The elevation of the indoor unit is significantly above the occupied space
  - The return air is not directly ducted from the space (e.g. a plenum return), or if outdoor air is ducted to the unit (whether conditioned or not).

Thermostat & Remote Sensor

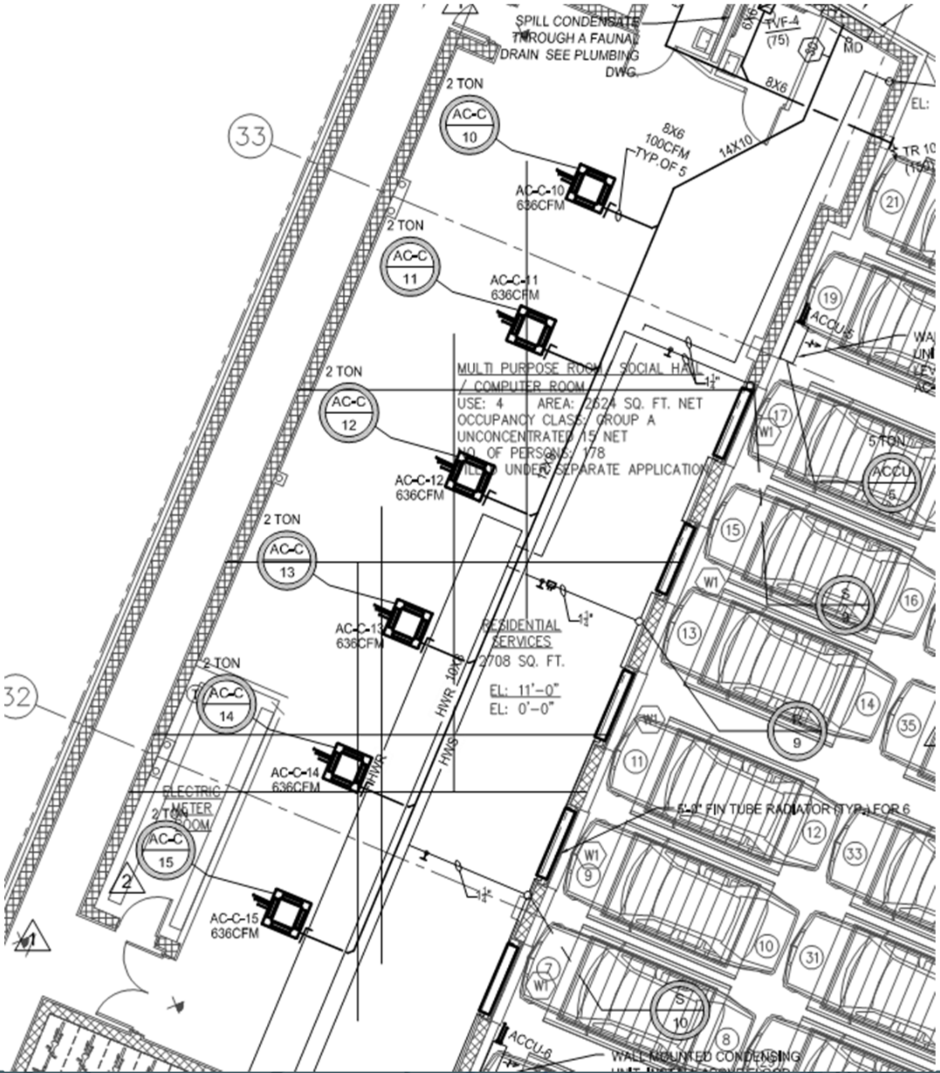
Ducted Return



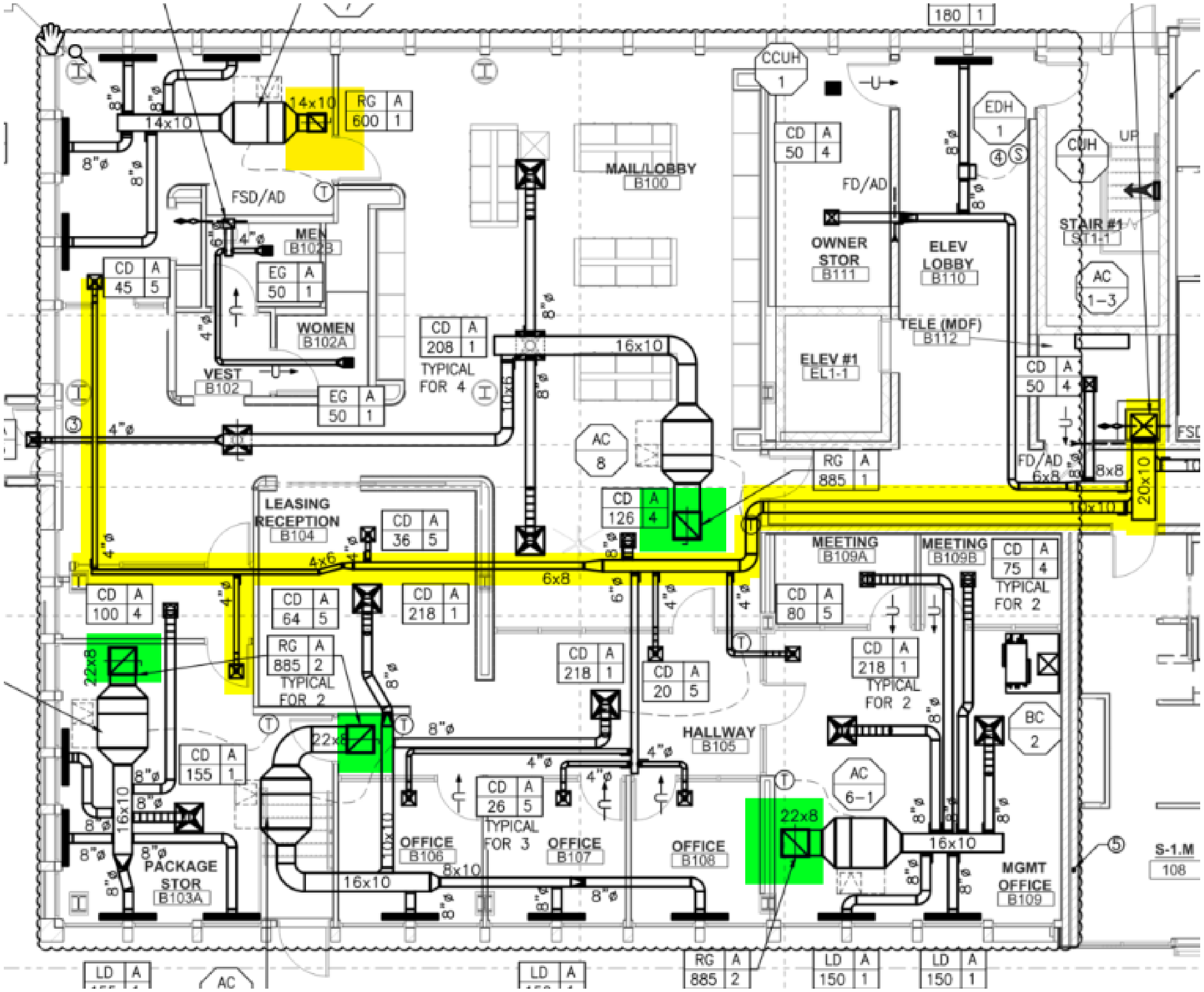
Plenum Return



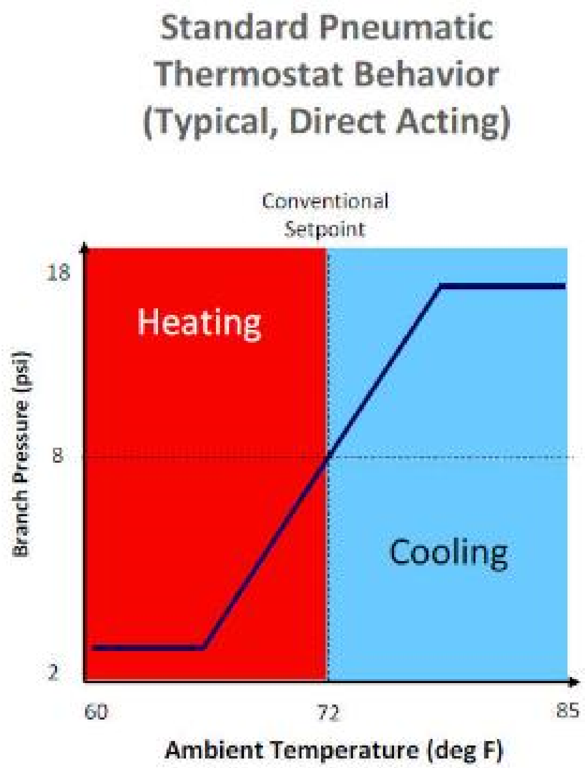
Multiple Indoor Units In the Same Space

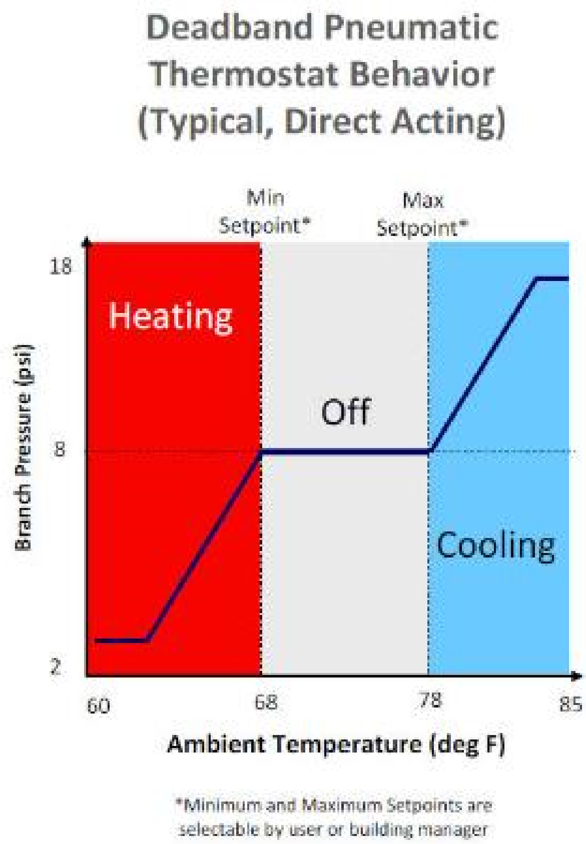


Fan Control


MAIL/LOBBY
B100
OWNER STOR
B111
ELEV LOBBY
