How NOT to Do Electrification

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Kimberly Llewellyn – Mitsubishi Electric Trane HVAC US LLC

PhiusCon, November 2023
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
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?
What does electrification mean?

The city program application asks:

What does decarbonization mean to you?
What does electrification mean?

- **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
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?
What does electrification mean?

Electrical Service Upgrade for Electric Boilers:

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.

This would require (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.
DHW: Electric water heaters

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

What does electrification mean?

Electrical Service Upgrade for Electric DHW:

Electrical

a) This replacement would require an electric service upgrade on ground that this

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 a back feed the existing 2000amp 208Y/120.

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 a back feed the existing 2000amp 208Y/120.
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?

Electrical Service Upgrade for Electric MAU:

Electrical

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

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.

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.
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 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.
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

Mid-Rise Multifamily, New Construction

Un-tempered Outdoor Air (OA)
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
Ventilation Design

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

Designed OA CFM + = Delivered OA CFM

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
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

<table>
<thead>
<tr>
<th>Component</th>
<th>MEP HL Calc Assumption</th>
<th>Designed Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Roof</td>
<td>R-25</td>
<td>R-32</td>
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<tr>
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<td>R-22</td>
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<td>Slab</td>
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<tr>
<td>Window</td>
<td>U-0.4</td>
<td>U-0.27</td>
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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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<tr>
<td>Slab</td>
<td>R-10</td>
<td>R-10</td>
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</table>

(60% derate at 0°F)
Choose your next move:

Path A: Very low-ambient capacity VRF
- PURY-HP192TSNU (Hyper Heat) Capacity Table
  - >100% Capacity at 0°F

Path B: High-efficiency low-ambient capacity VRF
- PURY-EP192TSNU (High-Efficiency) Capacity Table
  - 82% Capacity at 0°F

Mid-Rise Multifamily, New Construction

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

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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

<table>
<thead>
<tr>
<th>Space</th>
<th>MEP HL Calc (Btu/hr)</th>
<th>Equipment Size (Btu/hr)</th>
<th>BEC HL Calc (Btu/hr)</th>
<th>% Difference (Cap vs. actual HL)</th>
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<tbody>
<tr>
<td>2-Bd, FCU-1</td>
<td>18,117</td>
<td>20,000</td>
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<tr>
<td>2-Bd, FCU-2</td>
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<td>13,756</td>
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<td>2-Bd, FCU-3</td>
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<td>32,000</td>
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<tr>
<td>3-Bd, FCU-3</td>
<td>29,699</td>
<td>32,000</td>
<td>17,203</td>
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<tr>
<td>3-Bd, FCU-4</td>
<td>34,526</td>
<td>40,000</td>
<td>18,153</td>
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### Mid-Rise Multifamily, New Construction
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

<table>
<thead>
<tr>
<th>Equipment</th>
<th>MEP HL Calc (MBH)</th>
<th>Qty.</th>
<th>Total Load (MBH)</th>
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<td>Apt, FCU-3</td>
<td>32</td>
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<td>Apt, FCU-4</td>
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<td>Common, FCU-7</td>
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<td><strong>Total</strong></td>
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### Outdoor Equipment

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<th>Equipment</th>
<th>MEP HL Capacity (MBH)</th>
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<tr>
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<td>HP-2</td>
<td>215</td>
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<td>HP-3</td>
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<tr>
<td>HP-4</td>
<td>215</td>
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<td>HP-5</td>
<td>270</td>
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<tr>
<td>HP-6</td>
<td>215</td>
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<tr>
<td>HP-7</td>
<td>54</td>
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<tr>
<td><strong>Total</strong></td>
<td><strong>1454</strong></td>
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</table>
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
## Electric Resistance Heating

