How NOT to Do Electrification

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MITSUBISHI ELECTRIC
COOLING & HEATING

BUILDING EVOLUTION CORPORATION
Achieve Performance & Durability Through A Holistic Approach™

Agenda

- Introductions
- Orientation
- Case Studies (choose your own adventure?)
- Recurring problems and Common Pitfalls
- Sizing and humidity control matters
- How to avoid these pitfalls? (Open discussion)

Who are you? And why are you here?

- ❑Designers/Architects?
- ❑Engineers?
- ❑Consultants?
- ❑Builders?
- ❑Developers?
- ❑Advocates?
- ❑Students?
- ❑Volunteer who got roped into proctoring this session?

Orientation

Managing the Rush to Electrification

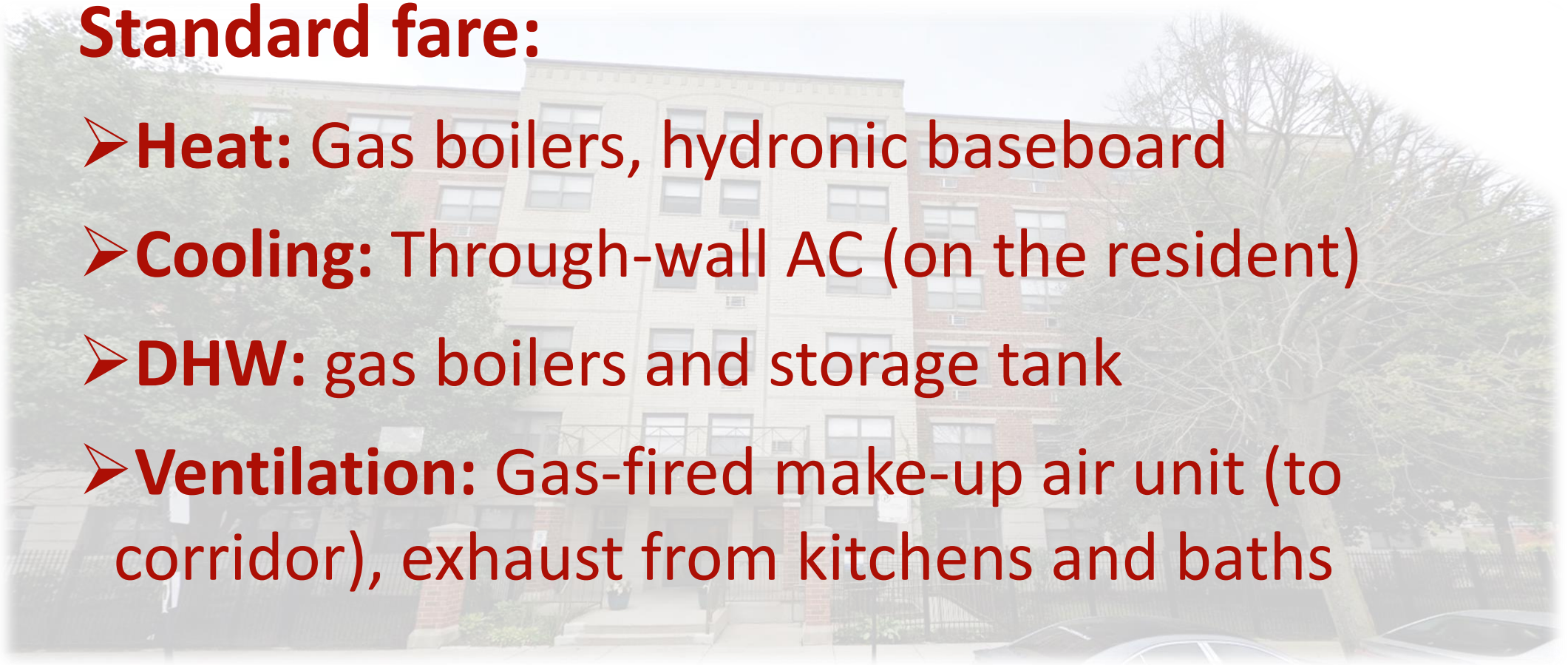

What does electrification mean to you?

Consider this proposed renovation…

- **Affordable senior housing, 60 units**
- **Originally Built ~2000**
- **Middle of country (between coasts)**
- **Cold Climate (zone 5)**

What does electrification mean?

Consider this proposed renovation…



Standard fare:

- **Heat:** Gas boilers, hydronic baseboard
- **Cooling:** Through-wall AC (on the resident)
- **DHW:** gas boilers and storage tank
- **Ventilation:** Gas-fired make-up air unit (to corridor), exhaust from kitchens and baths

What does electrification mean?

Consider this proposed renovation…

Property Acquired 2019 with plan to:

- **Maintain as 100% affordable senior housing**
- **Rehab all units to “like new”**
- **Refresh amenity spaces**
- **Allow all residents to remain in place**

What does electrification mean?

Consider this proposed renovation…

Spring 2023 Mid-design switch:

- **City launched Decarbonization Pilot**
- **Owner decided to take a leap**

What does electrification mean?

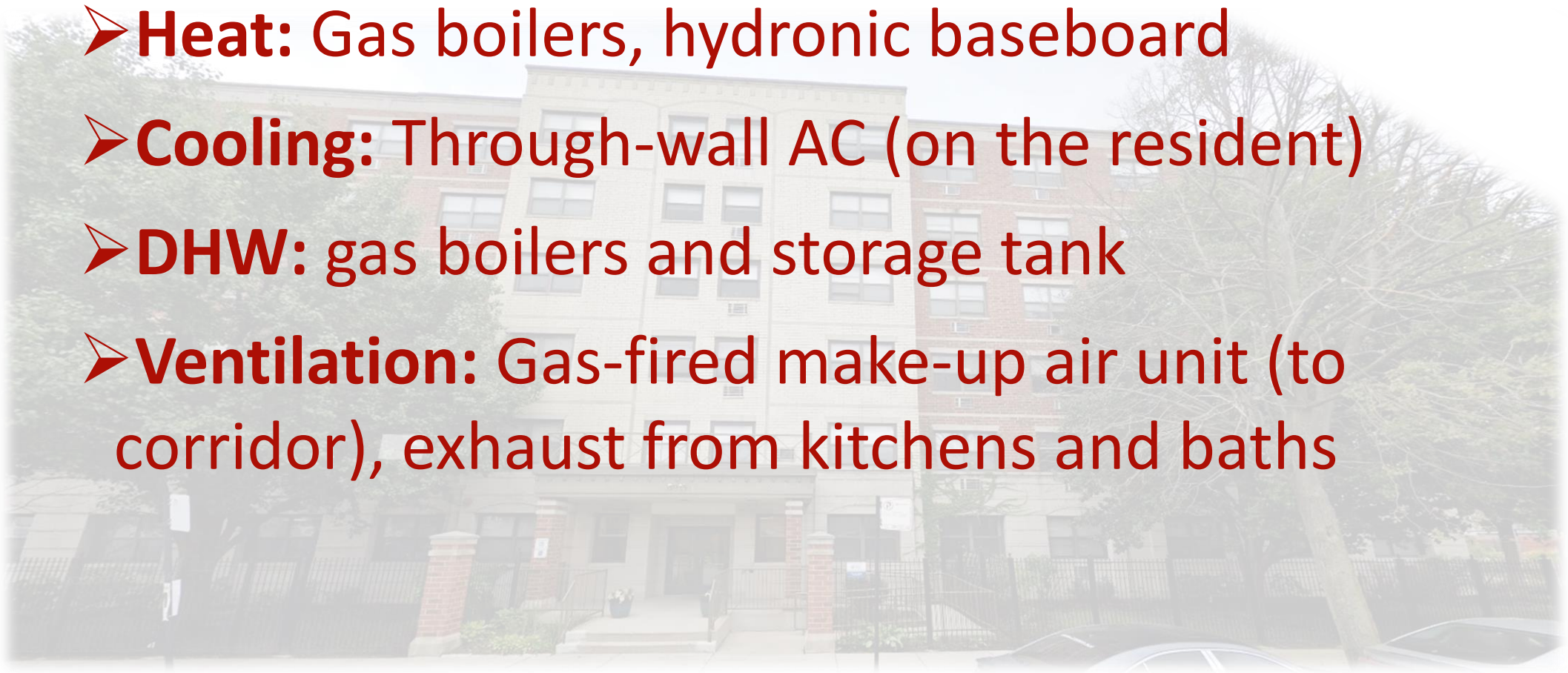
First Pass “Decarbonization” Plan

The city program application asks:

What does decarbonization mean to you?

What does electrification mean?

Initial Decarbonization Narrative



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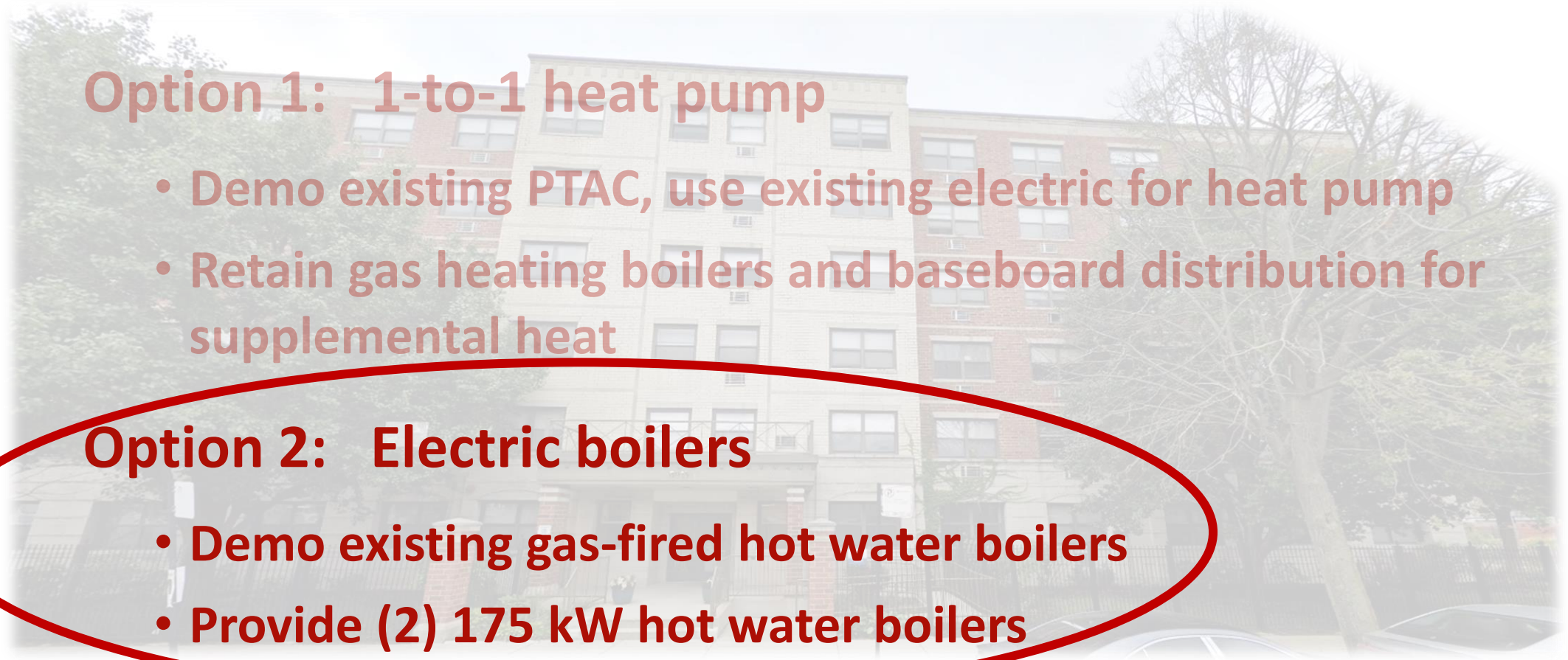
What does electrification mean?

Initial Decarbonization Narrative – Heating



Option 1: 1-to-1 heat pump

- Demo existing PTAC, use existing electric for heat pump
- Retain gas heating boilers and baseboard distribution for supplemental heat

Option 2: Electric boilers

- **Demo existing gas-fired hot water boilers**
- **Provide (2) 175 kW hot water boilers**

What does electrification mean?

Initial Decarbonization Narrative – Heating

Electrical Service Upgrade for Electric Boilers:

Electrical

a) This replacement would require an electric service upgrade on ground that this equipment is currently estimated to be 972amps (350kW) of new connected load to the building at 208y/120 service.

b) It is required that the electrical service be upgraded to accommodate the new equipment.

   i. This would require at least (1) existing parking space to be used to install a new exterior main switchboard at estimated 2500 amp at 208Y/120 with a back feed the existing 2000amp 208Y/120.

What does electrification mean?

Initial Decarbonization Narrative – Heating

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What does electrification mean?

Initial Decarbonization Narrative – DHW

DHW: Electric water heaters

- Demo existing gas-fired DHW boiler and tank
- Provide 175 kW electric commercial DHW heater with 150 gal storage

What does electrification mean?

Initial Decarbonization Narrative – DHW

Electrical Service Upgrade for Electric DHW:

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What does electrification mean?

Initial Decarbonization Narrative – Ventilation

Ventilation: Electric Resistance Make-Up Air Unit

- Demo existing gas-fired MAU and remove gas piping
- Provide new electric heating-only constant volume MAU sized for 10,000 cfm

What does electrification mean?

Initial Decarbonization Narrative – Ventilation

Electrical Service Upgrade for Electric MAU:

Electrical

a) This replacement would require an electric service upgrade on the grounds that this equipment:

i. This would require at least (1) existing parking space to be used to install a new exterior main switchboard at estimated 2500 amp at 208Y/120 with a back feed the existing 2000amp 208Y/120.

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What does electrification mean?

First Pass “Decarbonization” Plan

- **Costs 3 parking spots**
- **And a whole lot of “gear”**
- **Really high utility costs**

Progress?

What does electrification mean?

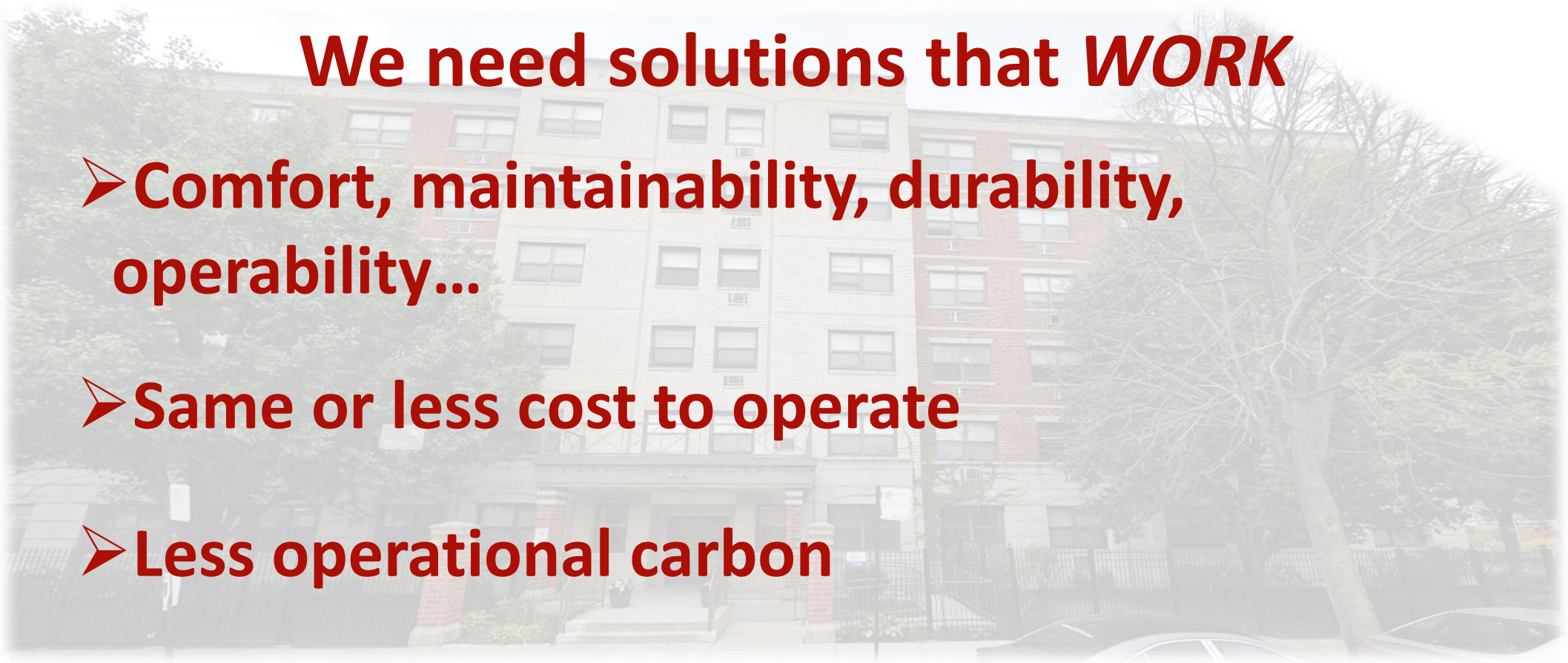
What do we need from electrification?

Goal: to *REDUCE* load on the grid

- **If electrification imposes new peaks on the grid, problems**
- **Equity issues with winter electric peak:**
  - **those stuck heating with gas face even higher costs, generation competes with heating**

What does electrification mean?

What do we need from electrification?



We need solutions that *WORK*

- **Comfort, maintainability, durability, operability…**
- **Same or less cost to operate**
- **Less operational carbon**

What does electrification mean?

Case Studies

Interviews with the first penguins

(Just a few)

DISCLOSURE:

The projects that we are about to discuss were

(Found Unwell on Arrival)

BEC bears no responsibility for any bad practices or unfortunate outcomes you are about to see.

Case study introduction

Mid-Rise Multifamily, New Construction

High-performance Design

What could go wrong…?

Mid-Rise Multifamily, New Construction

(De)Value Engineering Time! Choose your next move:

Path A:

Remove heat recovery from VRF system (changeover VRF)

Path B:

Remove energy recovery ventilation (outdoor air ducted to FCUs)

Design Team Answer: Path B

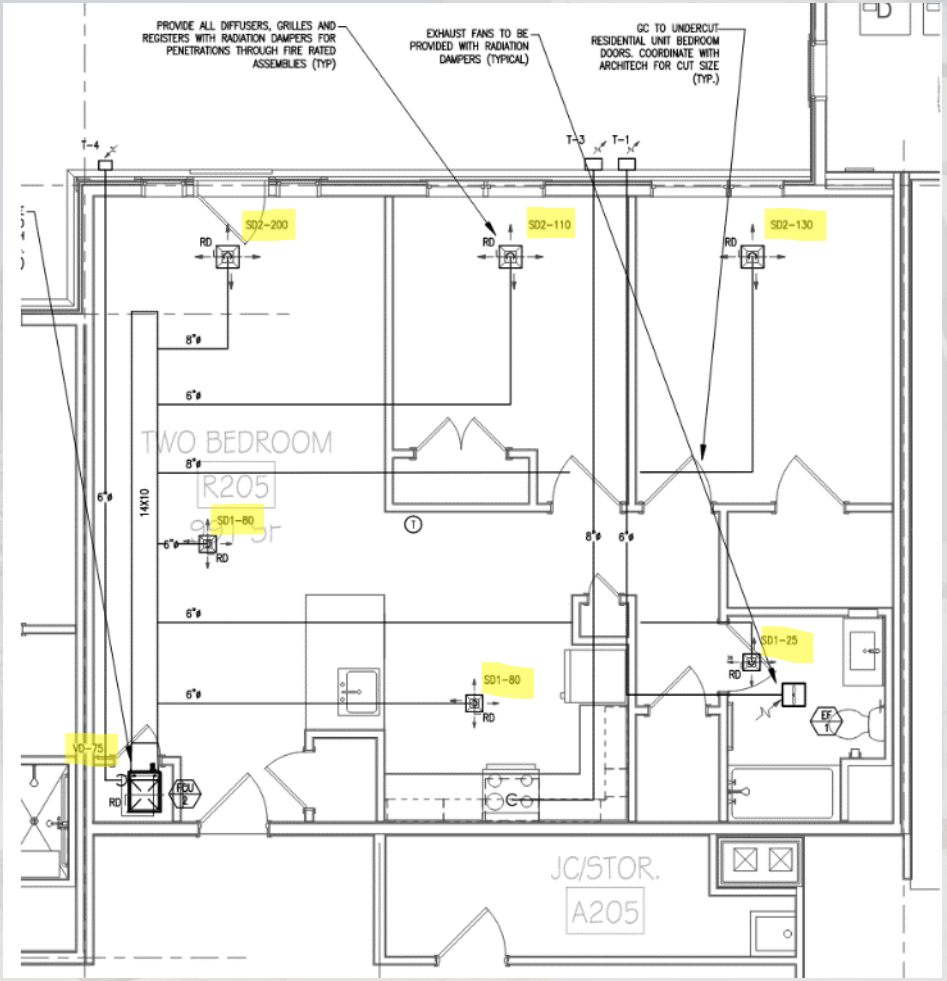
Un-tempered Outdoor Air (OA)

Mid-Rise Multifamily, New Construction

Ventilation Design

- 75 CFM OA ducted to FCU return plenum (2-bedroom)
- 30 CFM continuous Exhaust Air (EA) from bathroom
  - 110 CFM boost function
- 270 CFM intermittent kitchen EA

