The Next Frontier of Building Science: Air Leakage

Achilles Karagiozis
Global Director Building Science, Sustainability
Owens Corning
Acknowledgements

• Mikael Salonvaara, Owens Corning
• Andre Desjarlais, Oak Ridge National Laboratory
• Laverne Dagleish, ABAA
• Dave Wolf, Owens Corning
• Department of Energy, DOE
• Diana Hun, Oak Ridge National Laboratory
• Hartwig Kuenzel, Fraunhofer Institute of Building Physics
• Objectives (Short Term and Long Term)
• Simplification of the Physics
• Air Leakage performance structure
• Passive House wall Heat-Air-Moisture analysis
• Implementation of a approach for Design
Air flow

The windward side of a house has positive pressure; wind pushes air (and wind-blown rain) into windows, walls, roof penetrations, and leaky rim joists.

The leeward side has negative pressure; air is sucked out of the house.

The air inside the house is negatively pressurized relative to the windward side and positively pressurized relative to the leeward side. If indoor air is moister than outdoor air, moisture can be sucked into the framing on leeward sides.

Low-slope roofs
Swirls and eddies occur at corners of buildings. You can sometimes see them as snow patterns on a roof. These corners and connections are important to get airtight.
Motivations

• My Motivation – Owens Corning wants to provide higher performance level analysis (quantification) to building community

• ORNL/DOE Motivation – Increase awareness and upgrade in performance goals for USA building stock

• ABAA/Industry Motivation - Increase air tightness, understand impact and create a design approach

It is important for Building Science to get a better grip on this topic.
Question:

How much air Leakage does this woodpecker cause?

Building science is lacking…. Need Quantification
Winter
In winter, rising warm air escapes through the roof and is replaced by cold air sucked in through the floor. The effect is strongest in winter. This two-story house is under about 8 Pa of constant upward pressure.

Summer
In summer, the opposite happens because inside air is often cooler than outside air. As dense indoor air sinks, it pulls hot outside air in through the ceiling and roof. In summer, this house is under about 3 Pa of downward pressure.

Gas fireplaces can suck 1200 cfm
Bath fans typically remove 100 cfm
Range hoods can exhaust up to 2000 cfm
A clothes dryer can pull out 200 cfm
Furnaces need up to 150 cfm
Water heaters require up to 100 cfm

JStraube
Actual Measurements

Fresh off the press… Mika’s House Atlanta Aug 1-3

![Graph showing actual measurements in Pa](image)
### Actual Measurements

#### Summary for Attic

<table>
<thead>
<tr>
<th>Statistic</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean</td>
<td>-0.32797</td>
</tr>
<tr>
<td>StDev</td>
<td>0.23023</td>
</tr>
<tr>
<td>Variance</td>
<td>0.05301</td>
</tr>
<tr>
<td>Skewness</td>
<td>-0.3569</td>
</tr>
<tr>
<td>Kurtosis</td>
<td>12.2600</td>
</tr>
<tr>
<td>N</td>
<td>139131</td>
</tr>
<tr>
<td>Minimum</td>
<td>-4.48640</td>
</tr>
<tr>
<td>1st Quartile</td>
<td>-0.42250</td>
</tr>
<tr>
<td>Median</td>
<td>-0.32410</td>
</tr>
<tr>
<td>3rd Quartile</td>
<td>-0.24190</td>
</tr>
<tr>
<td>Maximum</td>
<td>3.21880</td>
</tr>
</tbody>
</table>

Anderson-Darling Normality Test

- A-Squared: 3235.72
- P-Value < 0.005

95% Confidence Interval for Mean

- Lower: -0.32918
- Upper: -0.32676

95% Confidence Interval for Median

- Lower: -0.32580
- Upper: -0.32250

95% Confidence Interval for StDev

- Lower: 0.22938
- Upper: 0.23109
Air Leakage Path

TYPICAL AIR LEAKAGE PATHS

Research has shown that air leaks occur at certain typical locations. Each of these contribute to the overall air leakage of the house, and should be carefully handled during the house construction process.

Penetrations (plumbing stacks and ceiling light fixtures)

Junction of Ceilings and Walls

Window and Door Openings

Floor Headers

Basement Slabs

Air leakage in buildings can cause serious water damage to walls and roofs, when moist indoor air contacts cold surfaces in the building assembly. The build up of condensation can freeze in winter, and promote the decay of wood framing members in summer. A leaky house is not only uncomfortable and expensive to heat, but also easy to invade by insects and other vermin.

