

Comparison of Commercial LEED Buildings and Non-LEED Buildings within the 2002-2004 Pacific Northwest Commercial Building Stock

David Baylon and Poppy Storm, Ecotope, Inc.

ABSTRACT

The percentage of new commercial buildings that seek certification under the U.S. Green Building Council's Leadership in Energy and Environmental Design (LEED[®]) has been steadily increasing over the past five years, with several jurisdictions now requiring the use of the LEED standard for all new buildings. As part of a larger New Commercial Baseline Study examining 345 randomly selected buildings throughout the Pacific Northwest, we examined the building and performance characteristics of 24 LEED buildings constructed between 2002 and 2005 in Washington, Oregon, and Idaho. The paper directly compares the characteristics of the LEED buildings to a larger sample of buildings in a field study of building practices across building types and states. Most of these buildings had been occupied at least two years.

The components of the study included:

- A plan and field review that included determining floor area, mechanical equipment, lighting fixtures and lighting power, and envelope characteristics.
- Collection of energy use data to determine the overall energy use intensity (EUI) of each building.

This paper provides an overview of the building characteristics and overall energy use in the LEED buildings included in this study. The EUI and other characteristics are compared to the larger sample of buildings collected from the random sample of new buildings and to previous regional samples.

Whereas typical LEED comparisons focus on differences between LEED building features and national code (or building performance and initial modeling), this paper is focused on the regional relevance of the LEED standard and implementation. Summaries of building characteristics reveal a pattern of consistent improvement in lighting and mechanical systems and a pattern of consistent increase in glazing area partially offsetting these engineering gains.

The LEED buildings in the sample had an observed performance only about 12% better than performance for the comparable buildings from the remaining sample. This may be partly due to the more stringent Oregon and Washington energy codes and partly due to performance offsets from glazing and control issues.

Introduction

The purpose of this paper is to determine the impact of the LEED standard on Pacific Northwest design trends. Whereas typical LEED comparisons focus on differences between LEED building features and national code (or building performance and initial modeling), this paper is focused on the regional relevance of the LEED standard and implementation. The paper directly compares the characteristics of 24 LEED buildings to a larger sample of buildings in a field study of building practices across building types and states.

Beginning in early 2006, the Pacific Northwest region embarked on an effort to review and characterize the baseline commercial building practices throughout the region. This project focused on a representative random sample of commercial buildings throughout Washington, Oregon, Idaho, and Montana. Montana was included in the regional sample, but no LEED buildings were identified in Montana. To assemble the sample a three year window was selected from the F.W. Dodge® database. This database tracks various stages of buildings in the planning, design, and construction phases. For this purpose we restricted the sample to buildings that began construction in the 2002-2004 time period. The sample was based on a Dalenius-Hodges stratification of the buildings constructed in each state with a random selection of buildings in each stratum based on a Neyman allocation. Using this same technique several supplemental samples were also drawn targeting particular utility service territories and specific building types that were a focus of regional efficiency programs.

The review protocol for all selected buildings began with a recruitment call to contacts developed initially from the F.W. Dodge database. In general, the process focused on the building owner and/or operator. The contact was asked for a set of as-built plans, access for auditors at some convenient time, and willingness to sign a utility release for their utility bills. About 60% of the buildings approached were recruited. When the recruiting failed the building was dropped and replaced with a random draw from the appropriate population.

Once a building was recruited the as-built plans were reviewed. This usually was the result of plans sent from the building operator but sometimes involved on-site review of the site copy of the as-built plans. Subsequently, a walk through audit was conducted verifying take-offs and equipment and fixture selection. These observations were later compared to manufacturer's literature or direct inquiries with installers or designers to verify nominal efficiencies and other specifics. Often this review was supplemented during the data assembly process with direct conversations with building operators. In addition to the plan reviews, on-site documentation of commissioning, testing and balancing reports, and control sequences were reviewed to establish the nature of the overall control systems of the HVAC and lighting systems.

