Effective Strategies for Building Enclosures

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Learning Objectives

1. Review building enclosure design best practices

2. Demonstrate effective methods of controlling air movement through assemblies and discuss the impacts on energy performance

3. Discuss common products details used for thermal control, focusing on the differences between cavity insulation and continuous insulation

4. Using case studies and project details, demonstrate unique considerations and for the five control layers
Control Layers

1. Rainscreen – Sheds the Majority of Water
2. *Drainage Plane* – *Water Resistive Barrier (WRB)*, moves water away from substrates (flashing, weeps)
3. Air Barrier – Prevent Air Leakage
4. Thermal – Prevent Conductive Energy Loss
5. Vapor Barrier – Prevents Warm Humid Air from reaching a Cold Surface and Condensing
Rainscreen - Cladding

Masonry
  Brick/CMU/Cast Stone (Anchored Masonry Veneer)
  Thin Brick/Cultured Stone (Adhered Masonry Veneer)
Fiber Cement Panels/Siding
Wood/Synthetic Wood Panels/Siding/Trim
Metal Panels/Trim
High Pressure Laminate Panels
EIFS
Cement Plaster
Cladding - Masonry
Panels/Siding/Trim – Directly Attached
Panels/Siding/Trim – Sub Framing Attached
EIFS/Cement Plaster
Design Strategies
Water Management Design

Barrier Systems
- Water Management by a continuous, impervious surface
- Vulnerable to any defects (continuity) in the cladding surface
- Relies on sealant at transitions

Drainage Systems
- Durable cladding resists bulk water penetration
- Continuous backup waterproofing layer (can also function as air barrier)

Rainscreen Systems
- Pressure Equalized
- Back Ventilated
Barrier Systems

Mass Masonry

Cast-in-Place concrete

Coating

Architectural Precast Concrete Panels

Image credit: Jeffrey D. Kerr, P.E.
Drainage Systems

Masonry Veneer

Adhered Masonry Veneer

Panels/Siding/Trim

Cement Plaster

Image credit: Jeffrey D. Kerr, P.E.
Rainscreen Systems

Lightweight panels and joints deflect most of the rainwater.

Ventilated cavity eliminates the remainder of the moisture by natural drainage and evaporation.
Barrier Systems
Rainscreen Systems
Attachment Design

Discrete Anchor Systems
Masonry Veneer/Siding/EIFS
Limited thermal bridging
Consider fastener penetration through water/air barrier

Ties
Attachment Design

Girt Systems
Panel Systems
Some thermal bridging
Provide improved detailing at penetrations
Combining clips and girts can improve thermal performance
Attachment Design

Adhered Systems
Thin masonry veneer/ Cement Plaster
Difficult to incorporate continuous insulation
Sensitive to installation environmental factors
Attachment Design

For Cladding Finish Systems: Girts

**Galvanized Girts**
- **Description:** Typical girts are usually galvanized steel. Most projects use these to support their cladding systems.
- **Thermal efficiency per SWA:** 43%-53%
- **Example Products:** Green Girt- Simple Z
  - 3% for Steel backup
  - 43% for CMU backup

**Fiberglass Girts**
- **Description:** Fiberglass girts are installed and used in the same way as typical metal girts. The fiberglass material reduces thermal bridging.
- **Thermal efficiency per SWA:** 91%-95%
- **Example Products:** Armatrain 2 Girl
  - 91% for Steel backup
  - 95% for CMU backup

**Thermoset Resin Girts**
- **Description:** These girts have a low thermal conductivity. Made of fire resistant resin material. Can be spaced 16” or 24” o.c. and is very strong.
- **Thermal efficiency per SWA:** 96%

**Galvanized Metal Clips**
- **Description:** These clips are usually galvanized steel and are used to support rainscreen and panel cladding systems.
- **Thermal efficiency per SWA:** 46-59%
- **Example Products:** A-Clip, MESSCHER
  - 46% for Steel backup
  - 59% for CMU backup

For Cladding Finish Systems: Clips

**Stainless Steel Clips**
- **Description:** Replacing galvanized steel clips with stainless steel ones can greatly reduce the thermal conductivity.
- **Thermal efficiency per SWA:** 63-74%
- **Example Products:** Alpha Brackets
  - 63% for Steel backup
  - 74% for CMU backup

