# Results and Lessons Learned From the DOE Commercial Building Partnerships

## Preprint

Adam Hirsch, Michael Deru, Rois Langner, Greg Stark, Ian Doebber, Jennifer Scheib, Michael Sheppy, Eric Bonnema, Shanti Pless, Bill Livingood, and Paul Torcellini

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*National Renewable Energy Laboratory*

**ABSTRACT**

Over the course of 5 years, the National Renewable Energy Laboratory worked with commercial building owners and their design teams in the U.S. Department of Energy Commercial Building Partnerships (CBP) to cut energy consumption by 50% in new construction (versus code) and by 30% in existing buildings for a selected set of pilot projects. The objective was to identify strategies that could be replicated across their building portfolios. A number of building types were addressed, including supermarket, retail merchandise, combination big box (general merchandise and food sales), high-rise office space, and warehouse. The pilot projects began in pre-design and included a year of post-construction measurement data to evaluate performance. This paper describes the application of the Low-Energy Building Design Process (LEBDP) in the pilot projects, gives an overview of the results, and provides lessons learned to inform future efforts of this type. Although the pilot projects did not all reach the aggressive CBP energy saving goals, we concluded that the LEBPD could be deployed successfully with large portfolio owners in the private sector. Several ingredients, including owner commitment and a team focus on the energy goal from pre-design through occupancy, were necessary for success. Short simple payback requirements, large plug and process loads, and concern about changing the look and feel of retail spaces posed the biggest challenges to reaching the energy goals.

## Introduction

The U.S. Department of Energy (DOE) launched the "Commercial Building National Accounts Partnerships" (later changed to the Commercial Building Partnerships or CBP) in 2009 to increase the speed and scale of energy efficiency improvements in U.S. commercial buildings. CBP gave large commercial building portfolio owners and their design teams tools and processes to help reach ambitious energy saving targets in existing building retrofit (RF) and new construction (NC) projects, and demonstrated the performance of energy-saving strategies in real projects to promote replication. The building owners had the final say about which strategies would be incorporated, subject to internal economic, branding, and operational criteria. DOE documented these decision points to help improve market penetration of successful energy efficiency strategies.

DOE supported efficiency in two commercial delivery models: 1) "prototypical" buildings and 2) leased office spaces. In the first model, building owners or operators create a "prototypical" set of building plans that is used to generate many buildings, tailoring them to reflect variability in climate and building codes. As a result, generations of existing buildings are similar, so that successful retrofit strategies can be applied to multiple existing buildings, and improvements in energy performance can be easily replicated in all NC. In the second model, owners or managers of multiple office buildings can apply successful strategies across many large buildings in their portfolios, each of which is subdivided into office spaces that are customized to the tenants' needs. The CBP objectives were to identify processes and strategies that yielded 30% whole-building site energy savings for RF, versus a minimally compliant ASHRAE 90.1 baseline or versus pre-RF energy use and 50% site energy savings versus ASHRAE 90.1 for NC and to establish a firm business case that would justify replication across the Partners' portfolios.

National Renewable Energy Laboratory (NREL) researchers were involved with nine CBP projects that completed the entire program, including design, construction, and post-occupancy evaluation. This group included six RF and three NC projects, listed in Table 1. The project teams also included Partner representatives with expertise in the building design and procurement process and in building subsystems, and private sector experts in low-energy design, energy modeling, commissioning, and energy monitoring. Pacific Northwest National Laboratory and Lawrence Berkeley National Laboratory participated on similar CBP projects. The number of projects was initially higher, but decreased for several reasons, including the disruption to capital availability, business planning, and construction schedules caused by the 2008-2009 recession. All the Partner companies are members of the DOE Better Buildings Alliance[1] and several (Best Buy, Kohl's, Prologis, Walmart, and Whole Foods Market) are Better Buildings Challenge[2] participants.