Historic Church, HVAC Replacement

### Electric Duct Heater Schedule (EDH)

<table>
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<tr>
<th>MARK</th>
<th>SERVES</th>
<th>MAKE</th>
<th>MODEL</th>
<th>SIZE (W x H)</th>
<th>CFM</th>
<th>EAT</th>
<th>LAT</th>
<th>KW</th>
<th>VOLT/PH</th>
<th>AMPS</th>
<th>CONTROL</th>
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<td>ERV-1 POSTHEAT</td>
<td>QMARK</td>
<td>FC/SC (OPEN COIL)</td>
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<td>1,425</td>
<td>46.9</td>
<td>73.5</td>
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<td>208/3</td>
<td>33.3</td>
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<td>EDH-4</td>
<td>ERV-4 POSTHEAT</td>
<td>QMARK</td>
<td>FC/SC (OPEN COIL)</td>
<td>12X12</td>
<td>750</td>
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<td>ERV-5 PREHEAT</td>
<td>QMARK</td>
<td>FC/SC (OPEN COIL)</td>
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<td>EDH-7</td>
<td>ERV-7 PREHEAT</td>
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<td>FC/SC (OPEN COIL)</td>
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<td>325</td>
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<td>EDH-8</td>
<td>VRF-IN-1-1 2ND STAGE</td>
<td>QMARK</td>
<td>FC/SC (OPEN COIL)</td>
<td>14X14</td>
<td>800-990</td>
<td>68.0</td>
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<td>208/3</td>
<td>55.5</td>
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**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
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.

<table>
<thead>
<tr>
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<th>QMARK</th>
<th>FC/SC (OPEN COIL)</th>
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<td>208/3</td>
<td>55.5</td>
<td>HYBRID</td>
<td>1,2</td>
</tr>
<tr>
<td>EDH-12</td>
<td>VRF-IN-3-2 2ND STAGE</td>
<td>QMARK</td>
<td>FC/SC (OPEN COIL)</td>
<td>16X16</td>
<td>1260-1475</td>
<td>68.0</td>
<td>118.2</td>
<td>20.0</td>
<td>208/3</td>
<td>55.5</td>
<td>HYBRID</td>
<td>1,2</td>
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<tr>
<td>EDH-13</td>
<td>VRF-IN-3-3 2ND STAGE</td>
<td>QMARK</td>
<td>FC/SC (OPEN COIL)</td>
<td>12X12</td>
<td>480-710</td>
<td>68.0</td>
<td>112.5</td>
<td>10.0</td>
<td>208/3</td>
<td>27.8</td>
<td>SCR</td>
<td>1,2</td>
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<tr>
<td>EDH-14</td>
<td>VRF-IN-4-1 2ND STAGE</td>
<td>QMARK</td>
<td>FC/SC (OPEN COIL)</td>
<td>16X16</td>
<td>1260-1475</td>
<td>68.0</td>
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<td>20.0</td>
<td>208/3</td>
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<td>EDH-15</td>
<td>VRF-IN-4-2 2ND STAGE</td>
<td>QMARK</td>
<td>FC/SC (OPEN COIL)</td>
<td>24X12</td>
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<td>EDH-16</td>
<td>VRF-IN-5-6 2ND STAGE</td>
<td>QMARK</td>
<td>FC/SC (OPEN COIL)</td>
<td>16X16</td>
<td>1000-1400</td>
<td>68.0</td>
<td>131.2</td>
<td>20.0</td>
<td>208/3</td>
<td>55.5</td>
<td>HYBRID</td>
<td>1,2</td>
</tr>
</tbody>
</table>

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

Historic Church, HVAC Replacement
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?
Answer: Trick question!

This one is working poorly

←

This one is dead!

→
What’s wrong with this replacement valve?
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
Answer:

A: Vertical

B: Horizontal
Poor installation – Refrigerant lines

Historic Church, HVAC Replacement
Poor installation – Refrigerant lines

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

Historic Church, HVAC Replacement
Early 2000s, Mid-Rise, Affordable Senior Housing, HVAC Retrofit
Initial Decarbonization Narrative

➢ **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?
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

Senior Housing Retrofit
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

Senior Housing Retrofit
Developing Options – Ventilation

Senior Housing Retrofit
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
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
### Annual Savings Comparison

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Utility Costs</td>
<td>10%</td>
<td>18%</td>
<td>13%</td>
</tr>
<tr>
<td>Site EUI</td>
<td>42%</td>
<td>49%</td>
<td>26%</td>
</tr>
<tr>
<td>Source EUI</td>
<td>11%</td>
<td>23%</td>
<td>13%</td>
</tr>
</tbody>
</table>

#### Does a Heat Pump Make it Better?

Senior Housing Retrofit

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

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

WHAT PART OF “SENIOR” DON’T YOU UNDERSTAND?
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
Project Direction Observed

Small scale retrofit
Project Direction Observed

Small scale retrofit
Observations (On Every Street)

Small scale retrofit
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...