**Aluminum Clips**
- **Description:** Aluminum clips are lightweight and strong. They are a more elastic and non-corrosive alternative to traditional metal clips.
- **Thermal efficiency per SWA:** 64-79%
- **Example Products:** Cascada Clip
  - 64% for Steel backup
  - 79% for CMU backup

**Fiberglass Clips**
- **Description:** Fiberglass clips have a much lower thermal transmittance coefficient than any metal equivalent.
- **Thermal efficiency per SWA:** 67-80%
- **Example Products:** Pet-Tie Thermal Clip, Nyloplane NY1 Thermal Clip
  - 67% for Steel backup
  - 80% for CMU backup

**Thermal Stop Clips**
- **Description:** This clip has a plastic thermal stop at the base and head to help mitigate thermal bridging.
- **Thermal efficiency per SWA:** 67-80%

- **Example Products:** Pet-Tie Thermal Clip, Nyloplane NY1 Thermal Clip
Attachment Design

For Brick Veneer Systems: Ties

**Galvanized Steel Brick Ties**
- Description: Typical brick ties are galvanized steel. Most brick veneer projects use this type of product.
- Thermal efficiency per SWA: 76-84%
  - 75% for Steel backup
  - 84% for CMU backup

**Stainless Steel Brick Ties**
- Description: Stainless steel ties are less conductive than galvanized steel ties.
- Thermal efficiency per SWA: 87-93%
  - 87% for Steel backup
  - 93% for CMU backup

**Thermal Break Brick Ties**
- Description: This stainless steel brick tie has a plastic coating, which reduces thermal bridging.
- Thermal efficiency per SWA: 88-94%
  - 88% for Steel backup
  - 94% for CMU backup

**Basalt Fiber Wall Ties**
- Description: Basalt fiber is a material made from fine fibers of basalt. They tend to be stronger and lighter than stainless steel wall ties and much less thermally conductive.
- There are used in place of brick ties. The combination of horizontal and vertical elements increases strength despite its small size.
  - These can be applied prior to liquid applied or barrier installation, so air tightness is improved.

**Connectors**

**For Brick Veneer Systems: Angles**

**Typical Shelf Angle**
- Description: Typically, shelf-angles are made of galvanized steel.
- Thermal efficiency per SWA: 58-69%
  - 58% for Steel backup
  - 69% for CMU backup

**Stand-off Shelf Angle**
- Description: This stand-off shelf angle allows insulation to be installed behind it. The bracket can be used with readily available shelf angles.
- Thermal efficiency per SWA: 73-81%
  - 73% for Steel backup
  - 81% for CMU backup

**Sheel Angle with Thermal Break**
- Description: The thermal break plate is inserted between the shelf angle and bracket to reduce the thermal bridge at these points.
- Thermal efficiency per SWA: 63-74%
  - 63% for Steel backup
  - 74% for CMU backup

**Example Products:**
- FAST (Fast-Angle Support technology), Armatherm Shelf Angle
Continuity of Control Layers

Readability – clearly communicate the intent

Durability – select materials appropriate for the life of the building

Maintainability – consider frequency and effort of maintenance

Sustainability – consider impact on the environment

Liability – shortcomings in the above can contribute to costly remediation
Detailing the Control Layers
Detailing the Control Layers
Detailing the Control Layers
Condensation Control

• Why does condensation form on the outside of a cold drink in the summer?

Dew point!
Detail Moisture Vapor Control Strategy

- First condensing surface must be above dew point temperature of ambient air
- Thermally broken windows
- Control indoor humidity conditions, specify: Proper local ventilation
- Construction moisture!
What is Dew Point?

- Warm air can hold more moisture than cold air
- The dew point is reached when the air is cooled to the point of saturation (100% Relative Humidity)
- When this occurs we call it condensation
Cold Weather Condensation

- Can occur when warm moist interior air contacts cooler surfaces such as windows.
- Condensation forms when the surface temperature is below the dew point temperature for the interior air.
Prevent Condensation

- Raise the temperature of the condensing surfaces
- Add a vapor retarder to inhibit the moisture from reaching the condensing surface
- Lower the interior space relative humidity
- Reduce the interior “moisture loading”
Airflow in Buildings

**Infiltration:** air movement into the building
Occurs in areas of negative pressure inside the building

**Exfiltration:** air movement out of the building
Occurs in areas of positive pressure inside the building
Air Flow in Buildings

3 Main Driving Forces:

• Stack effect
• Mechanical effect
• Wind effect
Air Flow in Buildings

Wind Driven Air Flow

Stack Effect

Mechanical Equipment
Air Sealing Priorities

• Stop the Stack Effect!