B110
STAIR #1
ST1-1
TELE (MDF)
B112
ELEV #1
EL1-1
MEN
B102B
WOMEN
B102A
VEST
B102
LEASING RECEPTION
B104
MEETING
B109A
MEETING
B109B
HALLWAY
B105
OFFICE
B106
OFFICE
B107
OFFICE
B108
MGMT OFFICE
B109
PACKAGE STOR
B103A
TYPICAL FOR 4
TYPICAL FOR 2
TYPICAL FOR 3
FSD/AD
FD/AD
16x10
14x10
20x10
22x8
6x8
4x6
8x10
10x6
16x10
18x10
8x8
6x8

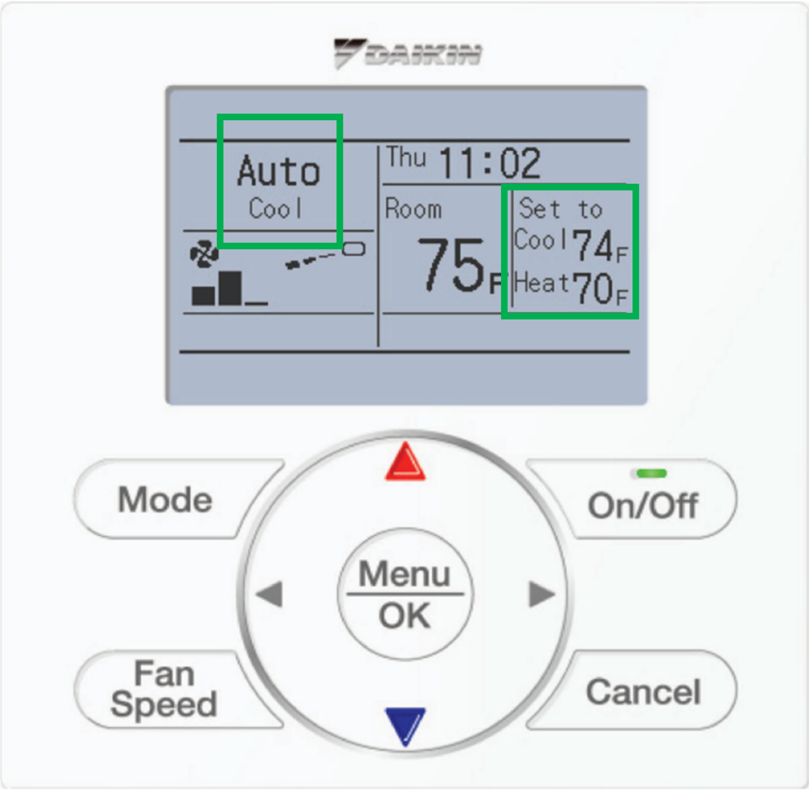
Deadband and Differential



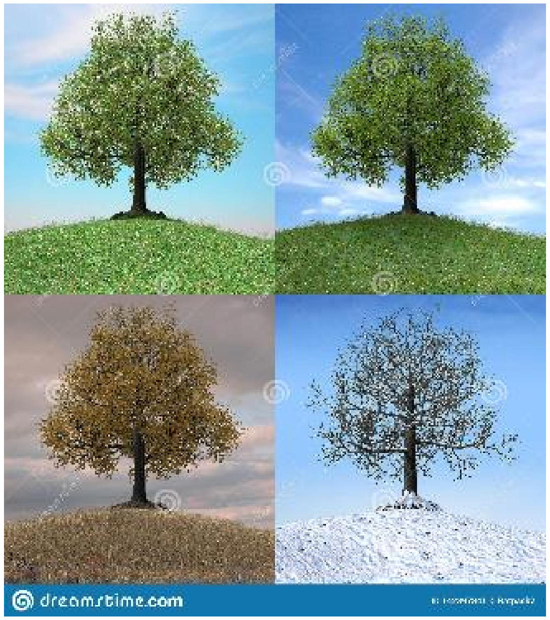


- Applicable in systems where there is an automatic changeover between heating and cooling modes

