



**A First Year Evaluation of the
Energy and Water Conservation of Epler Hall:
Direct and Societal Savings**

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Executive Summary

This study addresses three questions regarding the efficiency and conservation features of Portland State University's (PSU's) Stephen Epler Hall:

1. Is the building achieving the anticipated energy and water efficiency?
2. What are PSU's direct savings from these efficiency features?
3. Does the conservation generate additional societal benefits, beyond the direct PSU savings?

Epler Hall is a six story mixed use building erected in 2003. The first floor houses classrooms and offices while floors two through six each contain 26 efficiency apartments for individual occupancy. The building has a U.S. Green Building Council silver rating for Leadership in Energy and Environmental Design (LEED).

Actual Energy and Water Savings

During Epler Hall's first year, energy use was over 20% better than expected from pre-construction modeling and 50% better than the Baseline level. The Baseline represents energy use for a comparable structure with no conservation features other than those required by current building codes. The difference between Actual and Baseline usage determines the savings from voluntary conservation features. Figure ES-1 shows the building's Actual, Design (expected), and Baseline energy use, as well as that of PSU non-residential buildings and the neighboring King Albert residence hall.

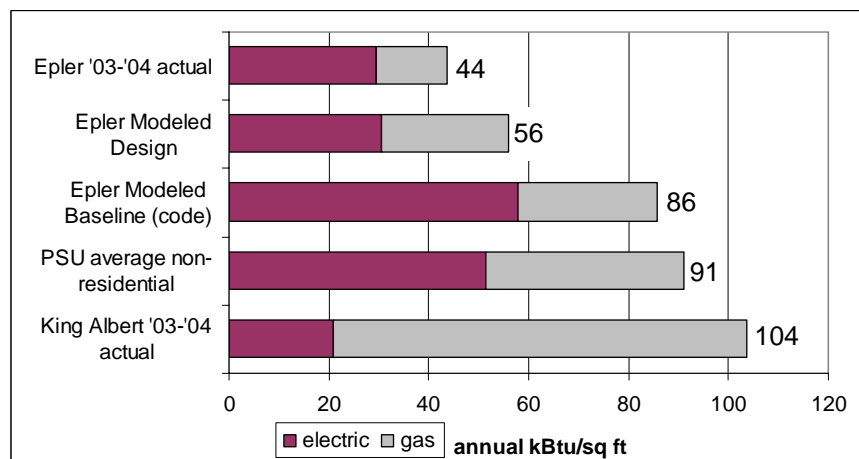


Figure ES-1: Energy use/square foot comparisons



Figure ES-2: East side ventilation. (7/2004)

None of the possible factors of weather, occupancy level, or hot water use appears to explain why energy use was even lower than expected. Remaining possibilities beyond the scope of this study include occupant behavior and better calibration of the characteristics of the initial modeling. The building’s energy saving features include integrated design of siting, window and ventilation placement, and lighting. Premium efficiency natural gas boilers provide heat to the first floor and heat for domestic hot water. Heat recovery units transfer heat from exhausting air to incoming air.

First year water use was 11% worse (higher) than the expected level for the total building and 17% worse for the residential area that represents the bulk of the water use. Even so, the residential use was 25% better than Baseline, as shown in Figure ES-3. Given the lack of detailed U.S. studies on actual water consumption by end use, it is possible that the difference between Actual and Design is within the accuracy of the general modeling assumptions made about average daily use of sinks and showers. Water use per resident is also well below the Portland average and only 38% of that in neighboring West Hall.

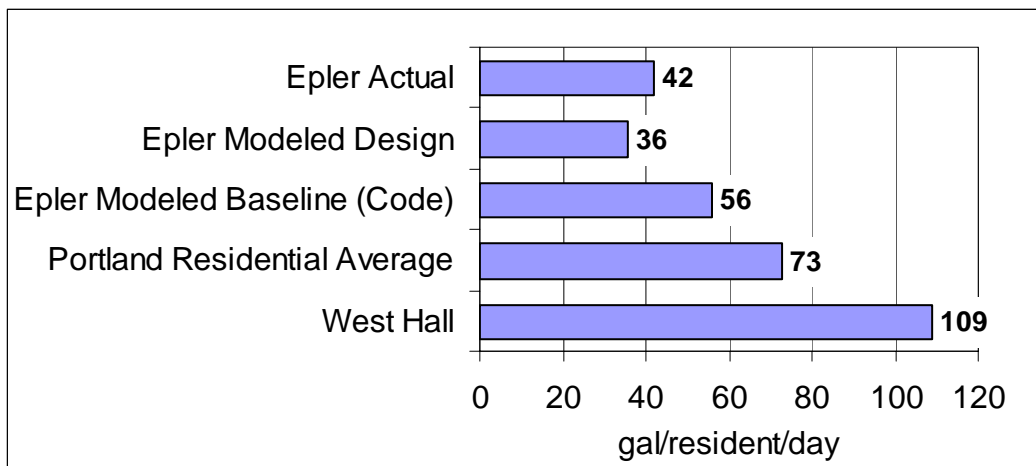


Figure ES-3: Water use per resident, 9/2003 – 8/2004
 All Epler amounts are for residential area only.
 Portland Residential Average from undated Water Bureau report

The water savings came almost entirely from the use of low flow fixtures throughout the building. Epler Hall’s water conserving features also include a rainwater harvesting system. The captured water is used in ground floor toilets and landscaping irrigation. This system did not

contribute materially to first year water savings. The fixtures connected to harvested water represent only a small portion of the building's total. In addition, first year problems with equipment and meters limited the initial performance. The water harvesting system does, however, delay and filter stormwater runoff. It is also one of the most visible green features of the building. It can serve useful roles in positioning PSU's sustainability focus and in providing information to all interested parties on rainwater harvesting in the Pacific Northwest.

Direct Financial Return on Conservation Investments

The design and construction costs for Epler Hall totaled \$10 million. That included a net investment in water and energy conservation features, after receipt of various conservation grants and incentive payments, of about \$290,000. If savings from lower water and energy usage continue at their initial levels, they will generate a return on that investment worth over \$700,000 and generate an average return of approximately 14% as shown in Table ES-1.

Table ES-1: Annual Direct Savings

	Incremental Initial Costs	Annual Savings	25 Year Present Value¹	Return on Investment	Break Even Year
Energy	\$200,000	\$34,000	\$600,000	17%	7
Water, sewer, and stormwater	\$90,000	\$7,000	\$120,000	5%	18
Total	\$290,000	\$41,000	\$720,000	14%	9

Epler Hall's demonstrated first year savings in water use allowed PSU to obtain a reduction of \$79,000 in the system development fees levied by the city on new construction. Similar arrangements may not be negotiable on future new buildings, so this saving is not included in Table ES-1. However, for Epler Hall, this fee reduction will more than cover all the initial costs of the water conservation features. The full report includes details on the various sources of costs and savings and allocation methodologies entering into the above summary.

¹ A present value represents the value today of payments to be received in the future. The present values in this table assume a real discount rate of 3%/year, which the National Institute of Standards specifies for long term life cycle costing of federal energy calculations. That means that, in the absence of inflation, the certainty of receiving \$1 one year from now would have the same value as having \$0.97 today.

Total Societal Benefits

The final study objective was to quantify conservation savings from the perspective of total society. Societal savings differ from the direct savings in three basic areas. The societal perspective excludes any incentive payments or tax reductions received by PSU. It also considers future utility rate increases in excess of inflation that might arise from current rates too low to cover long term marginal costs.² Finally, the societal perspective includes where possible an approximate value of environmental externalities, such as pollution from generating electricity, which are reduced as a result of conservation.

Electricity generation was the only area for which material environmental externality values could be approximated. For electricity, estimated total societal savings were between 90% and 180% of direct savings. (Societal savings of 100% of direct savings means no net increase in savings from the societal perspective.) Environmental externality values for electricity came primarily from the impact of air pollution on human health. Several “unpriced” externality effects remained, such as human and habitat impact of heavy metal emissions, the impact of fossil fuel extraction and depletion, and the environmental impact of dams. Although some published studies have attempted to value these effects on a broad ecosystem basis, linkages between those general studies and the local conditions were too remote to be applicable.

For water, sewer, and stormwater runoff reductions, societal savings were estimated between 110% and 160% of direct savings. In these areas, the societal increase came entirely from economic adjustments related to projected rate increases and estimated long term marginal rates for the current infrastructure. Current high costs, and projected large increases, in Portland’s sewer and stormwater rates show some of the externalities of past sewage handling practices being internalized in the current rate structure. As with the energy analysis, no good basis was found to price environmental externalities such as dam impacts on fish and habitat, or the current impact of stormwater runoff from the PSU campus.

² This aspect could logically be included with a long term view of direct savings. It was included with the societal portion because the likely allocation of these future cost adjustments between direct ratepayers and general taxpayers is often not clear.

Areas for Further Study

Several areas beyond the scope of this study warrant future investigation. Surveys of building users and residents could determine whether Epler's savings are associated with a better or worse perception of the indoor environment. Ongoing measurement of Epler results, and comparison with other new PSU buildings, is needed to determine whether the observed first year performance levels are likely to be maintained. Actual water harvesting system performance can be quantified after the mechanical parts and meters are working. A study of ways to facilitate funding more conservation investments by allocating current conservation savings could help PSU's long-term financial return and its reputation as a sustainable institution.

From the societal perspective, one of the most fruitful areas of research would be providing more basic scientific quantification of the ecological impacts of human activities. On the financial side, studies quantifying demand elasticity for utility services would help model the effect of incorporating externalities in customer rates. Good studies of the true long term marginal cost of utility infrastructures, such as the Portland water supply system, are also needed. With the right pieces in place, the region would be better positioned to address the next proposal for changing or expanding supply infrastructure, in the context of long term cost and environmental perspectives.

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Study Objective and Scope

This study examines the differences made by the conservation and efficiency features of Portland State University's (PSU's) Stephen Epler Hall, from the direct financial perspective of the building owner and also from the broader societal perspective of changes in environmental impacts. The study seeks to answer three questions:

1. Is the building achieving the anticipated energy and water efficiency?
2. What are PSU's direct savings from these efficiency measures?
3. Do the results generate additional societal benefits, beyond the direct PSU savings?

The answers to the first two questions come primarily from actual utility use during the first year occupancy of the building, compared to various benchmarks. These questions are immediately relevant to management of this building and decisions regarding future building at PSU. The third question is potentially relevant in a broader context. Social benefits include avoided costs of infrastructure enhancements or environmental remediation that would be required in the absence of conservation savings. Credible quantification of these benefits could help determine the degree to which society should logically be investing more to encourage environmentally friendly construction.

Residential and commercial buildings account for one-third of total U.S. energy use (Lippiatt, 2002). Franklin Associates (1998) estimated the country's annual construction and demolition waste to be the equivalent of 1000 pounds per person. Buildings affect our hydrology by changing the amount of impervious surface, our indoor air quality through indoor emissions from paints, solvents, and other chemicals used, and our regional air quality and global climate through emissions from generating the energy used in the building. For these reasons, it is no surprise that green building techniques, designed to reduce environmental burdens, are a popular topic. However, most literature on green building is prospective, based on initial design theories and modeling. Few publications analyze post-occupancy building operation or quantify results from a societal perspective that includes changes in environmental impacts. This project addresses that gap, by evaluating the initial actual savings in energy and water/sewer utilities for Epler Hall and the corresponding effects on the building's environmental impact.

Organization

This report begins with a brief literature review of past building performance evaluations, followed by a general description of Epler Hall. Then Part I of the study derives PSU's direct costs and savings in energy and water use, comparing actual performance with several alternative benchmarks. Part I concluding remarks include areas for further study of direct savings.

Part II of the study examines possible valuation of total societal benefits of PSU's conservation. Part II begins with general background on the theory of total social benefit, followed by attempts to apply this theory with relevant available information in the context of Portland, Oregon water and energy sources.

APPENDIX B, Epler Hall Summary Facts, APPENDIX D, Energy and Water Units and Conversion Factors, and APPENDIX F, Terms and Abbreviations may be useful for reference throughout the report.

Limitations and Precision

This study is limited to an analysis of the impacts of direct building operation. It does not extend to other sustainability issues such as life cycle impacts of materials used, urban form or transportation effects, building impacts on individual productivity, or valuing the building's effect on PSU's image. The study uses relevant information from the architect's filings for the U.S. Green Building Council's Leadership in Energy and Environmental Design (LEED) certification for the building. However, this paper is neither an evaluation of the LEED rating system nor of the specific calculations provided in the LEED submission.

The study relies on information available from the university's files, utility bills, and digital control meters in the building. Returns on investment and break-even years are approximate, limited by sparse detail on incremental costs of the building's efficiency components. The variability and uncertainty in the data and estimates used in this study often give credible results to no more than one or two significant figures. For example, one may reasonably say that the building uses about 2.8 billion Btu of energy per year. But stating annual usage of 2.7943 billion Btu would imply far more precision than is justified for future projections. More than two digits are often included in the tables in this report only to avoid magnified rounding errors in subsequent calculations and to facilitate consistency checks among

related numbers. However, the text will often refer only to rounded results. The discussion of societal benefit values in Part II contains additional description of uncertainty ranges.

Background and Related Studies

Building Rating Systems

The U.S. LEED ratings provide the primary third-party certification system in the U.S. for quantifying the “greenness” of a building. Table 1 summarizes the topics covered in the 69 maximum LEED points available. LEED’s evaluation categories are logically related to environmental and general sustainability impacts, and the general public may assume LEED scores to be precise measures of the environmental impact of a building. However, in a review of LEED point allocations from a full life cycle analysis perspective, Scheuer and Keolian (2002) state, “when considered in a life cycle perspective, LEED does not provide a consistent, organized structure for achievement of environmental goals” (p. 93). In addition to having a loose quantitative relationship to actual impacts, LEED’s scores for new buildings are based entirely on the design and construction phase; they do not require actual post-occupancy performance measurement.³ Hence, the LEED score alone for Epler Hall will not be sufficient to quantify the direct or broader societal environmental impacts of its conservation measures.

Table 1: Summary of evaluation points in LEED 2.1

Category / Sample topics covered	Maximum # of Points	Final Epler Points
Sustainable Sites Stormwater management, alternative transportation, heat island impact	14	8
Water Efficiency Water efficient landscaping, water use reduction	5	4
Energy & Atmosphere Expected energy use, renewable energy use, ozone depletion impact	17	5
Materials & Resources Construction waste, materials reuse, recycled materials, local materials	13	5
Indoor Environmental Quality Low-emitting materials, controllable systems, daylighting	15	8
Innovation and Design Credible building-specific items not otherwise addressed	5	3
Total Possible Points Minimum for: certification-26; silver-33; gold- 39; platinum-52	69	33

³ The U.S. Green Building Council has recently introduced a LEED-Existing Building certification process for verifying actual performance after the first five years, based on actual operating results.

Table 1 shows that Epler achieved roughly half the maximum possible LEED points in each category except for Energy & Atmosphere, where the design achieved only 5 of 17 points. Achieving full energy points would include requirements such as projected energy use 60% below building code requirements (Epler's projections were about 33% below), onsite renewable energy, and additional commissioning for fine-tuning building system settings and operations.

Other Green Building Studies

Several studies of building performance and environmental impacts suggest that significant energy and water savings are possible in relation to typical U.S. construction. Operating energy over the life of the building usually appears to be one of the largest sources of environmental impact and potential for direct savings. The following paragraphs briefly describe these studies, and APPENDIX A gives more detail.

Consultants for the Packard Foundation (Packard, 2002) used prospective models to evaluate expected costs, energy use, water use, and energy emissions for six alternative designs for a southern California office building. Modeled energy and water use decreased with increasing levels of green features. LEED silver and gold levels increased estimated building costs in this study by about 15%. After considering operating savings, however, the 30-year present value of all costs were estimated to decrease by 15%, driven primarily by lower energy bills. The authors noted the difficulty in placing values on avoided externalities, and used one study of health impacts of electricity generation emissions as an example of how energy use reductions might be valued.

A study of two new City of Seattle buildings for the Seattle Office of Sustainability and the Environment had a similar perspective: evaluating, in advance of building completion, the anticipated benefit/cost ratios of targeted LEED points (SBW, Inc., 2004). This study evaluated direct costs and savings to the owners, public costs and savings (including subsidy and incentive payments), and secondary or indirect costs such as improved productivity. On a direct basis, benefits ranged from 80% to 110% of incremental costs, with the lower ratio reflecting low occupancy of one of the buildings. Total societal benefits were estimated at 120% to 170% of costs. Most of the societal benefit increments came from improved productivity and comfort assumptions. Greenhouse gas emission was the only environmental externality included explicitly, with a small contribution to the total societal results.

Kats and others (2003) studied the average return on investment of commercial green building in California, including valuations of the social benefits from reduced environmental impacts.

Table 2 shows the 20 year present values of savings as summarized by the authors for areas that are also within the scope of this Epler Hall study⁴, with energy savings of \$5.79/square foot being the largest area by far. Kats' report identified two even larger impact areas than those shown in Table 2, which are not included in this Epler Hall study. Assumed savings from lower frequency of equipment repairs and replacement was valued at \$8.47/square foot over 20 years. For the Epler Hall study, I found no good experience data on which to base similar estimates. The Kats report estimated the value of improved productivity by occupants of green buildings to be over twice the value of savings from all other sources. Such estimates are outside the scope of this report, although evaluation of building occupant perceptions is an important area for future study.

Table 2: 20 year present value of savings in a typical green commercial building in California
(from Kats et al, 2003.)

Savings Source	20 Year Present Value (\$/sq ft)
Lower energy bills	\$5.79
Value of reduced environmental impacts of energy production	\$1.18
Water use reduction (primarily from lower bills; small environmental value also included)	\$0.51

A recent study by Torcellini and others (2004) gave one of the few published U.S. post-occupancy summaries of actual experience in green commercial buildings. The six buildings studied showed a range of energy savings of 12-67% in relation to typical building codes. Most of the buildings experienced energy use per square foot at least as good as design expectations. The authors did not attempt an environmental valuation or to examine impacts other than energy.

Scheuer and others performed a thorough life cycle analysis of the materials and energy impacts of a University of Michigan building, which provides useful background on sources of environmental impacts but no monetary valuation (Scheuer et al, 2003; Scheuer and Keoleian, 2002). The building was fairly similar to Epler Hall, with classrooms and offices on the first

⁴ Present values are often used to compare different irregular cash flow streams. A "present value" is the amount of money you would need in a savings account today to be able to exactly fund a future pattern of costs and savings. See further description in APPENDIX F.

three floors and hotel rooms on the upper three floors. As summarized in Figure 1, the authors found that energy use during occupancy constituted over 80% of all the life cycle energy and emissions from the building. Even for the solid waste generation component alone, the upstream impacts of energy (from mining and fuel transportation) accounted for over 60% of total life cycle impact. Similarly, Kesik (2002) reported Canadian commercial building operating energy represented 85% of a building’s total operating plus embodied materials energy. (Kesik was citing Cole and Kernan in Building and Environment 33(4): 307-317.) Environmental impacts of energy use should be somewhat lower in Portland, because of Portland’s milder climate and relatively high portion of electricity from hydroelectric power. My very approximate adjustment using eQuest modeling software suggests a 20-30% energy use reduction for Portland, compared to a similar building in Michigan, which would not affect these studies’ general conclusions.

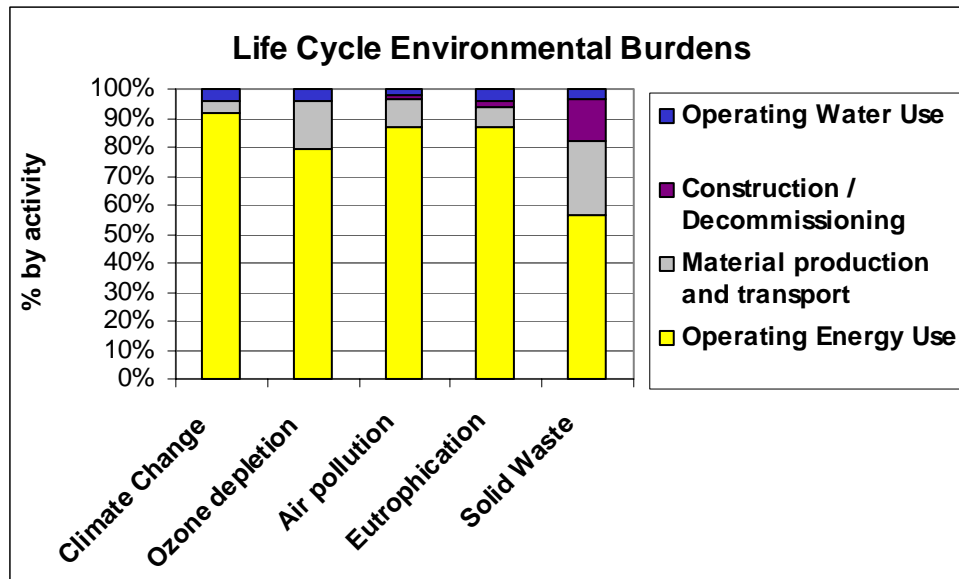


Figure 1: Environmental burdens by activity for a Michigan building (based on Scheuer et al, 2003)

Epler Hall Design

The first floor of Epler Hall houses classrooms and offices. Floors two through six each contain 26 efficiency apartments for individual occupancy.⁵ The building was designed to attain a LEED-silver rating. As was shown in Table 1, nearly two-thirds of Epler’s LEED points come

⁵ APPENDIX B contains a reference table of Epler Hall characteristics

from urban site characteristics, indoor air quality management, and material characteristics such as construction waste handling and use of recycled materials. Only one-third come from the water and energy features reviewed here. As discussed earlier, this paper focuses on the latter features because of the accessibility of data and the predominance of energy effects in other studies of environmental impacts.

Epler Hall's water conserving features consist of low flow fixtures and a rainwater harvesting system. This harvesting system is designed to reduce both urban run-off and city water demand. It captures run-off from the Epler Hall roof, half the roof of an adjacent building, and adjoining walkways. The captured water filters through a series of retention planters (shown in Figure 2) to an underground 8,600 gallon tank. From there it is used in flushing ground floor toilets and landscaping irrigation.



Figure 2: Stormwater planters drain to rainwater storage tank below the plaza (5/2004)

The building was designed to save energy through integrated design incorporating siting, structure, lighting, and mechanical systems. Figure 3 depicts some of these features. The architects optimized window and ventilation features on each face of the building, within the limitations of the small urban lot adjacent to a freeway exit. Air conditioning was eliminated by

providing operable windows in all rooms and stairwells, natural ventilation shafts in the east walls, and window sunshades on south and west walls.

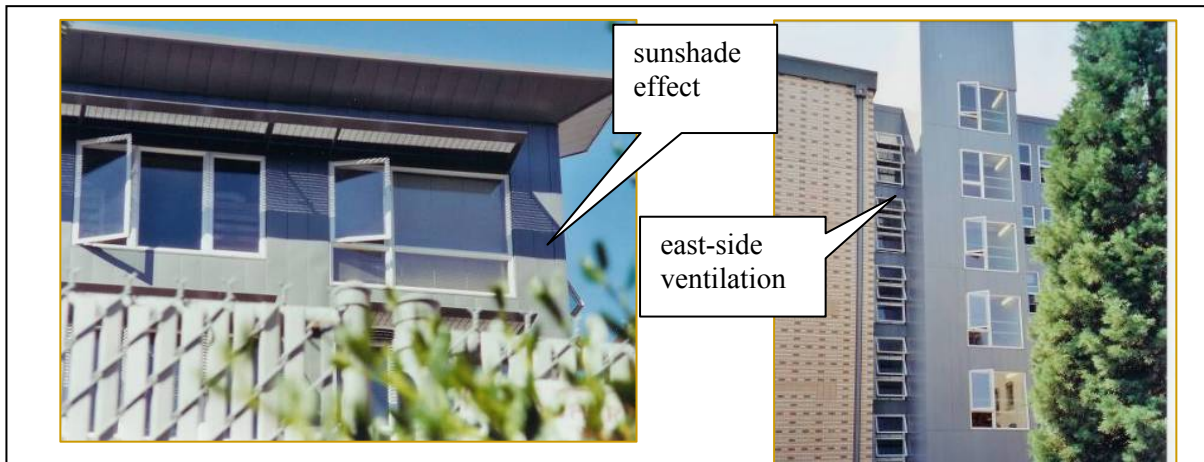


Figure 3: Epler south apartment windows and east ventilation shaft and stairway (7/ 2004)

A commissioning agent performed basic building systems verification and tuning during the year covered by this study. His work in adjusting equipment and the computerized control system should help achieve designed performance of the buildings green features, if future systems are monitored in accordance with the established operating plan and settings for the equipment. Because the control systems were not fully adjusted until part way through the year covered by this study, these first year results may be slightly less favorable than would be expected in future years.

Although this study does not evaluate the impact of materials use, LEED documentation states that at least 25% of all Epler materials meet minimum recycled content criteria.⁶ Manufacturers within 500 miles (the LEED version 2.1 definition of “regional”) supplied at least 20% of the materials. Nearly all internal materials and finishes are certified to be low emitters of volatile organic compounds often associated with indoor air problems.

⁶ LEED procedures specify that such percentages be calculated by cost. In other words, at least 25% of the cost of materials cost for the building was for recycled materials. Recycled materials are defined as those with at least 20% post consumer or 40% post-industrial recycled content.

PART I – DIRECT COSTS AND SAVINGS

Costs of Green Features

Epler Hall’s design and construction cost approximately \$10 million, or \$156/square foot⁷. Records available during the course of this study from the design, contracting, and value engineering stages building do not precisely capture specific costs related to the building’s green features. This lack of detail results from two common characteristics (in addition to the fact that this building study was only begun several months after the building was occupied). Integrated building design reflects many interactions between features, making single feature costs and effects hard to isolate. Further, construction budgeting typically works within a total acceptable price, with many rounds of trade-offs between features and value-engineering adjustments. Increased “costs” of the green features, if they exist, may actually be realized only in terms of other options that might have been foregone.

Table 3 lists approximate costs for the green features of the building, totaling nearly \$400,000. These cost increments give a rough indication of additional spending just for the building’s green features. It is not clear whether all green feature costs have been captured, nor whether proper credit has been taken for offsets such as smaller boiler sizing possible because of efficient integrated design. No cost credit has been taken in this table for the lack of an air conditioning system, which is discussed further in the section on energy performance. Offsetting credits total \$136,000. The Oregon Business Energy Tax Credit of \$42,000 came from a formula credit available to new LEED-certified buildings at Silver or higher levels.⁸ The \$15,000 grant for the rainwater harvesting system was provided by the city of Portland’s Office of Sustainable Development for installing the new conservation technology. The \$79,000 reduction in the city of Portland Systems Development fee for new construction was based on demonstrated first year water use significantly lower per person than the Portland average.

⁷ This cost may exceed that for some university dormitories because of Epler’s individual efficiency apartment format for all residents, each with its own bathroom and small kitchen area. PSU considered the style most compatible with the demands of its older student population.

