Evaluating Results for LEED Buildings in an Energy Efficiency Program

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ABSTRACT

The U.S. Green Building Council's (USGBC) Leadership in Energy and Environmental Design (LEED) certification program for commercial new construction lacks a mechanism to verify proposed energy savings. In examining whether LEED buildings achieve site and source energy savings relative to other commercial buildings, various studies have reported contradictory findings.

Energy Trust of Oregon (Energy Trust) offers an incentive track for LEED buildings that achieve savings beyond Oregon's energy code, and the program's third-party implementer reviews the LEED simulation models. Our team evaluated the performance of 36 LEED buildings receiving Energy Trust incentives from 2008 to 2011. The sample covered 35% of LEED projects incented during that time period, representing 70% of total reported savings. The paper focuses on three building types most prevalent in the sample: university, multifamily residential, and office. For each building, engineers conducted on-site verification of energy conservation measures, building design, and operational characteristics. We used these data, energy management system trend data, and post-occupancy utility bills to calibrate whole-building simulation models, and then modified code baseline models to reflect appropriate operational and design characteristics.

This paper reviews evaluation findings for program realization rates, savings relative to baseline consumption, and energy-use intensity (EUI), compared with the 2003 CBECS and an Oregon commercial new construction study. We found a statistically-significant, positive correlation between LEED Optimize Energy Performance points and evaluated energy savings. In most, but not all cases, these buildings also saved more source energy than other buildings in the reference study.

Background

Over the past decade, the U.S. Green Building Council's (USGBC) Leadership in Energy and Environmental Design (LEED) ratings system has expanded rapidly. The LEED ratings system represents the leading "green building" certification available to encourage higher performance on behalf of building owners and developers. To date, 237 new commercial buildings and major renovation projects in Oregon have achieved LEED certification through the New Construction or Core and Shell rating systems (USGBC 2014). The LEED rating system includes energy efficiency, and provides up to 10 points under Energy and Atmosphere credit 1 (EAc1, Optimize Energy Performance) for reduced energy consumption relative to a hypothetical baseline model, based on the ASHRAE 90.1 standard. LEED version 2.1 relied on a comparison to ASHRAE 90.1-1999, while version 2.2 relied on a comparison to the more recent ASHRAE 90.1-2004.

Energy Trust of Oregon (Energy Trust), an independent, non-profit organization, administers energy efficiency and renewable incentive programs (and other efforts) for customers of Oregon’s four major investor-owned utilities: Portland General Electric; Pacific Power; NW Natural; and Cascade Natural.

In 2003, Energy Trust began implementing the New Building program, its commercial new construction energy-efficiency incentive program. This program comprehensively assists owners of newly constructed or substantially renovated commercial and industrial buildings in achieving energy savings, via tracks for prescriptive and custom measures, and LEED whole building projects. LEED Track projects receive incentives for claiming energy savings as part of the USGBC’s certification, typically after receiving a post-construction verification site visit by the program implementer.

The projects examined in this paper received building permits under the 2007 Oregon state energy code (Oregon Structural Specialty Code, Chapter 13). This code enforced more stringent energy-efficiency requirements than ASHRAE 90.1-1999 and 90.1-2004 (various studies estimated Oregon’s 2005 code was 15% more stringent than ASHRAE 90.1-1999 and 5% more stringent than ASHRAE 90.1-2004) (Oregon Department of Energy 2007). The 2005 energy code was nearly identical to the 2007 energy code. Therefore, buildings constructed to LEED certification requirements in Oregon required a conversion from the relevant ASHRAE standard to Oregon energy code to ensure compliance and to determine whether the building achieved energy savings.

LEED Challenges

The intent behind LEED EAc1 credits is to save energy relative to existing commercial construction and other new construction projects not pursuing a green building rating. However, various studies have questioned whether LEED buildings do save more energy than other buildings, particularly in relation to source energy savings.

