Commercial Building Partnerships Sweeps up Savings

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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 project allowed companies with large building portfolios to explore energy-saving design alternatives that might be too technologically challenging or expensive to pursue without significant technical expertise. The expertise was provided as a partnership in a multi-year effort from several national laboratories that spanned many building sectors and corporate entities.

This paper presents a summary of how effectively the project met each of the original goals. The project was most successful at developing replicable energy savings methods. In other goals, like energy performance verification, many of the projects were unable to fully validate the original energy models. However the data from the verification efforts will assist the design teams to adjust and improve future building models. The data also helped corporate portfolio managers to make energy decisions for all locations and to cross-check portfolio energy management systems.

Introduction

The Commercial Building Partnerships (CBP) project was a public-private cost-share program addressing large new and existing commercial buildings in an effort to build or retrofit buildings to substantial energy savings. The CBP project was initiated in 2008 (CBP I), with a second funding opportunity presented in 2010 (CBP II) through the American Recovery and Reinvestment Act (ARRA). This paper provides an overview of the CBP program and evaluates the project's initial goals based on project outcomes.

The building projects were selected competitively, with strict energy savings requirements mandated by the Department of Energy (DOE). Once selected, each commercial partner committed to savings goals that were at least 50% greater than ANSI/ASHRAE/IESNA Standard 90.1-2004 (ASHRAE, ANSI, and IESNA 2004) or 2007 for new construction projects, and retrofit projects were designed to consume at least 30% less energy than either Standard 90.1-2004 or current building consumption (US Department of Energy 2011). CBP included 42 commercial partners working on 54 projects. The projects included new construction and retrofits of existing buildings. The total specific CBP projects include almost 8.3 million square feet of floor area and the commercial partner portfolios include almost 4 billion square feet, approximately 6% of the total commercial building stock in the U.S. (Antonopoulos, Dillon, and Baechler 2013; US Department of Energy 2011).

The CBP program partnered commercial companies with engineers, scientists, and consultants to design, implement and monitor energy efficient measures for building construction. The Pacific Northwest National Laboratory (PNNL) was one of the national laboratories and worked on 24 projects involving 20 partners resulting in 12 completed projects in CBP I and II. The building efficiency measures included envelope improvements, mechanical systems, electrical systems and approaches to operations and maintenance (O&M). Each project was optimized specifically for the goals of the commercial partner and the building location.

Commercial Building Partnerships

PNNL partnered on 12 constructed projects as part of CBP I and II. A summary of the projects, partners, and building characteristics is provided in Table 2. This paper does not describe the 12 projects that were not completed under the program, were completed after the program closed or that were completed as a modified design. Many of these other projects benefited from early design intervention and/or the development of plans for commissioning and measurement and verification . Each of the completed projects was outlined in a formal case study and the citation number references the documentation.

Table 2. Overview of the PNNL projects in CBP I and II.

Project	Partner	Project Type	Climate Zone	Building Size [ft^2]	Completion Date
JCPenney Existing (PNNL 2013d)	JCPenney	Existing Construction	4A	107,216	November 2011
JCPenney New (PNNL 2013c)	JCPenney	New Construction	3A	103,555	September 2011
Crowne Plaza (PNNL 2013b)	Crowne Plaza	Existing Construction	4A	144,000	May 2013
PNC Bank New (PNNL 2013e)	PNC	New Construction	1A	4,620	January 2013
PNC Bank Existing (PNNL 2013f)	PNC	Existing Construction	2A	4,612	January 2012
Granada Village (PNNL 2013g)	Regency	Existing Construction	3B	125,416	October 2012
Bank of America (PNNL 2013a)	Bank of America	New Construction	2A	4,200	October 2011
Seidman Center (PNNL 2015c)	Grand Valley State University	New Construction	5A	127,000	April 2013
GVSU Library (PNNL 2015b)	Grand Valley State University	New Construction	5A	150,030	April 2013
Home Depot (PNNL 2013h)	Home Depot	New Construction	3B	107,790	April 2012
Fort Bragg (PNNL 2015a)	U.S. Army	New Construction	3A	96,103	December 2013

Commercial Building Partnerships Goals

To evaluate the success of the CBP projects partnered with PNNL, each of the original project goals was considered. In general the CBP project was very successful in meeting the original program goals. Each goal is summarized and assessed in the subsequent sections of the paper.