⁸ Credits from this program may be used to directly offset Oregon taxes over a period of five years PSU used the option to pass-through the credit to a tax-paying entity, because the school is a state university without its own Oregon taxes to offset. The credit shown is the resulting single sum expected to be received in 2005.

Table 3: Identified approximate costs of Epler green features

Category	Feature	Incremental Cost	Offsetting Credits	Net
Energy	Window sun shades	\$125,000		
Energy	Internal energy-saving features	\$50,000		
Energy	Green power	\$6,300		
Energy	Subtotal	\$181,300	\$42,000 Building Energy Tax Credit	\$139,300
Water	Ultra low flow toilets	\$10,600		
Water	Rainwater harvesting system	\$62,000	\$15,000 innovation grant	
Water	Systems Development fee reduction		\$79,000	
Water	Subtotal	\$72,600	\$94,000	-\$21,400
Both water and energy	Building commissioning	\$90,000		\$90,000
Energy and Water	Subtotal of all above	\$343,900	\$136,000	\$207,900
Materials	Pre-demolition salvage, reclaimed old growth for lobby steps	\$25,900		
Indoor Air Quality	Vapor mitigation system, low VOC wheat-board cabinet panels	\$22,500		
Total	All available itemized increments	\$392,300	\$136,000	\$256,300

Most cost figures are from Facilities Department summary documents.

\$50,000 cost of internal energy-saving features from Mithun architects (personal communication).

The total identified costs are 3% (after credits) to 4% (before credits) of the total \$10 million building cost. This percentage is within the range recently reported in other green building studies. For example, Kats (2003) lists incremental costs ranging from 0% to 6.5% for 33 LEED-certified buildings. For another benchmark, the simplified calculations associated with the Oregon Building Energy Tax Credits, based solely on LEED building square footage, give an estimated incremental cost of \$330,000. The total incremental costs and credits in Table 3 are primarily for energy and water-related efficiency features, which are the subject of this study.

Comparison Benchmarks

Because Epler Hall was built in an already densely developed urban site, a number of comparison bases are possible, including regional averages, other PSU residence halls, and modeling in relation to industry standard benchmarks. A comparison of Epler utility usage against existing buildings is relatively straightforward, but limited in accuracy by differences in building ages, sizes, and apartment structures. At the time Epler was built, PSU owned nine other residence halls, with a wide variety of apartment designs and an average construction date

of 1934. The residence halls in Table 4 are the closest possible PSU comparables, and there are clearly major differences between these buildings and Epler Hall.

Table 4: Closest “comparable” PSU residence halls

Building	Year Built	No. of Apartments / Style / Avg Sq Ft per Resident (1)	Nonresidential Uses	Building Heat	Hot Water
Epler	2003	130 apts / all studios / 290 sq ft/resident	1 st floor classrooms and offices	Gas ⁹ and electric	Gas (also gas driers)
West	1986	189 apts / all 1 bedroom / 563 sq ft / resident	-	Electric (paid by residents; total electric usage not available)	Gas
King Albert	1931	64 apts / all studios / 300 sq ft / resident	-	Gas	Gas (also gas ovens)
Ondine	1966	288 apts / ½ with no kitchen; ⅔ with shared kitchens and baths / 230 sq ft / resident	1 st and 2 nd floors offices	Gas	Gas

(1) Per Resident amounts assume average of 1 person per occupied studio and 2 people per occupied 1-bedroom apartment. These assumptions may both be low (John Eckman, PSU Auxiliary Services, personal communication). However, no more precise data was available.

Terminology

State and local building codes specify minimum conservation features for many building components, including water fixture flow rates, insulation, and heating equipment efficiency. Throughout this report, the capitalized term “*Baseline*” refers to modeled performance of a building that is built to comply with, but not exceed, the requirements of those codes. A “green” building feature is considered here to be any optional feature that goes beyond the Baseline requirements. By this definition, a typical new building would probably include some green features. That is because building codes usually function only to prevent use of the least efficient structures and equipment, not to require everyone to use the most efficient technology available or even the most commonly used technology (Johnson, 2003).

The capitalized term “*Design*” refers to anticipated performance of a building with the actual features that are being incorporated. Modeling during the building design typically includes estimating both Baseline and Design performance. “*Actual*” in this study refers to

⁹ Throughout this paper, “gas” energy refers to natural gas.

measured energy or water use from September 2003 through August 2004, unless otherwise specified.

Energy Use

The original Design model estimated Epler Hall energy use at 36% below the Baseline usage of a comparable code-compliant building. As summarized in Table 5, anticipated savings came from lighting, heating, and domestic hot water heat, with lighting efficiency generating 56% of total expected savings. All modeled energy amounts come from eQuest model results reported in the LEED submissions of Mithun architects.

Table 5: Expected energy efficiency savings

All energy amounts in millions of Btu/year (MBtu/yr)

End Use	Baseline MBtu	Design MBtu	Modeled Savings		Design Changes
			MBtu	% of savings	
Heating, fans, pumps	2,305	1,531	774	34%	<ul style="list-style-type: none"> • More roof and wall insulation. • Low-e argon windows. • Heat recovery units for exhaust air. • Premium efficiency heating boiler, fans and pumps.
Lighting	874	384	491	56%	<ul style="list-style-type: none"> • Efficient fluorescent lighting: T8 tubes in public spaces and compact fluorescents in apartments. • Ground floor occupancy and light sensors.
Domestic hot water	1643	914	729	44%	<ul style="list-style-type: none"> • Water conserving fixtures. • Premium efficiency boiler.
Plug loads	758	758	na	na	<ul style="list-style-type: none"> • Assumed average apartment loads.
Total	5,580	3,586	1,995	100%	

Plug loads, representing energy use by office equipment and residential appliances plugged into normal electric outlets, are considered in modeling for Oregon’s State Energy Efficiency Design (SEED) program, although they are excluded from LEED calculations. The Baseline and Design amounts for plug loads in Table 5 are from the building engineers’ SEED filing. The building has no separate metering for measuring plug loads, so those loads are also automatically included in the tabulated actual energy use.

Direct Energy Savings

Actual versus Modeled Energy Use

The building used about 2.8 billion Btu (2,794 MBtu) of electric and natural gas energy in its first year of occupancy, 22% below the Design expectation and about half of the Baseline

model. Table 6 shows these amounts split by electricity and natural gas use for the total building and per square foot. The Actual-to-Design comparison answers the question of whether the building is performing as well as anticipated, showing that the building's energy use is actually outperforming expectations.

Table 6: Epler Hall first year energy metrics (9/2003 – 8/2004)

Measurement	Annual Energy Use			Savings (Baseline - Actual)		
	Baseline	Design	Actual	Saved Annual Energy	Dollars (1)	25 Yr Present Value \$ (2)
Total Building	MBtu			MBtu	Dollars	
electricity	3,709	1,961	1,884	1,825	\$27,000	\$469,000
gas	1,782	1,625	910	872	\$8,000	\$138,000
Building total (3)	5,491	3,586	2,794	2,697	\$34,000	\$606,000
Per Square Foot	kBtu/sq ft			kBtu/sq ft	\$/sq ft	
electricity	57.9	30.6	29.4	28.5	\$0.41	\$7.3
gas	27.8	25.4	14.2	13.6	\$0.12	\$2.1
Per square foot total (3)	85.7	56.0	43.6	42.1	\$0.54	\$9.5
Total as % of Baseline	100%	65%	51%	49%		
Total as % of Design		100%	78%			

- (1) Annual dollar savings based on PSU's Epler Hall rates in effect July 2004 (PGE schedule 83S, \$0.0496/kWh after tax; NW Natural gas schedule 03C, average \$0.89425/therm after tax).
- (2) 25 year Present Value (PV) of savings based on 3% real interest discount rate. All present values in this report assume middle-of-year cash flow timing.
- (2) Differences between total shown and sum of prior lines arises from rounding.

The dollar savings for electricity in Table 6 may slightly understate total electric bill reductions. The savings shown are based only on the per kilowatt-hour portion of electricity bills. Bills also include a demand charge, based on times when the total power being demanded by the building exceeds 30 kilowatts.¹⁰ Efficient equipment may reduce the amount of time in which this charge applies. Epler's variable demand charge, based on a rate for demand in excess of 30 kilowatts, is typically no more than 6% of a total bill.

The difference between Baseline and Actual energy use translates to \$34,000 in utility bill savings in the first year of the building. This report uses present values to put initial expenditures and ongoing future savings on a comparable basis. The present values cover a period of 25 years, which is fairly typical of building life cycle costing (Addison, 2004).

¹⁰ See APPENDIX F for definitions of energy use versus power demand. A 30 kW demand level has commonly been used in Oregon as a breakpoint between small and mid-sized non-residential electric users. Several PGE rate schedules, including Epler's, apply higher demand rates above that level.

Although Epler Hall is expected to have a much longer life than 25 years, the increasing uncertainty of costs in the distant future, plus the ongoing need to replace building mechanical components, make the results of longer projection periods less meaningful. Present values throughout this study use a discount rate of 3% real interest.¹¹ The 25 year present value of the ongoing energy savings in Table 6 is \$606,000, or about 6% of the total \$10 million cost of the building. Allocating the commissioning costs in Table 3 in proportion to the direct water and energy building costs gives a total incremental cost of energy-saving features of \$199,000 (net of the Business Energy Tax Credit). The annual savings provide a 17% return over 25 years on that initial investment, breaking even in year 7. These calculations assume that the rate of future price changes for electricity and natural gas will equal the rate of general inflation. This report considers possible future real price escalation with the societal adjustments in Part II, because such price increases are often associated with the environmental externalities of current energy purchases.

Possible Baseline Adjustments

Differences in building occupancy or weather could possibly explain some of the difference between actual energy use and the Design projections. Each will be considered below.

Weather. The 2003-2004 heating season was slightly warmer than the historic average, which could account for a small portion of the lower-than-expected energy use. The average temperature comparisons were based on heating degree-days (HDD) with a base temperature of 65° F. If a day's average temperature is 60°, that day represents 5 heating degree-days (1 day x 5 degrees below the benchmark temperature). Portland had 3,868 total heating degree-days for November 2003 through April 2004, indicating 6% less heating needed than with the historic average of 4,200 HDD.¹² This 6% difference would make less than 6% percentage difference in

¹¹ A real discount rate is one that reflects the excess of expected long term average interest yields over the general inflation rate. Using a real discount rate avoids the need to incorporate an estimate of general inflation in the future cash flow calculations. The National Institute of Standards and Technology specifies a 3% real discount rate for long term life cycle cost analysis of federal projects (Schultz et al, 2004).

¹² Temperatures from NOAA records for Portland, from ww.wrh.noaa.gov/Portland/climate/daily/temp6751.dly Daily average temperature = average of daily maximum and minimum. Historic average heating degree days based on 1940 through 2003. The "months" in the above summary align with utility billing months, ending on the 6th of the calendar month.

building energy use because not all of the building energy is for heat. Some studies have indicated that commercial building energy prediction should be based on a multivariate model incorporating wind, humidity, and internal heat gain (Krarti, 2000). However, a simple linear regression of energy use compared with temperature showed a good correlation ($r^2 = .90$) for both gas and electricity use in Epler's first year. The regression suggests that each heating degree-day above normal reduces electricity use by 40.3 kWh and reduces gas use by 1.08 therms. Applying those factors, actual electricity use would have been 3% higher, and actual gas use 5% higher, if the year had been as cold as the historic average. These refinements would give weather-adjusted actual energy use 19% below Design projections, with a \$580,000 present value savings over 25 years and a 16% return.

Occupancy. The residence portion of the building was fully occupied throughout the 12 months from its opening in September of 2003, so low occupancy rates are not a factor in lower energy use. Although first floor classroom utilization was lower than expected, the floor was still open and in partial use during normal class hours. Therefore, the underutilization would make minimal difference in total building energy.

The timing of PSU's winter break may result in slightly lower use than expected, if the lower winter break occupancy wasn't considered in the original energy modeling. PSU and its residence halls are open for the entire year including summer term, but there are no classes in most departments during the last three weeks of December or the first three weeks of September. Because PSU's utility billing months actually end mid-month, the December break falls primarily in the January billing month. Figure 4 shows Epler's January gas use to be below the regression line, although not enough lower to fail a statistical screen for suspect data.¹³ For more accurate statistical determination of whether energy use is lower in December, more than one year of data is needed. Figure 4 also shows the relationship between gas use and heating degree days for King Albert Hall over several years, and does not appear to show any consistent under-use in December or January.¹⁴

¹³ The standardized residual for Epler's January gas use is just under 2, the value with a probability of 5% of arising solely from random variation about the regression line.

¹⁴ The much older King Albert Hall may also lack some individually adjustable systems, which would make it less able to respond to lower winter-break occupancy than is Epler.

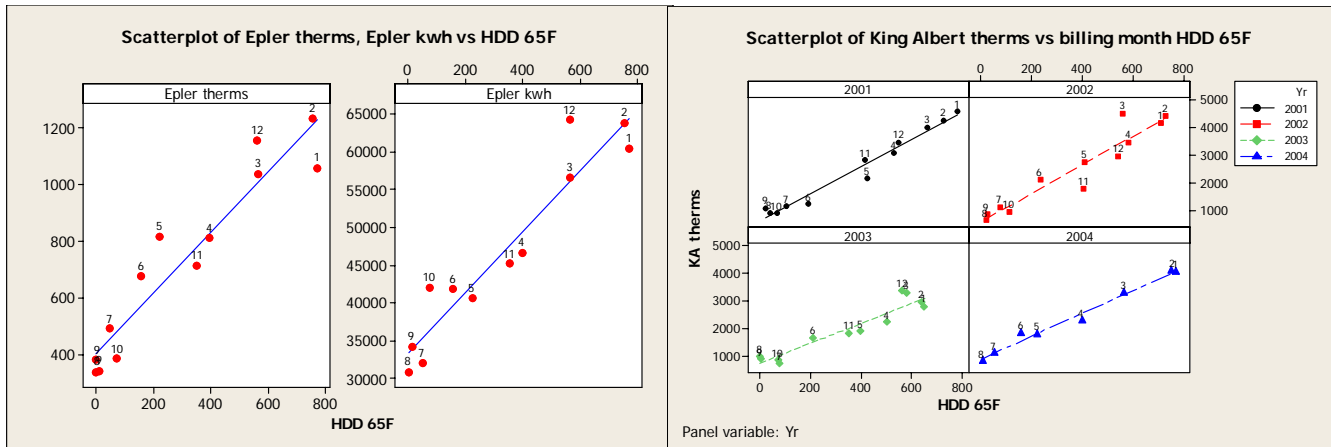


Figure 4: Epler and King Albert Hall energy use compared to heating degree days

Further understanding of the difference between modeled and actual results would require a combination of additional submetering and modeling, both of which are outside the scope of this paper. For example, Table 7 indicates one possible allocation of actual natural gas use between building heat and domestic water heating, based on the assumption that hot water heating is level throughout the year. The accuracy of the assumption could only be confirmed by additional measurement detail. This allocation shows both domestic water heating and general heating below expectations. Part of the lower energy used to heat water could theoretically arise from lower use of hot water. However, as will be seen in the section on water use, total water volume was actually slightly higher than Design expectations.

Table 7: Estimated allocation of first year gas usage by end use (MBtu)

Use	Design projection	First year estimate by use	First year estimate basis
Domestic hot water	914	400	12 x August use, assuming level hot water use through the year and no August building heat
Heating	710	510	Total minus domestic hot water
Total	1625	910	Actual first year total from Table 6

The building’s heat recovery units could perhaps explain a portion of the low gas use. It is not clear whether they were incorporated in the design modeling. These thermal wheels are designed to recover at least half the temperature difference between outgoing and incoming air, transferring that recovered heat to the incoming air (Dieckmann et al, 2003). If the heat recovery units did reduce gas use for building heat by 50% below the originally calculated Design levels, that would reduce total Design gas use by 22%.

The calculated Baseline minus Actual savings may also have been affected by heating configuration assumptions in the Baseline model. The allocation of savings between gas and electric bills in Table 6 is, in part, an artifact of the Baseline modeling, which assumed an electric heat pump for building heating. Because the final design used a hot water boiler for part of the heat, the savings appear to be primarily electric, while the underlying efficiency measures incorporate a premium efficiency *gas* boilers for central heat. It is possible that modeling a “to-code” Baseline with gas heat would generate materially different Baseline energy use.

The use of computers and other small appliances by building occupants is another source of variation that could not be measured with the information available for this study. That difference, however, would affect only electricity, while most of the difference between Design and Actual use was for natural gas.

Other Energy Use Comparisons

As noted in the Baseline minus Actual comparisons above, savings calculated in relation to a theoretical Baseline are affected by many nuances of Baseline assumptions. Thus high savings from this perspective doesn’t necessarily mean lower energy use than other current buildings. In fact, a study by the New Buildings Institute (2003) noted that office buildings designed with above-code efficiency features do not necessarily have the lowest energy use per square foot, even when adjusted for basic characteristics such as operating hours, density of computers, and density of occupants. Some differences arise from occupant and operator behavior, which are also a factor in the Baseline minus Actual comparisons. Other differences come from non-code building features that affect energy use but may not be in the “efficiency upgrade” calculation of savings. For example, the fact that the building was designed for natural ventilation in lieu of air conditioning represents a savings in initial equipment purchase and ongoing energy use, but that savings is not included in the Table 6 calculations. A literature review uncovered no general references for estimating net cost savings from eliminating air conditioning in a multi-story residential building in the Portland, Oregon climate. Because of the complex interactions of building heating and ventilation systems, a good estimate would require running a locally calibrated building energy model comparing air conditioning and natural ventilation. The closest estimate I found was from the Seattle Energy Matrix, a tool provided by

the city of Seattle for evaluating green building alternatives.¹⁵ That tool estimates savings for replacing air conditioning with natural ventilation for a 4 story, 50,000 square foot office building. The savings were \$370,000 in initial costs and \$700/year in ongoing electricity costs. Although the building is similar (slightly smaller) to Epler, and the climate is similar, the Energy Matrix tool cautions against extrapolating results to buildings of a different type.

Energy Use Intensity

To determine whether Epler Hall is a relatively low energy-user in this broader sense, comparisons should be made with actual energy use in comparable occupied buildings, but finding truly comparable buildings is difficult. Figure 5 shows Epler's actual energy use/square foot (Energy Use Intensity, or EUI) with a number of possible benchmarks. Comparing actual EUI among various buildings incorporates both building features and occupant behavior. The results are displayed on the following page.

¹⁵ www.ci.seattle.wa.us/Implement/matrix.asp?IDT_ID=8. Accessed 5/18/2004.

The benchmarks in Figure 5 fall into several basic categories:

Epler results from Table 6 for each of Actual, Design, and Baseline.

Other PSU buildings. The actual EUI for West, King Albert, and Ondine residence halls.

Because West Hall has individually billed electric heat in each apartment, total heating energy information was not available. Note, however, that West Hall's *non-heating* energy use intensity is almost as high as Epler's *total* energy use intensity. The average of PSU's non-academic buildings (Moore, 2003) is also shown.

Commercial Building Energy Consumption Survey (CBECS) data for several possible categories of comparable buildings (Energy Information Administration, 1999). Epler's actual performance is noticeably better than any of the categories shown (Energy Information Administration, 1999).

Energy Star Target use, as calculated with the EPA's online tool.¹⁶ This calculation shows that Epler's actual performance is within the Energy Star range, better than at least 75% of comparable buildings.

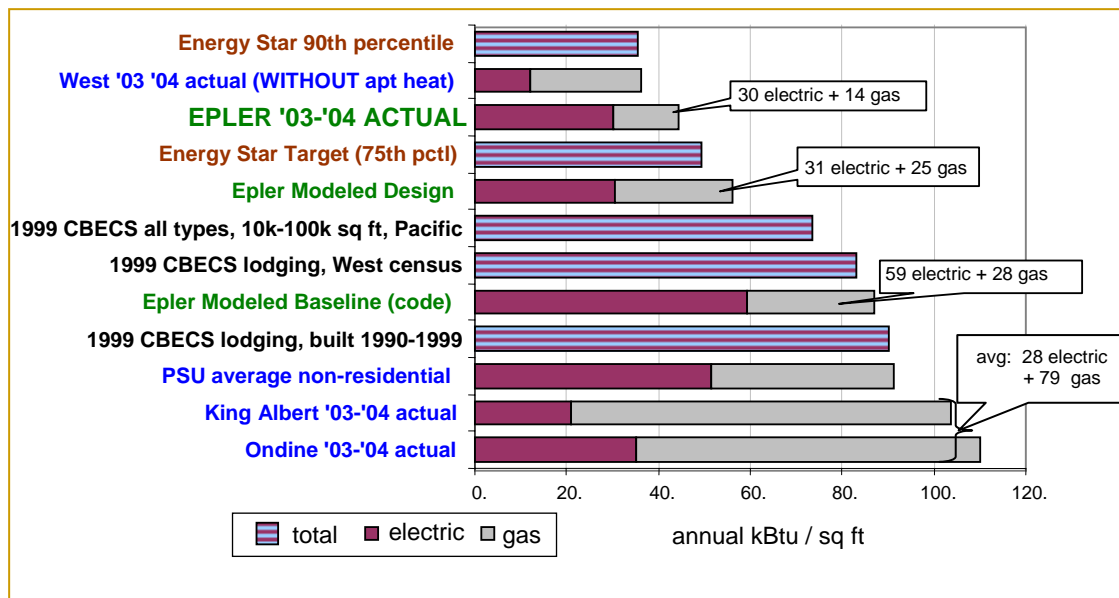


Figure 5: Energy Use Intensity comparisons

On the basis of these comparisons, Epler appears to be an efficient building in terms of overall energy use, as well as achieving modeled savings from its “better-than-code” features.

¹⁶ www.energystar.gov/index.cfm?c=target_finder.bus_target_finder. Input geographic location, floor area split between office and residence hall portions, occupancy of each portion, 100% heated and no air conditioning.

Instead of calculating savings in comparison to the modeled Baseline, one might compare Epler energy usage against the older residence halls, which Figure 5 shows to have average energy use per square foot nearly 2 ½ times that of Epler. This comparison demonstrates the magnitude of potential energy savings from upgrading or replacing the older buildings (excluding the costs of retrofitting an older building, which may often be prohibitive). The comparison with older buildings also brings out several complicating factors involved in determining a single dollar amount of annual “savings.” The “Older Halls” benchmarks used in Table 8 below are the simple average of King Albert and Ondine residence hall usage, expressed per resident and, alternatively, per square foot. The resulting total building savings are \$32,000 on a per-resident basis, but \$37,000 on a per square foot basis.

Table 8: Energy comparison with older residence halls

Basis for Savings Calculation	Annual Savings	
	MBtu/year	\$1000/year
Epler Modeled Baseline – Actual (from Table 6)	2,700	\$34
Older Hall Actual/res – Epler Actual/res (1)	3,600	\$32
Older Hall Actual/sq ft – Epler Actual/sq ft (2)	4,000	\$37

- (1) Resident-based total savings = (Other Halls/resident – Epler/resident) x 130 residents.
 (2) Area-based total savings = (Other Halls/sq ft – Epler/sq ft) x 64,000 sq ft.

The difference between the resident-based savings and the area-based savings reflects the smaller average floor area/resident in Ondine, a significant factor from the conservation perspective that is not reflected in EUI or modeled Baseline minus Actual comparisons. Also, the dollar savings in Table 8 are not proportionate to the energy savings because of the different mix of electricity and gas in the different buildings. Compared to the other residence halls, Epler derives a greater percentage of its energy from electricity, which currently costs more per kBtu than does natural gas.¹⁷ Hence Epler’s dollar savings in the residence hall comparison are not as high as would be expected on the basis of the Btu savings. These results show some of the potential pitfalls in comparing energy use and costs between different studies. Actual energy use and charges can be measured fairly precisely. However, differences in building characteristics, energy sources, and comparison basis must be considered before extrapolating cost savings from one building to another.

¹⁷ Electricity = \$0.0496/kWh x 0.293 kWh/kBtu = \$0.0145/kBtu.
 Gas cost = \$0.89425/therm x 0.01 therm/kBtu = \$0.00894/kBtu

Functionality

Increased energy efficiency means accomplishing the same useful service while using less energy. Without considering the satisfaction of the building's occupants, we know only whether a building has lower energy use, but not necessarily whether that comes from more efficiently delivering the same benefits to occupants. A series of post-occupancy evaluations by Standeven et al (e.g. 1999, 1998) found a wide variety of occupant perceptions of winter and summer temperature comfort, air quality, lighting, and noise levels. A general PSU residence hall survey done by College Housing in the spring of 2004 gathered a little information on general satisfaction with apartments and specific satisfaction with temperature control. Epler residents rated temperature control satisfaction just slightly above neutral: 4.3 on a scale of 1 to 7, compared to a 3.5 average for the other PSU residence halls in this study. This result suggests that Epler's heating efficiency measures did not reduce residents' winter comfort levels, although anecdotal reports suggest that apartment baseboard heaters were sometimes turned on while windows were open. The favorable total building energy usage resulted despite this residential behavior and some office use of supplementary space heaters by desks because of drafts from the heating and ventilation system.

The residents' survey was completed by students who had not yet experienced a summer in the building. Follow-up surveys or direct measurements regarding non-air conditioned apartment temperature in the summer would be informative. Anecdotal conversations with workers in the first floor office area suggest that their temperature control was far from optimal during the first summer. Operable windows could not be reached, making west-facing offices very hot. The Facilities Department subsequently corrected this situation by providing tools to reach and operate the windows, which should alleviate the problem in future summers.

Water Use

Epler Hall uses water in three distinct regions: the residence portion, classroom and office space on the first floor, and irrigation. The residence portion constitutes over 90% of total use. Total water savings come from two sources. The most significant in terms of volume is the use of fixtures with lower flow rates than the maximum rates allowed by building codes. Secondly, a rainwater harvesting system used for first floor toilets and irrigation, though small in relative volume, provides a prototype for evaluating the functionality of capturing rainwater in

this way. The analysis below looks first at total water use. A separate analysis of the water harvesting system follows.

Total Water Use

Figure 6 and Table 9 show average daily water use in Epler Hall, split by the three usage regions. The Baseline numbers reflect expected water use with fixtures compliant with the Energy Policy Act of 1992. The Design case, which reduces expected water use by 28%, reflects the same model calculations but with flow rates of the actual installed fixtures.¹⁸ Total first year actual use was 11% above the Design estimate, with a wide difference in actual/Design ratios by region.