• Go after biggest holes first, duh

• Top of the building is usually first priority

• Base of the building is next

• Center of building last, if even necessary
Methods of Heat Transfer

• Heat is a form of energy

• When heat moves from place to place, it is referred to as “Heat Transfer”

• Heat Transfer occurs in three ways:
  • Conduction
  • Convection
  • Radiation
Heat Transfer

Conduction

• Occurs when heat energy moves through a solid or fluid material

• Energy is transferred from one molecule to the next

• Examples of conduction:
Heat Transfer

Conduction
Convection

• Convection occurs when heat is carried from one place to another

• Convection requires a “fluid medium” (i.e. a gas or liquid)
Heat Transfer

Convection

• Convection in homes usually occurs when air in the house moves around due to temperature gradients

• Warm air is lighter (i.e. less dense) than cold air

• Cold air falls, warm air rises
Convection Loops

• When convection occurs in an enclosed space, the air (or fluid) will circulate around the space as it is heated and cooled, this is referred to as a convective loop

• Examples of places where convective loops could be found . . . ?
Heat Transfer

Radiation

• Heat radiates to cold surfaces. Must be an air gap between the two bodies.

• Examples of places where radiation effects can be found . . . ?
Air Barrier & Thermal Barrier
Air Barrier & Thermal Barrier
Air Barrier & Thermal Barrier
Air Barrier & Thermal Barrier
Air Barrier & Thermal Barrier
Air Barrier & Thermal Barrier
Air Barrier & Thermal Barrier
Air Barrier & Thermal Barrier
Air Barrier & Thermal Barrier

NOTE: PER PHUS+ PASSIVE HOUSE DESIGN REQUIREMENTS ROOF R-VALUE SHALL MEET A MINIMUM OF R-40. REFER TO COMPLIANCE REPORT FOR ADDITIONAL INFORMATION

1/2" APA STRUCTURAL 1 RATED 1 1/2" PLAYWOOD SHEATHING
CONTINUOUS AVB MEMBRANE, BASIS OF DESIGN: HENRY BLUEGRASS (LAP AND SEAL ALL JOINTS)

EEBA
Air Barrier & Thermal Barrier

Common Walls
Air Barrier

Demising Walls

Notes:
A, B, C: Intent: Reduce leakage between exterior / corridor wall and demising wall / interior partition

A. Options:
- Expanding foam
- Plywood, drywall or rigid foam board with edges caulked

A. Mineral wool or fiberglass batts are NOT acceptable as an air barrier

C. Option: Apply drywall adhesive to framing BEFORE installing drywall

Responsibilities:
Drywall: C
Mech/Bldg/Plumb: A, B
Vapor Control

Air Control Layer

Vapor Control Layer

Thermal Control Layer

Cladding

Control Layer

Structure
Vapor Control

Class I. <0.1 perms e.g. polyethylene sheet, sheet metal, or aluminum facing.

Class II. 0.1 - 1.0 perms e.g., faced batts, and some vapor control paints.

Class III. 1.0 - 10 perms e.g. latex or enamel paints.
Vapor Retarder Definitions

**Permeance [perm]**: the rate that moisture vapor moves through a given construction layer for the given thickness

**Permeability [perm in]**: the rate that moisture vapor moves through a given construction material at a standard thickness (1 in or 1 cm)

**Permeance = Permeability ÷ Layer Thickness**
Example:
A certain type of SPF has a permeability of 1.2 perm per inch
   A) What is the perm rating of 1.5 inches of SPFA?
   B) What vapor retarder class does this fall under?

Answer:
   A) Permeance = permeability ÷ layer thickness
      Permeance = 1.2 perm in/1.5 in = 0.8 perm

   Class III: 1.0 < perm <=10 perm
   B) Class II: 0.1 < perm <=1.0 perm
   Class I: < =0.1 perm
Vapor Control

**Code: CZ 1-3, 4A, 4B:** No Interior Vapor Control is required (or recommended) on the interior side of framed walls

**Wood sheathing and plywood:** 10 perms (very permeable) might allow drying to outside

**OSB:** 2 perms becomes more of a Vapor Retarder as it gets wet.
Vapor Control

(2015 IBC): **CZ 5-8, Marine 4:** Class I or II Vapor Retarders SHALL be provided on the interior side of frame walls.

