

**Sustainable Design  
Feasibility Study**

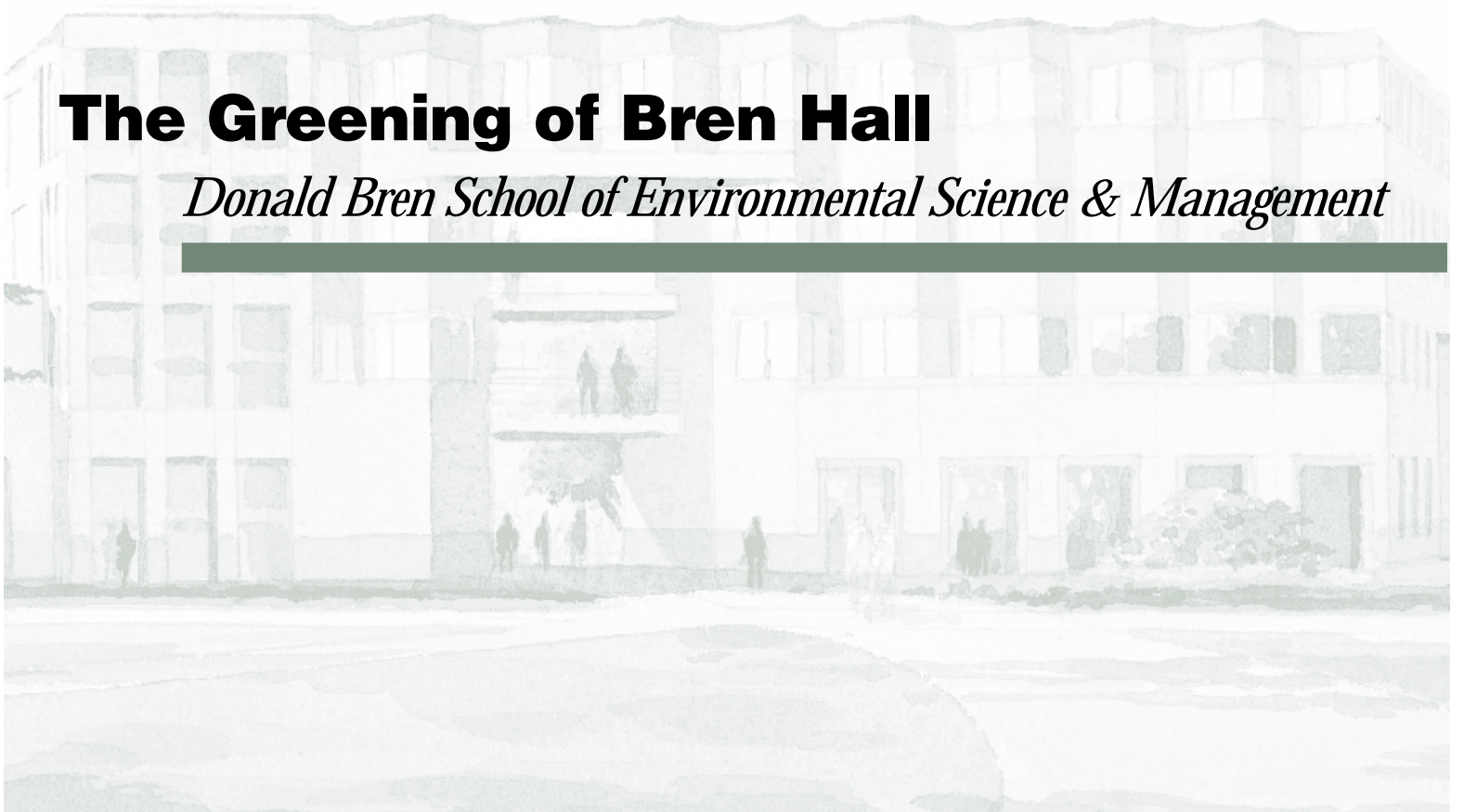
October 1999

**University of California,  
Santa Barbara**

# **The Greening of Bren Hall**

*Donald Bren School of Environmental Science & Management*

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**Greening Bren Hall** Feasibility Study



## **1. EXECUTIVE SUMMARY**

### **Introduction**

Design of the building to house the new School of Environmental Science and Management began in 1992, before the Dean or any Bren School faculty were hired. The building advisory committee used surrogate faculty from other campus departments to begin the design process. At that time, the State of California agreed to use the taxpayers' money to construct a building for faculty, students, and staff, but not to fund a building that is itself an experiment in environmental sensitivity. Construction was to start in 1995, but the failure of a statewide bond issue delayed funding until another bond issue passed in November 1998.

Jeff Dozier was appointed the first Dean in 1994, and the school was renamed the Donald Bren School of Environmental Science and Management in December 1997. The faculty that have been hired into the Bren School are very interested in constructing an environmentally sensitive building, and along with the support from the Bren School Advisory Board, we are making exceptional progress to this end.

In the 50% construction document (CD) phase, the Bren School aggressively pursued the "greening" of Bren Hall, commissioning reviews by the Rocky Mountain Institute, Southern California Edison, the Innovative Building Review Committee, the Sustainability Project, and the California Energy Commission. Many of the recommendations from these reviews have been adopted. Bren Hall will be the "greenest" building on the UCSB campus by a wide margin. We anticipate that Bren Hall may surpass stringent 1999 Title 24 standards by a comfortable margin; no other campus building meets these standards.