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

Goal 1: Aggressive Energy Efficiency Improvements

The primary goal of the CBP project was energy efficiency improvements in the specific partner buildings. To measure the energy improvements, each building had a goal to be at least 50% greater than ANSI/ASHRAE/IESNA Standard 90.1-2004 or 2007 for new construction projects, and retrofit projects were designed to consume at least 30% less energy than either Standard 90.1-2004 or historic building consumption. In general, the PNNL project designs came close to the energy savings goals of the program. The CPB I projects all met the energy efficiency targets or missed by less than 2%. In a few projects the corporate partners were aggressive and exceeded the energy efficiency targets. Summaries of the projects with the energy savings estimates are shown in Table 3.

Table 3. The overall energy efficiency improvements for each CBP building. In some projects final building performance measurement data were not available. Existing buildings targeted 30% reduction from ASHRAE 90.1 or existing operations, and new buildings targeted 50% reduction from ASHRAE 90.1.

CBP II Project	**Baseline**	**Baseline**[1] [kBtu/ft^2]	**Energy Design** [kBtu/ft^2]	**Actual Building** [kBtu/ft^2]	**Energy Design** [% reduction]	**Final Building**[2] [% reduction]
JCPenney Existing	Historic Operations	64	35	-	49%	-
JCPenney New	ASHRAE 90.1-2004	71.4	34.6	-	52%	-
Crowne Plaza	Historic Operations	147	104	-	29%	-
PNC Bank New	ASHRAE 90.1-2004	127	57	-	56%	-
PNC Bank Existing	Historic Operations	65	34	-	47%	
Granada Village	Historic Operations	104	75.2	-	28%	-
Bank of America	ASHRAE 90.1-2004	115.9	60.7	61.4	48%	47%
Seidman Center	ASHRAE 90.1-2007	106.1-82.2	50.1	71.1	39%	33%
GVSU Library	ASHRAE 90.1-2007	160.6	89.6	115.4	51%	28%
Home Depot	ASHRAE 90.1-2007	77	44.7	-	42%	~33%
Fort Bragg	ASHRAE 90.1-2007	64.9	41.3	45.9	36%	28%
CBP Average (Existing/New)		95 / 103	62 / 54		38% / 46%	

[1] Baseline energy data was collected from actual building operation for most existing buildings, and modeled as a code minimum building for new construction, in some cases new building models were based on measured data in similar buildings.
[2] Final building savings values based on variable data collection times, and detailed breakouts by fuel type are provided in each building's case study.

The CBP II projects had more trouble meeting the energy targets than CBP I due to the shift in baseline to the more stringent ASHRAE 90.1-2007. Other unique constraints on CBP II projects also created issues with energy savings. For example, the Seidman Center was already nearing the 50% design phase when the project joined CBP. For this reason no additional first cost for the project could be added which limited the types of EEMs that could be used. Figure 1 provides a summary of the EUI reductions in the buildings. Error bars show the range of final building performance based on monitoring of the final building when data was collected.

