Air infiltration Reduction
ECM Research
5 Case Studies

Presented by
Fran Boucher – National Grid
Martine Dion - SMMA
Will D’Arrigo - ICF
AIA Learning Objectives

1. Understand advanced building enclosure and air tightness best practices, as well as air infiltration reduction implementation challenges

2. Compare the air infiltration reduction Massachusetts Code criteria and associated energy savings to other standards criteria beyond Code such as the US Army standards and the Passive House US standard

3. Understand air infiltration building enclosure testing standards and methodology for multi-family facilities

4. Understand the air infiltration reduction energy savings value as an energy conservation measure beyond Code
Agenda

- Introduction
- Air Infiltration Reduction Research Overview
- Interactive discussion
- Wrap-up: Recommendations / Challenges
Why Now?

- Multi-Family market as a starting point
- State Regulations:
  - IECC 2018 criteria (C406)
  - MEPA
- Passive House’s key criteria
- New Grounds for the MA PA (Utilities):
  - Tacking the building enclosure
### Additional Efficiency Packages: Section C406

<table>
<thead>
<tr>
<th>IECC 2015</th>
<th>IECC 2018</th>
</tr>
</thead>
<tbody>
<tr>
<td>• More efficient HVAC systems</td>
<td>• More efficient HVAC systems</td>
</tr>
<tr>
<td>• Reduced lighting power</td>
<td>• Reduced lighting power</td>
</tr>
<tr>
<td>• Enhanced lighting controls</td>
<td>• Enhanced lighting controls</td>
</tr>
<tr>
<td>• On-site renewable energy</td>
<td>• On-site renewable energy</td>
</tr>
<tr>
<td>• Dedicated Outdoor Air System</td>
<td>• Dedicated Outdoor Air System</td>
</tr>
<tr>
<td>• High-efficiency service water heating</td>
<td>• High-efficiency service water heating</td>
</tr>
<tr>
<td></td>
<td>• Enhanced envelope performance</td>
</tr>
<tr>
<td></td>
<td>• Reduced air infiltration</td>
</tr>
</tbody>
</table>

*The Air Infiltration Reduction ECM Feasibility Research*
Airtight Building Enclosures are essential

- **Predictable Infiltration supports better HVAC sizing**
  - Benefits HVAC system’s first cost
  - Reduces energy use
  - Reduces dehumidification load

- **Fundamental for Passive house & Net Zero Energy (NZE)**
  - Supports lower energy loss
  - Requires controlled ventilation
  - Improves insulation efficiency by reducing uncontrolled air motion through insulation

*Once in a “building’s lifetime” opportunity…*
The Research Intent

- Feasibility
- Applicability
- Scalability
The Research Intent

Contribution to Energy Savings

- Target for 20% additional energy savings (by fuel)

- Evaluate the cost-effectiveness potential to utility and owners
  - Energy Conservation Measure (ECM) that fits the utility incentive model
  - Less than 15 yr. payback
  - Proven [measurable] savings
  - Demonstrate the utility’s influential role for adoption within individual projects
The Research Intent

Energy Analysis, Process and Needs

- Inform best practices and methodology
  - Building energy simulation (predicted savings)
  - Commercial whole building air infiltration testing (measured savings)
- Supports PA’s and other constituents buy in on Proven savings
- Identify Owners/Industry Process and needs
The Research Intent

Market Adoption Potential

• Assess scalability within multi-family market
• Inform scalability to other commercial building types
• Identify Resources availability to sustain growth/demand
• Identify owners/industry needs to accelerate adoption

Scalability
## The Research Intent

### Whole Building Infiltration Testing

<table>
<thead>
<tr>
<th>Standard</th>
<th>CFM/SF (gross enclosure area) @ 75 PA</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>IECC 2015 (MA Building Code)</td>
<td>0.4</td>
<td>References ASTM E-779</td>
</tr>
<tr>
<td>U.S. Army Corps of Engineers Standard</td>
<td>0.25</td>
<td>References ASTM E-779</td>
</tr>
<tr>
<td>PHIUS+ (v2.1) (Passive House US) Certification for Multifamily</td>
<td>0.08/0.11</td>
<td>References RESNET Standards Chapter 8. (0.11) criteria only applicable to noncombustible building enclosure assembly per the International Building Code (IBC).</td>
</tr>
<tr>
<td>Passivhaus Institute Standard (PHI) Darmstadt</td>
<td>N/A (uses ACH)</td>
<td>PHI requires 0.6 ACH50 maximum ACH metric vs. the CFM metric. Most US standards and Code require measurements using the CFM metric. ACH may be converted in CFM and vice versa.</td>
</tr>
<tr>
<td>EnergyStar Multifamily</td>
<td>N/A</td>
<td>The air infiltration testing is required for in-unit compartmentalization only, not whole building testing.</td>
</tr>
</tbody>
</table>
The Research Team