The design of Bren Hall includes some ideal features. To ensure efficient use of energy, the building is sited and designed to harvest natural light, heating, and cooling. Facing the ocean, the offices have no air conditioning, but rely on flow-through ventilation using operable windows. Daylight harvesting is coupled with a lighting plan that incorporates energy efficient fixtures and bulbs, along with controls for motion and ambient light. The ventilation system for the laboratories is the most energy-efficient available. Glazed windows reduce the heat load, and the new multi-building virtual chilled water loop will provide cost-effective cooling for the laboratory wing. The building makes extensive use of recycling and renewable resources. Mitsubishi has agreed to donate cement fueled by recycled tires and sludge instead of coal. The carpets, wallboard, ceiling tiles, furniture, and insulation will be made from recycled materials. Wood paneling in the building will come from certified sustainable forest harvests. The School has designed procedures to minimize the probabilities and consequences of spilling toxic materials in the laboratories and storerooms. The construction specifications require the contractor to separate and reuse waste to minimize debris transported from the site. The landscaping will perform several functional tasks. It will shade and shelter the building, create outdoor spaces for discussion, use drought-tolerant native plants adapted to the coastal location, and use reclaimed water for irrigation. The required fire road around the building will be made from a recycled content permeable turf-block with a grass overlay.

To push the envelope, the Bren School chose to sponsor an additional set of reviews. Following extensive discussions, and with the support of the Chancellor and Executive Vice Chancellor, UCSB commissioned Zimmer Gunsul Frasca Partnership and Eley Associates in July 1999, to write a sustainable design feasibility study for the Bren School. The purpose of the study has been to analyze the current design and to recommend measures that could be taken to improve it in terms of sustainability. This report explores various measures to identify means of implementation.

The Bren School is partnering with Southern California Edison (SCE) to make the building a living laboratory and environmental showcase facility to demonstrate cost effective, energy efficient technologies and operations. The faculty will work with the Design and Engineering Services at SCE to develop experiments to measure the performance of various energy efficiency measures. A comparative analysis of the performance, energy use, and cost effectiveness of the measures will be published. The goal of this joint venture is to push market transformation by educating clients and designers. SCE will also provide incentive for some of the instrumentation and certain energy efficiency measures. The design team and SCE are working together to identify appropriate measures for performance testing and for the incentive program.

### **Sustainable Design**

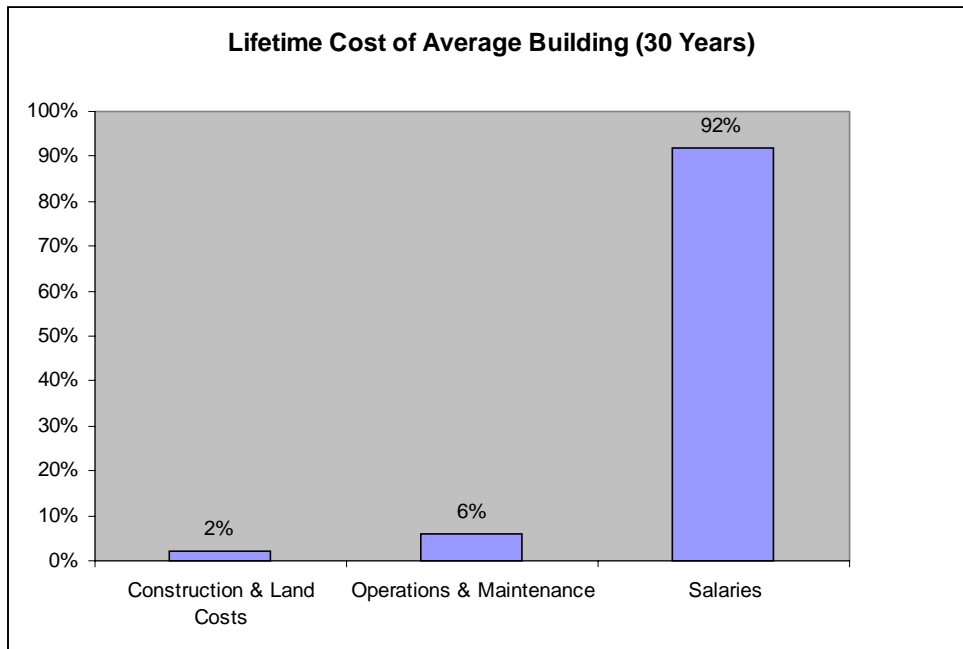
At the close of the 20<sup>th</sup> century, humans are becoming increasingly aware of the damage we have done to our environment and of the implications of this damage to future generations. Natural disasters such as encroaching deserts, deforestation, acid precipitation, soil erosion, species extinction, ozone depletion, and greenhouse gas buildup are compelling evidence of increasing environmental instability and danger. With the growing alarm at our situation comes a determination to halt and even reverse the destruction.



The term “sustainability” has become a catchphrase in discussions of the environment and our future. The commonly held meaning of the term stems from the UN’s Brundtland Commission Report of 1987, which defines sustainable development as “development that meets the needs of the present without compromising the ability of future generations to meet their own needs.”

By this definition, a cultural sea-change will be required before we can reach true sustainability; we will have to replace consumerism with less wasteful values. However, changes are taking place that argue the beginning of a transition to that desired future.

The design and construction of buildings are central to the sustainability discussion in both practical and philosophical ways. The environmental damage caused by building construction is considerable, and the opportunities for change are correspondingly abundant. Moreover, architecture holds a mirror before society: Design interprets our values, reassesses our priorities, and reflects them back to us. Sustainable design can embody ideas about environmental responsibility, inspiring and educating its users.



*Building first costs are a very small percentage of life cycle costs. Energy efficiency measures that decrease operations costs, and environmental improvements that boost user productivity have a tremendous impact on overall costs.*

Successful sustainable design must address economics. The common wisdom in the design community is that “sustainable design costs more.” However, methods such as life-cycle accounting often show that sustainable design initiatives are cost-effective when long-term considerations such as operational costs and user productivity are weighed against first costs.



The technology and understanding of sustainable design have progressed to the point that we can implement an environmentally responsible design and construction with confidence. This project, the greening of Bren Hall, offers the opportunity to set an example of what can be achieved by a conscientious application of sustainable design principles.