**UNLESS**
Continuous Insulation meets the required R value . . . than a Class III (latex paint) VR is allowed (Class I & II should not be allowed!).

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### EXTERIOR WALLS

| ZONE | CLASS III VAPOR RETARDERS PERMITTED FOR:
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Marine 4</td>
<td></td>
</tr>
</tbody>
</table>
Vented cladding over wood structural panels  
Vented cladding over fiberboard  
Vented cladding over gypsum  
Insulated sheathing with $R$-value $\geq R2.5$ over 2 x 4 wall  
Insulated sheathing with $R$-value $\geq R3.75$ over 2 x 6 wall |
| 5 |  
Vented cladding over wood structural panels  
Vented cladding over fiberboard  
Vented cladding over gypsum  
Insulated sheathing with $R$-value $\geq R5$ over 2 x 4 wall  
Insulated sheathing with $R$-value $\geq R7.5$ over 2 x 6 wall |
| 6 |  
Vented cladding over fiberboard  
Vented cladding over gypsum  
Insulated sheathing with $R$-value $\geq R7.5$ over 2 x 4 wall  
Insulated sheathing with $R$-value $\geq R11.25$ over 2 x 6 wall |
| 7 and 8 |  
Insulated sheathing with $R$-value $\geq R10$ over 2 x 4 wall  
Insulated sheathing with $R$-value $\geq R15$ over 2 x 6 wall |
Thermal Barrier & Vapor Control

T_{interface} = T_{indoor} - [(T_{indoor} - T_{outdoor}) \times (R_{cavity}/R_{total})]

Ok for some gut check math but Avg. temp is too arbitrary

<table>
<thead>
<tr>
<th>Average Daily Temperature °F</th>
<th>Minimum Recommended Exterior CI R-Value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>Dec/Jan/Feb</td>
<td>R21 Stud Cavity</td>
</tr>
<tr>
<td>34°</td>
<td>R 4</td>
</tr>
<tr>
<td>32°</td>
<td>R 5.5</td>
</tr>
<tr>
<td>30°</td>
<td>R 7</td>
</tr>
<tr>
<td>28°</td>
<td>R 8.5</td>
</tr>
<tr>
<td>26°</td>
<td>R 10</td>
</tr>
</tbody>
</table>

Washington, DC ~ CZ 4

Baltimore, MD ~ CZ 4

Worcester, MA ~ CZ 5
Thermal Barrier & Vapor Control

Exterior Insulation: 2" Polyiso (R-12)
Stud Bay Insulation: 5.5" F6 Batt (R-19)

Track of sheathing:
- $T_{inter} = (T_{inter} - T_{exterior}) \cdot \frac{R_{exterior}}{R_{total}}$
- $68^\circ - (68^\circ - 24^\circ) \cdot \frac{19}{31}$
- $68^\circ - 25.7^\circ$
- $42.3^\circ$ - In trouble if RH exceeds 38%

Tack of sheathing:
- $68^\circ - \frac{(68^\circ - 24^\circ)}{32.8}$
- $68^\circ - 33.5^\circ$
- $34.5^\circ$ - In trouble if RH exceeds 28%

2" Insulated Zip (R: 9.6)
- $T = 68^\circ - (68^\circ - 24^\circ) \cdot \frac{24.2}{35.8}$
- $68^\circ - 37.3^\circ$
- $30.7^\circ$ - In trouble if RH exceeds 32%

2.5" Insulated Zip (R: 12.6)
- $T = 68^\circ - (68^\circ - 24^\circ) \cdot \frac{24.2}{38.8}$
- $68^\circ - 42^\circ \cdot 0.675$
- $39.7^\circ$ - In trouble if RH exceeds 35%
Thermal Barrier & Vapor Control

This is also achievable with closed cell foam in the cavity (CZ 4, R8-ish)

Image credit: Green Building Advisor
Thermal Barrier & Vapor Control
Thermal Barrier & Vapor Control
Thermal Barrier & Vapor Control