The LEED rating system provides energy-savings points for the design intent reflected in a building's simulation model and for exceptional savings calculations. However, the LEED ratings process lacks a mechanism allowing the USGBC to verify whether proposed measures have been installed and operating, per the design’s intent.

In the steps from design to permitting to construction and final building occupancy, a building’s form and function may change in many ways. Building owners or developers may “value engineer” energy-efficiency measures out of the final building design as an unnecessary expenditure. Facility management staff may not effectively commission mechanical systems, although LEED provides points for building commissioning. Building operators may manually override HVAC controls to address tenant complaints about comfort issues.

Some studies have claimed that LEED buildings save energy over conventional new construction buildings (Diamond 2006). However, these analyses have examined actual building performance against modeled baseline performance—a hypothetical construct designed to express a code-compliant building with a similar form factor. Modeled baseline results do not offer a useful comparison without calibration to account for an as-occupied building’s operational parameters, usage patterns, and plug loads.

A study claimed to show energy savings by comparing median LEED building energy consumption against mean CBECS 2003 data for existing commercial construction (Turner and Frankel 2008). Another study highlighted concerns about the methodology used to compare LEED buildings with CBECS (Scofield 2009). This study also noted that LEED buildings may save site energy, but do not appear to save source energy relative to the CBECS reference buildings. *Site energy* represents heat and electricity consumed at a building's location. *Source energy*, as defined by the Environmental Protection Agency (EPA): “represents the total amount of raw fuel that is required to operate the building. It incorporates all transmission, delivery, and production losses.” A building may have lower site energy due to switching from natural gas to electric resistance heating, but this will increase source energy. EPA considers source energy to be a more appropriate benchmark of a building's performance and incorporates it into the Portfolio Manager benchmarking tool for ENERGY STAR certification.

Program Implementation

Energy Trust designed the LEED track to address some potential concerns regarding the LEED process. Portland Energy Conservation, Inc., a third-party program management contractor, implemented the 2009 to 2011 programs on behalf of Energy Trust. Science Applications International Corporation implemented the program prior to 2009.

Implementers conducted on-site verifications for all LEED track projects after construction (and before paying incentives) to ensure appropriate measure installations (Robbins et al. 2010). They reviewed building submittals to confirm measures such as insulation R-values and fenestration U-values. They also reviewed energy simulation models. Where relevant, they adjusted models to more accurately reflect installed measures and expected performance.

The rigor level in the implementer's review helped mitigate some LEED process shortcomings. The review provided a mechanism for the program to conduct post-construction inspections. Building owners and developers understood this process could reduce their incentive payments for measures not installed. The program's financial incentives offset costs and reduced the potential for value engineering to remove measures on which LEED points relied.

The Energy Trust program also offered incentives for participants to commission their buildings. The program did not assign savings for this measure, but assumed the effort would help buildings achieve reported savings for a suite of measures.

To calculate energy savings, implementers compared the differences in annual energy consumption between proposed baseline and design simulation models. The simulation contractor developed the LEED design based on the appropriate ASHRAE 90.1 standard (either 1999 or 2004, depending on when the building was permitted)—the required standard for establishing EAc1 points. The implementer then converted the consumption estimates to reflect Oregon’s energy code.

Program Impact Evaluation

Energy Trust retained Cadmus to conduct an independent impact evaluation of the New Buildings Program for the 2008–2012 program years. To date, our team has evaluated final results through the 2011 program year. The evaluation required at least one full year of post-occupancy utility billing data (and preferably more) to develop a more accurate characterization of building performance. As such, a one to two-year lag generally occurs between implementers’ approval of a new construction project and evaluators’ project studies.

