Results of Minnesota's Public Buildings Enhanced Energy Efficiency Program (PBEEEP)

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ABSTRACT

In September 2009 the State of Minnesota allocated federal stimulus funds to an existing building commissioning program for public buildings. As a direct result all government owned buildings over 100,000 square feet were considered for the program, allowing the program to not only help the state achieve its energy conservation goals, but also to better answer two key questions about existing building commissioning:

- What percentage of a total building population can be cost-effectively served?
- What are the energy savings that can be expected from these efforts?

The State of Minnesota's Public Buildings Enhanced Energy Efficiency Program (PBEEEP) is modeled after other successful utility programs. PBEEEP seeks to transform the existing building commissioning market in Minnesota from an audit based approach to a data-based investigation.

The distinctive features of PBEEEP are:

- high level of participation (75% of candidate buildings)
- long energy investigations (6-9 months for heating and cooling seasons)
- limited to government owned buildings
- funded independently of any utility company
- providers with a wide range of prior experience

Three hundred and seventy four (374) buildings containing over 31 million square feet located on 71 sites throughout the state applied. Screening was used to identify buildings where an energy investigation would be cost effective. Average calculated site energy savings were 10.8%. The program divided the measures into those with paybacks of under 3 years and those of 3 to 15 years for financial planning reasons and to meet State statue. The number of buildings that are good candidates for successful existing building commissioning projects is lower than has been projected in other studies and should be considered both by policy makers and practitioners who need to manage expectations of their services.

Background

To have an impact on the nation's building energy use existing buildings must be addressed. Thus, while evolving construction techniques and building codes promise large reductions in base energy use, there are much greater numbers and savings potential in existing buildings. Existing building commissioning is the process of investigating and optimizing the performance of a facility through detailed investigation of its systems. The goal is to make existing building systems perform as intended or meet the current needs of the building, post construction. The potential for energy savings through existing building commissioning is central to programs such as the DOE's Better Buildings Challenge whose stated goal is "to upgrade energy performance by a minimum of 20% by 2020 in 1.6 billion square feet of office, industrial, municipal, hospital, university, community college, and school buildings" (White House Office of the Press Secretary).[1]

The State of Minnesota chose to encourage existing building commissioning of all state government-owned buildings as a means of reducing the state government's overall energy use. Minnesota's legislature enacted legislation in 2008 to address two fundamental constraints to reducing energy consumption in state buildings (Minnesota Statutes 2008):

1. Access to expert technical assessment to identify measures to reduce energy consumption.
2. Access to financing to implement recommended measures.

The Public Buildings Enhanced Energy Program (PBEEEP) was the direct result of this legislation. The Center for Energy and Environment (CEE) responded to an RFP from the State's Department of Real Estate and Construction Services for program design and administration services. Subsequently, the State of Minnesota chose to allocate American Recovery and Reinvestment Act (ARRA) funds to this program, which increased the potential size of the program while effectively shortening the timeline. This paper will first discuss the program design and history of the program, then go over the results of the program to date and finally compare and contrast the overall results with those of prior studies. PBEEEP is broken into two components: State Government buildings (about 25% of the total building area) and Local Government buildings. This paper presents results from State Government PBEEEP.

Program Design

PBEEEP's design is based on CEE's past experience doing comprehensive existing building commissioning projects with a relatively small staff of three to four engineers. The approach used is data intensive, relying on trend data (typically collected continuously from several hundred points at 15 minutes intervals for six months) to identify and quantify energy saving opportunities that are unlikely to be found by observation or functional testing. This approach is distinctly different from an audit based approach where walk through observations plus interviews with the building staff are used as a basis for energy conservation recommendations. An auditor generally spends less than 20 hours in a building. With the trend data based approach data is collected for at least six months, effectively putting the building analyst on site for over 4,000 hours on a 24 x 7 basis. Temperature dependent data is collected from winter lows to summer highs, a range that often exceeds 100 degrees in Minnesota. The engineer can see how the systems run under design conditions and everything in between. Proper economizer operation, as well as set back and reset strategies are easily observed and can lead to changes in schedules and setbacks that lead to significant savings. Operational issues such as sensors that are out of calibration or dampers that are not operating properly are easily discovered by looking at the outside air, mixed air and return air temperature data. While this has always been CEE's approach, it does not represent the norm for recommissioning providers in Minnesota. One goal of PBEEEP was to encourage this market transformation.