2-Bedroom



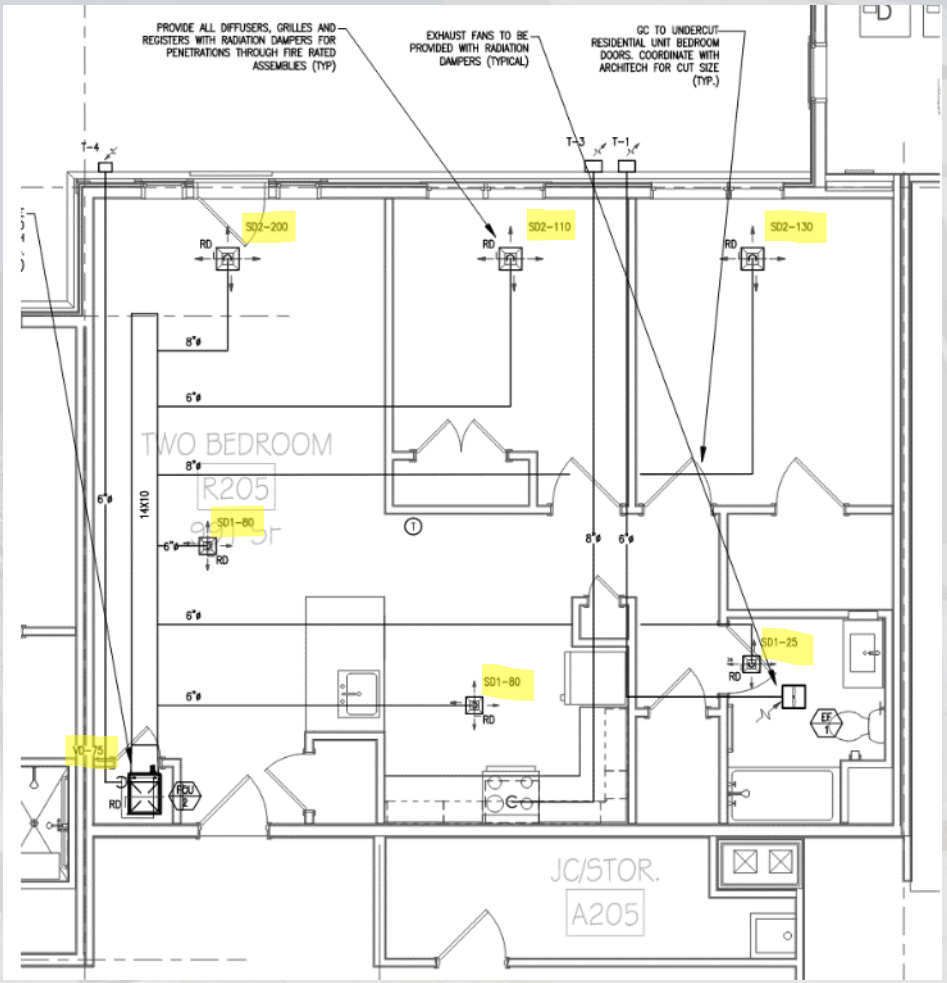
Mid-Rise Multifamily, New Construction

Ventilation Design

- OA controlled with Volume Damper (VD)
- No volume control at central return

Designed OA CFM +  = Delivered OA CFM

2-Bedroom



Mid-Rise Multifamily, New Construction

Humidity

Functional Testing Conditions:

- Outdoor Temp: 78-80 F
- Outdoor Dewpoint: 68 F
- Indoor Temp: 68-70 F

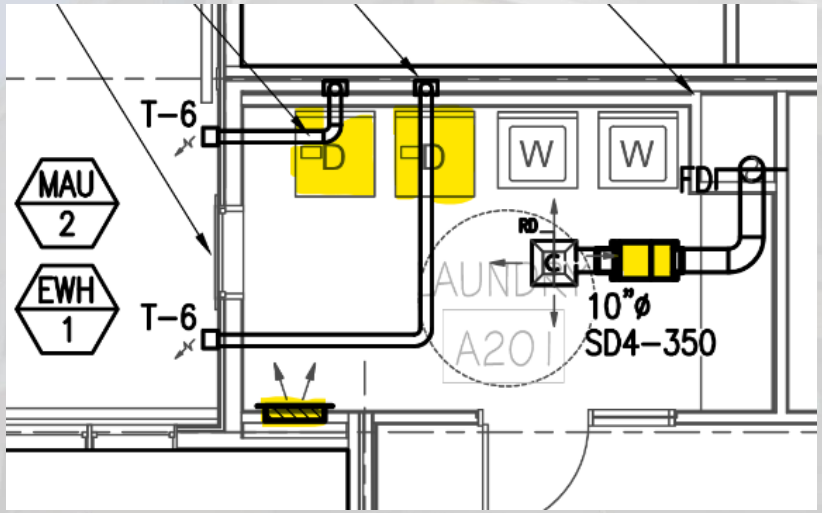
Condensation on plumbing

Symptoms

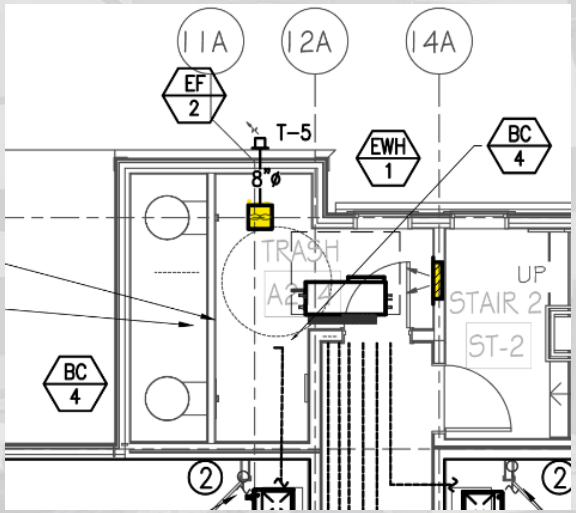
- Poor humidity control
- High energy bills
- Premature component failure

Mid-Rise Multifamily, New Construction

Reliance on electric resistance heating



- Trash rooms
- Entryways
- Stairwells
- Exhaust dryers
- Laundry makeup air units



Electric CUH, MAU with duct heater, exhaust dryers

Exhaust-only ventilation in trash room, heated with electric CUH

Mid-Rise Multifamily, New Construction

Case 1: Mid-Rise Multifamily, New Construction

Applied heat load calculation misinformation

Component	MEP HL Calc Assumption	Designed Value
Roof	R-25	R-32
Wall	R-22	R-22
Slab	R-10	R-10
Window	U-0.4	U-0.27

Equipment Assumptions

DeR - Derated Heating requirement (60% derate at 0F)

Case 1: Mid-Rise Multifamily, New Construction

Applied heat load calculation misinformation

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Roof	R-25	R-32
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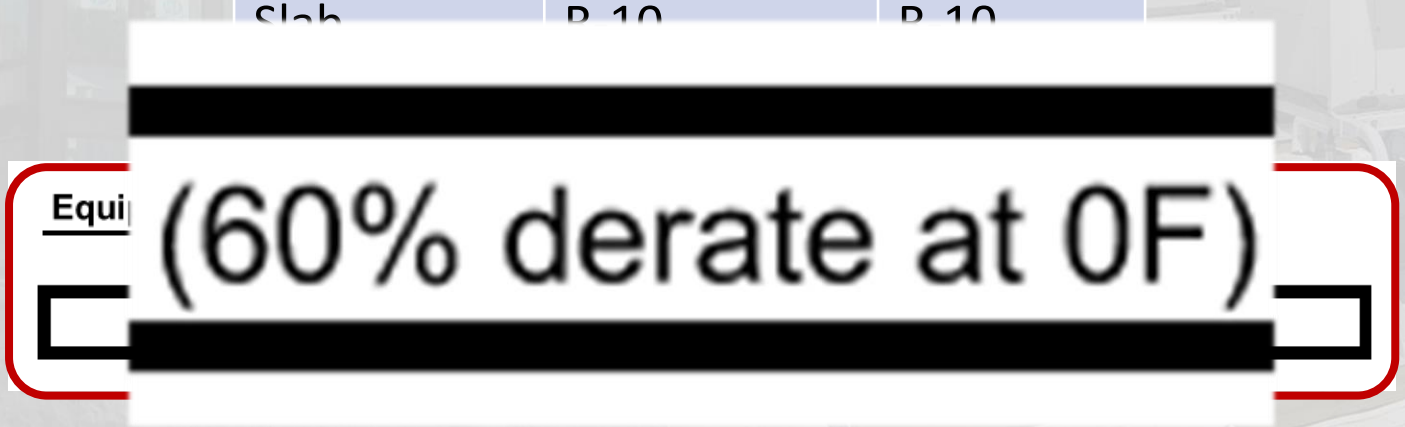
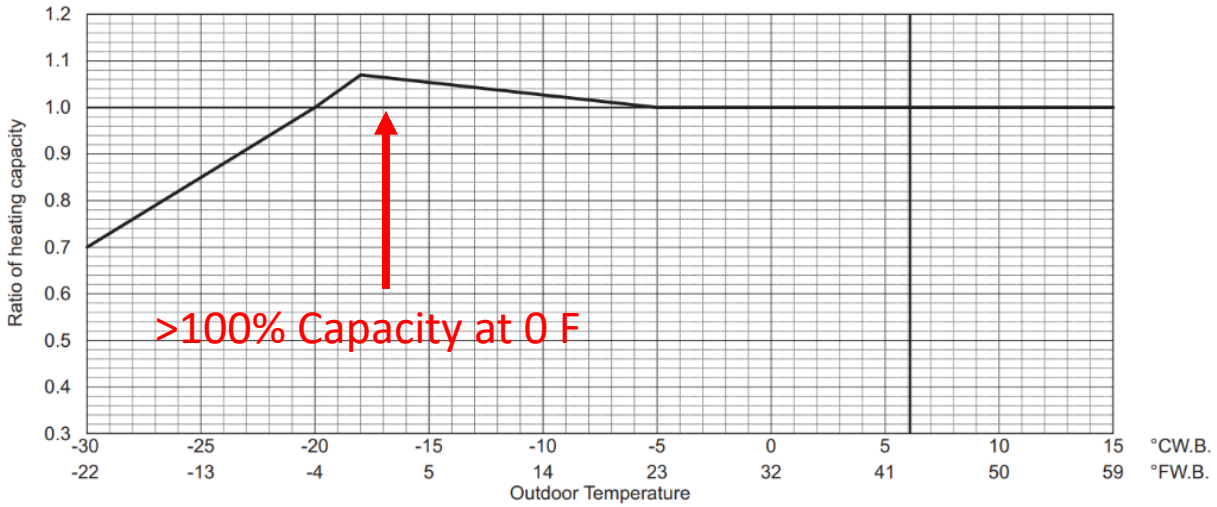


Choose your next move:

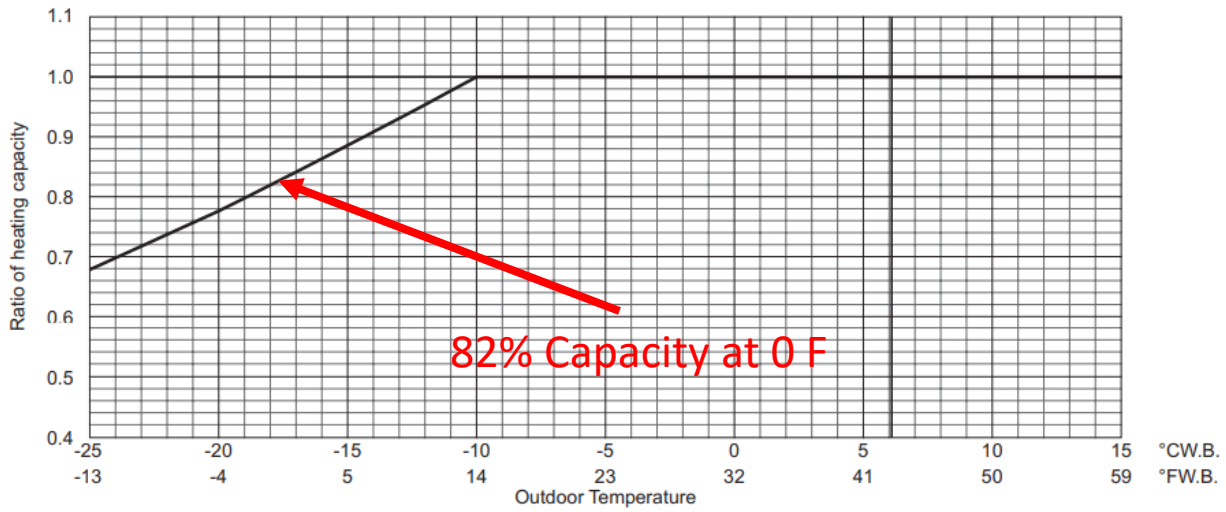
Path A: Very low-ambient capacity VRF

PURY-HP192TSNU (Hyper Heat) Capacity Table



Path B: High-efficiency low-ambient capacity VRF

PURY-EP192TSNU (High-Efficiency) Capacity Table



Mid-Rise Multifamily, New Construction

Design Team Answer:

Path A: Extreme low-ambient capacity VRF

- Higher equipment cost
- Lower efficiency
- Recommended by manufacturer for very cold climates

Path B: High-efficiency low-ambient capacity VRF

- Lower equipment cost
- Higher efficiency
- Recommended by manufacturer for local design conditions

Oversizing Indoor Equipment

Space	MEP HL Calc (Btu/hr)	Equipment Size (Btu/hr)	BEC HL Calc (Btu/hr)	% Difference (Cap vs. actual HL)
2-Bd, FCU-1	18,117	20,000	8,974	55%
2-Bd, FCU-2	24,717	27,000	13,756	49%
2-Bd, FCU-3	27,301	32,000	9,248	71%
3-Bd, FCU-3	29,699	32,000	17,203	46%
3-Bd, FCU-4	34,526	40,000	18,153	55%

Block Heating Load Calculation

MEP Calc:	Apts. Only	88.6 tons
BEC Calc:	Apts. Only	52.3 tons
	Whole building	67.4 tons

Total Installed Building Heating Capacity:

121 tons

Mid-Rise Multifamily, New Construction

Choose your next move:

Apply a diversity factor for outdoor equipment:

A: <100%

B: 110%

C: >125%

Diversity factor:

Ratio of indoor equipment capacity to outdoor equipment capacity

Design Team Answer:

Apply a diversity factor for outdoor equipment:

A: <100%

B: 110%

C: >125%

Diversity factor:

Ratio of indoor equipment capacity to outdoor equipment capacity

No load diversity applied

Indoor Equipment	MEP HL Calc (MBH)	Qty.	Total Load (MBH)
Apt, FCU-1	20	1	20
Apt, FCU-2	27	17	459
Apt, FCU-3	32	12	384
Apt, FCU-4	40	9	360
Common, FCU-5	13.5	8	108
Common, FCU-6	20	3	60
Common, FCU-7	28	1	28
Total			**1419**

Outdoor Equipment	MEP HL Capacity (MBH)
HP-1	215
HP-2	215
HP-3	270
HP-4	215
HP-5	270
HP-6	215
HP-7	54
Total	**1454**

How did first winter electric bills compare to anticipated?

A: About the same

B: 1.5 x

C: 2 x

D: 2.5 x

How did first winter electric bills compare to anticipated?

D: 2.5 x

$30-40k/Month

200 kW demand charge

$0.48/kWh (blended)

Funding risk for phase 2!

Historic Church, HVAC Replacement

Symptoms

- High energy bills
- Premature component failure
- Temperature not maintained

Historic Church, HVAC Replacement

Electric Resistance Heating

ELECTRIC DUCT HEATER SCHEDULE (EDH)												
MARK	SERVES	MAKE	MODEL	SIZE (W x H)	CFM	EAT	LAT	KW	VOLT/PH	AMPS	CONTROL	NOTES
EDH-1	ERV-1 POSTHEAT	QMARK	FC/SC (OPEN COIL)	24x14	1,425	46.9	73.5	12.0	208/3	33.3	HYBRID	1,2
EDH-2	NOT USED											
EDH-3												
EDH-4	ERV-4 POSTHEAT	QMARK	FC/SC (OPEN COIL)	12X12	750	46.0	71.3	6.0	208/3	16.6	SCR	1,2
EDH-5	ERV-5 PREHEAT	QMARK	FC/SC (OPEN COIL)	20x8	700	0.0	27.1	6.0	208/3	16.6	SCR	1,2
EDH-6	ERV-6 PREHEAT	QMARK	FC/SC (OPEN COIL)	20x12	950	0.0	26.6	8.0	208/3	22.2	SCR	1,2
EDH-7	ERV-7 PREHEAT	QMARK	FC/SC (OPEN COIL)	10x8	325	0.0	29.2	3.0	208/3	8.3	SCR	1,2
EDH-8	VRF-IN-1-8 2ND STAGE	QMARK	FC/SC (OPEN COIL)	14X14	800-990	68.0	93.5	8.0	208/3	22.2	SCR	1,2
EDH-9	VRF-IN-2-1 2ND STAGE	QMARK	FC/SC (OPEN COIL)	24X12	1260-1475	68.0	88.1	8.0	208/3	22.2	SCR	1,2
EDH-10	VRF-IN-2-2 2ND STAGE	QMARK	FC/SC (OPEN COIL)	24X12	1260-1475	68.0	88.1	8.0	208/3	22.2	SCR	1,2
EDH-11	VRF-IN-3-1 2ND STAGE	QMARK	FC/SC (OPEN COIL)	16X16	1260-1475	68.0	118.2	20.0	208/3	55.5	HYBRID	1,2
EDH-12	VRF-IN-3-2 2ND STAGE	QMARK	FC/SC (OPEN COIL)	16X16	1260-1475	68.0	118.2	20.0	208/3	55.5	HYBRID	1,2
EDH-13	VRF-IN-3-3 2ND STAGE	QMARK	FC/SC (OPEN COIL)	12X12	480-710	68.0	112.5	10.0	208/3	27.8	SCR	1,2
EDH-14	VRF-IN-4-1 2ND STAGE	QMARK	FC/SC (OPEN COIL)	16X16	1260-1475	68.0	118.2	20.0	208/3	55.5	HYBRID	1,2
EDH-15	VRF-IN-4-2 2ND STAGE	QMARK	FC/SC (OPEN COIL)	24X12	1260-1475	68.0	118.2	20.0	208/3	55.5	HYBRID	1,2
EDH-16	VRF-IN-5-6 2ND STAGE	QMARK	FC/SC (OPEN COIL)	16X16	1000-1400	68.0	131.2	20.0	208/3	55.5	HYBRID	1,2
NOTES:												
1. AIRFLOW SWITCH, DOOR INTERLOCKING DISCONNECT, DUCT THERMOSTAT												
2. PER MANUFACTURER'S INSTRUCTIONS, HEATER SHOULD NOT BE INSTALLED CLOSER THAN 18" DOWNSTREAM FROM A FAN OUTLET OR 24" UPSTREAM FROM ANY TAKE-OFFS, TRANSITIONS OR ELBOWS IN THE DUCTWORK												

Electric Resistance Heating

4) IN THE ZONES WITH SECOND STAGE ELECTRIC DUCT HEATERS OR SECOND STAGE ELECTRIC BASEBOARD (VRF-IN-1-8, VRF-IN-2-1, VRF-IN-2-2, VRF-IN-3-1, VRF-IN-3-2, VRF-IN-3-3, VRF-IN-4-1, VRF-IN-4-2, VRF-IN-5-6, VRF-IN-6-1, VRF-IN-6-4) IF THE ASSOCIATED THERMOSTAT (OR TEMPERATURE SENSOR) SENSES THAT THE SPACE TEMPERATURE HAS DROPPED 3°F BELOW SET POINT THE THERMOSTAT SHALL ENERGIZE THE SECOND STAGE ELECTRIC ELEMENT. THE VRF SYSTEM SHALL CONTINUE TO OPERATE WHILE THE SECOND STAGE HEAT IS OPERATING.

											ONTROL	NOTES
											HYBRID	1,2
											SCR	1,2
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EDH-9	VRF-IN-2-1 2ND STAGE	QMARK	FC/SC (OPEN COIL)	24X12	1260-1475	68.0	88.1	8.0	208/3	22.2	SCR	1,2
EDH-10	VRF-IN-2-2 2ND STAGE	QMARK	FC/SC (OPEN COIL)	24X12	1260-1475	68.0	88.1	8.0	208/3	22.2	SCR	1,2
EDH-11	VRF-IN-3-1 2ND STAGE	QMARK	FC/SC (OPEN COIL)	16X16	1260-1475	68.0	118.2	20.0	208/3	55.5	HYBRID	1,2
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EDH-13	VRF-IN-3-3 2ND STAGE	QMARK	FC/SC (OPEN COIL)	12X12	480-710	68.0	112.5	10.0	208/3	27.8	SCR	1,2
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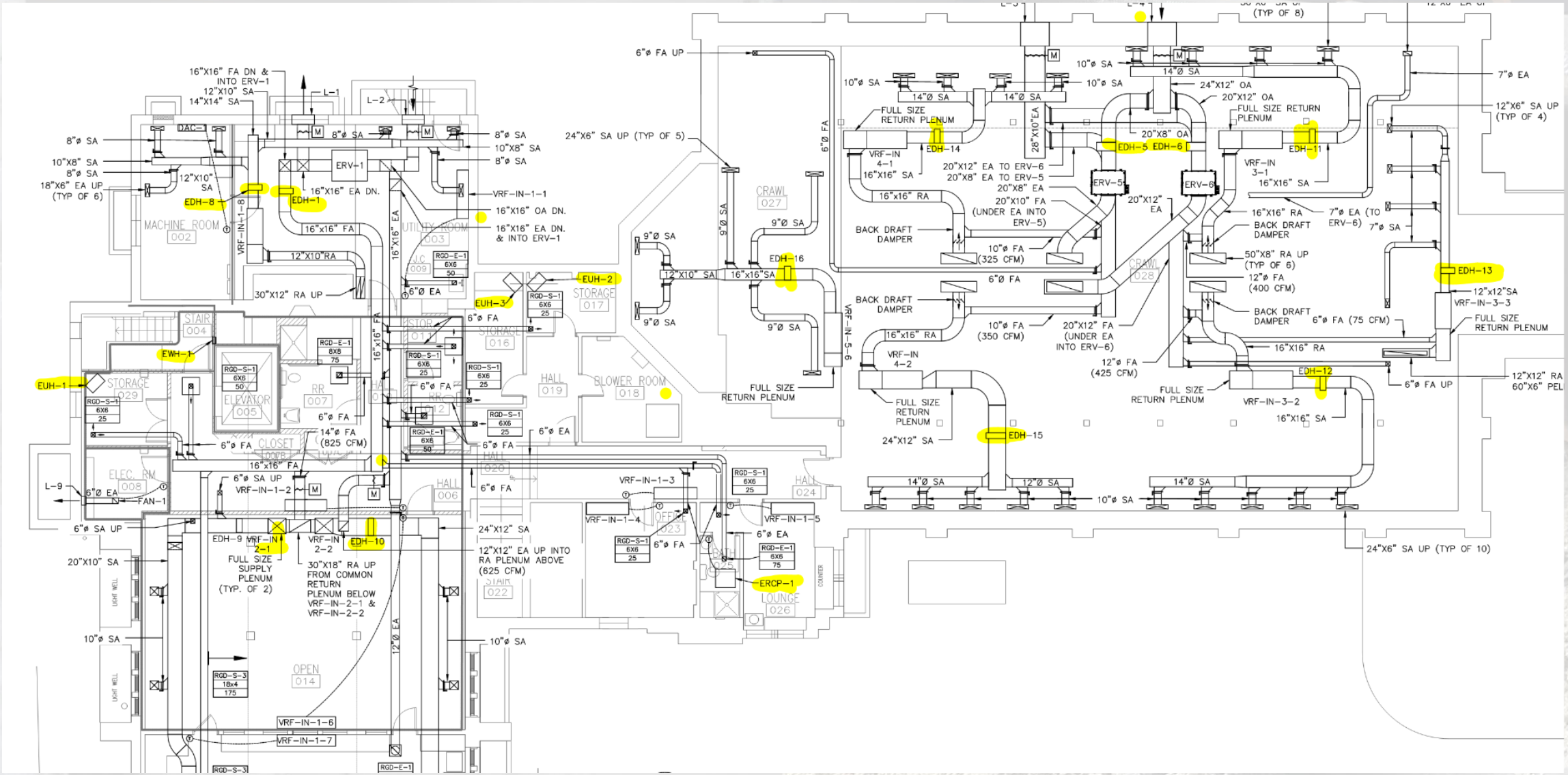
Electric Resistance Heating



Historic Church, HVAC Replacement

It’s time for a … Quiz Question!