To verify reported program participation and estimate gross energy savings in the impact evaluation, we estimated changes in gross energy consumption between calibrated baseline and as-built simulation models. Our starting point was the as-designed model, since this was the only one that could be used for calibration purposes (as a new construction program). The analysis focused on the following steps:

- Reviewing the baseline and as-designed simulation models provided by Energy Trust or simulation modeling contractors.
- Performing on-site verifications for as-built construction details, energy system operational parameters, and energy-efficient measure characteristics (such as quantities, capacities, and efficiencies). Where possible, we obtained energy management system trend data to develop a more detailed understanding of equipment operation cycles and set points.
- Calibrating as-designed simulation models to annual electricity and gas consumption using billing data obtained through the Energy Trust. We also calibrated consumption to actual weather data during the performance period. We reviewed monthly variations between modeled and actual consumption for discrepancies.
- Reviewing energy-efficient measure assumptions and performance variables for each building to develop input data revisions to the calibrated, as-built model. We then revised the baseline model to match the operational parameters for the as-built model (e.g., occupancy patterns, temperature set points, plug loads). If a simulation modeling contractor could not supply the baseline model, we created the baseline model by removing energy-efficient measures from the simulation to match code requirements.
- Comparing the results of calibrated, as-built model energy use with the baseline model to determine annual energy savings for individual buildings, after de-rating the baseline using the appropriate conversion.

Building Characteristics

The 2008 to 2011 program evaluations' sample included 36 LEED buildings, representing 35% of the LEED buildings receiving incentives during that time period, but 70% of total LEED savings, as shown in Figures 1 and 2. Figure 3 shows the evaluated LEED projects, distributed across a range of building types. The impact evaluation included a sample of both projects reporting the largest energy savings (certainty sample) and a random sample from the remaining program population.

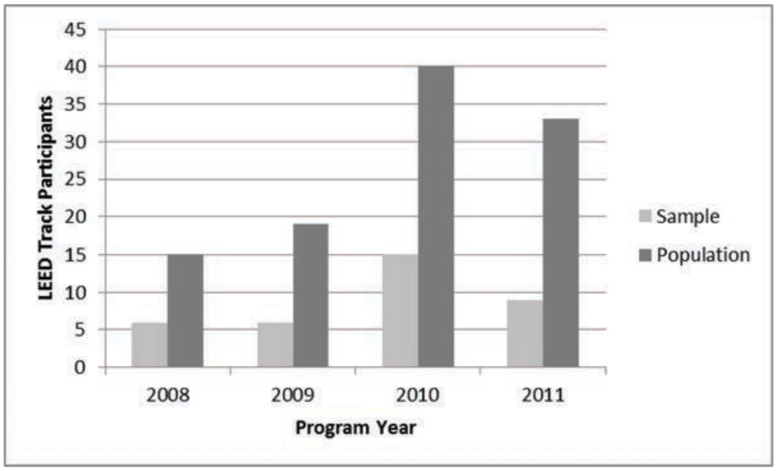

Figure 1. Number of LEED Buildings in Evaluated Sample and Program Population over the 2008–2011 Program Years.

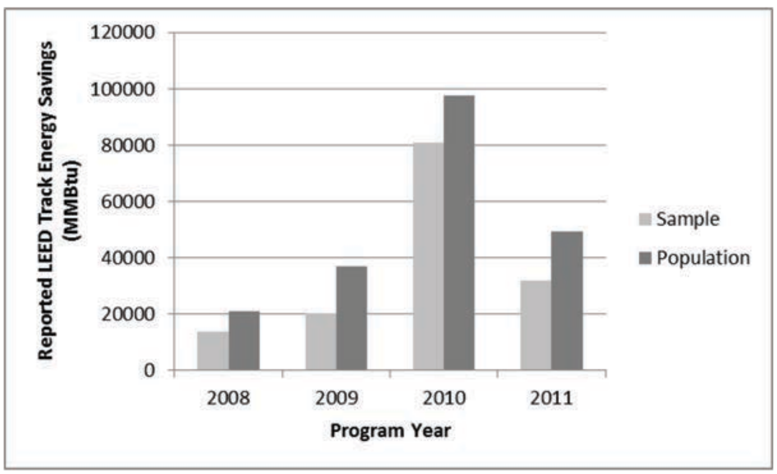

Figure 2. Quantity of Energy Savings in MMBtu Represented by the Evaluated Sample and LEED Track Population over the 2008–2011 Program Years.