No vapor control required on the interior side of framed walls in CZ 1, 2, 3, 4a, 4b
Thermal Barrier & Vapor Control

Plant hardiness zones are moving North at the rate of 13 miles per decade.
### Thermal Barrier & Vapor Control

#### TABLE 402.1.1
**INSULATION AND FENESTRATION REQUIREMENTS BY COMPONENT**

<table>
<thead>
<tr>
<th>CLIMATE ZONE</th>
<th>FENESTRATION U-FACTOR</th>
<th>SKYLIGHT U-FACTOR</th>
<th>GLAZED FENESTRATION SHGC</th>
<th>CEILING R-VALUE</th>
<th>WOOD FRAME WALL R-VALUE</th>
<th>MASS WALL R-VALUE</th>
<th>FLOOR R-VALUE</th>
<th>BASEMENT WALL R-VALUE</th>
<th>SLAB R-VALUE &amp; DEPTH</th>
<th>CRAWL/SPACE WALL R-VALUE</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1.2</td>
<td>0.75</td>
<td>0.30</td>
<td>30</td>
<td>13</td>
<td>3/4</td>
<td>13</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>2</td>
<td>0.65</td>
<td>0.75</td>
<td>0.30</td>
<td>30</td>
<td>13</td>
<td>4/6</td>
<td>13</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>3</td>
<td>0.50</td>
<td>0.65</td>
<td>0.30</td>
<td>30</td>
<td>13</td>
<td>5/8</td>
<td>19</td>
<td>5/13</td>
<td>0</td>
<td>5/13</td>
</tr>
<tr>
<td>4 except Marine</td>
<td>0.35</td>
<td>0.60</td>
<td>NR</td>
<td>38</td>
<td>13</td>
<td>5/10</td>
<td>19</td>
<td>10/13</td>
<td>10, 2 ft</td>
<td>10/13</td>
</tr>
<tr>
<td>5 and Marine 4</td>
<td>0.35</td>
<td>0.60</td>
<td>NR</td>
<td>38</td>
<td>20 or 13+5⁴</td>
<td>13/17</td>
<td>30³</td>
<td>10/13</td>
<td>10, 2 ft</td>
<td>10/13</td>
</tr>
<tr>
<td>6</td>
<td>0.35</td>
<td>0.60</td>
<td>NR</td>
<td>49</td>
<td>20 or 13+5⁴</td>
<td>15/19</td>
<td>30³</td>
<td>15/19</td>
<td>10, 4 ft</td>
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<tr>
<td>7 and 8</td>
<td>0.35</td>
<td>0.60</td>
<td>NR</td>
<td>49</td>
<td>21</td>
<td>19/21</td>
<td>38³</td>
<td>15/19</td>
<td>10, 4 ft</td>
<td>10/13</td>
</tr>
</tbody>
</table>

#### 2009 IECC

#### 2018 IECC
### TABLE 1405.3.2
CLASS III VAPOR RETARDERS

<table>
<thead>
<tr>
<th>ZONE</th>
<th>CLASS III VAPOR RETARDERS PERMITTED FOR:*</th>
</tr>
</thead>
</table>
| Marine 4 | Vented cladding over wood structural panels  
|         | Vented cladding over fiberboard          
|         | Vented cladding over gypsum              
|         | Insulated sheathing with R-value ≥ R2.5 over 2 × 4 wall  
|         | Insulated sheathing with R-value ≥ R3.75 over 2 × 6 wall  |
| 5      | Vented cladding over wood structural panels  
|         | Vented cladding over fiberboard          
|         | Vented cladding over gypsum              
|         | Insulated sheathing with R-value ≥ R5 over 2 × 4 wall  
|         | Insulated sheathing with R-value ≥ R7.5 over 2 × 6 wall  |
| 6      | Vented cladding over fiberboard          
|         | Vented cladding over gypsum              
|         | Insulated sheathing with R-value ≥ R7.5 over 2 × 4 wall  
|         | Insulated sheathing with R-value ≥ R11.25 over 2 × 6 wall  |
| 7 and 8| Insulated sheathing with R-value ≥ R10 over 2 × 4 wall  
|         | Insulated sheathing with R-value ≥ R15 over 2 × 6 wall  |
Thermal Barrier & Vapor Control
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Thermal Barrier & Vapor Control
Thermal Barrier & Vapor Control