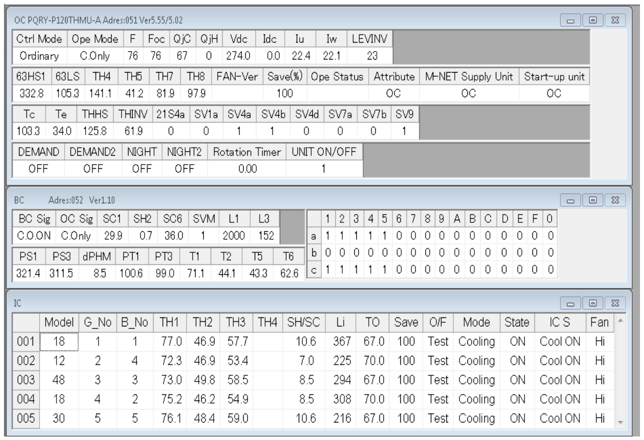
Typical Thermostat



Heat Pump VRF Mode Changeover



Start Up



OC PQRY-P120THMU-A Adres:051 Ver5.55/5.02

Ctrl Mode	Ope Mode	F	Foc	QjC	QjH	Vdc	Idc	Iu	Iw	LEVINV
Ordinary	C.Only	76	76	67	0	274.0	0.0	22.4	22.1	23

63HS1	63LS	TH4	TH5	TH7	TH8	FAN-Ver	Save(%)	Ope Status	Attribute	M-NET Supply Unit	Start-up unit
332.8	105.3	141.1	41.2	81.9	97.9		100		OC	OC	OC

Tc	Te	THHS	THINV	21S4a	SV1a	SV4a	SV4b	SV4d	SV7a	SV7b	SV9
103.3	34.0	125.8	61.9	0	0	1	1	0	0	0	1

DEMAND	DEMAND2	NIGHT	NIGHT2	Rotation Timer	UNIT ON/OFF
OFF	OFF	OFF	OFF	0.00	1

BC Adres:052 Ver1.10

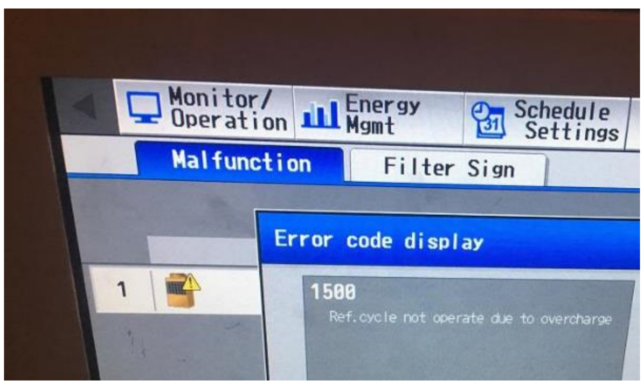
BC Sig	OC Sig	SC1	SH2	SC6	SVM	L1	L3
C.O.ON	C.Only	29.9	0.7	36.0	1	2000	152

PS1	PS3	dPHM	PT1	PT3	T1	T2	T5	T6
321.4	311.5	8.5	100.6	99.0	71.1	44.1	43.3	62.6

	1	2	3	4	5	6	7	8	9	A	B	C	D	E	F	0
a	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0
b	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
c	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0

IC

	Model	G_No	B_No	TH1	TH2	TH3	TH4	SH/SC	Li	TO	Save	O/F	Mode	State	IC S	Fan
001	18	1	1	77.0	46.9	57.7		10.6	367	67.0	100	Test	Cooling	ON	Cool ON	Hi
002	12	2	4	72.3	46.9	53.4		7.0	225	70.0	100	Test	Cooling	ON	Cool ON	Hi
003	48	3	3	73.0	49.8	58.5		8.5	294	67.0	100	Test	Cooling	ON	Cool ON	Hi
004	18	4	2	75.2	46.2	54.9		8.5	308	70.0	100	Test	Cooling	ON	Cool ON	Hi
005	30	5	5	76.1	48.4	59.0		10.6	216	67.0	100	Test	Cooling	ON	Cool ON	Hi



- Varied Startups Procedure
- Varied Manufacturer’s Rep experience
- Charge confirmation procedure
- Most startups do not focus on each FCU
- Data may be difficult to interpret

Start Up

DESCRIPTION OF WORK PERFORMED

5th + 6th – Addressed units Turned power on to all units. During Startup we add the additional Refrigerant 410 A = 14. Pounds.
7th + 8th – Started addressing all units. Unit 1 is Disconnected. set all addresses. Started equipment and added additional Refrigerant 14 #'s R410A.
9th + 10th FlR – Charged up System w/ 14#s R410A

Refrigeration Piping	Yes	No
Has all system piping been completed in accordance with installation guidelines?	✓	
Total Refrigerant Charge	21lbs 3oz	Lbs/Ozs
Refrigerant Charge marked on data plate?	13	lbs
Crankcase heater energized?	✓	
Condenser installed with proper clearances?	✓	
Service Checker run and data stored?		
Has all system piping been insulated, including RefNET and flare connections?	✓	

SUPER HEAT AT CONDENSER:	27.2
SUB COOLING AT CONDENSER:	14
COMPRESSOR#:	ENB62FB-U
INVERTER:	YES
CONSTANT:	YES
VOLTS:	214
PHASE:	3
FLA:	24
ACTUAL L1:	17
ACTUAL L2:	17
ACTUAL L3:	18
SUCTION PRESSURE:	124
HEAD PRESSURE:	334
HEATING/COOLING MODE:	COOLING
DISCHARGE LINE TEMPERATURE:	44

DATE: April 24, 2017

TO: Kelly Westby
Steven Winter Associates
307 7th Avenue #1701
New York, NY 10001

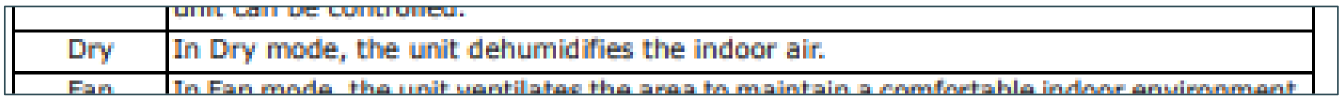
FROM:

Re: Unit Start-Up

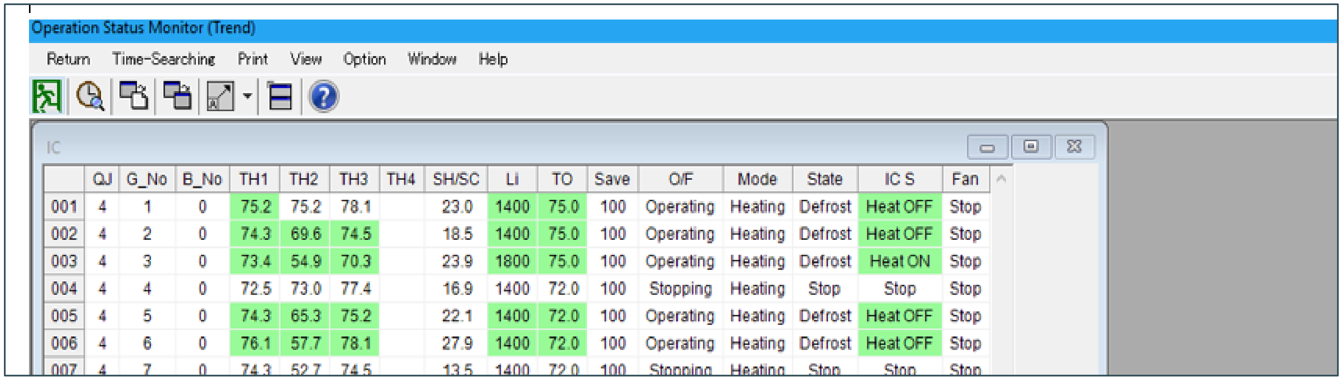
The following units and systems have been satisfactorily started at the above referenced project:

