

Building Envelope Campaign – Program Design and Stakeholder Engagement¹

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ABSTRACT

Building envelope technologies account for approximately 30% of the primary energy consumed by residential and commercial buildings. The Building Envelope Campaign (BEC), which is part of the US Department of Energy's Better Buildings program, is a market transformation effort to help building owners and managers invest in high-performance building envelope technologies for both new and existing commercial buildings. The success of the Campaign has depended on constructing a compelling program design and organizing a technical team with the ability to effectively recruit Participants and Supporters from across industry and keep them engaged.

The design of the Campaign included developing a strategy to leverage other technology campaigns within the Better Buildings program, identifying stakeholders (including diverse member groups that may have been underserved by previous technology campaigns), recruiting Supporters and Participants, and providing technical assistance in the form of a Campaign-specific Building Envelope Performance tool and metric to help benchmark various building envelope options.

Engagement had to overcome three main challenges: recruiting the Campaign Supporters/Participants, helping Participants to use the envelope tool to evaluate project options, and getting Participants to submit successful envelope projects for evaluation and recognition by the program.

The concepts of the Campaign are simple, but program design/implementation and, in particular, sustaining stakeholder engagement can be challenging. This paper highlights the approaches taken in designing the program, engaging industry members, identifying and reaching underserved stakeholders, demonstrating benefits of high-performance building envelope technologies, and making the case for engaging in this Campaign.

Introduction

According to the US Energy Information Administration, commercial buildings account for almost 20% of total energy consumption. In 2020, commercial buildings consumed approximately 18 quads of energy and contributed more than 820 MT of carbon emissions, or 16% of total US greenhouse gas emissions (US Energy Information Administration, 2021).

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Recognizing the environmental and economic impacts of energy consumption in residential and commercial buildings, the US Department of Energy (DOE) focused on supporting the development of innovative solutions to reduce energy demand.

Through the Better Buildings program, DOE works with the national labs to support the development of tools and resources to help building owners and managers improve the energy efficiency of their buildings.

One example is the technology campaigns and challenges that are available on the Better Building Initiative website (US Department of Energy, 2022). Currently, there are Better Buildings campaigns in building envelope, lighting, and smart diagnostic tools. (There are also additional technology campaigns being run by DOE that do not fall under the purview of the Better Buildings program, which will not be discussed here.) The goal of these campaigns is to provide tools and resources to accelerate the adoption of technologies that improve the energy performance of commercial buildings and multifamily residential buildings. Participants have access to tools, resources, and technical support to help them deploy energy conservation measures and technologies in new construction and retrofits. The campaigns are interactive and provide feedback on performance as a function of design for new construction and retrofits. This feedback provides Participants with the opportunity to evaluate design options and optimize for performance and cost. These campaigns also provide incentives for project teams to choose options that emphasize building performance, such as public recognition from the campaigns and DOE.

The focus of this paper is on the Building Envelope Campaign. The building envelope consists of walls, windows, roof, and foundation, and is one of the most overlooked areas of available energy savings in commercial buildings. Envelope technologies account for almost 30% of the primary energy consumed in residential and commercial buildings (Langevin, Harris, & Reyna, 2019). In addition to the energy demand for heating and cooling, buildings also play a key role in determining comfort level, natural lighting and ventilation.

The Building Envelope Campaign is aimed at providing momentum for building owners and managers to invest in high performance building envelope technologies for both new and existing commercial and multifamily residential buildings. The Building Envelope Campaign uses the Building Envelope Performance (BEP) metric, which was specifically designed to account for the performance of the building envelope and its effect on overall energy performance without the need to carry out whole-building energy simulations. This measure greatly simplifies the selection and evaluation of different design options.

BEP Metric

When designing new building enclosures or retrofitting existing ones, builders and owners rely on prescriptive measures to quantify the thermal performance of the building envelope. The most common measure is the insulation or R-value. The R-value is a measure of a material or system's ability to resist heat flow. The greater the R-value, the higher the resistance to heat flow. However, this simple concept does not capture the overall performance of the building envelope. Other factors need to be considered when evaluating the performance of the building enclosure, such as thermal mass, the thermal properties of fenestrations, air infiltration, and occupant behavior. All these factors play a role in determining the overall performance of the building envelope. Whole-building energy simulations account for these properties separately rather than combining them into a single value that is representative of the overall thermal performance of the building envelope. In addition, the effect of climate cannot be overlooked

when designing an energy-efficient building enclosure. For example, building envelopes optimized for cold climates do not necessarily perform well in warm climates. Depending on location, solar radiation may supplement heating loads in cold climates but increase cooling loads in warmer climates. Having a single value or representative value for the building envelope's performance facilitates the design process and provides a simple path toward optimization.