Which outdoor unit is not working?

Is it A?

←

Or is it B?

→

Historic Church, HVAC Replacement

Answer: Trick question!

This one is working poorly

←

This one is dead!

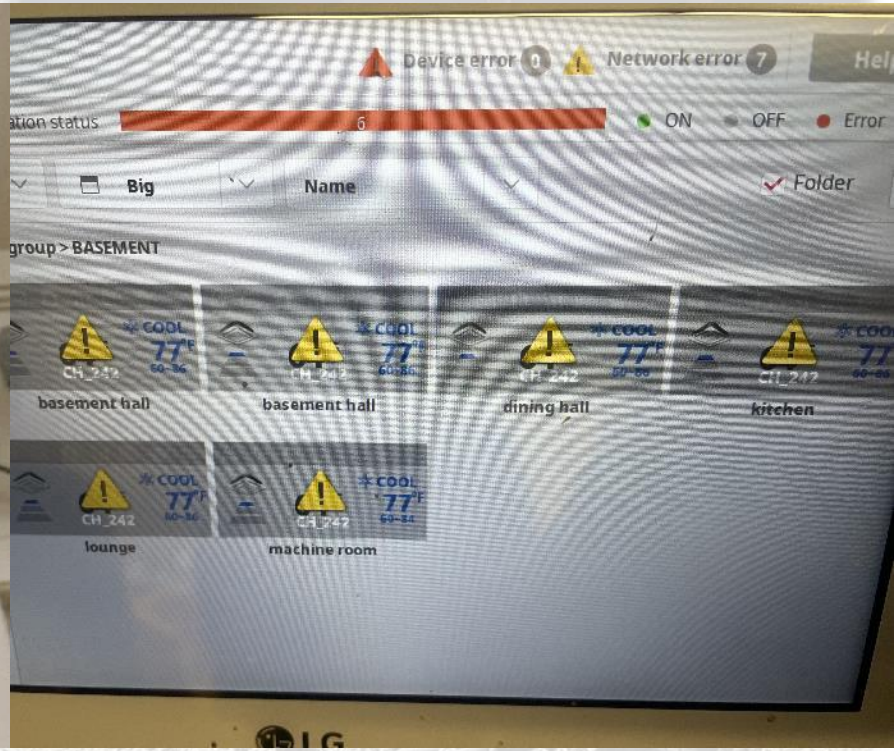
→

Historic Church, HVAC Replacement

What’s wrong with this replacement valve?

Historic Church, HVAC Replacement

Failing or Inoperable Equipment



Historic Church, HVAC Replacement

It’s time for another … Quiz Question!

How should refrigerant branches be oriented?

A: Vertical

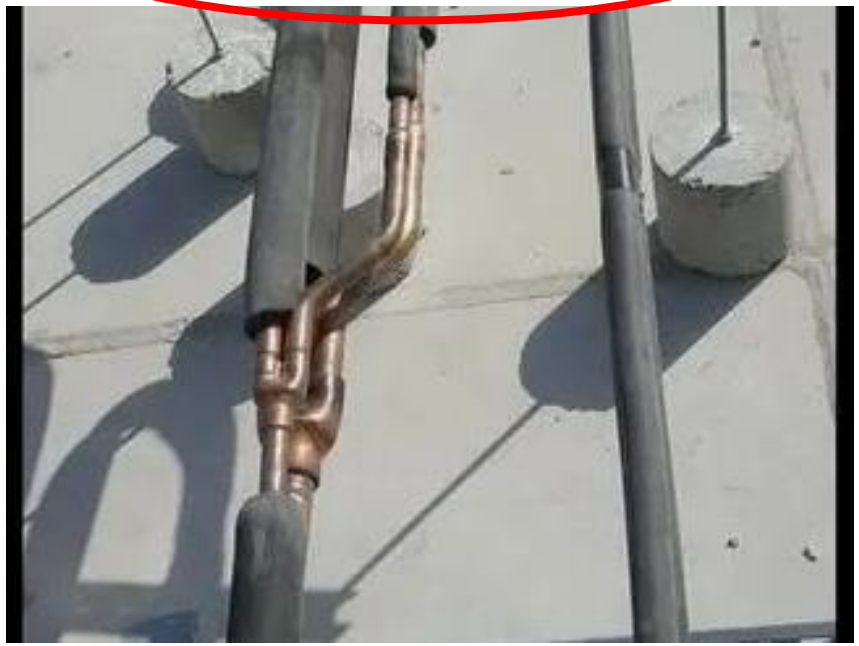
B: Horizontal

Historic Church, HVAC Replacement

Answer:

A: Vertical

B: Horizontal



Poor installation – Refrigerant lines

Historic Church, HVAC Replacement

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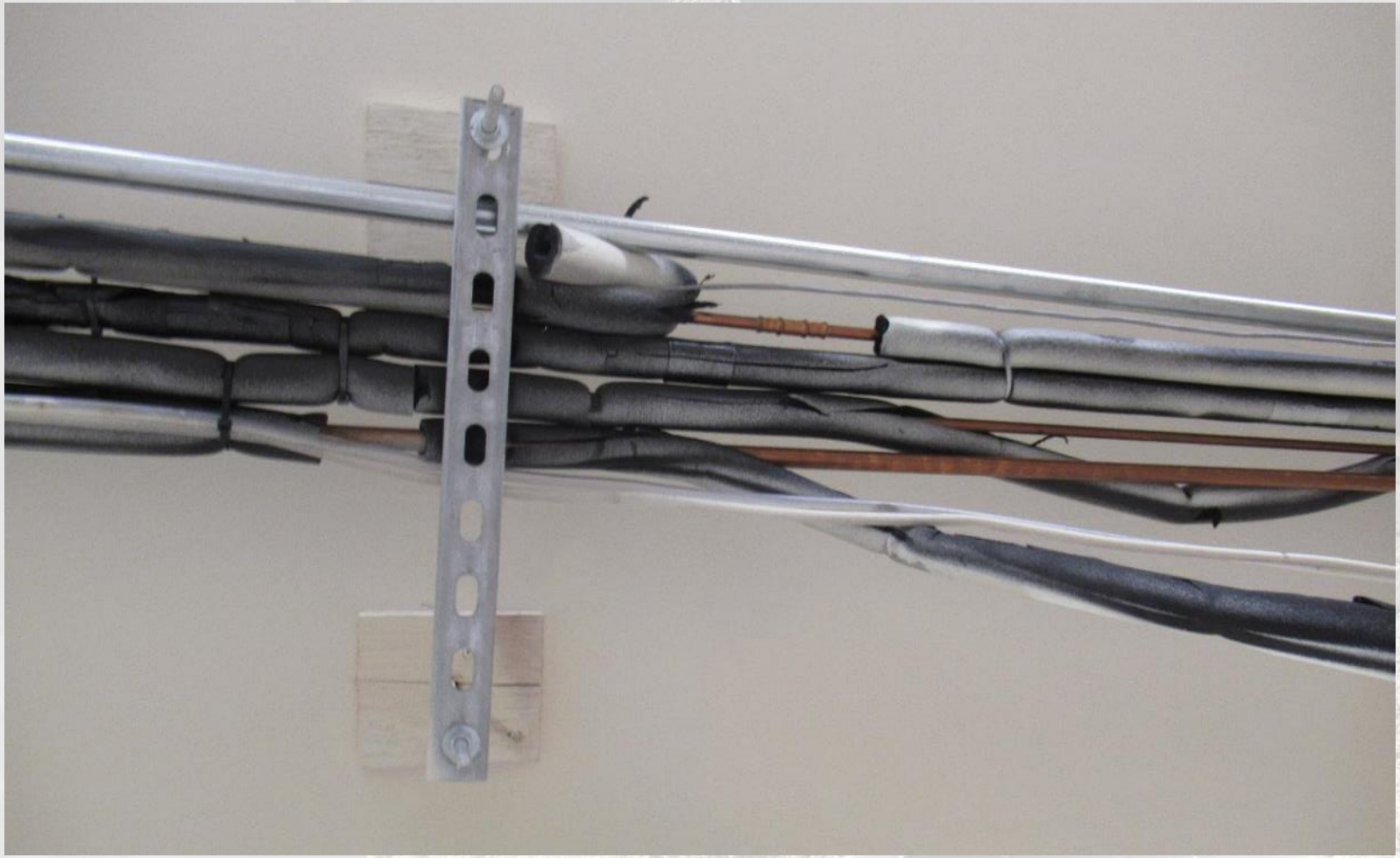
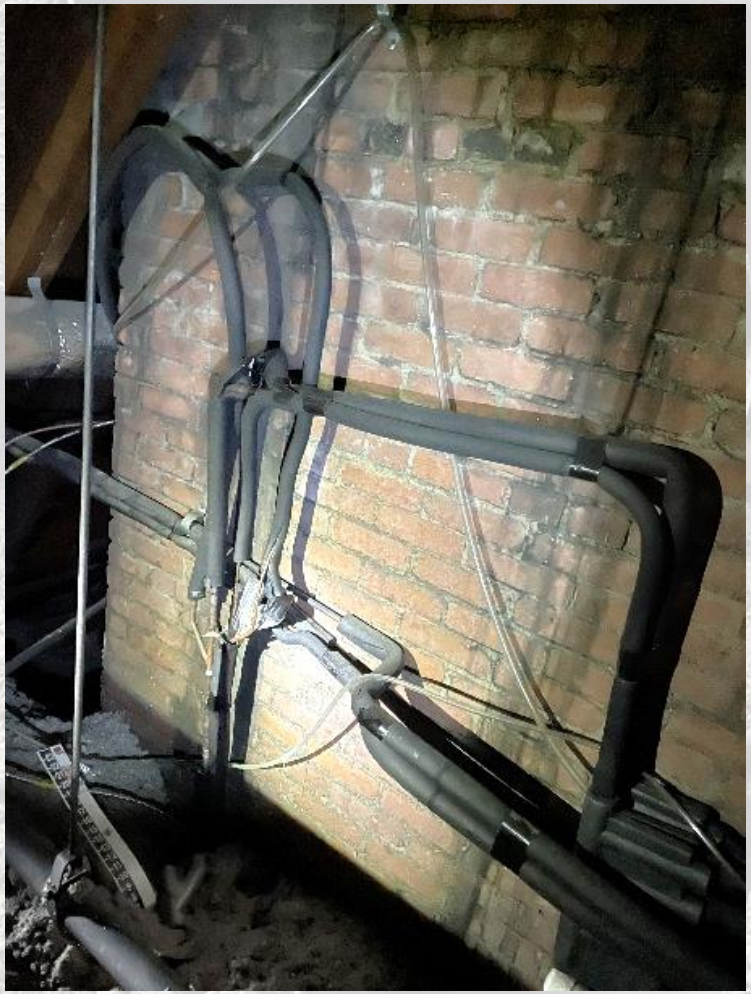
Historic Church, HVAC Replacement

Poor installation – Refrigerant lines



Historic Church, HVAC Replacement

Poor installation – Refrigerant lines



Historic Church, HVAC Replacement

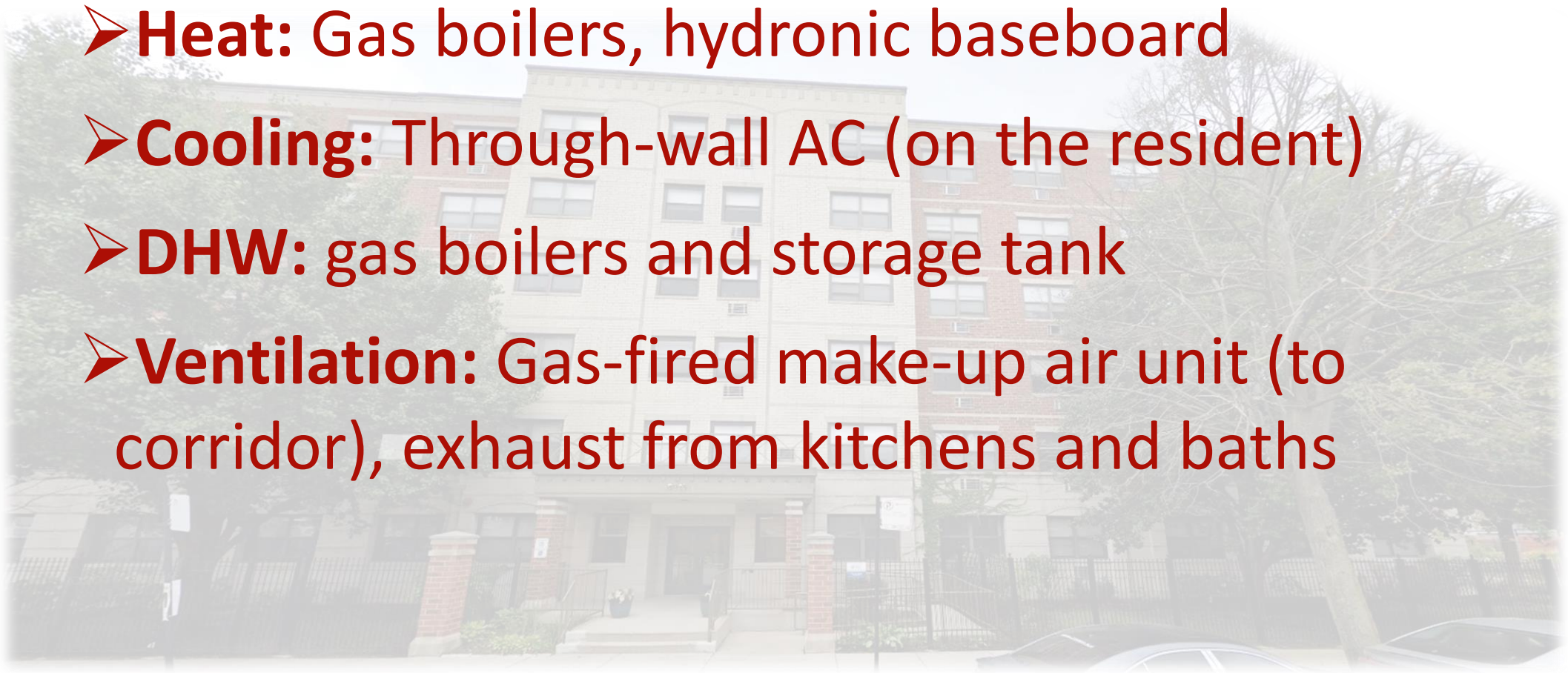
Poor installation – Wiring

Historic Church, HVAC Replacement

Poor installation – Condensate

Early 2000s, Mid-Rise, Affordable Senior Housing, HVAC Retrofit

Initial Decarbonization Narrative



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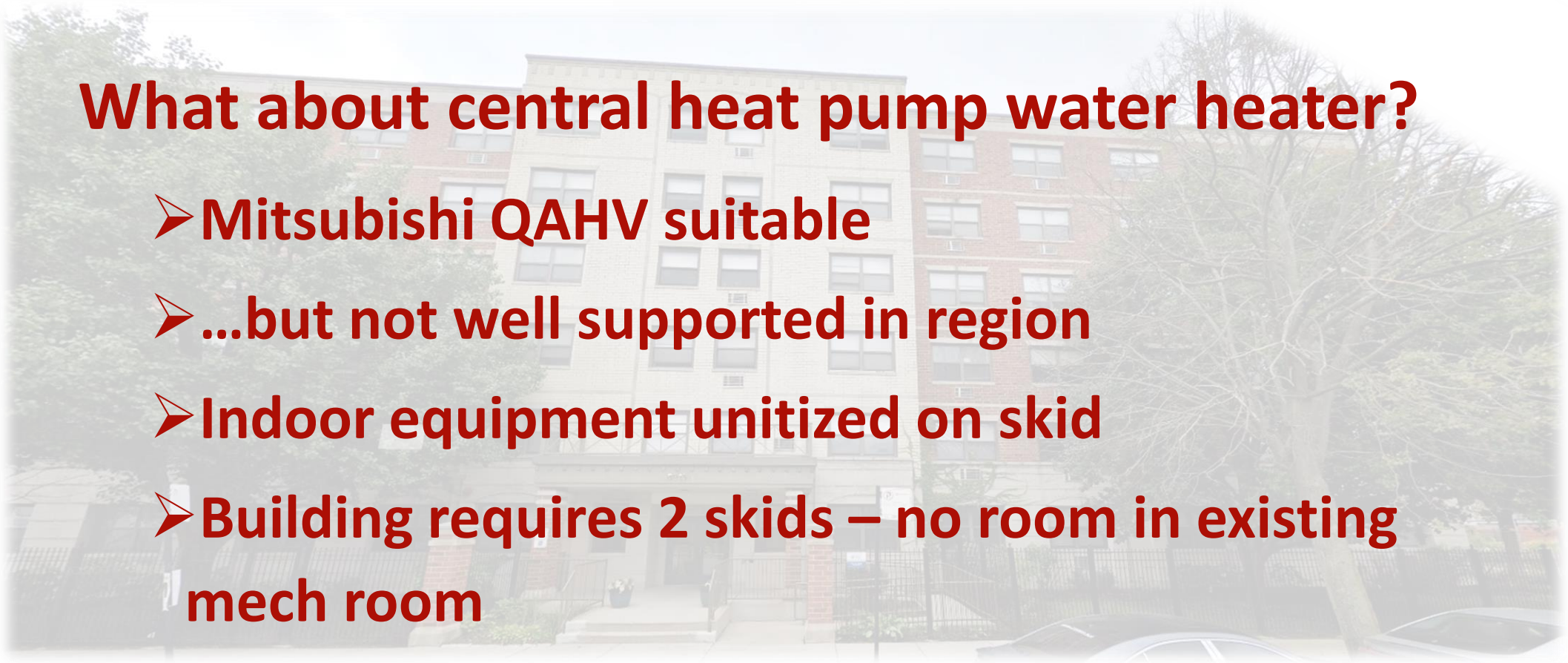
- **Cooling:** Through-wall AC (on the resident)
- **DHW:** gas boilers and storage tank
- **Ventilation:** Gas-fired make-up air unit (to corridor), exhaust from kitchens and baths

What does electrification mean?

Developing Options - DHW



What about central heat pump water heater?

