Commercial Building Partners Catalyze Energy Efficient Buildings Across the Nation

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ABSTRACT

In 2008 the US Department of Energy (DOE) launched the Commercial Buildings Partnership (CBP) project to accelerate market adoption of commercially available energy saving technologies into the design process for new and upgraded commercial buildings. The CBP represents a unique collaboration between industry leaders and DOE to develop high performance buildings as a model for future construction and renovation. CBP was implemented in two stages. This paper focuses on lessons learned at Pacific Northwest National Laboratory (PNNL) with companies starting in 2008 and discusses some partner insights from projects joining the program later. In 2008, PNNL and the National Renewable Energy Laboratory recruited CBP partners that own large portfolios of buildings. The labs provide assistance to the partners' design teams and make a business case for energy investments. From the owner's perspective, a sound investment results in energy savings based on the corporate prototypical design (new construction) or existing operations (retrofit).

Each partnership is focused on one or both of the following goals:

- Design, construct, and commission a new building that achieves 50% energy savings relative to ANSI/ASHRAE/IESNA Standard 90.1-2004 (90.1-2004). Projects that started in 2010 or after seek to achieve 50% savings relative to 90.1-2007.
- Retrofit an existing building that achieves 30% energy savings compared to the building's baseline operation or better than 90.1-2004 or 2007. The baseline for existing buildings is chosen after the CBP team determines if sufficient information about the existing building is available to determine the existing building performance or if there is an advantage using one or the other baselines.

The buildings receiving assistance serve as a template for the corporations involved in CBP, and many partners are now replicating the high performance measures across their portfolios. The pilot projects include many building sizes and types. This paper provides an overview of the CBP effort and the variety of buildings and partners currently participating with PNNL. Many of the projects are now completing construction and results from the design processes, building modeling, monitoring studies, and other analyses are discussed.

Introduction

The U.S. Department of Energy (DOE) developed the Commercial Buildings Partnerships (CBP) to allow companies with large building portfolios to explore energy-saving design alternatives that may be too technologically challenging or expensive to consider without the DOE-funded technical expertise of the national laboratories. The labs work with companies to create, test, validate, and deploy low-energy building designs.

The CBP objective is to develop a set of energy efficient building design solutions that are replicable within partner portfolios and widely deployable throughout industries represented by the partners. The national laboratories, their partners, technical teams, and measurement and verification contractors will thoroughly document the individual building projects to develop a business case for replicating the many technologies, techniques, and best practices used to achieve high performance. Partners have agreed to work with the national laboratories to design and construct buildings that use 50% less energy than ANSI/ASHRAE/IESNA Standard 90.1 (new construction) or 30% less energy (retrofit) relative to the baselines. Depending on the project start date the baseline is either 90.1-2004 or 90.1-2007, with the newest projects using 90.1-2007. In exchange for the companies' commitments, DOE provides the technical expertise of the national laboratories and other expert consultants to help the companies meet or exceed their goals.

The goals of the project are ambitious:

- Implement aggressive energy reduction savings measures for either or both an existing building renovation and/or a new construction design.
- Create design packages that meet partner business criteria for financial performance, branding, operations, and company policies.
- Develop the business and technical feasibility case for replication of aggressive energy reduction savings across a portfolio of buildings.
- Validate energy modeling results with energy performance verification.
- Help develop a competent workforce of technical experts for energy efficiency design/modeling that engages with industry.

CBP Design Process

CBP begins with the selection of a project industry partner. Project partners working with PNNL include Bank of America, Grand Valley State University, GSA, Hines, The Home Depot, the InterContinental Hotels Group, JCPenney, Job Corps, PNC Financial, Regency Centers, and the US Army. Typical project partners have large building portfolios they manage, own, or influence. In stage 1 after a partner commits to participate in the project, it works with the national laboratory to identify prototype building(s) to use as a show case for research on specific energy efficiency measures (EEMs). Many of the buildings were selected based on project timelines; a building that was already scheduled for construction or renovation would be suitable for the project if it meets the other criteria well.

