

# **LEED Building Performance in the Cascadia Region: A Post Occupancy Evaluation Report**

Prepared by Cathy Turner  
for the Cascadia Region Green Building Council

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### **Technical Review Panel**

Gina Franzosa, Cascadia Region Green Building Council  
Judith Heerwagen, J.H. Heerwagen and Associates  
Cathy Higgins, New Buildings Institute  
John Jennings, NW Energy Efficiency Alliance  
Vivian Loftness, Carnegie Mellon University Center for Building Performance  
Michael Rosenberg, Oregon Department of Energy  
Jerry Yudelson, Interface Engineering  
Leah Zagreus, Center for the Built Environment

### **Participating Building Owners**

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### **Project Manager**

Glen Gilbert, President, Cascadia Region Green Building Council

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## Introduction

As a pioneering region in the nation's green building efforts, Cascadia has over 30 LEED buildings that have been occupied for at least a year. This report gives an initial look at some actual performance results of 11 of these buildings. It summarizes energy and indoor water usage in relation to initial modeling and existing commercial building averages. Results also include surveys of occupant satisfaction with building comfort and functionality.

The Cascadia Region Green Building Council commissioned this study to encourage more such efforts while providing useful feedback to study participants and the green building community in general. Few building owners take the important step of measuring actual performance in relation to initial expectations. Barriers to performing these calculations include a perception in some cases of high time and cost requirements.

This study was designed to keep time and costs low and permit as many buildings as possible to participate. Thus, the process was limited to summarizing actual utility usage and prior model projections. It did not include any new modeling or follow-up analysis of questions. This level of review can be sufficient for buildings that appear to be operating efficiently. In other cases, it represents the first step toward identifying and addressing potential problems. The report therefore presents two types of results: basic building performance from the data collected, and the types of additional information that is sometimes needed to more fully understand initial results.

***One cautionary note*** – the comparisons in this report between actual energy usage and initial baseline modeling give only a very approximate initial estimate of energy efficiency savings.

This report contains the following sections:

- Study Approach
- Energy Efficiency Results
- Water Efficiency Results
- Occupant Survey Results
- Building Performance Recap
- Lessons from the Study Process

## Study Approach

### ***Participating Buildings***

The study was open to all 31 LEED buildings in the region that had been occupied for at least one year by September 2005. Results include the 11 buildings from this group for which the owners could provide the needed data during the limited study timeframe. At least five of the eligible buildings could not participate because they were integral parts of larger campuses, with

no separate metering that could provide historic energy and water usage specifically for their LEED building.

Participating buildings span a range of sizes and types. This report shows them sorted into two broad categories: seven offices or libraries, and four multi-family residential buildings. Even within each category, the buildings are very different. Table 1 briefly describes each one, and further detail is available in the separate individual building reports.

**Table 1: Participating Buildings**

<b>Building Code</b>	<b>Conditioned Square Footage</b>	<b>Occupied Stories/ LEED Level</b>	<b>Building Name, City/ Type</b>
<b><i>Office and Library</i></b>			
BG	18,000	3 <i>Silver</i>	Balfour Guthrie, Portland <i>Office</i>
HL	12,300	1 <i>Gold</i>	Hillsdale Branch, Multnomah County Library, Portland <i>Public library, plus below grade parking</i>
KSC	320,000	8 <i>EB-Gold (1)</i>	King Street Center, Seattle <i>Office with some first floor retail, plus below grade parking</i>
NCC	70,000	3 <i>Gold</i>	Jean Vollum Natural Capital Center, Portland <i>Office with 1<sup>st</sup> floor retail and restaurant, plus conditioned basement storage and equipment</i>
O-7	34,200	2 <i>Certified</i>	Anonymous <i>Office</i>
SL	363,000	11 <i>Silver</i>	Seattle Public Library's Central Library <i>Public library, plus below grade parking</i>
VP	15,000	3 <i>Certified</i>	Viridian Place, Portland <i>Office with 1<sup>st</sup> floor retail showroom</i>
<b><i>Multi-Family Residential</i></b>			
B	198,400	10 <i>Silver</i>	PSU Broadway Building (2), Portland <i>College housing studio apartments – 384 units; 2<sup>nd</sup> floor classrooms, PC lab, and offices; 1<sup>st</sup> floor retail</i>
E	64,000	6 <i>Silver</i>	PSU Epler Hall, Portland <i>College housing studio apartments – 130 units; 1<sup>st</sup> floor offices and classrooms</i>
H	220,000	12 <i>Gold</i>	The Henry, Portland <i>Condominiums – 123 units; 1<sup>st</sup> floor retail, plus 2<sup>nd</sup> – 4<sup>th</sup> floor parking</i>
TT	32,200	6 <i>Certified</i>	Traugott Terrace, Seattle <i>Low income 1 bedroom, studio, and single room housing – 50 units; 1<sup>st</sup> floor office and meeting space</i>

(1) Certified under the LEED Existing Buildings (EB) program

(2) Owned by the PSU Foundation

The LEED ratings shown in the above table reflect points in all six LEED categories, not just energy and water efficiency. While we offered participation only to LEED buildings, the objective was to review actual performance, not to evaluate the LEED rating methodology. Thus, all buildings able to provide both actual usage and initial Design modeling were included, whether or not they had achieved energy and water efficiency points.<sup>1</sup>

## **Definitions**

The following terminology is used throughout the report:

*Actual* refers to the building's metered energy or water usage. Actual data was usually compiled directly from utility bills.