### **History**

The mission of the Bren School is to “play a leading role in researching environmental issues, training research scientists and professionals, and identifying and solving environmental problems. An interdisciplinary approach will be adopted, reaching across the boundaries of formerly disparate disciplines to foster collaborative research and teaching. For a school that is dedicated to educating leaders to solve the environmental problems of the 21st century, the physical form of the school should speak to the principles of environmental stewardship. Therefore the building that represents the school should incorporate sustainable design principles in the form of innovative technologies and ecologically sensitive materials.

Sustainable design principles have been inherent to the design since its inception in 1993; features such as natural ventilation, drought-tolerant landscape, and energy efficient building systems are basic to sustainable design theory. However, revisiting the design principles after passage of the necessary bond issue in 1998 indicated opportunities to push the envelope, to investigate other technologies and materials that make this school into an educational example, a “building that teaches.”



## **LEED Rating System**

In this study, we have chosen to use the Leadership in Energy and Environmental Design (LEED) Green Building Rating System, both as a framework for exploration of sustainable design strategies, and as a rating system that allows us to objectively judge our progress.

The U.S. Green Building Council (USGBC) is writing the LEED System. This consensus-driven coalition includes organizations from all areas of the building industry. Under construction since 1993, the rating system is still in draft form, and a pilot phase has been undertaken to study how best to improve it before the proposed launch in the year 2000. Bren Hall has been nominated to be a Pilot Project during this initial phase. Our work on the Greening of Bren Hall is helping to shape the improvements to LEED that will be incorporated in the final version.

LEED is a credit-based system; a total of 44 credits, 6 bonus credits, and 10 prerequisites are available, arranged in five categories that describe major areas of sustainable design;

- Sustainable Site Planning
- Improving Energy Efficiency
- Conserving Materials and Resources
- Enhancing Indoor Environmental Quality
- Safeguarding Water

The number of credits achieved by a given project determines the rating received. The levels are:

Bronze	50% of available credits - not including bonus credits)
Silver	61%
Gold	71%
Platinum	81%

Each credit is structured to encourage innovation and progress in a particular facet of sustainable design, without being prescriptive. Credits are open to interpretation on the part of the individual designers, with final determinations made by the USGBC LEED committee.

We have found that the base (original) design of Bren Hall would meet all but one of the prerequisites, and would achieve a 12 on the scale of 50. The design, as revised in the addenda process, would achieve 16 credits. If all the recommendations of this report were to be taken, the design might achieve a score of 30 to receive a Silver rating. This is a considerable achievement: LEED has deliberately been written to a very high standard. As sustainable design practices become standard, it will become easier to achieve the ratings. In the interim transition toward sustainable design, the bronze and silver are very difficult to attain.



### Deciding Factors



*Three elegantly simple categories can be used to choose sustainable measures.*

**Ecology:** *Is this an environmentally intelligent choice?*

**Equity:** *Does this measure enrich people and communities?*

**Economy:** *Is this choice economically viable?*

*Good sustainable design occurs somewhere in the meeting of these three.*

While LEED provides a framework for exploration, it does not spell out the exact steps to take to create a “green” building, nor does LEED cover every possible way to build green, thus “innovation” credits are offered. Ingenuity, research, and thought are required of the designers. Varying and conflicting factors must be weighed. In choosing materials one might find that a given product is made from a renewable resource, but is made far away, so that fossil fuels are expended in transportation. Or one might find that the manufacturing process of a product involves toxic substances, but the end product is durable and does not emit volatile compounds. In designing building systems, measures that reduce energy consumption may appear to conflict with indoor environmental quality concerns.

Issues of cost, feasibility of construction, and the feasibility of getting a measure implemented late in the design process contributed to each decision. These concerns unfortunately precluded the realistic consideration of some effective measures, and hampered the implementation of other, less invasive ones.

The method has been simply to weigh all the factors together and make as informed and optimal a decision as possible. Deciding factors for each measure considered are identified in section 4, and in section 5 for measures that are not recommended.

Where possible, measures were recommended that would qualify for LEED credits. In a number of cases, the recommended measure falls short of meeting the credit criteria, but is still considered worth pursuing. Similarly, we have chosen not to pursue certain credits that seemed inappropriate to this climate or project.

Of course, LEED should not be the only yardstick for evaluating the sustainability of the building. LEED is generic, i.e. designed to apply to all buildings in all places. Therefore, measures that make sense in general may not make sense in a particular building in a particular place. Conversely, measures that can make a huge difference in a specific situation may not get much credit in the LEED system. One way to evaluate the value of energy efficiency measures, for example, is to look at total energy savings compared to a base case. Another metric is payback period, which can account for incremental cost increases as well as energy and other operating cost savings. Neither of these methods is accounted for by LEED.

### Implementation

As identified in section 4, certain sustainable design recommendations have been implemented during the bid phase, as addenda and supplemental information to the contractors who are bidding on the project.

A host of measures could be implemented as change orders during construction. That work is begun in this report; possible change orders have been researched and roughly estimated. The next step is to decide which ones to implement and identify funding sources. Design changes can then be documented and issued to the contractor. The architect can aid the university in negotiating the terms of the change order with the contractor.