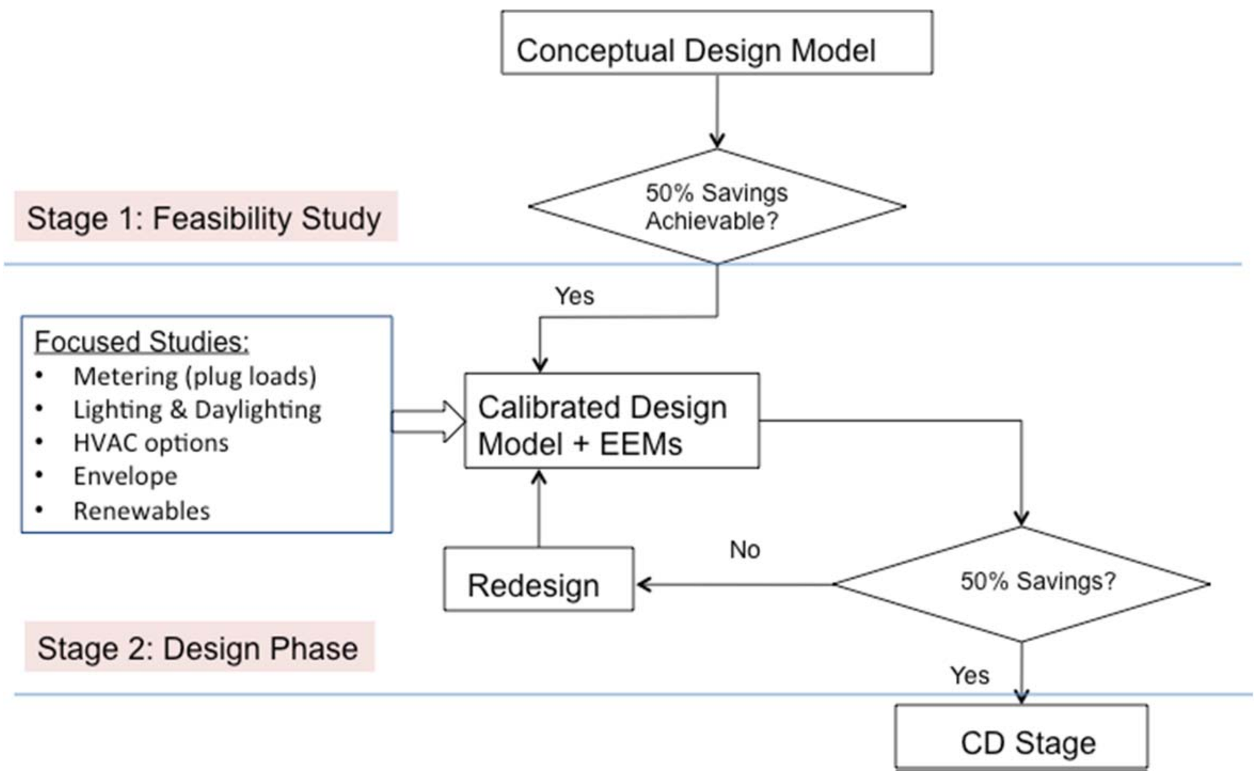
Participation in the CBP involves a long-term commitment through five stages of building design and construction, as follows:

- Stage 1: Pre-Design Planning – results in a decision whether to engage the project based on the feasibility of a proposed EEM package to meet DOE and partner goals and criteria. A preliminary analysis is conducted by the national laboratory and the technical expert teams to indicate whether the project can meet both the DOE-set energy efficiency targets and the partner's business criteria.
- Stage 2: Design/Redesign – involves detailed modeling and other analysis to fully develop the EEM package for inclusion in construction documents. The CBP teams work together to conduct a detailed analysis and model of the building to achieve

higher levels of efficiency. Figure 1 provides an example of the way the different team partners participate in CBP once projects have been selected.

- Stage 3: Construction and Commissioning –results in a new or renovated building and a decision about how to verify building performance. This stage is dominated by the partner. Stage 3 is the preparation to be able to demonstrate how the building performs compared to the design intent. In Stage 4, building operating performance data is collected and analyzed to determine the building's actual performance.
- Stage 4: Operating Performance Monitoring – includes monitoring of the building's performance after the intervention.
- Stage 5: Deployment – provides lessons learned and resulting changes throughout the firm's portfolio. The final stage is deployment of the building design and development of lessons learned.

Figure 1. The CBP Design Process for a PNC Bank Branch (Athalye et al. 2012)



The CBP process is similar to the integrated or whole building design process. The integrated design process is based on the following six stages (WBDG 2010): Preparation, Design Development, Contract Documents, Construction Phase, Commissioning, and Facility Performance Evaluation

The advantages of the integrated design process have been documented in the literature. Research by Larsson and Clark (Larsson & Clark 2000) indicated that the process introduces few additional costs and provides significant benefit to the project. Todesco (Todesco 1996) explores how far this design process could advance building performance. Torcellini (an active participant in the CBP) et al. outlines a detailed integrated design process as it was used to build the Zion National Park Visitor Center (Torcellini, Judkoff, & Hayter 2002).