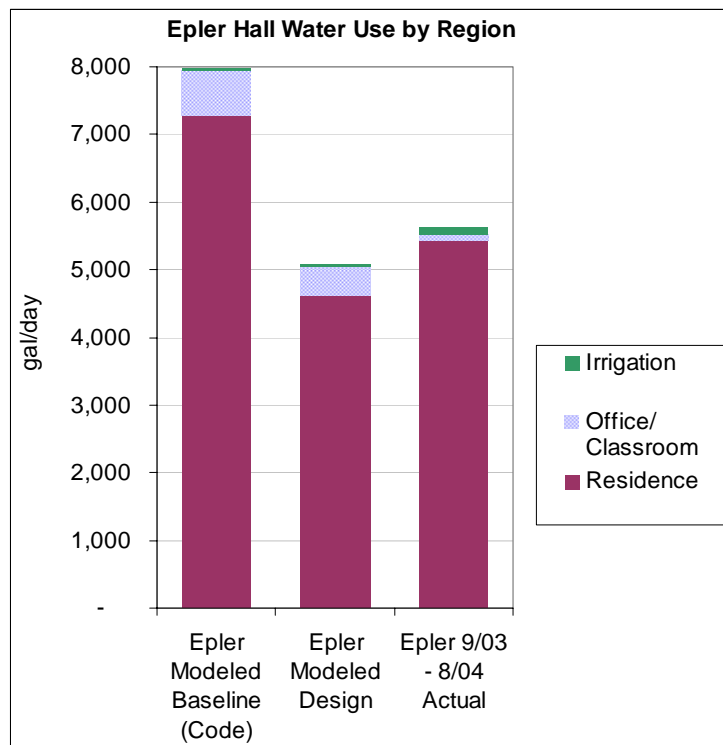


Figure 6: Comparison of average daily water use by region

¹⁸ Baseline and Design totals derived from modeled results in the LEED submission by Mithun architects. Design totals in this report were adjusted from those model results to reflect actual fixtures where the installed fixtures differed from the Design assumptions. This adjustment resulted in a slight reduction from the original Design expectations.

Table 9: Total water use (avg gal/day)

Region	Baseline (1)	Design (2)	Actual (3)	Actual / Baseline	Actual / Design
Irrigation (4)	47	25	104	223%	413%
Classroom/Office	663	424	97	15%	23%
Residence	7,280	4,621	5,428	75%	117%
Total	7,990	5,070	5,629	70%	111%

- (1) Epler Baseline, with fixtures compliant with the Energy Policy Act of 1992.
- (2) Epler Design, with flow rates of the final installed fixtures. (The primary final fixture from specifications was to replace just-compliant washing machines with high efficiency models.)
- (3) Actual for September 2003 through August 2004.
- (4) Baseline irrigation shows typical established lawn requirements.
Design irrigation reflects reduced requirements for established landscape plantings, as opposed to lawn.
All amounts in the table are average daily amounts over the entire year, so irrigation amounts/day shown in this table are much lower than they would be if averaged just over the summer months in which irrigation occurs.

First year irrigation was much higher than the Design level, in order to establish the new plantings, but campus landscape management expects ultimate irrigation requirements to be in line with the Design levels (Scott DeSelle, PSU Facilities, personal communication).

The classroom/office area used only 23% of its Design-anticipated water volume. The difference is largely because first year classroom occupancy was just 29% of the anticipated levels (detail in Appendix Table C-1). Water use in the classroom area is likely to increase in the future as classroom utilization grows.

The residential area uses most of the building's water, and residential use was 17% above the Design expectations. Additional water metering would be needed to determine the source of this excess. As shown in Table 10, showers and kitchen sinks were the two largest expected water users. Expected volumes incorporate assumptions of 9 min/person/day for showers and 6 min/person/day for use of kitchen sinks. Replacing those assumptions with 11 and 7 minutes respectively would be one hypothetical explanation of the above-expectations water use. There are few studies of actual average U.S. water-use durations at this level of detail. Particularly for these fixtures where hot water is usually used, the distance from the third floor hot water storage tank to rooms could also factor into relatively long tap times.

Table 10: Estimated residential water use by fixture type (gallons/day)

	Baseline	Design	% Total Design Volume
Bathroom sinks	325	130	3%
Toilets	520	481	10%
Laundry	1,560	499	11%
Kitchen sinks	1,950	1,170	25%
Showers	2,925	2,340	51%
Total	7,280	4,620	100%

Data sources:

Baseline: Stephen Epler Hall LEED Certification Application

Design, Pre-'80 and '80-'94 Fixtures:

$$\frac{\text{applicable flow rate} \times \text{Design volume}_{est}}{\text{Design flow rate}}, \text{ fixture flow rates shown in Appendix Table C-2}$$

Although actual residential use exceeded the Design expectations, it was still well below the Baseline level. Comparing with citywide averages, Epler’s total first year residential water use of 42 gallons/resident/day is much less than Portland’s overall average of 73 gallons/person/day (Portland OR, Bureau of Water Works, 2003). It is also below the range of 50 to 70 gallons/person/day reported for Portland multifamily dwellings (Portland OR, Bureau of Water Works, undated). As seen in Figure 7, other PSU residence halls use even more water than the Portland average, almost double the amount per resident used in Epler.¹⁹

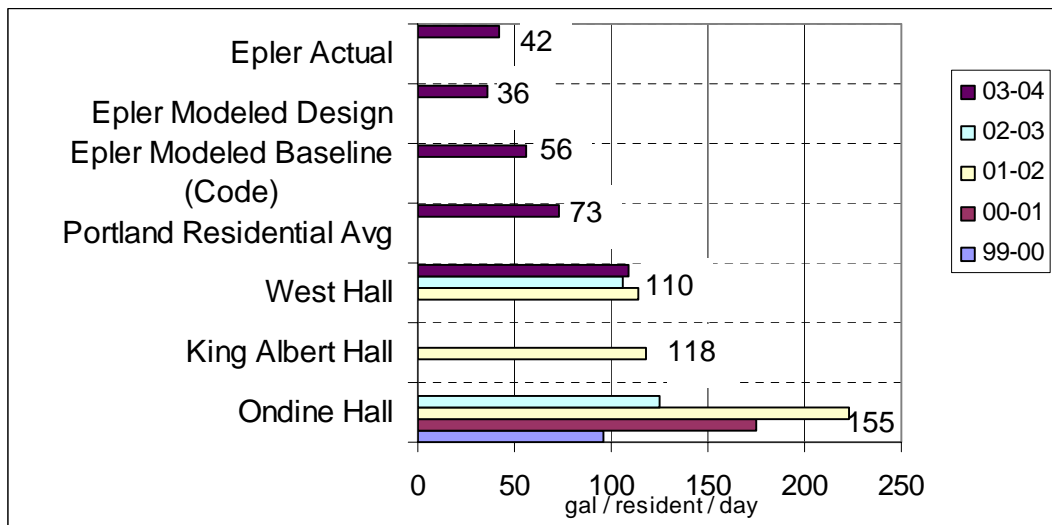


Figure 7: Water use/resident comparisons
 Epler amounts for residential area only
 Averages shown for halls with multiple years available

¹⁹ Actual water use data for other residence halls is missing for some years, and the Ondine pattern has been somewhat erratic, possibly affected by leaks or changes in handling of office use in the first two floors.

Residential Water Bill Savings

Epler's direct savings arising from lower water use were approximately \$6,200 the first year, as shown in Table 11. These savings were calculated just from the residential portion of the building, because irrigation use is small and with poor initial data, and the classroom/office use was affected by low initial occupancy.

Table 11: Residential water savings (9/2003 – 8/2004)

	Epler Baseline (1)	Epler Actual	Epler Savings Baseline – Actual
Gal/day/resident	56	42	14
ccf/yr for 130 residents	3,552	2,649	904
Annual water bill savings (2)			\$1,554
Annual sewer bill savings (3)			\$4,643
Annual total direct savings			\$6,197

(1) Epler Baseline from LEED calculations with fixtures compliant with the Energy Policy Act of 1992.

(2) Water bill savings use current (2004-2005) Portland Water Bureau band 1 rates of \$1.72/ccf.

(3) Sewer bill savings use current (2004-2005) Portland Environmental Services sewer volume rates of \$5.138/ccf.

PSU's ability to demonstrate low water use resulted in a \$79,000 reduction in the system development charge levied on the new buildings by the city (McBride, personal communication). This and other cost impacts related to water management will be totaled after the discussion of the rainwater harvesting system.

Water Harvesting System

The water harvesting system captures rain from 21,400 square feet of impervious rooftop and pavement plus 7,600 square feet of turf and landscape plantings (see Figure 8). The collected water then filters through stormwater planters and drains to a storage tank with a capacity of 8,700 usable gallons. From there it is further filtered, treated with ultraviolet light, and used in first floor restroom toilets and drip irrigation of 3,000 square feet of native landscaping. As was shown in Figure 6, the demand for harvested water is small in relation to total building water demand. However, in addition to serving as a demonstration project for a supplementary water source, the system delays and filters potentially polluted quick run-off that would otherwise flow through the city's stormwater pipes directly into the Willamette River.

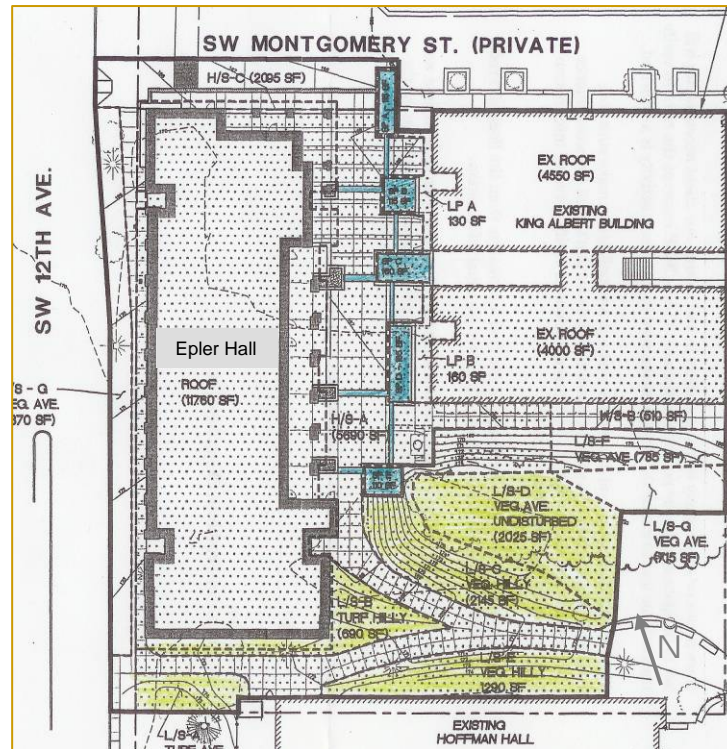


Figure 8: Site drainage to rainwater harvesting system

Dotted areas drain to stormwater planters. Vegetated areas in light green. Stormwater planters, rooftop runoff channels, and planter drainage connections in darker shading. (Diagram from Mithun architects' LEED submission)

Rainwater harvesting presents a challenge in western Oregon because abundant rain falls in the winter, while irrigation needs and system-wide peak water demands occur in the dry summer season. Figure 9 illustrates this pattern, based on average monthly rainfall and expected demand from the water harvesting system as calculated for the LEED submission by Mithun architects. Typical monthly fall, winter, and spring rainfall far exceeds the anticipated monthly demand for harvested water from the first floor restrooms and the capacity of the storage tank, which can be filled with just over $\frac{1}{2}$ inch of rain. In this Design model, average monthly summer rainfall appeared sufficient to supply almost all the modeled Design level summer demand. Irrigation demand in this view was based on the assumed requirements for mature landscaping, thus adding only a small increment in the summer over the assumed level demand from the restrooms.

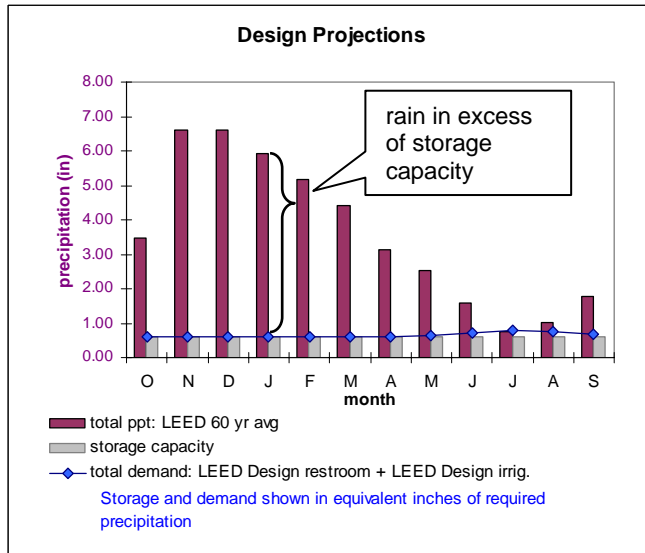


Figure 9: Design level water harvesting

Data sources:
 All from Stephen E. Epler Hall LEED submission
 Irrigation at predicted levels for established landscape

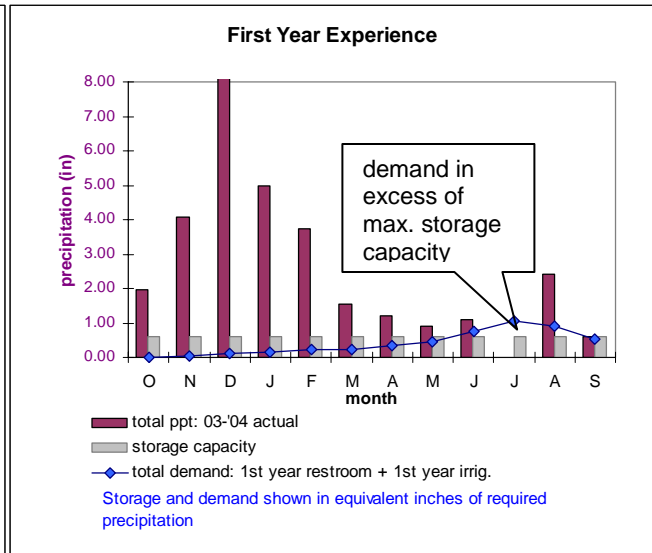


Figure 10: 2003-04 water harvesting potential

Data sources:
 Precipitation: city Hydra gage at 12th and Clay
 1st Floor Rest rooms: approximate meter readings
 Irrigation: 1st yr . 4 x expected long term levels for established plantings

Precipitation in Epler Hall’s first summer differed from the average pattern, as seen in Figure 10. The storage tank holds less than 30 days of summer anticipated demand, so the *daily* pattern of rainfall and use, not just the monthly total, is what determines how long stored water will last. The summer of 2004 had a stretch of 57 days, June 9 to August 5, with measurable rain on only three days, and none of those days had over 0.03 inches. Those barely measurable amounts were too little, given dry starting conditions, to provide water for the harvesting system. (See Appendix Table C-3 for additional rainfall statistics.) On the first year demand side, total restroom plus irrigation demand was above Design projections for July and August, because of higher first year irrigation for new plantings. The long dry spell meant that storage tank capacity would be depleted by the middle of peak irrigation season, even with lower than anticipated first floor restroom use.

Several first year problems prevented gathering reliable data on how much harvested water was actually used in the first year. Figure 10 shows approximate first year demand for harvested water. However, the system was using city water for portions of that demand, even when harvested water should have been available, for parts of the year. The harvesting system was temporarily shut down while waiting for replacement parts. In addition, the pump bringing

water out of the storage tank developed an overheating problem in the summer of 2004. Thus the harvesting system was only operating intermittently during the potentially most useful season. Further, an incompatibility problem between the initial water meters installed and the computerized Siemens systems controller caused only sporadic and incomplete water readings to be available during the first year of operation. Actual first floor and irrigation results in this paper are therefore estimated based on intermittent reliable readings. Also, a stuck valve in the water main leading to the irrigation system at the beginning of May, 2004 resulted in a waste of 29,000 gallons of water over the course of one weekend. That represents about 1% of buildings total annual water use, and is one factor to consider in the precision of first year results.

Despite these data limitations, the available information suffices to generally evaluate the initial projections, estimate potential savings from the system, and develop a template for future more precise monitoring of Epler results. Because of the problems with the first year water harvesting system, estimated future harvest volumes will be used for the calculations of net benefits. (See Appendix Table C-4 for assumptions in the estimated future harvesting demand.)

Water Harvesting System Direct Costs and Net Savings

Table 12 summarizes PSU's costs and savings for the water harvesting system. Although harvested rainwater reduces the use of city water, the resulting savings at current billing rates are just \$180/year, only slightly higher than the projected annual operating and maintenance costs of the system.

Table 12: Costs and savings components of water harvesting system

Description	Cost	Savings	Source / assumptions
Initial system	\$71,000 initial		\$62,000 total contractor's cost, minus \$15,000 city of Portland Emerging Technology grant, plus \$24,000 allocated costs from building commissioning
First year engineering support for commissioning	\$800 initial		Est 8 hrs at \$50/hr for Facilities Engineering time correcting water meters, dealing with required part replacements, etc.
Operations and Maintenance - planter drainage - filter, pump, UV unit	\$200/yr \$110/yr	future est. \$500/yr	<u>cost estimates:</u> Est 4 hrs planter maintenance at \$50/hr (1) Est 2 hrs maintenance at \$50/hr, plus \$10/yr for electricity to pump and UV treatment unit (2) <u>stormwater runoff savings estimates:</u> from BES discount program calculator
Water bill savings		\$180/yr	Long term irrigation levels as in LEED design, projected classroom/office use at 75% of LEED design assumptions (volumes in Appendix Table C-4)
Total	\$71,800 initial \$310/year	\$680/year	

- (1) Bureau of Environmental Services suggests stormwater planter inspection and maintenance 2 – 4 times per year, and within 48 hours of each major storm event.
- (2) Pump electricity: Gould 33GS 30 – 3 h.p. = 2.24 kw. Assume average 20 gal/min when pumping.
71,000 gal/yr → 59 hrs/yr → 132 kwh/yr. 132 kwh/yr x \$.066/kwh = \$8.74/yr
UV treatment electricity: 24 gpm unit uses 95 watts (for Raindance model S-24Q, which appears typical.)
Assume operating when pump operates.
59 hrs/yr → 5.6 kwh/yr. 5.6 kwh/yr x \$.066/kwh = \$0.37/yr
Pump and UV replacement costs, not explicitly included:
 - o Average sump and well pump lifetime – 10 yrs. (WA State General Administration Dept , undated)
 - o UV treatment system maintenance: frequent cleaning; ballast replace after 10 yrs; quartz sleeve replace after 5 yrs (EPA, 1999a)

Portland's Bureau of Environmental Services (BES) is planning a future discount for stormwater run-off charges, applicable to property with onsite systems to delay and reduce runoff. The Epler stormwater planters gather runoff from 21,400 impervious square feet and would be eligible for this discount. Preliminary estimates show that Epler's stormwater planters may reduce future stormwater charges by about 24% (\$500/year at current rates of \$6.06/month/1000 impervious square feet).²⁰ BES has not yet determined whether additional reductions will be available for the water harvesting features, beyond those generated by the front-end collection portion of the system.

²⁰ From Environmental Services Clean River Incentive and Discount Program: Commercial, Industrial, Institutional and Multi-Family Residential Calculator (Available: www.portlandonline.com/shared/cfm/image.cfm?id=36306), with 21,400 impervious sq ft draining to planters.

Total Water Costs and Savings

Table 13 summarizes all identified direct costs and savings of water conservation features. Combining all these features, the total ongoing utility bill savings in water, sewer, and stormwater charges could recover the total incremental costs of all water conservation measures after 18 years, yielding a 5% real rate of return over the first 25 years. If the one time reduction in the Systems Development fee is included, the break-even year moves up to 2006 (the year in which the annual fee reduction is assumed to begin), and the total conservation features provide a 19% return on initial investment over 25 years. As in the section on energy costs and savings, these present value calculations use a real discount rate (the excess of interest rates over inflation) of 3% and assume that future billing rates will increase at the same rate as inflation. Currently expected increases in water and sewer rates actually exceed the rate of general inflation, a fact which would further increase the projected total value of savings. This effect is reviewed further in Part II of the study, regarding total social savings of the building's green features. The direct costs and savings are discussed in more detail below, separately for the low flow fixtures and for the rainwater harvesting system.

Table 13: Lifetime direct costs and savings of water conservation features

Feature	Incremental Costs	Direct Savings	Net 25 Year Present Value (5)
Lower flow fixtures (1)	<ul style="list-style-type: none"> • \$11,000 initial purchase, installation • \$6,000 allocated commissioning cost 	\$1,600/year water \$4,600/year sewer	+ \$90,000
Water Harvesting System (2)	<ul style="list-style-type: none"> • \$47,800 initial purchase, installation • \$24,000 allocated commissioning cost • \$200/year inspection and maintenance of stormwater planters 	\$500/year potential future stormwater runoff charge reduction	- \$64,000
Harvested water use (3)	<ul style="list-style-type: none"> • initial cost included above • \$110/year periodic part replacement and maintenance 	\$180/year city water savings	
Total before Systems Development (SD) Fee reduction	\$88,800 initial \$310/year	\$6,890/year	+ \$26,000
SD Fee reduction (4)		\$79,000 yr 2	+\$74,000
Total after SD Fee reduction			+\$100,000

(1) Fixture savings average from Table 11.

- (2) Initial costs for entire stormwater harvesting system. Stormwater planter direct savings from Table 12, assumes stormwater discounts take effect 7/2005.
- (3) Harvested water costs and savings from Table 12.
- (4) For demonstrated water use significantly below average, assumed received in 2005.
- (5) Present values assume real interest discount rate of 3%.

Most of the utility bill savings from lower flow fixtures add directly to PSU's bottom line. Plumbing fixtures and appliances are available at a wide variety of prices, and most of the reduced flow fixtures used are not identifiably more expensive than alternatives. The \$11,000 initial incremental cost shown in Table 13 was for adjustment of the 130 apartment toilets to use 1.4 rather than 1.6 gallons per flush. The building design team rejected water reduction alternatives with higher costs, such as dual flush toilets, in the value-engineering stage. Further, discussion with building engineers reveals no reason to anticipate additional maintenance for the systems and fixtures using city water. Actual water use below the Baseline level also generates energy savings, through reduced requirements for hot water heating. These savings would be roughly 13% of total energy savings, worth about \$3,000/year.²¹ To avoid double counting in this report, these energy savings are not included in the water conservation total. However, a return on investment calculation just for low flow fixtures, used for example to decide whether to replace existing faucets with lower flow models, should include the energy savings. In this example, adding the \$3,000/year energy savings to the total water-related costs and savings would increase the present value of fixture savings in Table 13 from \$90,000 to \$141,000.

In contrast to the low flow fixtures, the water harvesting system results in a net direct cost to PSU. Direct savings come from the reduction in city water bills for harvested water replacing city-provided water and from projected future reductions in stormwater runoff charges. The run-off related savings could be achieved just from rain collection and filtering through the stormwater planters, without the more complex pumping, treating, and plumbing required to use the rainwater on site. The schematic in Figure 11 illustrates the division of the total system between the front end detention/delay and back-end harvesting and use components.

²¹ Assume the shower and kitchen sink modeled water volumes in Table 10 give a rough estimate of the percentage reduction in hot water use, resulting in Design hot water use equal to 72% of Baseline. Then the expected reduction in energy use shown in Table 5 would come about half from lower hot water use (Design = 72% of Baseline) and half from higher boiler efficiency (Design efficiency of 97% vs. Baseline of 75%). That would result in expected water heating savings from lower hot water volumes of about 350 MBtu/year, about 13% of the total energy savings for the building. The corresponding savings in natural gas bills would be about \$3,000/yr.

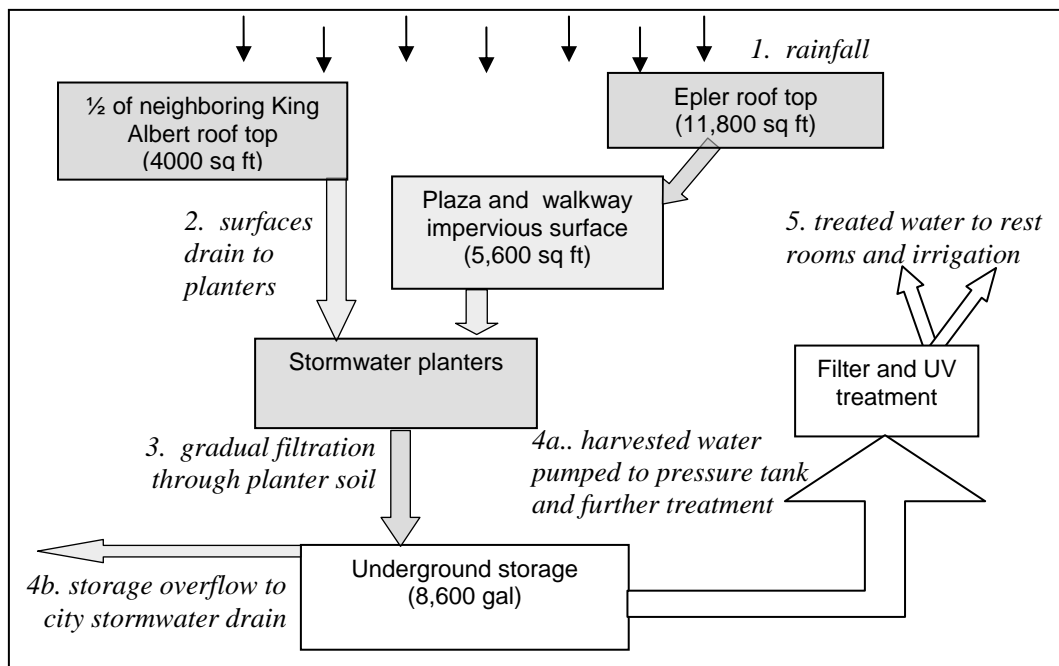


Figure 10: Stormwater harvesting system schematic

Front-end run-off delay portion shaded gray

Back-end water harvesting and reuse portion in white

I could find no cost tables breaking the entire harvesting system cost between these collection/detention and usage components, but generic cost studies suggest that a non-potable water harvesting system costs 20 – 30% of a system providing potable water (Fuller et al, 2002). Although the Epler Hall harvested water is not brought to potable standards, the filtration and UV treatment are significantly more than might be used for the simplest irrigation system. So a rough estimate of the cost of the front-end run-off delay portion of the system only might be about \$30,000, half of the total \$62,000 design through construction cost. A front-end only system would also eliminate periodic part replacement and maintenance for the pumps and UV light installed for using the harvested water.

Direct Savings Conclusions

During Epler Hall's first year, energy use was more than 20% below the Design level expected from initial modeling and 49% below the Baseline representing a building just to code. Residential water use was 17% above the expected Design level, but still 25% better than (below) the Baseline level. Given the lack of detailed U.S. studies on actual water consumption by end use, it is possible that the difference between Actual and Design is within the accuracy of the general modeling assumptions made about daily use of sinks and showers. Table 14

summarizes these and the related financial results. The present value of annual savings from conservation features is over \$700,000, or 7% of the total initial cost of the building. After subtracting the net incremental costs of the building's conservation features, the net present value of savings is still in excess of \$400,000. Those savings generate an aggregate rate of return of 14%/year on those initial investments.