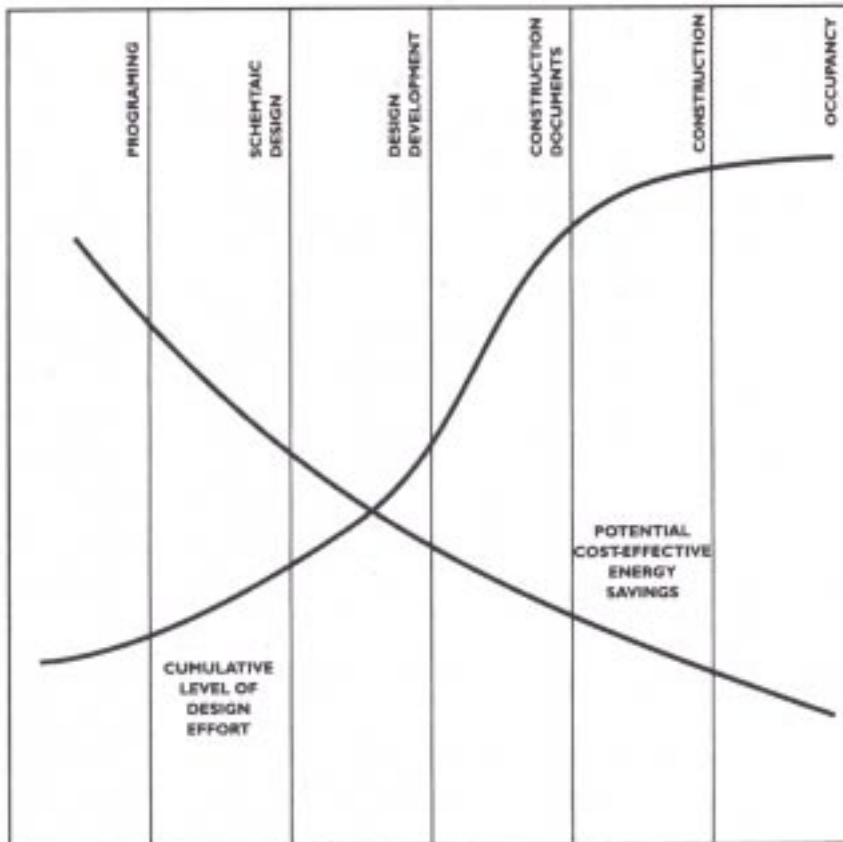
Should the school decide to go ahead and officially rate the design using the LEED rating system, additional extensive documentation will be required.



## Lessons Learned

Sustainable design should be incorporated into the design and construction process from the very beginning. While it may be possible to implement a fair number of measures, and even to achieve a Bronze LEED rating, many effective and far-reaching measures could not be considered because of the lateness of the decision to evaluate and implement additional sustainable measures.

Energy Savings Opportunities and the Design Sequence



Time of Design Process

*Successful sustainable design must begin at the beginning of the project, and include all team members. Integrated design can save money and time.*

Good design is an interdisciplinary, integrated process. Most decisions are not isolated in their origin or effect, but have implications that carry through many areas of the design. When making changes late in design, one must either build on the existing “good bones” of a project, or take actions that are limited in their scope. In addition to design limitations, one must contend with restrictions on time and budget that severely curtail the ability to make extensive changes.



Many of the tenets of sustainable design were integrated into the Bren School design from its inception; many of the recommended measures of this report build on these first good decisions. Natural ventilation, use of daylight, reclaimed water, efficient mechanical systems were all there from the beginning. Operable window/HVAC interlocks, reclaimed water at toilet room fixtures, and variable volume fans all are recommendations that simply expand on measures already included in the design.

Other recommended measures focus on design changes that are limited in scope and therefore possible to undertake at this late stage. Many of the material changes fall in this category; recommended materials are similar to the ones they replace in terms of cost and construction method. Thus, mineral wool batt insulation is specified to replace fiberglass batt insulation; the materials are almost identical in application and cost. The use of blown-in insulation, arguably a more environmentally responsible material, could not realistically be considered because of the cost differences and design implications. This would not have been so had the choice been made during design development, or had the state's guidelines supported added first costs in light of life cycle cost benefits.

Many recommendations require the Bren School to find additional funds to pay for design time and changes during construction. This means the changes will cost more than they would if they had been part of the original design. Thus, the resizing of exhaust fans and stacks and use of variable speed motors has been recommended as a possible change order, but the resizing of the entire system that could logically follow this change may well prove too costly and time-consuming to implement.

Some of the simplest and most effective sustainable design measures could not be considered at this point. For example, the building is sited so that one long façade faces due west, considerably raising the cooling load on the building systems. The laboratories on this side cannot be protected from the late afternoon sun; sunshading or other protective devices would simply be ineffective because of the building orientation and sun angle. The effective solution would be to reorient the building, but that is not a possibility at this point. Instead trees will have to be planted to provide shade, and they will take time to grow.

There are two apparently conflicting lessons here: that sustainable design should be integrated into a project from the beginning, and that it is never too late to implement sustainable design.

### **Report Format**

This report is laid out as follows: Part 1 contains the history and context of the project. Part 2 includes a LEED Rating Summary Checklist, with available credits and projected scores. Part 3 summarizes, mostly in tabular form, all measures considered in the study, organized by LEED category, and including rough costs. This section also identifies means of implementation: base design, addendum, or future change order. Part 4 discusses each recommended measure in detail, describing the measure, its relevance to sustainability, effectiveness, and implementation. Part 5 describes measures deemed inadvisable.



## 2. LEED RATING SYSTEM SUMMARY CHECKLIST

The following charts identify all 50 LEED credits, estimate the points achieved, and reference the associated measures. Four totals are shown: the first column describes the maximum possible points (although in fact it would not be possible to attain all 50 points); the second shows points achieved in the base design; the third column totals the base design points with those added by addenda; and the fourth lists the points that might be achieved should all the recommendations of this report be implemented.

This report uses LEED Version 1.0. Version 2.0, currently in very rough draft form, will be publicly launched in March 2000. This revised version contains some fundamental changes from Version 1.0. Prescriptive measures, such as the requirement to install delimiters at cooling towers, are no longer used. Instead, all measures are performance based. This encourages an integrated design approach, and allows the credits to be more equally weighted. In addition, innovation credits will reward ingenuity.