Development of PNC's bank branch offers an example of how the design process worked within the CBP as shown in Figure 1 (Athalye et al. 2012). Within this process, several studies were performed between stage 1 and stage 2 to aid in making decisions for the selection of specific energy efficiency measures. Because of the emphasis placed on reducing loads in order to achieve net zero energy performance, a monitoring study was done to characterize building loads (Xie et al. 2012). This study had dramatic impacts on the design team's understanding of PNC prototypical load characteristics, how poorly non-calibrated models were simulating building energy performance, and how monitoring one building influenced immediate corporate action to properly size equipment that resulted in both capital-cost and energy savings.

The studies of specific measures for glazing, insulation, HVAC equipment, lighting, and renewable generation allowed for input early in the design process to accommodate EEMs in both this specific building design, and changes to PNC's prototype design. Detailed load characteristic data, along with the measure analyses, ultimately resulted in modeled savings of 57% for the branch in Fort Lauderdale, Florida.

Results

The CBP partners engaged with PNNL since 2008 have a combined portfolio size of more than 950 million square feet, representing around 1.4% of the US commercial building area based on CBECS (EIA 2003). The 20 buildings chosen for the project (961,681 square feet) represent a unique cross-section of functions including education, retail, and offices. The buildings are split evenly between new construction and renovations. Most of the projects have entered Stage 2 or Stage 3, but a few have already completed construction and are now in Stage 4 of the process.

Most of the projects have projected energy savings close to the program targets of 30% of baseline consumption for existing buildings and 50% better than Standard 90.1-2004 or 2007 for new construction and 5 of the buildings modeled are expected to exceed the targets.

Energy Efficiency Measures (EEMs)

The large variety of project types resulted in a diversity of selected energy efficiency measures. A summary of the types of EEMs selected is shown in Table 1. The most popular energy measures selected by all the projects included increasing roof and wall insulation. Most projects also reduced lighting power density (LPD) in the common areas of the buildings, often using LED lighting solutions. Occupancy sensors were also found to be cost effective for most projects. All projects increased the efficiency of the heating and cooling equipment and many also included demand control ventilation and energy recovery strategies.

Most of the EEMs shown in Table 1 were determined to be cost effective based on the partner's criteria (ROI, NPV, or payback). Many of the EEMs were presented as integrated "packages" to improve the payback of the measures. For example, envelope improvements were frequently combined with high efficiency mechanical systems to offset the relatively high price of the measures.

Table 1. Summary of the Types of EEMs Selected Across the CBP Buildings Considered.

Recommended EEM[1]	Number of Projects Implemented[2]	Number of Projects Considering
Envelope Measures		
Increase wall insulation above code levels to maximum reasonable or cost effective	4	1
Increase roof insulation above code levels to maximum reasonable or cost effective	7	
Install high performance fenestration optimized for daylighting and U-factor	4	2
Add exterior shading	1	
Reduce air infiltration	1	1
Lighting		
Daylighting and daylighting controls	4	
Reduce lighting power density (LPD)	6	1
LED lighting	3	1
Occupancy sensor controls	5	1
Reduce lighting schedules to turn off lights during periods of lower occupation (staff or stocking times)	2	
Reduce exterior lighting power density	6	
LED based exterior lighting in parking lots and signs	6	
Reduce exterior lighting schedules	3	

Chart continues on next page.

Recommended EEM[1]	Number of Projects Implemented[2]	Number of Projects Considering
Mechanical		
High efficiency heating or cooling equipment	7	
Radiant heating in some areas of the building	1	
Variable air volume systems	1	1
Demand controlled ventilation	4	1
Enthalpy or energy recovery strategies	4	
Increase fan power efficiency	1	1
Change thermostats or system setpoints	2	1
Optimize control strategy with commissioning	0	1
Plug Loads and Other EEMS		
High efficiency computers and monitors	2	
Plug-in strip occupancy sensor to turn off monitor during off hours	2	
Occupancy sensors for vending machines	1	1
Energy Star appliances	1	1
Programmable shut off controls on computer CPUs, MFD, TVs and other equipment	2	

1. Some EEMs (like renewable energy) are not listed but were evaluated by many of the projects.
2. The number of projects is based on the total of 7 buildings that had completed Stage 2 of the process at the time of publication.