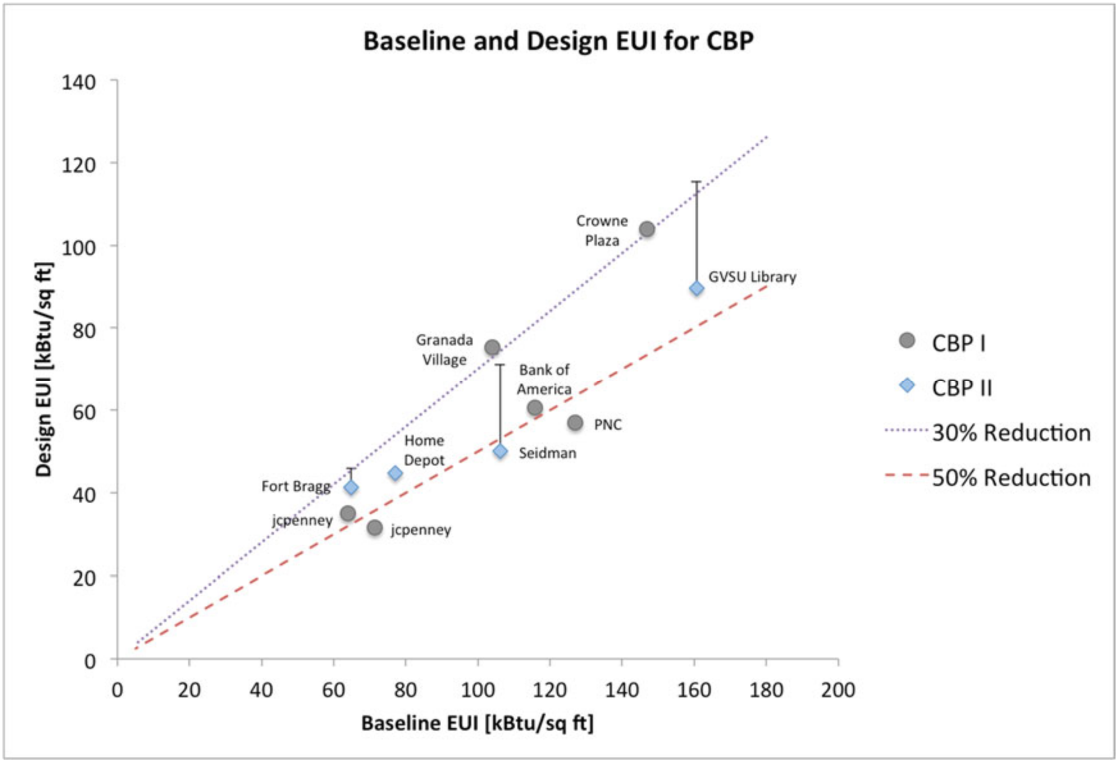

Figure 1. Baseline and Design EUI for CBP buildings. Existing buildings targeted 30% reduction from ASHRAE 90.1 or existing operations, and new buildings targeted 50% reduction from ASHRAE 90.1.

Since most of the CBP buildings came close (2-4% lower on average) to meeting the aggressive energy design targets for the program this goal is considered successful. The challenges with meeting 50% improvement over ASHRAE 90.1-2007 suggests that energy code requirements are tracking cost effective energy improvements closely. In future programs of this type it may be more useful to target net zero energy buildings rather than a percent savings relative to a specific code baseline.

Goal 2: Design Packages and Criteria

Energy Efficiency Packages

For each CBP building the technical experts worked to develop a suite of energy efficiency measures (EEMs) that would achieve the most energy savings compared to installation cost and technology costs. The building efficiency measures included envelope improvements, mechanical systems, electrical systems and approaches to operations and maintenance (O&M).

Each project was optimized specifically for the goals of the commercial partner and the building location.

The large variety of project types resulted in a broad set of energy efficiency measures. The cost effectiveness of these measures was not uniform. Both costs and paybacks varied. Often, combinations of measures were needed to make less cost effective measures feasible. Many of the EEMs were incorporated into 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 mechanical systems.

A summary of the types of EEMs selected is shown in Table 4. The measures were determined to be cost effective based on the partner's criteria (ROI, LCC, or payback). The most popular energy measures selected by most of the projects included increasing mechanical system efficiency. Most projects also reduced lighting power density (LPD) in the common areas of the buildings, often using LED lighting solutions. These solutions have continued to advance since the time of the projects. Occupancy sensors and demand control ventilation were also found to be effective for most projects. Very few of the projects found renewable energy to be cost effective within the criteria used, however as the price of photovoltaics has dropped significantly since the beginning of the CBP designs this may be less true for future projects. One project included photovoltaics to achieve corporate goals for environmental stewardship.

Table 4. Summary of EEMs selected by project partners on CBP. The table was updated from an earlier version (Baechler, Dillon, and Bartlett 2012).