- **Mitsubishi QAHV suitable**
- **…but not well supported in region**
- **Indoor equipment unitized on skid**
- **Building requires 2 skids – no room in existing mech room**

Choose your next move:

Path A:

Use central Heat Pump water heater: Take space from community room to expand mechanical room

Path B:

Retain gas heating boilers and DHW storage tank

Design Team Answer:

Path A:

Use central Heat Pump water heater: Take space from community room to expand mechanical room

Path B:

Retain gas heating boilers and DHW storage tank

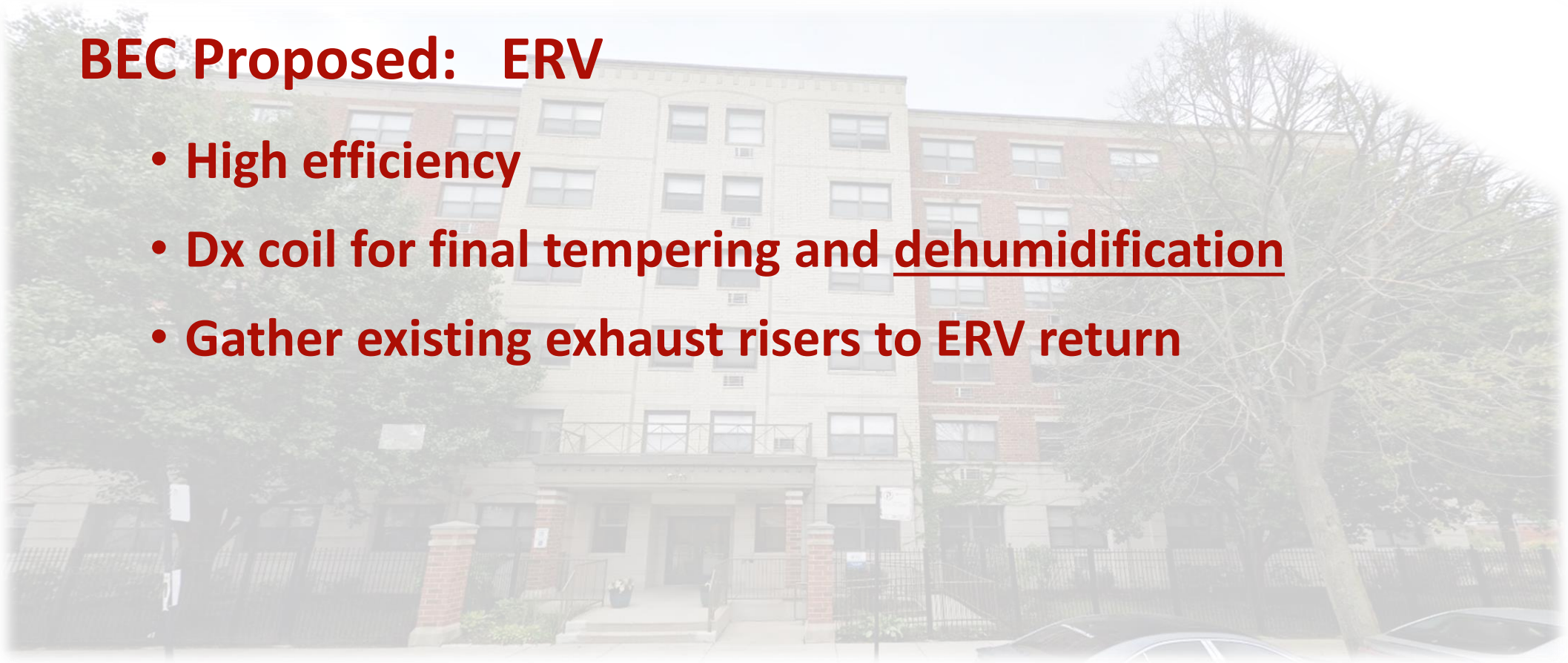
Developing Options – DHW

Staying with gas… for now

Developing Options – DHW

Staying with gas for now … and hope that something better comes along

Developing Options – Ventilation



BEC Proposed: ERV

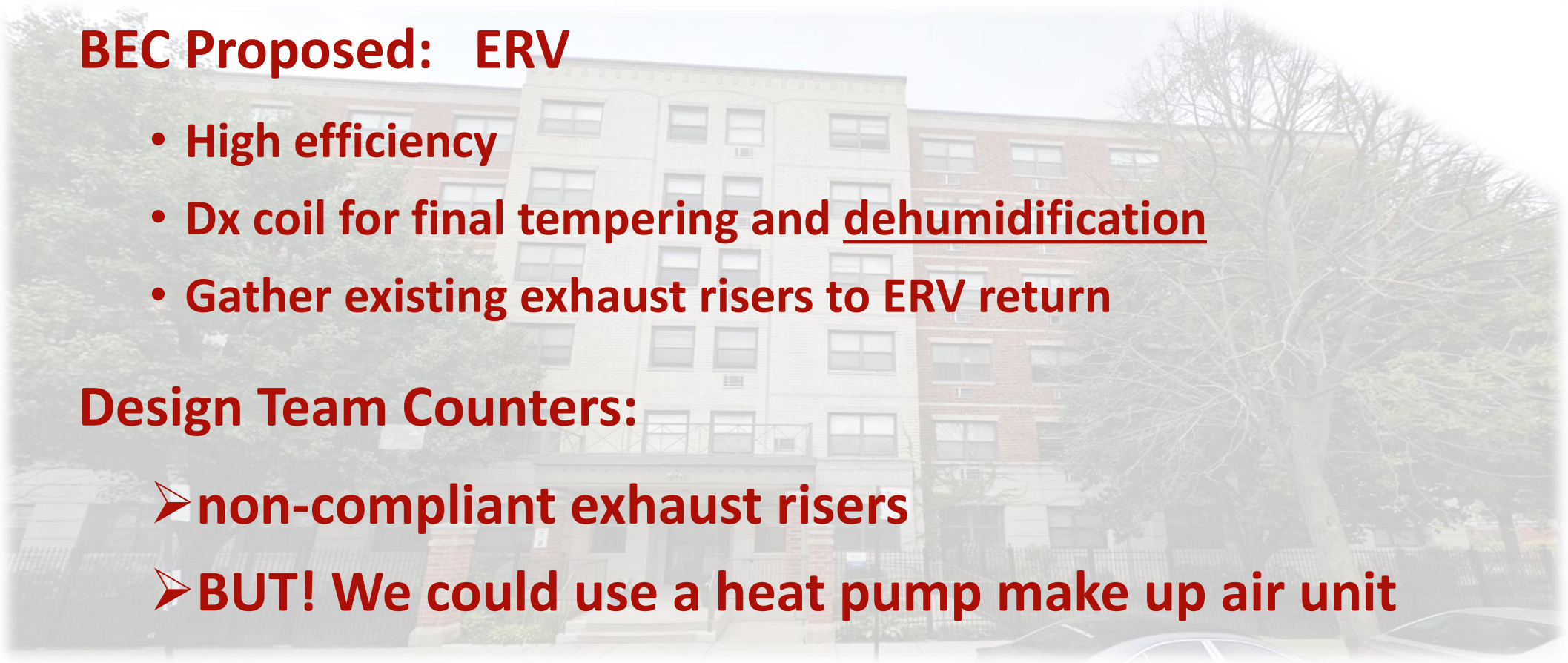
- **High efficiency**
- **Dx coil for final tempering and dehumidification**
- **Gather existing exhaust risers to ERV return**

Developing Options – Ventilation

Developing Options – Ventilation

Senior Housing Retrofit

Case 3: Developing Options – Ventilation



BEC Proposed: ERV

- **High efficiency**
- **Dx coil for final tempering and dehumidification**
- **Gather existing exhaust risers to ERV return**

Design Team Counters:

- **non-compliant exhaust risers**
- **BUT! We could use a heat pump make up air unit**

Choose your next move:

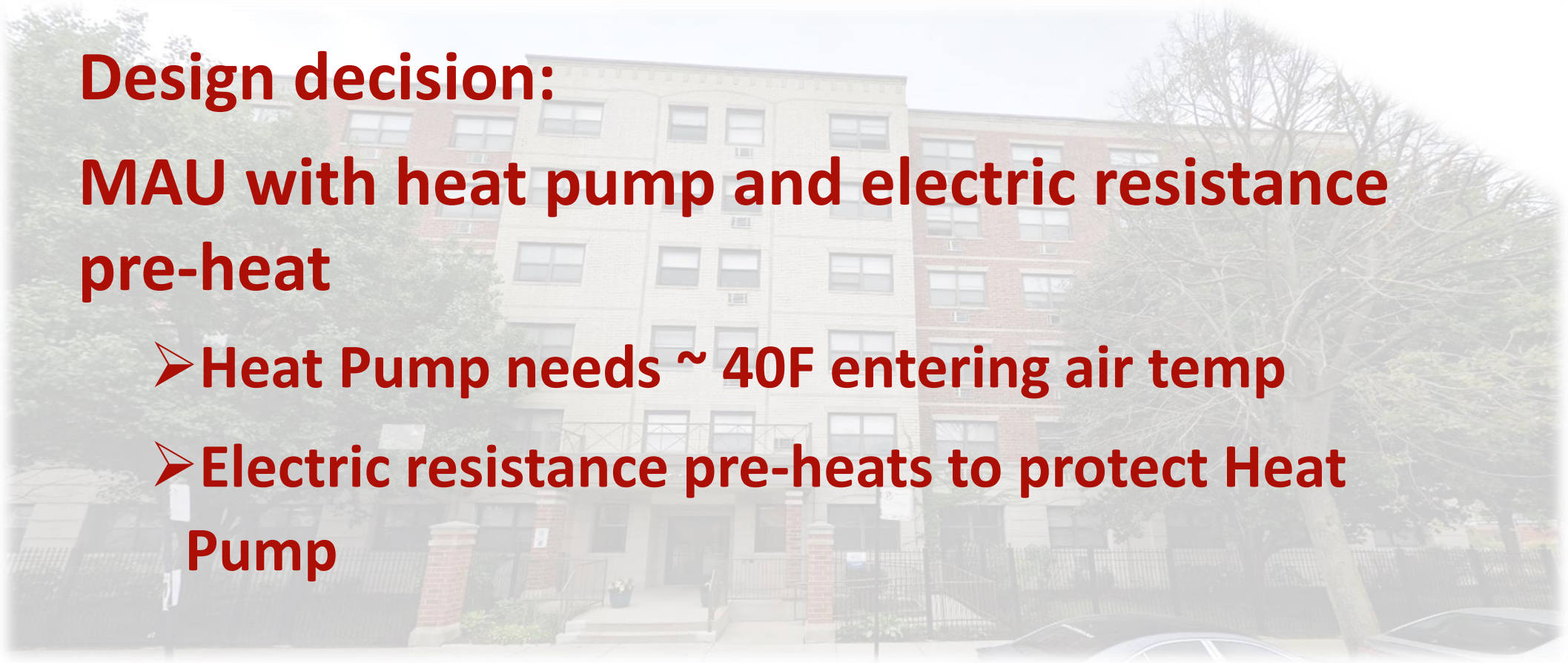
Path A:

Use High Efficiency ERV: Demo ceilings to install fire/smoke damper and ductwork at each toilet exhaust

Path B:

Go back with 100% outdoor air make-up air unit (MAU) that has heat pump heating

Developing Options – Ventilation



Design decision:

MAU with heat pump and electric resistance pre-heat

- **Heat Pump needs ~ 40F entering air temp**
- **Electric resistance pre-heats to protect Heat Pump**

Does a Heat Pump Make it Better?

Annual Savings Comparison			
	Heat Pump MAU No Energy Recovery	Heat Pump MAU (w/ Energy Recovery)	Gas-Fired MAU (No Energy Recovery)
Utility Costs	10%	18%	13%
Site EUI	42%	49%	26%
Source EUI	11%	23%	13%

Senior Housing Retrofit

Mid-Rise Multifamily, Senior Living, New Construction

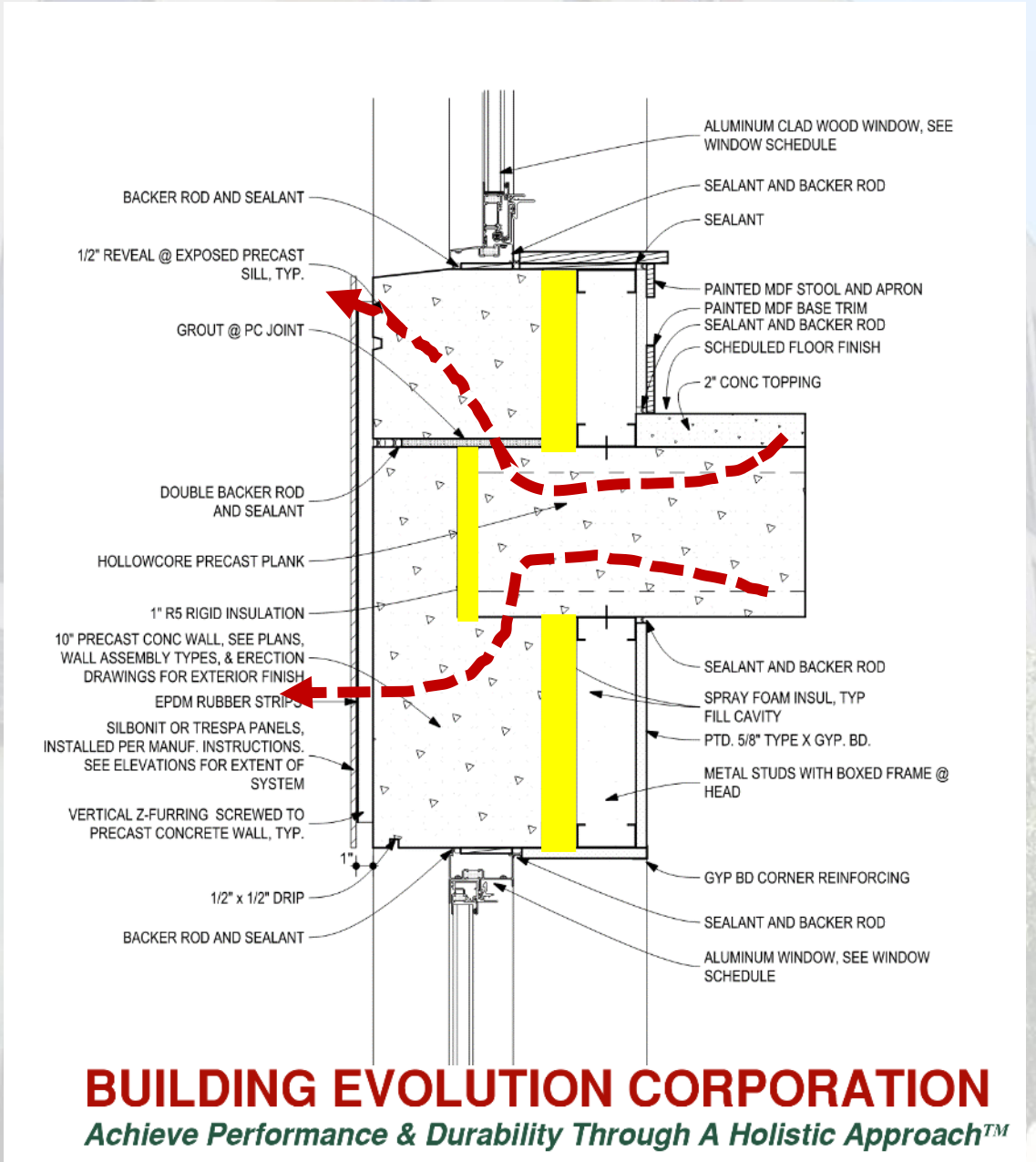
Mid-Rise, Senior Living, New Construction

Problems:

- Poor comfort
- High operational cost

Mechanisms for Problems

- Poor enclosure
- VRF Discharge Air Temp
- Poorly conceived and executed Ventilation

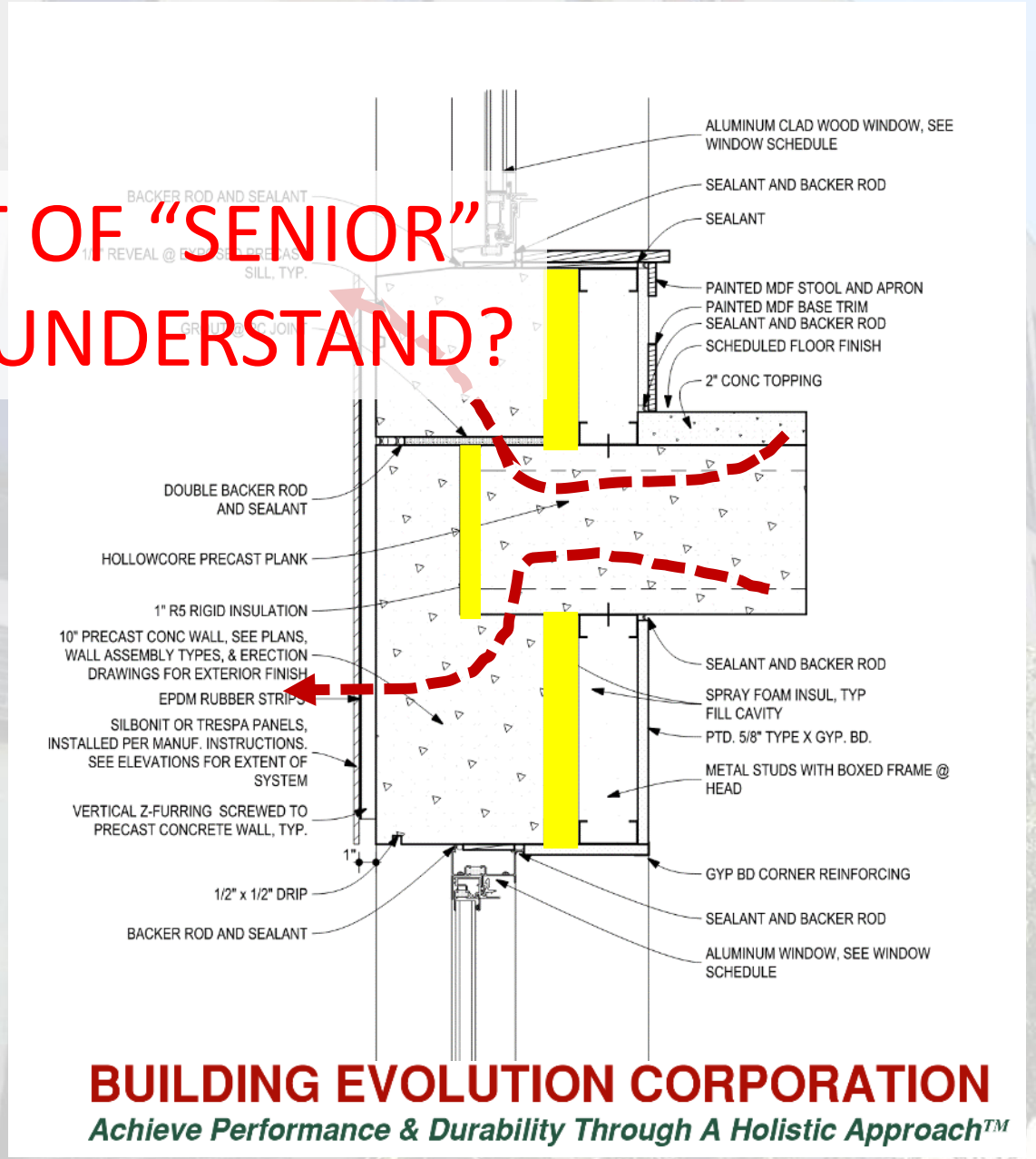


Mid-Rise, Senior, New Construction

Mechanisms for Problems

- Poor enclosure
- VRF Discharge Air Temp
- Poorly conceived and executed Ventilation

WHAT PART OF "SENIOR" DON'T YOU UNDERSTAND?



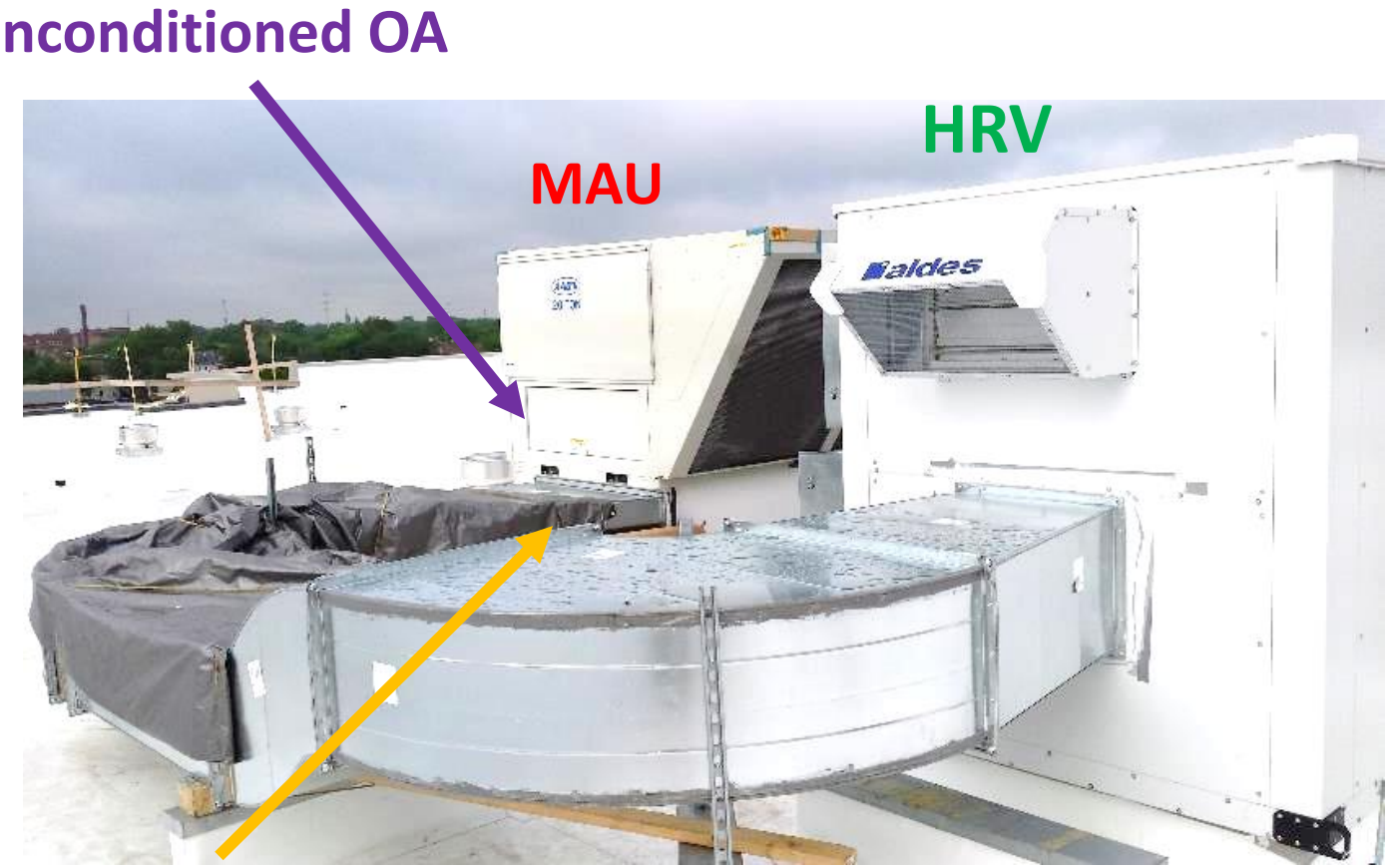
BUILDING EVOLUTION CORPORATION

Achieve Performance & Durability Through A Holistic Approach™

Mid-Rise, Senior, New Construction

Poorly Conceived, Poorly executed Ventilation

- ~60% eff ERV
- ERV supply MIXED with outdoor air



Mid-Rise, Senior, New Construction

Poorly Conceived, Poorly executed Ventilation

- Cool ventilation air discharged to heads
- Compensate by increasing set point for gas-fired Make-up Air Unit (MAU)

How to fix this?