As early as 1975, ASHRAE attempted to develop a method to quantify the performance of the building envelope in response to increased cooling loads in hot climates (ASHRAE, 1975). ASHRAE introduced the concept of overall thermal transfer value, defined as the maximum allowable thermal transfer through the building's enclosure, including the roof, in response to solar loads and temperature differences across the enclosure. The approach was theoretically practical, but it had limitations. The most significant was the inability to account for internal loads. With the advent of more sophisticated whole-building energy models, such as EnergyPlus, all these loads could be accounted for independently rather than being aggregated into a single measure. The approach was abandoned in the revision ASHRAE 90.1 – 1989 (ASHRAE, 1989).

Later efforts recognized the importance of quantifying the benefits or effects of thermal mass and climate along with internal loads. To capture the relationship between the properties of the building envelope and its dynamic behavior in response to the external climate, the M-factor was developed. The M-factor was developed to quantify the effect of thermal mass on the overall thermal performance of the building envelope and is defined as the ratio of the dynamic heat flux of a masonry wall to theoretical steady state values (Ferrari & Zanotto, 2016). The value is then used as a correction factor to the steady-state heat flux to account for the effect of thermal mass. The M-factor was limited in its application because it did not account for other factors such as thermal loads.

In the late 1990s, a different approach was used to quantify the effects of thermal mass: the dynamic benefit for massive systems (Kosny, Kossecka, & Desjarlais, 1998). This approach accounted for all materials that made up the building envelope, including heating and cooling load requirements as a function of climate. To calculate the value, identical walls were constructed with one exception—a thermal mass was introduced into one wall. The insulation values were calculated and the ratio of the two was defined as the dynamic benefit for massive systems value. This work highlighted the effect of thermal mass on the overall performance of the building envelope.

A similar approach was used to understand the effect of a green roof on heating and cooling loads. Depending on location or climate zone and the soil's moisture content, green roofs could increase energy demand. To understand the effect of a green roof on energy demand, the dynamic benefit of green roofs was defined (Moody & Sailor, 2013). This measure considered not only the insulation value of the roof but also the HVAC load. Moisture-dependent material properties and climate or location were later used to validate the metric.

These are just a few examples of different approaches used to capture the dynamic effects of the building envelope with respect to material properties, thermal mass, and climate. Unfortunately, the effects of internal loads and air leakage were not included in these approaches. Similar to other measures, they could not capture all the properties in one value that could be used to help with the design of more energy-efficient building enclosures, whether for new or existing constructions.

To help builders and owners understand how design decisions on the building envelope affect energy demand, the BEP metric was developed (Pallin, Hagentoft, Aldykiewicz, DeGraw,

& Bhandari, 2021). The BEP metric evaluates the performance of the envelope as a system that accounts for geometry, thermal resistance, thermal inertia, thermal performance of fenestrations, and air leakage. In general, the heating and cooling loads (Q_{HVAC}) depend on the heat transfer across the building envelope (Q_{env}), along with contributions from internal loads (Q_{int}), as shown in Eq. (1). Those contributions can be further divided, leading to Eq. (2), where the heat transfer across the building envelope (Q_{env}) depends on the insulation value of the opaque wall (Q_{cond}), sum of the thermal mass (C), air leakage across the assembly ($Q_{env,air}$), and solar loads ($Q_{gain,sol}$). The temperature and time are represented by the variables T and t , respectively, in equation (2).

$$Q_{HVAC} = Q_{env} + Q_{int} \quad (1)$$

$$Q_{env} = Q_{cond} + Q_{env,air} + Q_{gain,sol} - C \frac{dT}{dt} \quad (2)$$

The BEP metric is then the sum of all the loads normalized to the building envelopes surface area (A_{env}), as shown in Eq. (3).

$$BEP = \frac{\sum_{t=1}^{8760} |Q_{env}(t)| dt}{A_{env}} \quad (3)$$

The difference between the energy use intensity and the BEP is that the energy use intensity is calculated as a function of the conditioned floor space. BEP represents energy consumption owing to the performance of the building envelope and is independent of how much conditioned floor space it encloses.