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

Small scale retrofit
On Every Street

Yes, it’s handsome but...

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

Small scale retrofit
On Every Street

Yes, it’s handsome but...

**But is this opportunity common?**

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

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

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
On Every Street

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
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

>100% Capacity at 0 F
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

Pitfalls and Challenges
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

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

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Pitfalls and Challenges
Here’s what happens

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- Not understanding the Technology / Applied misinformation
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- Blindspots

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- High bills
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- Poor comfort
- Unnecessary reliance on back-up systems
- Refrigerant leaks
- Increased operational carbon

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Pitfalls and Challenges

BUILDING EVOLUTION CORPORATION
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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
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.

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

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

\[
= 0.03\text{cfm} \times 2,000 \text{ ft}^2 + 7.5\text{cfm} \times (1+3)
\]

\[
= 90 \text{ cfm} - 20 \text{ cfm infiltration credit @3ACH50}
\]

\[
= 70 \text{ cfm}
\]
PARTIAL LOAD (think “SHOULDER” or “SWING SEASON”) HRS/yr

<table>
<thead>
<tr>
<th>City</th>
<th>HRS/yr</th>
</tr>
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<tbody>
<tr>
<td>San Diego</td>
<td>8465</td>
</tr>
<tr>
<td>Jacksonville</td>
<td>6139</td>
</tr>
<tr>
<td>Austin</td>
<td>5843</td>
</tr>
<tr>
<td>New Orleans</td>
<td>5831</td>
</tr>
<tr>
<td>Miami</td>
<td>5518</td>
</tr>
<tr>
<td>Atlanta</td>
<td>5412</td>
</tr>
<tr>
<td>Charlotte</td>
<td>5187</td>
</tr>
<tr>
<td>Fort Worth</td>
<td>5058</td>
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<tr>
<td>Seattle</td>
<td>5038</td>
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<tr>
<td>Columbus</td>
<td>4657</td>
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<tr>
<td>Baltimore</td>
<td>4617</td>
</tr>
<tr>
<td>Washington/ Arlinton</td>
<td>4419</td>
</tr>
<tr>
<td>Phoenix</td>
<td>4370</td>
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<tr>
<td>Boston</td>
<td>4275</td>
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<tr>
<td>Saint Louis</td>
<td>4204</td>
</tr>
<tr>
<td>Kansas City</td>
<td>4189</td>
</tr>
<tr>
<td>Nashville</td>
<td>4184</td>
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<tr>
<td>Chicago</td>
<td>4002</td>
</tr>
<tr>
<td>Denver</td>
<td>3772</td>
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</table>

Partial Load Frequency, 50-80°F DB
# HUMID PARTIAL LOAD HRS/yr

Partial Load Conditions Hrs/Yr (50-80 & >65gr/lb)

<table>
<thead>
<tr>
<th>City</th>
<th>Hrs/Yr</th>
</tr>
</thead>
<tbody>
<tr>
<td>Miami</td>
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<td>San Diego</td>
<td>4113</td>
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<td>Mobile</td>
<td>4018</td>
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<tr>
<td>New Orleans</td>
<td>4009</td>
</tr>
<tr>
<td>Austin</td>
<td>3852</td>
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<td>Atlanta</td>
<td>2906</td>
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<tr>
<td>Nashville</td>
<td>2737</td>
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<td>Charlotte</td>
<td>2672</td>
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<td>Fort Worth</td>
<td>2633</td>
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<td>Kansas City</td>
<td>2263</td>
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<td>Baltimore</td>
<td>2194</td>
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<tr>
<td>Columbus</td>
<td>2173</td>
</tr>
<tr>
<td>Washington/Arlington</td>
<td>2118</td>
</tr>
<tr>
<td>Chicago</td>
<td>1976</td>
</tr>
<tr>
<td>Saint Louis</td>
<td>1965</td>
</tr>
<tr>
<td>Boston</td>
<td>1786</td>
</tr>
<tr>
<td>Denver</td>
<td>958</td>
</tr>
<tr>
<td>Seattle</td>
<td>612</td>
</tr>
<tr>
<td>Phoenix</td>
<td>270</td>
</tr>
</tbody>
</table>
50-80°F DB & >65 grains/Lb da