Energy Efficiency Estimates

A summary of the projected energy efficiency improvements for the projects that are close to completing the design stage are shown in Table 2. For each project the type of construction and the reduction in Energy Use Intensity (EUI), normalized by building size, is shown. For existing buildings the energy reduction target is 30%, and average modeled reduction in energy use is 34 kBtu/ft^2 or 36%. For new construction the project goal is 50% savings over

90.1-2004. For these projects the average modeled reduction in energy use is 53 kBtu/ft^2, or 54%. All the energy reduction estimates are based on modeling results and may not represent realized energy performance in the completed buildings.

If the average reduction in EUI observed for the existing buildings could be applied to the full portfolio of the CBP partners (partner portfolio size has been estimated) that PNNL worked with, it would result in energy savings of more than 31 trillion Btus annually. This magnitude of energy savings is possible based on early feedback from many of the project partners. Several partners have indicated that LED parking lot lighting solutions have proven so cost effective that they are already planning to roll them out to the full corporate portfolio as standard wear and maintenance proceeds. Other EEMs like high efficiency rooftop units have also been well received.

Table 2. Summary of Projects Which Have Completed Preliminary Design.

Partner	Project Type	Project Stage	Project Size	Baseline EUI [1]	Design EUI	Annual EUI Reduction
Units			*ft^2*	*kBtu/ft^2*	*kBtu/ft^2*	*kBtu/ft^2*
JCPenney	Existing	Stage 4	107,216	64	35	29
Crowne Plaza	Existing	Stage 2	212,000	147	102	45
PNC Bank	Existing	Stage 4	4,600	57	39	18
Regency Partners	Existing	Stage 3	128,180	104	61	43
JCPenney	New	Stage 4	105,000	73	30	29
Bank of America	New	Stage 4	4,200	116	61	55
PNC Bank	New	Stage 3	4,620	128	56	72
Average				98.4	54.8	43.6

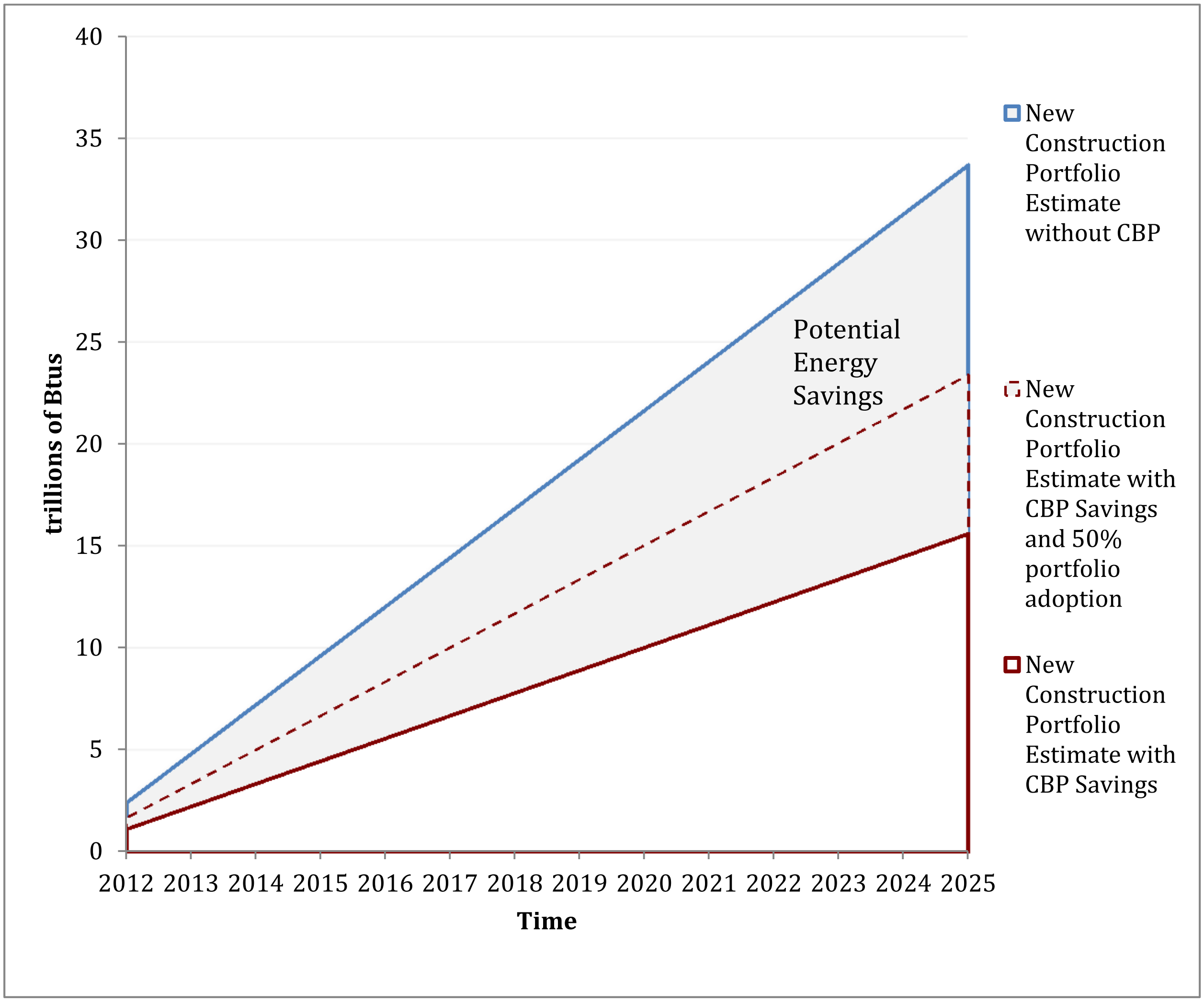
1. All values are based on modeling estimates and may not reflect the actual energy savings in the buildings. The baseline assumptions for new and existing construction are not the same.