Building Envelope Campaign

The Building Envelope Campaign, as part of the Better Buildings program, is designed to provide tools, resources, and technical support to building owners and managers to help reduce energy consumption by addressing the performance of the building envelope. It is a web-based tool that uses the building envelope metric to quantify building envelope energy performance. By participating in the Building Envelope Campaign, users can quantify the benefits of building enclosure improvements. For new construction, the envelope performance can be calculated as a function of building envelope properties and elements and benchmarked against current energy codes. For retrofits, improvements can be compared with the current system, provided the information on the existing envelope design is known. This comparison provides users with performance and cost data to facilitate more informed design decisions.

To use the BEP metric to calculate building envelope performance, users need to register with the Campaign as either Participants or Supporters. For either role, there is no obligation or fee to join. Once the users are registered, they will have access to the BEP tool, along with other resources and technical support. Participants can be building owners, managers, architects, general contractors, and/or consultants. By participating in the Campaign, users have the benefits of using the tool and having access to the accompanying resources, and the opportunity for their building to be recognized by the Better Building Initiative as a project that attained a level of performance that exceeds current standards.

The distinction between Participants and Supporters is that Supporters do not necessarily have buildings to assess using the tool. However, like Participants, Supporters have access to the

BEC tools and resources. Supporters could be manufacturers, researchers, utility companies, and industry organizations, for example, that are invested in high-performing building envelopes—and therefore, the Campaign—even though they are not working on projects or submitting buildings for recognition. Registered users can switch between Supporter and Participant at any time.

Participation in the Campaign culminates in annual recognition for new construction and retrofits. The criteria for awards are based on the level or percent improvement with respect to energy codes for new construction and percent improvement over existing construction for retrofits. The categories are Novel for new construction and Retro for retrofits, and there are two tiers within each category. Novel recognition awards are given to those designs that result in a minimum of 20% or 40% improvement in performance compared with locally relevant code. Retro recognition awards are given to those retrofit projects that result in a minimum of 30% or 50% improvement in performance between the building pre- and post-retrofit. At the end of each Campaign year, DOE recognizes projects that have achieved the Novel and Retro levels of performance improvement.

There are several additional types of recognition available to registered Participants. The first is the Honorable Mention award, in which a project does not reach either of the Novel 20 or Retro 30 thresholds but is deemed by Campaign staff to still be deserving of formal recognition. In Year 1 of the Campaign, there was a Role Model award to recognize Participant(s) who went above and beyond in their pursuit of a high-performing building envelope. In Year 2 of the Campaign, this category has been split into a Technology Role Model and an Equity Role Model. The former is intended to recognize projects that are incorporating new or novel technologies into their envelope system. The latter is intended to recognize projects that are addressing equity in the energy sector in terms of building location, community served, and so on.

Program design

To encourage participation, the BEP tool needed to be simple and informative. Figure 1 shows a process diagram of the inputs required to calculate the building envelope metric. The first step is to select the building type—new construction or retrofit. The next step is to select the climate zone based on DOE’s definitions (US Department of Energy, 2022). In addition to climate zone, the environment is defined (i.e., whether the building is in a rural, urban, or open landscape). After the variables are selected that define the external environment, users can define the building, starting with a general building type based on DOE’s reference commercial buildings (US Department of Energy, 2022). The tool provides users with the flexibility to adjust conditioned floor area, wall and window areas, and number of floors in accordance with their building design. The last step is to define the building components and material properties, including the wall insulation value, wall façade materials, roof insulation value, and roof surface material. Note that the surface materials play an important role in solar heat gain. Finally, users will indicate airtightness of the building. If a blower test was conducted, users can input the result. If users anticipate some level of improvement in airtightness, they can indicate the percent improvement expected.



Figure 1. Process flow diagram that shows the inputs required by users to calculate the BEP metric.

Once all the information is provided, users can run the calculation to obtain the BEP metric. For new construction, comparisons will be made to current code (ASHRAE 90.1). For retrofit improvements, comparisons will be made to the existing construction as defined by users. Figure 2 shows an example of part of the output users see after running the calculation. The results show the BEP metric for the building that meets code and the metric after the improvements. In this example, the insulation value of the walls and roof were increased, and airtightness was improved by 25%. The net improvement was a 14% improvement in performance.