Fran Boucher
Project Director

Martine Dion
Project Manager

Kristen Simmon
Project Owner’s Coordination & Energy Analysis

Will D’Arrigo
Project Owner’s Coordination & Energy Analysis

Sustainable Energy Analytics
Constructive Code Consultants
Center for Eco-Technology

Air infiltration testing firms

The Air Infiltration Reduction ECM Feasibility Research
The Research Approach

5 Multi-Family projects
- New construction/major renovation
- Construction phase
- Electric heating and/or natural gas heating
- MassSave Multi-Family Incentives program

1 Passive House project

Owner’s and Construction Team “Buy In”
ICF lead the coordination with project owners/design teams

Timeline: May 2018 – October 2018
The Research Criteria

Residential units already undergoing Energy-Star Certification air infiltration testing. The residential unit air infiltration testing does not capture the full building enclosure air infiltration reduction.
### Selected Projects Overview

#### Air Infiltration Reduction ECM Research

<table>
<thead>
<tr>
<th>Project Description</th>
<th>Location</th>
<th>Area (SF)</th>
<th>Storey (#)</th>
<th>Units (#)</th>
<th>High Perf. Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>Project 1</td>
<td>Northampton, MA</td>
<td>58,019</td>
<td>4</td>
<td>70</td>
<td>High</td>
</tr>
<tr>
<td>Project 2</td>
<td>Saugus, MA</td>
<td>37,740</td>
<td>5</td>
<td>39</td>
<td>Low*</td>
</tr>
<tr>
<td>Project 3</td>
<td>Haverhill, MA</td>
<td>27,300</td>
<td>3</td>
<td>24</td>
<td>Low*</td>
</tr>
<tr>
<td>Project 4</td>
<td>Leominster, MA</td>
<td>47,776</td>
<td>4</td>
<td>43</td>
<td>Mid-range</td>
</tr>
<tr>
<td>Project 5</td>
<td>West Roxbury, MA</td>
<td>95,000</td>
<td>4</td>
<td>82</td>
<td>Mid-range</td>
</tr>
<tr>
<td>Project 6</td>
<td>Quincy, MA</td>
<td>150,000</td>
<td>4</td>
<td>140</td>
<td></td>
</tr>
<tr>
<td>Project 7</td>
<td>Cambridge, MA</td>
<td>24,943</td>
<td>4</td>
<td>19</td>
<td>Low</td>
</tr>
<tr>
<td>Passive HS</td>
<td>Boston</td>
<td>33,500</td>
<td>4</td>
<td>30</td>
<td>High</td>
</tr>
</tbody>
</table>

*Code to Low High Performance Enclosure and HVAC efficiency measures reduce cost effectiveness and associated savings*

**No incentives were paid for air infiltration reduction savings on the Distillery Project**

Project 5 - National Grid Natural Gas & Eversource Electric
Project 7 - Eversource Natural Gas & Eversource Electric
### Project Criteria

#### Air Infiltration Reduction ECM Research

<table>
<thead>
<tr>
<th>Project Name</th>
<th>Location</th>
<th>Area (SF)</th>
<th>Storeys</th>
<th># units</th>
<th>Walls</th>
<th>Roof</th>
<th>Glazing</th>
<th>WWR</th>
<th>HVAC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Project 1</td>
<td>Northampton, MA</td>
<td>58,019</td>
<td>4</td>
<td>70</td>
<td>R19.5+R7.5ci</td>
<td>R-61</td>
<td>0.2/0.3</td>
<td>24%</td>
<td>VRF          yes</td>
</tr>
<tr>
<td>Project 2</td>
<td>Saugus, MA</td>
<td>37,740</td>
<td>5</td>
<td>39</td>
<td>R21+R7.6</td>
<td>Code</td>
<td>Code</td>
<td>24%</td>
<td>HB Central no</td>
</tr>
<tr>
<td>Project 3</td>
<td>Haverhill, MA</td>
<td>27,300</td>
<td>3</td>
<td>24</td>
<td>Code</td>
<td>Code</td>
<td>0.29/0.26</td>
<td>23%</td>
<td>HB TW-AC no</td>
</tr>
<tr>
<td>Project 4</td>
<td>Leominster, MA</td>
<td>47,776</td>
<td>4</td>
<td>43</td>
<td>R23+R7ci</td>
<td>R-45</td>
<td>0.31/0.27</td>
<td>17%</td>
<td>Central blr/Fan Coil yes</td>
</tr>
<tr>
<td>Project 5</td>
<td>West Roxbury, MA*</td>
<td>95,000</td>
<td>4</td>
<td>82</td>
<td>Code</td>
<td>R-38</td>
<td>0.27/0.3</td>
<td>26%</td>
<td>HA Split Syst. no</td>
</tr>
<tr>
<td>Project 6</td>
<td>Quincy, MA</td>
<td>150,000</td>
<td>4</td>
<td>140</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Project 7</td>
<td>Cambridge, MA**</td>
<td>24943</td>
<td>4</td>
<td>19</td>
<td>R-20+R6ci</td>
<td>Code</td>
<td>Code</td>
<td>20%</td>
<td>HA Split Syst. No</td>
</tr>
<tr>
<td>Passive HS</td>
<td>Boston, MA</td>
<td>33,500</td>
<td>4</td>
<td>30</td>
<td>R26.1+R12.9ci</td>
<td>R-46</td>
<td>0.13</td>
<td>31%</td>
<td>Ductless Mini-split yes</td>
</tr>
</tbody>
</table>