- Duplex domestic water pumps
  - CWP-1
- Domestic hot water heaters
  - HWH-1
  - HWH-2
- Energy Recovery Ventilator
  - ERV-1
- Rooftop air handling units
  - AHU-1
  - AHU-2
- Apartment evaporators and associated condensing units for floors 3 through 25
  - EVAP-1
  - EVAP-1A
  - EVAP-2
  - ACCU-TYP1
  - ACCU-TYP2
  - ACCU-25.1
  - ACCU-25.2
- 26th floor evaporators and associated condensing units
  - ACCU-26

Communication and Controls



	unit can be controlled.
Dry	In Dry mode, the unit dehumidifies the indoor air.
Fan	In Fan mode, the unit ventilates the area to maintain a comfortable indoor environment.



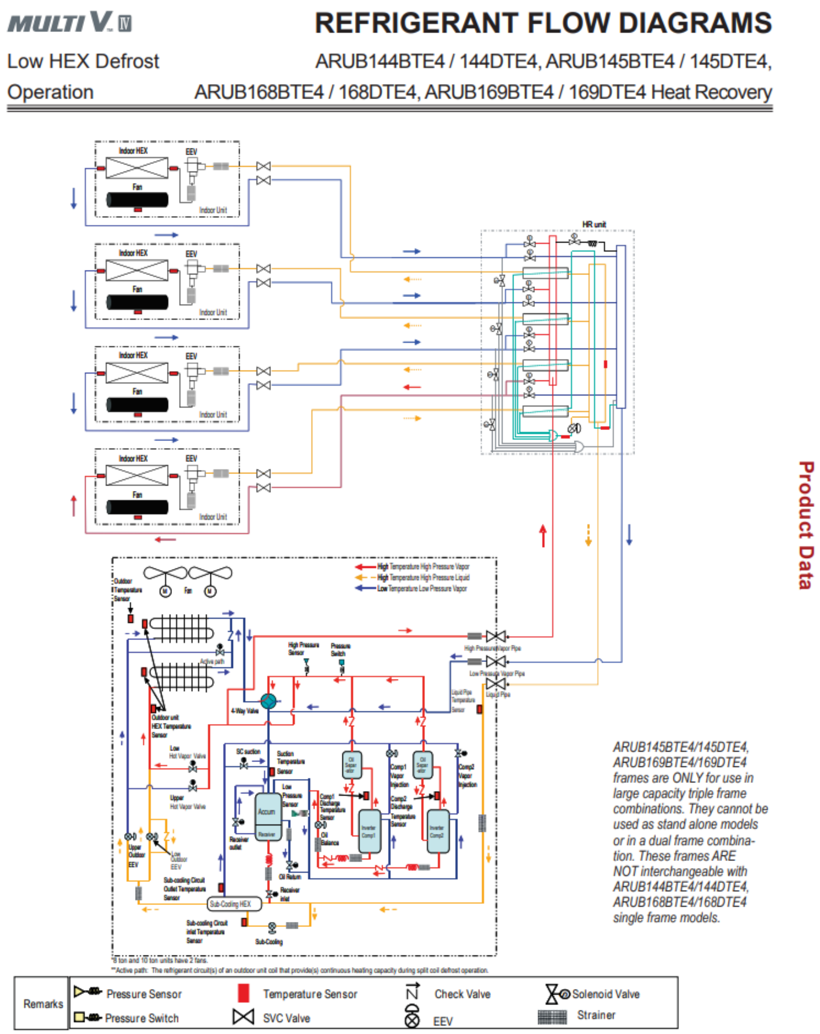
Operation Status Monitor (Trend)

Return Time-Searching Print View Option Window Help

IC

	QJ	G_No	B_No	TH1	TH2	TH3	TH4	SH/SC	Li	TO	Save	O/F	Mode	State	IC S	Fan
001	4	1	0	75.2	75.2	78.1		23.0	1400	75.0	100	Operating	Heating	Defrost	Heat OFF	Stop
002	4	2	0	74.3	69.6	74.5		18.5	1400	75.0	100	Operating	Heating	Defrost	Heat OFF	Stop
003	4	3	0	73.4	54.9	70.3		23.9	1800	75.0	100	Operating	Heating	Defrost	Heat ON	Stop
004	4	4	0	72.5	73.0	77.4		16.9	1400	72.0	100	Stopping	Heating	Stop	Stop	Stop
005	4	5	0	74.3	65.3	75.2		22.1	1400	72.0	100	Operating	Heating	Defrost	Heat OFF	Stop
006	4	6	0	76.1	57.7	78.1		27.9	1400	72.0	100	Operating	Heating	Defrost	Heat OFF	Stop
007	4	7	0	74.3	52.7	74.5		13.5	1400	72.0	100	Stopping	Heating	Stop	Stop	Stop

- Setpoint satisfied (Fan on or off)
- “Pre-heating”, “standby”
- Several other modes besides heating/cooling (defrost)



Communication & Controls

- Controller/ BMS Integration
- Integration with Auxiliary Equipment
- Heat Pump Only: Transition from heating to cooling