For new construction the average EUI reduction may be used to project impact to future construction and growth. The 2003 CBECS reported new construction annually of 1.6 billion ft^2, which may no longer be the case based on recent economic issues, but is the best available information for this estimate (EIA 2003). Since the CBP partners working with PNNL represent roughly 1.4% of the total commercial building area in 2003, these portfolios could impact more than 22 million ft^2 of new construction each year. If the average EUI reduction observed for new construction projects is implemented, the savings would be more than 1 trillion Btus per year. If only half of the energy efficiency measures planned for the prototype buildings were adopted by the project partners the program savings would still be close to 0.7 trillion Btus per year. The compounding nature of the annual savings is shown in Figure 2. This projection assumes a linear addition of 22 million ft^2 of new construction each year by the project partners, and assumes that the code baseline would not change.

Project Structure Advantage

The CBP project represents a new paradigm for pursuing energy efficient buildings in the commercial sector. Traditionally projects that target improved energy efficiency in buildings have focused on partnering with utilities. Utilities or other local agencies often provide incentive funding or other assistance and specific buildings are modified within a targeted geographical region. In many cases only a few buildings would be directly impacted and solutions tended to be climate specific. This paradigm for improving efficiency is discussed by Nadel (Nadel 1992).

Figure 2. Projection of Possible Energy Savings if Average EUI Reductions are Implemented by Project Partners in Future Construction[1].



1. New construction estimate without CBP assumes the 22 million ft^2 per year of new construction would be built at the average EUI for new construction of the partner projects (106 $kBtu/ft^2$).

One of the most exciting aspects of CBP is the opportunity to influence a full partner portfolio representing millions of square feet of buildings across the nation. This approach of working at the corporate level is well suited to DOE's structure, given that it requires a relatively small staff commitment. Most of the heavy lifting is left to participating partners. Since many of the partners operate a large building portfolio they often have corporate building prototype designs or “templates”. The opportunity to directly impact the corporate building templates is a unique opportunity but also introduces additional challenges. Corporate building templates and policies may have strict return on investment (ROI) criteria for implementing new energy measures. Other corporate policies may be outdated or based on older technology, for example one partner team resisted LEDs as a replacement for fluorescent lighting because corporate design policy required T8 linear fluorescents.

The opportunity to influence the corporate template has been very successful. At least one partner has already modified the corporate building template to achieve 50% savings over 90.1-2007 in most climates in which the partner currently builds. Other partners have made changes to corporate energy management systems to reduce lighting schedules or better diagnose HVAC problems that were suggested by the design teams as part of the research project. Some partners have implemented company policies that will have a broad influence over existing buildings. These actions include changes in decorative and branding lighting, and in central control of computer systems and other plug loads that will be rolled out across both new and existing buildings over time. Central control strategies can be rolled out almost instantaneously once properly designed. These changes are already saving energy in partners’ building portfolios across the country.