Energy Efficiency Measure	**Number of Projects Implemented**	**Number of Projects that Considered**
Envelope Measures		
Increase wall insulation to maximum reasonable or cost effective	6	2
Increase roof insulation to maximum reasonable or cost effective	6	1
Optimize window performance for thermal performance, daylighting, and cost effectiveness	5	1
Optimize orientation	1	
Add exterior shading	2	
Reduce air infiltration	1	1
Reduce window-to-wall ratio		1
Lighting		
Daylighting and daylighting controls	6	1
Reduce lighting power density (LPD)	8	
LED lighting	5	1
Occupancy sensor controls	6	2
Reduce lighting schedules to turn off lights during lower occupation times	1	
Reduce exterior lighting power density	6	
LED based exterior lighting in parking lots and signs	2	
Reduce exterior lighting schedules	2	
Mechanical		
High efficiency heating or cooling equipment	8	
Radiant heating in some areas	2	
Variable Air Volume (VAV) systems	2	1
Ground source heat pump	1	
Demand control ventilation	6	1

Enthalpy or energy recovery systems	5	
Increase fan power efficiency	2	1
Improved air distribution	2	
Change thermostats or setpoints		2
Optimize control strategy with commissioning and schedules	3	
High efficiency hot water heating	3	
Low flow water systems		1
Reduce the conditioned space in the building with a smaller floor space	2	1
Plug loads and other EEMs		
Local occupancy sensors	1	
Occupancy sensors for vending machines		1
Energy star appliances or high efficiency equipment	4	2
Programmable shut off controls on equipment	1	1
Occupant education	1	
Renewable Energy		
Solar water heating		1
Solar walls for air preheat		1
Photovoltaic (PV) solar energy	1	1

Preliminary analysis of the EEMs selected by the partners indicated some measures, like LED lighting in parking lots, had already been shown to be so cost effective that corporate partners started implementing them in other buildings immediately (Baechler et al. 2012). Other projects found that some EEMs were not cost effective for the specific building participating in CBP, but would be cost effective for other buildings in the corporate portfolio (PNNL 2013h). Additional details about the EEM modeling and selection process are documented in the individual project case studies.

Business criteria

Each CBP building had a unique set of cost and feasibility requirements. The variety of constraints led to creative solutions in many applications. Cost requirements included Life Cycle-Cost analysis (LCC), Return on Investment (ROI), simple payback time, etc. Many of the projects had a fixed construction budget to meet as well, making initial costs a constraint in the design.

The feasibility constraints included consumer safety, military security, site orientation, aesthetics, and maintenance needs. In some cases the corporate policy was outdated, for example one partner team resisted the use of LED lighting because the corporate requirement for replacements were focused on T-8 linear fluorescents and the management team was not able to react to a change in policy. While not implemented in the CBP building, the discussion and dialog with management may serve as the catalyst for a new lighting maintenance policy. One of the GVSU projects had a unique design criterion for occupant education on green buildings as part of the university mission. The design team evaluated EEMs in terms of overall feasibility and ranked them by educational value (PNNL 2015b).

The technical teams successfully addressed the cost and feasibility requirements in different ways. The most important method for helping the partners explore higher first cost EEMs was full building energy models that allowed packages of EEMs to be modeled in an integrated way. This type of analysis allows for tradeoffs in both energy savings and costs. For example, improved envelope efficiency contributes to lower capacity requirements and capital costs of heating and cooling equipment. In a bank branch project, reduced LED lighting costs were traded to enable other EEMs (PNNL 2013a). As a package the efficiency measures met corporate requirements for internal investments. In another project the team worked on developing green leasing agreements. This strategy allowed more expensive EEMs and high efficiency mechanical systems to be more cost effective for the owner (PNNL 2013g).

In most of the building projects the design teams developed packages or groups of combinations of EEMs, which helped to meet partner corporate requirements for internal investments. This became more difficult in the CBP II projects, as discussed, however most buildings reported a project payback of 5 to 20 years with shorter payback periods for many of the selected EEMs. The wide range of cost constraints for the EEM packages made it important that the partners were working directly with the technical experts to optimize specific buildings. A more generic list of EEMs furnished to partners would have been less successful since no tradeoffs could be made to match partner constraints with energy targets would be possible.

Goal 3: Feasibility and Replication

While the CBP project directly engages with only one or two buildings in an organization's building portfolio, replication of CBP program measures to all portfolio buildings could result in significant energy and cost savings. In 2013 Antonopoulos et al. worked to quantify the way that new energy measures and building strategy might propagate (Antonopoulos, Baechler, and Dillon 2014; Antonopoulos et al. 2013). The study surveyed 12 organizations participating in CBP projects and conducted personal interviews to analyze how replication might occur in the corporate partners.