SEATTLE 612 HRS
SAN DIEGO 4,113 HRS
CHICAGO 1,976 HRS
FORT WORTH 2,633 HRS
AUSTIN 3,852 HRS
NEW ORLEANS 4,009 HRS
MIAMI 4,375 HRS
BOSTON 1,786 HRS
NYC 2,229 HRS
BALTIMORE 2,194 HRS
ATLANTA 2,906 HRS
JACKSONVILLE 4,223 HRS
ST. LOUIS 1,965 HRS
COLUMBUS 2,173 HRS
MOBILE 2,345 HRS
Daily Latent Load @ 80 cfm (Pints/Day)
FREQUENCY AND MAGNITUDE

Hours per Year and Pints per Day

- Hrs 50-80 & >65gr/lb
- Daily Latent Load @ 80 cfm (Pints/Day)
How Much Is Coming In?

Hours/Year & Ventilation Load Pints/Day @ 60 cfm

- Miami: 32.3
- Jacksonville: 30.0
- San Diego: 13.3
- New Orleans: 31.6
- Austin: 28.9
- Atlanta: 22.6
- Nashville: 23.6
- Charlotte: 24.6
- Fort Worth: 24.2
- Mobile: 18.9
- Kansas City: 19.3
- Baltimore: 21.0
- Columbus: 17.9
- Washington/Arlington: 18.6
- New York: 13.1
- Chicago: -1.4
- Saint Louis: 2.5
- Boston: 11.0
- Denver: 12.0
- Seattle: 13.0
- Phoenix: -5.0

Legend:
- Hrs 50-80 & >65gr/lb
- Daily Latent Load @ 60 cfm (Pints/Day)
DESIGN CONDITIONS: 92°F DRY BULB/74.7°F WET BULB

**SENSIBLE HEAT RATIO = 0.72**
### Hourly Data Binning and Statistics

**Weather Data Statistics for selected schedule:**

#### Define selection criteria:

<table>
<thead>
<tr>
<th>Description</th>
<th>Units</th>
<th>Minimum</th>
<th>Maximum</th>
<th>Wet Average</th>
<th>Mean</th>
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</thead>
<tbody>
<tr>
<td>Dry bulb temperature</td>
<td>°F</td>
<td>55.04</td>
<td>79.68</td>
<td>70.23</td>
<td>77.46</td>
</tr>
<tr>
<td>Dew point temperature</td>
<td>°F</td>
<td>54.71</td>
<td>78.62</td>
<td>64.53</td>
<td>76.69</td>
</tr>
<tr>
<td>Wet bulb temperature</td>
<td>°F</td>
<td>55.04</td>
<td>78.30</td>
<td>66.11</td>
<td>76.67</td>
</tr>
<tr>
<td>Humidity ratio</td>
<td>g/lb d.a.</td>
<td>N.A.</td>
<td>N.A.</td>
<td>N.A.</td>
<td>70.00</td>
</tr>
<tr>
<td>Relative humidity</td>
<td>%</td>
<td>45.14</td>
<td>100.00</td>
<td>81.94</td>
<td>75.7</td>
</tr>
<tr>
<td>Enthalpy</td>
<td>Btu/lb d.a</td>
<td>23.33</td>
<td>41.93</td>
<td>31.09</td>
<td>36.63</td>
</tr>
<tr>
<td>Wind speed</td>
<td>mph</td>
<td>0.00</td>
<td>28.06</td>
<td>7.56</td>
<td>14.43</td>
</tr>
<tr>
<td>Wind direction</td>
<td>degrees</td>
<td>0.00</td>
<td>360.00</td>
<td>167.58</td>
<td>180.00</td>
</tr>
<tr>
<td>Atmospheric pressure</td>
<td>psia</td>
<td>14.45</td>
<td>14.94</td>
<td>14.72</td>
<td>114.69</td>
</tr>
</tbody>
</table>

**Select Binning Type:**

- Standard
  - Bin on: Dry Bulb
  - Bin size: 2
  - Joint Frequency
    - Tab size: 2
    - W size: 2

**Select Months:**

- January
- July
- February
- August
- March
- September
- April
- October
- May
- November
- June
- December