Table 14: Summary conservation results: Actual vs. Baseline

Conservation Area	Savings as a % of Baseline Usage	Incremental Costs (1) (\$1000s)	Utility Bill Savings (\$1000s)	25 Year Present Value of Annual Savings (\$1000s)	25 Year Present Value of Savings minus- Costs (\$1000s)
Energy	49%	\$199 initial	\$34/year	\$606	\$407
Water (2)	25%	\$89 initial \$0.3/year	\$6.9/year	\$116	\$26
Total		\$288 initial \$0.3/year	\$41/year	\$720	\$433

(1) Incremental costs of green features, net of credit and incentive payments.

(2) Water savings as % of Baseline shown for residential use only. (See discussion with Table 9 of atypical first year results for office/classroom area).

Additional savings of \$79,000 one time reduction in Systems Development fee, which was achieved for Epler but may not be available for future buildings, not included in this table.

While this study has identified a number of areas in which costs and benefits are only approximate, the general results appear sound and encourage additional green building efforts on campus. At the same time, attention to continued management of building systems will be necessary to assure that the initial level of savings is maintained over future years.

Direct Savings Areas for Further Study

This study mentioned several topics for which complete data was not available. Some warrant additional study specifically for Epler Hall's features, to provide more useful feedback to PSU while strengthening the sustainability component of PSU education. For other topics, although the effort needed to recreate historic detail for Epler may not be justified, the experience points to areas to keep in mind as other buildings are constructed or remodeled.

Impact on Occupants

The summer experience of first floor office workers and lack of any summer-time information from upper story residents strongly suggests investigating occupant satisfaction with the building climate control and lighting features. Results could help determine whether there would be better ways to increase comfort while still achieving energy reductions. A survey or

focus group discussion could elicit useful feedback. Models for such surveys may be found in several sources (e.g. Standeven et al, 1999 and 1998; sample occupant survey from the UC Berkeley Center for the Built Environment, www.CBEsurvey.org). Building residents may also benefit from information on efficient operation of natural ventilation and energy-efficiency features. The Mithun architects originally conceived a “users’ guide” for the building, covering features such as manual operation of stair and hallway windows. The firm may still be willing to provide information for resident training. Although overall building energy performance is very good, anecdotal reports of heaters operating with open windows have the potential of perpetuating stories about the ineffectiveness of green buildings, as well as using excess energy.

Ongoing Measurement

Reviewing the building’s energy and water use again after a second year has been completed should show whether building systems have remained optimized after the end of the commissioning year. Comparisons of energy and water use for Epler, the new Broadway housing building as a whole, and that building’s environmental-interest floor could provide additional information on the effectiveness of PSU’s move toward sustainable energy and water use. If PSU is considering applying for the new LEED-Existing Building recertification after Epler Hall is five years old, setting up systems to capture relevant experience data as it emerges should substantially simplify that later filing.

Post-occupancy verification of savings for future new building or major remodeling of campus buildings will be simpler if the key items to be evaluated are determined during the planning process and records are retained of related incremental direct and indirect costs. A much more credible calculation of energy savings could be obtained through better documentation of the initial building energy model, coupled with post-occupancy calibration of the Design version of that model. A building energy engineering course would be one place to combine education with creation of a usefully validated model for a PSU building.

Water Harvesting System Performance

Much of this report’s analysis of the water harvesting system was based on estimated or potential harvested water usage amounts. While this approach was sufficient to determine approximate financial savings from the system, it does not provide the type of performance analysis that would be desirable for an innovative demonstration project. Published literature

contains very few actual evaluations of the effectiveness of installed rainwater management systems. After Epler's system components and meters are fully functional, a thorough study of the operation of the system would be educational in guiding future efforts. Such a study could quantify the minimum rainfall needed for run-off to reach the storage tank, the amount of time that the stormwater planters delay overflow to the city run-off system, whether the assumed factors were accurate for the percent of rainfall captured by the system, and whether actual experience is consistent with theoretical models of water storage and use. Because there is no automatic readout of the amount of water in Epler's rainwater storage tank at any given time, such a study would require frequent manual measurements or installation of a water-level meter. Water quality measurements in the planters immediately after heavy rain and in the harvesting tank could quantify the pollutant-filtering benefit of the flow-through planters.

Value of Natural Ventilation

Portland's relatively mild summer climate provides good opportunities to eliminate the installation, maintenance, and electricity cost of air conditioning, particularly in buildings without excessive internal heat loads from dense equipment and human occupancy. However, there appear to be few studies that quantify the potential benefits of natural ventilation in this climate. A thorough study should include integrated design modeling of whole buildings with air conditioning and natural ventilation. Monitoring of actual summer time temperatures and building occupant perceptions would be an important companion piece

Indoor Air Quality

Indoor air quality improvements, a topic not included in this study, are often cited as a major benefit of green building. Periodic air quality measurements in new buildings with low volatility materials would be instructive to validate this green building practice.

Re-investing Savings.

This study has shown significant lifetime savings from integrating efficiency and conservation measures into Epler Hall. In a period of tight budgets and rising tuition, however, increased initial costs may still inhibit sound investments in features to achieve such future savings. The most direct response to this challenge is first to identify initial savings achieved by conservation measures, such as the avoidance of air conditioning, and apply such savings to other efficiency measures that have a higher initial cost. Beyond this strategy, one conceptual

approach discussed by some institutions is to allocate current savings from previous efficiency investments to funding similar future investments (e.g. Anne Eskridge, University of Washington, EFS West Conference on Sustainability and Higher Education, October, 2004). Over the long term, efficiency projects could largely become self-funding.

Some challenges may limit the degree to which such an approach is implemented. The first requirement is a practical means of determining credible savings amounts. An acceptable approach must simultaneously be believable, simple to use, and not readily subject to manipulation. Alternatives range from running credible individual building baseline models, as used in this study, to establishing some general benchmark metrics by type of building. The second requirement of a workable system is that the method be acceptable within the accounting standards and regulations governing the university. For example, current regulations may not permit PSU to directly set aside past conservation savings for future year expenditures. Even in that case, the cumulative expenditures and savings can help establish one logical basis for budgeting funds toward new conservation. Once a credible savings baseline was established, measured current savings in relation to that baseline could help determine budget allocations to new green investments. Whatever approach is chosen, the underlying tracking of actual expenditures and savings can provide valuable feedback for monitoring and refining the overall conservation program.

While environmental economics literature contains much discussion of the value of ecosystem services, I found little that would achieve my objectives of credibly quantifying the total societal value of Epler Hall conservation. Assumptions in general studies are often not applicable to specific local conditions. Further, while the case can often be made that disturbance of a forest or free-flowing river, for example, will reduce the services provided by the disturbed ecosystem, these effects may not be simple linear functions of size or volume (e.g. Cairns, 2002; Gill et al, 2002; Phillips, 2004). General studies may estimate a relevant value of natural resources and ecosystem services as a whole, but not quantify the relationship between an incremental impairment to the resource and the value of the resource. In other situations, a general theory and model may be available, but the local conditions have not been analyzed to determine the applicable factors needed to apply the model. In many cases, this study, which relies on previously published research for valuation, could do no more than attempt a general order-of-magnitude estimate of local effects and identify potential sources of uncertainty.

Adjusted Direct Costs

From the perspective of economic value, the “right” price of an item is the price at which the marginal cost of delivering the next unit equals consumers’ marginal willingness to pay for that next unit. Any lower cost would cause consumers to allocate more funds to purchase the utility, in place of other commodities they may prefer with proper pricing. Inefficient pricing stimulates excessive demand and distorts our understanding of the worth of conservation.

The additional costs of providing a utility service, or the benefit of incremental saving in utility usage, can be broken into three main categories. (Planning and Management Consultants, 1992; Council of Australian Governments, 2003; CPUC, 2001).

1. All costs are variable in the long run, and a long run analysis should consider the expected future needs for infrastructure maintenance and replacement. This topic is described in more detail below.
2. The cost for most utility services increases during peak demand times, and changes in demand during those peak times should be valued at peak marginal cost rates.
3. Integrated resource planning techniques for valuing conservation benefits must also include the potential savings from deferring or eliminating the need for future capacity expansion (McNeill and Tate, 1991; Fane and White, 2003).

Long Term Cost Levels

The irregular pattern of expenditures for maintaining a utility infrastructure demonstrate the need to look at costs over the long term, not just for a single year. Periodic large expenses occur when major portions of the infrastructure reach the end of their useful lives and need to be replaced. Figure 12 shows a simplified picture of the general pattern. The line with multiple peaks represents total costs as they arise, combining ongoing level operating costs with periodic significant expenditures on infrastructure replacement. A short term analysis would look at only the current year costs to deliver a unit of service. However, over the long term the total cost of the service must also cover periodic infrastructure replacement. One could approximate that effect by explicitly projecting irregular expenditures. Alternatively, one can estimate the level expenditure which equates over time to the irregular pattern. That result is shown in the solid horizontal line in Figure 12, representing the long range marginal cost of the power or water provided. This approach to long range marginal costs is described in Munasinghe and Schramm (1983). The level value is equal to the present value of the expected costs divided by the present value of the expected volumes sold. This results in a level rate that would cover costs over time, assuming that excess income in low cost years is carried forward with interest as assumed in the present value.²² Neither the timing nor amount of those future capital expenditures is certain, but ignoring them can result in a significant misstatement of the unit value of the utility being provided.

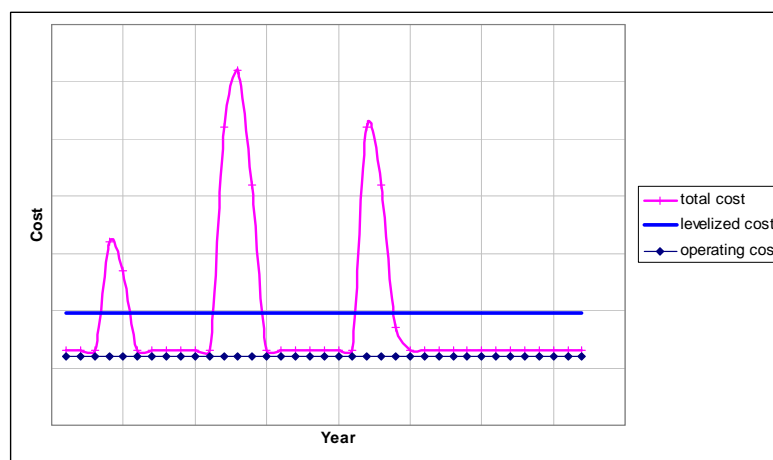


Figure 12: Levelizing an irregular cost pattern

²² For situations where large expenditures arise before sufficient rate margin has been set aside the calculation should provide for the utility's cost of borrowing over the requisite period.

Integrated Resource Planning

“Integrated resource planning” refers to a method of prioritizing utility system expenditures for meeting demand in which potential conservation savings are given equal consideration with expanded generation and delivery capability²³. Feldman, Maddaus, and Loomis (2003) provide a useful literature review of the concept as originally developed for the electricity industry, with comments on the way it may be adapted to water supply planning. The Northwest Power and Conservation Council (2004) provides a good example of the prioritization process for regional power planning. The authors identify 42 alternatives for additional resources, including both conservation efforts such as more efficient lighting, new renewable energy sources such as methane from landfills, and building more traditional generating plants. Each is evaluated from the perspective of achievable energy and average cost per kWh. This study refers to the methodology of integrated resource planning in the discussions of marginal gains from conservation. Estimations of the value of deferring needed infrastructure expansion also use this methodology.

General Theory of Environmental Impact Valuation

An externality arises when a purchase has two characteristics: it has a negative (or positive) impact on someone other than the buyer and seller, and that impact is not reflected in the purchase price paid. For example, the price to purchase city water may not reflect the impact on plants and animals in the source watershed of altered streamflow and riparian areas. That impact is then a negative externality of the water supply system. Externalities typically arise when private activities make use of public goods,²⁴ such as free-flowing streams or the atmosphere, which cannot be easily priced by the marketplace. The services provided by the natural ecosystems of our environment are priceless because they are essential to human life. However, because the natural environment consists largely of non-priced public goods, it can often be harmed by marketplace decisions. Several economic techniques are available to set a value on at least some environmental externalities, allowing a better idea of the total social cost

²³ Conservation savings are referred to as “demand side resources.” “Supply side resources” are traditional facilities that provide additional energy or water.

²⁴ Characteristics of public goods include “nonrivalry,” meaning a large number of users can enjoy the same good at the same time, and “nonexcludability,” referring to the lack of practical means of excluding nonpayers from using the good

of a private activity. Many publications describe the wide variety of methods used in estimating financial equivalence values for externalities (e.g. Desvousges, Johnson, and Banzhaf, 1998; Sundqvist and Söderholm, 2002). The following brief descriptions cover only those methods used in the valuations relevant to this report.

Observed Marketplace Costs

The most straightforward valuation techniques base prices of environmental impacts on surrogate items which are directly bought and sold.

Avoided Costs

The *avoided cost* method values an environmental amenity as the cost society would otherwise have to pay to provide a direct substitute for a natural ecosystem service. An often cited example was New York City's 1997 decision that the forested watershed source of their drinking water was worth at least \$6 billion, because that would be the cost of a water filtration system needed if the forest were cleared for development (Daily and Ellison, 2002). For the purpose of this paper, "avoided cost" methods will also include the similar concept of "*mitigation costs*," which determine value on the basis of the cost to remediate an externality after it occurs. For example, the cost of ferrying salmon around dams might be a mitigation cost of purchasing hydroelectric power. Similarly, the "*abatement cost*" of changing technology, procedures, or materials to reduce an externality is another surrogate often used.

Valuations on the basis of avoided or abatement costs have intuitive appeal, *if* they are clearly grounded in actual expenditures being made in the open market. In many cases, however, it may not be clear that society would really have chosen to fund the supposedly avoided activities.

Tradable Securities

In some situations, environmental impacts have been monetized through the creation of tradable securities. The most commonly cited method is the tradable sulfur dioxide emission permit system created under the U.S. Clean Air Act. Under this system, power plants are issued annual permits summing to a targeted total nationwide, annual emission amount, which is scheduled to decline over 30 years. Plants that can achieve even lower emissions than permitted can sell their tradable permits to others, theoretically providing an economic incentive to perform even better than the level allowed by regulation. Markets are also emerging for tradable carbon

sequestration certificates. In this case, participation by U.S. companies is totally voluntary. The marketplace value at which tradable permits or sequestration certificates trade reflects individual firm assessments of current and anticipated regulations.

Secondary Costs

These methods value the degradation of natural resources on the basis of the costs of secondary impacts. A common example is calculating the value of clean air on the basis of the costs associated with the health and mortality impacts of air pollution. The requirements and uncertainties for this technique are discussed further in the section on the impacts of emissions associated with electricity generation.

Transfer between Locations

Transfer of any valuation from one specific study site to another area has limited validity unless several precautions are taken. The potential problems with transferring estimated values are discussed in the economics literature under the general term “benefit transfer” (e.g. Desvousges , 1998; Smith, 1992; Willis et al, 2002). Value transfers between studies should only use variables measured in both the original study site and a closely comparable new site. Ideally, but rarely in practice, the original study will have identified valuation functions that allow some adjustment for differences of site characteristics. Because of the uncertainties involved in valuing externalities, credible results should nearly always present a range of possibilities. The range applicable to a new site to which values have been transferred is typically wider than the original range, because of imperfect characteristic matches and because differing results from multiple original studies may be used.

Valuations in This Paper

Economic valuations of externalities do not typically capture all of the value or utility of the amenity being degraded. The more precision demanded of the estimate, the longer the list of components that are not valued. The resulting partial valuations may still be useful if they can provide meaningful rankings among alternatives. However, partial valuations also create the risk that the numbers will be remembered while the caveats and non-valued element descriptions will not. This project sought to determine whether the externality savings associated with Epler Hall’s conservation are significant in relation to the direct associated savings. As seen in the

following sections, available information is often insufficient for solid results of even a partial valuation.

Societal View of Energy Savings

This section seeks to quantify the extent to which Epler Hall's achieved energy savings have benefits to society in addition to direct utility bill impacts. The bulk of the discussion concerns electricity savings, rather than natural gas, because that is the energy source that creates the largest externalities and for which the most general analysis has been published.

Electricity Industry Characteristics

Electric utilities supply power to their customers from the interconnected energy grid covering the region. Because grid electricity must be used as it is generated, different power plants will be brought online, or turned down, as total demand fluctuates.²⁵ Power plants are generally prioritized so that the lowest cost plants available plant will be first on line. Timing solely on the basis of generation cost is tempered by the fact that some plants, such as coal burners, cannot be switched on rapidly. "Base plants" are those that operate most of the time. Peak plants are those that can be turned on quickly for short term needs, meeting the marginal increases and decreases in demand. The true marginal cost of energy is therefore determined by the pattern of available generating capacity and the minute-to-minute pattern of total demand.

Adjusted Energy Costs

This study assumes that the utility company's levelized long term costs are approximately equal to the direct consumer bill savings, making no adjustment for better reflection of periodic investments in new infrastructure. This approach may give a reasonable rough approximation given the basis on which electricity rates are approved. Rate filings to the utility commission provide the utility with a profit return on its infrastructure investments as well as covering on going operating costs. This simplification also assumes that the differences in rate schedules among different classes of ratepayers reasonably reflect differences in cost characteristics of

²⁵ Electricity "demand" refers to the instantaneous level of power being drawn from the grid. For example, turning on a 1,000 Watt heater creates 1 kilowatt of demand. Electricity use is the amount of energy used over time. Leaving the heater on for 1 hour uses 1 kilowatt hour of energy.

servicing those ratepayers. This assumption may not always be true in practice, and represents one source of possible error in the simple approximation.

Marginal Rates and Peak Costs

On a region-wide basis, the marginal savings of reduced energy use depend on when the usage reductions occur and the available sources and costs of power in each of the affected periods. These complexities are incorporated in large models for regional energy planning (Northwest Power Planning Council, 2004) and in individual utilities required integrated resource planning documents (PGE, 2004). However, none of those publications provide true marginal cost rates in a form that could be directly applied to Epler Hall’s electricity savings. The rough approximation in this study therefore assumes that PGE’s time-of-use billing rates reasonably reflect marginal costs by period. If energy reductions occur primarily during peak hours, when more expensive peak power is being purchased by the utility, the value of savings should be higher than originally estimated. Alternatively, if usage reductions are primarily in non-peak hours, the value of the savings is probably lower.

Examining Epler’s usage pattern against the PGE time-of-use rates results in relatively little change in cost. To estimate this impact, I summarized the hourly data log of Epler’s electricity use from February 21 to March 21, 2004,²⁶ according to the peak, intermediate, and off-peak periods in PGE’s time-of-use billing option. The applicable hours and rates are shown in Table 15.

Table 15: PGE time-of-use rate periods

	Summer (5/1 – 10/31)			Winter (11/1 – 4/30)			Rate/kWh
	M-F	Sat	Sun, holiday	M-F	Sat	Sun, holiday	
on-peak	3p-8p			6a-10a 5p-8p			\$0.07817
mid-peak	6a-3p 8p-10p	6a-10p		10a-5p 8p-10p	6a-10p		\$0.04677
off-peak	10p-6a	10p-6a	all day	10p-6a	10p-6a	all day	\$0.02865

Source: PGE Power Options: Time-of-use.

http://www.portlandgeneral.com/business/products/power_options/time_of_use/ [11/19/2004]

²⁶ February 21 was the earliest date for which the direct digital control data logger was working.

Evening electricity usage peaks in Epler Hall tend to coincide with overall evening peak use periods. Figure 13 shows the daily pattern of use for a typical week in the winter period examined, along with the time of use rates. As summarized in

Table 16, Epler’s overall usage pattern is similar to the average. The same analysis done for the month of July produced similar results.

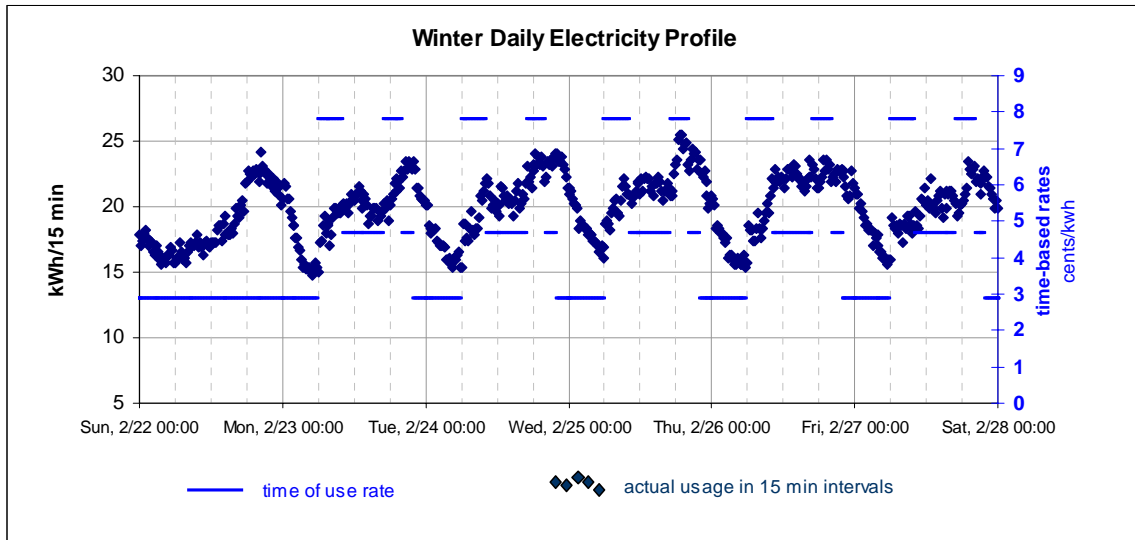


Figure 13: Electricity use by time of day
Stepped segments indicate time-of-day rates

Table 16: Electricity time of use distribution: 2/21/04 – 3/21/04

Period	Epler Usage %	Typical Usage %	Time of Use Rate/kWh
Peak	21%	21%	\$0.07817
Intermediate	36%	43%	\$0.04677
Off Peak	43%	36%	\$0.02865

Typical usage and time-of-use rates from http://www.portlandgeneral.com/business/products/power_options/time_of_use/ [11/19/2004]

Adjusting rates to a time-of-use basis would lower total electric charges by about 3%, because Epler uses a slightly above average percentage during off-peak hours. Epler’s electricity efficiency changes were primarily from more efficient equipment, not from efforts that would change the time of day in which equipment is used. Therefore, the time distribution of electricity *saved* through the efficiency features should roughly match the analyzed time distribution of electricity *used*. That implies that the Part I calculated direct savings in Epler’s electricity

bills (\$34,000/year in Table 6) might actually overstate utility marginal avoided costs by about 3%. The adjustments were not considered in Part I because PSU has not chosen a time-of-use billing schedule for Epler Hall. In general, such billing approaches are only cost-effective from the customer’s perspective if they have a very unusual operating schedule or if equipment is being installed with the specific objective of taking advantage of lower off-peak power rates.

Taxes and Incentives

A portion of every gas and electric bill goes to a variety of taxes and fees supporting general government purposes. From the standpoint of measuring total societal benefits of reducing energy use, these taxes are an economic transfer payment, merely moving from one segment of total society to another. Thus, they should be excluded from the total of net social savings (California Public Utilities Commission, 2001). The billing rates used to calculate the \$34,000 annual direct energy savings in Part I include taxes and fees of 3.6% for natural gas and 5.1% for electricity. In addition, PSU’s net savings included the expected one-time credit from the Oregon Business Energy Tax Credit (BETC) program of approximately \$42,000. These amounts, which from the societal perspective must be subtracted from direct savings, are summarized in Table 17. Their total present value of \$69,000 is about 12% of the total direct present value energy bill savings in Part I of \$606,000.

Table 17: Summary of energy tax and incentive savings

Calculation	Amount	Timing
BETC	\$42,000	single sum, 2005
Natural gas	\$300	annual 3.6% of savings
Electricity	\$1,300	annual 5.1% of savings
Total Present Value	\$68,000	25 years discounted at 3%

Percentages of gas and electric bill savings applied to the Part I direct savings, reduced by the described adjustments for weather and peak period timing.

Power Generation Externalities

Negative externalities of power generation may include damages from air emissions, resource depletion, upstream life cycle impacts from fuel extraction, and, in the case of hydropower, river and riparian habitat damage (Lee, 2002). As described earlier, this study includes a dollar value for external costs only where published studies support an estimate of avoided social costs directly applicable to Portland’s energy impact characteristics. Most published studies that place a financial value on energy externalities focus on the human health impacts of air emissions during electricity generation (e.g. Krupnick and Burtraw, 1996 ; U.S.

EPA, 1999b; Krewitt, 2002; Sundqvist and Söderholm, 2002). An alternative type of valuation is based on the costs that would be incurred in scrubbing or other technology to reduce plant emissions.

Energy Externalities in Other Building Studies

Only a few other building studies have attempted to quantify the value of reduced energy externalities associated with building features, as summarized in Table 18.

Table 18: Energy externalities in other building studies

Study	Energy Externality Treatment	Result
Packard, 2002	Selected one study of health impacts of electricity generation emissions to use as example of how externalities might be calculated	Electricity externalities value of about 15% of direct electricity costs
SBW, 2004	Energy externalities only priced for greenhouse gas emissions	Greenhouse gas externalities valued at less than 2% of energy costs
Kats et al, 2003	Market prices for emission trading of NO _x , SO ₂ , CO ₂ , and particulate matter	Emissions value about 20% of energy costs
Scheuer et al, 2003	Incorporated in life cycle analysis on the basis of average grid emissions for the Midwest, but not valued financially	Building energy use contributed 50% of all life cycle solid waste impacts, and 80-90% of climate change, ozone depletion, air pollution, and eutrophication impacts

General Studies of Electricity Externalities

Figure 14 shows a schematic diagram of the primary stages in calculating the value of health impacts from electricity generation. For an accurate bottom-up calculation, relevant data is needed at each step.

1. At the power plant, the total emissions per kWh of generated electricity must be known, based either on reports of actual emissions or average emission rates for the type of fuel and technology used.
2. Local and regional geography and weather conditions then determine atmospheric concentrations of pollutants at various distances from the power plant.
3. Total human exposure depends on the size of the population in the area affected by the resulting pollution. Crop and forest impact similarly depends on the exposure volumes in the affected areas.
4. Human impact depends on mortality and morbidity studies of the effects of the calculated pollution levels.

5. Finally, dollar values of these impacts are typically based on some combination of economic values of a lost year of human life and the direct and lost-income costs of disability.