*Baseline* refers to modeled usage from the LEED Energy Cost Budget or Water Use Baseline Case, approximating a building similar to the initial design but constructed just to meet code requirements. For energy, the LEED Baseline calculations are typically based on ASHRAE Standard 90.1, 1999, although energy codes in Oregon and Washington are more stringent than these ASHRAE standards. A building's Baseline energy is modeled by first modeling the building as designed, and then backing the energy efficiency measures out of that Design model.

*Design* refers to the modeled usage from the LEED Design Energy Cost or Water Use Design Case, reflecting the efficiency features included in the initial building design. Neither the Baseline nor Design calculations were updated to match final as-built conditions.

*Energy Use Intensity (EUI)* refers to kBtu (1000s of British thermal units) / square foot / year.

*Square footage* is expressed on the basis of gross conditioned square feet, excluding parking areas and other large unheated spaces, as provided by the building owner.

## **Data Sources and Methods**

This report is based on the information described below. In all cases, the data was obtained from building owners, or from sources such as architects or utility companies with the authorization of the owners. No additional or confirming site measurements were made.

*Conditioned square footage* of the building was provided by the building owner or taken from original modeling files, without independent verification. Inconsistencies in the basis of the square footage measurement among buildings may affect relative EUI comparisons, but should not affect a single building's conclusions regarding whether actual usage is greater than or less than the initial model.

*Actual energy and water usage* came from at least 12 months of utility billing records. Some estimation was occasionally required, and is further described in the separate individual building

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<sup>1</sup> LEED's energy efficiency criteria for new construction differ in several respects from the comparisons made in this study. First, they are based solely on modeled rather than actual usage. Second, they cover only ASHRAE regulated uses, excluding items such as plug loads and elevators. Finally, the LEED savings estimates are based on utility bill dollars for the projected mix of fuels, not kBtu. Thus LEED savings percentages can vary between buildings based on their energy mix and relative local costs of each energy source. Reconciling the savings presented here with LEED efficiency points was outside the scope of this study.

reports. When more than one year of data was available, annual and monthly patterns were reviewed for consistency. For these buildings, little difference was found over time, and the average over all years was used for this study.

Actual energy usage was temperature-adjusted to make it consistent with modeling, which assumes average weather conditions. Temperature-adjusted energy usage equals actual energy usage increased or decreased to reflect the difference between historic averages and the actual monthly heating/cooling degree days during the study period. The adjustment factors were taken from linear regression of monthly natural gas use versus heating degree days (HDD 65) and of electricity versus heating and/or cooling degree days, depending on how electricity was used in the building. The temperature-adjustment typically made less than a 5% difference in the total energy.

For energy, the conversion factors used by the EPA for the Energy Star program were used to convert all energy billing units (kWh, therms, etc) to kBtu (1000s of British thermal units).

Energy and water usage throughout this report is expressed per conditioned square foot.

*Initial modeling results* of projected energy and water usage came from the building's LEED submittal for energy optimization (EA-1) and indoor water use reduction (WE-3).

*Savings estimates* were made by comparing actual results to these modeled usage levels, without further calibration or adjustment. However, these LEED Baseline and Design models were originally prepared primarily to estimate the value of individual energy efficiency measures, not necessarily to accurately predict the absolute level of total utility usage in a building. Thus, this study's simple calculation of efficiency savings as the difference between actual usage and the modeled Baseline is at best very approximate. More precise conclusions would require further analysis of changes between design and as-built systems as well as non-conservation-related differences, such as actual occupant numbers, building usage patterns, and building management practices. For energy, an alternate savings estimate compared actual energy use intensity to the Energy Star median.

*Savings dollar values* were based on the most recent available volume rates (i.e. only the portion of the bill that varies directly with kWh, therms, ccf, etc) for each building, typically rates that were in effect during the summer of 2005.

*Incremental initial building costs for the water and energy efficiency features* were requested of the building owners, to permit calculating rates of return on the green investments. However, in most cases this cost information had not been tracked and retained. The overall process of budgeting, revisions, and value-engineering during planning and construction, combined with the whole-building approach to energy efficiency design, makes it easy to lose track of true incremental costs and savings unless a conscientious effort is made to monitor them.

*An occupant survey* was conducted during the course of this study in all but one building. (The Seattle Library was not able to participate during the study timeframe.) In all participating buildings except Traugott Terrace, all occupants were invited via e-mail to participate in the online survey, which took about 10 minutes to complete. Traugott Terrace occupants completed

a paper survey during a monthly residents' meeting, because most did not have internet access in their units.

## Energy Efficiency Results

This section presents energy performance using three different metrics.

*Actual compared to Design* shows whether the building performance is consistent with originally modeled expectations. As noted earlier, a difference between actual and design may mean that the building is more or less efficient than anticipated, *or* it may mean that modeling assumptions differed from the actual occupant behavior, operating practices, or as-built systems.

*Actual compared to Baseline* gives one very rough estimate of the efficiency savings relative to a comparable new building constructed just to ASHRAE (approximate to-code) standards. This comparison is likely to be a more accurate estimate of savings when actual performance is close to modeled Design performance.

*Actual compared to the Energy Star median* gives an estimate of efficiency savings relative to general commercial building stock. For Energy Star certification, this EPA program requires performance at the 75<sup>th</sup> percentile or better, i.e. Energy Star buildings use less energy per square foot than 75% of similar building types in the same climate region. To estimate savings relative to an average building, this study compares actual to the 50<sup>th</sup> percentile level, i.e. the level for which half the buildings are better and half are worse. This median energy use intensity was determined by using the Energy Star Target Finder<sup>2</sup> applied to commercial office buildings and dormitories of the size and locations covered by the study.