* National Grid Natural Gas - Eversource Electric
** Eversource Natural Gas - Eversource Electric

---

The Air Infiltration Reduction ECM Feasibility Research
## The Research Energy Savings Results

### Air Infiltration Reduction ECM Research

<table>
<thead>
<tr>
<th>Project Description</th>
<th>Location</th>
<th>Measured Air Infiltration</th>
<th>Original TA Study Savings</th>
<th>Savings incl. Air Infiltration</th>
<th>Δ Savings</th>
<th>Incremental Savings (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Location</td>
<td>CFM/SF @ 75 Pa Electrical</td>
<td>Nat. Gas Electrical Nat. Gas</td>
<td>Electrical Nat. Gas Electrical Nat. Gas</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Project 1</td>
<td>Northampton, MA</td>
<td>0.11</td>
<td>134,303</td>
<td>0</td>
<td>178,324</td>
<td>44,021</td>
</tr>
<tr>
<td>Project 2</td>
<td>Saugus, MA</td>
<td>0.34</td>
<td>51,301</td>
<td>527</td>
<td>48,420</td>
<td>1,035</td>
</tr>
<tr>
<td>Project 3</td>
<td>Haverhill, MA</td>
<td>0.34</td>
<td>49,799</td>
<td>560</td>
<td>49,831</td>
<td>576</td>
</tr>
<tr>
<td>Project 4</td>
<td>Leominster, MA</td>
<td>0.22</td>
<td>78,468</td>
<td>1,285</td>
<td>78,441</td>
<td>3,333</td>
</tr>
<tr>
<td>Project 5</td>
<td>West Roxbury, MA</td>
<td>0.33</td>
<td>90,019</td>
<td>6,424</td>
<td>85,973</td>
<td>8,001</td>
</tr>
<tr>
<td>Project 6</td>
<td>Quincy, MA</td>
<td>Cancelled Testing</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Project 7</td>
<td>Cambridge, MA</td>
<td>0.23</td>
<td>41,907</td>
<td>641</td>
<td>41,256</td>
<td>1,229</td>
</tr>
<tr>
<td>Passive HS</td>
<td>Boston</td>
<td>0.13</td>
<td>116335</td>
<td>600</td>
<td>139,585</td>
<td>600</td>
</tr>
</tbody>
</table>

*Code to Low High Performance Enclosure and HVAC efficiency measures reduce cost effectiveness and associated savings

**No incentives were paid for air infiltration reduction savings on the Distillery Project

Project 5 - National Grid Natural Gas & Eversource Electric
Project 7 - Eversource Natural Gas & Eversource Electric
# The Research Energy Savings Results

## Air Infiltration Reduction ECM Research

<table>
<thead>
<tr>
<th>Project Description</th>
<th>Testing Results</th>
<th>Energy Savings (Comprehensive)</th>
<th>Energy Costs Savings and Payback</th>
<th>Incentives</th>
<th>High Perf. Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>Location</td>
<td>Measured Air Infiltration</td>
<td>∆ Savings</td>
<td>Air Infiltration Savings</td>
<td>Testing Costs ($)</td>
<td>Payback (yrs)</td>
</tr>
<tr>
<td></td>
<td>CFM/SF @ 75 Pa</td>
<td>Electrical Nat. Gas</td>
<td>$0.17/kWh-$1.05/therm</td>
<td>ICF Mngmt w/ incent.</td>
<td>$0.35 kWh-$1.70 therm</td>
</tr>
<tr>
<td>Project 1</td>
<td>Northampton, MA</td>
<td>0.11</td>
<td>44,021 0</td>
<td>$7,484</td>
<td>$6,200</td>
</tr>
<tr>
<td>Project 2</td>
<td>Saugus, MA</td>
<td>0.34</td>
<td>(2,881) 508</td>
<td>$533</td>
<td>$950</td>
</tr>
<tr>
<td>Project 3</td>
<td>Haverhill, MA</td>
<td>0.34</td>
<td>32 16</td>
<td>$22</td>
<td>$4,800</td>
</tr>
<tr>
<td>Project 4</td>
<td>Leominster, MA</td>
<td>0.22</td>
<td>(27) 2,048</td>
<td>$2,146</td>
<td>$1,650</td>
</tr>
<tr>
<td>Project 5</td>
<td>West Roxbury, MA</td>
<td>0.33</td>
<td>(4,046) 1,577</td>
<td>$968</td>
<td>$4,600</td>
</tr>
<tr>
<td>Project 6</td>
<td>Quincy, MA</td>
<td>Cancelled Testing</td>
<td></td>
<td>$14,000</td>
<td>Cancelled testing</td>
</tr>
<tr>
<td>Project 7</td>
<td>Cambridge, MA</td>
<td>0.23</td>
<td>(651) 588</td>
<td>$507</td>
<td>$5,960</td>
</tr>
<tr>
<td>Passive HS</td>
<td>Boston</td>
<td>0.13</td>
<td>23,250 0</td>
<td>$3,953</td>
<td>$6,500</td>
</tr>
</tbody>
</table>