[1] Minnesota's share of the goal, based on population, is 27.5 million square feet.

The average annual savings for 30 CEE projects over a ten year period realized were 12% for kWh, 9% for kW and 17% for natural gas. However, a mechanism was needed to create the capacity required for a statewide program. CEE's team completed these projects totaling 10.5 million square feet between 1999 and 2008 and there are approximately 280 million square feet of public buildings in Minnesota, of which about 25% are owned by the State of Minnesota (see Table 1). To reach the necessary scale (4 times the building area in ¼ the time), CEE became the program administrator to leverage our experience and expertise from these past projects. The actual site work is performed by engineering firms under contract with the State.

Table 1. Public Buildings in Minnesota

Government Sector	# of Buildings	Total Building Area	Average Area ft^2	Buildings > 100,000 ft^2	Mean EUI (kBtu/ ft^2)
State	2,986	74,943,951	25,100	176	67
Schools	1,321	142,805,152	108,100	503	68
Cities	1,556	42,434,632	27,250	61	82
Counties	561	23,027,954	41,050	54	80

Source: Minnesota Benchmarking and Beyond Database

CEE worked with a partner who designs and operates utility programs in other states to create the detailed program. Like those programs, PBEEEP has four phases: Screening, Investigation, Implementation and Measurement/Verification. A completed project includes all four phases. PBEEEP provides state government facilities with access to technical services whose quality is assured by a formal program. Key elements of this program are: written performance guidelines, an ever-increasing body of training materials, and a review of all proposed energy savings measures, including supporting data and calculations, completed by experienced mechanical engineers (Minnesota Department of Administration, 2009). The technical services are provided by ten engineering firms under master contract with the State of Minnesota (State of Minnesota, Department of Administration, Real Estate and Construction Services. 2009). The firms were selected from an RFP for an array of energy engineering services that were issued prior to the design of the program. As a result, prior existing building commissioning experience was not a qualification.

Projects follow four distinct phases: Screening (determination if a site is a good candidate for cost-effective existing building commissioning, a one month process), Investigation (the actual study, a six to nine month process), Implementation (installation of energy savings measures, a several month process), and Measurement and Verification (done at the completion of Implementation with a duration determined by the measures to be verified). Each phase has a separate contract to create financial transparency for the state agency and mitigate the risk otherwise associated with a contract that does not have a well-defined budget. The overall duration of a project was expected to be about one year. Project financing was planned to make use of a combination of cost sharing grants funded by the state and lease purchase financing to avoid the time delays and political uncertainties associated with both capital appropriations and traditional bond funding (Zobler and Hatcher 2003).

Program Introduction

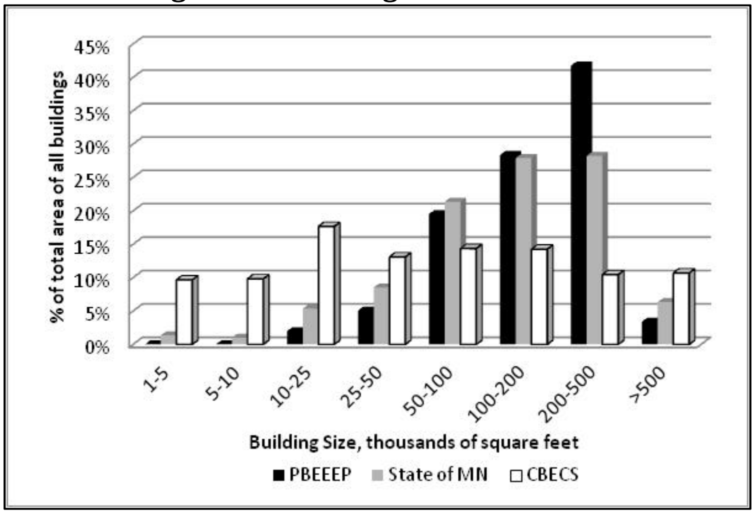
PBEEEP was launched in August 2009. The initial plan was for a five year program with three pilots in the first year. These would be followed by a six to nine month period during which each of the providers would perform a single project. Only when these were complete would a provider be allowed to perform simultaneous projects, based on experience and capacity to do the work. The original financing planned to involve a cost-share for the four phase projects between the agency (the customer) and the Department of Administration (the program sponsor).