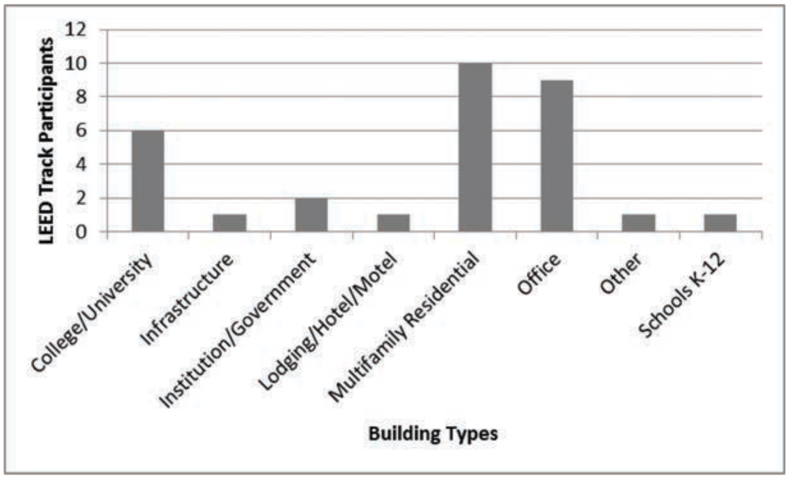

Figure 3. Building Types of Evaluated LEED Projects from 2008–2011 Program Years

We focused our analysis on 25 projects representing the three building types occurring most frequently in our sample: university, multifamily residential, and office. Table 1 shows: the characteristics of the sample buildings; LEED version; LEED rating; total number of LEED points achieved; and points achieved for EAc1 (Optimize Energy Performance).

Table 1. LEED Performance for the Evaluated Sample

Project Identifier	Building Type	Rating System	LEED Version	LEED Rating	EAc1 Points	Total Points
ETONB0825	College/University	NC	v2.1	Gold	3	39
ETONB0934	College/University	NC	v2.2	Platinum	8	54
ETONB1027	College/University	NC	v2.2	Platinum	8	53
ETONB1031	College/University	NC	v2.2	Gold	5	39
ETONB1102	College/University	NC	v2.2	Gold	5	42
ETONB1104	College/University	NC	v2.2	Silver	5	34
ETONB0807	Multifamily Residential	NC	v2.1	Gold	3	39
ETONB0821	Multifamily Residential	NC	v2.1	Gold	2	41
ETONB0902	Multifamily Residential	NC	v2.1	Platinum	10	54
ETONB0933	Multifamily Residential	NC	v2.2	Gold	10	41
ETONB1001	Multifamily Residential	NC	v2.2	Platinum	9	53
ETONB1004	Multifamily Residential	NC	v2.1	Gold	1	39
ETONB1017	Multifamily Residential	NC	v2.2	Platinum	10	53
ETONB1101	Multifamily Residential	NC	v2.2	Gold	5	39
ETONB1103	Multifamily Residential	NC	v2.2	Gold	5	42
ETONB1118	Multifamily Residential	NC	v2.2	Platinum	6	54
ETONB0828	Office	NC	v2.1	Gold	2	39
ETONB0847	Office	NC	v2.2	Gold	7	44
ETONB0921	Office	C&S	v2.0	Gold	6	42
ETONB0923	Office	C&S	v2.2	Platinum	8	49
ETONB1008	Office	NC	v2.2	Gold	6	41

ETONB1012	Office	C&S	v2.0	Platinum	3	47
ETONB1023	Office	C&S	v2.0	Platinum	7	48
ETONB1030	Office	NC	v2.2	Gold	5	42
ETONB1124	Office	NC	v2.3	Gold	5	40

Impact Evaluation Results

The impact evaluation for each program year allowed us to determine the achieved energy savings for each project. We calculated each project's "realization rate" as the ratio of evaluated to reported energy savings. For each project, we also obtained the building's gross square footage, annual electricity consumption, and annual natural gas consumption. These data allowed us to calculate each building's energy-use intensity (EUI) in kBtu/sf. Table 2 provides information on realized savings and the EUI for each sample building. We calculated the weighted average savings and EUI values using gross square footage (gsf). The projects achieved an average gsf-weighted savings of 23% over baseline building energy consumption and a gsf-weighted realization rate of 90%.