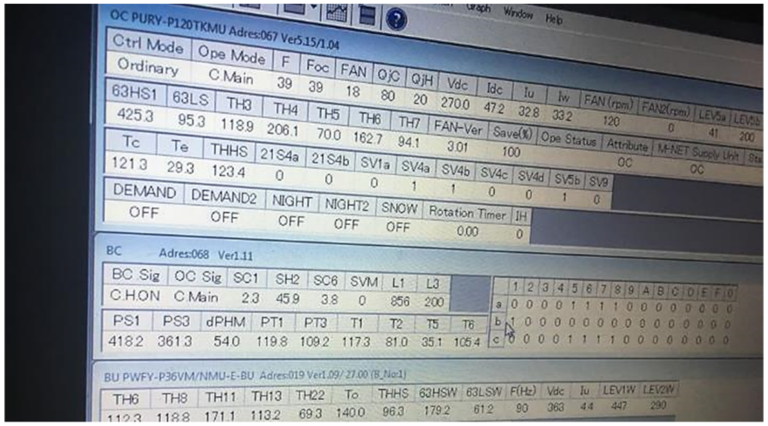
Heat Pump Changeover

The Various Heat/Cool Changeover Options

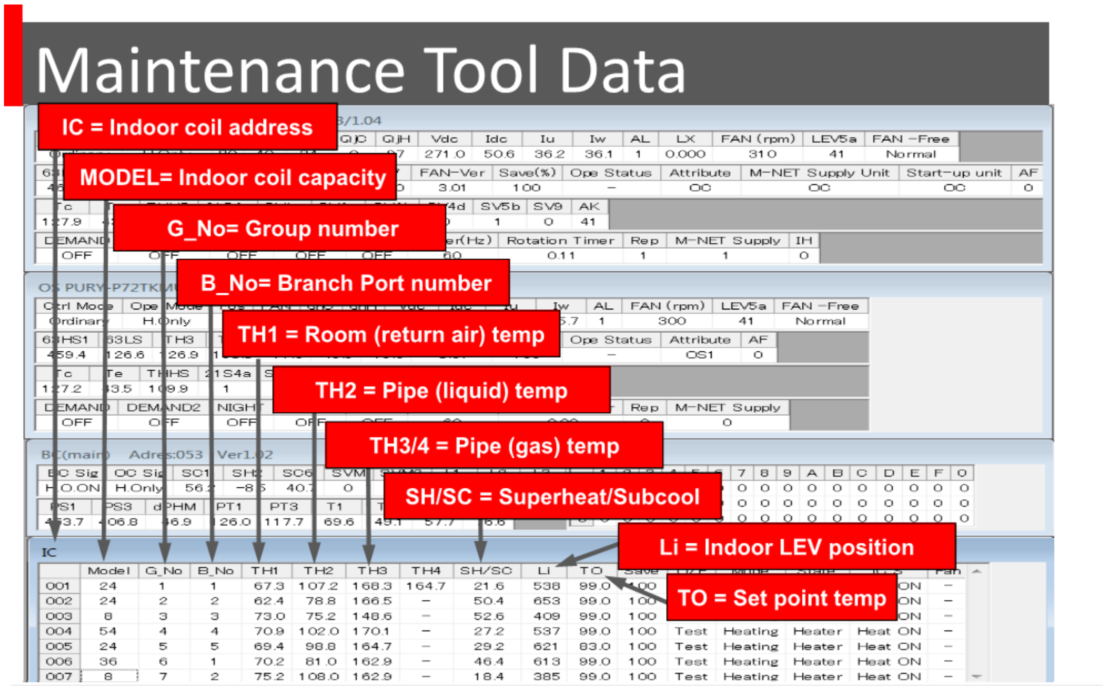
There are no less than six ways to provide heat/cool changeover

Commissioning

- Check discharge air temperatures
  - max heating
  - max cooling
  - combo (heat recovery)
- ‘Plug’ into system



Commissioning



Looks like CN52 Pins 1&4 for heating mode indication – requires PAC-725AD wiring harness
If CN25 is available, that can be used instead.

PEFY-P##NMAU-E2 Service Manual provided for your reference as well.

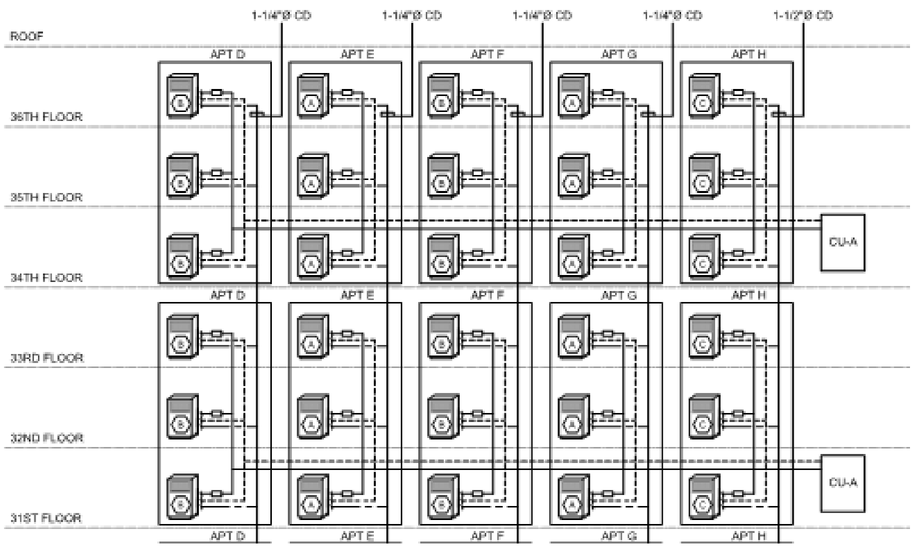
- Struggle to get manufacturer's and reps to site
- Technology changing too quickly
- Literature not always clear and accurate

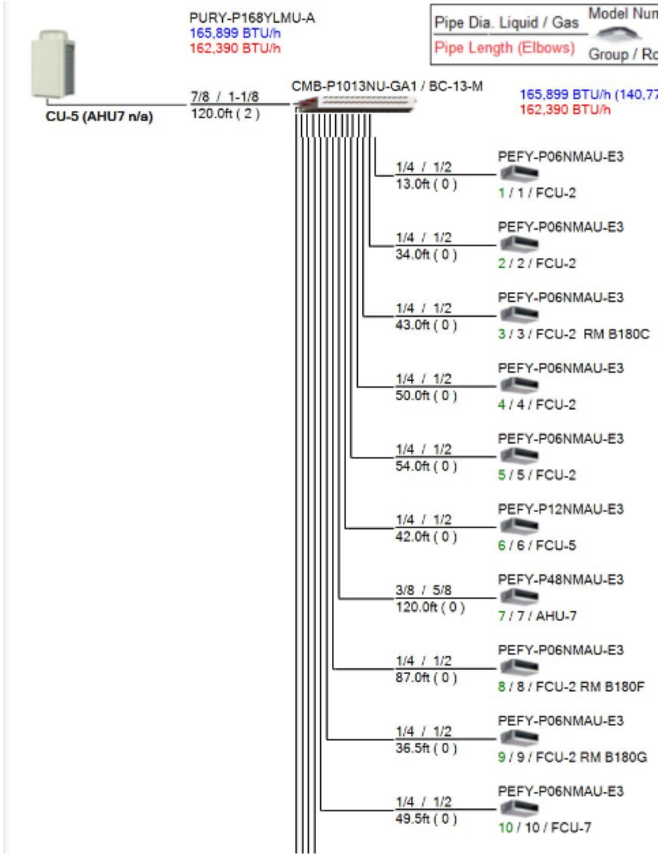
What to do?

