Hidden in Plain Sight: The Not So Secret Savings of the Building Envelope

Tuesday, May 16, 2017
3:45 to 5:00 pm
Panelists

Melissa Lapsa,
Oak Ridge National Laboratory (ORNL)

Laverne Dalgleish,
Air Barrier Association of America (ABAA)

Linda Jeng,
Dow Building Solutions
The commercial **building envelope** is the primary determinant of the amount of energy required to heat, cool, and ventilate a building.
Barriers Identified for Envelope Technologies

- **Cost**: uncertainties, high first costs, ROI hurdles
- **Supply issues**: product fragility, availability, volume
- **Installation issues**: workforce training, complex systems, quality control
- **Decision culture**: resistance to new products, risk averse, code minimum culture
- **Information gap**: real world case studies, data on long-term performance, communicating effectively
Air Leakage: Hidden in Plain Sight

Air leakage accounts for up to 40% of buildings energy losses.
Laverne Dalgleish

ABAA
Better Buildings Summit

Hidden in Plain Sight
Understanding Air Leakage and Innovative Technologies to Address
This is Air Leakage!
You cannot see air leakage!
You cannot see energy savings!

Understanding Air Leakage
You will see the results of air leakage!
40% of total US prime energy expended
70% of all US electric energy used
Building Energy Use

In 2013, 40% of total U.S. energy consumption was consumed in residential and commercial buildings, or about 40 quadrillion British thermal units (40,000,000,000,000,000 BTUs).

Commercial uses 18% (7.2 quadrillion)
Of that 43% used to heat and cool (3.1 quads)
15 – 40% due to air leakage (@40%=1.2 quads)

Residential uses 22%
Of that 27% used to heat and cool
10 – 40% due to air leakage
## Energy Losses in the Building Envelope

Primary energy consumption attributable to fenestration and building envelope components in 2010

<table>
<thead>
<tr>
<th>Building Component</th>
<th>Residential (quads)</th>
<th>Commercial (quads)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Heating</td>
<td>Cooling</td>
</tr>
<tr>
<td>Roofs</td>
<td>1.00</td>
<td>0.49</td>
</tr>
<tr>
<td>Walls</td>
<td>1.54</td>
<td>0.34</td>
</tr>
<tr>
<td>Foundation</td>
<td>1.17</td>
<td>-0.22</td>
</tr>
<tr>
<td>Infiltration</td>
<td>2.26</td>
<td>0.59</td>
</tr>
<tr>
<td>Window (conduction)</td>
<td>2.06</td>
<td>0.03</td>
</tr>
<tr>
<td>Window (solar heat gain)</td>
<td>-0.66</td>
<td>1.14</td>
</tr>
</tbody>
</table>

Adapted from the BTO Multi-Year Program Plan: https://energy.gov/eere/buildings/downloads/multi-year-program-plan
Understanding Air Leakages

Air Leakage in Existing Buildings

- **Average** = 7.9 L/(s.m²)
- **IECC 2012** = 2.0 L/(s.m²)

### Data Sources

- **NIST**
  - Persily and Grot 1986
  - Persily et al. 1991
  - Musser and Persily 2002 (n = 9)

- **FSEC**
  - Cummings et al. 1996
  - Cummings et al. 2000 (n = 88)

- **Camroden Associates**
  - Brennan et al. 1992 (n = 23)

- **Army Corp of Engineers**
  - n = 79

- **PSU**
  - Bahnfleth et al. 1999 (n = 2)

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**NIST**: National Institute of Standards and Technology  
**FSEC**: Florida Solar Energy Center  
**PSU**: Penn State University
Air Barriers are the key to significant energy efficiency and impact all other energy saving measures.
Air Barriers Impact

- Thermal insulation
- Window performance
- HVAC efficiency
- Occupant behavior

which all impact the energy use in a building
Phase 2: Preliminary Results

November 2011

Monthly Heat Loss (W.h/m²)