### **Actual Energy Compared to Design**

Six of the buildings were using less total energy than suggested by their initial Design models. (No design modeling was available for King Street Center, which was LEED-certified several years after construction, under the Existing Building program.) Figure 1 shows Actual and Design energy use intensities (EUIs), with office and residential buildings each sorted from lowest to highest actual EUI. Despite the variety of buildings in the study, 8 of the 11 have actual EUIs in the relatively narrow range of 44 to 55 kBtu/sq ft. As shown in Table 2, no single building's actual performance was within 20% of its Design model. The average actual/Design ratio was closer than that for any individual building: 110% for all buildings and 89% if the unusual results of building O-7 are excluded.

Building O-7's actual usage exceeded its Design model by 300%. This building experienced a number of HVAC systems and lighting control problems during its first few years. Building managers felt they had succeeded in tuning the systems and replacing components where necessary by the end of the study period, and follow-up monitoring will be instructive.

The Hillsdale Library, which shows the highest Design EUI of the group, had a number of site constraints and design requirements that may partially explain its energy usage level. In

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<sup>2</sup> [http://www.energystar.gov/index.cfm?c=target\\_finder.bus\\_target\\_finder](http://www.energystar.gov/index.cfm?c=target_finder.bus_target_finder) [12/15/2005]

addition, as the only single story building in this study, it has a higher surface to volume ratio than the rest of the buildings, which can also lead to greater heating and cooling requirements.

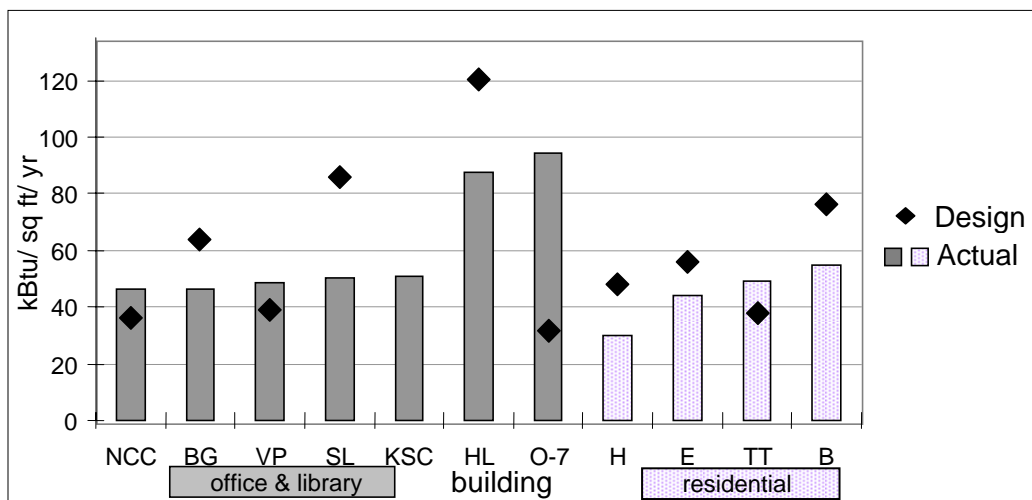


Figure 1: Actual and Design Energy Use Intensities

Table 2 shows the data on which the above figure is based.

Building	Design	Actual	Actual / Design
<i>office</i>			
NCC	36	46	127%
BG	64	47	73%
VP	39	49	124%
SL	86	50	58%
KSC	na	51	na
HL	120	88	73%
O-7	31	94	300%
Office average ratio			126%
			99% excluding O-7
<i>residential</i>			
H	48	30	63%
E	56	44	79%
TT	38	49	129%
B	76	55	72%
Residential average ratio			86%
Overall average ratio			110%
			89% excluding O-7

### Actual Energy Compared to Baseline

All buildings used less energy than their initial Baseline (approximate to-code) modeling, averaging nearly 40% below Baseline. Baseline values were not available for King Street Center or O-7. The former received its LEED rating under the Existing Buildings program based on EUI rather than a projected energy cost budget. O-7 did not apply for an energy optimization credit and performed no Baseline modeling. If each building's Baseline is assumed to represent the energy use of a comparable building without the final energy efficiency measures, then this comparison would estimate the actual savings from adding those measures. (See the discussion

below Figure 2 for limitations and alternate estimates.) Figure 2 shows Baseline values as a large X and actual results as colored bars. Thus the distance between the X and the top of the bar represents the estimated savings. These estimates range from 2 to 85 kBtu/square foot. Some of these values deserve extra comment. For example:

- While Traugott Terrace shows minimal savings on this basis, its actual energy use intensity of 49 kBtu/sq ft is within the central range for all buildings in the study. This building’s initial Baseline and Design model projections were near the lowest of all the buildings in the study.
- The two buildings with the highest Baseline to Actual savings, Hillsdale Library and Seattle Library, also have the highest Baseline modeling projections. These public libraries have very different occupancy patterns and schedules than the office buildings.