- Set expectations
- Provide checklist for install and start up
- Witness installation and testing when possible
- Perform functional tests
- Stay up-to date with manufacturer's requirements

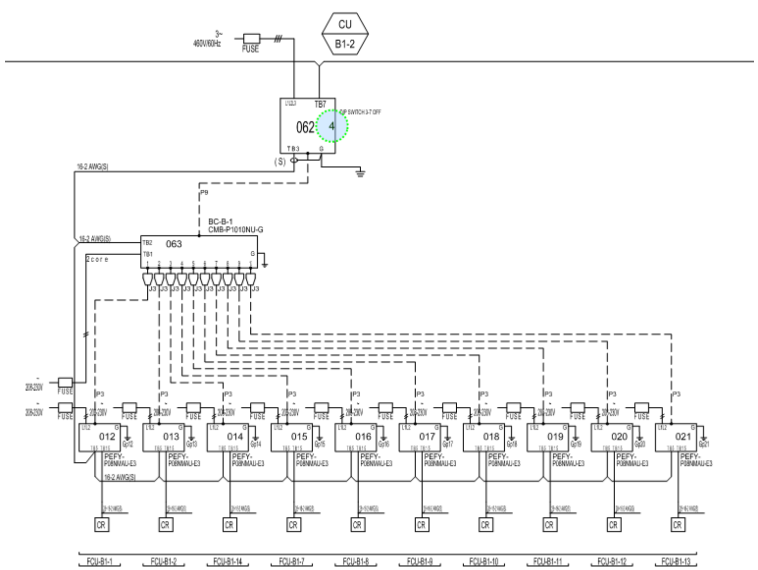
6. VRF Outdoor Unit - This section must be completed for all VRF outdoor units serving dwelling units or common spaces	**FT Agent Verified**	**N/A**
6.1 Installation Checks		
6.1.1 Pressure testing on refrigerant piping has been completed for this system (indicate exact test in / test out pressure (psig) / time (hours)): ________/________/________	☐	☐
6.1.2 Vacuum testing has been completed (indicate exact test in / test out pressure (psig) / time (hours)): ________/________/________	☐	☐
6.1.3 Refrigerant line lengths and height differences have been recorded from as-built shop drawings or field measured, and documentation of the measurement is available, if requested	☐	☐
6.1.4 Indicate required additional charge amount (lbs): ________	☐	☐

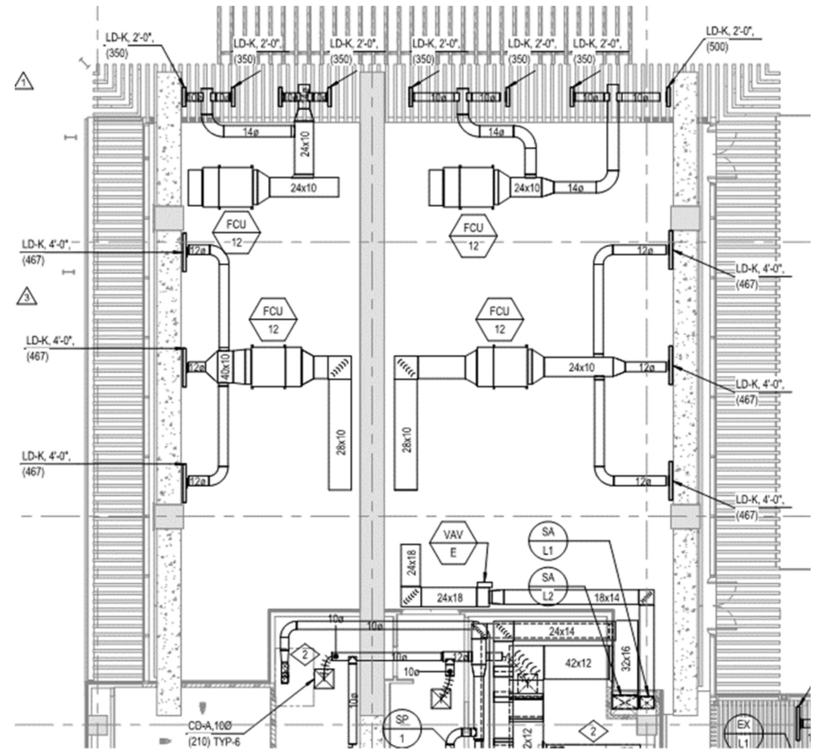
Design Review – Which VRF system is heat recovery?



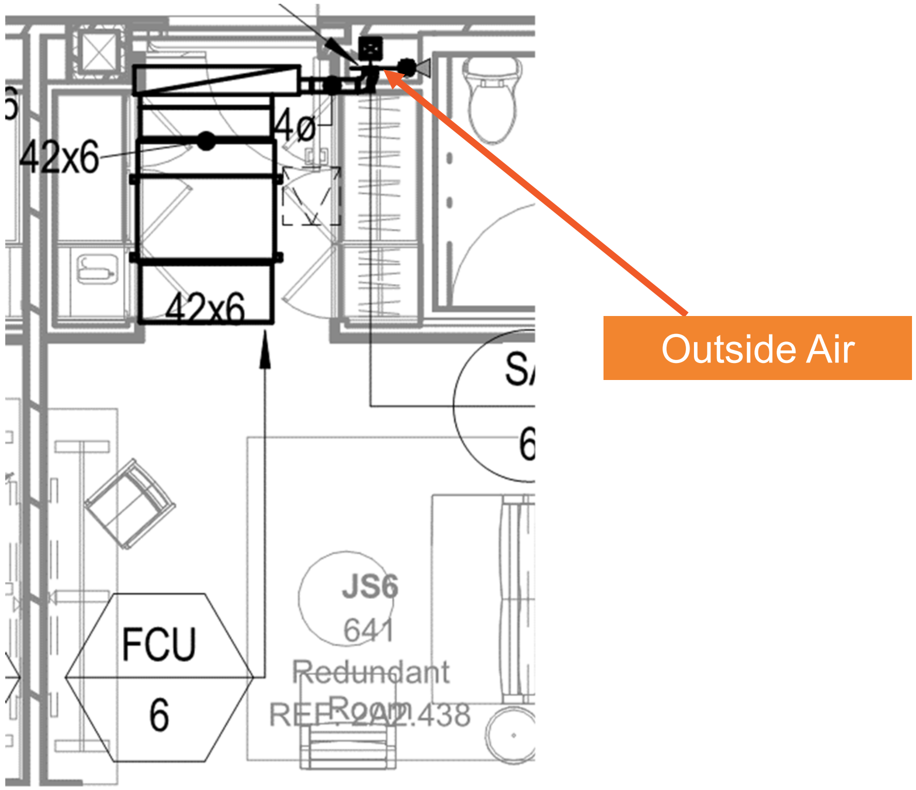


Design Review – How many thermostats?





Design Review - Return Air Temp or Space Temp



When poll is active, respond at **PollEv.com/swa335**
Text **SWA335** to **22333** once to join