Table 1. Overview of NREL CBP Projects

| Partner | Building Type | Project Type | Climate Zone | Floor Area ($ft^2$) | Date Construction Completed |
|---|---|---|---|---|---|
| Alliance for a Sustainable Colorado | Office Building | RF | 5B, cool and dry | 38,500 | May 2014 |
| Best Buy | General Merchandise | NC | 5B, cool and dry | 30,500 | March 2011 |
| Bryan Cave-HRO | Office Building | RF | 5B, cool and dry | 24,510 | October 2010 |
| Kohl's | General Merchandise | RF | 5A, cool and humid | 87,000 | November 2012 |
| Prologis | Warehouse | RF | 3A, warm and humid | 800,000 | October 2010 |
| Target | Combination Big Box | RF | 5B, cool and dry | 173,000 | November 2011 |
| Target | Combination Big Box | NC | 6A, cold and humid | 133,000 | July 2012 |
| Walmart | Combination Big Box | RF | 5B, cool and dry | 200,000 | June 2013 |
| Whole Foods Market | Supermarket | NC | 4A, mixed humid | 40,000 | March 2011 |

[1] http://www4.eere.energy.gov/alliance/node/9
[2] http://www4.eere.energy.gov/challenge/home

## The Low-Energy Building Design Process

The projects followed the Low-Energy Building Design Process (LEBDP) developed at NREL (Torcellini, Hayter, and Judkoff 1999). LEBDP is a multistep, integrated approach to designing and operating buildings that relies heavily on quantitative models of a building's energy use and occupant comfort throughout the design and construction processes. By taking advantage of passive design strategies, aggressively reducing internal loads to enable smaller (and therefore less expensive) building mechanical systems, and carefully tracking the impacts of all design decisions, energy consumption in new buildings can be reduced by 50-70% versus a minimally code-compliant equivalent building (Torcellini, Pless, and Crawley 2005; Torcellini, Pless, Deru, et al. 2006). The process as applied in CBP is outlined in Table 2 (Torcellini, Hayter, and Judkoff 1999). DOE funded the researchers to apply the LEBDP and document the results; DOE provided no money to the Partners for equipment and construction costs.

Table 2. The Low-Energy Building Design Process

| Step | Description | Summary |
|---|---|---|
| 1 | Simulate a base case building model. | Base case is solar neutral (model building orientation rotated by 90°-270° and the results averaged) and meets requirements of applicable energy-efficiency code such as ASHRAE Standard 90.1. |
| 2 | Design team brainstorms solution to energy problems. | In many CBP projects, commonly used strategies such as daylighting were not acceptable within the Partner's business model because the look and feel of the interior spaces would change significantly; in those cases the brainstorming focused on how to reduce internal loads, use waste heat, etc. to reach the energy target. |
| 3 | Perform simulations on variants of the base case relating to solutions developed in step 2. | Energy impact of each design package is determined by comparing the energy with the original base-case building and to the other variants. |
| 4 | Architectural team prepares preliminary set of drawings. | Drawings based on the decisions made during step 3. |
| 5 | Determine the HVAC system that is best suited to meet the predicted loads. | The HVAC system should work with the building envelope. Often, the HVAC system will be smaller than would be required in an energy-inefficient building. |
| 6 | Finalize plans and specifications. | Ensure the building is properly detailed to avoid questions or implementation errors during construction. Ensure that the specifications and controls sequencing are correct. |
| 7 | Rerun simulations before design changes are made during construction. | Unforeseen circumstances may result in design changes during construction. Verify that any changes made do not adversely affect the building's energy performance and occupant comfort. |
| 8 | Commission all equipment and controls. Educate building operators. | A building that is not properly commissioned will not meet the energy efficiency design goals. Building operators must understand how to properly operate the building to maximize its performance. |