The program did not follow the planned roll out and build up process. PBEEEP was selected by the state to receive ARRA funds (better known as "Stimulus Funds"). This greatly increased the available program funds from about $1 million to over $5 million and accelerated the rate of implementation to satisfy the job creation objectives of ARRA. The project financing component of the program was changed significantly. Screening and Investigation would be provided at no cost to the state agency in exchange for their commitment to implement all measures with a payback of three years or less. The availability of this funding has been a mixed blessing for the program. On the one hand, it assured that a "free" investigation could be provided for every potential state government facility, greatly increasing participation; on the other hand, it accelerated the program delivery as the funds were expected to last three years, instead of five. The pilot phase was eliminated and the providers bid on multiple projects from the start. Because no one had experience in the program, projects were awarded to the low bidder.

Selection of Sites: The Screening Process

Participation in PBEEEP was offered to, and accepted by, all property owning state agencies. The Minnesota Benchmarking and Beyond (B3) database of all government buildings in the state was used to help identify candidate facilities (Minnesota Benchmarking and Beyond Database 2012). The initial selection criteria used was building size. Most studies suggest buildings over 100,000 square feet are the best candidates for existing building commissioning. Buildings smaller than this generally have less sophisticated control systems and, due to their proportionately smaller energy costs, often can't justify the fixed base cost of a full study.

Figure 1. Building Size Distribution



PBEEEP represents all buildings that applied to the program;
State of MN is all buildings owned by the State of Minnesota (Minnesota Benchmarking and Beyond);
CBECS is from the EIA's Commercial Buildings Energy Consumption Survey (CBECS 2003).

Figure 1 shows the distribution of buildings by size in PBEEEP and compares it to the nationwide building distribution (CBECS 2003) and all the government buildings in Minnesota. While the applicant pool was heavily weighted to large buildings (73% over 100,000 ft^2), a sizable number of smaller buildings were also included in the program, largely because they were part of campus sites with total areas over 100,000 ft^2. The average building in the program was 83,000 ft^2 and several were about 25,000 ft^2. While the building size distribution differs from that reported in CBECS, it includes a greater fraction of buildings larger than 50,000 ft^2, which is consistent with the buildings that are generally considered for existing building commissioning.

While building size provides a starting point for selecting buildings, it is not the sole criteria. We considered several other factors, including actual energy use, age and condition of mechanical equipment, the level of building automation, hours of operation and facility management practices to identify those state facilities that were our most likely candidates. Some of these, such as size, building age and monthly energy usage by fuel type, could be determined in advance from the B3 database. The performance data in B3 is similar to that found in Energy Star's Portfolio Manager. The general size and energy intensity characteristics of the sites considered for the program are shown in Table 2. The initial candidates included 107 sites with over 40 million square feet. All of these were directly contacted to gain additional information about the site, as were the 34 state facilities with building areas between 50,000 and 100,000 square feet. Ultimately 71 sites with 31.4 million square feet applied to PBEEEP.

Table 2: Building Candidate Pool for PBEEEP

Site Type	# of Sites	# of Buildings	Total Area	Median EUI
Community College	48	143	14,125,238	84
State University	7	141	12,793,064	114
State Prison	10	127	5,594,694	115
Office Building	22	23	3,532,414	88
Other*	9	14	2,425,476	92
Hospital & Nursing Home	5	14	1,847,505	309
Maintenance	6	22	767,110	61
Total	**107**	**484**	**41,085,501**	**108**

*Other includes community centers, laboratories, parking garages and museums

There were a variety of reasons that some facilities chose not to participate in the program. The most common were that they were already involved in an energy conservation program, had previously engaged in energy conservation efforts and now had below average energy use, or had an active major construction project involving their mechanical systems.