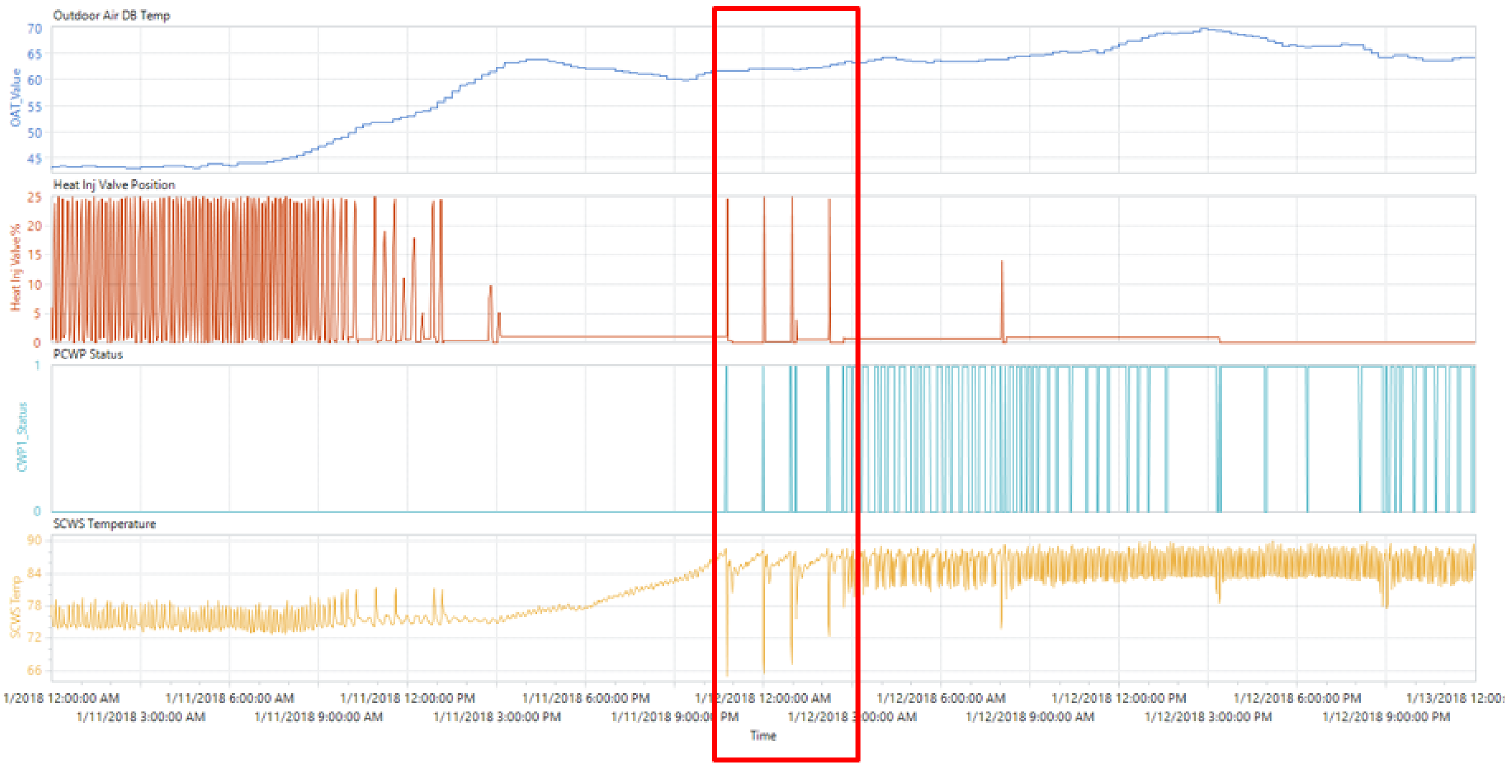
Should the unit be controlled off of return air temp or space temp?