To facilitate evaluation participation and to obtain participant utility billing data, we agreed to maintain anonymity for each facility. Because we determined the data, in conjunction with building types and program participation years, could be used to definitively identify each participant, this paper does not report each facility's gsf.

Table 2. LEED Building Impact Evaluation Results and EUI

PROJECT ID	Building Type	Reported Energy Savings (MMBtu)	Realization Rate	Evaluated Energy Savings (MMBtu)	Energy Use Intensity (kBtu/sf)
ETONB0825	College/University	1,867	77%	1,432	73.9
ETONB0934	College/University	1,045	74%	775	62.3
ETONB1027	College/University	2,413	155%	3,735	42.6
ETONB1031	College/University	10,575	66%	6,939	60.3
ETONB1102	College/University	2,166	24%	528	179.4
ETONB1104	College/University	933	103%	958	229.1
Weighted Average	College/University	4,923	73%	3,579	81.0
ETONB0807	Multifamily Residential	3,256	71%	2,303	22.2
ETONB0821	Multifamily Residential	1,565	55%	853	43.2
ETONB0902	Multifamily Residential	14,056	117%	16,415	31.5
ETONB0933	Multifamily Residential	818	68%	554	104.7
ETONB1001	Multifamily Residential	6,796	121%	8,225	30.3
ETONB1004	Multifamily Residential	2,148	120%	2,586	29.3
ETONB1017	Multifamily Residential	15,903	75%	11,902	54.6
ETONB1101	Multifamily Residential	4,553	73%	3,332	26.4
ETONB1103	Multifamily Residential	579	139%	807	29.5
ETONB1118	Multifamily Residential	2,885	59%	1,689	42.4
Weighted	Multifamily Residential	7,724	92%	7,114	35.8

Average					
ETONB0828	Office	2,131	68%	1,441	103.5
ETONB0847	Office	1,989	91%	1,803	42.3
ETONB0921	Office	1,655	46%	760	32.1
ETONB0923	Office	1,509	86%	1,290	84.3
ETONB1008	Office	2,090	90%	1,885	31.7
ETONB1012	Office	3,377	75%	2,548	28.2
ETONB1023	Office	365	84%	308	39.0
ETONB1030	Office	9,630	115%	11,043	59.1
ETONB1124	Office	6,450	83%	5,328	65.5
Weighted Average	Office	4,246	91%	3,882	45.7

In every case, the impact evaluation results indicated that evaluated savings varied from reported savings due to changes from initial assumptions for building characteristiercs, equipment specifications, operational parameters, and occupancy patterns. Figure 4 shows the evaluated energy savings for each project in comparison to energy savings reported by the program. The trend line provides a hypothetical visual representation of a 100% realization rate, in which the evaluated savings would equal the reported savings. Many projects achieved a realization rate below 100% (shown below the trend line).