**Stats for the selected hours fitting the selection criteria:**

- Number of hours: 2,118

---

**PARTIAL LOAD DESIGN CHECK**

**ARLINGTON, VA PARTIAL LOAD CONDITIONS 2,118 /YR**
### Design Conditions:

- **Dry Bulb**: 70.2°F
- **Wet Bulb**: 66.1°F

### Partial Loads

- **Arlington, VA**: 2,118 HRS/yr
- **Austin, TX**: 5,843 HRS/yr

### Sensible Heat Ratio

**Sensible Heat Ratio** = 0.67
**BOSTON 99% LOAD CONDITIONS = 88 HRS/YR**

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

<table>
<thead>
<tr>
<th>Scope</th>
<th>Net Ton</th>
<th>ft² /Ton</th>
<th>Area</th>
<th>Sen Gain</th>
<th>Lat Gain</th>
<th>Net Gain</th>
<th>Sen Loss</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Building</strong></td>
<td>1.41</td>
<td>1.475</td>
<td>2.085</td>
<td>13.967</td>
<td>2.993</td>
<td>16.960</td>
<td>23.213</td>
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<tr>
<td><strong>System 1</strong></td>
<td>1.41</td>
<td>1.475</td>
<td>2.085</td>
<td>13.967</td>
<td>2.993</td>
<td>16.960</td>
<td>23.213</td>
</tr>
<tr>
<td>Ventilation</td>
<td></td>
<td></td>
<td></td>
<td>1.055</td>
<td>1.283</td>
<td>2.338</td>
<td>5.100</td>
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<tr>
<td><strong>Zone 1 - Clg.: 59%, Htg.: 50%</strong></td>
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<td></td>
<td></td>
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</tr>
<tr>
<td>1-Entry</td>
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<td>0.295</td>
<td>0</td>
<td>295</td>
<td>949</td>
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<tr>
<td>2-Office</td>
<td></td>
<td></td>
<td>1.751</td>
<td>200</td>
<td>1.951</td>
<td>1.459</td>
<td></td>
</tr>
<tr>
<td>3-Bathroom/Closet</td>
<td></td>
<td></td>
<td>1.61</td>
<td>150</td>
<td>311</td>
<td>752</td>
<td></td>
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<td>1.786</td>
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**SENSIBLE HEAT RATIO = 0.82**
BOSTON PARTIAL LOAD CONDITIONS = 1,786 HRS/yr

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

<table>
<thead>
<tr>
<th>Scope</th>
<th>Net Ton</th>
<th>ft² /Ton</th>
<th>Area</th>
<th>Sen Gain</th>
<th>Lat Gain</th>
<th>Net Gain</th>
<th>Sen Loss</th>
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<td>2,085</td>
<td>10,155</td>
<td>2,757</td>
<td>12,913</td>
<td>176</td>
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<td>1,938</td>
<td>2,085</td>
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<td>2,757</td>
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### Design Conditions: 98°F Dry Bulb / 74°F Wet Bulb

#### Sensible Heat Ratio = 0.85

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<th>Scope</th>
<th>Net Ton</th>
<th>Ft²/Ton</th>
<th>Area</th>
<th>Sen Gain</th>
<th>Lat Gain</th>
<th>Net Gain</th>
<th>Sen Loss</th>
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<td>3,009</td>
<td>20,337</td>
<td>22,747</td>
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<td>1.69</td>
<td>1,230</td>
<td>2,085</td>
<td>17,328</td>
<td>3,009</td>
<td>20,337</td>
<td>22,747</td>
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# Austin Partial Load Conditions

3,852 Hrs/yr

## Design Conditions:

- 71° F Dry Bulb
- 67° F Wet Bulb

## Sensible Heat Ratio:

0.75

## Table:

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<thead>
<tr>
<th>Scope</th>
<th>Net Ton</th>
<th>ft² / Ton</th>
<th>Area</th>
<th>Sens Gain</th>
<th>Lat Gain</th>
<th>Net Gain</th>
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<td>299</td>
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Sizing is a balancing act
UNDERSTAND THE HEATING CAPACITY RANGES

@65 F OAT and 70 F IAT

Minimum Capacity of ~24,000 Btu/h
# System Capacity Ranges in Cooling

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<th>Indoor Unit</th>
<th>Rated</th>
<th>Max. Rated</th>
<th>Max. Rated</th>
<th>Max. Rated</th>
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<td>Q(Btu/h)</td>
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- **94** Q(Btu/h): 48180-46550, 33413-32275
  - Max. Rated: 37686, 34300, 33735, 20250
  - Min. Rated: 34766, 31695, 31290, 19300