NREL researchers used Opt-E-Plus (Long, Hirsch, Lobato, et al. 2010) to perform the energy simulations for LEBPD step 3. Opt-E-Plus leveraged DOE's supercomputing resources to run EnergyPlus (U.S. Department of Energy 2014) simulations for thousands of combinations of energy efficiency measures (EEMs), eventually tracing out the strategies that could work together to reach the CBP energy performance goals at comparable—or even lower—lifecycle costs compared to a baseline building. The optimization capabilities of Opt-E-Plus are being incorporated into OpenStudio (Long et al. 2013; Hale et al. 2014), a free suite of tools with the ability to run multiple EnergyPlus models on cloud computing resources that, while not free of charge, are publicly accessible. When applying the LEPBD process, optimization was a helpful tool, but not an essential component. Even when optimization is not an option, industry-standard energy modeling software should be used to analyze the energy impact of design decisions on the overall building energy budget. There was also an assumption that other building owners and designers without the resources to invest in energy modeling would deploy the EEM packages demonstrated in the CBP pilot projects, based on the examples provided by the Partners.

The universe of EEMs explored during early design was drawn from the experience of the Partners, from the national laboratories, from private sector subject matter experts, and from earlier energy analyses performed to support the development of DOE Advanced Energy Design Guides for 50% energy savings in general merchandise stores and grocery stores (Hale, Leach, and Hirsch, 2009; Leach, Hale, and Hirsch, 2009). The combination of strategies found to reach the energy saving goal was shared with the Partners, who then screened the EEMs using their criteria for economic returns and potential impacts on operations, sales, and branding. The list of recommended EEMs was often screened one item at a time using a simple payback criterion of just 2-3 years, rather than looking at an entire package of EEMs using a time horizon more consistent with equipment lifetime. In some cases, this could be traced to a short building lease period, which led to uncertainty about whether an investment would be recouped in saved energy costs. In terms of operations, sales, and branding, sometimes EEMs were rejected because they changed the look and feel of a retail space or placed a perceived barrier in front of a customer (for example, putting doors on refrigerated display cases, turning off electronic merchandise on a sales floor, or changing lighting quality or intensity). In some cases, the Partner may have felt that more research or testing was needed before committing to a technology.

## Results

Table 3 shows results from the projects that ran to completion. Some projects used a 90.1-2007 (rather than -2004) minimally compliant ASHRAE baseline because they started later than the others, in a second phase of CBP pilot projects. As a result, a full year of post-occupancy energy consumption data was not available for comparison to the baseline to evaluate energy savings. The completed projects fell into four categories:

1. Expected to reach the CBP energy saving goal and reached the goal (Target RF, Kohl's RF, Prologis RF, Walmart RF);
2. Expected to reach the goal and did not perform as expected (Bryan Cave-HRO RF, Target NC);
3. Not expected to reach the goal (Best Buy NC, Whole Foods Market NC); and,
4. Completed too late to provide a full year of performance data for this paper (Alliance for a Sustainable Colorado RF).

Table 3. CBP Whole-Building Energy Results

| Project | Baseline | Energy Use Intensity ($kBtu/ft^2 \cdot yr$) | | % Savings Versus Baseline | |
|---|---|---|---|---|---|
| | | Expected | Measured | Expected | Measured |
| Alliance for a Sustainable Colorado RF | ASHRAE 90.1-2007 | 37 | TBD | 31 | TBD |
| Best Buy NC | ASHRAE 90.1-2004 | 68 | 71 | 25 | 22 |
| Bryan Cave-HRO RF | Pre-Retrofit | 33 | 43 | 38 | 19 |
| Kohl's RF | ASHRAE 90.1-2004 | 45 | 39 | 39 | 48 |
| Prologis RF | Pre-Retrofit | 11 | 11 | 41 | 41 |
| Target RF | ASHRAE 90.1-2004 | 77 | 81 | 37 | 33 |
| Target NC | ASHRAE 90.1-2004 | 53 | 72 | 52 | 44 |
| Walmart RF | ASHRAE 90.1-2007 | 106 | 95 | 24 | 32 |
| Whole Foods Market NC | ASHRAE 90.1-2004 | 303 | 291 | 33 | 36 |