The overall study produced 345 building energy audits which focused on energy-using characteristics including: building envelope efficiency; glazing type and glazing area; lighting fixtures, controls and overall lighting power; and building mechanical system design, controls and efficiency. Energy bills were gathered to compare energy use across various building types. Due to the availability of energy bills, energy use intensities (EUIs) were calculated for about half of these buildings. The sampling process identified 24 LEED certified buildings. Three of these buildings were multi-family residential structures with no commercial uses and were removed from this analysis. Three other LEED buildings were added to the analysis at the request of one of the sponsoring utilities, bringing the final total to 24 buildings. In all cases, these buildings were reviewed using the same auditing protocol as the other buildings in the sample.

Current Literature

There have been several efforts to establish the building performance improvements represented by the LEED certified buildings. The most recent and comprehensive study was developed by New Buildings Institute for the U.S. Green Building Council (Turner & Frankel, 2008). This study focused on the actual energy use of the buildings compared with the predicted values and with the building performance from the 2003 Commercial Building Energy

Consumption Survey (CBECS) database. This comparison showed a substantial improvement in the energy use between the sample used in the CBECS database (to represent the entire commercial sector nationally) and the more contemporary LEED population of buildings. In addition, several efforts have been made to compare predicted building EUI to actual performance (Diamond, et al, 2006; Turner, 2006). These efforts have shown reasonable correspondence between predicted energy use and actual metered energy use. The question remains, however: how do buildings built to the LEED standards compare with other contemporary buildings built to local code standards?

LEED Comparison

Because local code standards are relatively stringent in the Pacific Northwest, individual LEED requirements in this region do not ensure energy efficiency improvement over standard code compliance. Since LEED uses the ASHRAE 90.1-1999 standard as a base for its energy performance, the LEED buildings compared in this paper were designed using performance runs against the ASHRAE 90.1-1999 baseline building. In almost every case, the buildings were required to meet either the Washington or Oregon energy code, which is often more stringent than the ASHRAE 90.1-1999 code. Thus, it is theoretically possible for a building to be certified under a LEED rating system without being more energy efficient than is required under minimum code language in these states. On the other hand, virtually all the LEED buildings in this sample participated in some sort of local utility or state program designed to facilitate energy efficiency in new buildings and provide incentives for efficiency measures in those buildings. As a result the incremental measures needed to achieve the LEED ratings were generally part of an incentive package and buildings generally performed beyond code minimum. This was true even for LEED buildings that did not claim a significant number of energy points in their application.

This paper is designed to identify the features of the LEED buildings in this sample. The criteria for their inclusion in the LEED program, or the specific savings or efficiency claims, were not reviewed directly, and the observed characteristics were not compared to the modeled performance developed as part of the LEED submittal. The comparison is based on a similar level of data collected for the remaining buildings. In addition, the EUIs of these buildings can be compared in a similar way. This is a much more uncertain proposition since 1) not all buildings have energy use information; and 2) the details of how individual buildings compare to one another on an EUI level is subject to a great deal of uncertainty associated with the particular occupancy, schedule, and building type involved.

In this paper the following components are compared: the building envelope, especially glazing performance and glazing area; components of the lighting system, especially overall lighting power density (LPD), lighting controls and fixture selection; and components of the mechanical system, especially system configuration, fuel selection, and commissioning.

To facilitate this comparison, LEED and regional buildings have been divided into main building types. This is often somewhat uncertain since a great many of these buildings are public buildings with a certain amount of specialized usage such as police facilities, jails, libraries, and related public uses. Where possible these uses have been lumped together as institutional buildings. Office buildings are classified in a separate, relatively consistent, category and efforts were made to classify all applicable buildings as such even if they were part of another municipal or public facility. Finally, labs and research facilities were included in the

same categories as hospitals. While this comparison glosses over occupancy variations in all the buildings, at least at the level of the mechanical system design and lighting design the building characteristics were fairly comparable.