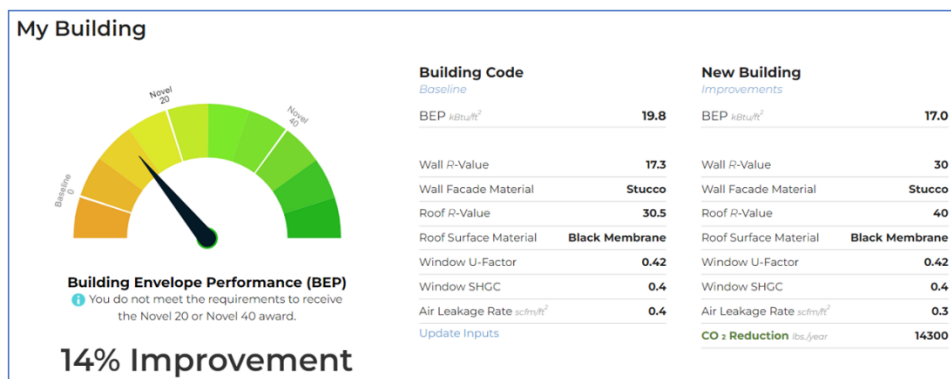


Figure 2. Output from the BEP calculation. This example shows a new construction that compared improvements with a baseline according to energy codes for 2022.

The BEP calculation is web-based and hosted by the US Department of Energy's Oak Ridge National Laboratory, and users must register to use the tool (Oak Ridge National Laboratory, 2020). By registering, users can save their projects and make changes later and/or compare different design options.

Engaging industry members

Initial industry engagement was facilitated by DOE’s Better Building Initiative and the Campaign’s Organizers—the American Institute of Architects (AIA), the International Institute of Building Enclosure Consultants (IIBEC), and the International Facility Management Association (IFMA)—who were all able to provide crucial feedback from the industry perspective. The Organizers were all onboarded prior to launch, and the majority of the initial Participants and Supporters who registered were members of Better Buildings, AIA, IIBEC, or IFMA. Engaging these large groups early was crucial since many additional Participants and Supporters learned about the Campaign through word-of-mouth or web searches that could be directly linked to these early registrants.

Recruiting Participants and Supporters is important and keeping them engaged is equally important. The original plan was to have each Participant or Supporter matched with a team member, who would keep in touch with them on a semi-regular basis, such as a quarterly check-in. However, distributing communications in this way would lead to inconsistent engagement, so more general means of communications were developed, including offering an intake call to each new Participant and Supporter, as well as creating a newsletter that is published on an approximately monthly basis. This newsletter allowed the Campaign to maintain regular contact with its network.

Because awards go out on an annual basis, there is a natural fluctuation in the frequency of communication with the registered members. Monthly calls are held throughout the year with the Organizers, and Supporters are typically engaged on an as-needed basis, such as in preparing for a webinar, providing social media copy, or drafting articles to be shared with their networks. Emails and phone calls directly to Participants increase in the months leading up to the submittal deadline in early April. This contact includes deadline reminders; documentation requests as their submittal is reviewed and validated; and, if eligible for awards, work with the Participant to prepare for the recognition event and develop artifacts (such as short videos and one-page fact sheets) to post on the Building Envelope Campaign website and share on social media, etc. in the future.

The Building Envelope Campaign launched (virtually) at the Better Buildings Summit in June 2020; the COVID-19 pandemic has prevented travel since prior to the Campaign’s launch. Ideally, the Campaign team would have traveled and presented the Campaign in person at meetings and conferences. However, the Year 1 recognition event was held virtually, and the Year 2 recognition event (summer 2022) will likely be held virtually, as well. As travel restrictions are lifted, Campaign staff hopes to be able to increase recruitment and engagement by interacting with current and potential Participants and Supporters in person.

Identifying and reaching underserved stakeholders

Year 1 of the Campaign was dedicated to building a large network of registered Supporters and Participants, and Better Buildings and DOE presented a new challenge for Year 2 of the Campaign. In line with the Biden administration’s Justice40 Initiative, the Campaign staff was asked to consider the Campaign through the lens of energy equity (Young, Mallory, & McCarthy, 2022).

The first change was to incorporate an Equity Role Model award into Year 2 of the Campaign, as previously described. This allowed for Campaign staff to explicitly call attention to the issue of energy equity as a priority for the Campaign, as well as give projects in this area

an opportunity for extra recognition. The Campaign staff anticipates that in particular, multifamily residential retrofit projects would be eligible for this additional award, as public housing and other multifamily units correlate to high energy burdens in historically underserved communities. The Campaign staff also hopes that this award might incentivize landlords to lower the energy burden of their buildings, as tenants often have high energy burdens because of building characteristics that are out of their control (Brown, Soni, Lapsa, Southworth, & Cox, 2020).

