Addressing the Envelope: Recognizing Building Enclosure Improvements

February 19, 2020
POLL 1
Better Buildings Alliance – Background

- The Alliance includes more than 230 organizations, representing over 11 billion commercial square feet across 5 key market sectors:
  - commercial real estate,
  - healthcare,
  - higher education,
  - hospitality, and
  - retail, food service, and grocery.

- Previous Alliance technology campaigns, led by DOE’s National Labs, aim to accelerate the adoption of efficient building technologies by providing technical assistance, resources, and guidance on implementation best practices.
Better Buildings Alliance – Background
Connecting Better Buildings partners with advanced building envelope technology solutions

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

Envelope technologies accounting for approximately 30% of the primary energy consumed in commercial buildings, playing a key role in determining levels of comfort, natural lighting, ventilation, and how much energy is required to heat and cool a building.
### Previous Better Buildings Alliance Campaigns

<table>
<thead>
<tr>
<th>Campaign</th>
<th>Launch Year</th>
<th>Result</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lighting Energy Efficiency Campaign (LEEP)</td>
<td>2012</td>
<td>$23.6 million in electricity cost savings through energy use savings of 227 million kWh annually across 560 million ft² of parking facilities</td>
</tr>
<tr>
<td>Interior Lighting Campaign (ILC)</td>
<td>2013</td>
<td>$24 million in electricity cost savings through energy use savings of nearly 229 million ft² of building space</td>
</tr>
<tr>
<td>Advanced Rooftop Campaign (ARC)</td>
<td>2013</td>
<td>$90 million in electricity cost savings through energy use savings of 903 million kWh annual from of 114,000 RTUs</td>
</tr>
<tr>
<td>Smart Energy Analytics (SEA)</td>
<td>2016</td>
<td>$9 million in electricity cost savings through 400 billion Btu/year savings across 15 participants’ portfolios with energy management and information systems (EMIS) installed</td>
</tr>
</tbody>
</table>
Our Campaign

- Launches in June at the Better Buildings Summit!
- Will use the Building Envelope Performance (BEP) metric

Currently, we are
- Developing the Campaign website
- Seeking input from Beta testers
- Validating the tool and tiers
- Recruiting Campaign participants
Envelope Campaign Goals

- **Motivate action and increase awareness** of the value of investing in high performance building envelope technologies for both new and existing commercial buildings
- **Recognize leaders** adopting and achieving high performing building envelope systems
- **Demonstrate and document** energy and cost savings with integrated design, construction, commissioning, and maintenance from implementation of high performing envelope systems
Refining Campaign Targets and Metrics

**TAG Participants**
- **ASHRAE**, Chris Mathis
- **BCxA**, Liz Fischer
- **IFMA**, Dean Stanberry
- **ConEd**, Paul Romano
- **Eversource NH**, Michael Loughlin
- **Tishman-Speyer**, Jonathan Flaherty (Chair LEED Steering Committee)
- **HoK**, Anica Landreneau (LEED Advisory Committee Member)

**TAG Next Steps**
- Continue gather feedback (monthly/quarterly)
- Add additional members, as appropriate (BOMA, etc.)

- **Seek Technical Advisory Group (TAG) feedback on the Envelope Campaign**
  - Support for testing and validation of Building Envelope Performance (BEP) Metric
  - Support for establishing reasonable recognition tiers

- **Input on resources to support meeting Envelope Campaign targets**
  - Provide technology pathway guidance, fact sheets, case studies, etc.
Potential Recognition Tiers and Categories

Existing Building – Envelope Retrofit

<table>
<thead>
<tr>
<th>Recognition Tiers</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Retro 30</strong></td>
</tr>
<tr>
<td>Building envelope heat loss/gain reduction of 30(^a), due to implementation of building envelope improvements</td>
</tr>
<tr>
<td><strong>Retro 50</strong></td>
</tr>
<tr>
<td>Building envelope heat loss/gain reduction of 50(^a), due to implementation of building envelope improvements</td>
</tr>
</tbody>
</table>

(a) Reduction may consist of any energy retrofit measure that involve the building envelope thermal performance (R-value, Air leakage, Attachments, etc.)
Potential Recognition Tiers and Categories

New Construction

<table>
<thead>
<tr>
<th>Recognition Tiers</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Novel 20</strong></td>
</tr>
<tr>
<td>Building envelope heat loss/gain reduction of 20%(^a) over code(^b), due to incorporation of emerging high-performance envelope technologies</td>
</tr>
<tr>
<td><strong>Novel 40</strong></td>
</tr>
<tr>
<td>Building envelope heat loss/gain reduction of 40%(^a) over code(^b), due to incorporation of emerging high-performance envelope technologies</td>
</tr>
</tbody>
</table>

\(^a\) Follow ASHRAE Advanced Energy Design Guides Reduction  
\(^b\) Most recent national energy code (ASHRAE 90.1 - 2016)
Potential Recognition Tiers and Categories

Proposed Additional Recognition

### Role Models
An additional level of recognition will be available to those buildings which meet a campaign recognition tier and also incorporate an additional advanced strategy or technology into their building envelopes, serving as role models within the industry.