Air barrier provided by building materials such as concrete, glass, and wall sheathing.

Air barrier provided by an air barrier assembly.
Attention to all construction
Details are a Must!!

Specifying the details… and then training our contractors to do it right!
Interior Air Sealing Strategies
Systems Approach to Air Leakage

- Roof/Exterior Wall Junction
- Exterior Walls
- Basement Details
- Angled Walls (Bay Windows)
- Floor Over Garage & Bay Window Floor
- Ceiling Air/Vapour Barrier Details
- Second Floor Header
- Ground Floor Header
- Windows and Doors
Objectives

Short-Term
• Include air leakage thermal losses in envelope calculations
• Include the impact of air leakage in moisture flow calculations
• Be able to address durability design analysis

Long-Term
• Include 2-D, 3-D WUFI Analysis
• Full building leakage

1-D WUFI Analysis
2-D, 3-D WUFI Analysis
WUFI+Passive
Create the basic understanding

Intentionally Leaky… added holes

Temperature

Relative Humidity

Small amounts of air leakage can have thermal degradation

But

Major moisture impact !!!

Minneapolis: Study by ORNL and BSC
Air leaks through walls

- Explain the basics needed to be captured in WUFI model
- Show the process
- Take science data to the field (From an academic exercise to reality)
What is future?

2 Storey Building

For a particular joint

Air Barrier system
Air leakage modes

• **Air flow through the wall**
  - Through insulated wall cavity
  - Between components (where the majority of the leakage flow happens)

• **Wind-washing**
  - No flow through – flow in and out (insulation)
Roles of Air Barriers

• Wind barrier
  – Prevent “wind-washing” of insulated cavity

• Air barrier
  – Prevent air flows through the wall

Terminology Session: Where is Professor Eric Burnett?
Infiltration/Exfiltration is the unwanted air movement through a building and is caused by a pressure difference (air moves from high pressure to a lower pressure).
Multi-dimensional flows to 1D

- Add heat and moisture source to
  - Exterior cavity (air from outdoors/ins. cavity)
  - Insulated cavity (air from ext. cavity/indoors)
Linear Transport Laws

• **Fourier’s Law** – Heat is transferred from a region of higher temperature to a region of lower temperature

\[ Q = -kA \frac{dT}{dx} \]

• **Fick's law** – Mass is transferred from a region of higher concentration to a region of lower concentration

\[ J = -DA \frac{dC}{dx} \]
Governing Equations

Mass Balance

\[ \frac{\partial \rho_a(T)}{\partial t} + \nabla \cdot (\rho_a(T) \vec{v}_a) = 0 \]

Momentum Balance

\[ \frac{\partial (\rho_a(T) \vec{v}_a)}{\partial t} + \nabla (\rho_a(T) \vec{v}_a \cdot \vec{v}_a) = -\Delta P_a + \frac{\mu_a(T)}{K_a} \vec{v}_a + \rho_a(T) \vec{g} \]

Energy Balance

\[ \rho_m(u,T)C_p(u,T) \frac{\partial T}{\partial t} = -\nabla \cdot (\rho_a C_p(T) \vec{v}_a T) + \nabla \cdot (k(u,T) \Delta T) + L_v(\delta_p(u,T) \nabla P_v) \]

Convection

Conduction

Evaporation

Condensation
Solve each equation/element

Mesh containing 590 elements

Mesh containing 2360 elements
Flow balance

- Air can leak one-dimensionally all the way through, or some of the air may be lost (or added!)
- Initially, let’s assume that all flow will go through and there are no leaks
  - Flow direction would cause problems in assigning the source (attic, etc.)
Procedure to Calculate Sources and Sinks

- **Calculate pressures $P$**
  - **Wind**
    - Wind pressure coefficients and locations
    - Wind speed and direction
  - **Stack**
    - Neutral pressure plane
  - Mechanical ventilation and building pressure balance

- **Calculate flow through**
  - Air leakage characteristics
Wind pressure on buildings

- ASHRAE Fundamentals 2005
  - Bernoulli’s equation

\[ p_v = \frac{\rho_a U_H^2}{2} \]

where
\[ U_H = \text{approach wind speed at upwind wall height } H, \text{ m/s} \]
\[ \rho_a = \text{ambient (outdoor) air density, kg/m}^3 \]

- Wind pressure coefficient on the wall \( C_p \)