Target saved 33% versus ASHRAE 90.1-2004 in its RF project (28% versus pre-RF). It subsequently worked with the researchers to simulate energy savings of the EEMs used in the project for other climate regions and rolled out the EEM package to more than a dozen existing stores in the year following the RF. Kohl's halved the energy used to light its sales floor by replacing existing three-lamp T8 fluorescent fixtures with light-emitting diode (LED) fixtures, on the way to reducing whole-building energy use by 48% versus ASHRAE 90.1-2004 (38% versus pre-RF) and is considering whether to use LED fixtures for ambient lighting more broadly. Prologis retrofitted nearly 1,000 metal halide high-intensity discharge fixtures with T-5HO fixtures to cut energy use by 41%. This last project, a lighting RF in an unconditioned warehouse, was somewhat more straightforward than the others and did not require intensive EnergyPlus modeling. Prologis is replicating this RF project across its portfolio of buildings.

In the Bryan Cave-HRO law office RF, plug loads were higher than expected and retrofitted variable-speed air handling unit fans saved less energy than expected. In the Target NC project, plug loads and lighting used more energy than expected, and the main sales floor air handling unit was programmed to turn on earlier than it should have, leading to excess electricity and natural gas consumption. This error was corrected, cutting monthly winter gas consumption dramatically during the winter of 2013 versus 2012.

The two projects that were not expected to reach the savings goals had high plug and process loads (PPLs) that could not be significantly reduced, leaving less scope for overall building energy savings. In the case of Best Buy, a substantial fraction of the store's energy was consumed by products on display, which were required to remain on during the day. Whole Foods Market had extensive food preparation and a commercial refrigeration system. These are energy-intensive end uses that increased the challenge of achieving significant energy savings cost-effectively. The projects were still followed to completion because, although the companies were expected to make efforts to reach the energy goals, it was understood that they would do this within the constraints of their business models. Valuable lessons were learned from both projects and the EEMs used in CBP continue to be used in their buildings.

Another important result of the pilot projects was the list of EEMs used by the Partners. Table 4 includes some notable technologies grouped by end use and project, representing a new business as usual.

Table 4. Prominent Energy Efficiency Measures

| End Use | EEM | Projects Featuring This EEM |
|---|---|---|
| Envelope | Increase roof insulation R-value beyond code requirements | Target (NC), Best Buy (NC) |
| | Skylights for daylighting | Best Buy (NC), Whole Foods (NC), Walmart (RF) |
| Lighting | Photosensors and dimmable electric lighting sources to take advantage of daylighting. | Best Buy (NC), Whole Foods (NC), Walmart (RF) |
| | Reduce sales floor lighting power density below 1.0 W/sf | Target (NC, RF), Best Buy (NC), Kohl's (RF), Whole Foods (NC), Walmart (RF) |
| | Vacancy sensors in offices, stockrooms, walk-in coolers/freezers, and restrooms | Target (NC), Walmart (RF) |
| | LED accent lighting | Target (NC, RF), Kohl's (RF), Whole Foods (NC), Walmart (RF) |
| | LED exterior lighting | Walmart (RF) |
| | LED ambient lighting to provide the same illuminance using less power | Kohl's (RF), Alliance for a Sustainable Colorado (RF) |
| HVAC | Variable-speed HVAC supply fans | Target (NC, RF), Kohl's (RF), Bryan Cave-HRO (RF) |
| | Widen temperature deadband set points | Target (NC, RF) |
| | Evaporatively cooled condensers | Target (NC, RF), Walmart (RF) |
| | Energy recovery ventilators | Target (NC, RF) |
| | Desiccant dehumidification | Target (NC), Whole Foods (NC) |
| | Performance-based indoor air quality compliance | Target (NC, RF) |
| | Demand controlled ventilation | Best Buy (NC), Kohl's (RF), Alliance for a Sustainable Colorado (RF) |
| | Capture of medium temperature refrigeration system waste heat for ventilation pre-heating | Walmart (RF), Whole Foods (NC) |
| Plug Loads | Computers enter standby mode when not in use | Target (NC, RF) |
| | Checkout stands and registers have standby mode and turn off during unoccupied hours | Target (NC, RF) |
| Refrigeration | Doors on medium temperature refrigerated display cases | Walmart (RF), Whole Foods (NC) |
| | Electronically commutated evaporator fan motors | Target (NC, RF), Walmart (RF), Supermarket (NC) |
| | Floating control for saturated suction and saturated condensing temperatures | Target (NC, RF) |