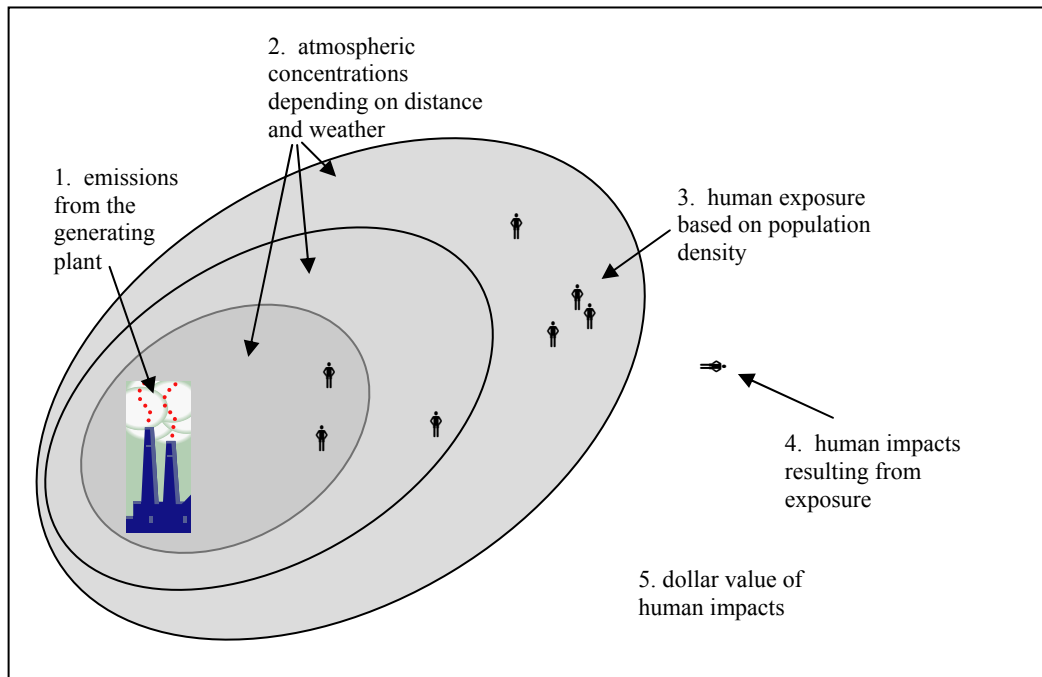


Figure 14: Stages in translating air emissions to human impacts

Results of studies of the human health impacts of electricity generation span a wide range. Krewitt (2002) summarized the history of European valuations over the prior ten years, as seen through changes in the estimated impact of a single coal-fired generating plant. Early estimates in 1992 suggested a negligible health impact. Subsequent estimates increased in stages because of scope expansion from local to regional impacts and newer studies showing higher mortality from exposure to fine airborne particles. After reaching a peak of 4.5 Euro-cents/kWh in 1996, the estimates then decreased to less than 1 Euro-cent/kWh in 2002. The primary factor in the reduction was a change in methodology for valuing increased mortality risk. While the high estimate had applied an estimate of the economic value of a human life for each death, the more recent, lower, method used a value per estimated life-year lost.

Sundqvist (2001) analyzed 107 studies of external cost estimates for electricity generation. As shown in Figure 15, results varied by several orders of magnitude for every generation type, and even the 25th to 75th percentiles often varied by a factor of one hundred. Only two characteristics of the studies appeared to explain significant portions of the variability

when results were subject to statistical analysis of tables. Studies that used abatement costs to estimate value tended to produce higher results than studies attempting to value environmental damage. Also, coal- and oil-burning plants generated higher external values than wind and solar. As with many meta-analyses, firm conclusions were made difficult by lack of comparable underlying data among studies. For example, population density in the affected area would logically seem connected to the magnitude of damage results, but that variable did not appear statistically significant. Sundqvist suggested that unvalidated benefit value transfer used in some studies, and other studies that attempted a hypothetical valuation of a generic plant, could possibly account for that result.

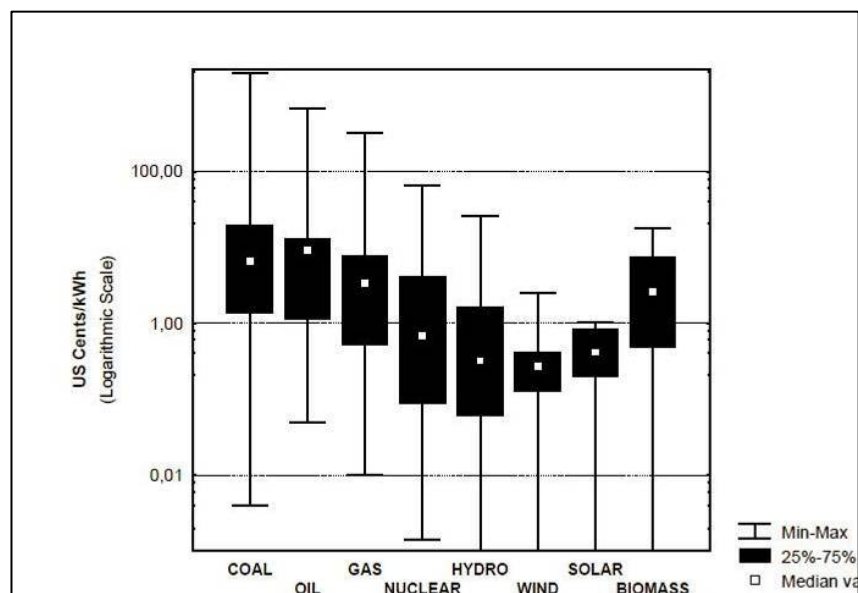


Figure 15: External cost estimate range for power generation
Graphic from Sundqvist, 2001, p 14.

The Environmental Protection Agency periodically evaluates the costs and benefits of the Clean Air Act. The most recent completed study summarized net monetized benefits (benefits minus costs) of \$510 billion for the period 1990 to 2010 (U.S. EPA, 1999b). While these estimates cover more activities than power generation, characteristics of the methodology and conclusions are informative. Because of the uncertainties in underlying assumptions, the 90% confidence interval was fairly broad, ranging from a net cost of \$20 billion to a net saving of

\$1.4 trillion. All but 10% of the total net benefits came from estimates of improved mortality.²⁷ About 6% came from improved health. Just 4% came from ecological and welfare impacts. In the ecological and welfare category, the recreation value of improved visibility was the largest component. Reduced acidification, increased agricultural and timber yields, and increased worker productivity were also included in the ecological and welfare category. The study notes the likelihood that the monetized ecological impacts were only a small part of the true total. The study's list of effects for which no sufficiently rigorous data was found included toxification of freshwater fish, long term effects of reduced biodiversity, and reduced filtration and flood control services from impaired watersheds.

Other Pacific Northwest Treatment of Energy Externalities

Statements about the regional impact of energy usage are often limited to lists of emission rates, with no attempt to value those effects financially. Further, emission rates are often based on readily available averages of, for example, power generated in the state. Because of the large connected electricity grid, the power generated in a state is not the same as the total power used in the state. In addition, the generation source of interest when discussing conservation is not the average source but rather the marginal source: the particular type of plant that would be "dialed down" when, for example, an extra light is turned off.

In their evaluation of the cost per kWh of alternative resources, the Northwest Power and Conservation Council includes only true marketplace costs, with no quantification of externalities. The potential of climate change damage is incorporated in variability analysis by testing a range of possible carbon emission taxes between \$0 and \$30 per ton.

The Energy Trust of Oregon evaluates energy efficiency projects for funding on the basis of their anticipated reduction in utility company avoided costs as well as societal avoided costs. The former is based on a model from the Northwest Power and Conservation Council that incorporates peak load patterns and direct costs of the anticipated equipment and the complexities of regional grid energy sources. The latter includes an estimate of environmental benefits based solely on a factor applied to CO₂ emissions.

²⁷ The study estimated improved mortality effects based on the value of a statistical life, noting that results would be about 50% lower if the value of life-years lost method were used. This is roughly consistent with the Krewitt comments on sources of value changes for mortality impacts.

The only regional attempt I located to value the marginal emission changes from local conservation was one Wisconsin study (Erickson et al, 2004). While Wisconsin is very different from Oregon in both climate and electricity sources, the general results of this detailed study are informative. The analysts used a complex model incorporating the change in hourly energy demand and the relative order in which facilities would come on line to meet demand, in order to quantify the impact of energy savings on emissions. In terms of marginal power sources, they found that emissions per MWh generated were significantly lower during peak power demand periods than off-peak periods. For example the summer peak emission rates for SO₂ and NO_x were roughly 70% of the summer off-peak emission rates. Thus, peak-period conservation did not necessarily reduce emissions in proportion to the total amount of energy saved. Coal-fired plants were more typically used for continuously operating base load, while more quickly adjustable gas-fired plants were brought online for peak needs.

The monetary value of reduced emissions in the Wisconsin study was quantified based on recent prices for the trading of SO₂, NO_x, and CO₂ emission certificates. The authors also used a value of \$16,000/ton (cited as “the EPA’s price”) for mercury emissions, which have no tradable certificates and for which there are no current peer-reviewed studies of damage value. On this basis, their total estimate of the external value of reduced emissions was about \$0.012/kWh²⁸.

Despite the thorough modeling in the Wisconsin study, the authors still listed a number of unanswered questions. In particular, they were not successful in completely identifying the geographic scale of local conservation efforts. Their model incorporated all generators in the nine states and two provinces of the Mid-America Interpol Network and the Mid-Continent Area Power Pool, because they could not more accurately pinpoint which generators would be affected by reduced Wisconsin demand. Similarly, they were unable to determine whether reduced Wisconsin energy use would actually reduce Wisconsin generation and emissions as assumed. The Wisconsin power generators might possibly replace in-state sales with sales to other states. Another possibility, where emission caps were stated in terms of total emissions from a plant as opposed to emissions per MWh generated, was that plant operators could combine reduced generation with use of lower cost, more polluting fuel.

²⁸ Because mercury emissions per MWh of power are very low, the high impact cost/ton used for mercury made relatively little contribution to the total.

The next section of this report will look at specific information for PGE power generation, to determine to what extent one can apply any of the general studies and methods described above.

PGE Power Sources

Although 73% of the electricity generated in Oregon in 2002 was from hydropower (Energy Information Administration, 2003) over half of PGE’s power comes from burning fossil fuels. Different reports present a wide variety of energy mixes for PGE, probably because of the complexity of identifying true sources when over 40% of PGE electricity is purchased on the open market (Moore, 2003). Figure 16 shows two distributions typical of the ranges cited for PGE.

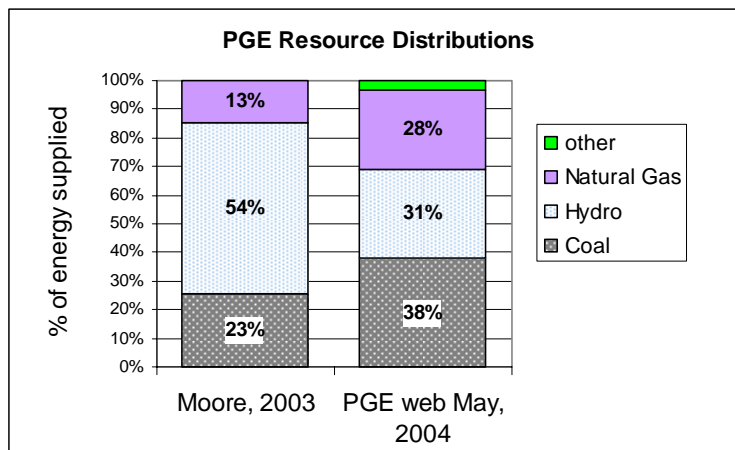


Figure 16: Range of PGE resource distributions

The Figure 16 distributions summarize sources for all of PGE’s sales. The capacity directly owned by PGE is approximately 40% coal, 40% natural gas, and 20% hydro (PGE, 2004). As a very rough estimate for PGE electricity sources, coal might be considered the marginal generation source between 10 p.m. and 6 a.m. and combined-cycle gas at other times of the day (Jeff King, Northwest Power and Conservation Council, personal communication). About 1/3 of Epler’s electricity usage occurs in the nighttime period when coal is the marginal generation source.

Pollutant Emission Rates

Table 19 shows average emission rates per megawatt hour generated by each of PGE’s fossil fuel plants. Its single largest generating resource, and its most polluting, is a coal plant in

Boardman, Oregon, about 160 miles east of Portland. This plant generates about 20% of the total energy sold by PGE (PGE, 2004). It was completed before the 1977 New Source Performance Standards of the Clean Air Act. This plant burns low-sulfur coal but uses no desulfurization equipment, which explains the difference shown in Table 19 between the sulfur dioxide (SO₂) emissions in Boardman and in Colstrip, where scrubbing equipment is installed. PGE's current Integrated Resource Plan shows the Boardman coal plant operating at least through 2020 (PGE, 2004).

Table 19: Emission rates from PGE fossil fuel plants

Emission	lb/MWh generated			
	PM-10	NO _x	SO ₂	CO ₂
Coal Plants (% of PGE-owned coal generation)				
Boardman, OR (54%)	0.12	4.64	8.02	2,271
Colstrip, MT (46%)	na	4.77	2.27	2,358
Natural Gas Plants (% of PGE-owned gas generation)				
Beaver, Clatskanie, OR (57%)	0	3.27	0.04	1,160
Coyote Springs, Boardman, OR (43%)	0	0.12	0.00	916

PM-10 (Particulate matter below 10 microns in diameter) from Environmental Defense 1999 Scorecard. Other emissions are 1998 through 2000 averages from eGRID (U.S. EPA, 2003).

The reason for the particularly high emissions of nitrogen oxides (NO_x) at the Beaver natural gas plant and the unusually low NO_x emissions at Coyote Springs is not clear. The low Coyote Springs rates may in part result from cogeneration savings at the site.

Pollutant Impacts

Sundqvist and Söderholm's survey (2002) found studies valuing the impacts of coal-fired generation plants at costs up to 68 cents/kWh, with a median above ten cents. However, because of the very low populations surrounding the PGE fossil fuel plants, it seems unlikely that the estimates of human health impact made for other studies are transferable.

Valuations Based on PGE Plant Emissions

I found reference to only two environmental cost studies that were made in unpopulated areas. Both were done by the consulting firm EcoNorthwest, specifically covering eastern Oregon and Washington coal plants. The estimates considered health, agricultural, and visibility impacts, with the predominant effect by far being health. The estimated external costs of pollution in Table 20 come from those studies, as summarized by Ottinger et al (1990). Table 20 shows the emission rates from Table 19 for the Boardman coal plant, the external cost of those emissions, and the resulting external cost per MWh of electricity used. The carbon dioxide

(CO₂) cost per pound in this table comes from carbon sequestration trading. Both the most recent annual report of the Climate Trust, an organization that markets carbon sequestration credits, and the Chicago Climate Exchange trading for December, 2004 – January 2005, show carbon credits trading at about \$2/ton (Chicago Climate Exchange, 2005). While this value reflects real market transactions, its accuracy is limited because such sequestration credits are little used in the U.S. and the markets are new.

Table 20: One estimate of environmental cost of Boardman coal emissions

	PM-10	NO _x	SO ₂	CO ₂	Total
Boardman emissions: lb/MWh generated	0.12	4.6	8.0	2,300	
External \$ cost/lb emitted (1), (2)	\$0.003	\$0.125	\$1.437	\$0.001	
\$ cost / MWh used (3)	\$0.00	\$0.64	\$12.63	\$2.53	\$16

- (1) External cost rates for non-CO₂ emissions as reported by Ottinger et al (1990). The published values, reported in 1989 dollars, were inflated in this table to 2004 using the general increase in the Consumer Price Index.
- (2) External cost rates for CO₂ based on Chicago Climate Exchange average 12/1/04 – 1/14/05.
- (3) Dollar costs/MWh used include 9% increase for transmission and distribution line losses (Kaiper, 2004). So cost/MWh = [emission/MWh x cost/lb emitted]/(1-.09).

The total cost per MWh of electricity used from the Boardman coal plant is rounded in Table 20 to \$16/MWh-used (\$0.016/kWh). Because of the large lack of precision in the underlying valuation rates, this final cost is at best a ballpark estimate of the high side of externality costs for the specific effects being valued. For these effects, several downward cost adjustments would make the estimate more representative for Epler’s overall impact. Applying the same externality costs to the average of Boardman and Colstrip coal-generation reduces the \$16/MWh to \$12/MWh, still applicable only to periods where coal is marginal. Applying the same methodology and prices to the two PGE gas-fired plants gives an average externality value of \$1.40/MWh-used when gas is marginal. Using the Epler electricity distribution of 1/3 at night when coal is marginal gives an overall weighted average externality cost for Epler electricity of \$4.70/MWh (\$0.005/kWh), approximately 10% of the PSU’s electricity billing rates used for the direct valuation. This estimate still excludes many impacts, ranging from specific harmful emissions such as mercury to the broader externalities listed at the beginning of this section.

Alternate Emission Valuation Rates

The impact values per pound of emission used in the preceding section have the advantage of being calculated for rural eastern Oregon. However, those values have the disadvantage of relying on a single consulting study, done over 15 years ago. Even for current studies, the bottom-up concentration-response calculations as used here often give different

results than looking at marketplace trading of emission certificates or evaluations of abatement costs. Table 21 displays some alternate methodologies based on those other cost approaches. Using the six month 2004 trading prices from the Chicago Climate Exchange, would reduce the \$4.70/MWh estimate to about \$3.90/MWh, about 8% of PSU's billing rates. As further demonstration of the variability is cost assumptions, recall the \$30/ton high end of the carbon emission tax range modeled by the Northwest Power and Conservation Council. That level equals \$0.015/pound of CO₂, fifteen times the highest current trading cost shown in Table 21 for carbon sequestration.

Table 21: External costs per pound of emission from various sources

Method	NO _x	SO ₂	CO ₂
Boardman emission valuation	\$0.125	\$1.44	
Chicago Climate Exchange Certificates: 12/1/04 – 1/14/05	na	\$0.33	\$0.001
Chicago Climate Exchange Certificates: 3/04 – 10/04	\$1.02	\$0.11	\$0.0004
Carlson et al, 1994 mean Marginal Abatement Cost	na	\$0.34	na
Carlson et al, projected 2010 Marginal Abatement Cost		\$0.15	

Sources: Table 7 for Boardman values; Chicago Climate Exchange, 2004 and 2005; Carlson et al, 2000.

Tradable Renewable Credits (Green Tags)

Green Tags from the Bonneville Environmental Foundation (BEF) give another marketplace valuation source for the total value of fossil-fuel generated Pacific Northwest emissions. These Tradable Renewable Credits have been available from BEF since 2000. The credits are associated with funding of net increases in regional generating capacity of nonpolluting energy, reflecting the current cost of developing alternative power sources. BEF currently sells Green Tags at a price of \$20 per megawatt hour, suggesting an even higher total value for energy externalities than the calculated Table 20 values for the Boardman coal plant. A cost of \$20/MWh represents about 40% of PSU's billing rates.

Natural Gas

The premium efficiency natural gas boilers in Epler Hall generate CO₂ but relatively little additional pollution. Including that impact would have an immaterial effect on the total. The Wisconsin study of marginal efficiency savings (Erickson et al, 2004) is one of the few with any analysis of on-site natural gas use. Table 22 summarizes one estimate of natural gas emission externalities, using mid-range emission factors from the Wisconsin study and the 2004 average costs from the Chicago Climate Exchange. The result is just \$0.50/MWh, less than 15% of the lowest estimate above (\$3.90/MWh) for electricity. The \$0.50/MWh for natural gas equals

\$0.015/therm, which is less than 2% of the PSU billing rate used to determine direct natural gas savings.

Table 22: One estimate of environmental cost of on-site natural gas use

	PM-10	NO _x	SO ₂	CO ₂	Total
Emission rates: lb/MWh of energy input (1)	0.00	0.33	0.002	400	
External \$ cost/lb emitted (2)	na	\$1.02	\$0.11	\$0.0004	
\$ cost / MWh used (3)	\$0.00	\$0.34	\$0.00	\$0.16	\$0.50

(1) Erickson et al, 2004, converted to a per MWh basis for comparability with electricity numbers.

(2) Chicago Climate Exchange 3/2004 – 10/2004 from Table 21.

(3) lb/MWh x cost/lb.

Discount and Interest Rates and Combined Energy Results

The discounted present value of a future series of expenses represents the current amount of cash that, if all invested now, could exactly provide the future cash flows. The present values in the section on direct savings used a 3% real discount rate, as is done in the EPA's life-cycle costing software (Addison, 2004). Some natural resource economists recommend reducing or even eliminating the discount rate applied to externalities that could impair the quality of life of future generations (e.g. Krewitt, 2000; California Public Utilities Commission, 2001). Others suggest keeping nonquantitative considerations such as beliefs about intergenerational equity separate from the financial calculations (e.g. Pearce and Turner, 1990). This report follows the latter approach. Potential impact on future generations is therefore one more unpriced social consideration which must be considered within the constraints of broader social values.

The simple present values done initially for direct savings assume that energy prices will change at the rate of general inflation. However, costs may rise more quickly than inflation for a number of reasons, including increasing scarcity of resources and possible more stringent emission limitations. These above-average energy price increases are logically included in this societal view; many of the causes of these increases are related to current externalities that may or may not be internalized in future prices. For example, the Northwest Power and Conservation Council's (NWPCC) draft Fifth Power Plan (2004) projects a range of average electricity supply costs over the next 20 years from \$21 to \$59/MWh. If compared to a current supply price of \$30, this cost range would be equivalent to an annual real price change of -3% to +5%. The NWPCC's underlying assumptions incorporate a variety of scenarios for natural gas costs, demand changes, carbon taxes, and import costs. Thus, they include some of the previously calculated externality costs in this paper. It is not possible with available information to precisely determine the portion of the projected cost increases that does not overlap with

previous externality costs. But it seems clear that using the high end of the NWPCC increase plus the separately calculated emission costs could result in some double counting. A smaller range of 0% to 3% real annual increases will be used in the summary in this report.

Combining all the rough approximations in this paper can at best give a general order of magnitude regarding the total value of Epler Hall's energy savings. Even so, it is instructive to see the relation among the various components and the sources of variability in the estimates. Table 23 starts with the first year direct annual savings from Table 14, and then summarizes adjustments for each of the three societal areas discussed above. The low end of the range shown for evaluated externalities comes from the Chicago Climate Exchange-based values per pound of pollutant emitted applied to the time and source averaged PGE emissions. The high end of the range uses the BEF Green Tag price.

Table 23: Combined societal cost components of energy conservation

Net Savings Component	\$25 Year Present Value (dollars in 1000s)
Net direct savings	\$400,000
Adjustment for marginal peak power pricing	minimal
Deduction for taxes and incentives	-\$70,000
Evaluated externalities	+\$40,000 to \$190,000
Real energy price escalation (0 to 3%/yr)	+\$0 to \$220,000
Net societal savings	\$370,000 to \$740,000

Figure 17 displays the same results schematically, following the general design presented in Figure 11. The \$370,000 low end of the range for final societal savings comes from the \$400,000 direct savings, minus the \$70,000 deduction for taxes and incentives in those direct savings, plus the minimum evaluated externality value of \$40,000. The full range of societal saving estimated is equal to 90% to 180% of Part I direct savings. Most of the direct savings and most of the emissions are associated with electricity. The societal savings just from gas would range be no more than 120%.²⁹

²⁹ The first component of natural gas societal adjustments is the reduction for taxes incorporated in the direct bills and a proportionate share of the Business Energy Tax Credit, which would take the societal savings down to 90% of direct savings. The offsetting increase to get to a maximum 120% value would be an assumed real price inflation equal to the high assumption for electricity of 3%. Natural gas prices have been particularly volatile over recent years, which causes an uncertainty risk that is not priced in this study.

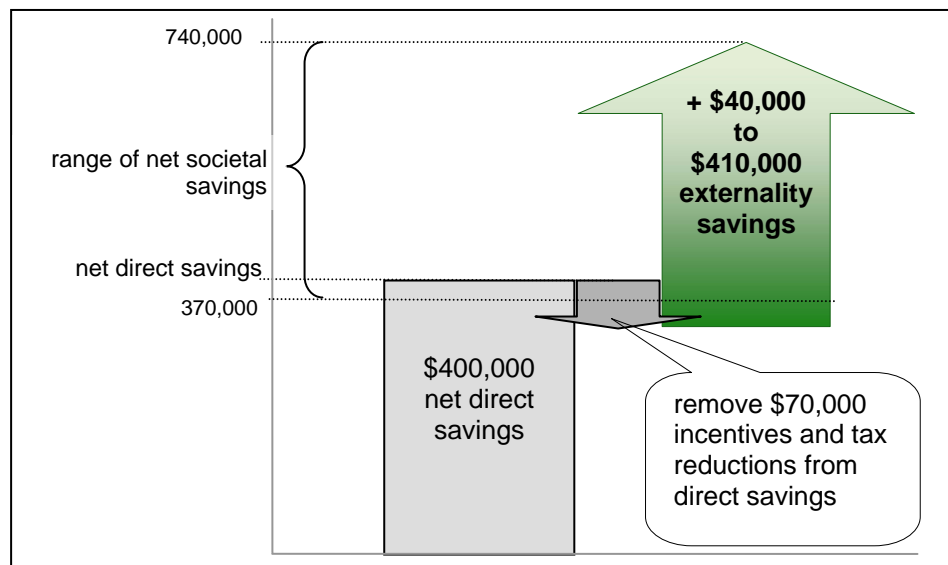


Figure 17: Schematic depiction of societal energy savings components

Epler Hall was designed for a lifetime of well over 25 years, and some externality impacts such as climate change will remain beyond the current century. However, it does not appear reasonable to extend the period for this specific calculation, because of ongoing replacement requirements for various building components and the expanding uncertainty regarding the priced externalities. After 20 years, the results become dominated by the assumption for the real price increase of energy. The low to high bottom line results range in Table 23 was derived simply by adding the high numbers and low numbers respectively for each component. This approach may overstate a realistic range. As previously mentioned, the high estimate of real price increases potentially overlaps some of the evaluated externalities. The two are not necessarily identical, however, because some of the effects that were not specifically evaluated such as resource depletion and heavy metal emissions may also be reflected in estimated real price increases.

Societal View of Water and Sewer Savings

This section considers the possible value of several societal cost components of water conservation. The broad categories are as in the energy section. The first adjustments covered are those necessary to reflect long term marginal costs, including both sustainable ongoing maintenance of the current infrastructure plus appropriate marginal costs of peak period demand. Then potential saving from conservation-deferred need for capacity expansion is added. The

next step is to estimate, where possible, the value of environmental externalities not already internalized in the previous adjustments. Finally, compatible assumptions for future real price increases are incorporated for calculating a present value over 25 years. The following sections explain methodology and results, first for the drinking water supply system and then for the sewer system. Results are then summarized in Table 26.

Drinking Water System

Water Supply Characteristics

From the beginning of the 20th century, nearly all of Portland's public water supply has come from the Bull Run watershed, on the lower, western slopes of Mount Hood (Portland OR Bureau of Water Works, 2004). The primary storage areas have capacity of 9.9 billion gallons behind Dam 1, built in 1929 and 6.8 billion gallons behind Dam 2, built in 1962. With average winter precipitation in the watershed between 80 and 180 inches, depending on elevation, most of the normal Bull Run River volume overflows the reservoirs in the winter. Reservoir levels typically start to decline in late June, potentially to minimum levels, and begin refilling in late September (VanRheenen, Palmer, and Hahn, 2003). Annual diversions from the Bull Run River take about ¼ of its total natural flow over the course of the year (Herret et al, 2004).