We have briefly analyzed Bren Hall with LEED Version 2.0, and find that it would probably achieve a similar rating to that reached with Version 1.0.





Credit/Prerequisite	Possible	Base	Addenda	Future	Section Reference
<b>Planning Sustainable Sites (S)</b>					
Credits					
1 Landscaping for Erosion Control	1	1	1	1	3.1.1
2 Landscaping/Exterior design to reduce heat islands	2		1	1	3.1.2, 6, 7, 9, 10
3 Infill Development	1				3.1.11
4 Reduced Habitat Disturbance	1				3.1.12
5 Site Preservation/Restoration	1	1	1	1	3.1.3
6 Efficient building location	1	1	1	1	3.1.4
7 Alternative transportation facilities	2	1	1	2	3.1.5
Bonus Credits					
1 Alternative fueling facilities	1			1	3.1.8
2 Brownfield development	1				3.1.13
<b>Improving Energy Efficiency (E)</b>					
Prerequisites					
1 Building Commissioning	✓		✓	✓	3.2.15, 16
2 Energy Efficiency	✓	✓	✓	✓	3.2.1
Credits					
1 Energy Efficiency	5	1	1	3	3.2.2-7, 9-14, 17-28, 32, 33
2 Natural ventilation, heating, cooling	1				3.2.8
3 Waste heat recovery system	1				3.2.34
4 Renewable/alternative energy	3			2	3.2.29, 30
Bonus Credits					
5 International Performance Measurement and Verification Protocol	1			1	3.2.31
<b>Conserving Materials and Resources (M)</b>					
Prerequisites					
1 Elimination/phase out of CFCs and halons	✓	✓	✓	✓	3.3.1
2 Storage and collections of recyclables	✓	✓	✓	✓	3.3.2
Credits					
1 Existing building rehabilitation	2				3.3.40
2 Resource reuse	2				3.3.31
3 Recycled content	2			1	3.3.3-15, 17-26, 32, 34, 35, 37, 38, 42-
4 Construction waste management plan	2	1	1	2	3.3.27, 39
5 Use of local materials	1			1	3.3.40
6 Elimination of CFCs, HCFCs, Halons	2		1	1	3.3.19, 28, 48
7 Occupant recycling	1				3.3.49



Credit/Prerequisite	Possible	Base	Addenda	Future	Section Reference
<b>Enhancing Indoor Environmental Quality (IEQ)</b>					
Prerequisites					
1 Elimination/control of asbestos	✓	✓	✓	✓	3.4.13
2 Indoor air quality/ventilation/fresh air intakes	✓	✓	✓	✓	3.4.1
3 Smoking ban	✓	✓	✓	✓	3.4.2
4 Thermal comfort	✓	✓	✓	✓	3.4.3
Credits					
1 Construction IAQ management plan	2	1	1	2	3.4.4, 3.4.10
2 Use of low VOC materials	2	1	1	2	3.4.6, 8
3 Permanent air monitoring system	1			1	3.4.12
4 Design of chemical storage area	1	1	1	1	3.4.5
5 Architectural entryways	1		1	1	3.4.9
<b>Safeguarding Water (S)</b>					
Prerequisites					
1 Water conservation	✓	✓	✓	✓	3.5.1
2 Lead in drinking water	✓	✓	✓	✓	3.5.2
Credits					
1 Water conserving fixtures	1				3.5.9, 10
2 Water recovery system	1			1	3.5.3, 11
3 Water conserving cooling towers	1	1	1	1	3.5.4
4 Water efficient landscaping	1	1	1	1	3.5.5
5 Surface runoff filtration	1	1	1	1	3.5.6
6 Surface runoff reduction	1				3.5.7, 12, 13
7 Biological waste treatment	1				3.5.14
Bonus Credits					
1 International Performance Measurement and Verification Protocol	1				3.5.15
<b>Improving the Design Process (D)</b>					
Bonus Credits					
1 LEED Certified Designer	1		1	1	3.6.1
<b>Total Credits</b>	<b>50</b>	<b>12</b>	<b>16</b>	<b>30</b>	

Points Required for LEED Ratings:

- 22 - 26 = Bronze
- 27 - 30 = Silver
- 31 - 35 = Gold
- 36 + = Platinum



### 3. SUMMARY OF RECOMMENDED MEASURES

Using the LEED checklist as a skeleton, recommended measures were proposed and assessed. Each measure has been weighed in terms of economy, ecology, and equity. The tables on the following pages identify each measure studied, referencing the LEED credit addressed, and giving a recommendation. Recommended measures are fully discussed in part 4 of this report. Additional measures are covered in part 5.





### 3.1 Planning Sustainable Sites

These measures address the impact construction and development can have on local ecology. Steps are taken to improve the quality and reduce the volume of surface runoff. Infill development and alternative transportation combat the loss of natural habitat and increased use of fossil fuels associated with urban sprawl. Problems associated with the heat island effect are addressed.

Measure Description	LEED Credit	Initial Cost Impact	Recommendation
<b>Included in Base Design:</b>			
1 Landscaping for erosion control	S-C1		Included
2 Landscaping/Exterior Design to Reduce Heat Islands	S-C2		Included
3 Site Preservation/Restoration	S-C5		Included
4 Efficient Building Location	S-C6		Included
5 Alternative Transportation Facilities	S-C7		Included
<b>Included as Addenda:</b>			
6 Additional trees	S-C2	\$	Recommended
<b>Proposed as Future Change Orders:</b>			
7 Increased roof reflectance factor	S-C2	\$	Recommended
8 Alternative Fueling Facilities	S-BC1	\$\$	Recommended
<b>Not Advised:</b>			
9 Landscaping/Exterior Design to Reduce Heat Islands – credit #2	S-C2		Not appropriate
10 Alternate roofing system	S-C2	\$\$\$	Not appropriate
11 Infill Development	S-C3		Not applicable
12 Reduced Habitat Disturbance	S-C4		Included
13 Brownfield Development	S-BC2		Not applicable