| | | |
|---|---|---|
| | LED refrigerated display case lighting | Target (NC, RF), Walmart (RF), Supermarket (NC) |
| | Modulate anti-condensate heaters based on sales floor dew point | Target (NC, RF), Whole Foods (NC) |
| | Variable-speed condenser fans | Target (NC), Whole Foods (NC) |
| | Install electronic expansion valves to lower minimum condensing temperature from 75°F to 55°F | Whole Foods (NC) |
| Commercial Kitchen | Close-proximity hood controlled by temperature and particulates | Target (NC), Whole Foods (NC) |
| | Install side panels on all exhaust hoods to lower flow rate while capturing all exhaust fumes | Whole Foods (NC) |

## Lessons Learned

Several common lessons emerged from the projects that will help the Partners and other commercial building owners design and operate high-performance buildings. The most important general lesson learned was that the building owner and design team must stay focused on the energy target in all the stages from pre-design through post-occupancy monitoring and performance maintenance to achieve high energy performance. Ultimately, this focus depended on building owners who prioritized energy efficiency, were willing to stick to an energy goal, and were willing to rethink their building design and operation processes.

**Coordinating Deployment and Research**

Deployment of successful technical solutions across building portfolios was a CBP priority from the start. Partners with large building portfolios and standardized building designs were chosen for participation so that the initial investment in pilot projects could be leveraged to achieve large savings when the solutions were applied broadly. Although many Partners confirmed that EEMs from the pilot projects would be included in broad RF efforts and in future prototypical designs, programs such as CBP would benefit from a follow-on phase in which the national laboratories stay engaged with the Partners to document replication and the long-term impact on the design process over time.

The research dimension focused on whether model predictions about operational energy use of the building were accurate at the subsystem level (lighting, HVAC, PPLs, and refrigeration). While mismatches between model predictions and measurements could be used to correct modeling assumptions and to identify building operational issues, discrepancies arose for one (or more) of three reasons:

1. The submetered energy data were occasionally inaccurate. In most cases, NREL had control over the quality of the data coming from the projects; however, in some projects, when submetering was provided by a third-party contractor, sensor calibration and labeling issues were discovered by NREL after reviewing the data.
2. The energy modeling has inherent uncertainties. For example, the interactions between refrigeration and HVAC systems were complex and hard to capture accurately. Newer

technologies such as complex dehumidification systems were challenging to represent accurately in EnergyPlus.

3. Some of the buildings operated outside their original design specifications, leading to excess energy use. It was not uncommon, even in new buildings, for lights to be left on at night, or HVAC set points to be overridden in unanticipated ways. Installed PPLs were different than those in design estimates, or the assumptions about those loads may have based on benchmarking measurements rather than a detailed model. Creating an accurate PPL model required creating an inventory of all equipment and understanding how that equipment would be used.

Resolving these discrepancies required significant effort at the tail end of the projects, when performance data were available for analysis and when momentum behind the project may have diminished. The CBP projects showed that continued engagement and resources were required after the "completion" of the project to understand whether the original design-phase expectations for energy performance at the end-use level were realistic and whether the building was being operated in a way that maximized energy savings. Unless the building owner's project requirements specified comparison of operational energy performance with energy model predictions in some sort of project closeout, the design team might move on to other projects after construction and initial commissioning and not achieve the expected energy savings. In some cases, energy-saving technologies proved to be "plug-and-play," but in many cases work was still required to integrate them successfully.