<table>
<thead>
<tr>
<th>Air leakage @ 75 Pa [L/(s.m²)]</th>
<th>Level 1 (&lt; 0.02)</th>
<th>Level 2 ≅ 0.21</th>
<th>Level 3 ≅ 0.72</th>
</tr>
</thead>
<tbody>
<tr>
<td>November 2011</td>
<td>564</td>
<td>629</td>
<td>990</td>
</tr>
<tr>
<td>December 2011</td>
<td>983</td>
<td>1057</td>
<td>1506</td>
</tr>
</tbody>
</table>

December 2011

Monthly Heat Loss (W.h/m²)
Air Barriers cannot be dealt with without understanding that they are part of a wall (building) assembly”

N.B. Hutcheon’s CBD-48 - Requirements for Exterior Walls
A. ENVIRONMENTAL MANAGEMENT

1. HEAT FLOW
2. AIR FLOW
3. VAPOUR FLOW
4. RAIN PENETRATION
5. RADIATION (LIGHT, SOLAR...)
6. NOISE
7. FIRE SEPARATION

B. GENERAL CHARACTERISTICS

8. STRENGTH, RIGIDITY
9. DURABILITY
10. AESTHETIC
11. ECONOMIC
12. CONSTRUCTABLE
13. MAINTAINABLE

ENVELOPE REQUIREMENTS (PRIMARY FUNCTIONS)
Air Barriers

Six Sides of the Building

roof – walls - foundation
Understanding Air Leakage

Table B1 — Gust Wind Pressure Differences ($P_3$) on Vertical Edge at Maximum Building Height (Courtesy of ULC S742)

<table>
<thead>
<tr>
<th>Maximum Building Height above grade (H), m</th>
<th>Gust Wind Pressure Differences ($P_3$) for geographic areas where the sustained 1 in 50 hourly wind pressure difference ($P_1$) is not greater than, Pa</th>
</tr>
</thead>
<tbody>
<tr>
<td>20</td>
<td>1080</td>
</tr>
<tr>
<td>40</td>
<td>2000</td>
</tr>
<tr>
<td>60</td>
<td>2160</td>
</tr>
<tr>
<td>80</td>
<td>2290</td>
</tr>
<tr>
<td>100</td>
<td>2400</td>
</tr>
<tr>
<td>120</td>
<td>2480</td>
</tr>
</tbody>
</table>
### Understanding Air Leakage

#### Air Barrier Performance Requirements

<table>
<thead>
<tr>
<th>Category</th>
<th>Requirement</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Air Barrier Material</strong> - the big pieces</td>
<td>0.004 CFM/ft²@ 1.56 lbs/ft² pressure difference (ISO 14857 ASTM E2178)</td>
</tr>
<tr>
<td><strong>Air Barrier Accessory</strong> – tapes, strips, caulking, etc.</td>
<td>0.004 CFM/ft²@ 1.56 lbs/ft² pressure difference (ASTM E283)</td>
</tr>
<tr>
<td><strong>Air Barrier Component</strong> – windows, doors, skylights, etc.</td>
<td>0.04 CFM/ft²@ 1.56 lbs/ft² pressure difference (ASTM E283)</td>
</tr>
<tr>
<td><strong>Air Barrier Assembly</strong> - wall assembly, roof assembly, foundation assembly</td>
<td>0.04 CFM/ft²@ 1.56 lbs/ft² pressure difference (ASTM E2357)</td>
</tr>
<tr>
<td><strong>Air Barrier System</strong> - Whole Building</td>
<td>0.40 CFM/ft²@ 1.56 lbs/ft² pressure difference (ISO 9972, ASTM E 779 ABAA AB-001)</td>
</tr>
</tbody>
</table>

(Requirement for Air Barrier Systems needs to be updated to 0.10)
Air Barrier

- Materials
- Accessories
- Components
- Sub-assemblies
- Assemblies
- Sub-systems
- Systems
Air Barrier Materials

Peanut butter

- Kraft smooth peanut butter
- Applied at 20 mils wet
- Tested to ASTM E2178
- Air leakage result - 0.0021 L/s·m² (0.0004 CFM/ft²)
- Is an air barrier material but cannot be installed as a continuous one and **will not stand up to service-life conditions** – not an air barrier material!
Air Barrier Accessories