Primary conclusions of CBP partner replication analysis included (Antonopoulos et al. 2014, 2013):

- 100% of CBP partners surveyed indicated they would replicate some or all energy efficiency measures (EEMs) and CBP approaches.
- Three EEMs, low wattage exit signs, occupancy sensors and energy management systems, have a 100% replication rate, and will be adopted by all partners.
- Lighting and HVAC technologies were most broadly adopted by CBP partners.
- Six partners confirmed that LED lighting technology and design will now be used in their building portfolios thanks to participation in the CBP program.
- The CBP program provided a test-bed for future construction projects within the partner portfolio.
- CBP partners are motivated by cost savings more than other benefits. Interviewed companies confirmed that the energy cost analysis performed in the project motivated change.

The interviews revealed additional insights about CBP partner's implementation strategies based on their experience with the CBP program (Antonopoulos et al. 2014, 2013). Two partners indicated that they now have a detailed plan for measurement and verification (M&V) programs that will be rolled out to all building engineers within the organization. One partner identified significant savings potential from plug loads, an area that was not focused on before participation in the CBP program. One partner indicated that the entire package of CBP EEMs would be replicated in all buildings owned by the organization. Three partners indicated that LEED standards are mandated in all new construction and other partners indicated that enhanced climate modeling and EEM package optimization were primary takeaways from program participation.

The research also quantified the way the broader building community might experience technology diffusion as the EEMs were adopted. The second portion of the study used the diffusion of innovations theory to explore possible market impacts of the CBP program throughout the commercial building industry in the United States. The findings from the diffusion model predict the maximum diffusion of CBP methods to impact more than 97,000 buildings by 2030 if EEMs are adopted widely by industry beyond the partners. The conservative diffusion model based only on the DOE CBP data predicts an impact of at least 2,900 buildings by 2030 if EEMs are adopted only by the industry partners as shown in Figure 2 (Antonopoulos et al. 2014, 2013). The more conservative diffusion model predicts energy savings of roughly 2.3 billion Btus annually by 2030 with a maximum energy savings of 77 billion Btus annually by 2030.

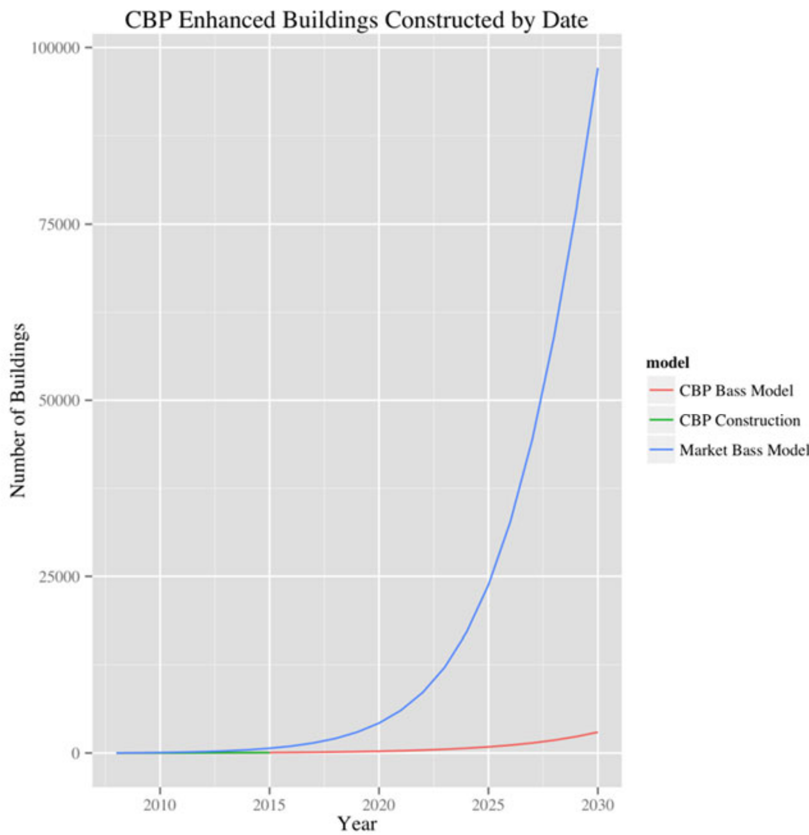

Figure 2. CBP diffusion prediction based on the Bass Model (Antonopoulos et al. 2014, 2013).