**Design Lessons**

1. **Energy goals motivate innovative thinking**. In most cases, the energy-saving targets encouraged the Partners to consider strategies they had not tried before. In some cases the Partners decided these strategies were worth pursuing and that implementation challenges could be overcome; in other cases they decided that the strategies repaid too slowly through energy savings or would disrupt their customers' shopping experiences. The iterative energy modeling approach from the LEBPD process gave Partners the energy cost savings information they needed to make the business case for pursuing new technologies. The integrated design perspective of the LEBPD process helped the Partners to search for ways to reach the energy goals while holding fast to their stringent economic criteria.
2. **A "bundled" approach to analyzing EEMs can increase savings**. Many Partners selected EEMs on an "a la carte" basis, where the economic performance of each EEM was considered separately from the others and eliminated from consideration if the return on investment was considered unacceptable (often using a 2-3 year simple payback threshold). However, some Partners looked more broadly at the business case of multiple EEM "bundles." In the best case, all the EEMs were considered together using an integrated approach. The business case included energy savings, utility incentives for efficient equipment, and HVAC first cost savings achieved by reducing internal gains. Within an EEM package, several EEMs with a quick payback can help make the economics of the entire package acceptable, increasing energy savings. In the performance evaluation phase of the project there was also a temptation to calculate the performance of each EEM in isolation instead of the energy savings of the integrated package at the whole-building level, in support of the "a la carte" approach.

3. **Standard baseline assumptions are needed for commercial refrigeration and kitchen systems**. When the projects began, ASHRAE 90.1 did not address commercial refrigeration and kitchen equipment. Yet, the Partners took actions in these areas that resulted in energy savings versus their usual practices. This situation was problematic for supermarkets, where refrigeration consumed 30-50% of a store's energy. To allow the Partners to take credit for refrigeration energy efficiency improvements, a baseline refrigeration system was defined to allow benchmarking of the low-energy designs, intended to represent a typical circa-2010 commercial refrigeration system. That baseline has since been updated to reflect recent regulations on refrigeration equipment energy consumption (Doebber et al., 2014).

**Operational Lessons**

1. **Commission early and comprehensively**. Often a delay occurred between building handover and commissioning and then a further delay before the issues were addressed. In many cases, equipment or control problems were not discovered or fixed until several months had passed, leading to higher energy use (higher EUIs) than expected in the first year of operation (the period used for evaluating the pilot project performance). However, with continued engagement, many issues were corrected, such as the winter heating issue mentioned for the Target NC project, bringing the EUI closer in line with expectations. Commissioning best practices can be found in ASHRAE Guideline 0-2013, "The Commissioning Process," which focuses on capturing the building owner's project requirements in the design documents from the earliest project phases and establishing the criteria for documenting that these requirements have been met (ASHRAE 2013a). Refrigeration system-specific information can be found in the "Refrigeration Commissioning Guide for Commercial and Industrial Systems" (ASHRAE 2013b). Some commissioning issues can be subtle, requiring a detailed understanding of the design intent. For example, one Partner installed a complex dehumidification system with an active desiccant wheel. However, the unit was installed without the intended bypass so that even when dehumidification was not required, air had to pass through the wheel, incurring a fan energy penalty caused by the increased pressure drop.
2. **Compare expected energy consumption with measured use**. The traditional commissioning process does not consider energy, per se, or include a comparison between measured and modeled energy use. However, comparing expected and measured energy use for subsystems and the whole building was an important clue to whether the building was operating as designed and therefore whether the money invested in energy efficiency was providing real savings. To provide useful information at the end-use level, the energy submetering system needed to be designed and commissioned along with the rest of the building, not added as an afterthought, at least at the level of aggregated building end uses of lighting, HVAC, PPLs, and refrigeration (National Science and Technology Council 2011). The final design energy model can be used as an operational energy model to provide expected energy use.
3. **Screen building data for operational problems**. Two Partners (Target and Kohl's) used information systems to automatically identify operational problems such as building lighting or HVAC systems being on at full power for multiple days. This automated alert system was standard practice for these Partners, not initiated as part of CBP. At the same time, close scrutiny is required to catch fault patterns that may not have been

programmed into the detection system. For some Partners who did not use this strategy, high performance lighting and HVAC systems were often undermined by operational patterns that fell outside design intent and should have been corrected. Defining a process to find and fix problems that result in wasted energy was important for maintaining energy savings, especially after the initial building acceptance period.