Materials and components that connect the air barrier materials and the air barrier assemblies

- Tapes
- Strips
- Mastic
- Sealants
- Etc.
Air Barrier Components

Not only do they have to be airtight but you need to connect to them

- Doors
- Windows
- Skylights
- Curtain walls
- Etc.
Air Barrier Sub-Systems

- Assembly sub systems
  - Air leakage of penetrations, fasteners, etc
  - Adhesive attachment
  - Substitution of accessories
Air Barrier Assemblies

➢ **Wall Assemblies**
  ➢ ASTM E 2178

➢ **Roof Assemblies**
  ➢ ASTM E 1680
  ➢ ASTM D 8052

➢ **Foundation Assemblies**
  ➢ TBD
Air Barrier System (Whole Building)

- **System**
- **ASTM E779, ISO 9972, ABAA 001**
Air Barrier System Sub-Systems

- **System - Sub-systems**
  - Compartmentalization
    - Separate floors
    - Separate units
    - Separate common areas
Air Barrier Future

- **Whole Building Testing is where you start – Everything else leads to there**

- **Then break it down to the needs to get there**
  - **Air Tightness within a Building**
  - **Key Requirements to make a good Air Barrier Assembly**
  - **Airtightness of Components**
  - **Sub Assembly Requirements**
Air Barrier Future

Air leakage is where the energy saving are both new and existing buildings

Actual energy savings required to actually save energy

Air barrier industry in its infancy
Air Barriers Are The Future

Thank you

Mr. Laverne Dalgleish
Idalgleish@airbarrier.org
Linda Jeng

Dow Building Solutions
EFFECTIVE AIR SEALING FOR BUILDINGS

Linda Jeng | Dow Building Solutions
Beware of little expenses; a small leak will sink a great ship.

Benjamin Franklin
Agenda

+ Air Leakage Performance Targets
+ Air + Water Barrier Options
+ Case Study
+ Summary
<table>
<thead>
<tr>
<th>Commercial Building Air Leakage Performance Targets</th>
<th>Version</th>
<th>ASTM E779 [cfm @75 Pa/ft²]</th>
</tr>
</thead>
<tbody>
<tr>
<td>US Army Corps of Engineers</td>
<td>2009</td>
<td>0.25</td>
</tr>
<tr>
<td>US General Services Admin.</td>
<td>2010</td>
<td>0.40</td>
</tr>
<tr>
<td>Naval Facilities Eng. Command</td>
<td>2011</td>
<td>0.25</td>
</tr>
<tr>
<td>US Air Force</td>
<td>2011</td>
<td>0.40</td>
</tr>
<tr>
<td>Washington State Energy Code <em>(Optional)</em></td>
<td>2012</td>
<td>0.40</td>
</tr>
<tr>
<td>IECC Commercial <em>(Optional)</em></td>
<td>2012-15</td>
<td>0.40</td>
</tr>
<tr>
<td>IgCC <em>(required)</em></td>
<td>2015</td>
<td>0.25</td>
</tr>
<tr>
<td>ASHRAE 90.1 <em>(test or verification program)</em></td>
<td>2016</td>
<td>0.40</td>
</tr>
<tr>
<td>IECC Commercial <em>(test or verification program)</em></td>
<td>2018</td>
<td>0.40</td>
</tr>
</tbody>
</table>
Air + Water Barrier Options

**Sheet Wraps**
- Thin, non-perforated sheet fastened to substrate
- Requires sheathing back-up (exterior drywall)
- Insulation is exposed to the exterior conditions

**Peel and Stick**
- Self Adhered sheet membrane adhered to substrate
- Need Exterior Drywall
- May need a primer
- Insulation is exposed to the exterior conditions

**Fluid Applied Full Coverage**
- Site applied liquid (typically sprayed or troweled)
- Requires supporting surface
- Insulation is exposed to the exterior conditions

**Sheet and Fluid Applied Flashing**
- Combines rigid, sheet installation with fluid applied seams
Sheet Wraps

- **Pros**
  - Easy
  - Fast
  - Lightweight

- **Cons**
  - Need sealant around penetrations and seams
  - Fasteners required
  - Tears in the wind
  - Sequencing required
  - Multiple trips around the building