Common WSHP Issues

- Central Plant Programming

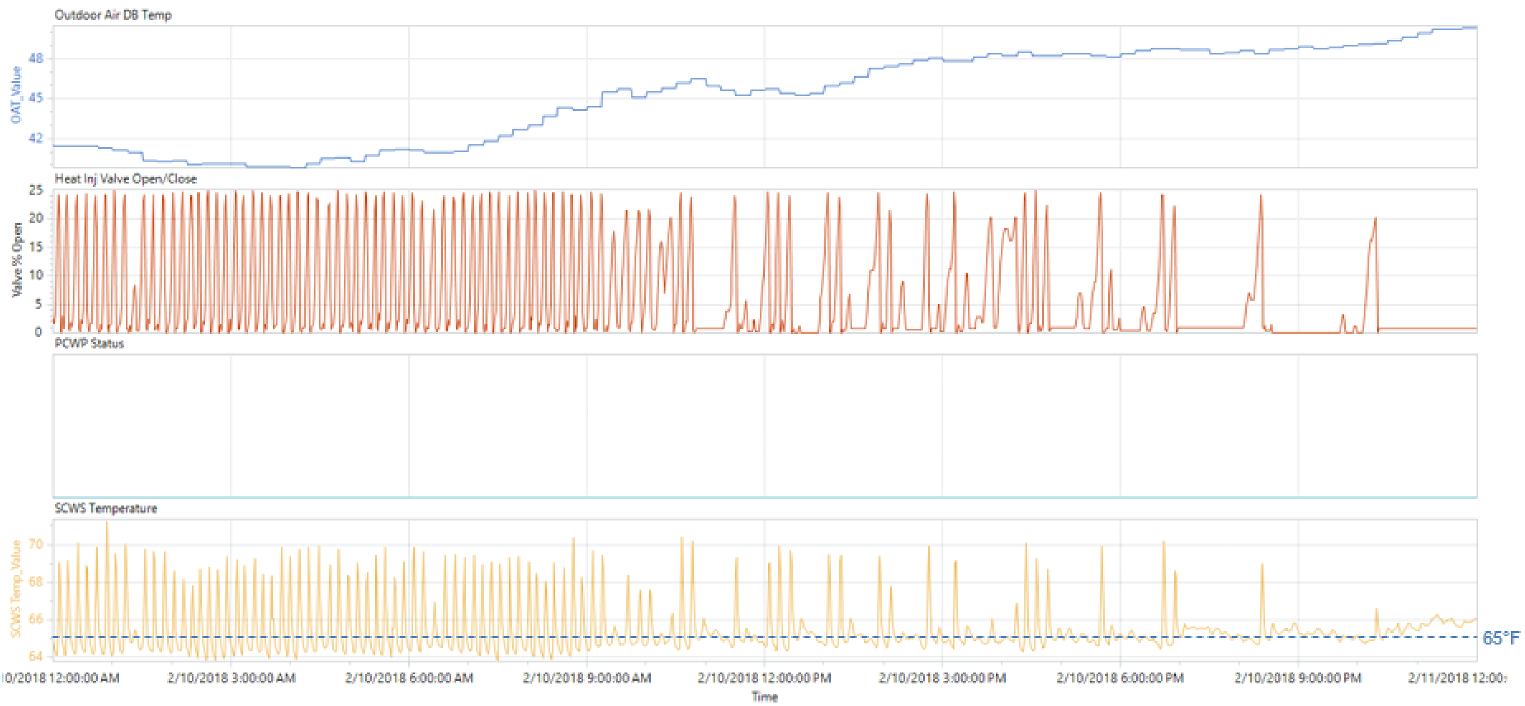
WSHPs

Figure 1 - January 11-12 Heat Injection and Heat Rejection



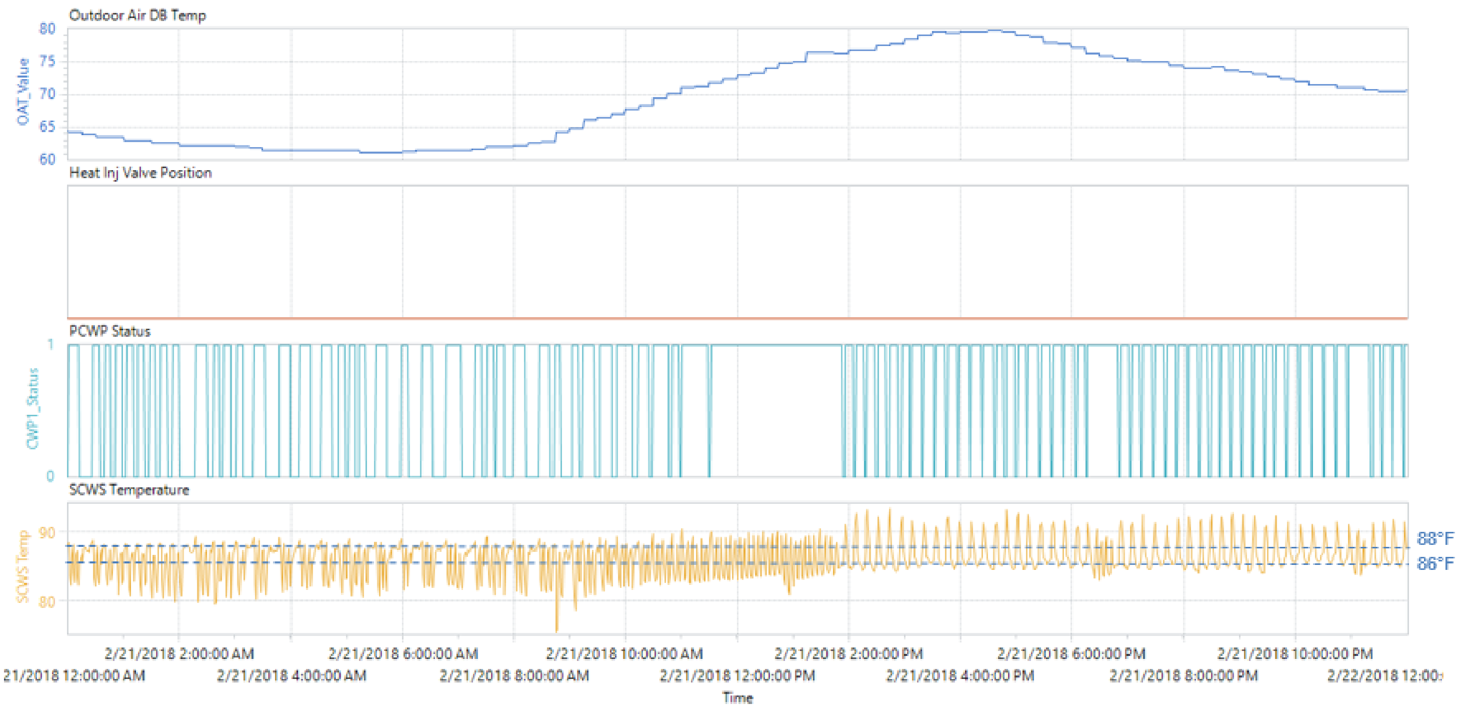
WSHPs

Figure 2 - Heat Injection and Rejection Feb 10, 2018



WSHPs

Figure 3 – Heat Injection and Rejection Feb 21, 2018



Discussion

Join Us for More Trainings!

- **Module 8**: Construction Manager/Subcontractor/Tradesperson Training: Classroom and Field Training

Register here: https://www.newpaltz.edu/sustainability/view-programs-and-progress/zero-net-carbon-training/workshop-schedule-registration--details/

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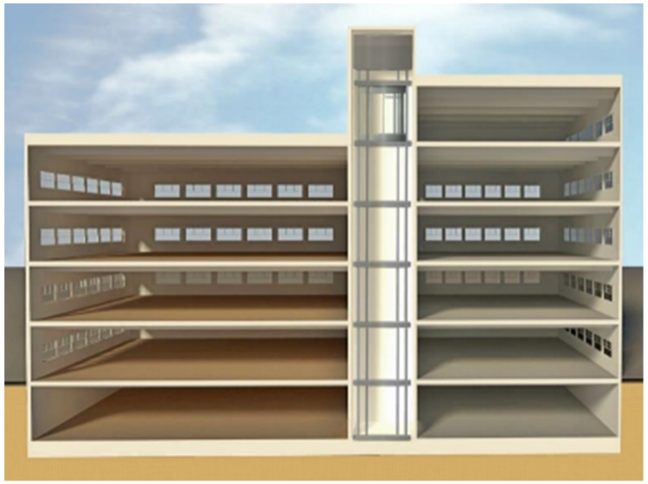
Future Proofing

- Code Compliant ≠ Good Performance
- Energy Model ≠ Actual Energy Performance
- Occupant Behavior = Your Problem

Future Proofing

Hindsight is 2020 → The future is murky → But there are things we KNOW we should consider

Consider This: Future Proof Design



- Infrastructure for the future
  - Master/Submeter Configuration
  - Robust Monitoring and Control Systems
  - Incorporate design details that enable low-cost future electrification
  - For hydronics: LOW temperature loop
  - For DHW: Allow space for or include storage (MF/Hospitality)
- Enclosure
  - Get the details right now!

Consider This: Electrify

- Plan for & Maximize Solar Now
- Consider Electrification
  - Electrify if you can
- Pay attention to new Refrigerant Options

Consider This: Watch it!

- Verification
- Commissioning
- Ongoing Monitoring

Resources

- https://www.drawdown.org/solutions/materials/refrigerant-management
- https://www.epa.gov/snap/refrigerant-safety
- https://refrigeranthq.com/r-410a-refrigerant-history/
- https://www.epa.gov/sites/production/files/2015-07/documents/phasing_out_hcfc_refrigerants_to_protect_the_ozone_layer.pdf
- https://www.epa.gov/sites/production/files/2015-08/documents/section_608_of_the_clean_air_act.pdf
- https://www.epa.gov/sites/production/files/documents/ConstrAndDemo_EquipDisposal.pdf
- http://www.daikinac.com/content/assets/DOC/White-papers-/TAVRVUSE13-05C-ASHRAE-Standard-15-Article-May-2013.pdf
- https://www.fluorineproducts-honeywell.com/refrigerants/press-releases/honeywell-unveils-new-nonflammable-refrigerant-with-low-global-warming-potential-for-chillers-and-heat-pumps/
- https://www.danfoss.com/en-us/about-danfoss/news/cf/three-danfoss-technologies-named-winners-of-2020-ahr-expo-innovation-awards/

Resources

- https://emersonclimateconversations.com/2015/04/30/co2-as-a-refrigerant-criteria-for-choosing-refrigerants/
- https://www.energy.gov/eere/femp/magnetic-bearing-chiller-compressors
- https://www.energy.gov/sites/prod/files/2016/07/f33/The%20Future%20of%20AC%20Report%20-%20Full%20Report_0.pdf
- https://wbdg.org/FFC/DOD/UFC/ufc_3_410_01_2013_c4.pdf
- https://www.gov.uk/government/publications/impacts-of-leakage-from-refrigerants-in-heat-pumps
- https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/303689/Eunomia_-_DECC_Refrigerants_in_Heat_Pumps_Final_Report.pdf
- https://www.hvacrschool.com/new-refrigerants-from-honeywell/

Resources

- https://www.epa.gov/ghgemissions/overview-greenhouse-gases#carbon-dioxide
- https://www.epa.gov/ghgemissions/inventory-us-greenhouse-gas-emissions-and-sinks
- https://science.sciencemag.org/content/361/6398/186
- https://www1.eere.energy.gov/buildings/publications/pdfs/building_america/inverter-driven-heat-pumps-cold.pdf
- http://ma-eeac.org/wordpress/wp-content/uploads/Ductless-Mini-Split-Heat-Pump-Impact-Evaluation.pdf
- https://publicservice.vermont.gov/sites/dps/files/documents/Energy_Efficiency/Reports/Evaluation%20of%20Cold%20Climate%20Heat%20Pumps%20in%20Vermont.pdf