The proportional relationship is shown in the following equation, in which the difference \( p_z \) between the pressure on the building surface and the local outdoor atmospheric pressure at the same level in an undisturbed wind approaching the building is

\[ p_z = C_p p_v \] (3)

where \( C_p \) is the local wind pressure coefficient for the building surface.
Wind speed at the building (wall) height

- Location affects the wind speed

Table 1  Atmospheric Boundary Layer Parameters

<table>
<thead>
<tr>
<th>Terrain Category</th>
<th>Description</th>
<th>Exponent $a$</th>
<th>Layer Thickness $\delta$, m</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Large city centers, in which at least 50% of buildings are higher than 21.3 m, over a distance of at least 0.8 km or 10 times the height of the structure upwind, whichever is greater</td>
<td>0.33</td>
<td>460</td>
</tr>
<tr>
<td>2</td>
<td>Urban and suburban areas, wooded areas, or other terrain with numerous closely spaced obstructions having the size of single-family dwellings or larger, over a distance of at least 460 m or 10 times the height of the structure upwind, whichever is greater</td>
<td>0.22</td>
<td>370</td>
</tr>
<tr>
<td>3</td>
<td>Open terrain with scattered obstructions having heights generally less than 9.1 m, including flat open country typical of meteorological station surroundings</td>
<td>0.14</td>
<td>270</td>
</tr>
<tr>
<td>4</td>
<td>Flat, unobstructed areas exposed to wind flowing over water for at least 1.6 km, over a distance of 460 m or 10 times the height of the structure inland, whichever is greater</td>
<td>0.10</td>
<td>210</td>
</tr>
</tbody>
</table>

\[
U_H = U_{met} \left(\frac{\delta_{met}}{H_{met}}\right)^{a_{met}} \left(\frac{H}{\delta}\right)^a
\]
Local wind pressure coefficient $C_p$ – need to simplify

Fig. 4  Local Pressure Coefficients ($C_p \times 100$) for Tall Building with Varying Wind Direction
(Davenport and Hui 1982)
Simplified wind pressure coefficients

- Default value: assume average wall coefficient (tall buildings)
Simplified wind pressure coefficients

- Default value: assume average wall coefficient (low-rise)
Stack pressure

- Buoyancy effect: Density difference of air outdoors and indoors

\[ \Delta P = \frac{pM}{R} \left( \frac{1}{T_{\text{out}}} - \frac{1}{T_{\text{in}}} \right) \cdot g \cdot H \]

\( \rho_{\text{in}} = \frac{pM}{RT_{\text{in}}} \)

Dense, cold, heavy air

\( \rho_{\text{out}} = \frac{pM}{RT_{\text{out}}} \)

Light, warm air

Neutral pressure plane

Wall level
Zone pressures

• Building pressure calculations

• Building zones
  – Room to room balance
  – Stratification (bottom to top)
    • Location of the leak in the building and in the element matters!

• Have an attic zone, and a crawlspace zone
Total pressure difference

\[ \Delta P = \Delta P_{\text{wind}} + \Delta P_{\text{Stack}} + \Delta P_{\text{Mechanical}} \]

\[ \Delta P = \Delta C_p \cdot \frac{1}{2} \rho U^2 + \frac{pM}{R} \left( \frac{1}{T_{\text{out}}} - \frac{1}{T_{\text{in}}} \right) \cdot g \cdot H + \Delta P_{\text{Mechanical}} \]
Hourly

Wind pressure * C
C=0.1
168 Moving average

Pressure potential, Pa

Hour of year

Atlanta  Baltimore  Chicago  Minneapolis  New Orleans  Portland  San Francisco  Seattle
Climate Stack Pressure

Hourly

Stack pressure
H = 7.5 m
168 Moving average

Pressure potential, Pa

Hour of year

Atlanta, Baltimore, Chicago, Minneapolis, New Orleans, Portland, San Francisco, Seattle
In addition to exterior cavity, we have now air leaks in and through insulation layer.

Wind Pressure Difference and Thermal Buoyancy result in a pressure difference across the wall.