Efforts were made to collect energy billing information on every building in the sample. In some cases, energy bills from the LEED buildings (and from other sample buildings) were unavailable because they were part of a campus facility in which the building itself was not separately sub-metered. In some cases inconsistencies in utility billing releases and addresses led to bill information that could not be recovered. These factors reduced the number of buildings available for comparison in both the LEED sample and in the larger sample.

Building Comparisons

Comparisons between the LEED buildings and the overall sample have been constructed to minimize the bias that would be introduced by the particular distribution of building types in the overall sample. Thus for comparison among total populations the weighting used reflects the LEED building population applied to the overall population. As a result, the overall populations of the non-LEED regional summaries were not used in calculating the totals shown. Comparisons are made for each of the three major building components: building envelope, building lighting systems, and building HVAC systems.

Building Envelope

Table 1 shows the comparison of normalized building heat loss rates by building type. This summary uses the building heat loss rates calculated from all the components of the building envelope, but not from the ventilation or other mechanical system losses in the buildings. As can be seen, the heat loss rates are relatively similar in some building types but generally the LEED buildings have a lower level of heat loss especially in the health and institutional building types. This decrease is partly due to the scale of the buildings in the LEED group. There are virtually no LEED buildings which correspond to “big box” construction characterized by single-story concrete walls and large, simple building footprints. In fact, the overall building envelope heat loss seems to exceed the minimum code requirements in all the jurisdictions where “big box” buildings occurred. A more significant part of this discussion, however, should focus on glass and glazing materials.

Table 1. Overall UA/s.f of LEED Sample and Regional Sample

Building Type	LEED Buildings		Regional Sample	
	UA/sq. ft.	N	UA/sq. ft.	N
Education	0.108	6	0.135	61
Health Services	0.088	1	0.135	15
Hospital	0.124	1	0.103	24
Institution	0.113	8	0.193	17
Office	0.148	4	0.160	23
Residential/Lodging	0.117	1	0.122	17
Retail	0.281	2	0.206	76
Warehouse	0.366	1	0.256	40
Total	0.142	24	0.168	273

Table 2 shows the percentage of glazing in the LEED buildings by category and the percentage observed in the rest of the sample. In some cases, a few of these LEED buildings have extremely large glazed areas that represented a very high fraction of all the glass in those sectors. This distorts, to some extent, the summary by building type. Even when that is taken into account, however, the amount of glazing used in buildings certified under LEED in this sample is 1.8 times higher than what was observed in the rest of the sample. This increase is partly an indication of design strategies to achieve additional credits for daylighting, natural ventilation, and lighting, but it also leads to a larger heat loss rate in the building envelope and attendant increase in HVAC loads associated with those decisions. In spite of this increase in glazing level, the overall efficiency of the building envelope in the LEED sample improved over the sample as a whole. This is partly due to improved window specification, but also improved building insulation.

Table 1. Glazing Observed in LEED Sample and Regional Sample (% Floor Area)

Building Type	LEED Buildings		Regional Sample	
	% Glazing	N	%Glazing	N
Education	10.1	6	7.0	61
Health Services	13.3	1	11.9	15
Hospital	18.7	1	7.4	24
Institution	17.3	8	9.1	17
Office	22.9	4	15.1	23
Residential/Lodging	14.4	1	12.7	17
Retail	27.4	2	6.2	76
Warehouse	15.0	1	1.9	40
Total	16.5	24	9.2	273

Table 3 shows the distribution of glazing performance between LEED buildings and the rest of the sample buildings by building type. As can be seen, there seems to be an effort to ensure that glazing systems in LEED projects are of higher quality (larger number of low-e coatings and lower SHGC) than the more typical glazing systems. This effort results in about a 15% improvement in nominal glazing performance.