Using Screening to Effectively Identify Projects with Potential Savings

While existing building commissioning is inexpensive relative to many building construction activities, it is still a discretionary cost that needs to be economically justified. According the Lawrence Berkeley National Laboratory 2009 Report, the average cost for energy investigations was $0.14/ft^2 (Mills 2009).[2] Average cost for the Minnesota facilities investigated in PBEEEP was projected to be $0.23/ft^2. The cost is higher than the national average due to the fact that both heating and cooling are important in Minnesota's climate.[3] Studies were expected to take an average of nine months to complete vs. three months in many utility programs. With an average project size of about 400,000 ft^2 the investigation cost is about $100,000 and the cost of implementation is expected to be comparable. Economic feasibility is determined by ability to pay back financing out of savings realized by the energy improvement project. As a general rule, PBEEEP assumed that at a minimum annual savings should be comparable in magnitude to the cost of the study to consider the project a success. The purpose of screening was to help assure that the estimated value of energy savings at each site could justify the costs at that site.

The original program design used criteria from a successful California utility based program that called for a screening process that used a combination of utility bill analysis (to compare the site energy use with benchmark values) and information from the application. However, this approach would have resulted in less than ten (of 100) Minnesota applicants being approved for energy investigations (Table 3). There are several reasons for this. The first is that so many of the buildings were already performing well below their B3 benchmark value[4]. This

[2] Based on Mills, 2009, pages 26-27. This cost is based on the statement that the investigation averaged 45% of total project costs and that average cost of existing building commissioning was 0.30/sq. ft. (2009 dollars).
[3] Minnesota's Climate Zones are classified as follows: CBECS Region 2, Division 5; ASHRAE Climate Zone 6, Cold – Humid(6A) with IP Units 7200 < HDD65ºF ≤ 9000 and SI Units 4000 < HDD18ºC ≤ 5000; or Cold-Dry(6B) with IP Units 7200 < HDD65ºF ≤ 9000 and SI Units 4000 < HDD18ºC ≤ 5000.
[4] The Minnesota Benchmark and Beyond (B3) benchmark EUI values are computed using the State's 1991 Building Code for modeling parameters, rather than using peer group averages. The average energy use of all state buildings in the database is 78% of the computed benchmark values.

provides an important cautionary note when using the results of energy modeling to judge actual performance. The second is that the California program's scale is weighted towards very large buildings (over 250,000 ft^2) with relatively new mechanical systems (under 15 years and not previously commissioned). These are not common in our population.

The determination of which sites to investigate in some programs is based only on material submitted on an application. In PBEEEP, screening was done by a program engineer and the program manager who visited each site. This represented a small change to the initial program design as screening was carried out by the program administrator instead of bidding it out to the providers. Initially this was largely done for expedience. Avoiding the bidding and contracting process saved three to six months of time and shortened the overall program schedule. It also had numerous other benefits, including a consistent approach to all the sites and an opportunity for the program engineer to review the energy saving findings and calculations to become familiar with the site prior to the start of the project. Screening by the program also allowed a much more in-depth and unbiased assessment of each facility than an application form, while still keeping costs low. We recommend it as a best practice based on our experience.

Screening visits take at least half a day and often a day or more (4 hours minimum for up to 300,000 ft^2, one additional hour per 100,000 ft^2 hour after that). The screeners collected basic information on systems and building operations and made observations of building management practices. Table 3 contrasts the metrics for screening used by PBEEEP with those from an established utility program. Among the significant differences are the use of motor sizes in PBEEEP vs. HVAC cooling capacity (reflecting the difference between a heating dominated climate, Minnesota, and a cooling dominated one, California), the use of absolute energy intensity (partly a surrogate for total energy cost), and the use of hours of operation to capture the potential for scheduling based measures. Because PBEEEP requires trend data for diagnosis and calculations in support of energy savings, sites were favored that had building automation systems (BAS) with digital direct control (DDC) that had the capability to simultaneously trend (and save) millions of data points from hundreds to thousands of control points (Seidl 2006). Without BAS trending, PBEEEP would require a large number of data loggers which would need to be manually placed at the site and then be collected and downloaded several times over the length of the study, greatly increasing the cost, often beyond the potential value of savings. Finally there were differences in benchmarking. CBECS benchmarks did not exist for many sites in PBEEEP, either because of the building type (for example, prisons) or because they were hybrids (for example, about half the facilities were community colleges which had widely varying proportions of classroom, laboratory and shop space).