Peel and Stick

- **Pros**
  - Thick
  - Damage Resistant
  - Easy to inspect

- **Cons**
  - Around penetrations
  - Shingling / Overlaps required
  - Expensive
  - Sequencing is important
  - Multiple trips around the building

Fluid Applied Full Coverage

- **Pros**
  - Easy
  - Fast

- **Cons**
  - Dependent on weather
  - Drying / curing Time
  - Accessories needed
  - Higher material cost
  - Sequencing
  - Multiple trips

Sheet and Fluid Applied Flashing

- **Pros**
  - Easy
  - Fast
  - Lightweight
  - Easy to inspect

- **Cons**
  - New trade skills
  - Some weather dependency
Case Study | College of DuPage
Homeland Security Training Center, Glen Ellyn, IL

$16MM
39,714 SF
2016

LEGAT ARCHITECTS

Firing Range
Call Center
Classrooms
“It’s difficult to make a building energy efficient when 5/8 of it is a shooting range”
- Jay Johnson, AIA

Walls: R13 + R7.5ci min
LEED Certified (baseline +10%)
Optional: Whole building blower door test < 0.40 cfm @75Pa/SF

THERMAX XArmor™ (2” = R-13)
foil-faced insulation board
LIQUIDARMOR™ CM flashing & sealant
STYROFOAM™ CM SPF (2” for R13)

Design
Legat Architects

Code
2009 IECC

Installed
CI + liquid flashing
Case Study | College of DuPage

**Oak Ridge National Lab**
LIQUIDARMOR Evaluation

DOE’s Commercial Building Integration Program to demonstrate the performance of new building envelope technologies

**Thermal Moisture Imaging™ (TMI®)**
Blower Door Testing

ASTM E779-10
12 fans, 10 hours
Case Study | College of DuPage

TMI® ASTM E779

- Leakage rate at 75 Pa
- Airflow 13,921 cfm
- Air Changes per Hour 1.0
- Air Leakage Avg. 0.15 cfm/sq ft

63% Better than 2015 IECC

- 0.40 cfm/sq ft at 75 Pa
Case Study | College of DuPage

Air Leakage (cfm/SF) at 75 Pa

<table>
<thead>
<tr>
<th>Category</th>
<th>Air Leakage (cfm/SF)</th>
</tr>
</thead>
<tbody>
<tr>
<td>All Buildings</td>
<td>0.72</td>
</tr>
<tr>
<td>Buildings Without AB</td>
<td>0.86</td>
</tr>
<tr>
<td>Buildings With AB</td>
<td>0.28</td>
</tr>
<tr>
<td>College of DuPage</td>
<td>0.15</td>
</tr>
</tbody>
</table>

Note: Comparison source Emmerich and Persily (2014)
Note: Results of HVAC cost are based on modeled comparison of example building in a specific climate zone
Summary

- **Design**
  - Energy Efficiency Delivered
  - Architects are rising to the challenge of energy efficiency + functionality

- **Innovation**
  - Fluid Applied Elastomers
  - Fluid applied elastomers are making it easy + fast to achieve best in class performance on the job

- **Installed**
  - CI + Liquid Flashing
  - Combining CI + liquid flashing can get the best of “old” and “new”
Acknowledgement

Work described were sponsored by the Commercial Buildings Integration program within the Building Technologies Office of the US Department of Energy Office of Energy Efficiency and Renewable Energy. The authors wish to acknowledge the contributions of Amy Jiron in guiding this work and the insightful review comments of Som Shrestha of Oak Ridge National Laboratory.

This work would not have been possible without the help of David Lesniak, who allowed us to collect data from the Homeland Security Training Center at the College of DuPage; and Jay Johnson, Principal Studio Director from Legat Architects, who provided access to the design details and choose to use a high-performance wall system for energy efficiency.
Better Buildings Alliance: How is it organized?