Table 3. Distribution of Glazing Performance

Building Type	LEED Buildings		Regional Sample	
	Window U	Window SC	Window U	Window SC
Education	0.40	0.37	0.51	0.48
Health Services	0.48	0.30	0.52	0.41
Hospital	0.41	0.37	0.44	0.34
Institution	0.43	0.30	0.45	0.36
Office	0.42	0.39	0.45	0.31
Residential/Lodging	0.41	0.43	0.55	0.45
Retail	0.43	0.35	0.59	0.47
Warehouse	0.41	0.33	0.54	0.39
Total	0.42	0.35	0.49	0.40

Lighting

The LPD in LEED buildings is compared to the LPD in the regional sample in Table 4. In this comparison, it is quite clear that even with the relatively small number of buildings in the LEED sample, there is a noticeable trend towards lower levels of lighting power density in these buildings. This may well be the main feature of LEED buildings that they tend to have a

noticeably lower LPD than comparable buildings in the sample. It is not true, however, that they are uniformly much lower—some buildings in the LEED sample have a higher than average LPD and rely on other factors to demonstrate an improved energy use estimate

Table 4. LPD of LEED Sample and Regional Sample (watts/sq. ft.)

Building Type	LEED Buildings			Regional Sample		
	LPD	Code LPD	N	LPD	Code LPD	N
Education	0.96	1.26	6	1.09	1.29	61
Health Services	1.36	1.30	1	1.54	1.41	15
Hospital	0.91	1.57	1	1.36	1.52	24
Institution	0.99	1.25	8	1.03	1.22	17
Office	0.88	1.21	4	1.17	1.24	23
Residential/Lodging	1.19	1.50	1	1.15	1.43	17
Retail	1.27	1.91	2	1.32	1.78	76
Warehouse	0.84	1.08	1	0.63	0.90	40
Total	1.00	1.31	24	1.12	1.30	273

Given the sample size, the lighting fixture comparison has been limited to the most common fixtures. Thus, the comparison focuses on the linear fluorescent fixtures which account for about 75% of the lighting watts in the LEED buildings. The lighting fixture selection is compared in Table 5 (LEED sample) and Table 6 (regional sample). In general, lighting fixtures observed in the LEED buildings are similar to the aggregates observed throughout the entire sample. However, in the cases of T5 “High Output” fixtures, the incidence of this technology in LEED buildings is 50% higher than in the remaining buildings. In general, the selection of ambient fluorescent lighting in LEED buildings is similar to the rest of the sample. What is not similar is that the reliance on linear fluorescents in LEED buildings is noticeably higher than in the comparative buildings as a whole. In the LEED sample, linear fluorescent technologies accounted for almost 75% of the lighting power. In the remaining sample about 60% of the lighting power was linear fluorescent. This difference suggests that the basic nature of the lighting efficiency improvements observed in LEED buildings is due not so much to fixture selection as to the more extensive reliance on linear fluorescent technologies.

**Table 5. Lighting Fixture Selection within LEED Sample
(% of Total L.F. Watts for Each Building Type)**

Building type	Linear Florescent Type		
	F-T12	F-T5HO	F-T8
College	0.00	0.00	100.00
Education	0.45	9.42	90.13
Health Services	0.00	33.85	66.15
Hospital	0.00	22.22	77.78
Institution	0.00	16.52	83.48
Office	0.00	34.62	65.38
Residential/Lodging	4.55	20.45	75.00
Retail	0.00	0.00	100.00
Warehouse	0.00	0.00	100.00
Total	0.33	18.65	81.02

Table 6. Lighting Fixture Selection within Regional Sample (% of Total L.F. Watts)

Building Type	Linear Florescent Type			
	F-T12	F-T5HO	F-T8	F-T8HP
College	0.20	2.34	97.15	0.00
Education	0.33	8.66	89.11	1.86
Grocery	1.18	0.34	98.48	0.00
Health Services	0.22	12.09	87.32	0.00
Hospital	0.49	10.69	88.25	0.00
Institution	0.00	19.14	80.86	0.00
Office	0.09	9.54	89.47	0.90
Residential/Lodging	3.95	5.54	90.51	0.00
Retail	5.05	15.39	72.36	7.12
Warehouse	6.58	22.01	71.41	0.00
Total	2.05	12.19	83.43	2.22