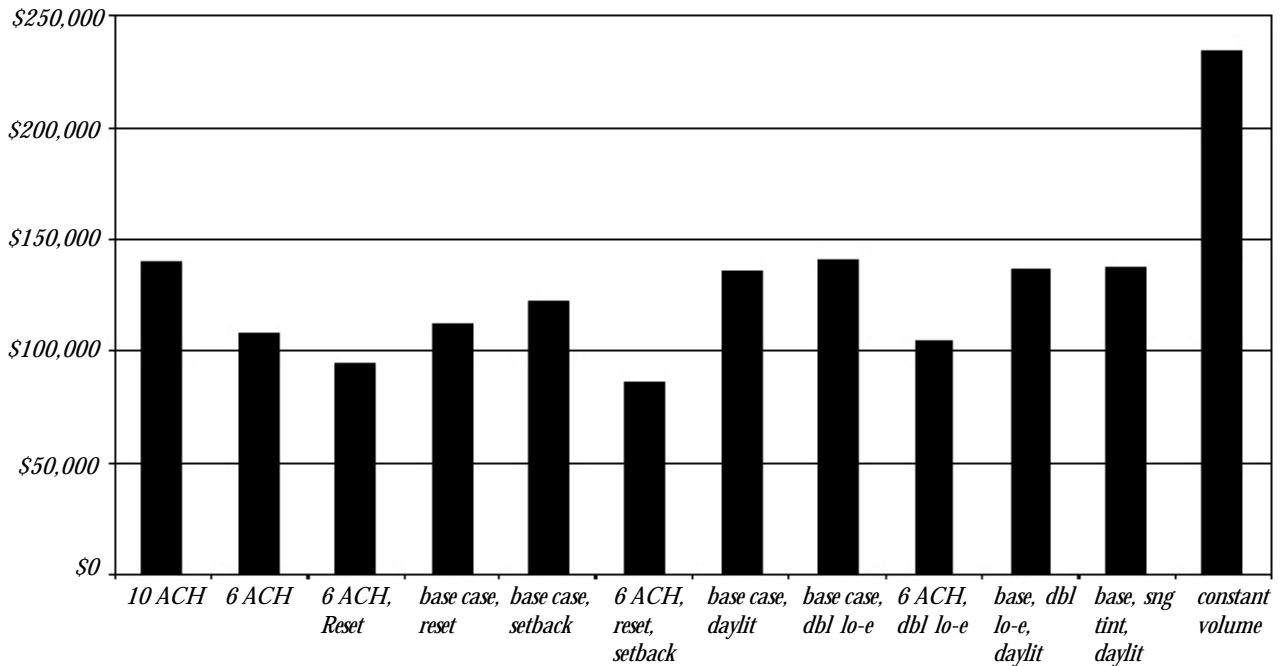
Cost Key: 0=No cost change; \$=up to \$10,000; \$\$=\$10,001 to \$50,000; \$\$\$=over \$50,000; (\$)=Cost savings



### 3.2 Improving Energy Efficiency

Buildings consume 30% of the total energy in the U.S. and 60% of the total electricity. By increasing energy efficiency, both pollution and operating costs can be considerably reduced. Some measures can cost more up front, but pay for themselves within a few years. Others result in up-front as well as long-term savings.

These measures help to mitigate the damaging effects of energy production. Fossil fuel combustion emits gases that cause global climate change and a variety of more localized problems, including acid rain and photochemical smog. Hydroelectric generation is clean but the required dams damage river ecosystems and their attractiveness for recreation.



*Lab Space Energy Use Alternates, measured in energy cost per year*



Measure Description	LEED Credit	Energy Impact (\$000/y)	Initial Cost Impact	Recommendation
<b>Included in Base Design:</b>				
1 Energy Efficiency	E-P2			Included
2 Daylighting	E-C1			Included
3 Variable frequency drives	E-C1			Included
4 Energy efficient lighting	E-C1			Included
5 Outside air economizer	E-C1			Included
6 Variable Volume Lab Exhaust	E-C1			Included
7 Reduce lab air change requirements	E-C1	20-40		Included
8 Natural Ventilation	E-C2			Included
<b>Included as Addenda:</b>				
9 Energy Efficiency	E-C1			Highly recommended
10 CO2 controlled ventilation	E-C1	10-20	\$	Recommended
11 Reduce ambient lighting @ offices	E-C1	3-6	(\$)	Investigate
12 Electronic ballasts	E-C1	1-2	0	Highly recommended
13 Lighting controls	E-C1	2-4	\$	Recommended
14 Enhanced EMCS	E-C1	10-50	\$\$	Recommended
15 Building commissioning - GC	E-P1	20-60	\$	Highly recommended
<b>Proposed as Future Change Orders:</b>				
16 Full commissioning -agent	E-P1	30-150	\$\$\$	Highly recommended
17 Convert lab exhaust fans	E-C1	40-70	(\$\$)	Highly recommended
18 Daylighting controls	E-C1	3-6	\$\$	Investigate
19 Reduce cooling system capacity	E-C1	10-50	(\$\$\$)	Highly recommended
20 High efficiency condensing boiler	E-C1	2-4	\$\$	Investigate
21 Operable windows/HVAC	E-C1	3-15	\$\$	Recommended
22 Chilled water loop integration/ elimination of chiller.	E-C1	0	(\$\$\$)	Investigate
23 High efficiency chiller	E-C1	2-6	\$\$	Investigate
24 HVAC control additions	E-C1	50-100	0	Highly recommended
25 HVAC component sizing	E-C1	2-10	\$	Recommended
26 Hood controls	E-C1			Recommended
27 Increase cooling tower efficiency	E-C1	2-6	\$	Recommended
28 Performance contracting	E-C1	5-50	\$\$	Recommended
29 Renewable/alternative energy	E-C4		\$	Recommended
30 Photovoltaic panels	E-C4	10-20	\$\$\$	Recommended
31 International Performance Measurement and Verification	E-BC1			Recommended
<b>Not Advised:</b>				
32 Radiant slab heating.	E-C1	2-5	\$\$\$	Not feasible
33 High performance glazing and/or shading devices.	E-C1	0	\$\$\$	Not effective
34 Waste heat recovery system	E-C3	0	\$\$	Investigate