On Every Street

On Every Street

- ✓~ 100 y.o.
- ✓Walking distance to downtown
- ➢Major renovation

Small scale retrofit

Choose your next move:

Path A:

Install Heat Pumps to get heating off fossil fuels

Path B:

Retrofit a robust air and water barrier and install thick continuous exterior insulation

Small scale retrofit

Project Direction Observed

Small scale retrofit

Project Direction Observed

Small scale retrofit

Observations (On Every Street)

Small scale retrofit

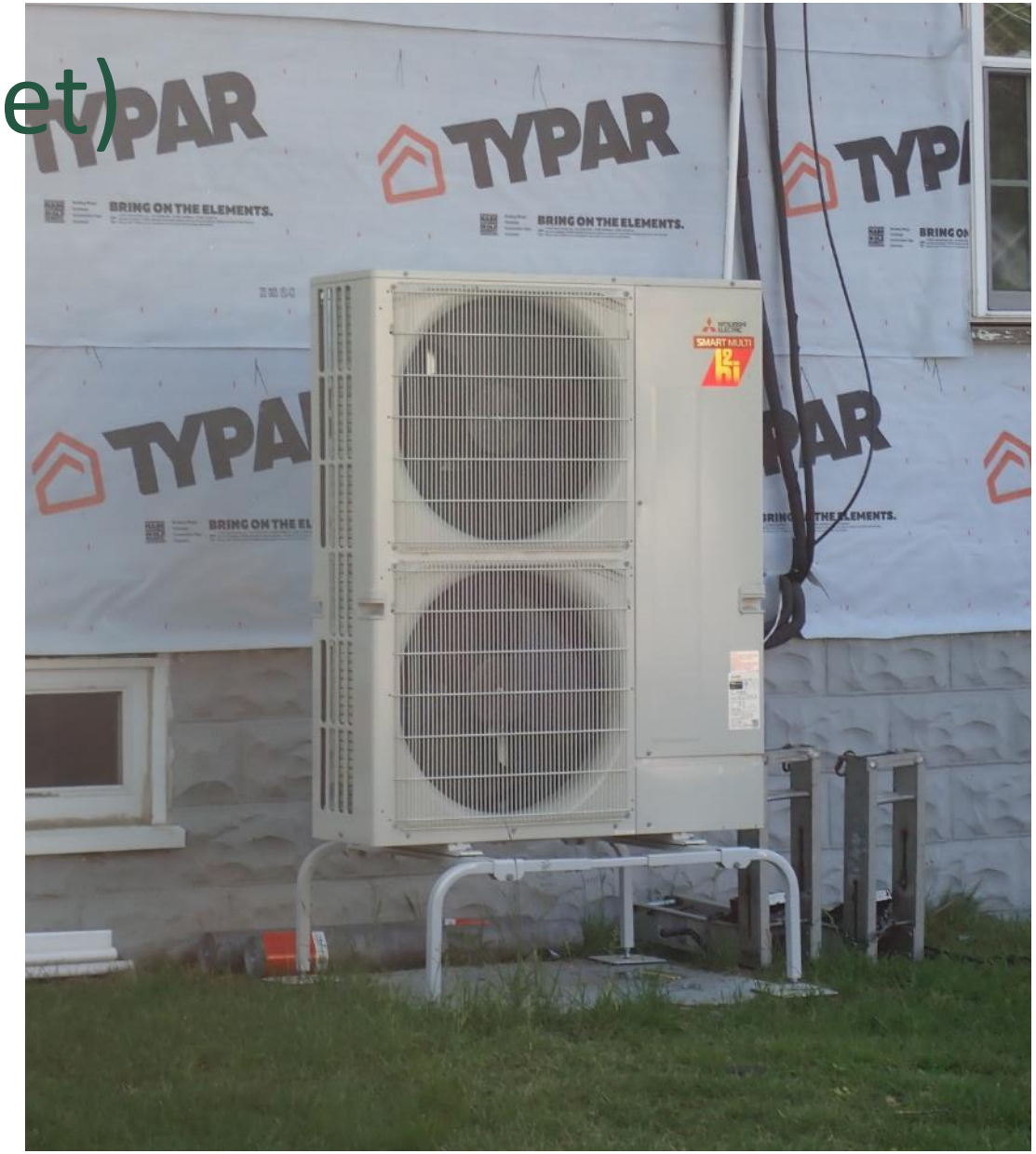
Observations (On Every Street)

Small scale retrofit

Observations (On Every Street)

Small scale retrofit

Observations (On Every Street)



Small scale retrofit

On Every Street

Yes, it's handsome but…

missed opportunity to

- **Significantly reduce loads**
- **Improve durability**
- **Increase resilience**
- **Set the stage for better air quality**

Small scale retrofit

On Every Street

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Small scale retrofit

On Every Street

Yes, it's handsome but…

missed opportunity to

- Significantly reduce loads
- Improve durability
- Increase resilience
- Set the stage for better air quality

But is this opportunity common?

Small scale retrofit

On Every Street

Small scale retrofit

On Every Street

Small scale retrofit

On Every Street

Small scale retrofit

On Every Street

Small scale retrofit

On Every Street

Small scale retrofit

BUILDING EVOLUTION CORPORATION

Achieve Performance & Durability Through A Holistic Approach™

On Every Street

Small scale retrofit

On Every Street

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Small scale retrofit

On Every Street

Small scale retrofit

On Every Street

Small scale retrofit

On Every Street

What are we missing?

Small scale retrofits represent opportunity to…

- **Reduce loads on grid (equity, societal infrastructure cost)**
- **Decarbonize regardless of heating strategy**
- **Improve durability (protect embodied carbon)**
- **Increase resilience, comfort**
- **Set the stage for better air quality**

Small scale retrofit

Common Pitfalls, Recurring Challenges

This stuff just keeps happening!

Here’s what we see

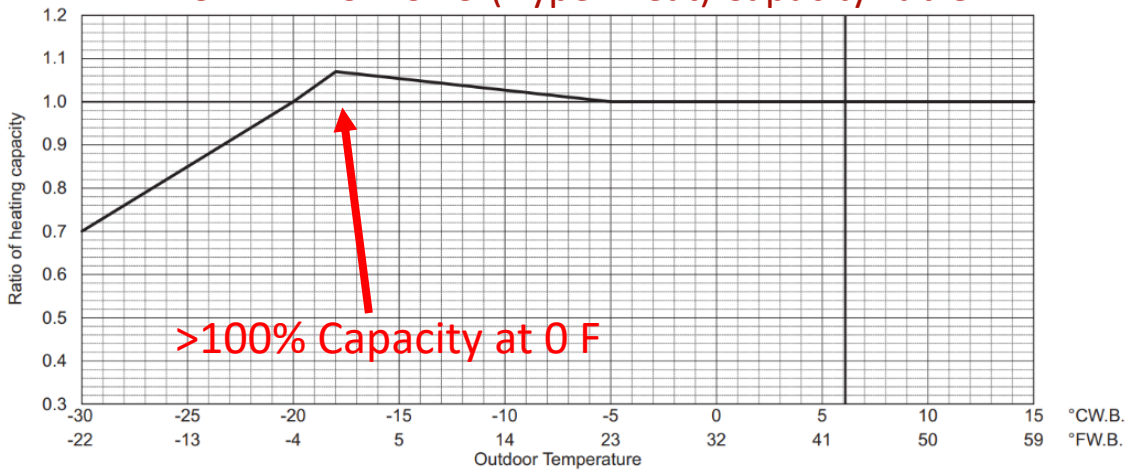
- Entrenched Habits
- Not understanding the Technology / Applied misinformation
- Workmansh#t
- Devalue Engineering
- Blindspots

Here's what we see

- Entrenched Habits
  - "Rule of Dumb" sizing
  - Ignoring load diversity in sizing
  - Assuming cooling = dehum.
  - We don't need ERV/HRV
  - Assume heat pumps derate in cold climates

(60% derate at 0F)

PURY-HP192TSNU (Hyper Heat) Capacity Table



Here's what we see

- Not understanding the Technology / Applied misinformation
  - Equipment not appropriate for climate
  - Assume heat pumps don't work in cold climates
  - Ignoring high-performance enclosure
  - Assuming cooling = dehum.
  - Assume heat pumps derate in cold climates
  - Ignoring load diversity in sizing

Here’s what we see

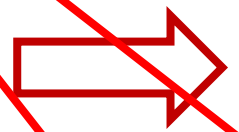
- Workmansh#t
  - Refrigerant traps
  - Bad connections
  - Pipes/linesets left open to atmosphere

Here's what we see

- Devalue Engineering
  - Not including highest efficiency recovery on ventilation
  - Non-heat recovery VRF
  - Not doing Cx
  - Pull back on enclosure performance
- Blind spots
  - Missing enclosure opportunities

Here's what happens

- Entrenched Habits
- Not understanding the Technology / Applied misinformation
- Workmansh#t
- Devalue Engineering
- Blindspots



- Over-sized systems
- Shortened equipment life
- High bills
- Poor humidity control
- Poor comfort
- Unnecessary reliance on back-up systems
- Refrigerant leaks
- Increased operational carbon

Here's what happens

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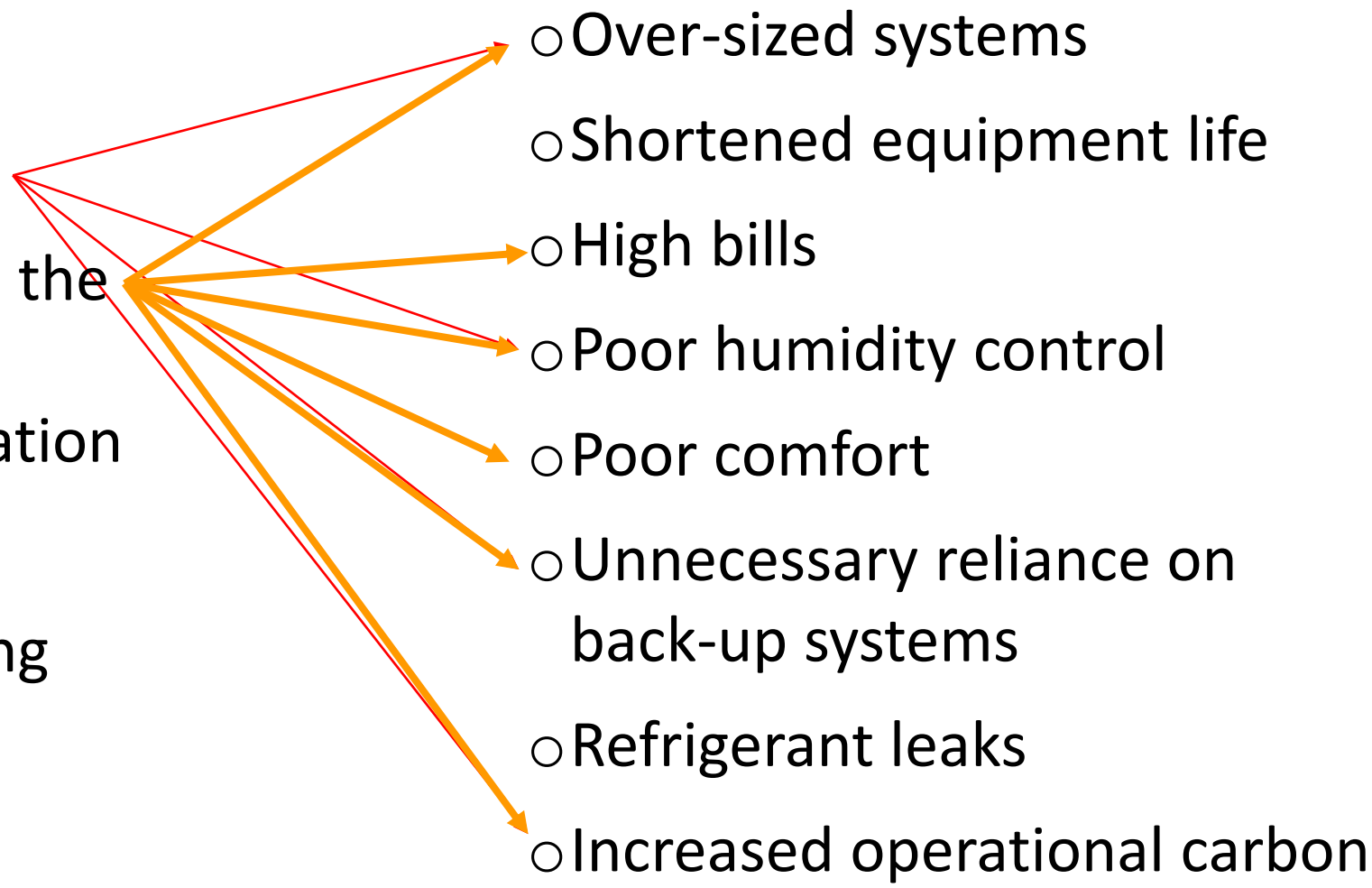
- Blindspots



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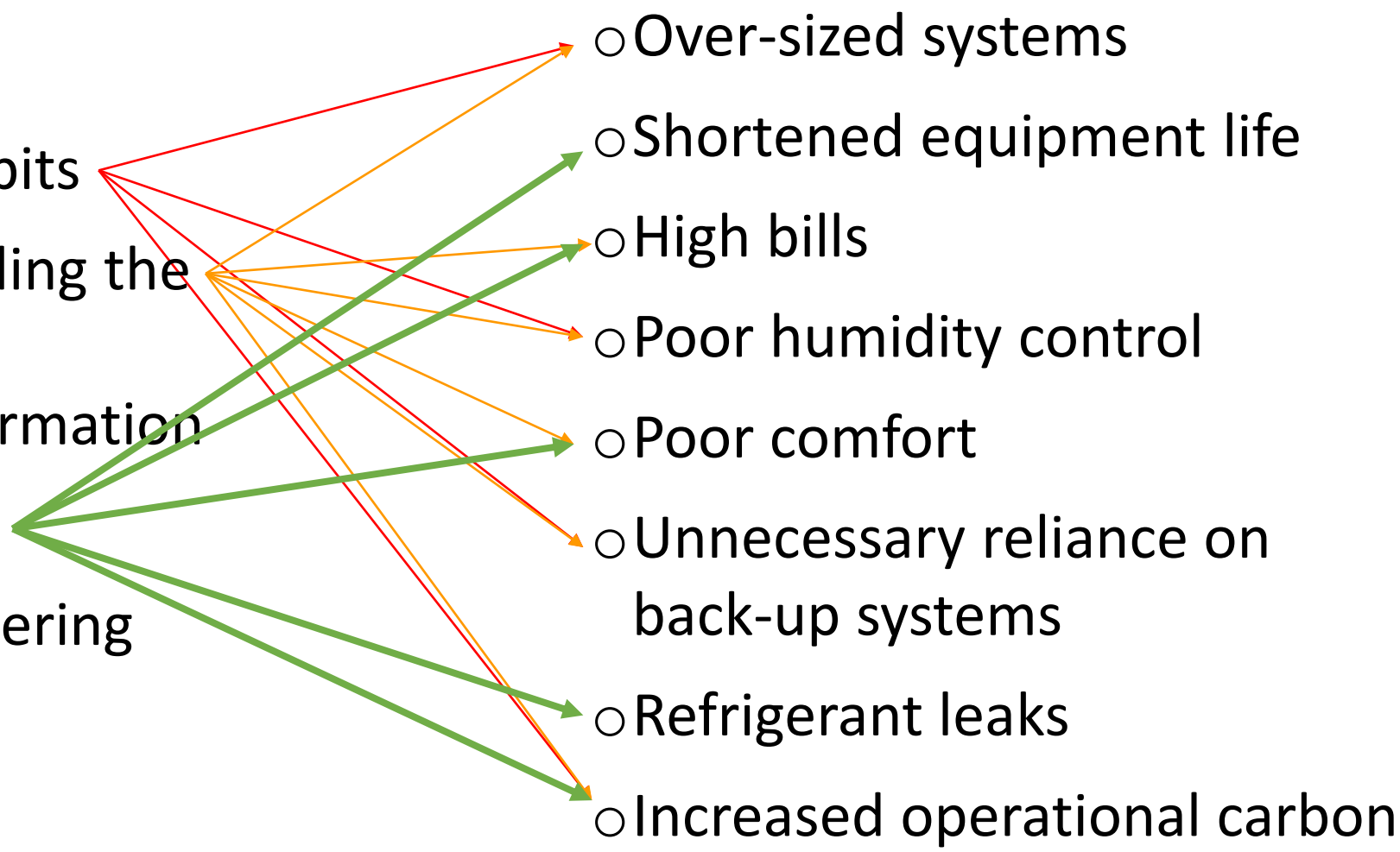

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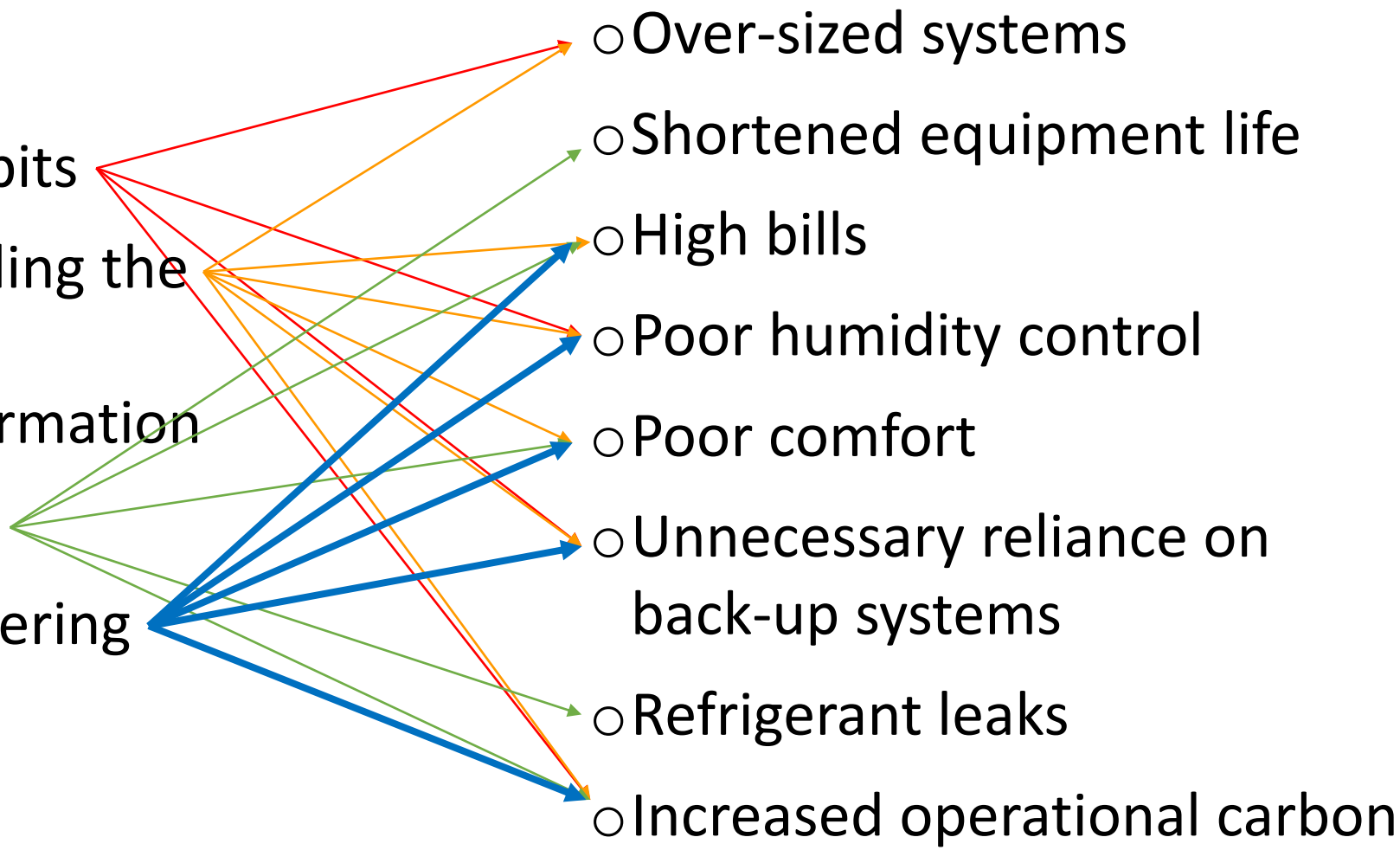

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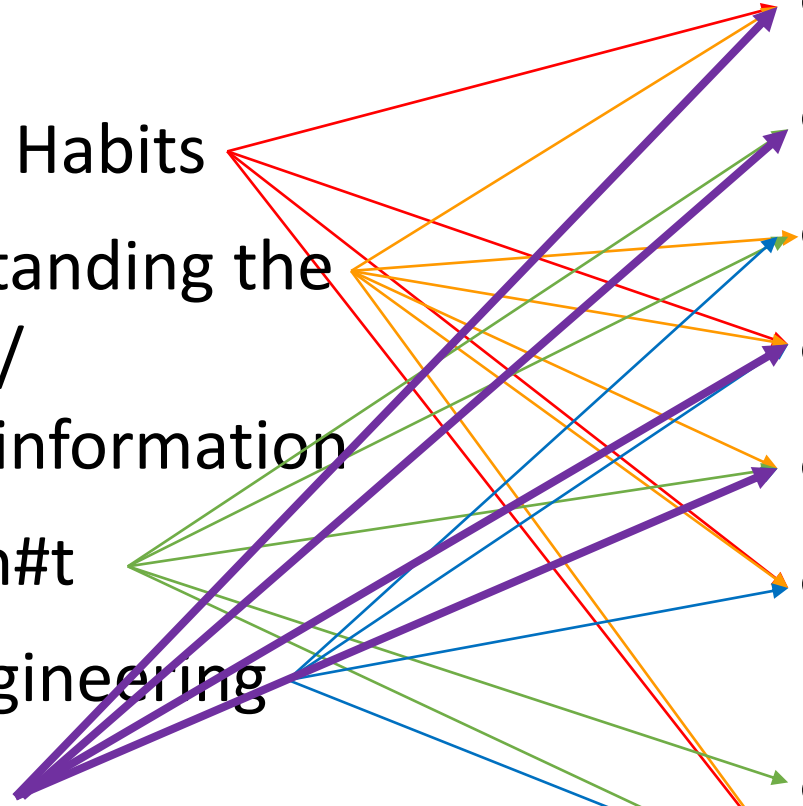