Lighting Controls

Table 7 shows the comparison of lighting control decisions in the LEED buildings and the regional sample. Overall, the LEED sample has about twice the level of lighting system controls as exhibited in the sample as a whole. In this summary the controls are divided into four categories:

1. EMS control describes the use of a centralized lighting control system that allows the lighting to be scheduled and operated by a central controller. This allows a level of lighting management beyond switch controls.
2. Sweep controls are required in several regional energy codes and allow all of the building lighting to be operated with a predetermined schedule and be switched off during off occupancy hours.
3. Daylight control uses photocell and daylight zoning to operate some portion of the lighting systems. Daylighting controls are preferentially used in LEED buildings and are typically designed to operate based on daylighting zones near windows and/or clerestories. When daylighting controls are compared, the bulk of the daylighting in the regional sample is from “top” daylighting. This typically occurs in “big box” stores where skylights and overhead lighting control are used.
4. Occupancy sensors are designed to turn off lighting zones based on occupancy. This sort of control is very common in LEED buildings particularly for control of lighting zones with intermittent occupancy.

Table 7. Lighting Control Strategies Implemented (% of Lighting Controlled by Strategy)

Building Type	Lighting Controls							
	EMS		Sweep		Daylight		Occupancy	
	LEED	Region	LEED	Region	LEED	Region	LEED	Region
Education	91.4	25.3	82.3	33.2	100.0	16.6	100.0	74.4
Health Services	0.0	37.3	0.0	47.9	100.0	5.2	100.0	24.8
Hospital	100.0	58.7	0.0	48.0	100.0	19.3	100.0	47.5
Institution	71.5	34.3	98.5	27.8	71.5	7.7	99.2	34.8
Office	100.0	28.2	66.5	30.3	66.5	4.8	66.5	38.0
Residential/Lodging	0.0	7.6	0.0	5.5	0.0	5.4	0.0	14.1
Retail	72.6	59.9	0.0	59.9	72.6	27.0	100.0	31.8
Warehouse	100.0	3.2	100.0	18.0	0.0	0.0	100.0	51.3
Total	77.7	31.9	68.7	32.6	74.3	11.0	90.0	44.9

HVAC

In general, the building mechanical system designs in the LEED buildings were somewhat different and somewhat more creative than typical commercial buildings in our sample. Systems that were relatively rare in the rest of the sample were more prevalent in LEED buildings. For example, nearly all of the under-floor air distribution (UFAD) systems and several examples of geothermal systems observed in the sample were in LEED buildings. Table 8 shows the distribution of mechanical systems between the main sample and the LEED buildings. Because the LEED sample is dominated by large buildings (generally above 125,000 SF), the comparison of systems has been divided into large and small buildings. The summary by building size provides a more accurate comparison. The use of multi-zone systems is confined to buildings that are multi-story and have complex mechanical systems. The vast majority of the buildings in the regional sample do not use that sort of system, usually because they are single-story systems with packaged single-zone units as the dominant HVAC type. Table 8 reflects the use of single-zone systems in the regional sample. Even where building size is taken into account this, system is dominant since it is the system of choice for virtually all the “big box” retail systems.