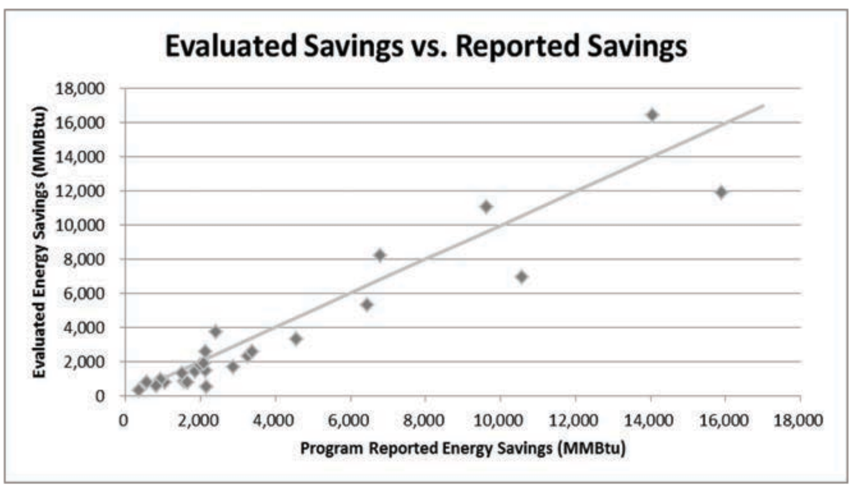

Figure 4. Evaluated Energy Savings Compared with Reported Energy Savings.

On average, the 2008 and 2009 projects achieved a lower realization rate as implementers incorrectly applied the ASHRAE-to-Oregon code de-rating factor (as discussed) during those two program years. This paper does not adjust realization rates to remove the impact of this variance; so it may appear many buildings significantly underperformed relative to initial expectations when we reduced savings partially for the de-rating discrepancy. However, the implementer corrected the issue for the 2010 and 2011 programs. Despite this, the variance in realization rates shows how difficult it can be to predict the performance of new buildings.

Results also provided an opportunity to compare evaluated percent savings over baseline consumption against each project's EUI, as shown in Figure 5. This comparison demonstrates a statistically-significant correlation that increased savings, at least in this sample's context, served to drive down EUIs, regardless of building size.

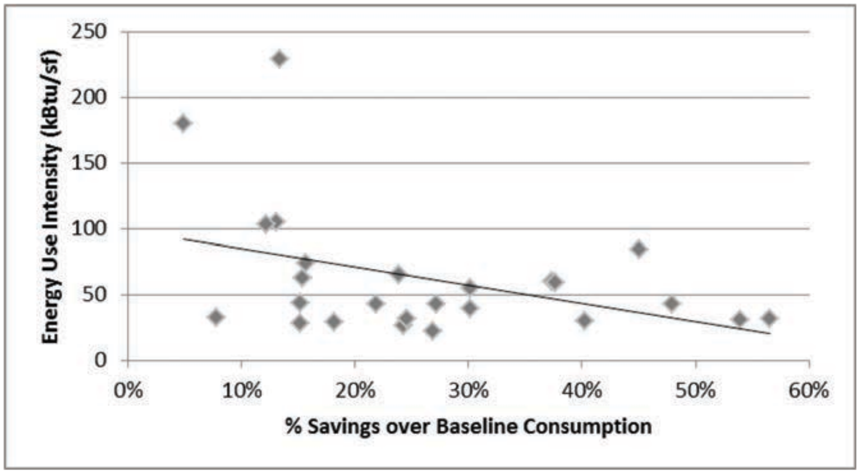

Figure 5. EUI Compared with Evaluated Energy Savings

In regard to the LEED process, results indicated a statistically-significant correlation between site energy savings achieved and the number of EAc1 points achieved. We determined the number of EAc1 points represented a better comparison metric than the LEED rating due to variations in the other selections reported for buildings within each rating category. For example, the LEED Gold buildings reported EAc1 scores ranging from two to ten points, depending on the energy saving strategies the building owner or developer targeted for each particular site.

To examine correlations between savings and EAc1 points, we normalized evaluated energy savings by the gsf for each facility. These energy savings per square foot are shown in Figure 6. The resulting correlation has a *t*-statistic of 2.539. This value signifies there is a statistically significant positive correlation between the quantity of LEED EAc1 points achieved and the evaluated energy savings in the evaluated sample.