Cost Key: 0=No cost change; \$=up to \$10,000; \$\$=\$10,001 to \$50,000; \$\$\$=over \$50,000; (\$)=Cost savings



### 3.3 Conserving Materials and Resources

These measures address the impacts building materials have on human health and on the environment. Issues such as embodied energy, resource extraction methods, production, toxicity, and transportation are weighed when deciding which materials to specify. Where possible, materials have been deleted altogether.

Until recently, “green” materials tended to cost more than their traditional counterparts; this is no longer the case.

The problems of solid waste disposal are addressed by the implementation of a construction waste program and the use of recycled and recyclable materials.



*New uses must be found for “waste” materials such as these tires.*

Measure Description	LEED Credit	Initial Cost Impact	Recommendation
<b>Included in Base Design:</b>			
1 Elimination of CFC's/Halons	M-P1		Included
2 Storage and Collection of Recyclables	M-P2		Included
3 Recycled aggregate base course.	M-C3		Included
4 Recycled glass content concrete paving	M-C3		Included
5 Recycled glass mulch	M-C3		Included
6 Recycled HDPE porous paving	M-C3		Included
7 Recycled content tree grates	M-C3		Included
8 Organic compost	M-C3		Included
9 Recycled content steel	M-C3		Included
10 Wood from certified forests	M-C3		Included
11 Recycled content ceiling tile	M-C3		Included



Measure Description	LEED Credit	Initial Cost Impact	Recommendation
<b>Included as Addenda:</b>			
12 Recycled content asphalt paving	M-C3	0	Recommended
13 Fly ash content @ concrete	M-C3	(\$)	Recommended
14 Mulch from site demo/trimming	M-C3	0	Recommended
15 Recycled content trash receptacles	M-C3	(\$)	Recommended
16 Certified wood benches		(\$)	Recommended
17 Recycled content casework substrate	M-C3	0	Highly recommended
18 Recycled content wall insulation	M-C3	\$	Recommended
19 Delete polyisocyanurate	M-C3	(\$)	Highly recommended
20 Steel instead of alum.door frames	M-C3	(\$\$)	Recommended
21 Recycled content ceramic tile	M-C3	0	Recommended
22 Recycled content carpet tile	M-C3	\$	Recommended
23 Recycled content rubber flooring	M-C3	\$	Recommended
24 Linoleum	M-C3	\$	Recommended
25 Recycled content toilet partitions	M-C3	(\$)	Recommended
26 Recycled content wall panel fabric	M-C3	\$	Recommended
27 Construction waste management plan	M-C4	(\$)	Recommended
28 Elimination of CFC's, HCFC's	M-C6	(\$)	Recommended
<b>Proposed as Future Change Orders:</b>			
29 Verify centralized recycling	M-P2		Recommended
30 Delete all VCT		(\$\$\$)	Highly recommended
31 Resource Reuse	M-C2	\$	Recommended
32 Recycled Content	M-C3		Recommended
33 Alternate Concrete		(\$\$\$)	Recommended
34 Recycled content countertops	M-C3	\$	Recommended
35 Alternates to wood veneer	M-C3	\$	Recommended
36 Alternate upholstery fabric		\$	Recommended
37 Recycled content carpet	M-C3	(\$)	Recommended
38 Recycled content signage	M-C3	(\$)	Recommended
39 Construction waste management - 2	M-C4		
40 Use of local materials	M-C5	(\$)	Recommended
<b>Not Advised:</b>			
41 Existing building rehabilitation	M-C1		Not applicable
42 Rubberized asphalt paving	M-C3	varies	Not appropriate
43 Stainless steel @ exterior	M-C3	\$\$\$	Not necessary
44 Recycled content drain pipe	M-C3		Not available
45 Recycled content site benches	M-C3		Not recommended
46 Recycled content acoustic panel fabric	M-C3		Not recommended
47 Exposed concrete in lieu of VCT			Not appropriate
48 Elimination of CFC's, HCFC's	M-C6		Not available
49 Occupant recycling	M-C7		Not feasible

Cost Key: 0=No cost change; \$=up to \$10,000; \$\$=\$10,001 to \$50,000; \$\$\$=over \$50,000; (\$)=Cost savings



### 3.4 Enhancing Indoor Environmental Quality

These measures ensure the quality of the indoor environment. During construction, sequencing and protection of the air handling system mean that the building systems will not spread toxic substances to the occupants. Building materials are chosen that will release fewer and less harmful contaminants.

Measure Description	LEED Credit	Initial Cost Impact	Recommendation
<b>Included in Base Design:</b>			
1 Fresh Air Intakes	IEQ-P2		Included
2 Smoking Ban	IEQ-P3		Included
3 Thermal Comfort	IEQ-P4		Included
4 IAQ Construction Management Plan	IEQ-C1		Included
5 Chemical Storage Area Design	IEQ-C4		Included
<b>Included as Addenda:</b>			
6 Low VOC Materials	IEQ-C2		Highly Recommended
7 Urea-formaldehyde-free substrate @ casework, veneer	IEQ-C2	(\$)	Recommended
8 Reduced VOC's @ carpet	IEQ-C2	(\$)	Recommended
9 Architectural entryways	IEQ-C5	\$	Recommended
<b>Proposed as Future Change Orders:</b>			
10 Enhanced IAQ Construction Management Plan	IEQ-C1	\$\$\$	Recommended
11 Duct Insulation			Investigate
12 Permanent Air Monitoring System	IEQ-C3		Investigate
<b>Not Advised:</b>			
13 Elimination/Control of Asbestos	IEQ-P1		Not applicable



### 3.5 Safeguarding Water

Depletion of freshwater sources is a familiar issue in Southern California. These measures reduce the amount of water used and ensure that water returning to the storm drain system is as clean as possible. Reclaimed water is used in lieu of potable water where possible, reducing both the drain on freshwater sources as well as the volume of water going into the drain system.