Table 8. HVAC System Type.(% Capacity by Building Size)

System Type	Sample and Building Size					
	Regional Small	Regional Large	Regional Total	LEED Small	LEED Large	LEED Total
Furnace/AC	31.1	31.6	31.5	8.4	11.6	11.4
Other Furnace	17.3	9.2	15.4	4.5	0.5	0.6
PTAC/HP	2.9	1.9	2.7	0.0	0.1	0.1
Radiant Heaters	3.2	3.1	3.1	5.9	0.1	0.3
Zone/Unit Heater	10.0	17.8	12.2	3.2	3.0	3.0
Single Zone VAV	0.9	3.1	1.5	0.0	5.3	5.1
HP Loop	4.5	3.2	4.2	11.8	1.2	1.6
Multi-zone/Const. Vol.	4.7	3.4	4.5	34.5	7.7	8.7
Misc Complex	5.1	5.1	5.1	4.9	10.2	10.0
2 pipe/4 pipe Hydronic	6.9	4.8	5.3	12.2	0.9	1.3
VAV	13.7	15.4	13.4	5.7	49.6	48.0
UFAD	0.0	1.4	0.4	9.0	9.9	9.9

Another observed difference between LEED buildings and the overall sample is the choice of heating fuel type. As Table 9 shows, the use of electric resistance heat, is higher among the LEED buildings than in the regional sample. Electric reheat has been a standard part of mechanical system design in the Pacific Northwest for decades. In the LEED sample this trend seems to continue. In fact the use of electric reheat in the overall sample was much less than the LEED buildings. It should be noted that the systems in Table 9 reflect the primary heating fuel. In many cases, a secondary fuel is also present. For complex systems with reheat, the reheat fuel was always categorized as the primary fuel. This is because from the point of view of overall energy use most buildings in the Pacific Northwest rely on the reheat fuel for the vast majority of their space heating. This characteristic of the LEED sample is a somewhat surprising finding since the performance simulation under the ASHRAE standard penalizes the electric heat as an end use. Presumably other efficiency measures were used to offset the disadvantage of electric resistance heat in this process.

Table 9. Heating Fuel Type (% sq. ft. (by Building Type) Served by Fuel Type)

Building Type	Heating Type							
	Electric		Heat Pump		Natural Gas		Other	
	LEED	Region	LEED	Region	LEED	Region	LEED	Region
Education	16.5	19.1	8.9	3.8	74.6	46.5	0.0	30.7
Health Services	2.3	5.1	0.0	12.5	97.7	76.0	0.0	6.4
Hospital	1.2	30.3	18.1	4.5	80.7	37.4	0.0	27.8
Institution	49.0	4.6	0.0	0.1	51.0	93.4	0.0	1.6
Office	34.7	14.3	0.2	3.1	50.9	69.2	14.2	13.3
Residential/Lodging	65.3	28.6	2.8	26.1	31.9	37.9	0.0	4.9
Retail	0.0	28.8	0.0	28.3	100.0	42.9	0.0	0.0
Warehouse	20.1	3.7	75.0	6.1	4.9	88.2	0.0	2.1
Total	26.8	14.0	10.6	10.5	57.6	66.7	4.7	8.3

Table 10 shows the distribution of the cooling system types among the LEED and regional samples. It should be noted that the use of “no cooling system”, while occasionally used in LEED buildings, is not as prevalent as the regional sample as a whole. This is partly because the smaller buildings and buildings in cooler climates often elect to avoid cooling equipment altogether. Also in cooler areas within the region (Idaho and Montana), the use of economizer cooling without compressors is relatively common, and even though some effort was made in LEED buildings to get similar performance, these efforts were usually supplemented by mechanical cooling which ultimately becomes an important part of the building operation. The “Economizer Only” cooling is based on systems with no compressor but with cooling controls and dampering that controls outside air to provide cooling. This category also includes a few evaporative systems although no such systems were present in the LEED sample.