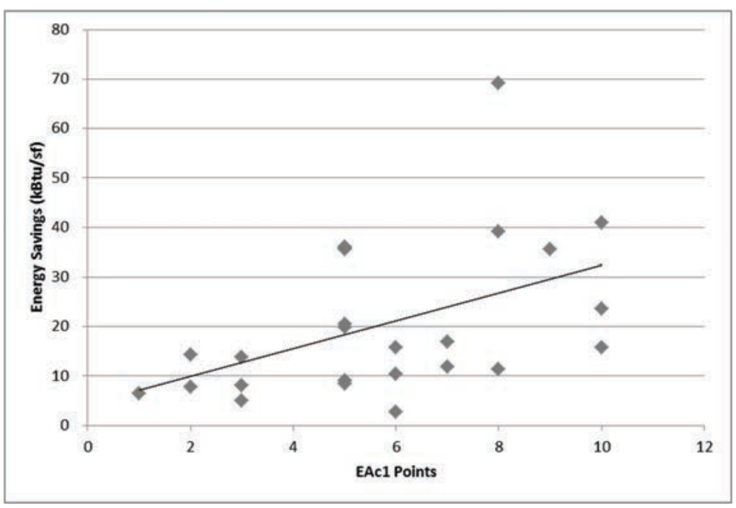

Figure 6. Normalized Energy Savings (kBtu/sf) Compared with Achieved LEED EAc1 Points

We also found a statistically significant correlation between the number of EAc1 points and percent energy savings over baseline energy consumption. The correlation had a t-statistic of 2.678 and is shown in Figure 7.

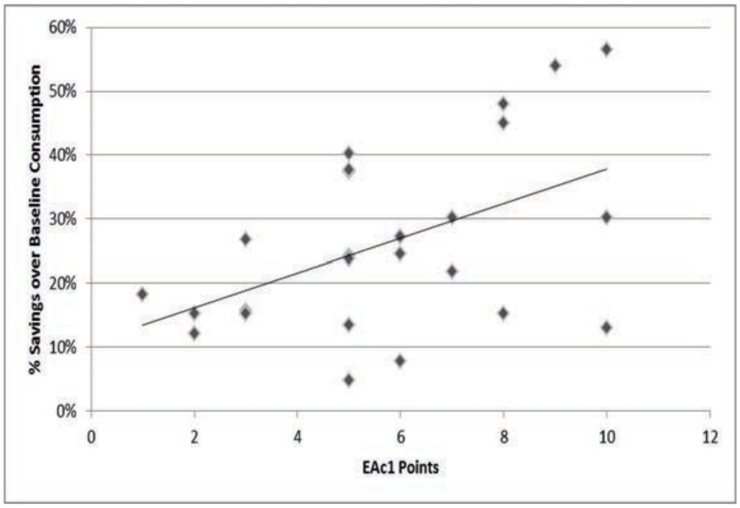

Figure 7. Percentage of Energy Savings Compared with Achieved LEED EAc1 Points

Finally, we examined site EUI against the number of EAc1 points achieved. These results did not indicate statistically significant correlations.

For comparison purposes, we examined the gsf-weighted average EUI for all buildings in each category (Table 3). To calculate the gsf-weighted average EUI, we summed the site electricity and natural gas consumption for all buildings in each category, and then used that number to divide by the combined gsf for all buildings in the category. We then compared these results against several reference studies, including an examination of commercial new construction characteristics conducted by Ecotope throughout the Pacific Northwest from 2002 to 2004 (Baylon, Robison, and Kennedy 2009, Baylon et al. 2013). For comparison purposes, we compared the College/University EUI against the CBECS category for "Education," which primarily included classroom spaces. The NEEA RBSA study results for multifamily buildings could include a sample of LEED-certified buildings and therefore skew the weighted average EUI downward, relative to a comparable sample of non-LEED buildings. With the exception of Colleges/Universities in comparison to the Ecotope study, the sample projects had a lower average EUI than similar building types in the reference studies. The lower EUIs likely result from energy savings achieved through participation in the LEED track of Energy Trust's program and the resulting scrutiny from the implementer.