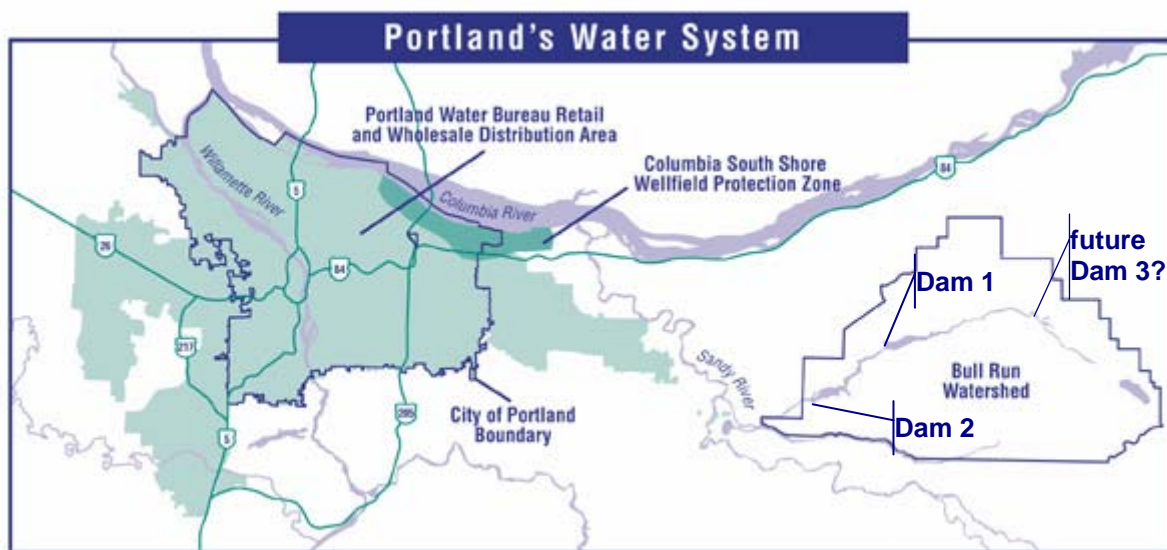


Figure 18: Source and distribution of Portland's water supply
(Portland Water Bureau diagram)

The water distribution system in Portland consists of 1,800 miles of distribution mains, many of which were installed in the early 1900's. Portland supplements its watershed supply

when necessary from well fields on the Columbia River. The well fields have been used 16 times since 1985, occasionally for brief periods when the Bull Run turbidity is high, and more frequently to supplement low reservoir levels during summer and early fall (Portland OR Bureau of Water Works, 2004). The Water Bureau provides water to Portland business and residents and also has wholesale supply contracts with some neighboring jurisdictions.

Full Infrastructure Maintenance and Replacement Costs

Several studies project growing, currently unfunded, replacement costs of the country’s aging water supply infrastructure (American Water Works Association (AWWA), 2001; Beider and Tawil, 2002; U.S. EPA, 2002). Many supply systems still contain distribution pipes and other components put in place around 1900. Water supply infrastructure clearly demonstrates the general characteristic of very irregular total utility costs over time, as displayed in Figure 12, and sizeable increases in infrastructure replacement costs may be expected in the next 20 years. For example, the American Water Works Association (AWWA, 2001) estimates a 125 year average lifespan for iron distribution pipes used in the late 1800s, a 100 year lifespan for pipes used in the 1920s, and a 75 year lifespan for pipes used in the 1950s. This national theme is echoed in Portland. The Water Bureau’s Capital Improvement Program (CIP) for 2004 to 2009 notes the aging infrastructure and need to develop a master plan to address future maintenance needs (Portland OR Bureau of Water Works, 2003). Even before these evaluations are completed, the capital improvement budget, which is currently about half the Water Bureau’s total budget, is projected to increase dramatically over the next few years, as summarized in Table 24.

Table 24: Proposed Water Bureau capital improvement budget

Fiscal Year	Proposed Budget (\$millions)
average 1998-2003	31.0 (actual)
2004-05	47.8
2005-06	65.0
2006-07	72.2
2007-08	74.3
2008-09	64.7

Past average from Auditor’s report. Subsequent years and proposed budget from Water Bureau CIP.

A 2004 Portland Auditor’s report gave an average lifetime of distribution pipes of 100 years, while noting that Portland’s current replacement rate would take 400 years to replace the

entire distribution system. Statements of average replacement rates and cost per mile of replacement vary, but approximate calculations in Table 25 show that this factor alone, if incorporated into water rates, could increase them by \$0.05 to \$0.25/ccf on a levelized basis. This estimate probably understates the total adjustment for infrastructure replacement, because water mains are just one component of the system (Anne Conway, Portland Water Bureau, personal communication). The EPA estimated future costs for total infrastructure replacement in the U.S. to be about twice the costs just for water distribution pipe replacements (U.S. EPA, 2002). The range of unfunded costs in Table 25 could also understate upcoming replacement costs if Portland will need to replace a disproportionate percentage of its pipes over the next two decades.

Table 25: Unfunded water main replacement costs

Basis	Base miles /yr (1)	Needed miles /yr (2)	Replacement cost \$ millions /mile (3)	Unfunded replacement cost \$/ccf (4)
Audit/AWWA (5)	5	18	1.0	0.25
CIP/AWWA (6)	6	18	0.7	0.16
CIP/CBO-low (7)	6	11	0.5	0.05

Notes for Table 25:

AWWA = American Water Works Association, 2001

CIP = Capital Improvement Program, Portland OR Bureau of Water Works, 2003

CBO = Congressional Budget Office study by Beider and Tawil, 2002

- (1) Assumed miles/year of replacement covered by current rates, with assumptions in (5) through (7)
- (2) Average miles/year to replace entire 1800 mile distribution main system within assumed lifetime, with assumptions in (5) through (7)
- (3) Replacement cost assumption basis as specified in (5) through (7)
- (4) Unfunded replacement cost per unit of water

$$= \frac{(\text{needed_miles / yr} - \text{base_miles / yr}) \times \text{cost / mile}}{51,000,000 \text{ ccf / yr}}$$

based on annual 38 billion gallons (51 million ccf) of water provided as stated in CIP

- (5) Base miles and cost/mile from audit report summary of actual 1998 – 2003. Needed replacement miles/year = 1% of total 1800 miles, from AWWA average assumption of 100 year lifetime.
- (6) Base miles from CIP average replacement expected 2004 – 2009. Cost/mile from average cost for Portland, Oregon from AWWA. Needed replacement miles/year = 1% of total 1800 miles, from AWWA assumption of 100 year lifetime.
- (7) Base miles and cost/mile from CIP average replacement expected 2004 – 2009. Needed replacement miles/year = 0.6% of total 1800 miles, from low estimate of CBO study, looking forward 20 years and based on current average age of U.S. city distribution mains.

Peak Season Marginal Costs

As previously described, societal savings from conservation should be valued at an economically efficient price, reflecting the long run marginal cost of delivering the last gallon of water. Several studies suggest that water charges are not typically set at this level. Garcia and

Raynaud (2004) determined that most utilities were charging less than efficient prices, based on marginal cost and demand curves derived from a system of equations for 200 water utilities in France, determining that most utilities were charging less than efficient prices. Their analysis showed that a change to efficient pricing would reduce consumption by 0.4% and increase total surplus by 0.4% (numbers only coincidentally the same). Renzetti (1999) predicted much larger changes from hedonic analysis³⁰ of data from 77 water and sewage utilities in Ontario, Canada. All utilities were charging prices below marginal costs. Renzetti concluded that efficient prices would reduce consumption by 6% to 55%, depending on characteristics of the utility district. The largest decreases came from districts with sizeable industrial water users, which were much more sensitive to price than residential users, and from districts that charged flat monthly rates with no volume-based addition. Neither of these studies directly stated the relative size of the rate increases required by efficient pricing. Even if they had, the specific results could not be transferred to Portland, because of differences in rate and cost structures, population characteristics, and supply systems.

Marginal water supply costs in Portland tend not to vary by hour, but costs are higher in the dry summer months, when water use is high and reservoir storage capacity is being depleted. The city's distribution mains are typically sized large enough to meet the requirements of fire-fighting, and do not limit normal residential and commercial demand. An appropriate determination of direct marginal costs for the Portland Water Bureau would work up from actual cost accounting detail. McNeill and Tate (1991) explain a way to calculate and implement economically efficient rates by a water bureau, even when the utility is subject to a mandate to charge customers on a break-even basis. However, no detailed analysis has been done by the Portland Water Bureau of marginal peak costs.³¹ Portland water rates are tiered, increasing rates

³⁰ A hedonic analysis applies multiple regression statistical techniques to situations where market prices are assumed to reflect a number of different attributes of the purchased good. The results, when statistically significant, allow the analyst to estimate how demand varies with changes in individual attributes that are not bought and sold separately.

³¹ Note also that a Water Bureau study would not necessarily compute marginal costs on the levelized, long term basis being used in this report. From a short term perspective, many would limit the marginal costs of water delivery to the pumping energy and chemical treatment costs that clearly vary directly with volume (McNeill and Tate, 1991; Pekelney et al, 1996). Nearly all the costs associated with maintaining the delivery system are independent of short term volume. Although the Water Bureau may not take quite this short a viewpoint, the city requirement that they budget annually on a break-even basis would probably limit the manner in which long term replacement costs were considered.

as the customer's volumes increase, but the rate levels are somewhat arbitrary, not tied to marginal costs (Anne Conway, Portland Water Bureau, personal communication).

Because the Water Bureau's well fields are used primarily for supplemental summer supply, the cost of their development and operation may provide a rough estimate of incremental peak season marginal costs. APPENDIX D estimates an incremental cost for summer water usage on this basis. The range of peak rate increases is from \$0.40/ccf to \$1.08/ccf, with the differences arising from ways to convert the capital costs of the well field construction and maintenance to a levelized rate. The lowest costs contain no allocation from well field capital costs, on the grounds that the back-up supply is also needed for non-peak times when turbidity-causing storms, accidents, or system failure may make Bull Run water unavailable. An allocation of zero capital costs to peak season water probably understates the actual peak season cost. The high end of the range comes from levelizing all past and currently projected well field capital costs, over an ongoing base of summer well field capacity for the currently budgeted 60 days/summer. Assuming even longer summer time operation would decrease the levelized costs. Levelization assumed that the infrastructure components have an average life of 75 years, based on the AWWA average life of distribution mains installed since 1950. This lifespan estimate may be high, resulting in understated costs, for the pumps and other operating and water treatment equipment in the well field. AWWA gives lifespans of 25 to 70 years for such equipment. However, because the well field is not operating through much of the year, some of its equipment may last longer than average.

To keep full year revenue constant after increasing summer rates, consistent with Water Bureau break-even pricing requirements, I calculated an offsetting downward adjustment for off-peak rates during the remaining months. That adjustment gave off-peak rate reductions of \$0.20 to \$0.55. The calculated net impact of both adjustments assumes that the lower winter rates are a reasonable approximation to off-peak marginal costs. I have no good way of validating or correcting that assumption with available information. Applying the seasonally adjusted rates to the Epler residential water savings from Part I would increase the dollar value of savings by 4% to 11%.

The combined peak and off-peak adjustments give peak season rates that are \$0.60 to \$1.63 higher than off-peak rates. Two other calculations for water costs in the Pacific Northwest region may provide some check on the general reasonability of that increment. Seattle

introduced peak water pricing several years ago, based on a cost study done for them after the 1992 drought. The city currently has three tiers of peak season residential rates, stepping up as the consumer's bi-monthly water use increases. The three summer rate tiers exceed the single winter rates by \$0.53/ccf, \$1.00/ccf, and \$6.20/ccf. The highest tier typically affects about one-tenth of water users (Seattle Public Utilities, 2003). The second reasonability check comes from a recent water supply analysis by 24 jurisdictions including Portland and its greater metropolitan area (Regional Water Consortium, 2004). This report refers to 1998 work by Gary Fiske³² calculating marginal water supply costs for the entire region to be \$0.75 higher in the summer than the winter.

This analysis has calculated only single point estimates for peak and off-peak marginal costs, not full supply and demand curves. If actual peak prices were increased and off-peak prices decreased, economic theory would predict some upward shift in winter use and downward shift in summer use. McNeill and Tate (1991) describe a procedure for modeling this effect with scarce actual data on demand curves. However, given the number of additional unsupported assumptions needed regarding water bureau costs and Portland consumer demand elasticity, such model results would be useful at best only as very broad tests of the scale of sensitivity to different variables.

Infrastructure Capacity Expansion Costs

The Portland Water Bureau's most recent Infrastructure Master Plan (IMP) projects a need for additional water supply capacity before 2050 even if the some water conservation plans are implemented (Watson, 2001). Possibilities for expanded supply include raising the heights of the current two Bull Run dams and building a third dam. Water conservation efforts should defer the time at which such expansion is needed, or eliminate the expansion need altogether. Either effect would result in lower levelized costs, as schematically depicted in Figure 19. The reduction in levelized water supply costs per annual ccf conserved is one component of the marginal savings from conservation. It can be estimated from the projected water demands, expansion costs, and timing of various scenarios included in the Infrastructure Master Plan.

³² Report reference is to Gary Fiske, Evaluation of Marginal Supply Costs for the Portland Metropolitan Region, 1998.

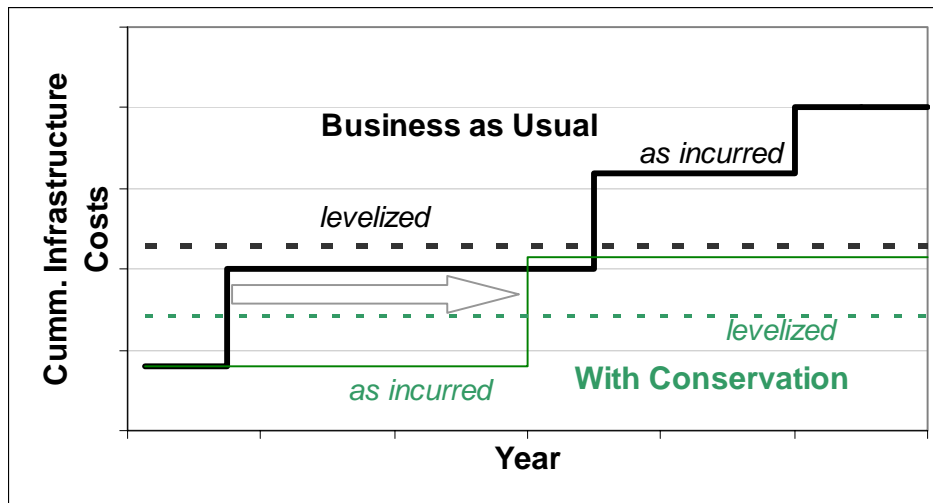


Figure 19: Conservation defers and reduces infrastructure expansion costs

The resulting rough estimates of marginal costs of water supply expansion range from a few cents to well over \$1 per summer ccf, as described in the following paragraphs. The wide range indicates the degree of uncertainty underlying the calculations. Result drivers include predictions of per capita demand, average weather conditions, and the desired ability of the system to provide full service in unusually dry years. In addition, possible changes in the geographic area supplied by the Bull Run reservoirs, with potential connections among different municipal systems, make simple point estimate or “most likely” forecasting impossible. The best this calculation approach can offer is a rough order of magnitude range for the value of deferring expansion needs.

The first capacity expansion considered in the Infrastructure Master Plan is to raise the heights of the current two dams. Using the costs, projected volumes, and timing scenarios in the IMP, I estimated that conservation could reduce the marginal cost of water supply associated with this expansion by \$0.024 to \$0.11 per peak season ccf conserved. The primary assumptions driving the difference in values were the projected volume conserved and the time horizon over which the costs were levelized. The lower estimate levelized construction costs over 100 years and used a conservation scenario projected to defer construction from 2012 to 2017. The higher estimate levelized construction costs over 50 years and used a larger difference in projected total conservation volume, which made expansion unnecessary for the next 50 years. Further details of the calculations are in APPENDIX D.

Projected climate change in the region may result in warmer, drier summers, decreasing peak season storage volume and increasing the probability of shortfalls (VanRheenen, Palmer, and Hahn, 2003). Such an effect could potentially increase the need for capacity expansion and therefore the marginal value of peak conservation. The magnitude of such an impact on prices would be difficult to quantify with the current information available.

The highest estimate of marginal savings from deferred expansion, \$1.33/ccf, comes from considering a third dam in the Bull Run Watershed. The Infrastructure Master Plan considered that possibility, higher in the watershed, between Dam 1 and Bull Run Lake. (See Figure 18.) The third dam would hold 20 billion gallons, doubling the capacity of the two dams with raised heights. The Infrastructure Master Plan showed this third reservoir to be needed in 2023 if the supply service area was expanded and no new conservation was implemented. It was not needed in any other scenario. The area's most recent Regional Water Supply Plan (Regional Water Consortium, 2004) cites a cost estimate of \$200 million for this possible new dam. However, the Water Bureau's current Capital Improvement Projects budget does not include any further study or refinement of the idea. A marginal cost of \$1.33/ccf comes from calculating a 100 year levelized cost of the dam, on the basis of two IMP scenarios: one with dam construction and no conservation, the other with conservation and no dam construction. This unit cost is significantly higher than the marginal costs for raising the current dams, largely because the new reservoir would produce much more available water than needed in Portland's current 50 year demand projections. This issue points out several effects of timespan and geographic boundary setting when analyzing infrastructure costs. Conclusions regarding the desirability of an additional dam may be different for the 18 water providers in the region than for Portland alone. A dam could also appear more cost effective if evaluated over a longer time span. On the other hand, building a large, theoretically long-term efficient new dam could also result in a near term effort to sell more water, to bring down the short term unit cost, which could be counterproductive to conservation efforts.

Environmental Impacts

The energy used in delivering water could cause negative externalities through related emissions. That effect should be smaller for Portland than for many systems because the local water supply is almost entirely gravity fed, minimizing pumping requirements. Because well field water does require pumping, the emissions impact would be largest for peak season water

costs. Given the relatively small magnitude and large uncertainty of both the electricity emission calculations of the prior section and the marginal water cost calculations here, I did not attempt to estimate this secondary effect.

The Bull Run Watershed is protected from development, entry, and logging by the Oregon Resource Conservation Act of 1996 and various federal laws, beginning with the Bull Run Trespass Act of 1904. These protections create a positive value to society arising out of the clean drinking water from the undisturbed forest and the additional air quality and wildlife habitat offered. One component of the clean drinking water value has been the lack of needed filtration in Portland's water system. An Advisory Panel on Bull Run Treatment alternatives to address new Clean Water Act requirements regarding *Giardia* and *Cryptosporidium* estimated costs that equate to a levelized \$0.05 to \$0.25/ccf for treatment that we have been able to avoid thus far because of our clean water source (Portland OR Bureau of Water Works, 2002).

Our use of water from the Bull Run River, however, has also reduced the value of some more indirect ecosystem services. Fish have not been able to migrate to the highest 11 miles of the Bull Run River since Dam 1 was built in 1928. In 1961, Dam 2 added a new river blockage another 5 miles downstream. The protection of the forest surrounding the streams does improve wildlife habitat. However, restricted fish passage, reduced summer stream flow, and higher summer stream temperatures may have contributed to the decline of ESA-listed steelhead trout and Chinook salmon (Taylor, 1998). Other plants and animals that share the same stream habitats are also affected. The current Capital Improvements Program budgets a total of \$1.67 million beginning in 2006 for actions to implement ESA and Clean Water Act requirements (Portland OR Bureau of Water Works, 2003). This capital budget is in addition to operating funds to complete agreements and environmental assessments. If this is the only cost of compliance, it would result in a negligible levelized amount. An expenditure of \$1 million each year equates to just \$0.02/ccf in levelized unit charges.

In the last few years the Water Bureau has been releasing 13 to 26 million gallons/day in the summer to maintain target water temperature for fish below dam 2 (Water Bureau public meeting on capital plans, 9/30/2004). This required minimum flow was already included in the volume projections used in APPENDIX D to calculate the savings from deferred capacity expansion, advancing the time of needed expansion slightly compared to when it would be needed if there were no extra summer releases. Thus, those early numbers already incorporate

some of the costs of abating species damage. The recently proposed 2005 to 2010 Capital Improvement plan adds a total \$10 million expenditure for modified water intake towers that would provide better temperature control and improve fish screening (Portland OR Bureau of Water Works, 2005). A single expenditure of \$10 million equates to less than \$0.01/ccf in levelized unit charges.

Many studies refer to the general negative impacts of dams on fish (e.g. Berkamp et al, 2000). Attempts at economic valuations of impaired rivers often rely heavily on reduced commercial fishing and recreational opportunities or on urban impacts such as real estate value or reduced flood risk (e.g. Postel and Carpenter, 1997; David Evans and Associates, 2004). However, I have found no studies with meaningful parameters on which to base a transfer of values to the conservation impacts on the Bull Run watershed. New projects in the watershed to further expand capacity should not significantly impact downstream fish, since all the new activity would be above the existing reservoirs. There would be habitat impacts within the watershed, including disturbance of ground and forest during construction, inundation of existing forest with expanded reservoirs or the new reservoir, and further reduction within the watershed of freely flowing streams. Because the watershed is already closed to all human activities other than water supply and hydropower maintenance, many economic techniques for quantifying changes in natural areas are inapplicable. A change that only impacts habitat within the closed area cannot affect commerce or recreation, unless it affects species that migrate in and out of the area.

Combined Effects of Water Rate Adjustments

The combined effect of all the adjustments discussed for water rates, plus projected Water Bureau rate increases, gives total 25 year present values 12% to 62% higher than the direct water savings present values in Part I. Table 26 summarizes the various components of this result. The combined infrastructure adjustments of rows 2 through 4 give an increase in the calculation of annual direct savings of 8% to 32%. The high cost/ccf of the potential, but currently unlikely, new dam was not included here. As discussed previously, some of the row 2 through 4 adjustments may be partly incorporated in currently anticipated Water Bureau rate increases, reported by the Oregonian (7/12/2004) to be +7%/year for the next four years. I have shown a range for real (net of inflation) Water Bureau rate increases of 1% to 6% per year for four years, because the source article did not make clear whether the 7% increases were in constant or

nominal dollars, and because the planned increases may incorporate some, but probably not all, of the adjustments in row 2.

Table 26: Components of societal benefits of water conservation measures

Category	Value
Reduced City Water Use	
1. Current volume-based water rate	\$1.72/ccf
2. Full amortized cost of infrastructure operations, maintenance, and replacement	+\$0.05 to 0.25/ccf for full maintenance of water main distribution system
3. Water Bureau current marginal cost excess	+\$0.40 to \$1.08/peak season ccf -\$0.20 to -\$0.55/off-peak season ccf net full year effect: +4% to +11%
4. Levelized cost of capacity expansion	Raise dams: \$0.024 to 0.18 / peak season ccf New dam: >\$1.00/peak season ccf
5. Air pollution impacts of Water Bureau activities	Probably minimal. Could be a small summer peak increment because of pumping requirements of well field use
6. Habitat impacts of flow reductions	Partially incorporated in costs of capacity expansion
7. Habitat impacts of increasing reservoir capacity	Not quantified
8. Combined effect of above	+8% to +32% over current rate ³³
9. Water Bureau's projected real rate increases	1% to 6%/yr for 4 years
10. Overall effect	+12% to +62%

Sewer and Stormwater System

This study assumes that potential externalities associated with sewer and stormwater services are to a large extent already being internalized in current and projected customer rates. The following paragraphs provide a little more background. I did not find data on which to make any better approximations for the economic considerations of full long term marginal infrastructure costs, or for the remaining environmental externalities. The following paragraphs provide a little more background.

Portland sewer and stormwater rates are among the highest in the nation. The Bureau of Environmental Services (BES) projects further increases of about 6%/year for the rest of the decade and 4%/year through 2020 (Portland OR BES, 2000), as shown in Figure 20. Updated estimates of the increment for the stormwater runoff rates are as high as 11%/year for the next

³³ Percentages in table row 8 derived from adjusted rates = (1) x [% adj. in (3)] + (2) + (4) = \$1.86 to \$2.27. These rates represent the average over the year of rates including the seasonal adjustments and are 8% to 32% above the \$1.72 base rate.

five years (Dan Vizzini, personal communication, 11/2004). These rates incorporate several environmental clean-up and protection activities: a \$1.4 billion project to eliminate combined sewer overflows, work to keep precipitation run-off from polluting local rivers and streams, and clean up of past contamination of Portland Harbor in the Willamette. Thus, current and projected sewer and stormwater rates incorporate charges arising out of damages and inadequate systems of the past. Very high current rates do not necessarily mean the absence of other incremental costs as were discussed for the water system. For example, the reports that discussed the impending rise in infrastructure replacement costs for water systems had similar comments about sewer systems (American Water Works Association, 2001; Beider and Tawil, 2002; U.S. EPA, 2002). Given lack of any detail from BES to further examine that issue, however, this study assumes the projected rate increases also include all maintenance and potential capacity expansion costs in the differential escalation rate for sewer and stormwater services.

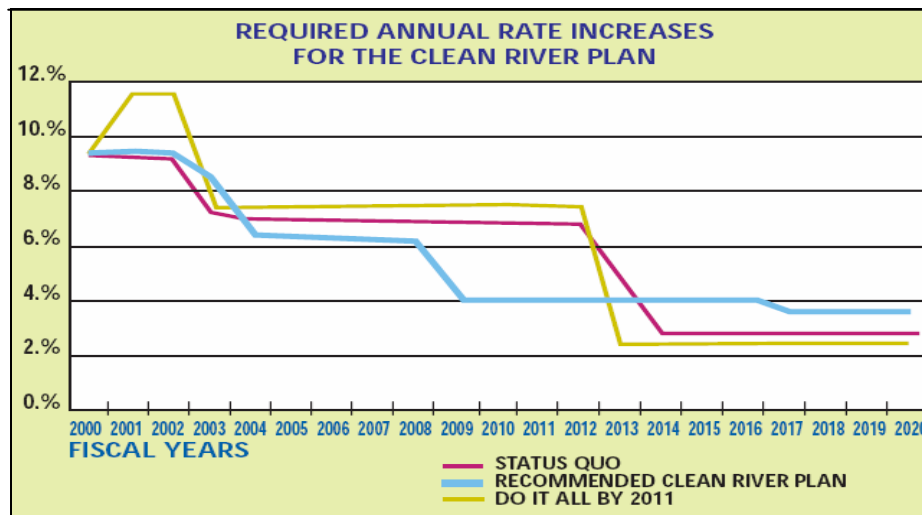


Figure 20: BES projected sewer and stormwater rate increases
 Figure from Portland OR BES, 2000

The 25 year present values of savings incorporating these projected real rate increases (the stated increases less the general inflation assumption) are 22% higher for sewer charges and 47% higher for stormwater run-off charges than the Part I direct present values. The use here of projected customer rate increases as the only basis of societal adjustment is equivalent to an assumption that an externalities which can be priced are being internalized already. That means that the larger “societal” savings expressed really represent the best estimate of PSU’s present

value of direct savings for stormwater and sewer charges. The schedules provided of possible future rate increases give just a single estimate of the magnitude of those changes. However, there is clearly considerable uncertainty surrounding these estimates. For lack of data to more precisely quantify a high and low end of the range, this study simply uses a factor of plus or minus 25% of the central estimates provided.