The cost to screen 31.4 million square feet was just under $320,000 or $.0102 per square foot (5% of the cost of a full investigation). The end product of screening is a report that provides lists of the major mechanical equipment, control points on the building automation system, and general information about facility operations. Screening was performed at the building level within each site. It was not uncommon to eliminate 10% or more of the building space at a site. Screening was not only useful in describing the characteristics of a facility for the RFP; it also provided a sound basis for deciding which projects should go forward.

As a result of screening, 57% of the original building space was promoted to have a detailed existing building commissioning investigation. By eliminating the less promising spaces there were considerable savings of both money ($2.7 million) and time.

Table 3: Screening Metrics Used by PBEEEP

Metric	PBEEEP	Other Utility Program
Conditioned Floor Area	Uses both Site Area AND Average Building Area (if a campus) Buildings under 100,000 ft^2 OK	Building Area only; Penalty if < 100,000 ft^2
Whole Building Energy Use No CBECS values exist for most PBEEEP building types	2 values used: Actual EUI > 110 And Relative to B3 Benchmark	Based on CBECS >110% of CBECS
Age of HVAC System	PBEEEP did not use	Used
HVAC Attributes	PBEEEP focused on pump and motor size	HVAC System type and complexity
Control System	PBEEEP emphasized trending ability	DDC > Hybrid > Pneumatic
O & M Practices	Observation of opportunities found in screening used instead	Below, Normal or Above average
Hours of Operation	Used	Did not use

Results of Energy Investigations

Of the 71 sites that applied to the program, full studies were performed at 43 with a total area of 15 million square feet. The results for the completed buildings are shown in Table 4. Overall total energy savings ranged from 1.0% to 27% per site, with a weighted average of 9.1% for all measures identified with a payback of 15 years or less. When traditional recommissioning measures that pay back in about three years or less are considered the number of findings drops in half from 12.8 per site to 6.4. The savings per site also decreases to an average of 4.3% with a range of 0.1% to 13.6%. Large savings were even found in sites with moderate energy use, similar to the results of Falk et al. (Falk et al. 2010). Some of the variation in the number of findings per site is due to the fact that some sites have multiple buildings and the same measure may be identified in several different buildings. The average number of findings per building was 3 with a range from 0 to 11. The number of measures identified also appears to be dependent on the provider doing the work, as is discussed below.

Table 4. Energy Savings Opportunities of Sites with Completed Investigations

Site Type*	# of Sites	# of Buildings	Total Area	Percent Savings		
				Median	Low	High
Community College	6	12	2,452,294	6.4%	4.5%	9.3%
State University	4	39	2,622,830	9.6%	2.1%	24%
State Prison	5	41	1,886,828	8.2%	2.9%	9.6%
Office Building	5	8	1,206,613	8.1%	1.0%	15.2%
Other*	5	5	1,087,084	15.2%	6.7%	28%
Total	**25**	**105**	**9,255,629**	**9.1%**	**1.0%**	**28%**

*No Nursing Homes or Maintenance Facilities were investigated; Program results shown as of 5/1/2012

The measures identified in PBEEEP are shown in Table 5. They are consistent with those found in other existing building commissioning programs, both in frequency and magnitude (Criscione, 2008, Della Barbra 2005, Effinger et al. 2009).

Table 5. Summary of Most Commonly Identified Energy Savings Measures

Number	Finding Type	Payback (Years)	Savings (kBtu/ft^2)
62	Time of Day enabling is excessive	1.5	3.9
37	Retrofit - Efficient Lighting	7.8	1.7
32	Equipment is enabled excessively	1.2	1.4
23	Over-Ventilation - Outside air damper failed open	2.5	7.3
23	Zone setpoint/setback not implemented or sub optimal	0.8	4.2
18	Low flow faucets and showers	1.7	1.7
13	Excess Outside Air	6.2	4.9
12	Economizer, Inadequate Free Cooling	1.8	0.4