Table 10. Cooling System Type

Cooling Type	% of Floor Area, System Size	
	LEED	Region
DX coils	23.78	53.45
Water Source Heat Pump	1.57	4.00
Chiller	61.95	17.07
Economizer Only	4.72	4.92
None	7.98	20.56

Commissioning

Building commissioning was relatively uncommon in our sample outside of Washington and Oregon. In Washington, a commissioning standard has been in the code for about five years, and is meant to apply to most buildings constructed in the state. Oregon does not have a similar requirement in its code; however, both of these states have about a quarter of their buildings commissioned. In the LEED sample, commissioning was not only more common, but was almost always used. While 25% of the floor area in Washington and Oregon buildings from the regional sample were commissioned to some degree, in the LEED sample commissioning was practically universal (probably because there is a commissioning requirement in the LEED standard). By the same token, the LEED buildings were often influenced heavily by local utility programs which tended to use commissioning (and offer incentives for commissioning) as part of their energy saving programs. LEED buildings were almost always part of some kind of utility program—either as part of design assistance or as part of a direct subsidy of individual building components. Commissioning in these cases could be supplied by any of the participants in the

building process (engineer, contractor, third party). The LEED buildings had a significant amount of third party commissioning (about 80% of the cases). In the remaining sample, third party commissioning accounted for about 50% of the cases.

Table 11. Commissioning Reported During Audit Interviews

Building Type	% Commissioned	
	LEED	Region
Education	100.00	55.93
Health Services	100.00	25.00
Hospital	100.00	50.00
Institution	100.00	53.85
Office	75.00	26.09
Residential/Lodging	100.00	25.00
Retail	50.00	36.23
Warehouse	100.00	5.88
Total	91.30	36.86

Like the lighting systems, the HVAC systems had a higher saturation of controls than the sample as a whole. In the case of HVAC control the largest difference was in the use of CO₂ sensors. The LEED buildings had a saturation of over 70% for this control as compared to about 33% in the sample as a whole. Throughout the sample, but especially in the LEED buildings, the CO₂ settings were such that very little benefit would result since the minimum air setting was in compliance with the ventilation standards at “full” occupancy. Thus, the amount of ventilation air is almost always greater than the occupancy requirements and the CO₂ sensor is ineffective. In one case (an office), the CO₂ sensor was miss set and the outside air was always adjusted to *100% outside air*. This mistake was not diagnosed and corrected until three years later in spite of almost continuous commissioning or retro-commissioning.

Energy Use

The energy use of the LEED buildings can be compared both to the predictions of their performance calculated using DOE2 or other standard building simulation programs, and to the EUIs of non-LEED buildings of similar type and location. This procedure relates the proposed LEED package to a theoretical building built to the ASHRAE 90.1-1999 code. Since only Idaho uses this code (by reference from IECC 2003) and both Oregon and Washington have some more stringent standards than the national code, it is reasonable to suspect that comparison to other buildings built to these local standards would be instructive. Table 12 shows the relationships between EUIs observed in the LEED buildings and the EUIs observed in similar buildings in two regional samples. The Commercial Building Stock Assessment (CBSA) sample was developed from a series of building audits conducted largely in new construction from 1986 through 2000 (Kema-Xenergy, 2003). The regional sample is restricted to buildings of the same type as the LEED sample for which we had data. Like the other comparisons in this paper the weighting is compiled to reflect the same distribution as the LEED sample and not the particular regional sample.

As can be seen, the LEED buildings generally exhibit an improvement over the older buildings observed in the earlier sample, although for the most part this improvement is not particularly striking considering the CBSA sample is drawn from buildings built to much earlier codes (or no energy codes at all). The comparison to the regional buildings shows a closer

correspondence although in the case of the “Office” uses the LEED buildings show a marked improvement. Unfortunately the size of this sample is restricted by the availability of billing information. This problem is shared among all the samples with at least 50% of the billing records being unusable, or unavailable.