**General Lessons**

1. **Clearly establish project goals and team roles**. CBP involved unique public-private collaboration between organizations with very different priorities. Therefore, good communication, a common understanding of roles and responsibilities, and a unified commitment the project goals were key elements of project success. It was also important that all stakeholders, including corporate branding and sales representatives were included on the project team. Because the project had a long duration, the team composition often shifted over time. It was crucial to orient new team members quickly about the project energy goals and how the LEBPD worked.
2. **Maintain a focus on performance goals**. The project teams sometimes lost focus on energy performance after occupancy because of the pressing concerns of other commitments and new NC or RF projects. The project was considered "done" as long as building set points were satisfied, without considering whether the expected return on investment in efficiency was being captured. Best practices for keeping the project team focused on energy goals all the way from project initiation through building occupancy can be found in Pless et al. (2013).
3. **Different goals have their own strengths and weaknesses**. Percent site energy EUI savings versus a minimally-code compliant baseline had the advantage of being a single number to focus the team's efforts. The energy code requirements were also clearly documented, for example in the form of ASHRAE 90.1 Appendix G. However, in practice this metric presented some challenges.
   a. Time and resources were required to build the baseline model and ensure that it met the prescriptive code energy requirements. This investment might be a disincentive for design teams in the private sector. For end uses not directly addressed by the energy code, such as PPLs, either no savings could be claimed for those end uses or a workaround had to be engineered to represent baseline conditions. Code-based baselines were also of limited interest to private organizations interested in improving performance against the current performance of their buildings or those of their peers. Several of the Partners already exceeded the ASHRAE baseline in their business-as-usual prototypical designs and did not consider this performance as imposing additional costs on their design and construction process. Reaching the CBP goals may not have been the furthest they could have stretched. Typically, an additional energy model representing the Partner's current building practices was created for the new construction projects, for the purpose of benchmarking the new design performance against business-as-usual for economic evaluation of EEMs.

   b. The definition of "minimally code compliant" shifts with subsequent versions of the energy code. Because of the time required to go through the entire design, construction, and performance verification process, relevant code for benchmarking can evolve significantly over the course of the project. It is challenging to know whether 50% energy savings versus ASHRAE 90.1-2004 (typical of local ordinances when CBP started) is still “good” compared to ASHRAE 90.1-2010 or 90.1-2013 unless another baseline model is created. A benchmark that doesn’t change may facilitate comparison of performance over time. Net zero energy performance provides one example of a clear-cut and unchanging performance metric.

A whole-building EUI can also make it difficult to compare the performance of one building type to another. For example, in Table 3, the supermarket appears to be in an entirely different class of energy use compared to, for example, the combination big box stores, even though the big box stores may have similar refrigeration systems. The reason is that the combination big box stores also have a large dry-goods sales area (with lower power consumption) so that when the large process refrigeration load is normalized by floor area, it appears much lower. Additional metrics, such as kW/ton of refrigeration, or normalizing energy use by another quantify such as sales volume would shed additional light on the inherent efficiency of one store versus another.

## Conclusions

By demonstrating that significant energy savings were possible while the Partners’ investment criteria were being met and without radically changing their corporate look and feel, CBP set the stage for replicating the pilot project efforts throughout their portfolios and setting examples for their peers to emulate. The projects demonstrated that the LEBDP can work for owners of large building portfolios who are dedicated to generating economic returns for their investors and to being good environmental stewards. Time will tell whether they continue to use the LEBDP with their design teams and maintain energy goals without the participation of the national laboratories. At the same time, the projects highlighted a need for a consistent benchmark for refrigeration and commercial kitchen energy use and the importance of focusing on energy performance from pre-design through occupancy. Maintaining a consistent “look and feel” for retail spaces and avoiding impacts on customer’s shopping experiences led to a conservative approach to energy EEMs such as daylighting and putting doors on refrigerated display cases. Clear demonstrations of the non-energy benefits of these strategies; for example, warmer supermarket aisles and more natural lighting quality may help them gain broader acceptance.

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