PSU's direct sewer bill savings created by using less indoor water may slightly overstate the savings to the Bureau of Environmental Services for treating sewage. Low flow fixtures, the source of the reduction, generally reduce the volume of sewage, but not the volume of total suspended solids. The Bureau of Environmental Services incorporates volume and solid loading factors into its ratemaking process, so the past total past effect from declining water use per capita has been incorporated into the historic change in sewage volume-based rates (Portland, OR BES, 2003). I assume any changes of this type arising from Epler conservation are also incorporated in the overall projected rate increases. I also assume that the volume-based rate charges for sewer service need no additional adjustment for marginal versus average long term costs. Environmental Services' ratemaking procedures allocate costs between a fixed amount and a volume-based charge. The fixed amount includes only the costs of customer services and billings. (Portland OR BES, 2003) Basic sewage processing does not reflect the same kind of peak-nonpeak demand and cost characteristics as found in some utilities.

Sewer bill charges also include a stormwater component, based on the amount of impervious surface on a commercial property. This charge is designed to cover the costs of managing and cleaning precipitation run-off, to reduce harmful impact on streams and habitat. Although the construction of Epler Hall increased the amount of impermeable rooftop and paving on the 39,000 square foot site, the design of the rainwater harvesting system offset that increase. The impervious area running directly to the city stormwater system reduced from 20,000 square feet when the previous building was on the property to 7,155 now.³⁴ The balance of the impervious area drains through the stormwater planters. From there, some goes to the rainwater harvesting system, with the latter overflowing to the city stormwater drainage pipes

³⁴ The remaining impervious surface generating unharvested runoff is from the half of the roof of the adjoining King Albert Hall that does not drain to the water harvesting system, plus sidewalks on the north, west, and south sides of the building.

going directly into the Willamette. Even for these overflows, though, the stormwater planter filtration should both delay the runoff, requiring less peak city volume capacity, and provide some initial cleaning.

As noted above, a large portion of sewer and stormwater charges are based on the costs of offsetting our negative impact on stream and groundwater quality. While separate calculations could be attempted for the value of currently impaired areas and species, those would not clearly relate to the incremental savings from Epler’s reduced sewage and quick runoff generation.

Water Externality Summary and Comparison with Other Studies

Part I showed that the largest component of direct savings from the Epler Hall’s water conservation features were from sewer and stormwater charges. The summary in Table 27 shows that to still be true after incorporating full long term marginal pricing. These results can be compared with other recent studies of the net benefits of green building.

Table 27: Unit values of direct and total water and sewer savings

	Base rate	% Increase	Total rate
Water	\$1.72/ccf	12% to 62%	\$1.93/ccf to \$2.78/ccf
Sewer	\$5.138/ccf	+17% to 28%	\$6.00 to \$6.57/ccf
Stormwater	\$6.06/1000 sq ft	+35% to 59%	\$8.20 to \$9.63/1000 sq ft

Kats’ study of California green building summarized total water plus sewer-related benefits at \$2.32/ccf saved (Kats, 2003).³⁵ That rate/ccf seems low in relation to even the direct utility bill savings in this Epler study. It may be that the California study used a shorter term view of marginal costs, or that there are some types of fixed cost components in the Portland numbers here that were not included in the marginal costs calculated by Kats. In addition, the underlying California Urban Water (CUWA) Association study on which Kats based his results was looking primarily at municipalities purchasing water from other suppliers, and it included minimal analysis of wastewater treatment costs. Kats noted several reasons that the CUWA results might be low, and then used twice the CUWA rates in his analysis. He mentioned further environmental externalities briefly but did not quantify them.

³⁵ \$2.32 was calculated from savings in that report, which were expressed as a \$12,498 present value at 5% of an annual usage reduction of 1 acre-foot/year.

The SBW study of recent Seattle buildings based all their water and sewer saving calculations on projected volume savings and direct utility rates. They assumed real utility rate escalation of 1.5% would cover all additional costs of full infrastructure replacement and potential expansion. Seattle's 2001-2002 water rates used in the study were \$1.69/ccf from mid-September through mid-May and \$2.75/ccf in the summer, fairly close to my adjusted Portland results after allocating well field costs to summer usage. The sewer rates were \$5.12/ccf. Nothing was included for changes in stormwater run-off of potential environmental externalities.

Societal Benefit Conclusions

This study left unpriced many potential impacts for which no good basis for even a rough estimate was found. Some of those impacts are listed in Table 28.

Table 28: Summary of unpriced savings

	Unpriced Savings
Electricity	Unpriced emissions (Hg, VOC, CO); Fossil fuel depletion, extraction, and distribution activity impact; Environmental impact of dams.
Natural gas	Fossil fuel depletion, extraction, and distribution activity impact; Price volatility impact.
Water	Dam impacts on fish and habitat; Emissions from water-delivery energy.
Sewer	Air and water emissions from sewage waste processing.
Stormwater	Current (before complete CSO fix) run-off impacts.

Table 29 summarizes the direct savings from Part I and the range of additional savings from Part II that could be roughly evaluated. The low ends of the range for all the entries in this table incorporate primarily financial impacts of tax adjustments and anticipated rate increases for infrastructure expansion. Electricity is the only category that had any material environmental impact prices. Even there, the prices came primarily from the direct impact of emissions on human health. As discussed in the summary of societal energy impacts, the high and low ends of each range have simply been totaled, which probably overstates the width of the range. It is unlikely that all the low-end effects or all the high-end effects would occur simultaneously. However, given the lack of precision in data underlying each estimate, there is no clear way to materially refine the total estimate. This table can be seen at best as a general guide to the order of magnitude of possible societal adjustments.

Table 29: Summary of direct and societal present value of savings (\$1000s)

	Ongoing Utility Savings (1)	Net Direct Savings (2)	Incentives, Tax Red'ns in Direct Savings (3)	Externality Additions (4)		Net Societal Savings (5)	
				Low	High	Low	High
Electricity	\$469	na	na	na	na	na	na
Natural gas	\$138	na	na	na	na	na	na
Total Energy	\$606	\$400	\$70	\$40	\$410	\$370	\$740
Water	\$29	na	na	\$4	\$18	na	na
Sewer	\$81	na	na	\$14	\$23	na	na
Stormwater	\$9	na	\$15	\$3	\$5	na	na
Total Water	\$119	\$26	\$15	\$21	\$46	\$32	\$57
Total	\$725	\$426	\$85	\$61	\$456	\$402	\$797

All amounts 25 year present values at 3% discount, in \$1000s.

na ⇒ results not allocated at this subcategory level.

Notes to Table 29:

- (1) Ongoing savings from calculations of reduced annual utility bills.
- (2) Net direct savings = (1) minus incremental costs.
- (3) Incentives and tax reductions to be subtracted from direct savings in determining societal savings.
- (4) Calculated increments for societal financial and environmental components that could be evaluated.
- (5) Net societal savings = (2) – (3) + (4).

The Value of Externality Pricing and Areas for Future Research

From the results of this study, it appears premature to credibly allocate externality pricing to local individual activities such as conservation savings from a single building. It may be that the initial objective of the study was imperfectly defined. A more focused question on any one of the single topics in the above table might have permitted a more thorough analysis and more definitive results. The background research in this study should at least permit identifying areas in which future research might be the most useful.

In any one of the topics covered, I see several basic areas of research needs. One is developing and using models that are complex enough to capture material variables while being straightforward and transparent enough to truly facilitate understanding. For example, the complex electricity system programs used by the Northwest Power and Conservation Council and the Wisconsin energy conservation study are able to consider energy grid characteristics and timing differences that can have a material affect on marginal emission determinations. Likewise, a regional water supply study needs the ability to model a wide variety of sources, users, interconnections, weather conditions, demand patterns, and infrastructure characteristics.

Another area of needed research is in the development of underlying data, without which no models can generate credible results. In the science arena, there appear to be very few studies quantifying ecological impacts of human activity in a way that can then be economically valued. Challenges include the variability of local habitats, complexity of large ecosystems, and the difficulty of performing experiments representative of the natural world. On the economic side, there is very little work that actually quantifies the supply and demand elasticities, for example, that would be needed to apply economic theory to price adjustments for local water use.

A third area of needed research relates to connecting the many layers that go from the micro-view of local emissions or other damaging effects all the way to the macro-view of ecosystem services to humanity. Further, if we desire, as at the outset of this study, to allocate that macro-view impact back down to the effect of a local individual activity, another set of linkages is required. Some life cycle analysis models (e.g. SimaPro from PRe Consultants) attempt to make these connections, but the underlying basis for the linkages is imprecise at best. The number and complexity of connections needed between layers of uncertain data can be overwhelming. We need individuals with sufficient understanding of the data and possibilities at each connection stage to help determine whether the task is a feasible one to undertake.

A publicly useful valuation must be both credible in the scientific and statistical sense and also believable to the general public. Incomplete results, and those with very wide uncertainty ranges must be used with care in public discussions. The valuation of externalities most effectively informs public debate when several conditions are met: the impact is clear and relatively immediate; the impact is at least partly local; and the impact creates a recognized need to spend current dollars for mitigation or substitute benefits. By developing the proper background studies, the pieces will be in place to put the next proposal for infrastructure expansion or change in the proper context.

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APPENDIX A. Green Building Performance Studies

The following tables summarize the general methods and conclusions of several recent green building studies.

Appendix Table A-1: New Seattle public buildings (SBW, 2004)

Study type	Prospective for 2 buildings under construction
Building type	Performance Hall and Justice Center
Region	Seattle
Items measured	Costs and Benefits of LEED compliance
Benchmarks	Seattle code requirements (which are more stringent than ASHRAE)
Metrics used	PV of costs and benefits by LEED category
Period	25 years
Real annual inflation rates	Water and sewer: +1.5% Electricity: -1.8% Gas: +0.3%
Discount rates	2% and 6% alternatives
Societal cost treatment	Valued where possible as part of secondary benefits
Energy	Green house gas only quantified\
Water	Assumed included in real inflation rate
Sewer	Assumed included in real inflation rate
Productivity	The major secondary benefit, valued on the basis of reduced sickness and increased indoor comfort
Conclusions	25 year Benefit /Cost ratios of Direct (primary) only: 0.8 to 1.1 Societal: 1.2 to 1.7

Appendix Table A-2: Various high-efficiency buildings (Torcellini, 2004)

Study type	Retrospective actual and simulated 6 actual high-efficiency buildings
Building type	Varied commercial
Region	Varied US (SW to NE)
Items measured	Energy
Benchmarks	ASHRAE standards and original building design
Metrics used	Energy cost/ft ² Energy kwh/ft ² Net savings %
Period	1 year
Real annual inflation rates	na
Discount rates	na
Societal cost treatment	Not included
Conclusions	Most buildings performed overall at least as well as predicted. All had difficulties with some systems.

Appendix Table A-3: California office buildings (Kats et al, 2003)

Study type	Aggregate comparison of average costs and benefits of green building, from a combination of survey, literature, and actual results
Building type	Commercial
Region	California
Items measured	Total building incremental costs for LEED certification Savings by category: energy, water, construction waste, productivity
Benchmarks	National averages and CA building codes
Metrics used	PV of costs and benefits
Period	20 years
Real annual inflation rates	Energy and water costs assumed to increase only at average inflation rate
Discount rates	5% (specified by CA Energy Commission)
Societal cost treatment	see below
Energy	Estimate of peak savings at marginal rates Market prices for emission-trading (NO _x , SO ₂ , PM-10, and CO ₂) to average emission rates for in-state generation.
Water	Not quantified (other than estimate of marginal versus average costs)
Sewer	Not quantified (other than estimate of marginal versus average costs)
Productivity	Valued on the basis of reduced sickness and increased indoor comfort
Other	Waste reduction – valued at total direct economic value of landfill diversion Building commissioning – assumed to reduce annual operating and maintenance costs by 5%
Conclusions	Net savings sources: productivity: 70% reduced O&M: 16% energy direct economic savings: 11% energy emissions value: 2% water : 1% waste: <1%

Appendix Table A-4: Southern California office building (Packard, 2002)

Study type	Prospective modeling, 6 different LEED level alternatives for one hypothetical building
Building type	Office
Region	Southern California
Items measured	Costs and savings from design construction, energy use, water use. Schedule impacts.
Benchmarks	Typical “market” code-compliant building
Metrics used	PV total costs for each alternative
Period	30 to 100 years for direct costs. 20 years for externalities
Real annual inflation rates	energy: +3.5%/yr
Discount rates	3.5% assumed real cost of capital
Societal cost treatment	see below
Energy	PG&E reported average emission rates times health impact costs from Levy, 1999
Water	Externalities not valued
Sewer	Externalities not valued
Productivity	Not valued
Conclusions	Significant PV direct cost savings from years 30 to 100. Energy externalities added about 15% to direct electricity bill savings

Appendix Table A-5: Michigan classroom & hotel building (Scheuer et al, 2003)

Study type	Life Cycle Analysis
Building type	Mixed use: classroom/office/hotel
Region	Michigan
Items measured	Detailed building materials inventory by mass; modeled energy and water use
Benchmarks	na
Metrics used	Environmental burdens (global warming, ozone depletion, acidification, nitrification, solid waste generation) by activity
period	75 yrs
Real annual inflation rates	na
Discount rates	na
Societal cost treatment	Burdens calculated on a life cycle basis: not valued or otherwise aggregated. Human toxicity impacts excluded for lack of detail on location of emissions. Resource depletion impacts excluded for lack of agreed-upon metric.
Conclusions	Operations phase energy use dominates all impact areas

APPENDIX B. Epler Hall Summary Facts

Appendix Table B-1: Epler Hall characteristics

Building opened	September 2003														
Cost	\$10 million														
Identified incremental costs for green features	<table> <tr> <td>Rainwater Harvesting System:</td> <td>\$62,000</td> </tr> <tr> <td>Ultra-low flow toilets (1.4 gal):</td> <td>\$10,600</td> </tr> <tr> <td>Sun shades:</td> <td>\$125,000</td> </tr> <tr> <td>Higher efficiency boilers and heat recovery units:</td> <td>\$50,000</td> </tr> <tr> <td>Commissioning:</td> <td>\$90,000</td> </tr> <tr> <td>Materials-and recycling related costs:</td> <td>\$26,000</td> </tr> <tr> <td>Indoor air quality related costs:</td> <td>\$22,500</td> </tr> </table>	Rainwater Harvesting System:	\$62,000	Ultra-low flow toilets (1.4 gal):	\$10,600	Sun shades:	\$125,000	Higher efficiency boilers and heat recovery units:	\$50,000	Commissioning:	\$90,000	Materials-and recycling related costs:	\$26,000	Indoor air quality related costs:	\$22,500
Rainwater Harvesting System:	\$62,000														
Ultra-low flow toilets (1.4 gal):	\$10,600														
Sun shades:	\$125,000														
Higher efficiency boilers and heat recovery units:	\$50,000														
Commissioning:	\$90,000														
Materials-and recycling related costs:	\$26,000														
Indoor air quality related costs:	\$22,500														
Footprint	173 ft x 61 ft, long orientation N-S														
Total floor area	64,000 sq ft														
1 st Floor	3 classrooms, office space, boiler room, bike storage														
2 nd – 6 th Floors	26 efficiency apartments/floor, each about 290 sq ft														
Heating (no air conditioning)	<p>Gasmaster Boiler GMI 300; Capacity 305 kBtu/hr Efficiency 95.6 – 99.8%</p> <p>Individual electric baseboards in apartments</p>														
Domestic Hot Water	<p>Gasmaster Boiler model GMI 1M; Capacity 1000 kBtu/hr Efficiency 94 – 97%</p> <p>400 gal tank</p>														
Ventilation and Energy Recovery	<p>Air-to-air thermal recovery wheels:</p> <p><u>for residential bathrooms and corridor</u> Greenheck ERH-55H-15, rooftop unit exhaust volume 3,900 cfm</p> <p><u>for first floor restrooms</u> Greenheck ERV-251S-20-A exhaust volume 550 cfm</p>														
Laundry facilities (3 washers and dryers on each of 5 th and 6 th floors)	<p>6 front load Speed Queen washing machines. model SWFB61WN 19.2 gal/load Modified Energy Factor (MEF) = 1.9 (min. for Energy Star qualification = 1.4)</p> <p>6 Alliance natural gas dryers model NUG419WF 25,000 kBtu/hr</p>														
LEED Rating	LEED silver 33 of 69 possible points														
Utility Providers, volume-based rates	<p>Water: Portland Water Bureau. 2004-05 rate \$1.72/ccf</p> <p>Sewer: Portland Bureau of Environmental Services. 2004-05 rates: \$5.138/ccf - sewer \$6.06/1000 impermeable sq ft/mo. - stormwater</p> <p>Electricity: Portland General Electric (PGE), schedule 83S, \$0.0496/kWh</p> <p>Gas: Northwest Natural, rate schedule 03C, \$0.89425/therm average</p> <p>Rates in effect 7/2004 to 6/2005</p>														
Building Design and Construction	<p>Architects: Mithun, Seattle, WA</p> <p>General Contractor: Walsh Construction, Portland, OR</p> <p>Structural/Civil Engineering: kpff Consulting Engineers, Portland, OR</p> <p>Mechanical/Electrical Engineering: Interface Engineering, Portland, OR</p>														

APPENDIX C. Direct Water Use Calculation Details

Total Water Use

Appendix Table C-1: Classroom/office expected water use

Occupancy Level	Design Assumption	% of Total Water Use	First Year Actual	% Change
Classroom person-hrs/day	960	90%	164	-83%
Office full time equivalent staff	8	10%	8	0%
Total	na	100%	na	-75%

Data sources:

Design assumptions - Stephen Epler Hall LEED Certification Application

First Year Actual classroom – listings of scheduled courses and registration counts for Fall 2003 through Summer 2004 terms.

First Year Actual office – estimate based on discussions with 1st floor Center for Environmental Education staff.

Appendix Table C-2: Water fixture flow rates

	Pre-'80 fixtures	'80-'94 fixtures	Baseline	Design
Bathroom sink (gal/min)	4	4	2.5	1
Toilets (gal/min)	5.5	3.5	1.6	1.44
Laundry (gal/wash)	56	51	60	19
Kitchen sink (gal/min)	4	4	2.5	1.5
Shower (gal/min)	5	5	2.5	2

Data sources:

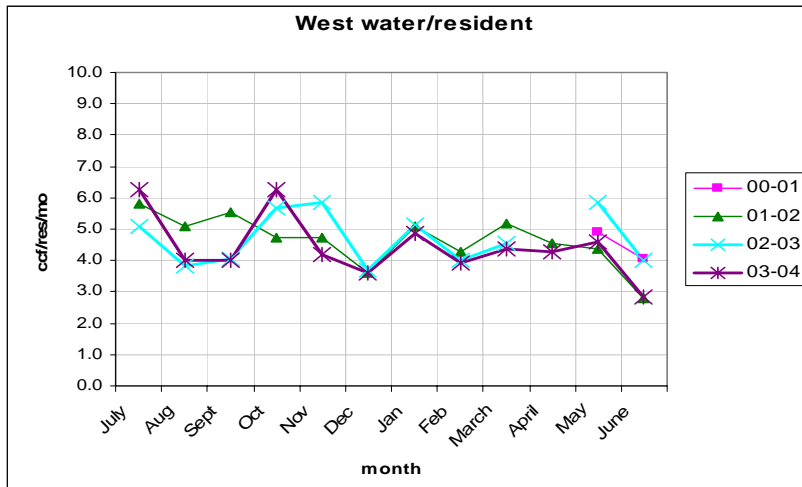
Baseline: Stephen Epler Hall LEED Certification Application

Design: Final commissioning report and appliance inspection

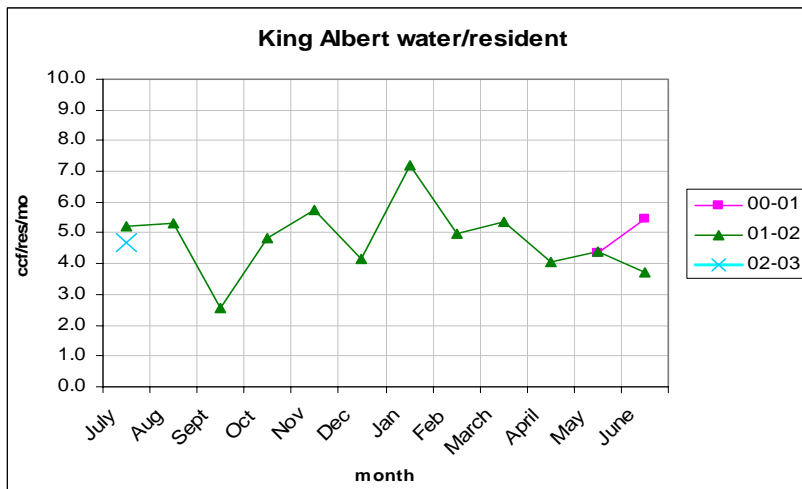
Pre-'80 and '80-94 fixtures: deMonsabert, S. and Liner, B.L. (1996)

Water Use in Other Residence Halls

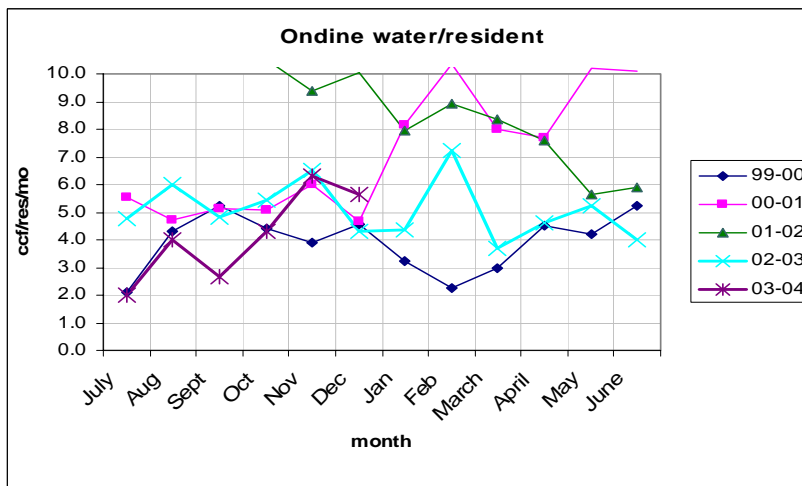
Water submetering data is not consistently available for historic use of all PSU residence halls. Of the three residence halls being used as comparisons, West Hall has fairly consistent water use readings over two recent years. King Albert also has similar result for dates between November, 2001 and July, 2003. The meters for King Albert have not been working correctly since that time. Ondine has the longest record available, but a very wide variation in reported use. There appears to be no relationship between water use per resident and the age of buildings.



West Hall:	
built:	1986
# residents:	189
total ccf/res/yr	
'01-02	55.8
'02-'03	51.8
'03-'04	<u>53.2</u>
Average	53.6



King Albert	
built:	1931
# residents:	64
ccf/res/yr:	
'01-02	57.6



Ondine	
Built:	1966
# residents:	288
Total ccf/res/yr:	
'99-00	46.9
'00-01	85.6
'01-'02	108.8
'02-03	60.9

Figure C-1: Historic water use/resident

Water Harvesting Calculation Assumptions

Runoff Surface Area.

The final submission for LEED certification excluded 4,000 square feet of roof surface feeding the harvesting system, because that roof is on a pre-existing neighboring building. For the purpose of the calculations in this study, however, all harvest area is relevant.

Precipitation Assumptions

“Design Case” monthly precipitation in Figure 9 shows average precipitation since 1941. These historic precipitation amounts are about 10 % less than the numbers used in the Water Harvesting Calculations submitted for LEED certification, which appeared high. For the purpose of filtering and delaying rainwater that would otherwise go immediately into the city’s storm system, the focus is on sufficient size of the flow-through retention planters to capture a design storm event. Average annual rainfall and summer average rainfall figures are largely irrelevant to that calculation. For the purpose of minimizing summer peak demand on the city’s water system, using lower expected rainfall amounts might result in larger storage tank sizing, particularly if the objective were to provide sufficient storage capacity to last through at least half of the summers.

Appendix Table C-3: Summer precipitation comparisons

	June	July	August	September	Total
Mean 1941 – 2003	1.57	0.58	0.85	1.60	4.60
Median 1941 – 2003	1.69	0.44	0.67	1.45	4.25
PSU Mean 2001 – 2004	0.89	0.24	0.78	0.82	2.74
PSU 2004	1.11	0.01	2.40	0.62	4.14

Data Sources:

63 year means and medians calculated from daily precipitation data since 10/1/1940, from National Weather Service: <http://www.wrh.noaa.gov/Portland/climate/daily/prec6751.lf>.

Total for Median row = median of the 4-month totals for each year, not the total of the monthly medians.

2000-2004 PSU data from hourly precipitation data from Portland Hydra gage at SW 12th and Clay (3 blocks from Epler), from http://or.water.usgs.gov/non-usgs/bes/twelfth_and_clay.rain.

During most of the year, rain falls frequently enough that the storage tank would be expected to remain fairly full. In the summer, however, a full tank will last for less than a month of Design-level irrigation plus rest room use. Less than 19% of the summers in the past 63 year had dry spells (periods with less than .1” rain) longer than the 2004 stretch of 57 days. However, 80% of summers have had a dry spell greater than the 30 days capacity of the harvesting tank. The median summer dry spell is 43 days. (All based on National Weather Service data).

Water Harvesting Direct Costs and Savings

Appendix Table C-4: Projected utility bill impacts of water harvesting system

Period	Future Demand		
	Irrigation (1) (ccf/period)	Restrooms (2) (ccf/period)	Total (ccf/period)
June – Sept	11.3	2.7	3.8
Oct – May	1.0	6.7	6.8
June – Sept	12.3	9.4	10.6

- (1) Irrigation demand reflects expected levels for established plantings.
- (2) Restroom demand assumes that classroom use will level off at 75% of the Design estimate, because one of the four original “classrooms” has been reassigned to office use, reducing potential student occupancy rates with no increase over the expected number of full time equivalent office workers.

APPENDIX D. Water Supply Infrastructure Cost Calculations

Estimating Peak Rates

Appendix Table D-1 estimates the incremental cost of summer season water on the basis of the costs of running the Columbia South Shore Well Field (CSSW), which provides supplemental volume during some part of most summers.