Lessons Learned

As described in the literature on integrated design, giving importance to communication in the design process has long been understood to improve chances of meeting project objectives. The CBP project team has observed that some partnership strategies were more successful than others.

Integrating into the Corporate Construction Process May Improve Results

The project teams often include the PNNL research staff, the corporate partner, and several contractor teams for design or commissioning. In some cases the energy modeling is done by PNNL researchers and in other cases a contractor was identified. In the cases where a contractor was identified using a competitive solicitation, two projects selected a contractor who is the existing corporate design contractor. This presents a challenge for the design contractor to manage two clients, but in both of these buildings the existing relationship the design contractor had with the partner was beneficial. For these two projects PNNL adopted a slightly different strategy for the project, and during Stage 1 of the process the contractor design team was educated by the laboratory researchers. The design teams met independently with PNNL lighting and mechanical experts to help them identify a long list of EEMs for consideration and modeling. This helped the design contractor to “think outside the box” of the typical prototype corporate design, but the actual implementation and modeling was performed using the energy modeling and cost tools the design contractor was most familiar with.

Within these examples, the teams required less time for meshing with the corporate partner’s communication process. Traditional conference call schedules and design meetings were adopted with the addition of the PNNL team, but established processes could be used seamlessly. Communication in these teams has been significantly better than those where the design team was new to the project and team.

In one example the design contractor was able to negotiate a completely new mechanical system for the building despite the relatively high cost using knowledge of corporate priorities. In the other example the contractor was able to directly implement almost all the selected EEMs concurrently in the corporate portfolio template to provide energy savings almost immediately. This team also tested some of the EEMs (like lighting) in buildings that were already under construction to prove customer responses and cost savings.

Projects where an external design team was used were also very successful, but the teams each went through a longer period of time before smooth communication methods were established. In one project the design team contractor funded through the CBP developed a close relationship with the corporate partner and became the preferred energy contractor for future projects, where prior to this project the partner did not traditionally hire an energy design team.

Measurement and Verification to Calibrate Models Introduces Early Benefits

Typically during Stage 1 and Stage 2 data gathering was conducted to understand existing plug loads, equipment performance, and to calibrate energy design models. This data gathering led to early and exciting energy saving strategies, which could be acted on immediately by the project partners. In one building this data gathering discovered that the corporate energy management system was not properly controlling the HVAC units. With a few tests and adjustments the partner was able to correct an issue that affected most of the corporate building portfolio.

Measurement and Verification Activities Found Additional Energy Savings Opportunities Late in the Design Process

Only a few of the CBP projects have entered Stage 4 for measurement and verification. One project that has reached this stage has observed energy consumption only 10% higher than the energy modeling work indicated. When the team investigated this to determine the reasons for the slight performance issue, operational schedules in the corporate energy system were found to be out of date with operation models. Projects have also found implementation changes needed for high performance HVAC systems and a few issues with perceptions of low lighting levels.

Conclusions

The CBP emphasizes replication of energy savings through partner portfolios. Once identified, some measures are shown to result in dramatic enough savings that they are adopted into prototype designs before construction and final design of demonstration buildings have been completed. The teams have worked carefully to determine cost effectiveness for common EEMs and evaluate them based on partner business criteria.

In most buildings where the team did not meet the energy savings target cost effectiveness was the primary barrier. Other project challenges include:

- A stagnant economy that stopped building development for some companies as the CBP was getting underway
- Corporate policies which prevented high performance components
- Safety or security requirements which prevented lighting reductions, window choices, and other component selection
- Reliability or operation constraints that require constant electricity (data centers for example)
- Conflicts between two EEMs, for example one building had a conflict between rooftop solar and air economizers that required analysis to select the most appropriate measure for the project
- Partner cost effectiveness policies; some corporations required ROI of less than 2 years or very low first cost to be demonstrated for the EEMs

In general PNNL observed a high level of commitment from corporate partners to meet the performance targets of the CBP project. In most partnerships a significant percentage of the EEMs will be adopted into the corporate prototype; in one case all the EEMs proposed have already been implemented in the corporate design. This model of increasing building energy efficiency may have more potential for successfully improving large amounts of the total commercial construction area than traditional mechanisms which focus on regional or local partnerships. Regional or state governments could work with local businesses, leasing groups, or franchises to extend this project model and use the funding model.

Acknowledgements

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