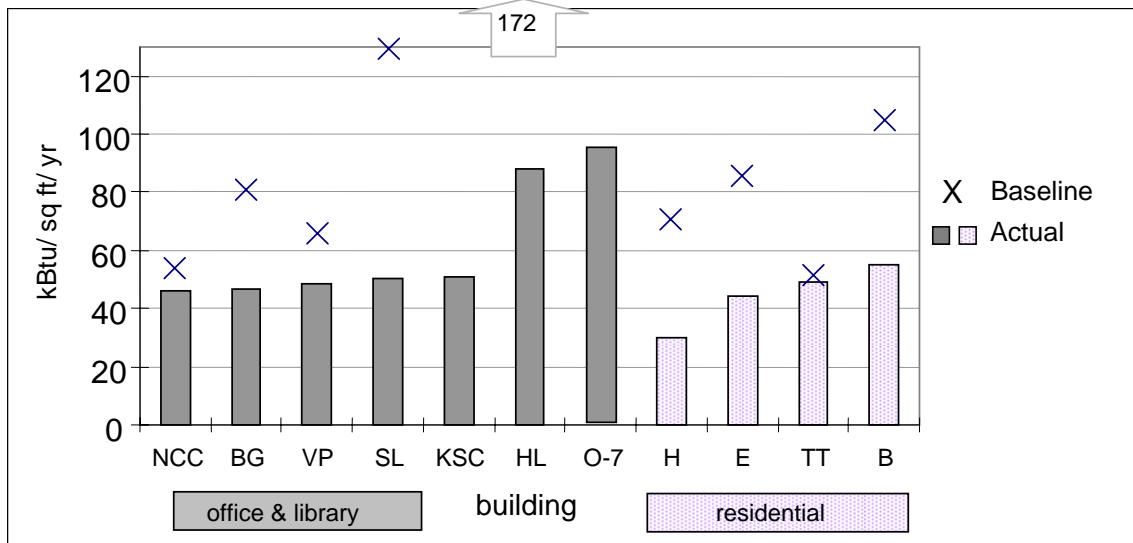


Figure 2: Actual and Baseline Energy Use Intensities

More precise savings estimates from Baseline models would require first determining the cause of major differences between actual and Design performance, creating a calibrated as-built model that matched actual results. Then a more appropriate Baseline model could be constructed by backing the building’s energy efficiency measures out of the newly calibrated Design model. This more extended analysis was beyond the scope of this study.

### Actual Energy Compared to Average Buildings

An alternate simple estimate of conservation savings is possible by comparing actual EUI to a more general “typical building” benchmark. On this basis, all but two of the study buildings show savings. Figure 3 adds a band between two dotted lines to Figure 2. That band shows the approximate 50<sup>th</sup> to 90<sup>th</sup> percentile range for EUIs generated by the Energy Star Target Finder for similar commercial office and dormitory buildings in Portland and Seattle. In other words, 50% of similar buildings have EUIs below about 65 kBtu/square foot and only 10% have EUIs below about 35 kBtu/square foot.<sup>3</sup> The 50<sup>th</sup> percentile, representing an average building in the region,

<sup>3</sup> The Energy Star calculations were performed for general office space and college dormitories. They are thus not necessarily applicable to the public libraries and condominium in the study.

can be used for estimating the level of savings in the buildings in this study. The 90<sup>th</sup> percentile is included to show the approximate best level of all but the most extreme buildings. The final column of Table 3 below shows an alternative savings estimate, using the difference between the building's actual EUI and this median of 65 kBtu/sq ft. On this basis, all but two buildings show annual savings in the range of 10 to 35 kBtu/sq ft.

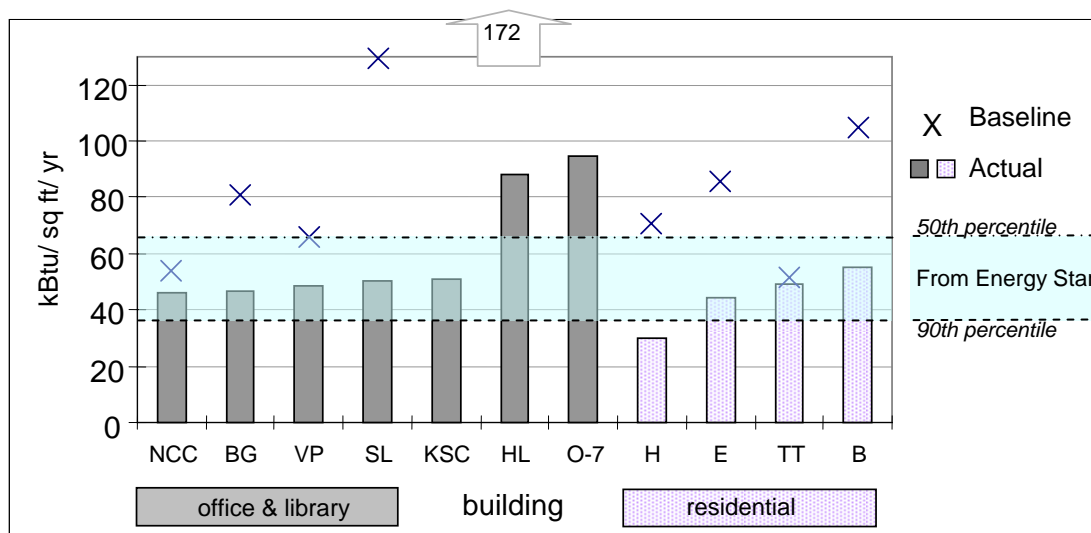


Figure 3: Actual, Baseline, and Commercial Building Ranges from Energy Star Database

The two buildings showing losses when compared to the regional median make an interesting comparison. O-7 is the building for which systems were not working properly during most of the study period; hence the lack of past saving is not surprising. Hillsdale Library, on the other hand, has the highest savings when expressed as the difference between Baseline and Actual, but shows losses when compared to the regional median. Further comparison of this building to other more similar facilities, or a review of the original modeling assumptions, would be needed to further interpret these results.