Appendix Table D-1: Levelized costs for Columbia South Shore Well Field

Cost Component	Amount (\$ million)	Levelized amount (\$/ccf)	Source
A. Capital expenditures before 2003	\$18.5		Water Bureau CIP (1) for groundwater supply and disinfection projects
B. Total budgeted capital expenditures 2004-2009	\$21.1		
C. Levelized capital costs		\$0 to \$0.68	<ul style="list-style-type: none"> • Low cost from assuming no allocation of CSSW capital expenditures to peak costs. • High cost from allocating all CSSW costs in A + B solely to summer use. (2)
D. Operating costs	\$1.0 / yr	\$0.40	2 x Water Bureau 2004-2005 budget increase request for increasing potential CSSW operation from 30 to 60 days
E. Total wellfield levelized cost		\$0.40 to \$1.08	Sum of C + D, applicable to peak season rate (2)
F. Reduction in off-peak rate		-\$0.20 to -\$0.55	Keeps Water Bureau total income constant (3)

Additional explanations by row:

A & B: CIP = Capital Improvement Program, Portland OR Bureau of Water Works, 2003

C: Levelized costs calculated as the present value of annual outlays for the CSSW divided by the present value of summer well field volumes.

- Present values at a 3% real discount rate.
- Time horizon = 75 years, the assumed lifespan of the equipment..
- New capital costs assumed to drop to 0 after 2009, for the balance of the assumed 75 year lifespan.

- Assumed financing of capital costs when incurred by 30 year bonds at 5% interest. (Triple A 30 year municipal bonds during August 2004 yielded 4.9% to 5.1%, from www.Bloomberg.com/markets/rates, 8/25/2004.)
- Assumed well-field water use of 1.8 billion gallons/year (= 30 million gallons/day x 60 days), based on recent summer daily usage and budgeted usage period.

D: Unit operating cost of \$0.40/ccf = \$1.0 million/yr divided by assumed summer well-field volume of 1.8 billion gallons (2.4 million ccf).

E: Because the current, non-seasonal, water rates cover all Water Bureau costs, there is theoretically some double counting if peak costs are estimated by adding the levelized well field cost in E to the full year-round rate. However, total levelized well field costs are only 3 to 7% of the \$100 million annual Water Bureau budget, depending on assumptions regarding future new capital costs and division between tier1 and tier 2 rates. Within the accuracy of this very rough approximation, the refinement of eliminating the overlap would be immaterial.

F: Off-peak reduction has the effect of keeping full year Water Bureau revenue constant while applying the higher peak rates to all water use in three summer months each year. Assumed total system volumes: 142 gallons/day summer, 106 gallons/day full year average (Anne Conway, Portland Water Bureau, personal communication).

Deferring Costs of Infrastructure Expansion

Appendix Table D-2 summarizes assumptions for the levelized cost calculations of deferring dam height increases in the Bull Run watershed.

Appendix Table D-2: Levelized costs for raising dam heights

Scenario	Low Estimate	High Estimate
Project Cost	\$14.5 million	
Volume basis	<ul style="list-style-type: none"> Expanded service area without conservation vs Expanded service area with conservation 	<ul style="list-style-type: none"> Expanded service area without conservation vs Current service area with conservation
Project timing	<ul style="list-style-type: none"> 2012 without conservation; Deferred to 2017 with conservation 	<ul style="list-style-type: none"> 2012 without conservation; Eliminated with conservation
Period for levelized costs	100 yrs from construction	50 yrs from construction
Present value of cost differences	\$2.0 million lower costs with conservation	\$14.5 million lower costs with conservation
Present value of volume differences	61 million ccf	131 million ccf
Levelized cost / peak season ccf	\$0.024	\$0.11
Master Plan scenario basis	# 3 – expanding service area, with conservation vs # 8 – expanding service area, without conservation	alt #3 – with conservation volumes, without dam raise vs # 8 – expanding service area, without conservation

Assumptions for levelized costs:

project costs: from Infrastructure Master Plan and other Water Bureau preliminary estimates. The source documents give only point estimates, not ranges, for the infrastructure expansion. Because these assumptions were prepared several years ago, the estimates are probably low.

volumes: peak season (4 month) volumes from Infrastructure Master Plan scenarios; level after 2050 for 100 year calculations

real discount rate: 3%

project financing: 30 year bonds at 5%, issued in year of construction

levelized marginal cost:
$$\frac{\sum_{y=1}^{IV+LT} (\text{cost}1_y - \text{cost}2_y)(1+d)^y}{\sum_{y=1}^{IV+LT} (\text{vol}1_y - \text{vol}2_y)(1+d)^y}$$

cost_{1y}, cost_{2y} = the bond repayment costs in year y for each option
vol_{1y}, vol_{2y} = total projected peak season volume in year y for each option
d = real discount rate
IV = years until project construction (incurred year)
LT = time horizon for cost levelization

Appendix Table D-3 shows an example of the calculation for the low cost case, with a construction deferral of 5 years and a levelized cost impact of \$0.024/ccf.

Other Considerations in Water Demand Projections

Needed future capacity is an estimated volume that depends on the level of reliability the city desires in the system. The projected demand and supply volumes in the Water Bureau's Infrastructure Master Plan (IMP) used a relatively dry summer, likely to be worse than those occurring in 29 out of 30 years. Society could reduce the need for capacity enhancements if we were willing to accept more frequent expected drought restrictions on water use.

Despite the projections of the IMP and statements in the 2004-2009 Capital Improvement Program document that "increased demands could exhaust existing supplies," (Portland OR Bureau of Water Works, 2003, p.5), water demand is no greater today than it was in the early 1990s, as seen in Figure D-1 (Portland OR, 2004; Portland OR Auditor's Office, 2004; Yudelson, 1998). The sources of that information attribute this fact to increased conservation after 1992 drought restrictions, newer building codes for plumbing fixtures, and recent loss of some wholesale customers jurisdictions outside of Portland.

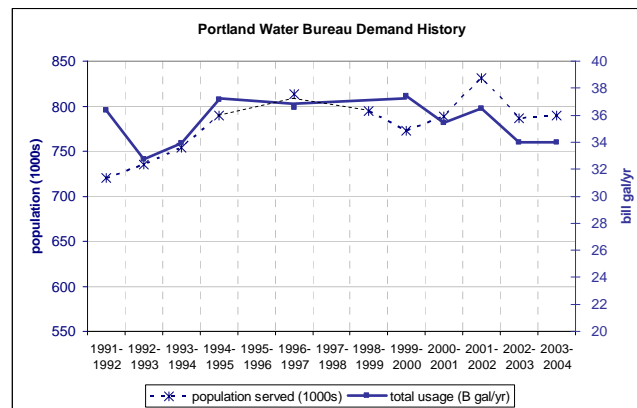


Figure D-1: History of Portland total water usage

"Population" is the total served by Water Bureau, both direct Portland and indirect wholesale customers.

About half of the population covered by the Regional Water Supply study is outside Portland city limits. The 2000 to 2003 population growth rates for covered areas were 3% for Portland and 7% for those other cities.³⁶ Uncertainties regarding long term customer area and interties between independent municipality supply sources complicate long term supply and demand projections.

³⁶ Growth rates based on cities identified in the Regional Water Supply plan and U.S. census population by city from the Oregon Blue Book (<http://bluebook.state.or.us/local/populations>).

APPENDIX E. Units and Conversion Factors

This study expresses most energy in British thermal units, so that electricity and natural gas use can be added. The table below gives factors for converting from a unit in the left column to a unit in the top row. For example, Table 6 shows actual gas use of 910 MBtu. From the last row of the table, we see that would be equal to $10 \times 910 = 9,100$ therms, the unit shown on a natural gas bill.

Appendix Table E-1: Energy conversion factors

To convert from ↓ to →	therm	kilowatt hour (kWh)	megawatt hour (MWh)	British thermal unit (Btu)	thousands of Btu's (kBtu)	millions of Btu's (MBtu)
1 therm =	1	29.3	0.0293	100,000	100	0.1
1 kWh =	0.03412	1	0.001	3,412	3.412	.003412
1 Mwh =	34.12	1,000	1	3,412,000	3,412	3.412
1 Btu =	10^{-5}	$2,931 \times 10^{-4}$	2.931×10^{-7}	1	0.001	10^{-6}
1 kBtu =	0.01	0.293	0.000293	1,000	1	0.001
1 MBtu =	10	293.1	0.2931	10^6	1,000	1

The table below gives conversion rates between common expressions of water use volume. Water and sewer bills are expressed in hundreds of cubic feet (ccf), where a cubic foot is 7.48 gallons.

Appendix Table E-2: Water volume conversion factors

To convert from ↓ to →	gallon (gal)	cubic foot (cf)	100 cubic feet (ccf)	gallons/day (gal/day)	gallons/year (gal/yr)	100 cubic feet/year (ccf/yr)
1 gallon =	1.	0.1337	0.001337			
1 cf =	7.48	1.	0.01			
1 ccf =	748.	100.	1.			
1 gal/day =				1	365.	0.488
1 cf/day =				7.48	2,730.	3.65
1 ccf/year =				2.05	748	1.

APPENDIX F. Terms and Abbreviations

ASHRAE	American Society of Heating, Refrigerating and Air-conditioning Engineers. A professional organization that establishes standards and guidelines for energy-efficient building systems. ASHRAE Standard 90.1, developed in 1999, is commonly used as a current benchmark for performance.
AWWA	American Water Works Association
Baseline Case	The performance basis to which Epler Hall is compared in determining savings or costs of green building features. When the term is capitalized in this study, it refers specifically to the theoretical calculations of energy or water that the building would have required if it had been built just to code. (see also Design Case)
Btu	British thermal unit. An energy measurement roughly equivalent to the energy from one burning match. 100,000 Btu's are equivalent to 29.3 kilowatt hours of electricity or 1 therm of natural gas. See APPENDIX E for more conversion factors
ccf	Hundred cubic feet = 748 gallons. Water and sewer bills are often expressed in ccf. Natural gas bills also typically show ccf of gas used, but the more relevant energy measurement is therms, also shown on the gas bill.
CIP	Capital Improvement Plan documents from Portland Water and Environmental Services Bureaus, showing planned capital expenditures by project over the next five years.
Cogeneration	A method of decreasing energy wasted during electricity production by combining power generation with thermal heating capacity. Waste heat from electricity generation may be used for local heating requirements. Alternatively, waste heat from thermal processes may be used for generating electricity.
Commissioning	Professional review and fine-tuning of building systems to verify that efficiency features are installed and functioning as intended and to optimize settings.
Conservation	Used in this document to refer to any activity that reduces the use of water, energy, or materials. Includes both efficiency measures (deriving at least as much benefit from less input) and the more narrow definition of "conservation" sometimes used, settling for less useful output.
Consumer Price Index (CPI)	An index compiled monthly by the federal government to measure changes in average prices over time. The consumer price index reflects current costs of a "typical" market basket of goods and services in relation to costs in a base year.
CSSW	Columbia South Shore Well Field. The source of the Water Bureau's supplemental water supply, during times that the Bull Run source is nearing depletion or quality-impaired.

Demand	When applied to electricity, refers to the amount of power being used at any given time. Maximum demand, typically measured in kilowatts, determines the needed sizing of generation and transmission facilities, even if the peak demands are relatively brief.
Design Case	The expected performance of Epler Hall, based on theoretical calculations using the final specifications of building features. (see also Baseline Case)
Differential Escalation Rate	The rate at which a cost (typically a utility charge) increases in relation to the assumed general inflation rate.
Discount Rate	An interest rate when used to discount or deflate future financial values to their current value equivalents.
Efficiency	In general, the measure of a useful output in relation to one or more required inputs, for example the amount of light provided by a light fixture per kWh of electricity consumed. In this report, “efficiency measures” refers to the subset of conservation measures that provide the same useful benefit with less required energy or water.
eQuest	A complex but relatively user-friendly building energy simulation tool by James Hirsch. The software provides a Windows-based wrapper for DOE-2, a widely recognized standard for building integrated design modeling since the early 1980’s.
EUI, Energy Use Intensity	Building energy use per square foot.
Eutrophication	Depletion of oxygen in a stream or lake caused by excessive nutrients (from sources such as run-off water containing excess fertilizer or deposition of nitrogen oxides from air pollution). The high nutrient level initially causes fast algae growth, which then depletes the oxygen supply as it decays.
Externality	A positive or negative effect of a financial transaction that is not reflected in the price of that transaction. The effect accrues to, or is borne by, parties other than the buyer and seller.
Green Building	Building with features designed to decrease environmental impacts
Infrastructure Master Plan (IMP)	The Portland Water Bureau’s most recent study of needed maintenance and future expansion of the water supply network. See Watson, 2001 in References.
Integrated Resource Planning (IRP)	A method of evaluating alternatives for meeting total energy or water needs that considers both supply-side changes, such as expanding electricity generating capabilities, and demand-side changes, such as introducing conservation measures.
kBtu	1000’s of Btu’s. See Btu (British Thermal Unit) and conversion factors in APPENDIX E.

kW	Kilowatt or 1000 Watts. A unit of power, or energy demand. For example, a 1500 Watt hair drier demands 1.5 kilowatts whenever it is on. If it is used for one full hour, it would use 1.5 kWh. If it is only on for 6 minutes, it uses 0.15 kWh.
kWh	Kilowatt hour. A unit of energy (representing the amount of work done over time) typically used in electricity bills. See also kW and APPENDIX E for conversion factors.
LEED; LEED-NC; LEED-EB	Leadership in Energy and Environmental Design. A program by the U.S. Green Building Council to certify green buildings meeting defined standards; LEED-NC applies to New Construction; LEED-EB is a new program providing making recertification available to existing buildings.
Levelized cost	A level annual cost that is equivalent over time to an irregular pattern of periodic costs. For example, a required expenditure of \$10 at the end of every tenth year, would be equivalent to a levelized cost of \$1/year, if interest is not taken into account. Its levelized cost equivalent would be slightly less than \$1/year if the levelized payments are assumed to earn interest between the year in which they are paid and the year in which the actual cost is incurred. See also "Present Value." A levelized cost may be calculated as the present value of the projected costs, divided by the present value of the units over which the cost is being apportioned. Those units may be simply 1/year, to calculate total levelized costs/year. Alternatively, the units may be expected volumes over which the costs will be charged, such as using the projected annual demand for water as the basis over which to levelized a cost per gallon or ccf of water.
Low-e	Low-emissivity. A window characteristic typically consisting of a thin metallic coating on one of the inner sides of a double pane window, to reduce re-radiated heat flow.
Life Cycle Analysis (LCA)	An evaluation of the full environmental impact of a product, incorporating the impacts of processes over the full product life cycle, from the mining or other acquisition of raw materials through manufacture, productive use, and final product disposal.
Marginal Power Source	The power source (specific plant or general type of plant) that is likely to be affected (generate more or less electricity) when demand increases or decreases. For example, gas-fired natural gas generators are often marginal power sources because they can be turned on or off relatively quickly. Coal-burning plants, once on, are generally kept on-line for long periods of time, because of the time it takes to fire them up to the proper temperature.
MBtu	Million Btu's. See Btu (British Thermal Unit) and conversion factors in APPENDIX E.

Nominal Discount Rate	A discount rate as it would commonly be expressed in conversation. It may be divided into two components: the general inflation rate plus the excess of the nominal rate over inflation. Used for calculations over time where future values are all expressed in then-current (inflated) dollars.																				
NO _x	Nitric oxide, NO, nitrogen dioxide, NO ₂ , contributors to photochemical smog when emitted to the atmosphere.																				
Peak Demand	Typical maximum levels of water or energy demand. For example, water peak demand in Portland is typically in the summer, when irrigation is being used. Electricity residential peak demand typically occurs 6-10 a.m. and 5-8 p.m..																				
PM-10	Airborne particulate matter of 10 microns or less diameter.																				
Present Value	<p>The amount of money needed in a savings account today to exactly fund a defined future cash flow pattern. To calculate a present value, an interest rate applicable to the hypothetical savings account must be assumed. For example, if the interest rate is 3%, and the cash flow at the beginning of years 1, 2, and 3 is \$50, \$20, \$40, then the present value is \$107.12, as can be seen below:</p> <table border="1" style="margin-left: auto; margin-right: auto;"> <thead> <tr> <th style="text-align: center;">year</th> <th style="text-align: center;">beginning acct balance</th> <th style="text-align: center;">needed cash flow</th> <th style="text-align: center;">interest earned at 3%</th> <th style="text-align: center;">ending acct balance</th> </tr> </thead> <tbody> <tr> <td style="text-align: center;">1</td> <td style="text-align: right;">\$107.12</td> <td style="text-align: right;">\$50</td> <td style="text-align: right;">\$1.71</td> <td style="text-align: right;">\$58.83</td> </tr> <tr> <td style="text-align: center;">2</td> <td style="text-align: right;">\$58.83</td> <td style="text-align: right;">\$20</td> <td style="text-align: right;">\$1.17</td> <td style="text-align: right;">\$40.00</td> </tr> <tr> <td style="text-align: center;">3</td> <td style="text-align: right;">\$40.00</td> <td style="text-align: right;">\$40</td> <td style="text-align: right;">\$0</td> <td style="text-align: right;">\$0</td> </tr> </tbody> </table> <p>The “savings account” analogy is used here for simplicity of description. In actual practice, the applicable interest rate may be rate at which money can be borrowed. For example, in several cases in this study there is an initial cost to a feature, which may be “repaid” by reductions in future annual costs. The present value of the entire cash flow equals the present value of those future savings less the initial cost.</p>	year	beginning acct balance	needed cash flow	interest earned at 3%	ending acct balance	1	\$107.12	\$50	\$1.71	\$58.83	2	\$58.83	\$20	\$1.17	\$40.00	3	\$40.00	\$40	\$0	\$0
year	beginning acct balance	needed cash flow	interest earned at 3%	ending acct balance																	
1	\$107.12	\$50	\$1.71	\$58.83																	
2	\$58.83	\$20	\$1.17	\$40.00																	
3	\$40.00	\$40	\$0	\$0																	
Real Discount Rate	A rate net of general inflation. Used for calculations where future values are expressed in constant dollars. Long term real rates have typically averages 2% to 4%. This study uses 3%, as currently specified by the National Institute of Standards and Technology for long term life-cycle costing.																				
SO ₂	Sulfur dioxide.																				
Social Benefits and Costs	Private benefits or costs (direct financial impacts on buyer and seller) plus related externalities borne by other parties.																				
T-8	A fluorescent light tube 1 inch in diameter, more efficient than the older T-12 (1.5 inch diameter) tubes.																				
Therm	A unit of energy typically used in natural gas bills. See APPENDIX E for conversion factors.																				

APPENDIX G. Selected Annotated References

This appendix contains brief descriptions of some useful general reference works for the green building, externality, energy, and water topics covered in this paper. Complete citation information can be found in APPENDIX I.

Environmental Economics

Daily and Ellison, 2002. The New Economy of Nature: the Quest to Make Conservation Profitable.

A set of in depth case studies of individuals seeking to internalize environmental externalities in the free marketplace, through a range of activities from ecotourism to attempts to create marketable environmental securities. Follows efforts over a period of years, demonstrating both some successes and also the many roadblocks to successful implementation. Contains one of the most thorough histories of the often-cited decision by New York City to pay to protect the source watershed of pure drinking water instead of allowing development and then building a filtration system.

Desvousges, Johnson, and Banzhaf, 1998. Environmental Policy Analysis with Limited Information: Principles and Applications of the Transfer Method.

A brief evaluation of the basic approaches to environmental valuation, followed by an in-depth discussion of methods for transferring the results of one study to a different site or context. Includes evaluation of accuracy and relevance, key parameters at each linkage stage, and practical limitations of published studies. Concludes with several case examples in the area of human health impacts of air quality.

Independent Economic Analysis Board, 1999. River Economics: Evaluating Trade-offs in Columbia River Basin Fish and Wildlife Programs and Policies.

A good overview of the considerations involved in cost benefit analyses of habitat and conservation activities, in the context of power generation along the Columbia River. The discussion includes the limitations of the role of economics, the types of commercial impacts of fish and wildlife restoration projects, the role and limitations of economic estimates of noncommercial impacts, making evaluations in a dynamic rather than static context, and societal considerations of the distribution of cost and benefit effects across regions, sectors, and classes of individuals.

Green Building Practices

Fuller et al, 2002. R.S. Means Green Building: Project Planning and Cost Estimating.

A comprehensive high level overview of green building in the U.S., containing general background on design, component, and impact considerations; description of common tools for energy modeling, impact assessment, economic evaluation, and building rating schemes; reference tables for lighting needs, heating calculations, and geographic climate characteristics. Also contains typical cost tables for some green building features such as solar energy systems and grey water treatment.

Green Building Savings Evaluation

California Public Utility Commission, 2001. *California Standard Practice Manual: Economic Analysis of Demand-Side Programs and Projects*

An explanation of the valuing energy conservation savings from the various perspectives of conservation program participant, ratepayer, utility, and society.

IPMVP, Inc., 2002. *International Performance Measurement and Verification Protocol: Concepts and Options for Determining Energy and Water Savings*

Contains thorough descriptions from the perspective of building managers or commissioning agents of data needs and methodologies of verifying actual building performance and savings. Includes discussions of statistical credibility tests and practicality of data acquisition. Volume I includes a general introduction and discussion of verifying savings for existing building retrofits. Volume II covers indoor air quality. Volume III applies the M&V techniques to cases of new construction.

Kats et al, 2003. *The Costs and Financial Benefits of Green Buildings: a Report to California's Sustainable Building Task Force*

A thorough attempt at valuing typical direct and externality savings from green commercial construction in the context of California energy and water supply sources. Includes Well documented methodology and sources.

Kumar, 2004. "Roof water harvesting for domestic water security: who gains and who loses?"

A study of roof water harvesting in various regions of India. Although the economic, social, and environmental situations of this study are different than Portland, several methodologies could be transferred. Those include the approach to analyzing average versus marginal costs, defining water harvesting system adequacy in the context of dry year exceedance probabilities, and the impact on various social groups.

Planning and Management Consultants, 1991. *Evaluation of Urban Water Conservation Programs: a Procedures Manual*

A report done for the California Urban Water Agencies, describing how to calculate use and cost impacts from the various perspectives of conservation program participant, ratepayer, utility, and society.

Scheuer et al, 2003. "Life cycle energy and environmental performance of a new university building: modeling challenges and design implications" and Scheuer, C.W. and Keoleian, G.A., 2002. *Evaluation of LEEDTM using life cycle assessment methods*

These companion reports evaluate building energy conservation from a full life cycle analysis perspective. The 2003 article discusses results for life cycle areas of material extraction through deconstruction allocated to environmental burden areas of climate change, ozone depletion, air pollution, eutrophication, and waste generation. The 2002 report, published by the U.S. National Institute of Standards and Technology, uses the results of the analysis to evaluate the relation between modeled environmental burdens and the point allocations in LEED.

Energy Impact Pricing

Levy et al, 1999. “Development of a new damage function model for power plants: methodology and applications”

A relatively brief and readable description of estimating the health and mortality impacts of emissions from an oil and gas cogeneration power plant in Boston. Explains the rationale, data sources, and uncertainty of the health and mortality value factors. Also provides a methodology for allocating impacts among the several useful products of a cogeneration plant: steam, chilled water, and electricity.

Ottinger et al, 1990. Environmental Costing of Electricity

An extremely thorough review of published literature and many private studies on the environmental externality costs of electricity generation in the U.S.. Although the studies reviewed are now all over 15 years old, there are not more current comparable studies in many cases. One primary area in which advances have been made is in more recent approaches to dose-response calculations of air pollution effects. Even so, the Ottinger study provides good background and an example of attempts to cover a wide range of impacts.

U.S. EPA, 1999. The Benefits and Costs of the Clean Air Act 1990 to 2010

A lengthy and thorough discussion of the sources, calculation methodology, uncertainties, and results of examining direct and indirect economic impacts of the Clean Air Act. See in particular Appendix H on the valuation of the human health and welfare effects. An update with projections through 2020 was underway in 2004, with some preliminary discussion documents on changes in methodology publicly available at www.epa.gov/air/sect812/blueprint.html.

Water Conservation Pricing

Fane and White, 2003. “Levelised cost: a general formula for calculations of unit cost in integrated resource planning”

A discussion, with formulas but no examples, of the rationale for various methods of calculating levelized costs for conservation savings.

McNeill and Tate, 1991. Municipal Water and Wastewater Rate Manual: a New Approach to Rate Setting

A good overview of the economic theory behind marginal pricing, followed by detailed examples of applying the theory to real water and sewer utilities.

Planning and Management Consultants, 1992. Evaluation of Urban Water Conservation Programs: a Procedures Manual

A report done for the California Urban Water Agencies explaining how to evaluate the costs and benefits of water conservation programs, from the perspectives of participating customers, the utility and total society. A similar study for evaluating electricity conservation programs is in the California Standard Practice Manual by the California Public Utilities Commission (2001).

APPENDIX H. Individuals Providing Supporting Information

Name	Company	Information
Barney, Steve	EESI, Commissioning Agent	Building systems calibration
Beijer, Kirsten	College Housing NW	Epler electricity and Other Residence Hall electricity, gas, and water billings for periods before 7/1/2004
Bertoli, Avis	PSU Facilities, accounting	Utility payment and bill history for Epler Gas
Conway, Anne	Portland Water Bureau, Principal Financial Analyst	Portland water infrastructure pricing
Crim, Michele	PSU Facilities, Sustainability Coordinator	Epler Hall background and specific contact information
DeSelle, Scott	PSU Landscaping Manager	Irrigation plans for water harvesting area
Eckman, John	PSU Auxiliary Services, Associate Director	Resident counts per occupied room
Hill, Cassie	PSU Business Accounting Office	Epler electricity and Other Residence Hall electricity, gas, and water billings for periods after 7/1/2004
Hiscoe, Steve	PSU Facilities, HVAC Controls Technician	Epler building management system records
Koontz, Richard	PSU Facilities, HVAC Controls Technician	Water meters, utility allocation calculation's
Liptan, Tom	Portland Bureau of Environmental Services	Current stormwater overflow pathway
Maclean, John	PSU Accounting	Total budget and costs for Epler construction
McBride, Francis	PSU Facilities, Architect	LEED commissioning and related information
McDonald, Steve and vanderVeen, Ron	Mithun	Architectural design information
Ritchie, Ron	PSU Facilities, Assistant Director	General information on PSU building systems
Pickett, Kristen	PSU Facilities	Epler classroom utilization rates
Vizzini, Dan	Portland Bureau of Environmental Services	Stormwater runoff charge outlook and preliminary calculations for stormwater discount program
Yackley, Don	PSU Residence Life, Director	May 2004 residents' survey

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Michele Crim, project advisor and PSU Sustainability Coordinator during much of the project.

Dr. Joseph Maser, academic advisor, Assistant Professor of Environmental Science.

Dr. David Ervin, Research Professor of Environmental Science.

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