### Honorable Mentions
Buildings which do not meet a campaign recognition tier but still make a noteworthy impact on the campaign (e.g., substantial square footage) may apply for an Honorable Mention.
## Anticipated Schedule

<table>
<thead>
<tr>
<th>Phase</th>
<th>Task/Action</th>
<th>FY’20 Q1</th>
<th>FY’20 Q2</th>
<th>FY’20 Q3</th>
<th>FY’20 Q4</th>
<th>FY’21 Q1</th>
<th>FY’21 Q2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Exploratory</td>
<td>Test and Refine Metric</td>
<td></td>
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<tr>
<td></td>
<td>Define Challenge Targets and Metrics</td>
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<td></td>
<td>Gather Industry Feedback via TAG</td>
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<tr>
<td></td>
<td>Engage ETRT Focus Group to test metric</td>
<td></td>
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<tr>
<td>Develop</td>
<td>Identify Early Supporters/Adopters</td>
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<td>Develop Supporting Resources</td>
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<tr>
<td>Launch</td>
<td>Inaugural Participants/Launch/Announce</td>
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<td></td>
<td>Run Campaign (e.g., trainings, outreach, recruitment)</td>
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<td></td>
<td>Support Data Collection/Achievement</td>
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</tr>
<tr>
<td>Recognize</td>
<td>Conduct Recognition Event/Awards</td>
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</tr>
</tbody>
</table>
The Building Envelope Performance (BEP) Metric
The Building Envelope Performance (BEP) Metric

**Target - Fuel Economy**

**Variables**

- Engine
  - Size
  - # of Cylinders
  - Valve resistance + timing
  - Combustion time
  - etc.
- Fuel System
- Air Supply
- Shape (aerodynamics)
- ...

**Performance Indicator**
The Building Envelope Performance (BEP) Metric

<table>
<thead>
<tr>
<th>Target – Energy Efficiency</th>
<th>Variables</th>
<th>Performance Indicator</th>
</tr>
</thead>
<tbody>
<tr>
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</tr>
</tbody>
</table>
The Building Envelope Performance (BEP) Metric

**Target – Energy Efficiency**

**Variables**

- R-value
  - Walls
  - Roof
  - Foundation
  - Fenestration

- Thermal Bridges

- Installation Quality
  - Joints
  - Penetrations
  - Perforations

- Airtightness

- Building Type

- Thermostat Setpoints

- HVAC Characteristics

- User Behavior

- Indoor Climate

- Outdoor Climate

- ...

**Performance Indicator**

- EUI [kBtu/ft²]
- Predicted EUI (Simulations)
- ...

ExcelTable

<table>
<thead>
<tr>
<th>Performance Indicator</th>
<th>Variables</th>
</tr>
</thead>
<tbody>
<tr>
<td>EUI [kBtu/ft²]</td>
<td>R-value</td>
</tr>
<tr>
<td>Predicted EUI</td>
<td>Thermal Bridges</td>
</tr>
<tr>
<td></td>
<td>Installation Quality</td>
</tr>
<tr>
<td></td>
<td>Airtightness</td>
</tr>
<tr>
<td></td>
<td>Building Type</td>
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<tr>
<td></td>
<td>Thermostat Setpoints</td>
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<td>HVAC Characteristics</td>
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<td>User Behavior</td>
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<td>Indoor Climate</td>
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<td></td>
<td>Outdoor Climate</td>
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<tr>
<td></td>
<td>…</td>
</tr>
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</table>
The Building Envelope Performance (BEP) Metric

Variables
- R-value
  - Walls
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- Thermal Bridges
- Installation Quality
  - Joints
  - Penetrations
  - Perforations
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- Building Type
- Thermostat Setpoints
- HVAC Characteristics
- User Behavior
- Indoor Climate
- Outdoor Climate
- ...

Performance Indicator
- EUI [kBtu/ft²]
- Predicted EUI (Simulations)
- ...

- Only Applicable to Existing Buildings
- One-way Connection
- Highly Influenced by Building Usage
The Building Envelope Performance (BEP) Metric

**Variables**
- R-value
  - Walls
  - Roof
  - Foundation
  - Fenestration
- Thermal Bridges
- Installation Quality
  - Joints
  - Penetrations
  - Perforations
- Airtightness
  - Building Type
  - Thermostat Setpoints
  - HVAC Characteristics
  - User Behavior
  - Indoor Climate
  - Outdoor Climate
  - ...