Photo: Pavel Bendov
Thermal Barrier & Vapor Control
Thermal Barrier & Vapor Control
### 2015 IBC

#### TABLE 1203.3

**INSULATION FOR CONDENSATION CONTROL**

<table>
<thead>
<tr>
<th>CLIMATE ZONE</th>
<th>MINIMUM R-VALUE OF AIR-IMPERMEABLE INSULATION*</th>
</tr>
</thead>
<tbody>
<tr>
<td>2B and 3B tile roof only</td>
<td>0 (none required)</td>
</tr>
<tr>
<td>1, 2A, 2B, 3A, 3B, 3C</td>
<td>R-5</td>
</tr>
<tr>
<td>4C</td>
<td>R-10</td>
</tr>
<tr>
<td>4A, 4B</td>
<td>R-15</td>
</tr>
<tr>
<td>5</td>
<td>R-20</td>
</tr>
<tr>
<td>6</td>
<td>R-25</td>
</tr>
<tr>
<td>7</td>
<td>R-30</td>
</tr>
<tr>
<td>8</td>
<td>R-35</td>
</tr>
</tbody>
</table>

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a. Contributes to, but does not supersede, thermal resistance requirements for attic and roof assemblies in Section C402.2.1 of the *International Energy Conservation Code.*
Thermal Barrier & Vapor Control

Details for a Thick Roof

- Rigid foam insulation installed above the roof assembly can create an energy-smart roof. With three layers of 1½-in. polyisocyanurate insulation above the sheathing and approximately ¾ in. of cellulose insulation in the rafter cavities, the roof shown here has an R-value of approximately 63. The three layers of foam help to seal air leaks, but to make this assembly perform well, you need to incorporate some unconventional details.

- Metal roofing is shown here. Other types of roofing work as well. Check manufacturer’s warranties for some basic rules:
  - Use a felt base when covering flat roofs.
  - Use a felt base when covering flat roofs.
  - Use a felt base when covering flat roofs.

- Self-adhesive membrane

- ⅜-in. OSB or plywood for securing roofing

- Three layers of 1½-in. rigid insulation with staggered seams. Tape the seams of the first layer. For polyisocyanurate or XPS, use contact’s tape or foil tape. For XPS, use foam secured. To make the assembly even tighter, tape or foam all of the layers.

- ⅛-in. structural roof sheathing

- Long screws penetrate the rafters to secure the top layer of sheathing.

- The fascia should be installed before the peel-and-stick roof membrane so that the membrane can wrap over the fascia by at least 1 ⅞ in. To provide solid nailing for the fascia, install a stack of beveled or ⅞-in. or ⅝-in. as at the edges.

- To maintain a continuous air barrier, install a long stack of rigid foam as the blocking between the rafters. The same plane as the wall sheathing. Cut these foam strips short by about ¼ in. to allow room for the expanding foam.
Vapor Control

Elements of a Large Multifamily Passive House Building

- Continuous Insulation & Thermal Bridge-Free Construction
- High Performance Windows & Doors
- Airtight Envelope
- Energy Recovery Ventilation
- Domestic Hot Water
- Efficient Lights & Appliances

Multifamily Considerations

Energy Recovery Ventilation
Determining the right system for any project can be challenging. There are pros and cons to both central and decentralized systems. A certified Passive House consultant can help the project team decide which system is best for your building.

Domestic Hot Water
In large scale multifamily buildings in the US the majority of DHW systems are central systems with recirculation loops and high efficiency, natural gas water heaters. Minimizing pipe lengths and optimizing pump sizes and insulation are essential to meet the rigid Passive House primary energy and cooling thresholds.

Efficient Lights & Appliances
Multifamily projects face special challenges here because they must run corridor and egress lighting 24/7. They are also faced with a greater number of appliances per square foot compared with single family homes. Both of these factors result in increased cooling and primary energy demands. The use of controls and daylighting should be incorporated wherever possible to reduce energy use.
Vapor Control
Vapor Control
Vapor Control

Credit: PHIUS
Thank you!