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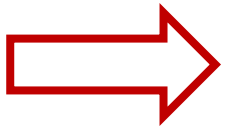

- Over-sized systems
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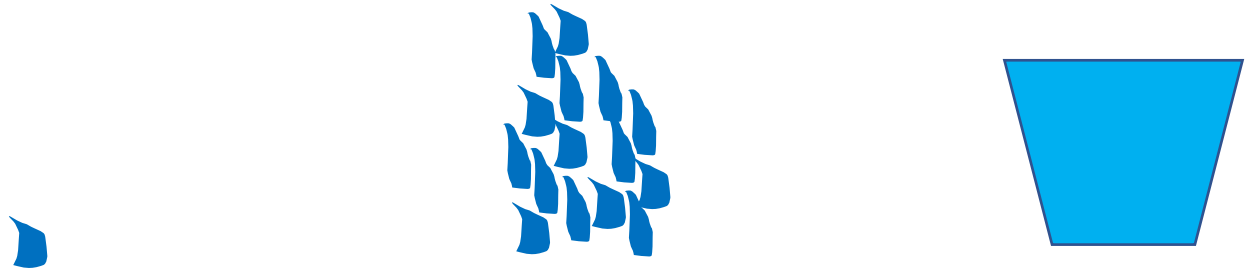
Humidity Ratio Grains/Lb da



Small Drip of H2O

~7,000 Grains = 1 Pint

1 Pint= ~1,000 Btu/h

Humidity Ratio Describes the Amount of Water contained in 1 Lb of Dry Air at Standard Conditions

MITSUBISHI ELECTRIC
COOLING & HEATING

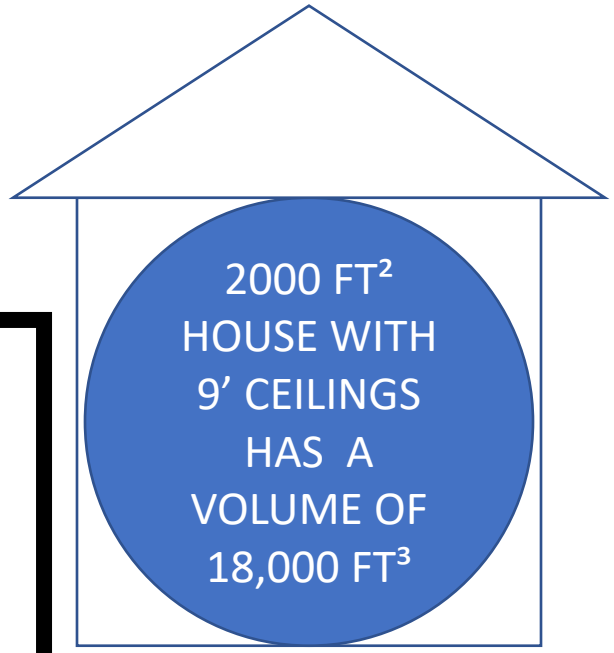
WHY 80 CFM? SPLIT THE DIFFERENCE

4.1.1 Total Ventilation Rate. The total required ventilation rate (Q_{tot}) shall be as specified in Table 4.1a or Table 4.1b or, alternatively, calculated using Equation 4.1a or Equation 4.1b.

$$Q_{tot} = 0.03A_{floor} + 7.5(N_{br} + 1) \qquad \text{(I-P)} \quad (4.1a)$$

where

Q_{tot} = total required ventilation rate, cfm
A_{floor} = dwelling-unit floor area, ft^2
N_{br} = number of bedrooms (not to be less than 1)



Required CFM 2,000 ft^2, 3 br home

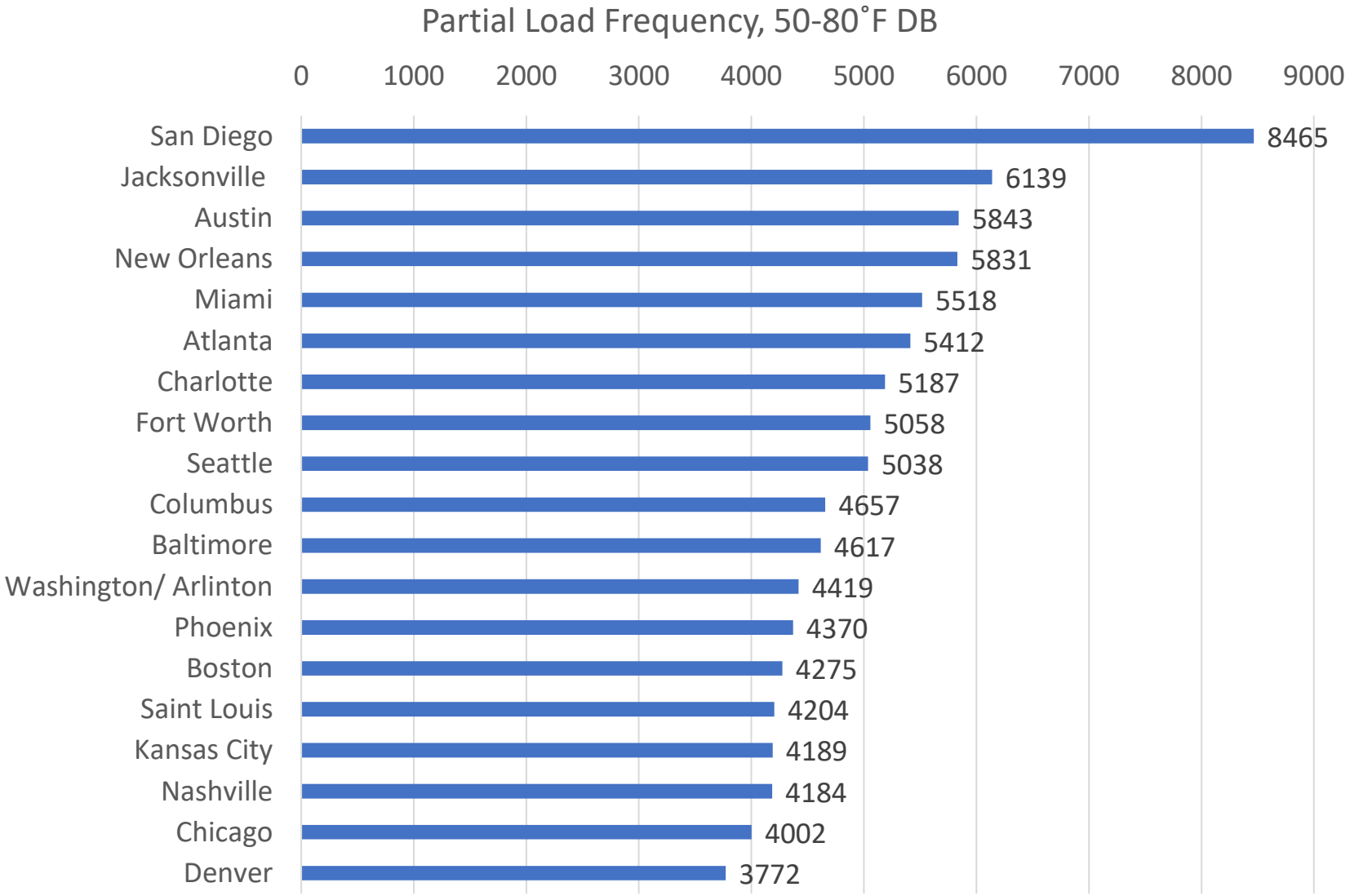
= 0.03cfm * 2,000 ft^2 + 7.5cfm * (1+3)

= 90 cfm -20 cfm infiltration credit @3ACH50

= 70 cfm

MITSUBISHI ELECTRIC
COOLING & HEATING

PARTIAL LOAD (think “SHOULDER” or “SWING SEASON”) HRS/YR



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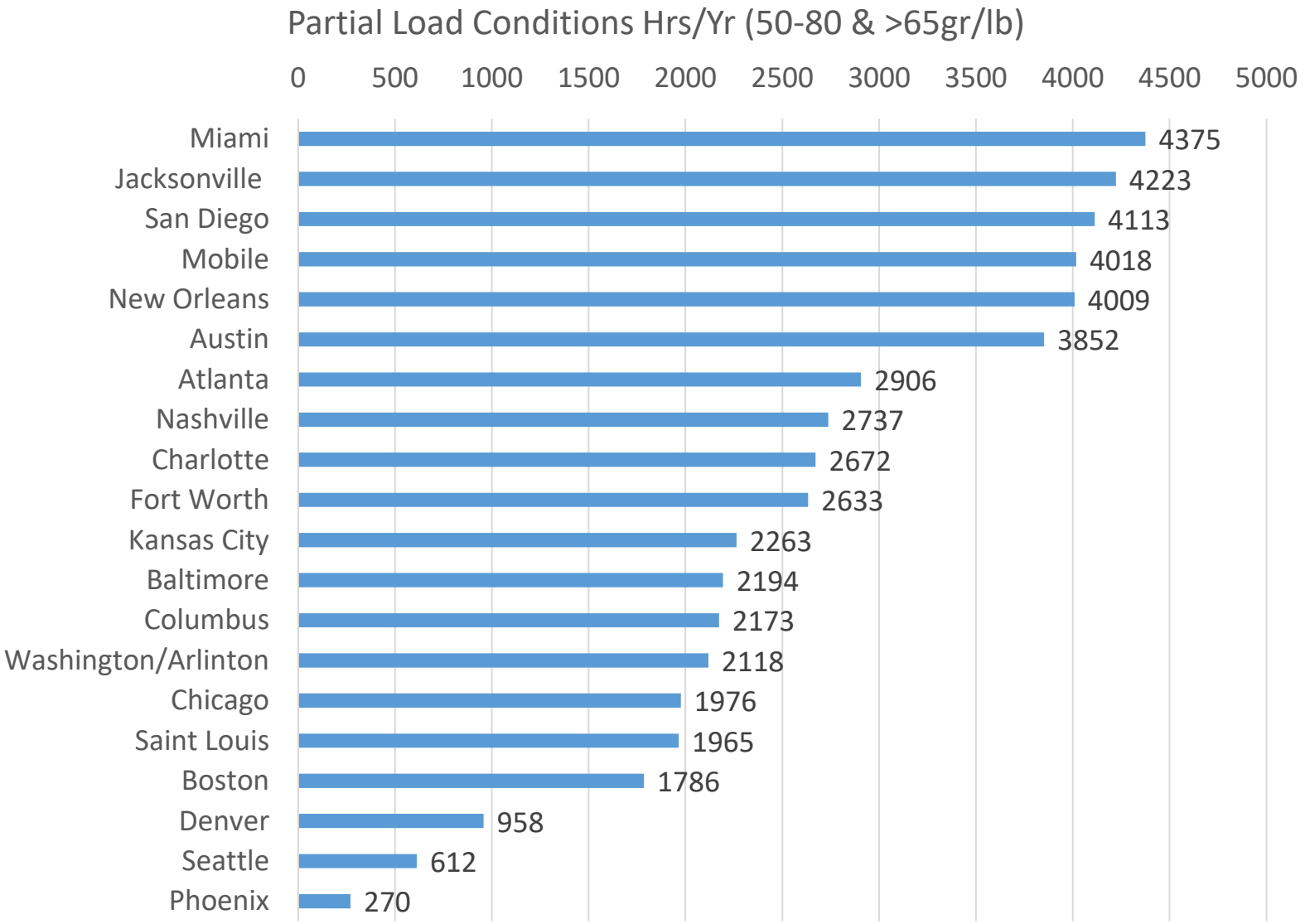
COOLING & HEATING

HUMID PARTIAL LOAD HRS/YR



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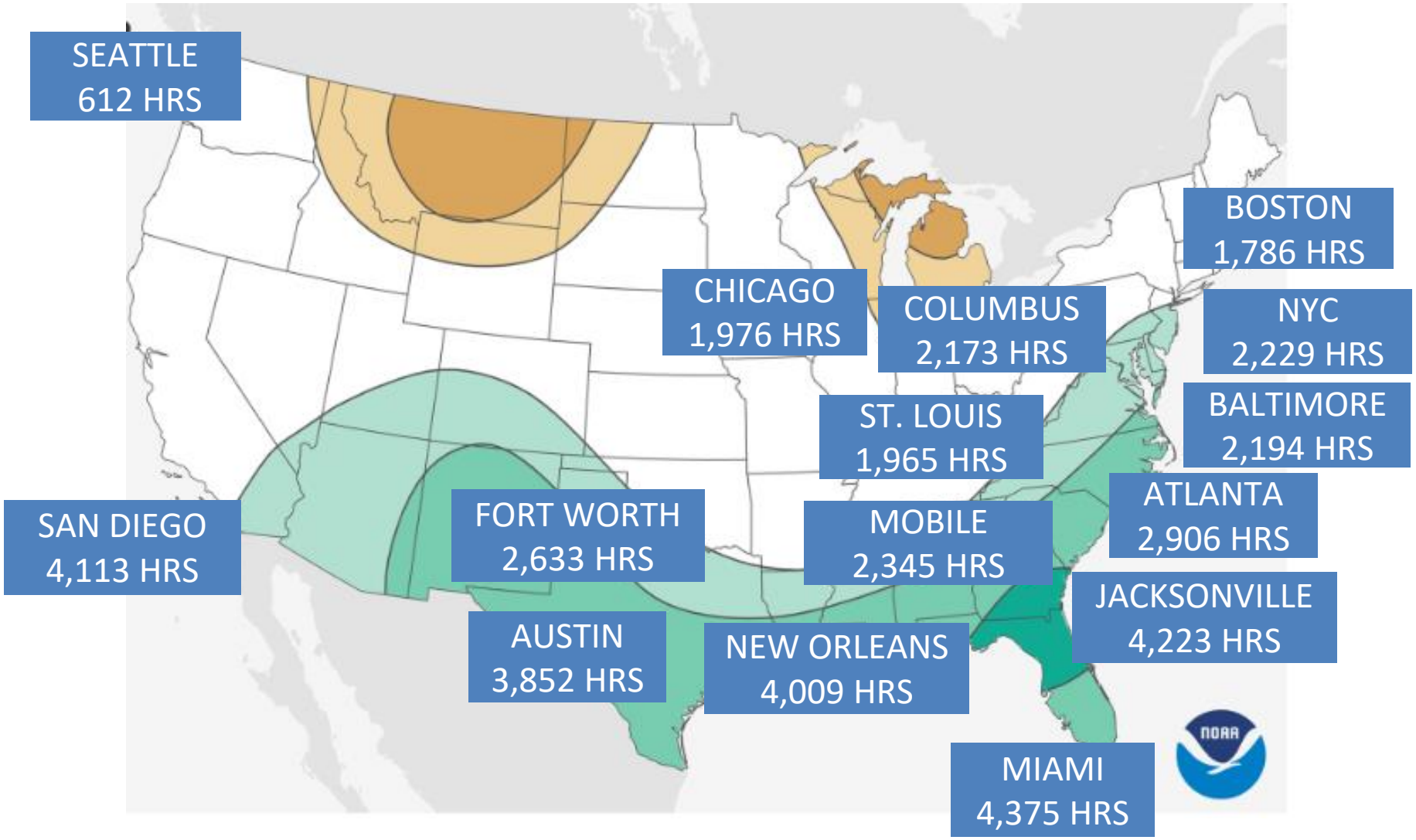
COOLING & HEATING

50-80˚F DB & >65 grains/Lb da



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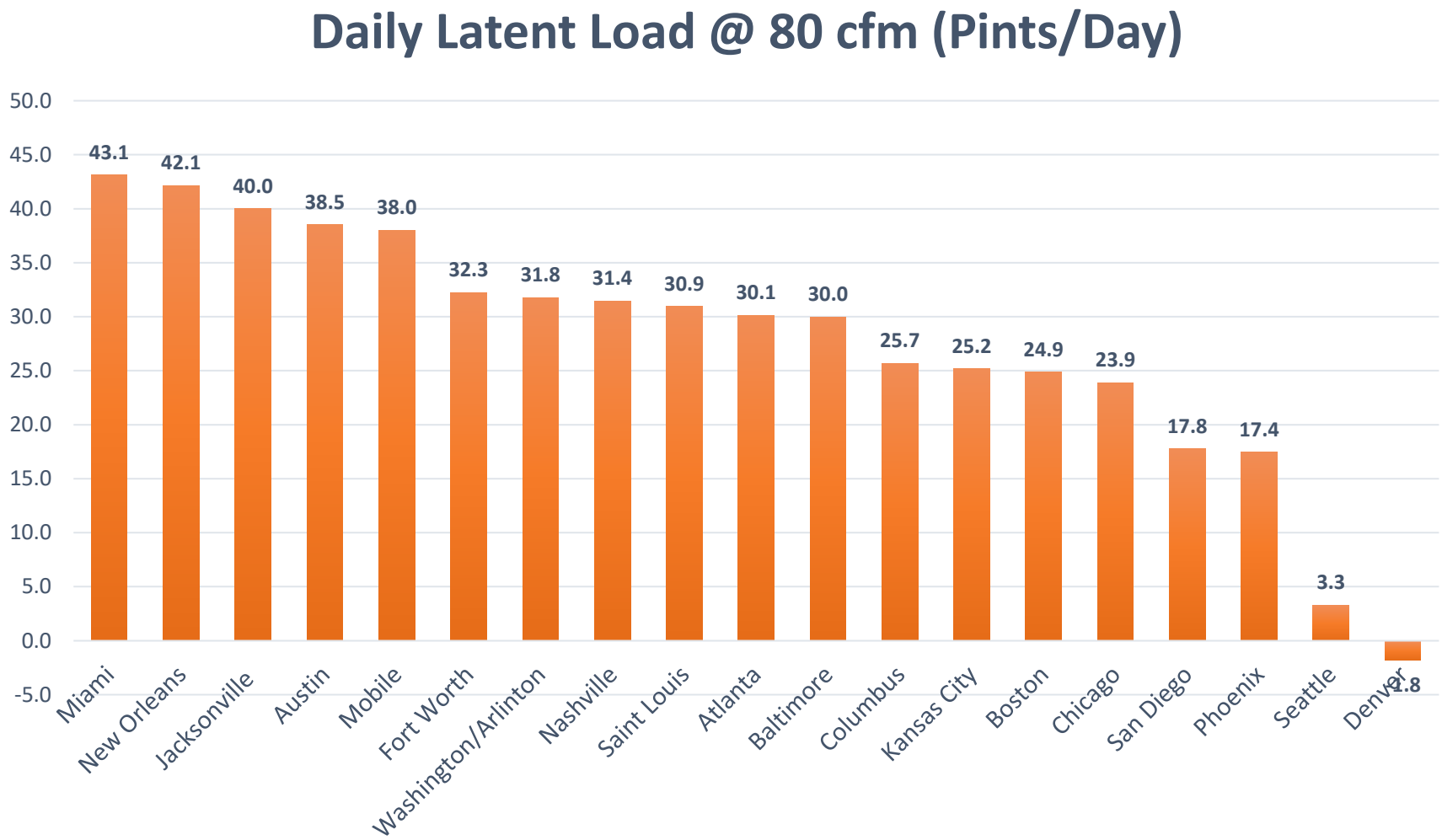
COOLING & HEATING

IS IT A PROBLEM?