**Performance Indicator**
- EUI [kBtu/ft²]
- Predicted EUI (Simulations)

EUI is not equivalent to “mpg”!

- Complicated
- Time Consuming
The Building Envelope Performance (BEP) Metric

Building Envelope Energy Demand

\[
\frac{Q_{HVAC}}{\eta} = Q_{net}^{env} + Q_{in}
\]

\[
Q_{net}^{env} = BEP \cdot A_{tot}^{env}
\]

Building Envelope Performance [kBtu/ft^2]
The Building Envelope Performance (BEP) Metric

Building Envelope Performance Metric

\[ BEP = \]
Overall Building Thermal Resistance

\[ \mathcal{R} = \frac{1}{\sigma \cdot R_{env}} + \frac{1}{R_{air}} + \frac{1}{R_{gain}} \]

- \( R_{env} \) = Building envelope conductive thermal resistance, \( R \)-value (\( (m^2 \cdot K)/W \) [\( (^{\circ}F \cdot ft^2 \cdot hr)/Btu \)]),
- \( \sigma \) = Opaque envelope solar and thermal radiation correction factor (-),
- \( R_{air} \) = Air leakage resistance (\( (m^2 \cdot K)/W \) [\( (^{\circ}F \cdot ft^2 \cdot hr)/Btu \)]),
- \( R_{gain} \) = Window solar internal heat gain resistance (\( (m^2 \cdot K)/W \) [\( (^{\circ}F \cdot ft^2 \cdot hr)/Btu \)]),
- \( I_{gain} \) = Window solar internal heat gain (W/m\(^2\) [Btu/(hr·ft\(^2\)]),
- \( I_{sol} \) = Opaque envelope exterior solar heat gains (W/m\(^2\) [Btu/(hr·ft\(^2\)])
## The Building Envelope Performance (BEP) Metric

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Length x Width x Height</td>
<td>20 x 15 x 4 m [65.6 x 49.2 x 13.1 ft]</td>
</tr>
<tr>
<td>Window Area</td>
<td>84 m² [275.6 ft²]</td>
</tr>
<tr>
<td>SHGC</td>
<td>0.352 (-)</td>
</tr>
<tr>
<td>R-value Wall/Roof/Window/Slab</td>
<td>1.013/3.509/0.391/adiabatic (m²·K)/W</td>
</tr>
<tr>
<td>Solar absorptance Wall/Roof</td>
<td>0.92/0.7</td>
</tr>
<tr>
<td>Surface heat transfer coefficient</td>
<td>8/25 W/(m²·K)</td>
</tr>
<tr>
<td>Interior/Exterior</td>
<td></td>
</tr>
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The Building Envelope Performance (BEP) Metric

Length x Width x Height: 20 x 15 x 4 m
Window Area: 84 m²
SHGC: 0.352 (-)

Solar absorptance Wall/Roof: 0.92/0.7

Surface heat transfer coefficient
Interior/Exterior: 8/25 W/(m²·K)

Air tightness: Not validated

The Building Envelope Performance (BEP) Metric

Cooling Demand (MMBtu/year)
Heating Demand (MMBtu/year)
The Building Envelope Performance (BEP) Metric
The Website
Campaign Process

Participant Milestones

1. Register with the Campaign
2. Use Assessment to Determine Building Performance
3. Send Results for Validation
4. Provide Verification Documentation
5. Be Recognized by DOE!

Team Responsibilities

1. Send Login Information
2. Provide Technical Support
3. Review Results, Request Verification Documentation
4. Confirm Award Level
5. Present Award!
POLLS 2 AND 3
Join Us!

Unsealed! The Envelope Campaign

Workshop scheduled for Wednesday morning, June 10th
Thank you!

- Simon Pallin, PhD, ORNL, pallinsb@ornl.gov
- Melissa Voss Lapsa, ORNL, lapsamv@ornl.gov
Reference Slides
The Building Envelope Performance (BEP) Metric

Overall Building Thermal Resistance

\[ R = \frac{1}{\sigma \cdot R_{env}} + \frac{1}{R_{air}} + \frac{1}{R_{gain}} \]