Table 3: Actual and Baseline Energy Use Intensities (kBtu/sq ft)

Building	Actual	Baseline	Actual / Baseline	Annual Savings		
				Building Baseline - Actual	Regional Median - Actual	
<i>office</i>	NCC	46	54	86%	8	19
	VP	49	66	74%	17	16
	BG	47	81	57%	35	18
	SL	50	129	39%	79	15
	HL	88	172	51%	85	-23
	KSC	51	na	na	na	14
	O-7	94	na	na	na	-29
<i>residential</i>	TT	49	51	96%	2	16
	B	55	105	52%	50	10
	E	44	86	52%	41	21
	H	30	70	43%	40	35

## Energy Cost Savings

Estimates of financial savings from energy efficiency measures correspond to the volume savings determined above. Table 4 shows the two alternate calculations of EUI savings from Table 3, accompanied by estimated dollar savings from the resulting lower utility bills. The dollar savings are for present values over 25 years,<sup>4</sup> assuming that energy usage remains constant and that utility rates change only at the rate of general inflation. Note that utility rates have actually increased faster than general inflation over the past several years, and many expect this trend to continue. Higher rate increases would result in even higher savings from efficiency.

A 25 year discount period is typical for summaries of this type. The buildings themselves may last much longer, while some building systems components, such as motion sensors or heat pumps, have a shorter average lifetime. A more refined life cycle costing calculation would incorporate replacement times and costs for major components, for both the actual and Baseline versions of the building systems.

The median of these 25-year savings is \$8/square foot using Baseline minus Actual, and \$2/square foot comparing actual to the fixed benchmark of 65 kBtu per square foot. A more refined methodology, such as calibrating the baseline model or varying the regional median to more accurately reflect building characteristics, would be needed to precisely estimate individual building savings.

**Table 4: Values of Energy Savings**

Building	Energy Savings (kBtu/sq ft)		Dollar Savings (1) (PV 25 year \$/sq ft)		
	Baseline – Actual	Regional Median – Actual	Baseline – Actual	Regional Median – Actual (2)	
<i>office</i>	NCC	8	18	\$0	\$1
	VP	17	16	\$4	\$2
	BG	35	18	\$7	\$3
	SL	62	14	\$26	\$5
	HL	88	-23	\$23	-\$5
	KSC	na	14	na	\$4
	O-7	na	-30	na	-\$9
<i>residential</i>	TT	2	15	\$2	\$12
	B	50	10	\$12	\$2
	E	41	20	\$11	\$5
	H	40	35	\$8	\$2

- (1) Apparent inconsistencies between dollar savings and kBtu savings, when comparing two buildings, arise from differences in utility rates by location and from differences among buildings in the proportion of savings coming from electricity vs natural gas or other fuel sources.
- (2) The “Regional Median–Actual” dollar savings calculation assumes the same savings proportion by source (e.g. electricity vs gas) as the “Baseline–Actual” results.

<sup>4</sup> A present value represents the value today of payments to be received in the future. The present values in this report assume a real discount rate of 3%/year. This is equivalent to assuming, in the absence of inflation, that receiving \$1 one year from now would have the same value as having \$0.97 today.

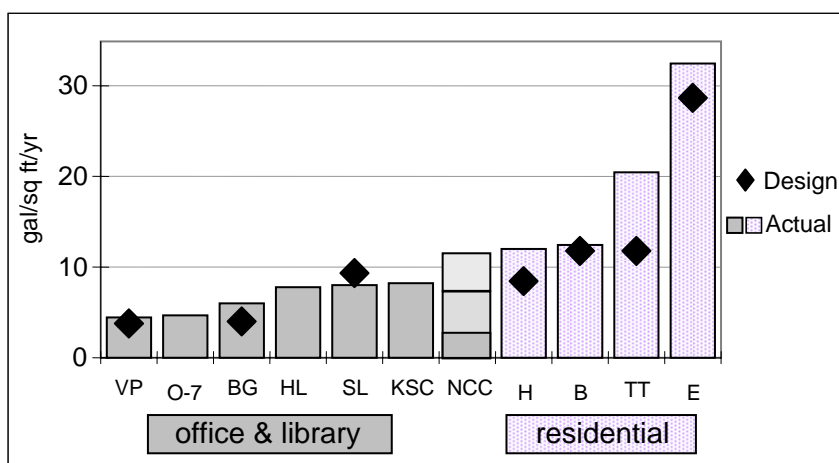
## Water Efficiency Results

The study compares indoor water usage to modeled Design and Baseline projections, similar to the approach used for energy.

### Actual Water Use Compared to Design

Of the seven buildings for which water Design projections were available, all but one used at least slightly more water than projected. Projections were not available for the Natural Capital Center, Hillsdale Library, or O-7 because they did not apply for LEED water use reduction credits. Design modeling was not required for KSC, which was certified under the Existing Buildings program.

Different fixture flow rates are just one of the reasons for the variations in the level of expected water usage seen in Figure 4. Design projections also vary in their assumptions regarding fixture use frequencies and duration. As with the energy review, differences between actual and Design may come partly from differences between designed and installed fixture performance and partly because of differences in occupant behavior.



**Figure 4: Actual and Design Water Use per Square Foot**  
See text for explanation of range of estimates for NCC.

The Natural Capital Center has just a single water meter, which records total water used. This total includes restaurant and conference areas plus some outside irrigation. The total NCC bar in Figure 4 shows the total 15 gallons/square foot average from this meter, with sections reflecting estimates of irrigation volume<sup>5</sup>, restaurant volume<sup>6</sup>, and resulting estimated volume from office and conference usage. Because of these uncertainties and the lack of LEED modeling, Natural Capital Center actual results are excluded from the remaining figures in this section.

For the Broadway Building, indoor water measurement was also complicated by lack of separate irrigation metering and also by some seemingly inconsistent readings. Table 5 shows an estimated range of results. The lower figure of 12.5 gallons was based on one winter quarter

<sup>5</sup> Based on the difference between winter and summer volumes

<sup>6</sup> Based on benchmark restaurant water use per square foot from an American Water Works Association study done by Aquacraft in 2000.

known to have no irrigation, a common technique for indoor water usage estimation. The figures throughout this section use that lower number.