**Equations for sinks/sources**

- **Wall assembly air leakage characteristics**
  \[ Q = C \Delta p^n \]

  - \( Q \) [m³/h-m²] Volume Flow Rate through the wall per m²
  - \( \Delta p \) [Pa] Pressure difference across the wall

- **Heat source:**
  \[ S_h = \rho_{in} \cdot Q \cdot C_{p,Air} \cdot (T_{in} - T) \]

  - \( S_h \): Heat Source [W/m²]
  - \( \rho_{in} \): Density of the incoming Air [kg/m³]
  - \( Q \): Air Flow Rate through the Wall [m³/h-m²]
  - \( C_{p,Air} \): Spec. Heat Capacity of Air [J/kg K]
  - \( T_{in} \): Temperature; Incoming air [K]
  - \( T \): Temperature in the Layer [K]

- **Moisture source:**
  \[ S_w = Q(c_{source} - c) \]

  - \( S_w \): Moisture Source [kg/m²s]
  - \( c_{source} \): Water Vapor Concentration in the incoming Air; [kg/m³]
  - \( c \): Water Vapor Concentration in the air in Layer [kg/m³]
Sub-Assembly Tests

- Characterize and identify major air leakage paths in walls
- Assess methods to seal significant sources of leakage

- Top plates and sheathing joints
- Bottom plate interface to studs, sheathing and foundation
- Penetrations for conduits
- Electrical outlets
All joints/openings in the building envelope should be air sealed.

But, some joints/openings must be more important than others.

Which ones?
Joints/Openings

Which ones?
  - A good question, but ...

Not so easy to answer.
  - Lots of different types of joints
  - Differing levels of construction quality
  - Not easy to isolate and measure
  - Then there’s this thing called “coupling”, where other things around the joints affect its leakage
DOE/ORN/Orn/TLerrco’s
ABAA

Tim Maddox

ASTM 2357 Cycling Pressures

- Each of the 8 Air Barrier Systems will be tested at least 5 to 15 different attachments each!
Example of Component leakage

Flow, cfm/ft² vs Pressure, Pa

- Wood frames
- Steel frames
- CMUs

Zoom in this region
Residential Application

Typical House | Biggest Bang for the Buck

What we want to know.

Tightness vs Sealing cost
- Moderately effective
- Least effective
- Most effective

Wolf, Salonvaara & Tyler; Owens Corning 2012
Interior Air Sealing

Most Effective Joints to Seal

- Duct boots
- Top plate-to-attic
- Recessed lights
- Band joists (top & bot.)
- Garage-to-house common wall

Graph showing the relationship between tightness and sealing cost, indicating that certain joints are more effective at reducing air leakage for a given cost.
Really nice to have **blower door** data

But what does ACH50 mean?

*We need* the actual loading between Housing Zones

*At Minimum ATTIC-MAIN-BASEMENT*
Equations for sinks/sources... cont’d

- Remember the serial order of sources/sinks
  - Insulated cavity gets air from exterior cavity or indoors (light weight wood frame wall, for example)

- Relate to three leakage classes (Envelope):
  - 1 ACH50
    - Good
    - No air sealing
    - 0.2 L/s m²
  - 3 ACH50
    - Acceptable
    - Band Joist
    - Top Plate to sheathing
    - Bottom Plate to Sheathing
    - 0.6 L/s m²
  - 5 ACH50
    - High
    - Bottom Plate to Slab
    - Corners
    - 1 L/s m²
Example: One to Two sources

- $Q = C \Delta p^n$

- No diffuse seeping flow through materials
  - Only sources and sinks
    - Exterior cavity (maybe, depends on flow path def.)
    - Insulated cavity

Source assigned to this layer. No sources to ‘impermeable’ that are bypassed by airflow.
Wind washing - sources/sinks

• Add heat and moisture source to
  – Insulated cavity (air from outdoors)
  – Flow mostly on the interior side of the insulated cavity (natural convection as a force)
  – Air tightness to be defined for cavity
  – Force for flow is stack (wind can be added with $C_{\text{bottom}}, C_{\text{top}}$)
Capture and understand

Double stud Walls
With cellulose insulation
Work in Progress

Passive House
Air Leakage Study
Independent of Insulation Type

Passive House Technical Committee
Air Leakage Paths

• Short Direct Paths
  – By-pass insulated cavity
  – Most of whole house BE leakage
  – Effects: Thermal > Moisture
    • If any air moves into the insulated cavity, moisture effects are multiplied

• Long Indirect Paths
  – Flow through insulated cavity
  – Less flow than through direct paths
  – Effects: Moisture > Thermal
Air Leakage Rated at 75Pa

- Air barrier
  - Materials 0.02 L/sm$^2$ @75Pa
  - Assemblies 0.2 L/sm$^2$ @75Pa
  - Systems 2.0 L/sm$^2$ @75Pa