The second change was to pursue underserved stakeholders through the Campaign’s existing network. When onboarding calls were held for a new Supporter or Participant, Campaign staff brought this award to their attention and asked them to consider sharing the Campaign within their networks. These efforts did not get underway until partway through Year 2, and Campaign staff anticipates more growth in this area in Year 3.

Demonstrating benefits of high-performance building envelope technologies

In the Building Envelope Campaign’s first year, buildings representing approximately 1.5 million ft² of conditioned space were evaluated. The net energy savings realized were just under 9 million Btu/year. In the project’s first year, more than half of DOE’s reference buildings were represented, including in healthcare and education. The buildings extend from hot and humid climates to cold climates. Figure 3 shows the representation of building types and climate zones represented in the Campaign’s first year. Most building types were medium office buildings (based on DOE’s reference commercial buildings). Figure 4 shows the variation in improvement for the projects that were recognized for new construction awards and retrofit improvement awards. The new construction awards, Novel 20 and 40, were recognized for improving the building envelope performance by 20%–40% and greater than 40%, respectively. Retro 30 and 50 improvements were recognized for improving the building envelope performance by 30%–50% and greater than 50%, respectively.



Figure 3. The distribution of building types (a) and climate zones (b) represented in the first year of the Building Envelope Campaign.

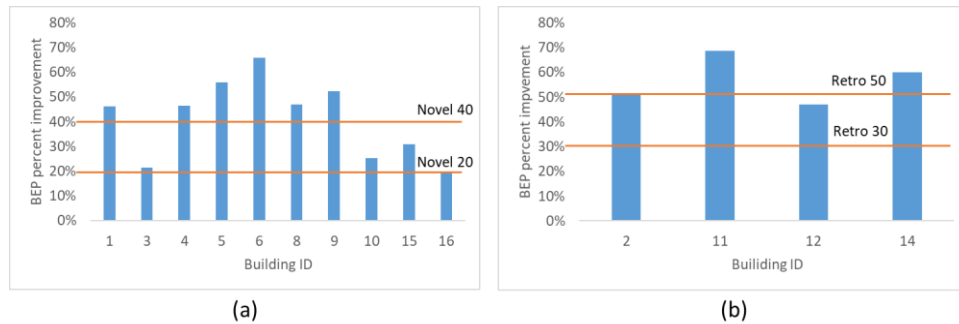


Figure 4. The BEP percent improvement for new construction and retrofit projects analyzed in the first year of the Building Envelope Campaign.

Benefits of engaging in this Campaign

In the Campaign's first year, 14 projects used the Building Envelope Performance metric to significantly improve envelope performance. For new construction, 10 projects realized building envelope performance improvements between 20% and 70% compared with code (Figure 4a). Four retrofit projects used the BEP metric to improve envelope performance between 30% and 70% compared with existing envelope structures (Figure 4b). The BEP metric facilitated design decisions with respect to the components and material properties of the building envelope. In addition, the BEP metric provided guidance with respect to what part of the envelope resulted in the most significant level of performance improvement. This guidance helped Participants make more informed design decisions and focus resources where the benefits would be the greatest. For example, a school in the mixed humid climate zone, 4A, was able to improve the envelope performance by significantly increasing the insulation value of the roof and reducing air leakage. Prior to the retrofit, the insulation value of the roof was approximately R5. When replacing the roof, designers also decided to increase the insulation value to R30. In addition, the improvement resulted in a 10% reduction in the measured air leakage. Together, these improvements lead to a reduction in the BEP metric of just over 20%. Another example was the new construction of a large office building in the hot-humid climate zone, 2A. The designers were able to improve the performance of the building envelope by addressing all elements: walls, roof, windows, and air leakage. Compared to the original design, the following modifications were made: the insulation value of the wall was increased by R23; the insulation value of the roof was increased by R10 and a cool roof surface material was used to minimize solar heat gain; the U factor of the windows was reduced by half from 0.58 to 0.27; and finally the air leakage requirement was reduced by over 75%, from 0.40 to 0.09 sfc_m/ft².

Concluding remarks

The BEP metric is a measure designed to quantify the thermal performance of the building envelope by accounting for external and internal loads, including dynamic effects such as climate and thermal mass. The goal of the Campaign was to develop a metric that was easy for the building owners and managers to use. By making the tool web-based and integrating it into DOE's Better Buildings Initiative, the Campaign was able to reach out to the Better Buildings community to encourage and promote participation. Additionally, the Building Envelope Campaign participated in Better Buildings communication and outreach programs, such as their

webinar series. The Campaign's foundation in the Better Buildings program has been crucial to its growth and success.

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