- \( R_{env} \) = Building envelope conductive thermal resistance, \( R \)-value \((\text{m}^2\cdot\text{K})/\text{W} \) [\((\circ\text{F} \cdot \text{ft}^2 \cdot \text{hr})/\text{Btu})\]),
- \( \sigma \) = Opaque envelope solar and thermal radiation correction factor (-),
- \( R_{air} \) = Air leakage resistance \((\text{m}^2\cdot\text{K})/\text{W} \) [\((\circ\text{F} \cdot \text{ft}^2 \cdot \text{hr})/\text{Btu})\]),
- \( R_{gain} \) = Window solar internal heat gain resistance \((\text{m}^2\cdot\text{K})/\text{W} \) [\((\circ\text{F} \cdot \text{ft}^2 \cdot \text{hr})/\text{Btu})\]),
- \( I_{gain} \) = Window solar internal heat gain \((\text{W}/\text{m}^2 \cdot [\text{Btu}/(\text{hr} \cdot \text{ft}^2)])\),
- \( I_{sol} \) = Opaque envelope exterior solar heat gains \((\text{W}/\text{m}^2 \cdot [\text{Btu}/(\text{hr} \cdot \text{ft}^2)])\),

\[ R_{env} = \frac{A_{env}}{R_{wall}} + \frac{A_{env}}{R_{roof}} + \frac{A_{env}}{R_{slab}} + U_{wind} \cdot A_{wind} \]

- \( R_{wall} \) = Wall thermal resistance \((\text{m}^2\cdot\text{K})/\text{W} \) [\((\circ\text{F} \cdot \text{ft}^2 \cdot \text{hr})/\text{Btu})\]),
- \( R_{roof} \) = Roof thermal resistance \((\text{m}^2\cdot\text{K})/\text{W} \) [\((\circ\text{F} \cdot \text{ft}^2 \cdot \text{hr})/\text{Btu})\]),
- \( R_{slab} \) = Slab thermal resistance \((\text{m}^2\cdot\text{K})/\text{W} \) [\((\circ\text{F} \cdot \text{ft}^2 \cdot \text{hr})/\text{Btu})\]),
The Building Envelope Performance (BEP) Metric

Overall Building Thermal Resistance

\[ R = \frac{1}{\sigma \cdot R_{env} + \frac{1}{R_{air}} + \frac{1}{R_{gain}}} \]

- \( R_{env} \) = Building envelope conductive thermal resistance, \( R \)-value ((m\(^2\)·K)/W [(°F·ft\(^2\)·hr)/Btu]),
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Equivalent Surface Temperature

\[ \sigma = \frac{T_{avg} - T_{in}}{T_{eq} - T_{in}} \]

\( T_{avg} \) = Average exterior surface temperature, \( T_{eq} \) = Equivalent airside surface temperature, \( T_{in} \) = Inside surface temperature
The Building Envelope Performance (BEP) Metric

Overall Building Thermal Resistance

\[ R = \frac{1}{\sigma \cdot R_{\text{env}}} + \frac{1}{R_{\text{air}}} + \frac{1}{R_{\text{gain}}} \]

- \( R_{\text{env}} \): Building envelope conductive thermal resistance, \( R \)-value \( (m^2 \cdot K)/W [^\circ F \cdot ft^2 \cdot hr]/Btu) \).
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- \( I_{\text{gain}} \): Window solar internal heat gain \( (W/m^2 [Btu/(hr\cdot ft^2)]) \).
- \( I_{\text{sol}} \): Opaque envelope exterior solar heat gains \( (W/m^2 [Btu/(hr\cdot ft^2)]) \).

Average Annual Air Leakage Rate

\[ R_{\text{air}} = \frac{A_{\text{env}}}{\dot{V} \cdot \rho_{\text{air}} \cdot C_{\text{air}}} \]

- \( A_{\text{env}} \): Building envelope area.
- \( \dot{V} \): Average annual ventilation rate.
- \( \rho_{\text{air}} \): Air density.
- \( C_{\text{air}} \): Air correction factor.

The diagram illustrates the thermal resistance components and their interactions within a building envelope system.
The Building Envelope Performance (BEP) Metric

Overall Building Thermal Resistance

\[ R = \frac{1}{\sigma \cdot R_{\text{env}}} + \frac{1}{R_{\text{air}}} + \frac{1}{R_{\text{gain}}} \]

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- \( I_{\text{sol}} \) = Opaque envelope exterior solar heat gains (W/m\(^2\) [Btu/(hr·ft\(^2\))]).

**Average Annual Solar Load**

\[ R_{\text{gain}} = \frac{(T_{\text{out}}^{\text{avg}} - T_{\text{in}}) \cdot A_{\text{env}}^{\text{avg}}}{Q_{\text{load,in}}} \]

\[ Q_{\text{load,in}} = \text{SHGC} \cdot \left( I_{\text{sol, E}}^{\text{avg}} \cdot A_{\text{win, E}}^{\text{avg}} + I_{\text{sol, S}}^{\text{avg}} \cdot A_{\text{win, S}}^{\text{avg}} + I_{\text{sol, W}}^{\text{avg}} \cdot A_{\text{win, W}}^{\text{avg}} + I_{\text{sol, N}}^{\text{avg}} \cdot A_{\text{win, N}}^{\text{avg}} \right) \]