- Exponent n=?
  - Needed for estimating the flow at building pressures

- These simulations used n=0.5 which gives the highest flow rates at low pressures (safety factor for design)
Flow Characteristic: Exponent $n$

$Q = C^*d^p^n$

Worst Case used

- $n=1$
- $n=0.65$
- $n=0.5$
Assembly Leakage to Whole Building

- Assume
  - 30ft x 40ft two story building
  - Average ceiling height 8.5ft
  - Walls and roofs leak the same 0.2 L/sm\(^2\)@75Pa
  - Flow characteristic n=0.65 or n=0.5 (Q=C*dp\(^n\))

<table>
<thead>
<tr>
<th></th>
<th>L/sm(^2) @75</th>
<th>cfm/ft(^2) @75</th>
<th>cfm/ft(^2) @50</th>
<th>L/sm(^2) @50</th>
<th>ach50</th>
</tr>
</thead>
<tbody>
<tr>
<td>n=0.65</td>
<td>0.2</td>
<td>0.04</td>
<td>0.031</td>
<td>0.154</td>
<td>0.32</td>
</tr>
<tr>
<td></td>
<td>0.4</td>
<td>0.08</td>
<td>0.061</td>
<td>0.307</td>
<td>0.64</td>
</tr>
<tr>
<td></td>
<td>0.6</td>
<td>0.16</td>
<td>0.123</td>
<td>0.461</td>
<td>0.95</td>
</tr>
<tr>
<td>n=0.50</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>0.3</td>
<td>0.033</td>
<td>0.031</td>
<td>0.163</td>
<td>0.34</td>
</tr>
<tr>
<td></td>
<td>0.6</td>
<td>0.065</td>
<td>0.065</td>
<td>0.327</td>
<td>0.68</td>
</tr>
<tr>
<td></td>
<td>0.9</td>
<td>0.131</td>
<td>0.131</td>
<td>0.490</td>
<td>1.01</td>
</tr>
</tbody>
</table>

For all the worldly units
Airflow Paths

Vinyl
19 mm cavity
WRB
OSB
10 in Insulation
Gypsum
Paint 10 perms

North Orientation… mostly exfiltration

Start Time 1 Oct. 2075
Indoor Moisture Loads

• Loads were calculated assuming
  – 9 L/d moisture production (20 lb/d) (SPC160, 2 bdr)
  – 500 m$^3$ house volume (17553 cf)
  – ach=0.25 (leakage and occupancy effects)

• These result in moisture load of +3 g/m$^3$ when no dehumidification by cooling system

Old and new SPC160 moisture loads.
Average house size f(#bdr) considered.
Boston - Indoors

![Graphs showing moisture load and temperature vs. time.](image-url)
Houston - Indoors

![Graphs showing moisture load and temperature fluctuation over time.](image-url)
Minneapolis - Indoors
Seattle - Indoors

- Moisture Load, g/m³
  - Time, hours

- Temperature, T, °F and RH, %
  - Time, hours

Lines and dots represent data changes over time for Moisture Load and Temperature, RH over a specified time period.
Mold Growth Estimates

- Predicted maximum Mold Growth Index after exposure to indoor/outdoor weather
  - Layers included: WRB and everything inwards
Results – Atlanta – Max Mold

- Flow rate (rating at 75Pa): 0, 0.2, 0.4, 0.6 L/sm²
Results – Baltimore – Max Mold

- Flow rate (rating at 75Pa): 0, 0.2, 0.4, 0.6 L/sm²
Flow rate (rating at 75Pa): 0, 0.2, 0.4, 0.6 L/sm²
Results – Houston – Max Mold

* Flow rate (rating at 75Pa): 0, 0.2, 0.4, 0.6 L/sm²

Peak, then: More air, lower Mold
Results – Houston (-5Pa) – Max Mold

- Flow rate (rating at 75Pa): 0, 0.2, 0.4, 0.6 L/sm²
- Mechanical underpressure 5 Pa
  - Note: No vapor retarder in Houston

More air, higher Mold
Results – Houston (-5Pa) – Max Mold

- Flow rate (rating at 75Pa): 0.6 L/sm²
- Mold growth mostly not at the flow path
Results – Minneapolis – Max Mold

- Flow rate (rating at 75Pa): 0, 0.2, 0.4, 0.6 L/sm²
Results – Seattle – Max Mold

- Flow rate (rating at 75Pa): 0, 0.2, 0.4, 0.6 L/sm$^2$
Results - RH

- Examples of airflow effect on relative humidity inside the wall
Results – Minneapolis - RH