*Code to Low High Performance Enclosure and HVAC efficiency measures reduce cost effectiveness and associated savings

**No incentives were paid for air infiltration reduction savings on the Distillery Project

Project 5 - National Grid Natural Gas & Eversource Electric
Project 7 - Eversource Natural Gas & Eversource Electric

---

The Air Infiltration Reduction ECM Feasibility Research
The Research Energy Savings Results

$0.01-0.04/\text{SF}$ saved for natural gas heated facilities

$0.13/\text{SF}$ saved for electrically heated facilities

60% avg. savings - therm (natural gas heating)

30% Avg. savings - kWh (electrical heating)

1-3% Total Savings (kBtu)

The Air Infiltration Reduction ECM Feasibility Research
The Research Energy Savings Results

**Cost effective when including the testing fee**

- Payback without Incentives**: 2-10 yrs.
- Payback with Incentives**: 0.4-2.5 yrs.

Air Infiltration Testing Fees*

*$0.05-0.18/SF

*Fees were originally estimated at $0.20-$0.30/SF

**assuming $0.35/kWh-$1.70/Therm. –Excludes facility #3

The Air Infiltration Reduction ECM Feasibility Research
Additional Criteria Affecting Measurements

• Stack effect

• Latent cooling
  • Improves insulation efficiency by reducing uncontrolled air motion through insulation
  • Reduces dehumidification load

• Applicability and Challenges for High Rise Facilities
  • Audience Feedback Welcomed
Implementation & Market Response

- **An effort that is not routinely achieved in the current projects’ “built to code”**.
  - Proven fairly achievable, with support (role of ICF and Utility Programs)
  - 60% participation rate (projects already in construction!)
  - Address barriers that may restrain its rate of adoption.
  - MA PA’s have the potential to address these barriers, however we have not yet examined how PAs would or if PAs should take on such role.

- **Best proven through the whole building air infiltration testing**

- **Research revealed availability of regional resources (testing firms)**
Implementation & Market Response

Findings & Challenges

- Scheduling and completion needs to adapt to the construction schedule delays.
- Most projects experienced delays.
- Testing Firms will benefit from ongoing training/education
  - Evolve & improve the methodology by learning from each other
  - Additional field training
  - Consistency for testing/measuring methodology
Testing Process Recommendations

- Single zone for whole building testing (wherever possible)

- Process and Scheduling:
  - Testing milestones to be included in the construction schedule
  - Coordination meeting prior to the testing - include contractor, owner, appropriate subs, testing company, etc.
  - Create an Air Infiltration Testing Plan

Testing Plan to identify:

1. Fan/testing Equipment locations
2. Areas to be sealed
3. Field checklists & Data Collection
4. Staff Responsibilities for various tasks:
   - Disabling HVAC Equipment
   - Wired or wireless equipment set up
   - Notes and Photographs as critical documentation
Market Practitioners Feedback – ABx 2018

Recommendations
• Infra-red analysis
  • Support results (during construction)
  • Imagery to support client proposal
• Building Enclosure Commissioning (BE Cx)
  • Standardized site monitoring
• Incentives
  • Tax credits (Ownership)
  ◦ How do we quantify/qualify the drafts?

Hone the client proposal ("pitch")
• Promote non-energy benefits:
  • Comfort
  • Mold remediation
  • Resiliency
  • Tenants retention
  • Acoustics
  • Air quality: air particle content Improvement (standard?)

How/who can work together to overcome challenges
Interactive Discussion

- **Owners perspective**: What is needed to obtain buy in?

- **D&C Professionals perspective**: What do they need to know when?

- **Applicability** to other type of projects

- **Name Top 5 Challenges** for design and for construction industry

- Additional questions?