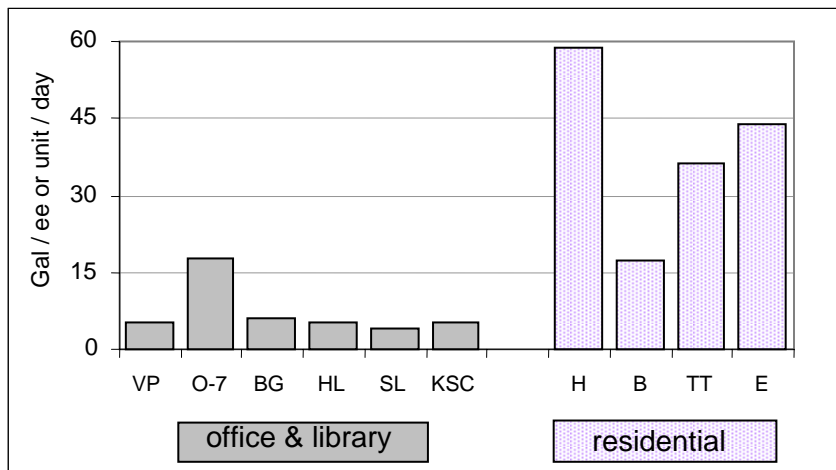
The reason for the variation in usage among the other buildings is generally not clear, either from the underlying data or discussions with owners.

**Table 5: Actual and Design Water Use Intensities (gal/sq ft/yr)**

	Building	Design	Actual	Actual / Design
<i>office</i>	NCC	na	3 – 15 *	na
	VP	3.9	4.4	115%
	BG	3.9	6.0	152%
	SL	9.4	8.1	86%
	HL	na	7.9	na
	KSC	na	8.3	na
	O-7	na	4.6	na
<i>residential</i>	TT	11.9	20.5	172%
	B	11.9	12.5 – 22 *	106%
	E	28.8	32.5	113%
	H	8.6	12.0	140%

\* See explanation in preceding text

Indoor water use might be expected to vary more by number of occupants than by floor space. Figure 5 shows buildings in the same order as Figure 4, but displaying water usage per office building employee or residential building unit rather than per square foot.



**Figure 5: Actual Water Use per Office Employee or Residential Unit**

For the office buildings, O-7 has the greatest floor space per employee, which gives it a higher water usage when viewed on this basis. Note that the usage levels per occupant shown for the two libraries would be even lower if we had estimates available of average total building occupants, including public visitors, as opposed to just staff counts.

For residential buildings, the Henry has the largest units. It therefore shows the highest water use/unit even though it has the lowest water use/square foot. Information on the average number of residents per unit would further improve this comparison. Precise counts are not available, but limited data from the occupant survey suggests averages may be slightly less than two

occupants/unit in the Henry and closer to one/unit in the other residential buildings. Those rough estimates would put the Henry usage/occupant similar to that of Traugott Terrace and Epler.

### Actual Water Use Compared to Baseline

Of the seven buildings for which modeling was available, four were saving more than 8% of their initially projected Baseline water usage. Epler shows the largest savings on this basis, but it also has the highest water use per square foot. The apparent inconsistency is because of its high Baseline number, and that high Baseline comes primarily from underlying assumptions of higher water use durations. The reason for the higher actual usage is unclear, although the building has had some metering problems.

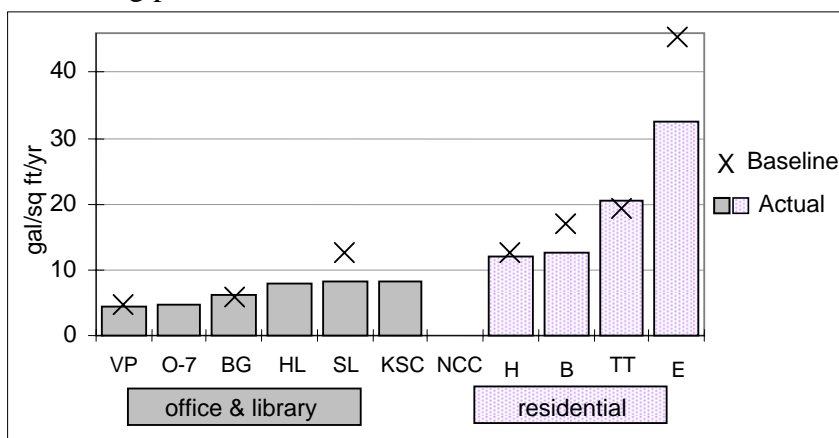


Figure 6: Actual and Baseline Water Use Intensities

Table 6 displays the actual and Baseline water performance data that is graphed above. The final column shows savings estimated as the difference between the modeled Baseline and Actual results. As was true for energy, possible inconsistencies in Baseline modeling limit the comparability among buildings of savings calculated on this basis. For commercial building water usage, there is no good publicly available database of usage levels comparable to the Energy Star benchmarks for energy usage.

Table 6: Actual and Baseline Water Use Intensities (gal/square foot/yr)

Building	Actual	Baseline	Actual / Baseline	Baseline – Actual	
<i>office</i>	NCC	3 - 15	na	na	
	VP	4.4	4.8	92%	0.4
	BG	6.0	5.7	104%	-0.3
	SL	8.1	12.6	64%	4.4
	HL	7.9	na	na	na
	KSC	8.3	na	na	na
	O-7	4.6	na	na	na
<i>residential</i>	TT	20.5	19.3	106%	-1.1
	B	12.5 - 22	17.1	73%	4.6
	E	32.5	45.3	72%	12.8
	H	12.0	12.6	95%	0.6

At the level of current water and sewer billing rates, the dollar value of these water volume savings per square foot is minimal. However, because the incremental cost of low flow fixtures is also small, their use can still be a good financial decision.