Table 12. EUIs of LEED and Regional Buildings (of Similar Size and Type)

Building Type	CBSA Sample		LEED Sample		Regional Sample	
	kWh/sq. ft.	N	kWh/sq. ft.	N	kWh/sq. ft.	N
Education	31.7	5	20.3	1	18.2	2
Other Health	41.9	9	29.1	1	27.2	8
Hospital	45.1	3	70.3	1	54.9	6
Institution	42.6	19	24.2	4	23.6	11
Office	25.3	45	16.3	5	27.1	12
Total	34.6	81	24.8	12	27.5	39

In this relatively small sample, the EUI comparisons between the regional sample and the LEED buildings suggest that an improvement of 10 to 15% was present in aggregate. In the Office sector, however, almost a 60% improvement seems to have occurred. The size of these improvements may be due to actual improvements in the LEED buildings, but with this number of buildings, a difference of this size is not statistically significant.

Conclusions

The stringency of local energy codes in the Pacific Northwest greatly influenced the relative energy efficiency gains achieved by LEED buildings compared to non-LEED buildings. The majority of the buildings reviewed were built during formative years of the LEED rating system. Although this certification process has been in place for about 10 years, these buildings were permitted from 1999-2003 (using codes and standards from that period) and began construction between in the 2002-2004 time frame. While designers and architects attempted to adapt sustainable design principles to their particular designs, it is clear that some of these efforts were heavily influenced by local design standards.

In general, architects seem convinced that the use of daylighting justifies almost any amount of glazing. This trend is partly offset by better detailing in the rest of the building and by the use of daylighting controls. However, it is unlikely that the impacts of this level of glazing are completely offset by these components.

There is evidence that especially the mechanical engineers spent an unusual amount of design time on these buildings. Building mechanical systems were often much more heavily designed and use more careful sizing and equipment configurations that are not typical elsewhere in the sample. The designs in the LEED sample used various techniques to manage zoning, scheduling, fan power, and ventilation. These techniques resulted in the use of geothermal power, efforts to control ventilation using CO₂ sensors, and some effort to promote natural ventilation. These systems may work relatively poorly without adequate training or follow-up. Nevertheless, the result appears to improve the overall efficiency, particularly in the “Office” sector.

The lighting systems seem to be consistently better than the sample average, although the degree to which they are better seems to be focused on the use of more linear fluorescent lighting than is typical. The use of lighting controls, especially daylighting controls, is more common in

the LEED buildings over the sample as a whole. In fact the use of lighting controls is one of the defining features of the LEED buildings.

The design improvements in lighting and HVAC are partially offset by the use of extensive glazing and average building envelope performance. Furthermore, these complex mechanical systems required increased commitment in operator training.

Overall, the LEED buildings in this sample represent a diverse attempt to improve energy efficiency in these buildings. These attempts are somewhat uneven, but provide evidence that improved building performance is not only possible, but of great interest and concern to the design teams and ownership of the buildings reviewed. In that context, more direct understanding of building efficiency and building efficiency principles would be helpful especially when designing the building envelopes and daylighting systems, so that HVAC systems and the overall comfort and operation of the building can work in a systematic way to allow for a substantial reduction in energy use in these building types.

References

- Baylon, D., Kennedy, M. 2008. *Baseline Characteristics of the 2002-2004 Non-Residential Sector: Idaho, Montana, Oregon, and Washington*. Portland, Oregon: Northwest Energy Efficiency Alliance.
- Diamond, R., Opitz, M., Hicks, T., Von Neida, B., Herrera, S. 2006. *Evaluating the Energy Performance of the First Generation of LEED-Certified Commercial Buildings*. Proceedings of the 2006 ACEEE Summer Study. Washington DC: ACEEE.
- Kema-Xenergy, Inc. 2004. *Assessment of the Commercial Building Stock in the Pacific Northwest*. Portland, Oregon: Northwest Energy Efficiency Alliance.
- Turner, C. 2006. *LEED Building Performance in the Cascadia Region: A Post Occupancy Evaluation Report*. Portland, Oregon: Cascade Green Building Council.
- Turner, C., Frankel, M. 2008. *Energy Performance of LEED for New Construction Buildings*. White Salmon, Washington: New Building Institute.
- U.S. Green Building Council. 2001. *LEED Reference Guide*. Version 2.0.