- **90** Q(Btu/h): 48180-46550, 33413-32275
  - Max. Rated: 37686, 34300, 33735, 20250
  - Min. Rated: 34766, 31695, 31290, 19300

- **86** Q(Btu/h): 48180-46550, 33413-32275
  - Max. Rated: 37686, 34300, 33735, 20250
  - Min. Rated: 34766, 31695, 31290, 19300

- **78** Q(Btu/h): 48180-46550, 33413-32275
  - Max. Rated: 37686, 34300, 33735, 20250
  - Min. Rated: 34766, 31695, 31290, 19300

- **74** Q(Btu/h): 48180-46550, 33413-32275
  - Max. Rated: 37686, 34300, 33735, 20250
  - Min. Rated: 34766, 31695, 31290, 19300

- **68** Q(Btu/h): 48180-46550, 33413-32275
  - Max. Rated: 37686, 34300, 33735, 20250
  - Min. Rated: 34766, 31695, 31290, 19300
YOU NEED: COOLING LOAD AND CAPACITY OVERLAP

LOAD RANGE

PEAK LOAD @ 94° F ~20,000 Btu/h

CAPACITY RANGE

Min. ~17,000 Btu/h

Max. 48,000 Btu/h
MXZ 5C42: COOLING LOAD AND CAPACITY OVERLAP

LOAD RANGE

PARTIAL LOAD @ 64° F ~10,000 Btu/h

CAPACITY RANGE

Min. ~18,000 Btu/h

Max. 48,000 Btu/h

Min. ~18,000 Btu/h
Humidity Control: Deal with it at the source!

Pitfalls and Challenges

Un-tempered Outdoor Air (OA)

Post-tempered ventilation from ERV with DX heating/cooling
Conventional vs. Passive House Enclosure

**Conventional Conditions**
- Envelope: R-10
- Window: R-3
- Outside Temp: 0°F

**Int Walls** 68°F
**Ext Walls** 62.9°F
**Glass Surface** 51.2°F
**RH** 20-50%

**PH Conditions**
- Envelope: R 60
- Window: R .9 Triple glazed (Climate specific)
- Outside Temp: 0°F

**Int Walls** 68°F
**Ext Walls** 67.1°F
**Glass Surface** 62.4°F
**RH** 40-50%
Quality Assurance Commissioning (QACx)

Project Timespan
Enhanced Cx – Quality Assurance

Fundamental Cx - Quality Control*

Pre-Design | Design | Construction | Occupancy & Operations Phase

- Develop Cx Scope and Budget
- Develop Initial Cx Plan
- Provide Assistance with OPR
- Review BOD
- Review Design Integration Meetings
- Design Review: SD/Di/CD
- Update & Issue Issue Construction Cx Plan
- Coordinate Cx Activities with Contractors
- Prepare Construction Checklists for Contractors
- Prepare & Issue Functional Performance Tests
- Perform Site Visits, Conduct Cx Meetings
- Perform Functional Tests
- Verify Construction Checklists
- Witness/Review Startup & TAB
- Perform Functional Tests
- Submit Systems Manual
- Review O&M Manuals
- Verify Completion of Training
- Prepare Cx Report
- Provide O&M Demonstration
- Perform O&M Demonstration
- Perform Occupancy Surveys
- Perform 10-Month Warranty Review
- Optimize O&M Systems Manual
- Update OPR & Systems Manual
- Debrief Updates with Client & O&M Team
- Building is Initially Commissioned
- Perform Continuous Commissioning
- Benchmark Building Performance
- Monitor & Adjust Against CFR

*Fundamental Cx may not include full extent of scope shown within the Construction phase.
Fundamental Cx includes: Review OPR, BOD, and a Design Review

BUILDING EVOLUTION CORPORATION
Achieve Performance & Durability Through A Holistic Approach™
Here’s what we see….

➢ Entrenched Habits
➢ Not understanding the Technology / Applied misinformation
➢ Workmansh#t
➢ Devalue Engineering
➢ Blindspots
Questions, Thoughts, Discussion
Thank You.

Ken Neuhauser, M.Arch, MSc. Arch, CEM, CPHC® - President

Chris Kennedy, CEM, CCP, CPHC® - Building Performance Consultant II

Kimberly Llewellyn, MS Eng, CPHC® - Emerging Markets, Senior Product Manager – Mitsubishi Electric Heating & Cooling

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