## Occupant Survey Results

An occupant survey was conducted for all but one building. (The Seattle Library was not able to participate during the study timeframe.) The survey sought to determine perceptions of building comfort and functionality in the categories of temperature, air quality, lighting, noise, and plumbing fixtures. Response options were on a 5 point scale with a central neutral point, as shown in the sample questions of Figure 7. All those working in office buildings or living in residential buildings were invited to participate. The number of occupants ranged from a high of 1,400 for King Street Center to a low of 20 for the Hillsdale Library staff. As noted in the methods section, the survey was conducted on-line for all buildings but Traugott Terrace.

**\* 10. How satisfied are you with the temperature in your workspace?**

Very Satisfied      Somewhat Satisfied      Neutral      Somewhat Dissatisfied      Very Dissatisfied

**\* 11. Overall, does the temperature in your workspace help or interfere with getting your job done?**

Helps significantly      Helps somewhat      Neither helps nor interferes      Interferes somewhat      Interferes significantly

Figure 7: Sample Office Survey Questions

For office buildings 40% to 73% of occupants responded to the survey. A response rate of 50% or higher is the target for surveys of this type: census surveys in which all occupants are invited to participate. For sampling methods, a much higher participation rate would be required. King Street Center's 40% response rate was the only one below this 50% target. However, this large building still had many more respondents (553) than the other, smaller, buildings in the study. While results from a building achieving a lower response rate, or with very few occupants, are not as statistically rigorous as one might prefer, they can still be useful in identifying issues in the building.

Residential response rates were extremely low, with the exception of Traugott Terrace, which conducted a paper survey during a meeting of residents. Thus the following summary displays only the office results.

Office respondents were generally very satisfied with their building overall and somewhat satisfied with their personal workspace. The Center for the Built Environment (CBE), at UC Berkeley, which uses a similar but longer survey, has also reported building satisfaction typically higher than personal workspace satisfaction.

Satisfaction ratings for most categories, with the exception of noise level and sound privacy, were typically positive. Light levels and air quality were both generally perceived as being somewhat helpful in getting work done. The dissatisfaction with noise levels and sound privacy

has also been reported on surveys by others, and is often associated with open office environments. Workspaces of survey respondents were typically low partition cubicles or desks with no partitions.

Figure 8 summarizes the range of office building response averages for the primary survey questions. It also shows the range across buildings of the percentage satisfied or very satisfied.