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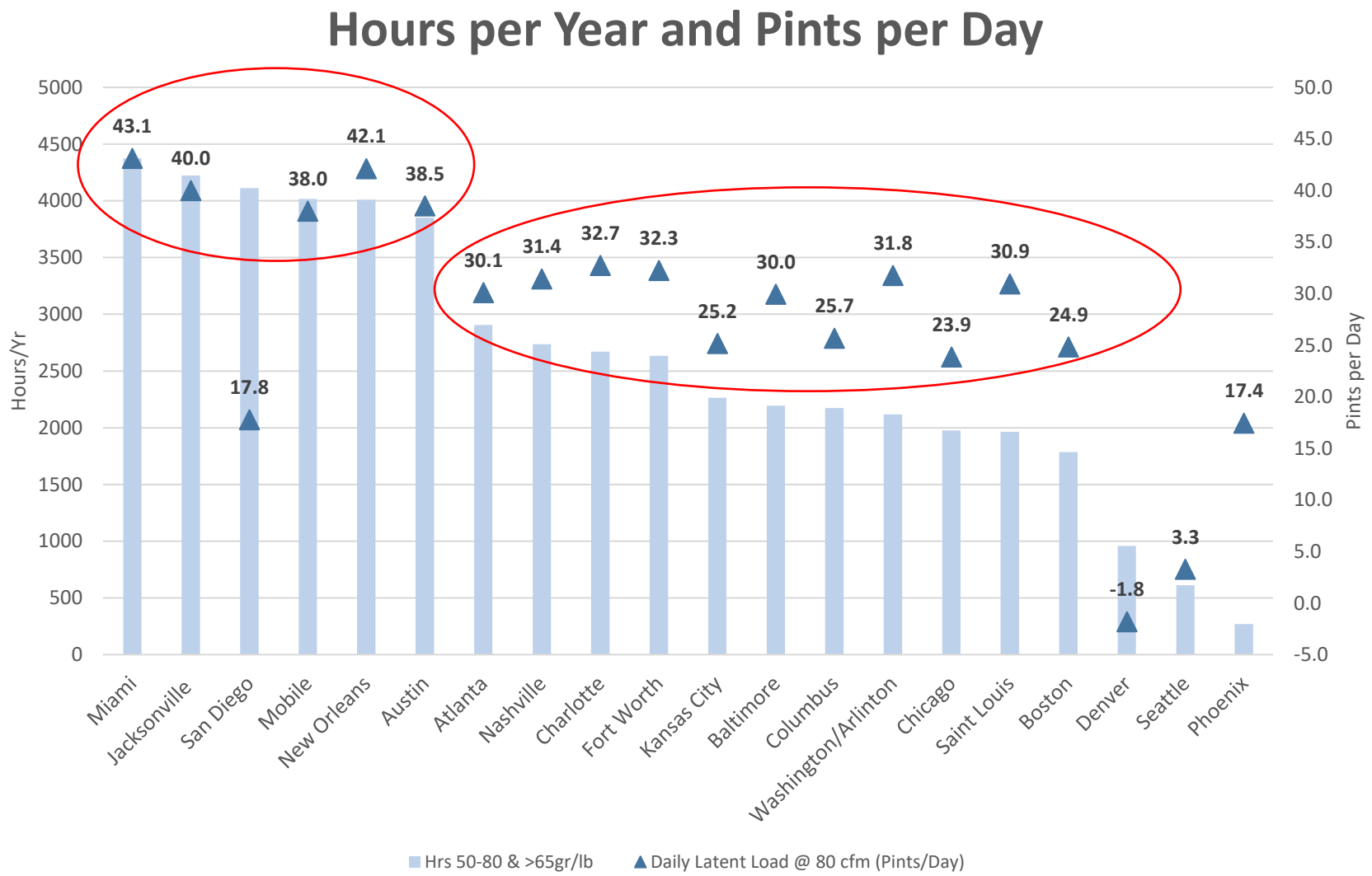
FREQUENCY AND MAGNITUDE



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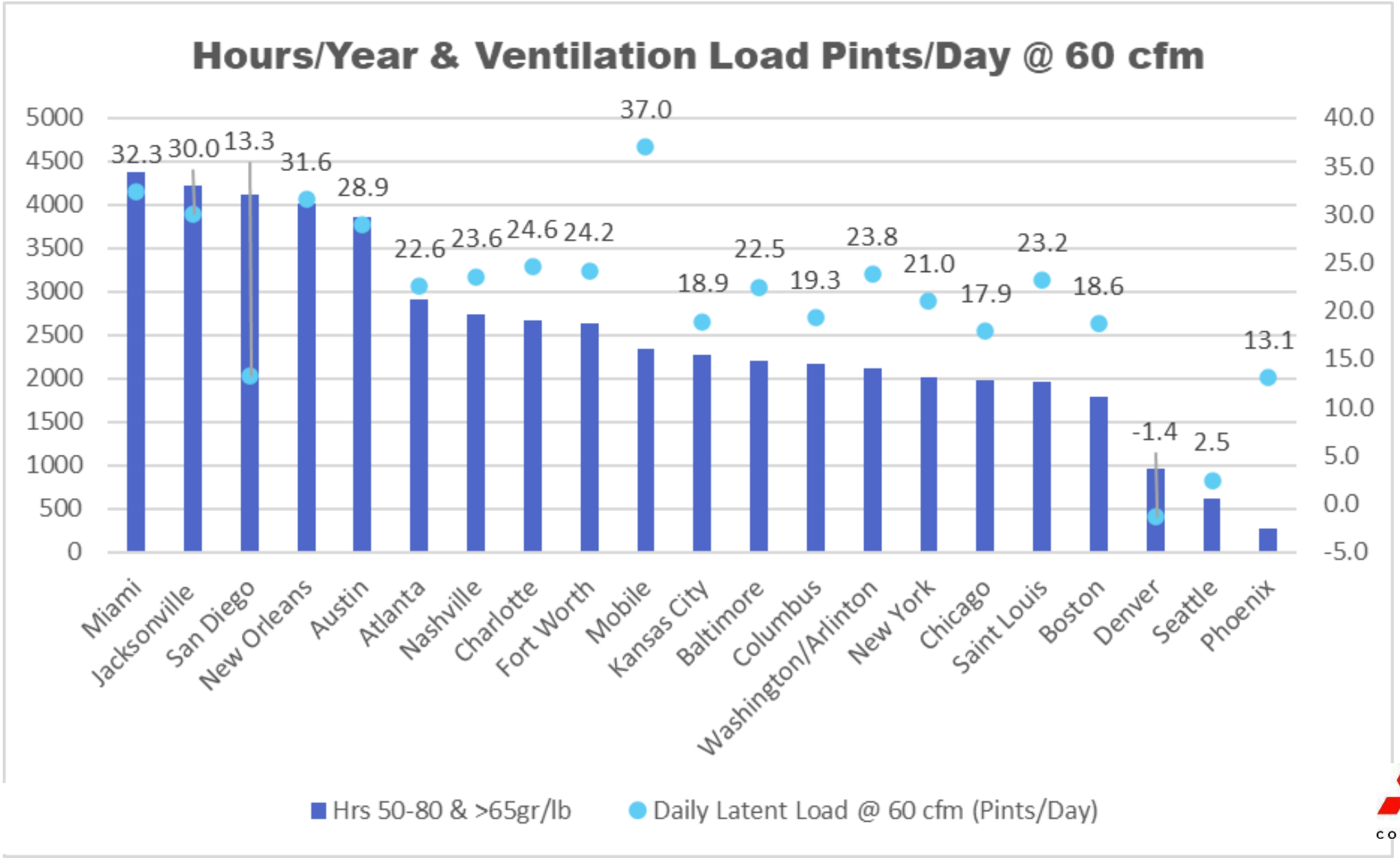
COOLING & HEATING

How Much Is Coming In?



MITSUBISHI ELECTRIC
COOLING & HEATING

ARLINGTON PEAK LOAD CONDITIONS= 88 HRS/YR

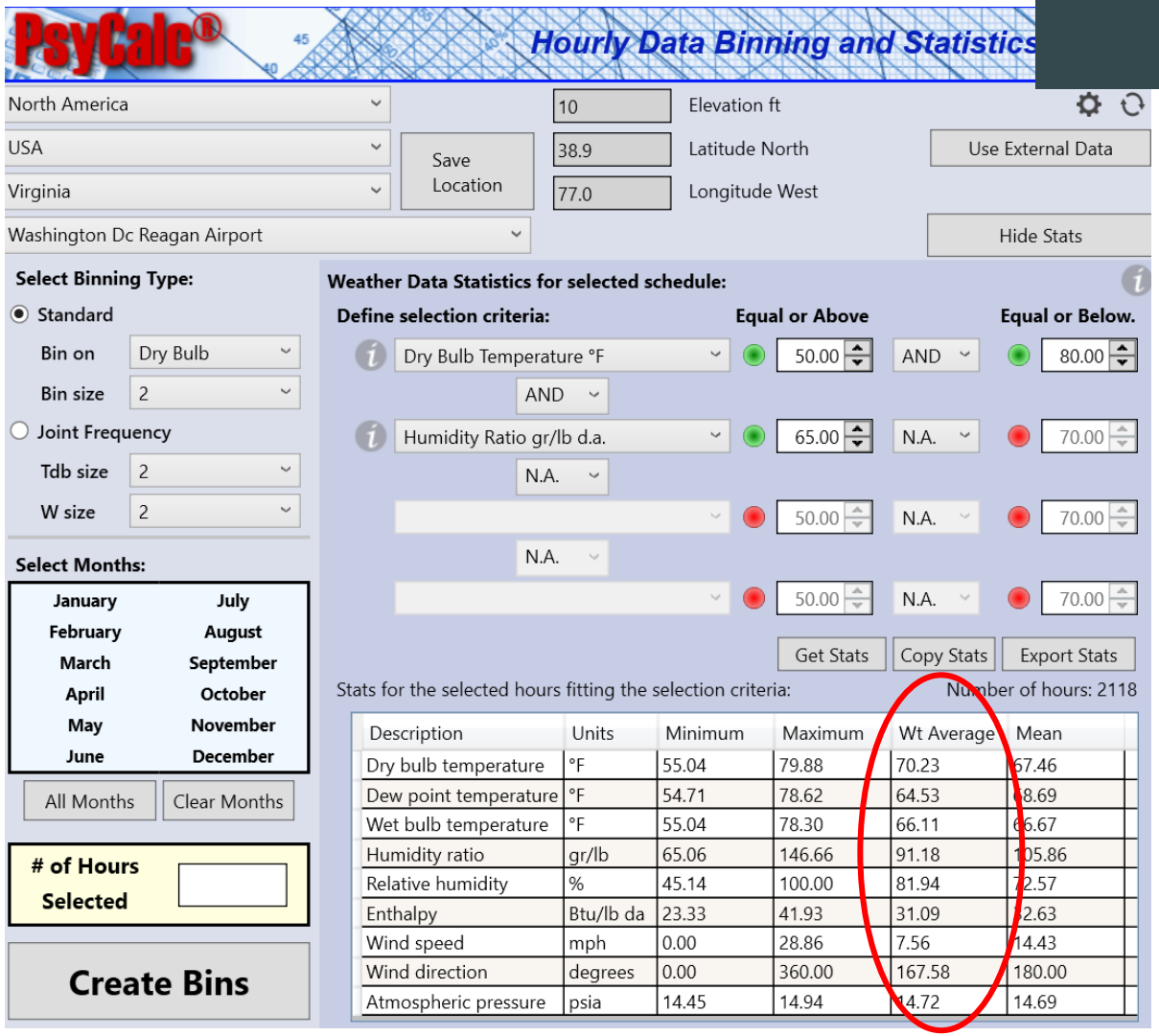
DESIGN CONDITIONS: 92˚F DRY BULB/74.7˚F WET BULB

Scope	Net Ton	ft²/Ton	Area	Sen Gain	Lat Gain	Net Gain	Sen Loss
Building	**1.61**	**1,932**	**3,102**	**13,948**	**5,317**	**19,265**	**15,116**
System 1	**0.84**	**1,867**	**1,561**	**7,476**	**2,558**	**10,034**	**7,835**
Ventilation				466	1,258	1,725	686
Zone 1			**1,561**	**7,010**	**1,300**	**8,310**	**7,149**
1-Entry			128	143	0	143	332
2-Laundry			195	791	0	791	890
3-Office			164	1,422	200	1,622	1,291
4-Bath 1			45	25	0	25	116
5-Utility			64	0	300	300	6
6-Kitchen / Lr / Dr			869	4,275	800	5,075	4,083
19-Lower Stairs			96	354	0	354	431
System 2	**0.77**	**2,003**	**1,541**	**6,472**	**2,758**	**9,231**	**7,281**
Ventilation				466	1,258	1,725	686
Zone 1			**1,541**	**6,006**	**1,500**	**7,506**	**6,595**
7-Bedroom 3			144	734	200	934	905
8-Bedroom 3 Closet			46	92	0	92	171
9-Bedroom 4			170	885	200	1,085	1,059
10-Bath			63	105	100	205	82
11-Bedroom 4 Closet			46	92	0	92	171
12-Utility			29	434	0	434	110
13-Hall			117	158	0	158	152
14-Guest			166	1,102	400	1,502	1,030
15-Guest Bath			100	354	100	454	449
16-Master Bath			168	247	100	347	218
17-Master Closet			106	236	0	236	433
18-Master Bedroom			290	1,403	400	1,803	1,562
20-Upper Stairs			96	164	0	164	253

SENSIBLE HEAT RATIO= 0.72

MITSUBISHI ELECTRIC
COOLING & HEATING

PARTIAL LOAD DESIGN CHECK



ARLINGTON, VA PARTIAL LOAD CONDITIONS 2,118 /YR

MITSUBISHI ELECTRIC
COOLING & HEATING

ARLINGTON, VA PARTIAL LOADS= 2,118 HRS/YR

DESIGN CONDITIONS: 70.2˚F DRY BULB/66.1˚F WET BULB

Scope	Net Ton	ft²/Ton	Area	Sen Gain	Lat Gain	Net Gain	Sen Loss
Building	**1.14**	**2,713**	**3,102**	**9,226**	**4,493**	**13,719**	**-5**
System 1	**0.62**	**2,527**	**1,561**	**5,268**	**2,146**	**7,414**	**-3**
Ventilation				-132	846	715	-3
Zone 1			**1,561**	**5,399**	**1,300**	**6,699**	**0**
1-Entry			128	42	0	42	0
2-Laundry			195	583	0	583	0
3-Office			164	1,157	200	1,357	0
4-Bath 1			45	-7	0	-7	0
5-Utility			64	0	300	300	0
6-Kitchen / Lr / Dr			869	3,389	800	4,189	0
19-Lower Stairs			96	235	0	235	0
System 2	**0.53**	**2,932**	**1,541**	**3,958**	**2,346**	**6,305**	**-3**
Ventilation				-132	846	715	-3
Zone 1			**1,541**	**4,090**	**1,500**	**5,590**	**0**
7-Bedroom 3			144	471	200	671	0
8-Bedroom 3 Closet			46	34	0	34	0
9-Bedroom 4			170	582	200	782	0
10-Bath			63	80	100	180	0
11-Bedroom 4 Closet			46	34	0	34	0
12-Utility			29	414	0	414	0
13-Hall			117	110	0	110	0
14-Guest			166	820	400	1,220	0
15-Guest Bath			100	220	100	320	0
16-Master Bath			168	180	100	280	0
17-Master Closet			106	100	0	100	0
18-Master Bedroom			290	963	400	1,363	0
20-Upper Stairs			96	81	0	81	0

SENSIBLE HEAT RATIO= 0.67

MITSUBISHI ELECTRIC
COOLING & HEATING

BOSTON 99% LOAD CONDITIONS= 88 HRS/YR

DESIGN CONDITIONS: 87.6 F DRY BULB/71.6 F WET BULB

Scope	Net Ton	ft.² /Ton	Area	Sen Gain	Lat Gain	Net Gain	Sen Loss
Building	**1.41**	**1,475**	**2,085**	**13,967**	**2,993**	**16,960**	**23,213**
System 1	**1.41**	**1,475**	**2,085**	**13,967**	**2,993**	**16,960**	**23,213**
Ventilation				1,055	1,283	2,338	5,100
Zone 1 - Clg.: 59%, Htg.: 50%			**1,104**	**9,417**	**610**	**10,027**	**9,031**
1-Entry			96	295	0	295	949
2-Office			144	1,751	200	1,951	1,459
3-Bathroom/Closet			144	161	150	311	752
4-Utility			144	818	0	818	1,335
5-Kitchen			216	2,536	260	2,796	1,786
6-Dining/Living			360	3,856	0	3,856	2,750
Zone 2 - Clg.: 18%, Htg.: 26%			**585**	**2,913**	**550**	**3,463**	**4,619**
7-Stairs			225	454	0	454	1,635
8-Bedroom 2			144	1,201	200	1,401	1,556
9-Bath 2			72	305	150	455	469
10-Bedroom 3			144	953	200	1,153	959
Zone 3 - Clg.: 22%, Htg.: 25%			**396**	**3,563**	**550**	**4,113**	**4,463**
11-Master Bedroom			288	3,228	400	3,628	3,302
12-Master Bath			108	336	150	486	1,161

SENSIBLE HEAT RATIO= 0.82

MITSUBISHI ELECTRIC
COOLING & HEATING

BOSTON PARTIAL LOAD CONDITIONS= 1,786 HRS/YR

DESIGN CONDITIONS: 69 F DRY BULB/65 F WET BULB

Scope	Net Ton	ft.² /Ton	Area	Sen Gain	Lat Gain	Net Gain	Sen Loss
Building	**1.08**	**1,938**	**2,085**	**10,155**	**2,757**	**12,913**	**176**
System 1	**1.08**	**1,938**	**2,085**	**10,155**	**2,757**	**12,913**	**176**
Ventilation				0	1,047	1,047	40
Zone 1 - Clg.: 62%, Htg.: 49%			**1,104**	**8,195**	**610**	**8,805**	**67**
1-Entry			96	138	0	138	7
2-Office			144	1,554	200	1,754	11
3-Bathroom/Closet			144	61	150	211	6
4-Utility			144	630	0	630	9
5-Kitchen			216	2,309	260	2,569	13
6-Dining/Living			360	3,503	0	3,503	21
Zone 2 - Clg.: 16%, Htg.: 24%			**585**	**2,123**	**550**	**2,673**	**33**
7-Stairs			225	165	0	165	12
8-Bedroom 2			144	942	200	1,142	11
9-Bath 2			72	224	150	374	3
10-Bedroom 3			144	791	200	991	7
Zone 3 - Clg.: 21%, Htg.: 26%			**396**	**2,819**	**550**	**3,369**	**36**
11-Master Bedroom			288	2,686	400	3,086	27
12-Master Bath			108	134	150	284	9

SENSIBLE HEAT RATIO= 0.79

MITSUBISHI ELECTRIC
COOLING & HEATING

AUSTIN PEAK LOAD CONDITIONS 88 HRS/YR

DESIGN CONDITIONS: 98° F DRY BULB/74° F WET BULB

Scope	Net Ton	ft.² /Ton	Area	Sen Gain	Lat Gain	Net Gain	Sen Loss
Building	**1.69**	**1,230**	**2,085**	**17,328**	**3,009**	**20,337**	**22,747**
System 1	**1.69**	**1,230**	**2,085**	**17,328**	**3,009**	**20,337**	**22,747**
Ventilation				1,981	1,299	3,280	3,445
Zone 1 - Clg.: 58%, Htg.: 68%			**1,104**	**10,279**	**610**	**10,889**	**13,060**
1-Entry			96	445	0	445	1,023
2-Office			144	2,052	200	2,252	2,207
3-Bathroom/Closet			144	256	150	406	1,071
4-Utility			144	986	0	986	2,123
5-Kitchen			216	2,568	260	2,828	2,709
6-Dining/Living			360	3,972	0	3,972	3,927
Zone 2 - Clg.: 18%, Htg.: 16%			**585**	**3,221**	**550**	**3,771**	**3,174**
7-Stairs			225	726	0	726	1,125
8-Bedroom 2			144	1,265	200	1,465	1,068
9-Bath 2			72	306	150	456	323
10-Bedroom 3			144	923	200	1,123	658
Zone 3 - Clg.: 24%, Htg.: 16%			**396**	**4,373**	**550**	**4,923**	**3,068**
11-Master Bedroom			288	3,837	400	4,237	2,270
12-Master Bath			108	536	150	686	798

SENSIBLE HEAT RATIO= 0.85

MITSUBISHI ELECTRIC
COOLING & HEATING

AUSTIN PARTIAL LOAD CONDITIONS 3,852 HRS/YR

DESIGN CONDITIONS: 71° F DRY BULB/67° F WET BULB

Scope	Net Ton	ft.²/Ton	Area	Sen Gain	Lat Gain	Net Gain	Sen Loss
Building	**1.12**	**1,862**	**2,085**	**10,060**	**3,381**	**13,440**	**0**
System 1	**1.12**	**1,862**	**2,085**	**10,060**	**3,381**	**13,440**	**0**
Ventilation				0	1,671	1,671	0
Zone 1 - Clg.: 63%, Htg.: 0%			**1,104**	**7,936**	**610**	**8,546**	**0**
1-Entry			96	140	0	140	0
2-Office			144	1,679	200	1,879	0
3-Bathroom/Closet			144	63	150	213	0
4-Utility			144	630	0	630	0
5-Kitchen			216	2,132	260	2,392	0
6-Dining/Living			360	3,292	0	3,292	0
Zone 2 - Clg.: 13%, Htg.: 0%			**585**	**1,698**	**550**	**2,248**	**0**
7-Stairs			225	175	0	175	0
8-Bedroom 2			144	767	200	967	0
9-Bath 2			72	149	150	299	0
10-Bedroom 3			144	609	200	809	0
Zone 3 - Clg.: 23%, Htg.: 0%			**396**	**2,950**	**550**	**3,500**	**0**
11-Master Bedroom			288	2,802	400	3,202	0
12-Master Bath			108	149	150	299	0

SENSIBLE HEAT RATIO= 0.75

MITSUBISHI ELECTRIC
COOLING & HEATING

EQUIPMENT SELECTION

Sizing is a balancing act

MITSUBISHI ELECTRIC
COOLING & HEATING

UNDERSTAND THE HEATING CAPACITY RANGES

MXZ-5C42NA2
2) HEATING

Rated
Q(Btu/h): 45000
W: 3575

Max.
Q(Btu/h): 53600

Indoor D.B. / Outdoor W.B. (°F)	(°C)		80°F/26.7°C Max.	Rated	75%	50%	25%	Min.	70°F / 21.1°C Max.	Rated	75%	50%	25%	Min.	60°F/15.6°C Max.	Rated	75%	50%	25%	Min.
65	18.3	Q[Btu/h]	49353	54003	40502	27002	-	24012	51679	55878	41909	27939	-	24846	53600	57599	43199	28799	-	25611
		W	6714	4572	3812	2415	-	1447	6406	4353	3670	2324	-	1388	6160	4226	3563	2257	-	1348
60	15.6	Q[Btu/h]	49353	50948	38211	25474	-	22397	51679	52847	39635	26423	-	23232	53600	54544	40908	27272	-	23977
		W	6714	4359	3675	2328	-	1407	6406	4196	3537	2241	-	1355	6160	4074	3434	2175	-	1315
55	12.8	Q[Btu/h]	49353	47893	35920	23947	-	20727	51679	49815	37361	24908	-	21559	53600	51489	38616	25744	-	22283
		W	6714	4153	3501	2218	-	1384	6406	3961	3339	2115	-	1320	6160	3845	3242	2053	-	1281
50	10.0	Q[Btu/h]	49353	44838	33629	22419	-	19060	51679	46784	35088	23392	-	19888	53600	48434	36325	24217	-	20589
		W	6714	4038	3404	2156	-	1347	6406	3889	3278	2076	-	1297	6160	3739	3152	1997	-	1248
45	7.2	Q[Btu/h]	49353	41783	31337	20892	-	17398	51679	43752	32814	21876	-	18218	53600	45379	34034	22689	-	18895
		W	6714	3905	3292	2085	-	1323	6406	3726	3141	1990	-	1262	6160	3583	3020	1913	-	1214
40	4.4	Q[Btu/h]	40982	34855	26141	17428	-	15739	43091	36649	27487	18324	-	16549	44787	38091	28568	19046	-	17200
		W	6433	3963	334													2	-	1180