Join the conversation - #EEBASummit2019

Save the dates for next year:

HIGH PERFORMANCE HOME SUMMIT 2020
SEPT 29 - OCT 1 / DENVER
Durability & Comfort

• Ductwork thermal losses can range from 10-45%

• Interior ducts locations may impact cost, aesthetics and envelope loads

1. Ducts in unvented attic
2. Ducts in dropped ceiling
3. Ducts in modified truss in attic
4. Ducts between floors
Durability & Comfort

- Ducts deeply buried under loose-fill insulation
- Ducts with R-8 insulation encapsulated in 1.5 in of ccSPF running above the truss chords
- Flex duct with R-8 insulation encapsulated in 1.5 in of ccSPF
- Duct-boot connection over ceiling supply register encapsulated in 1.5 in of ccSPF
- Gyp. board ceiling
- Truss lower chords
Durability & Comfort
Durability & Comfort

How ventilation works

- Fresh air is fed into the system via an external or internal vent. With an optional air-ground source geothermal heat exchanger, the heat exchangers use geothermal energy to pre-temper outside air before it enters the system.
- The Zehnder ComforFresh ventilation devices recover up to 55% of the energy from the exhaust air and return it to the fresh air. This can be increased to 100% monitored, heated, and conditioned using optional components.
- The Zehnder ComfoFresh air distribution system distributes optimally tempered fresh air to individual rooms as needed and vents exhaust air to the outside. The air volume can be adjusted individually for each room.

Benefits:
- Continuous supply of fresh air
- Serves energy through heat recovery
- Retains property value by preventing mildew
- Promotes good health
- Protects against outside noise
- Government subsidized (in select markets)

- Warms incoming winter air (or the reverse)
- Good to remove humidity
- Good for favorable humidity levels in & out

Warmed Fresh Air
Cooled Stale Air to Living Space
Exhausted
Warm Stale Air from Living Space
Cold Fresh Air from Outdoors

EEBA
Durability & Comfort
### Durability & Comfort

#### MERV Rating Chart

<table>
<thead>
<tr>
<th>MERV</th>
<th>Efficiency (%</th>
<th>MERV Description</th>
<th>Applications</th>
</tr>
</thead>
<tbody>
<tr>
<td>14</td>
<td>90-95%</td>
<td>&gt;98%</td>
<td>Most Tobacco Smoke, Smoking Lounges</td>
</tr>
<tr>
<td>13</td>
<td>89-90%</td>
<td>&gt;98%</td>
<td>Proplet Nuceli (Sneeze), Superior Commercial Buildings</td>
</tr>
<tr>
<td>12</td>
<td>70-75%</td>
<td>&gt;95%</td>
<td>1.0-3.0 pm Particle Size, Legionella, Superior Residential</td>
</tr>
<tr>
<td>11</td>
<td>60-65%</td>
<td>&gt;95%</td>
<td>Humidifier Dust, Lead Dust, Better Commercial Buildings</td>
</tr>
<tr>
<td>10</td>
<td>50-55%</td>
<td>&gt;95%</td>
<td>Milled Flour, Auto Emissions, Hospital Laboratories</td>
</tr>
<tr>
<td>9</td>
<td>40-45%</td>
<td>&gt;90%</td>
<td>Welding Fumes, Pleated Filters - Disposable, extended surface area, thick with cotton-polyester blend</td>
</tr>
<tr>
<td>8</td>
<td>30-35%</td>
<td>&gt;90%</td>
<td>3.0-10.0 pm Particle Size, Commercial Buildings</td>
</tr>
</tbody>
</table>

*Box Filter* - Rigid Style Cartridge
*Bag Filter* - Nonsupported microfine fiberglass or synthetic media, 12-36 in. deep, 6-12 pockets
*Pleated Filters* - Disposable, extended surface area, thick with cotton-polyester blend media.
Durability & Comfort

Particulates: It’s Not Just Dirt

Average Concentration of Chemicals in Dust (NG/G)

Chemicals: Phthalates, Phenols, Flame Retardants, Fragrances, Fluorinated Chemicals
Durability & Comfort

Particulate Matter Size (in Microns)

- MERV 13: Mold Spores, Auto Emissions, Hair Spray
- MERV 11: Lung Damaging Dust, Pet Dander, Insecticide Dusts
- MERV 8: Human Hair, Carpet Fibers, Pollen, Dust Mites, Plant Spores

1.0 - 3.0

Smog, Tobacco Smoke, Cooking Oil, Burning Wood

0.3 - 1.0

Bacteria
Durability & Comfort