Table 3. Sample Weighted Average EUI Compared to Reference Studies

Building Type	Weighted Average EUI (kBtu/sf)	Ecotope New Construction EUI 2002-2004 (kBtu/sf)	CBECS 2003, Zone 3[1] (kBtu/sf)	NEEA RBSA (2013) kBtu/sf)
Colleges/University	81.0	65.9	93.5	-

[1] CBECS Zone 3 is the predominant climate zone for the buildings in this study. http://www.eia.gov/consumption/commercial/census-maps.cfm

Multifamily Residential	35.8	58.5	-	39.6
Office	45.7	81.9	95.4	-

Each building type in our sample included at least one outlier with a significantly higher EUI than the others. For college/university sites, both projects with the largest EUIs included a relatively high proportion of laboratory equipment, resulting in higher energy loads. We would normally expect large energy users in a given sample of university buildings; so their impact cannot be entirely discounted as outliers. Both of the office buildings and the multifamily residential building with the largest EUIs all represented major renovation projects, with a relatively small gsf, in which an existing building retrofitted more than 50% of its structure. These projects achieved reasonable energy savings for their size, but still suffered from limitations of achievable improvements on building envelopes during retrofits.

Source Energy Savings

We also examined the relationship between site and source EUI to determine whether the LEED buildings in this sample did, in fact, save source energy. We calculated the weighted average site EUI by fuel type for the evaluated sample of buildings, and then calculated the source energy EUI using fuel factors from the amount of energy needed to generate one Btu of electricity and natural gas in Oregon (Deru and Torcellini 2007). Oregon's electricity generation is predominantly driven by hydroelectric power; therefore, it represents a relatively rare case in which the source energy for electricity consumption is less than that for natural gas consumption. We applied the same fuel factors to electric and gas EUIs for buildings in the Ecotope New Construction reference study. We compared the evaluation and reference study results in Table 4. With the exception of college/university buildings, the evaluated LEED buildings achieved lower source energy EUIs as the reference study buildings.

Table 4. Comparison of Source Energy EUI

Building Type	Weighted Average (kBtu/sf)	Ecotope New Construction (kBtu/sf)
Multifamily Residential	29.1	47.2
Colleges/University	66.4	47.1
Office	34.8	54.0

Conclusion

The Energy Trust New Buildings impact evaluation results provided an opportunity to compare energy consumption details for a sample of LEED-certified buildings. These results, however, could not be extrapolated to the general population of LEED projects as they represented a relatively small set of data points in one geographic region for only three building types.

Still, the results show a statistically-significant correlation between the number of achieved LEED EAc1 points and evaluated energy savings. There is also a correlation between the number of LEED EAc1 points and percent energy savings over baseline consumption. These correlation are likely strengthened by the intervention of Energy Trust's program incentives and third-party implementation staff. The incentives encourage building owners and developers to retain the energy-efficiency measures used to estimate EAc1 points, which otherwise may not be deemed cost-effective. The implementer's scrutiny of the simulation models and energy savings encourages simulation modelers to apply realistic assumptions. The program's commissioning measure also provides an incentive to optimize performance of mechanical systems and controls, which should better reflect the design intent of the LEED certified building.

These results also show that, with the exception of college/university buildings, LEED buildings that participated in the Energy Trust program have lower EUIs than comparable reference buildings, and achieve source energy savings relative to those buildings. While the sample is small, these results may provide guidance for utilities and/or green building organizations when considering energy-efficiency implementation strategies. The Energy Trust program processes could improve the likelihood that a LEED-certified building will save energy over the ASHRAE 90.1 baseline design and comparable reference buildings.

Future Work

We will continue to add data points, based on further impact evaluations of the New Buildings Program and other studies using primary data collection and simulation model calibration. Additionally, Northwest Energy Efficiency Alliance's next Commercial Building Stock Assessment, expected in late 2014 or early 2015 will provide another reference for building EUIs, although it too may be somewhat skewed by the inclusion of LEED buildings in the sample.

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