The findings of Antonopoulos et al. (Antonopoulos et al. 2014, 2013) confirm that the CBP project has successfully led to adoption of significant energy efficiency measures in commercial buildings. The CBP focus on optimizing a single partner building was particularly effective at targeting the variable cost drivers among many of the partners. In the long term the modeling work predicts that CBP measures and technique will influence a wide spectrum of future buildings.

Goal 4: Validate and Verify

As part of CBP, each project established a measurement and verification (M&V) plan. This facet of the projects helped to determine if early modeling work in the design phase of the project would lead to measureable energy savings in the final buildings. Some of the projects used measurement and verification early in the design process. For example, the Seidman Center future occupants were monitored in an existing work location to understand plug loads (PNNL 2015c). In retrofit projects existing operations were monitored to help calibrate energy models. In other buildings similar spaces were monitored to determine plug loads and other model inputs. In one of the bank branch projects, monitoring of similar facilities indicated nearly 75% of branch energy came from plug and lighting loads, allowing the design team to focus on these aspects of the building features (PNNL 2013e). The monitoring also determined that heating and cooling equipment was consistently oversized for the actual load. This finding led to a revised sizing approach for all new buildings and buildings receiving new HVAC equipment.

Many of the projects only had a few months of energy measurements after the building was completed. In most projects the measurement and verification teams reported operation data significantly higher than expected from the energy design phase. This is consistent with findings from the entire building energy modeling industry (Berardi 2011; Frankel, Edelson, and Colker 2015; Mathew et al. 2015), but creates an important feedback mechanism that may not often occur in energy efficient building design. The teams reported many reasons for the reductions in expected performance.

- Weather during the first few months or year of operation was significantly different than the typical meteorological year (TMY) used for energy design.
- Complex high performance mechanical system controls require time and commissioning to confirm correct operation. In many cases this occurs during the first year of operation.
- Even simple controls, such as timers, could be set in a way that compromised energy savings.

One of the CBP buildings compared very well to the energy design. The Bank of America branch was monitored for a year after construction. Early in the process a review of utility statements revealed that a few schedule changes needed to be implemented. After the change the bank operated at 98% of the predicted energy performance (PNNL 2013a).

Overall the CBP projects indicate that verification of the original energy design is a critical aspect of energy efficiency projects. Design teams need the feedback from the final performance of the building to adjust and improve future building models, and commissioning teams need the data from the building monitoring to adjust complex mechanical systems and operational controls. Owners need the data from the building monitoring to better engage building occupants in supporting high performance buildings, and corporate portfolio managers need monitoring data to make energy decisions for all locations and to cross-check portfolio energy management systems.

This last point raises an important consideration for monitoring studies. These studies can be expensive. However, if the results provide insights into the performance of a large number of buildings within a company's portfolio, the return on the monitoring investment is much greater, and the costs are effectively spread out over a broader base.

Goal 5: Develop a Workforce and Engage with Industry

The primary method that CBP used to engage technical experts with industry was through technical teams that worked directly with the corporate entity. Depending on the project the technical experts included national laboratory staff or expert green building firms. When the technical teams were primarily national laboratory staff the teams focused on working closely with the industry partner's in-house and/or consultant technical staff. Often this included training the technical team and bringing them up to speed on the best analysis techniques, emerging technologies, and cost analysis for energy measures. For example, the PNNL lighting and mechanical experts would help the corporate team develop a list of innovative EEMs for consideration. This helped the corporate team to "think outside the box" of traditional EEMs that may be applied to the project.

The corporate technical teams also brought unique capabilities to the design process. Much of this insight included detailed knowledge of corporate capabilities that typically might not be brought to bear on building design. Examples include requirements around security, branding, equipment procurement, and IT services. Integration with the existing corporate structure made the communication in the design team smoother and resulted in better decisions. In one of these teams specific EEMs that had high first cost were adopted due to knowledge of corporate priorities. In another project the corporate partner tested lighting measures in other corporate buildings to test customer responses and cost savings.