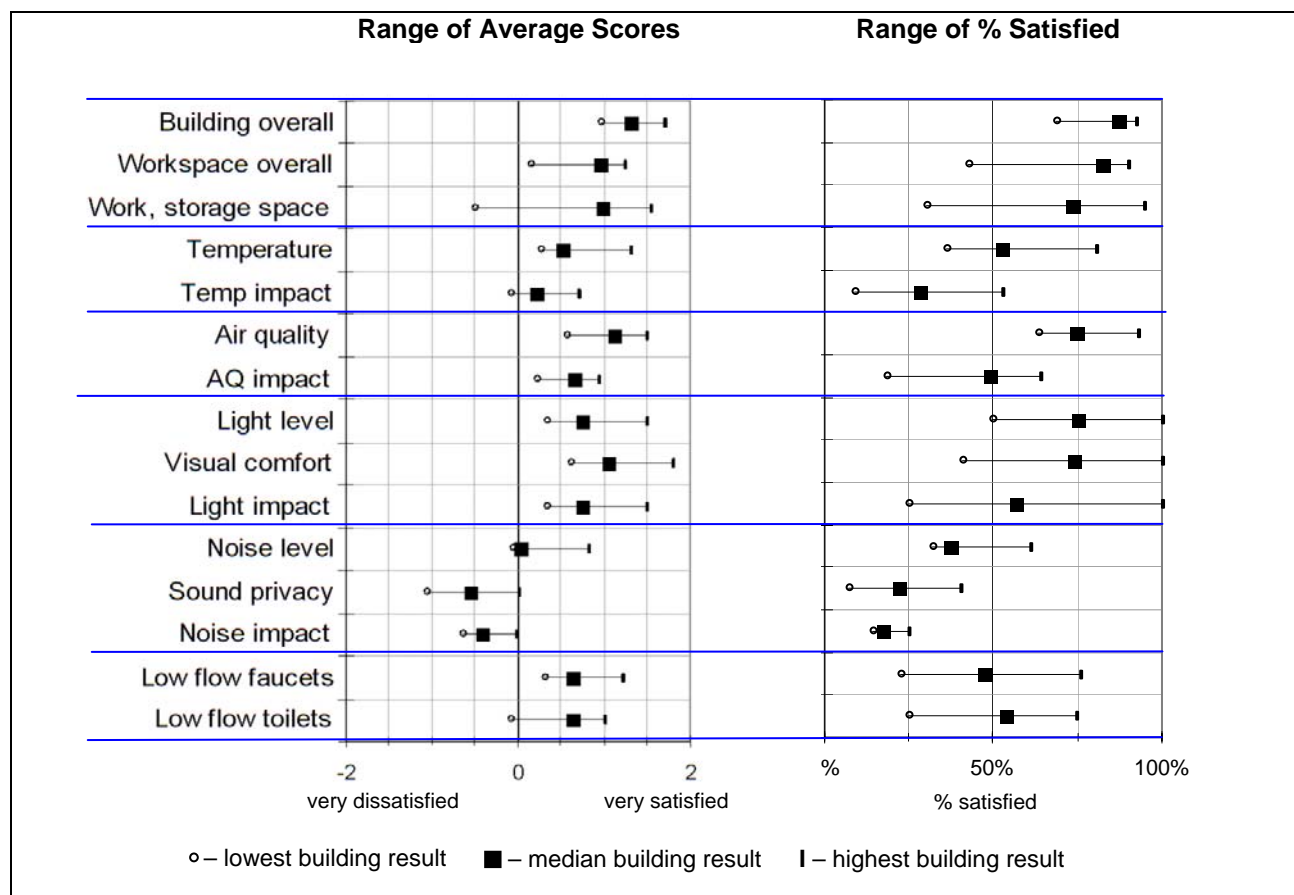


Figure 8: Office Building Ranges of Average Scores and Percentage Satisfied

Within the categories receiving positive ratings, temperature conditions had the lowest median scores, with satisfaction falling in the “somewhat satisfied” range. Also, a relatively low percentage of occupants perceived temperature conditions as helping to get their job done. Complaints mentioned in follow-up questions were for areas familiar to most building maintenance personnel, including drafts, uneven heat distribution, and inaccessible temperature controls. A more in-depth occupant study could investigate whether these problems were concentrated in specific building locations or with specify types of occupants. Because this survey included only LEED buildings, we can’t compare results with those for “non-green” offices. However, the similarly structured CBE surveys, which cover a broad spectrum of office buildings, have reported slightly negative thermal comfort satisfaction, as opposed to the slightly positive results here.

One purpose of an occupant survey is to determine whether low energy consumption is possibly being achieved through reducing comfort for occupants. In this limited sample, there was no clear relationship (positive or negative) between the level of temperature satisfaction and building energy use intensity.

Despite the very low response rate from the residential surveys, their results range was similar to those above, with the exception of higher satisfaction with sound levels.

## **Building Performance Recap**

Most buildings in this study are experiencing real energy savings in relation to their original Baseline modeling. Most buildings are also performing well in relation to general commercial office space, with median EUI of 50 kBtu/square foot for the covered office buildings. The average 25 year present value of dollar savings for buildings in this study, when compared to the regional median, is \$2/square foot. However, there is a large variation in estimated savings depending on the calculation method used, showing that the simple data requested for this study is not adequate to precisely calculate savings for an individual building.

The majority of buildings also show some savings for indoor water usage in relation to original Baseline modeling. As with the energy results, the Baseline projections weren't calibrated for actual occupant behavior, and wide differences between Design and actual results limits the accuracy of these savings estimates. For commercial building water usage, there is no good publicly available database of usage levels to provide an alternate savings basis. The savings in water usage are less material from a financial perspective, because of the relatively low billing rates per gallon.

Occupancy surveys show high satisfaction with office buildings overall and generally positive averages for all categories other than noise conditions. There was no clear relationship (positive or negative) between the level of temperature satisfaction and building energy use intensity.

## **Lessons from the Study Process**

First-stage data gathering and review, as in this study, can show that a building is performing well or identify areas that raise questions to be investigated. The following paragraphs summarize the data items or analysis processes identified throughout the report that were beyond the scope of this basic review.

### **Information that would be useful if captured during design and construction**

One of the primary impediments to even the simplest studies can be the lack of basic utility usage information. Appropriate initial metering, combined with a simple tool to track and evaluate usage, might help address this situation.

As many other studies have noted, accurate conditioned square footage numbers are necessary to accurately compare energy use intensities among buildings.

Capturing key information relating to initially expected building performance might facilitate understanding actual performance levels without full Design model recalibration. The information to capture would include: key modeling assumptions, changes made to efficiency

features during construction and value-engineering, and the main reasons for particularly high or low expected EUIs in the initial Design model.

To determine whether the savings from efficiency investments generate a good long term return on the initial incremental costs, these incremental costs and savings must be captured during the design and value-engineering process. A complete life cycle cost comparison also requires sound information on the lifetimes and replacement costs of the major components being compared (although lifetime estimates must be at least partly speculative for newer technologies).

Better benchmarking of energy or water use per building occupant would be possible with information on number of occupants per residential unit and average number of public visitors to commercial buildings.

**Information requiring public data gathering or additional individual building analysis**

A publicly available database such as that for the Energy Star program provides a useful alternative way to estimate efficiency savings in relation to an average commercial building of several types. Similarly comprehensive public benchmarks would be useful for other building types, such as multifamily residential, and for commercial building water use.

Better studies of water usage patterns – frequencies, durations, and whether these factors change when low-flow fixtures are in place – are needed for more consistent indoor water modeling and better correlation between modeled and actual results. Difficulty in measuring a building’s actual fixture usage frequency and flow rates creates a further barrier to diagnosing apparent high levels of actual water usage.

This study’s limited sample suggests that Design modeling rarely comes within 10% of actual energy utilization levels. Complete recalibration of a building’s Design model to match actual performance could provide valuable feedback to the building designers and engineers, but is often more than is needed or desired by current building owners. If a more precise estimate is needed for actual savings for a single new building, a revised Baseline model, based on a calibrated Design model, may also be required.

For an occupant survey to be a useful diagnostic tool for a single building, it is important to have the time and ability to analyze results according to the location and occupant characteristics generating negative responses. For a survey to be more broadly useful in comparing buildings or interpreting overall building satisfaction, a baseline database of results from the same survey in other buildings should be available as a benchmark.