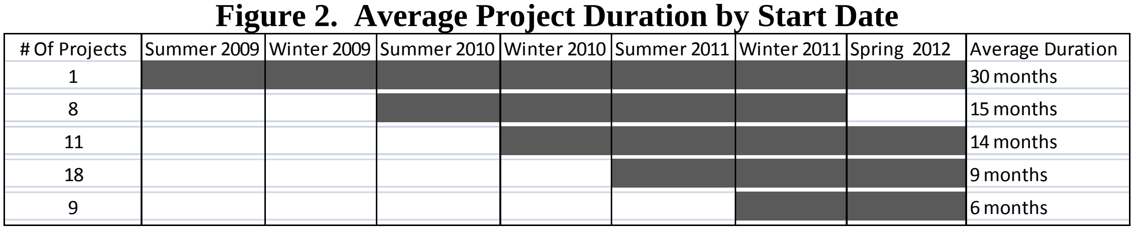
Data from 24 completed projects with a total of 307 energy savings measures. The payback and savings values are averages for each measure across all sites where it was found. For multi-building campuses, savings are calculated based on the affected building area (entire campus for measures affecting the central plant).

Many of the average savings per measure are larger than those reported by Effinger et.al (maximum value of 2.1 kBtu/ ft^2 vs. 8.0 here), but the number of measures per building is smaller in our populations (3 vs. 8). The overall savings per site for measures paying back in 3 years or less is 3.7 kBtu/ft^2, somewhat higher than the value of 2.9 kBtu/ ft^2 found by Effinger et. al. The number appears to be consistent with the trend they observed of greater savings as the ASHRAE Climate Zone number increased. As would be expected, the measures found in Minnesota are primarily ones that save energy in the heating season, not the cooling season, another difference from other studies that have included a large number of buildings where cooling was the dominant energy use.

Lessons Learned from Energy Investigations

The initial projects had much longer than expected project durations (32 months vs. 12 months), which decreased customer satisfaction and the profitability for providers. Figure 2 shows schedule performance over the length of the program. While on-time performance appears to have improved as providers gained experience with the program, the existence of a hard end date for project funding can't be ignored as a key determinant. ARRA funds required all investigations to be completed (for billing purposes) by April 30, 2012.

Figure 2. Average Project Duration by Start Date

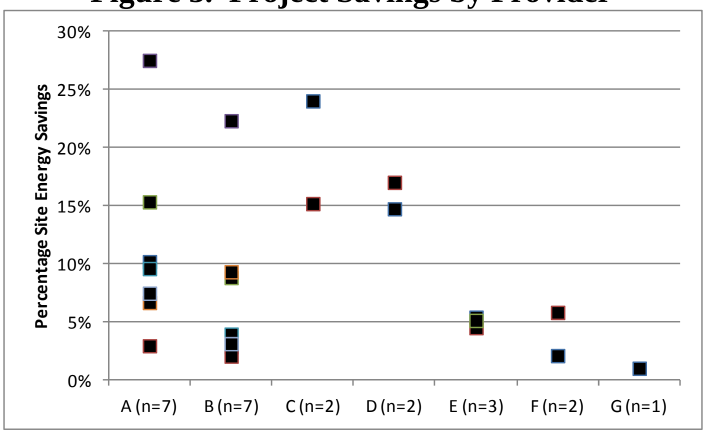


All of the providers overestimated their capacity to take on this work without additional training. The program provided mandatory individualized training of each provider prior to their first project, however it was not as effective as it might have been, primarily because the providers' did not realize the need for it until they were much further along in the projects. The quality assurance process includes extensive feedback; however this was not often utilized at a level commensurate with the effort to produce it.

The success of the program is completely dependent on the performance of the individual providers on each project. The intent of the program was for providers to perform the projects profitably and, by exhibiting excellence in their results, use them as a business development tool. We were surprised how often this was not the case. Rather than taking ownership of the relationship with the customer, several providers deferred communications, such as status updates, to the program administrator and thus failed to take advantage of a chance to build a customer relationship. This resulted in customer complaints of non-responsive providers and required program administrator mediation. While this has a negative impact on both the program and the provider, we did not develop any successful strategies to prevent its recurrence.

Finally, there appears to be a wide variation in the results achieved by the providers, as is shown in Figure 3, something that has been seen in other programs (Long 2008). The average

Figure 3. Project Savings by Provider



Percentage of energy savings identified at each project by provider.