**MARKET SOLUTIONS TEAMS**
- Energy Efficiency Project Financing
- Leasing and Tenant Build-Out
- Energy Data Access
- High Performance Property Valuation and Mortgages

**TECHNOLOGY SOLUTIONS TEAMS**
- Lighting & Electrical
- Space Conditioning
- Plug & Process Loads
- Refrigeration

- Energy Management Information Systems
- Renewables Integration
- NEW! Building Envelope

To join, contact Melissa Lapsa at lapsamv@ornl.gov
Building Envelope Technology Team

Connecting Better Building Alliance members with advanced building envelope technology solutions

- Technology verification studies
- Specification documents
- Case studies and fact sheets
- Calculators and analytic tools

Melissa Lapsa, M.B.A.

Building Envelope Technical Team Lead

Simon Pallin, Ph.D.

Building Envelope Technical Lead

Mahabir Bhandari, Ph.D.

Building Envelope Tech Team Support

Caroline Hazard, M.S.

Building Envelope Tech Team Support
What will the Envelope Tech Team be doing?

Engage and support Members in efforts to accelerate adoption of building envelope technologies

- **Build awareness** with guidance and information on envelope technology solutions
- Conduct envelope technology verification studies
- Offer **technical assistance** for envelope projects
A New Team of Members and Friends

**Members**

(includes: Building Owners/Mgrs, Property Managers, A&E, Construction/Installers)

- Arlington Initiative to Rethink Energy (AIRE)
- Association for Energy Affordability
- Clark Atlanta University
- exp US Services, Inc.
- HOK
- Hersha Hospitality Mgmt

- Instituto Superior de Engenharia do Porto
- Legacy Health
- Newmark Grubb Knight Frank
- Schmidt
- US Army Corps of Engineers
- z2zero

**Friends**

(Includes: Researchers, Academics, Trade Associations, Energy Service Providers, Manufacturers, Subject Matter Experts)

AppleBlossom Energy, Inc., Argonne Nat’l Lab, Birch Point Consulting, Building Envelope Materials (BEM), Covestro LLC, ICF, NRG Insulated Block, Renovate by Berkowitz, Rmax Operating, LLC, SOLARIA, QuadLock, USG Corporation
Check out the Envelope Tech Team Web Resources

- **Topic Areas**
  - Windows
  - Walls
  - Roofs

- **Resources**
  - Case Studies
  - Calculators
  - Design Guides
  - Fact Sheets
  - Toolkits
  - …and more…

https://betterbuildingsinitiative.energy.gov/alliance/technology-solution/building-envelope
Get involved in Envelope Technology Verification Analysis Opportunities

<table>
<thead>
<tr>
<th>Technology</th>
<th>Air Barrier Systems</th>
</tr>
</thead>
<tbody>
<tr>
<td>Buildings Criteria</td>
<td>Upcoming building envelope retrofit that includes improvements to the air barrier system</td>
</tr>
<tr>
<td>Key Sectors</td>
<td>All</td>
</tr>
</tbody>
</table>

Email Melissa Lapsa: lapsamv@ornl.gov
Access to Technical Assistance

- Building awareness for key aspects of commercial building airtightness requirements
  - Conducting an evaluation of market practices, methods to demonstrate compliance
  - Gathering input from stakeholders
- Working with Team Members to identify prioritized resource needs
  - Envelope commissioning guidance
  - Technology verification analysis/ information on specific window, wall, or roof technologies
  - Decision analysis tools
What do you think?

What kind of resources or activities would help you make more investments in envelope technologies?

- Perhaps technology specific?
- Perhaps market barrier specific?
- Perhaps installation best practices?
- Perhaps related to building enclosure commissioning (testing)?
- Other?
Join the Envelope Tech Team!

Email: lapsamv@ornl.gov

Next Team Meeting: June 13\textsuperscript{th} at 2pm ET

Topic: Envelope Retro-commissioning
Questions and Answers

Melissa Lapsa
Laverne Dalgleish
Linda Jeng

Join us tomorrow

Stranger Things: Building Materials of the Future, 2:00pm
Thank You

Provide feedback on this session in the new Summit App!

Download the app to your mobile device or go to bbssummit.pathable.com