@65 F OAT and 70 F IAT

Minimum Capacity of ~24,000 Btu/h

MITSUBISHI ELECTRIC
COOLING & HEATING

SYSTEM CAPACITY RANGES IN COOLING

MXZ-5C42NA2

1) COOLING

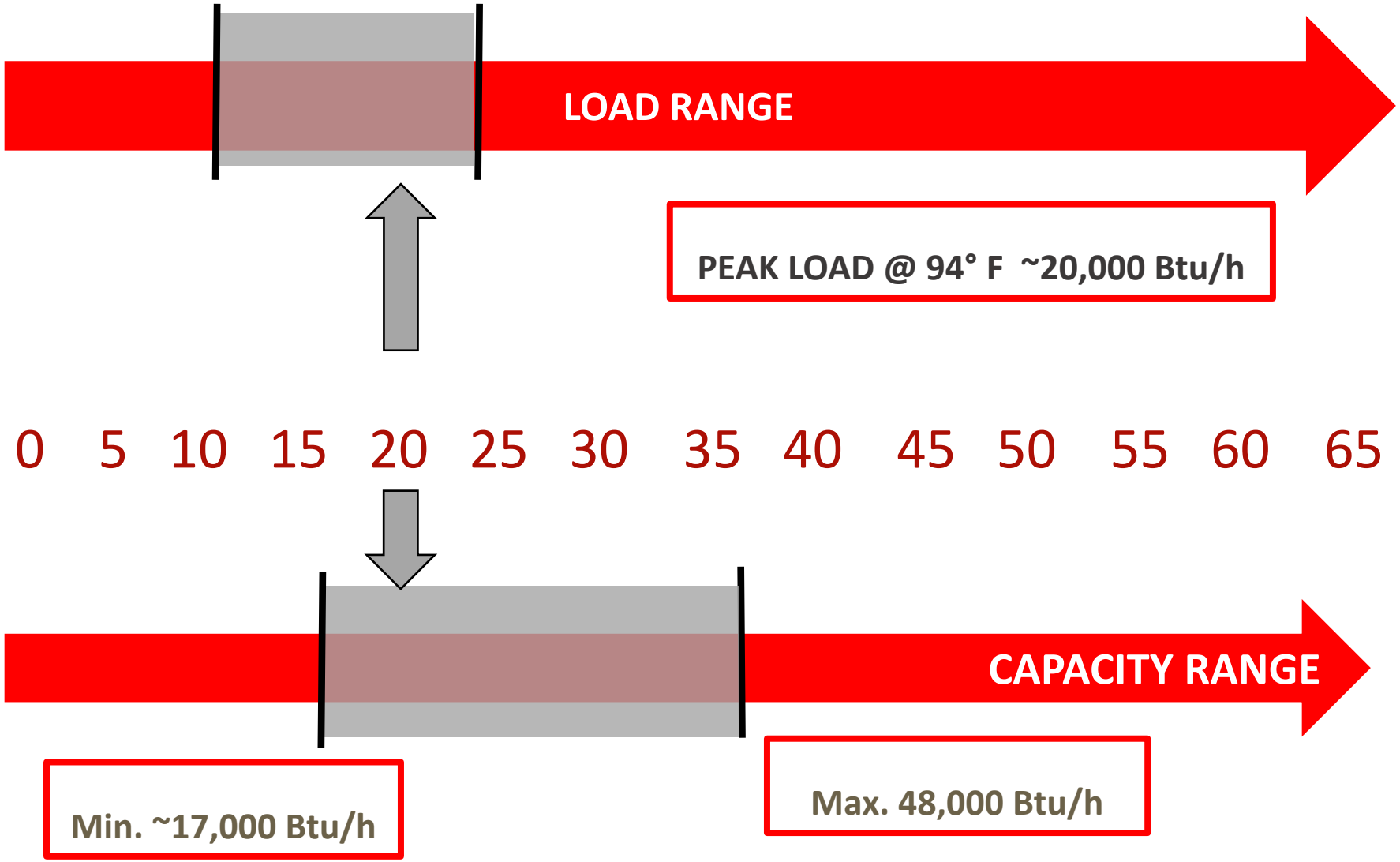
Rated Q(Btu/h): 40500 W: 4403

Max. Q(Btu/h): 43000

Indoor W.B. / Outdoor D.B. (°F)	(°C)		72°F / 22.2°C						67°F / 19.4°C						64°F / 17.8°C						61°F / 16.1°C					
			Max.	Rated	75%	50%	25%	Min.	Max.	Rated	75%	50%	25%	Min.	Max.	Rated	75%	50%	25%	Min.	Max.	Rated	75%	50%	25%	Min.
115	46.1	Q(Btu/h)	41193	32400	24300	16200		-13953	39649	31185	23389	15593		-13430	39134	30780	23085	15390		-13255	36044	28350	21263	14175		-12209
		W	5213	3434	2174	1470		- 1357	5748	3787	2397	1621		- 1497	5948	3919	2481	1677		- 1545	5614	3699	2341	1583		- 1462
110	43.3	Q(Btu/h)	43628	40176	30132	20088		-14817	40901	37665	28249	18833		-13891	37822	34830	26123	17415		-12845	30786	28350	21263	14175		-10456
		W	5322	4773	3021	2043		- 1340	5597	5019	3177	2148		- 1409	5014	4496	2846	1924		- 1262	3732	3346	2118	1432		- 939
106	41.1	Q(Btu/h)	46187	42525	31894	21263		-15750	41788	38475	28866	19238		-14250	37830	34830	26123	17415		-12900	30791	28350	21263	14175		-10500
		W	5612	5019	3177	2148		- 1389	5415	4843	3066	2073		- 1340	4786	4281	2710	1832		- 1185	3544	3170	2007	1357		- 877
102	38.9	Q(Btu/h)	47140	42930	32198	21465		-16128	42693	38880	29160	19440		-14606	38245	34830	26123	17415		-13089	31130	28350	21263	14175		-10650
		W	5418	4931	3122	2111		- 1319	5224	4755	3010	2035		- 1272	4585	4173	2642	1786		- 1116	3386	3082	1951	1319		- 824
98	36.7	Q(Btu/h)	47827	43740	32805	21870		-16487	43398	39690	29768	19845		-14960	38084	34830	26123	17415		-13128	30999	28350	21263	14175		-10686
		W	5153	4755	3010	2035		- 1250	4962	4579	2899	1960		- 1204	4289	3958	2505	1694		- 1040	3149	2906	1839	1244		- 764
94	34.4	Q(Btu/h)	48180	44550	33413	22275		-16860	43800	40500	30375	20250		-15327	37668	34830	26123	17415		-13181	30660	28350	21263	14175		-10729
		W	4857	4579	2899	1960		- 1178	4670	4403	2787	1884		- 1133	3970	3743	2369	1602		- 963	2895	2730	1728	1168		- 702
90	32.2	Q(Btu/h)	48180	44550	33413	22275		-17241	43800	40500	30375	20250		-15673	37668	34830	26123	17415		-13479	30660	28350	21263	14175		-10971
		W	4857	4579	2899	1960		- 1108	4670	4403	2787	1884		- 1065	3970	3743	2369	1602		- 906	2895	2730	1728	1168		- 661
86	30	Q(Btu/h)	48180	44550	33413	22275		-17618	43800	40500	30375	20250		-16017	37668	34830	26123	17415		-13774	30660	28350	21263	14175		-11212
		W	4857	4579	2899	1960		- 1038	4670	4403	2787	1884		- 998	3970	3743	2369	1602		- 849	2895	2730	1728	1168		- 619
82	27.8	Q(Btu/h)	48180	44550	33413	22275		-17998	43800	40500	30375	20250		-16361	37668	34830	26123	17415		-14071	30660	28350	21263	14175		-11453
		W	4857	4579	2899	1960		- 968	4670	4403	2787	1884		- 931	3970	3743	2369	1602		- 791	2895	2730	1728	1168		- 577
78	25.6	Q(Btu/h)	48180	44550	33413	22275		-18373	43800	40500	30375	20250		-16702	37668	34830	26123	17415		-14364	30660	28350	21263	14175		-11692
		W	4857	4579	2899	1960		- 898	4670	4403	2787	1884		- 863	3970	3743	2369	1602		- 734	2895	2730	1728	1168		- 535
74	23.3	Q(Btu/h)	48180	44550	33413	22275		-18763	43800	40500	30375	20250		-17057	37668	34830	26123	17415		-14665	30660	28350	21263	14175		-11940
		W	4857	4579	2899	1960		- 825	4670	4403	2787	1884		- 793	3970	3743	2369	1602		- 674	2895	2730	1728	1168		- 492
70	21.1	Q(Btu/h)	48180	44550	33413	22275		-19133	43800	40500	30375	20250		-17394	37668	34830	26123	17415		-14959	30660	28350	21263	14175		-12176
		W	4857	4579	2899	1960		- 755	4670	4403	2787	1884		- 726	3970	3743	2369	1602		- 617	2895	2730	1728	1168		- 450
66	18.9	Q(Btu/h)	48180	44550	33413	22275		-19501	43800	40500	30375	20250		-17728	37668	34830	26123	17415		-15246	30660	28350	21263	14175		-12410
		W	4857	4579	2899	1960		- 686	4670	4403	2787	1884		- 659	3970	3743	2369	1602		- 561	2895	2730	1728	1168		- 409
62	16.7	Q(Btu/h)	48180	44550	33413	22275		-19867	43800	40500	30375	20250		-18061	37668	34830	26123	17415		-15532	30660	28350	21263	14175		-12642
		W	4857	4579	2899	1960		- 617	4670	4403	2787	1884		- 593	3970	3743	2369	1602		- 504	2895	2730	1728	1168		- 368

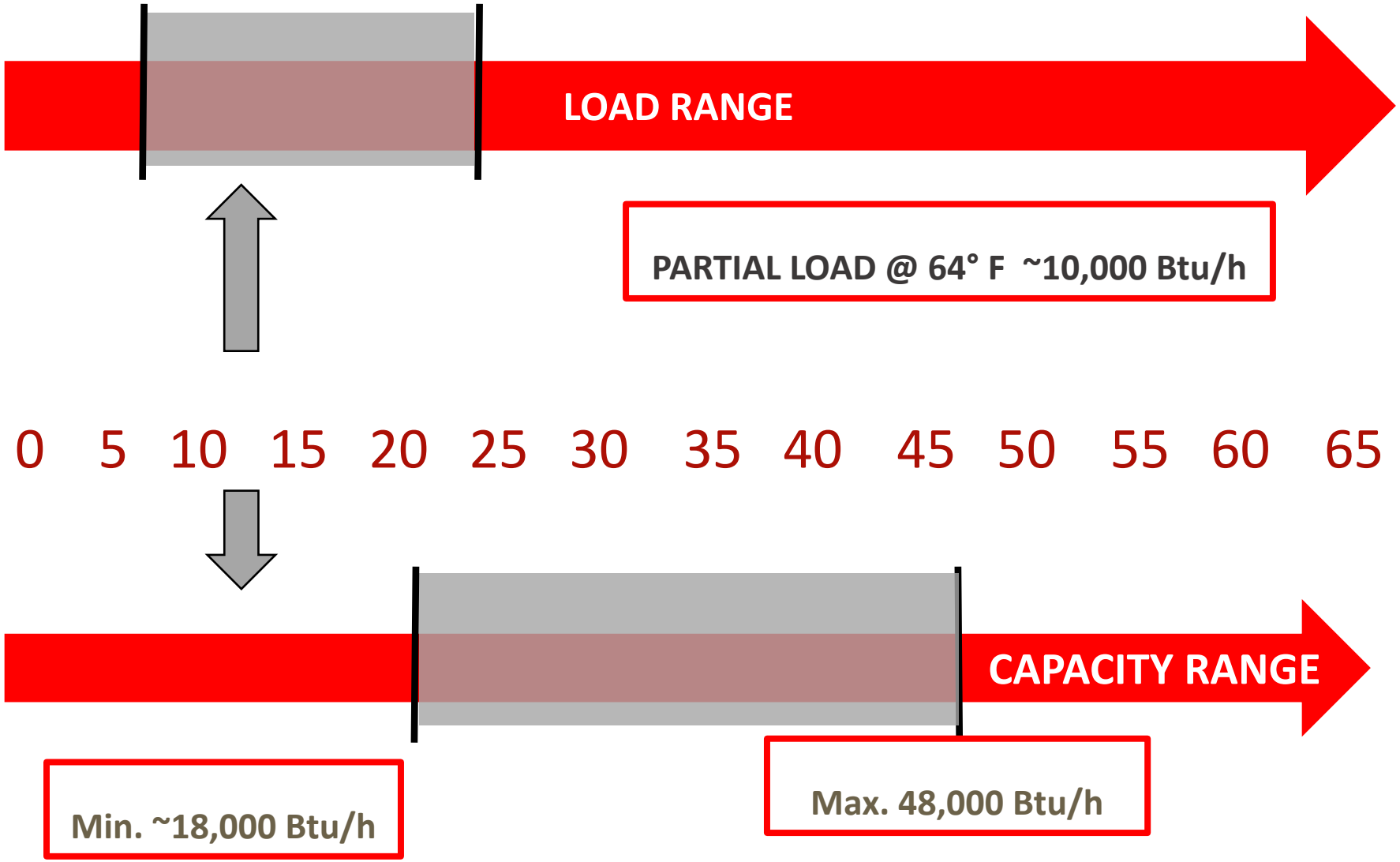
MITSUBISHI ELECTRIC
COOLING & HEATING

YOU NEED: COOLING LOAD AND CAPACITY OVERLAP



MITSUBISHI ELECTRIC
COOLING & HEATING

MXZ 5C42: COOLING LOAD AND CAPACITY OVERLAP



MITSUBISHI ELECTRIC
COOLING & HEATING

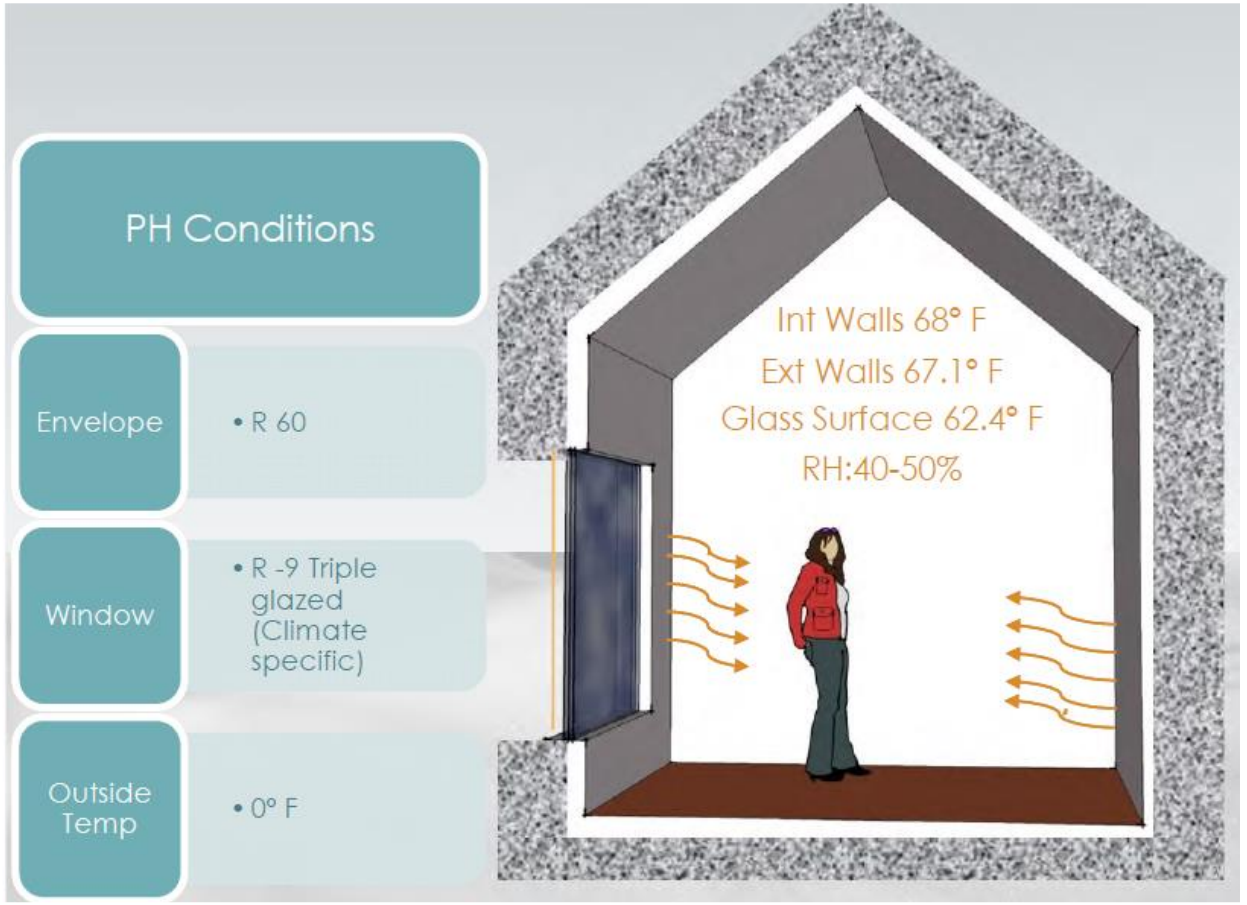
Humidity Control: Deal with it at the source!

Un-tempered Outdoor Air (OA)

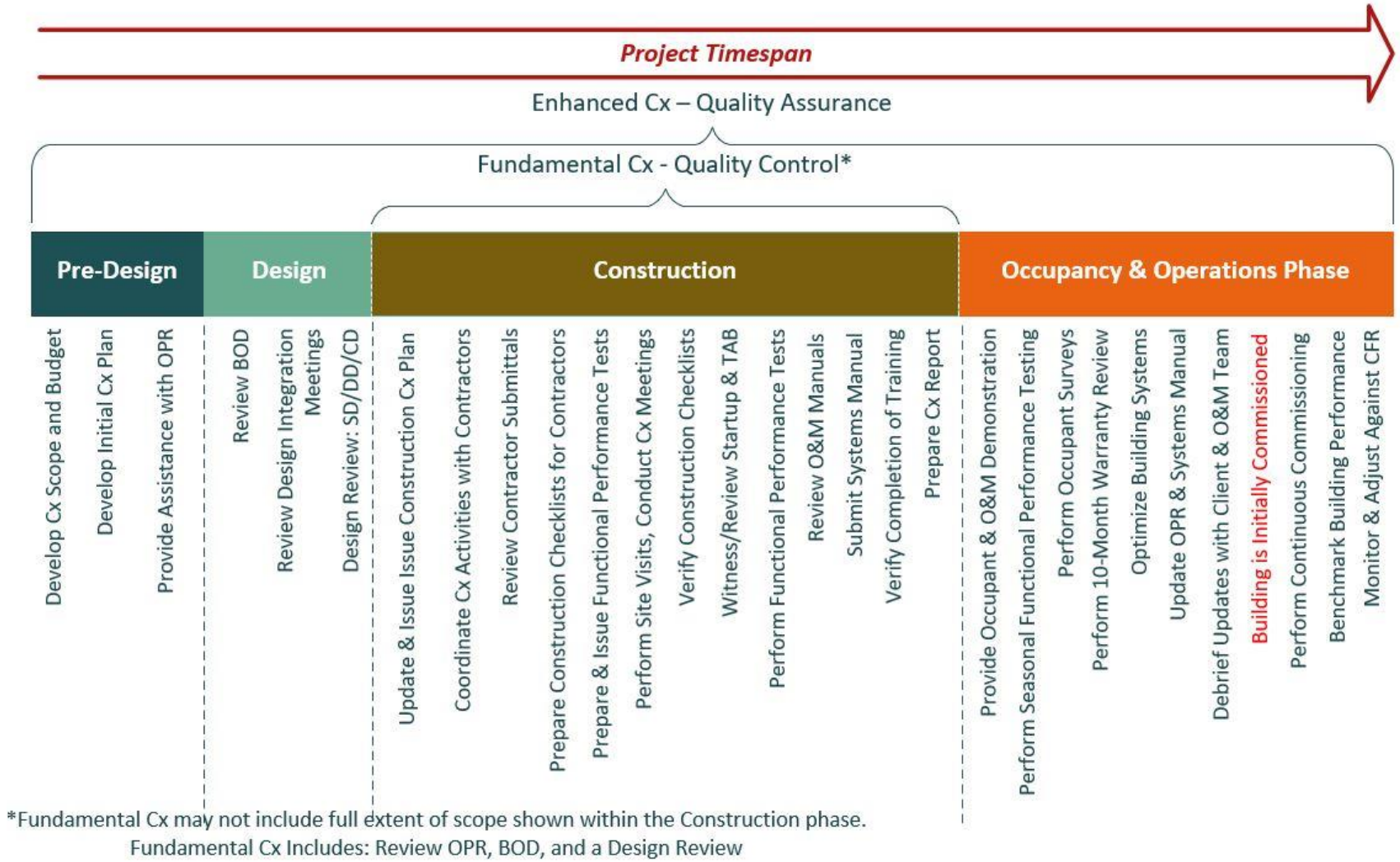
Post-temperd ventilation from ERV with DX heating/cooling

Pitfalls and Challenges

Conventional vs. Passive House Enclosure



Quality Assurance Commissioning (QACx)



Here’s what we see…. What do you see?

- Entrenched Habits
- Not understanding the Technology / Applied misinformation
- Workmansh#t
- Devalue Engineering
- Blindspots

Questions, Thoughts, Discussion

Thank You.

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