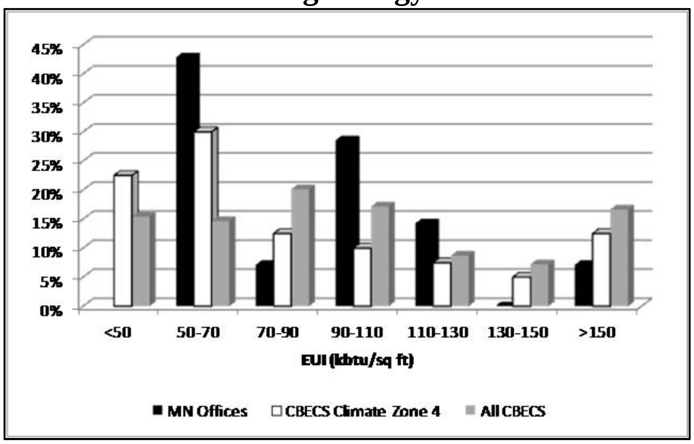
savings delivered by each provider ranges from 0.1% (a provider whose contract had to be terminated for poor performance) to 19%. We did observe improvement over time with most providers, generally following the feedback from our engineers' reviews of their results during the quality assurance phase. For these providers, this represents the successful achievement of the program's goal of improving the rigor and thoroughness of existing building commissioning projects in Minnesota.

Summary: Impact on Policy Goals

The population of existing buildings that can be cost effectively commissioned using a rigorous engineering labor intensive process such as that used by PBEEEP may be smaller than has been generally suggested. While PBEEP focused on the true spirit of existing building commissioning, make what you have work better, retrofits were in scope for PBEEEP where the retrofit could meet the statue of less than a 15 year payback. Because of its unique funding model, PBEEEP allowed an entire population of buildings to be evaluated for existing building commissioning. Most utility programs are limited to a self-selected population of buildings that are good candidates for energy savings. There was no such sampling bias in PBEEEP. The building screening process eliminated 52% of the buildings as poor candidates. Some of the buildings that were included early in the program would probably have been excluded in hindsight, but had the benefit of serving as a test of the screening process. The remaining 48% of the applicant buildings were fully investigated for energy saving opportunities. In these buildings, total savings with paybacks of 15 years or less of 10.8% were found, with 5.7% total savings due to measures paying back in 3 years or less. It is important to note that energy saving opportunities are likely to exist in the buildings that were not investigated, however it appeared unlikely that they could be identified cost effectively using the rigorous process of this program.

The state of Minnesota's building population is a reasonable surrogate for the commercial building stock represented in CBECS. In particular, as Figure 4 shows, the office buildings, which are a major target of existing building commissioning efforts, appear to be representative of the national building stock. Figure 4 compares these two building populations and shows that the savings realized in PBEEEP are therefore likely to be a good, or even optimistic, representation of what could be achieved in commercial buildings at large.

Figure 4. Comparison of Office Building Energy Use Distributions PBEEEP vs. CBECS



The State of Minnesota office buildings do not include as many low or high energy use intensity (EUI < 50; EUI > 130) buildings as the CBECS population, but the averages are similar, 111 kBtu/ft^2 for the Minnesota buildings and 103 kBtu/ft^2 for the CBECS nationwide population.

It has previously been suggested that the high level of savings (16.7%) found in a select population of recommissioned buildings could be applied to the 60 billion square feet of commercial building stock nationwide when formulating the potential for energy saving in the United States (Mills, 2009). Our results imply that approximately half of the buildings are good candidates for existing building commissioning and the savings per project is between 35% and 64% of the level suggested. Thus, our results suggest that the potential for nationwide energy savings from existing building commissioning is $6 to $11 billion per year and for carbon dioxide emission reductions of 70 to 125 megatons per year. An important note is that our sample is only based on governmental buildings that have slightly different characteristics than that of typical commercial building stock and much different economic judgment criteria for infrastructure improvements. Still impressive numbers, but between 20% and 37% of that presented in the results of Mills, which has been used by many others as a basis for large scale program and policy decisions (McKinsey 2007, Mills 2009, Henton et al. 2010).

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