When the technical teams were expert building design firms, a longer time period for team integration was required. However in some cases the corporate entity found the partnership so beneficial they engaged the energy design firms directly in other portfolio projects. This was a large change in procedure since some of these corporations had not traditionally hired energy experts for building design work.

The CBP goal to develop technical experts has been successful. In some cases the technical expertise of the existing corporate entity was improved and in other projects outside experts became an integrated part of the corporate structure. This change offers great long-term potential energy savings and the technical experts continue to design higher performance buildings in the future. At least one partner has already modified the corporate building template to achieve 50% savings over 90.1-2007 in most climates.

Conclusions

After review of each of the program goals, each one is summarized below. Most have been successful, with the most room for improvement in measurement and verification.

1. *Implement aggressive energy reduction savings measures for either or both an existing building renovation and/or a new construction design.*

Most CBP projects came close to the energy targets in the design phase (2-4% lower on average) although many of the buildings after construction did not reach the design EUI. Figure 1 provides a visual method for assessing how each project performed.

2. *Create design packages that meet partner business criteria for financial performance, branding, operations, and company policies.*

In most of the building projects the design teams were able to find combinations of EEMs that could creatively meet the partner constraints for cost. The wide range of cost constraints for the EEM packages made it important that the partners were working directly with the technical experts to optimize specific buildings. A more generic list of EEMs furnished to partners would have been less successful since no engineering creativity to match partner constraints with energy targets would be possible.

3. *Develop the business and technical feasibility case for replication of aggressive energy reduction savings across a portfolio of buildings.*

The modeling and survey work of Antonopoulos et al. indicates the CBP methods will impact between 2,900 and 97,000 buildings by 2030 (Antonopoulos et al. 2014). The survey results and partner interviews strongly support the potential savings exceeding the minimum as partial replication diffuses through the existing partner buildings stock and spreads to other non-partner sectors.

4. *Validate energy modeling inputs and results with energy performance verification.*

Most of the CBP projects that had verification did not performed as predicted by the energy design, but four were close (less than 10% variance in percent savings). This finding suggests an important next step for programs of this type, that more measurement and verification work that spans the initial building design with a feedback element to the original team is important. Encouraging more robust measurement and verification in buildings will be a critical element of high performance buildings in the future.

5. *Help develop a competent workforce of technical experts for energy efficiency design/modeling that engages with industry.*

The CBP goal to develop technical experts has been successful. In some cases the technical expertise of the existing corporate entity was improved and in other projects outside experts became an integrated part of the corporate structure. This change offers great long-term possible energy savings and the technical experts continue to design higher performance buildings in the future. At least one partner has already modified the corporate building template to achieve 50% savings over 90.1-2007 in most climates.

The CBP projects have been successful at meeting most of the original program goals. A summary of energy savings for each of the projects is provided in Table 5. As shown, the direct energy benefits of the program will be 7.9 million kWh and 119 thousand therms in project buildings if design energy improvements are realized. Additional savings from educated corporate partners and replication will be much larger in the next 15 years.

Table 5. The expected energy savings for each CBP project. In some projects measured or updated energy savings values were provided as part of the measurement and verification process and those numbers have been used.

CBP Project	Expected Energy Savings [kWh]	Expected Energy Savings [therms of Natural Gas]
JCPenney Existing (PNNL 2013d)	991,000	1,800
JCPenney New (PNNL 2013c)	1,132,000	-500
Crowne Plaza (PNNL 2013b)	1,714,000	4,000
PNC Bank New (PNNL 2013e)	96,000	2
PNC Bank Existing (PNNL 2013f)	42,000	-
Granada Village (PNNL 2013g)	1,084,000	-
Bank of America (PNNL 2013a)	67,000	-
Seidman Center (PNNL 2015c)	314,000	34,000
GVSU Library (PNNL 2015b)	999,000	81,000
Home Depot (PNNL 2013h)	1,017,000	-1,400
Fort Bragg (PNNL 2015a)	510,000	-
Total	7,966,000	118,902

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