Full wall (left) and top only (right)
Results - Minneapolis - RH

0.2 rated air leakage through interior surface (interior air ‘flushing’ at rim joist)

Full wall (left) and top only (right)
Results - Minneapolis - RH

0.4 rated air leakage through interior surface (interior air 'flushing' at rim joist)
0.6 rated air leakage through interior surface (interior air ‘flushing’ at rim joist)

Full wall (left) and top only (right)
Results - Minneapolis

Air leakage comparison

Stack neutral plane at the bottom of the wall below rim joist
Total Moisture Minneapolis

- No air through
- 0.2 L/(sm²@75Pa)
- 0.4 L/(sm²@75Pa)
- 0.6 L/(sm²@75Pa)

Graph showing total moisture in liters per wall over time (d) starting from 0 to 350 days.
Minneapolis

Day 1

RH(-)

0.95
0.9
0.85
0.8
0.75
0.7
0.65
0.6
0.55
0.5
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05

Y(m)

X(m)

Y(m)

X(m)
Energy Impact - Assumptions

- Airflow exfiltrates or infiltrates through the wall
- Heat loss due to air flow
  - $E = Q_v \cdot \rho \cdot c_p \cdot \Delta T$ where
    - $\Delta T = T_{in} - T_{out}$, if exfiltrating
    - $\Delta T = T_{in} - T_{air@surface}$, if infiltrating
  - $T_{air@surface} = \text{air temperature at entrance to indoors at the wall surface}$
  - Airflow affect the conduction heat loss by exchanging heat with the wall
- Yearly sum of conduction heat loss and air heat loss
Baltimore

Conduction + Air Leakage

- No flow (int surface)
- Flow rated 0.2 L/sm² @75Pa
- Flow rated 0.4 L/sm² @75Pa
- Flow rated 0.6 L/sm² @75Pa

Graph showing the impact of different airflow rates on the energy consumption (Wh/m²) at different pressure ratings (75Pa).
Minneapolis

Conduction + Air Leakage

- No flow (int surface)
- Flow rated 0.2 L/sm² @75Pa
- Flow rated 0.4 L/sm² @75Pa
- Flow rated 0.6 L/sm² @75Pa

Graph showing the energy usage for different air flow rates at 75Pa.
Air Heat Recovery

- The wall is a heat exchanger
  - Air flow through the wall gives a small heat recovery

- Compare total heat loss
  1. Walls with air leakage
  2. Airtight walls with the same air flow rate taken directly from outside
    - No HRV
    - With HRV (efficiency=?)

- What air heat recovery efficiency does case (2) need in order to provide the same heat loss as case (1)?
Filtrating Air Heat Recovery

• More airflow means more heat flow
  – The question is whether the air flow is part of designed ventilation or uncontrolled (unwanted) air exchange
    • Uncontrolled flow not wanted and causes extra heat loss
    • If considered part of the house ventilation: Does the house have a HRV/ERV?

• Air that filtrates slowly through the insulating parts provides heat recovery benefits

• The higher the airflow rate per wall U-value, the lower the relative benefits (heat recovery)

• Air flow going through short cracks or openings provides low heat recovery effects
Total Moisture in Walls

- All layers included
- Only difference is the air leakage rate
Baltimore
Boston
Seattle
Conclusions

• Moisture performance (mold)
  – Standard walls (OSB exterior sheathing) have to be airtight at or below current assembly air tightness requirements (0.2 L/sm² / 0.04 cfm/sqft @ 75Pa) to reduce risk for mold growth

• Energy performance
  – At 0.2 L/sm²@75Pa rating the airflow through the walls increases the heat loss (combined conduction plus air) by roughly 25%
  – Flow through insulated cavities can provide some heat recovery, however
    • Flow path cannot be controlled, short circuiting will not provide heat recovery

Disclaimer: Results are not to be generalized and are valid only for the simulated structures
Next Steps

• Study the impact of low air leakage rates on the moisture performance of alternative wall structures such as with exterior continuous insulation
  – Risk reduction factors
Conclusions

• A big step forward in our analysis capability for airflow. Never done before to this level.
• Component air leakage testing with STATISTICS (mean values and spread) would be very useful to create libraries were each air sealing system would be documented.
• New testing apparatus like Owens Corning, TREMCO, ORNL and BSC can provide hard core data to create series and parallel resistance models for airflow calculations in envelopes.
• Revisit the analysis with OC measured data.
Final Thought

Just think about what we can do !!!