Measure Description	LEED Credit	Initial Cost Impact	Recommendation
<b>Included in Base Design:</b>			
1 Water Conservation	W-P1		Included
2 Lead in Drinking Water	W-P2		Included
3 Reclaimed water @ irrigation	W-C2		Included
4 Water Conserving Cooling Tower	W-C3		Included
5 Water-Efficient Landscaping	W-C4		Included
6 Surface Run-off Filtration	W-C5		Included
7 Pervious paving at firelane	W-C6		Included
<b>Included as Addenda:</b>			
8 Irrigation operations manual	W-C4	0	Highly recommended
<b>Proposed as Future Change Orders:</b>			
9 Automatic flush valves	W-C1	\$	Recommended
10 Footpedals @ lab sinks	W-C1	\$	Neutral
11 Reclaimed water @ toilets, urinals	W-C2	\$\$	Highly recommended
<b>Not Advised:</b>			
12 Surface Run-off Reduction	W-C6		Not appropriate
13 Pervious asphalt paving	W-C6	\$	Not appropriate
14 Biological waster treatment	W-C7	\$\$\$	Not appropriate
15 International Performance Measurement and Verification Protocol	W-BC1		Investigate

### 3.6 Improving the Design Process

Sustainable design is best implemented by designers already familiar with green building issues and technologies. Inclusion of a LEED certified designer on the design team helps ensure the success of a project.

Measure Description	LEED Credit	Initial Cost Impact	Recommendation
<b>Future:</b>			
1 LEED certified designer	D-BC1		Recommended

Cost Key: 0=No cost change; \$=up to \$10,000; \$\$=\$10,001 to \$50,000; \$\$\$=over \$50,000; (\$)=Cost savings



*To the east and south of the UC Santa Barbara lies the ocean, to the north the rolling California landscape. The favored means of transportation is the bicycle; Bren Hall provides ample bike parking and showers to facilitate this alternate transportation mode. Native, drought tolerant plants will fill the terrace planters, courtyard, and open space leading to the bluffs, providing a haven for native fauna. The orientation of the building takes advantage of the site's sea air and views.*





## **4. DISCUSSION OF RECOMMENDED MEASURES**

This is a detailed discussion of the measures summarized in the tables of the previous section.

### **4.1 Planning Sustainable Sites**

#### **4.1.1 Landscaping for Erosion Control**

This measure addresses the potential erosion caused by poor construction practices and landscape design. LEED Site Credit #1 requires the implementation of the Maryland Model Stormwater Ordinance and the Maryland Model Erosion and Sediment Control Ordinance. Tactics include prescribed grading methods, sequencing of construction, topsoil protection, and stormwater runoff retention.

The measures required by the State of California and by the University are as strict, if not stricter, than the Maryland ordinances. In California, erosion control is typical for site development that occurs on natural, undisturbed slopes. This project is being developed on a flat mesa within the overall campus, thus landscaping to control erosion of slopes is not needed.

#### **4.1.2 Landscaping/Exterior Design to Reduce Heat islands**

For one credit under LEED Site Credit #2, this measure requires that the structure's roof and exterior walls be clad with light-colored/high-albedo materials (50% reflectance value or better) to lower energy loads and reduce the heat island effect.

In this case, the exterior finishes will be light-colored plaster and exposed concrete. The roof at the lab wing has a white asphalt cap sheet, giving it 80% reflectance. The office wing has built-up roofing with white gravel, for a similar reflectance value.

The light roof color has little effect on energy load in this particular design, since there is very little HVAC at the fourth floor lab wing and none at the office wing. However, this measure does help to mitigate the local heat island effect.

Landscaping has been provided around the exterior building to reduce heat islands as a part of the base design. See 4.1.6 and 4.1.7 for additional measures.

#### **4.1.3 Site Preservation/Restoration**

LEED Site Credit #5 requires construction disturbance to be limited to 50 feet beyond the project footprint, a preservation plan be implemented for topsoil and existing trees, and that 50% of degraded habitat area be restored.

Development of greenfield space threatens biodiversity and the existence of individual plants and animals by reducing available habitats. The damage caused by the construction process is minimized and effort made to restore and maintain natural habitat.



The Bren Hall project replaces existing parking lots with native plants; where possible existing topsoil will be conserved, new topsoil will be local and mixed to match existing. The construction area will be limited as required. Existing trees are kept wherever possible, the exception being eucalyptus, which are not native.

#### 4.1.4 Efficient Building Location

To meet the criteria for LEED Site Credit #6, the building must be located within ¼ mile of two or more bus lines. This is already the case; to achieve the credit, documentation (a site plan with bus stop shown) will be required.

This measure reduces the use of private automobiles by encouraging the use of mass transportation, thus mitigating the environmental problems associated with automobiles, such as emissions that contribute to smog and the environmental degradation involved in oil extraction and petroleum refining.

#### 4.1.5 Alternative Transportation Facilities

This measure addresses LEED Site Credit #7, Alternative Transportation Facilities. This credit requires that the design includes bicycle racks for at least 5% of the building occupants, a shower and changing facilities for bicyclists, and preferred parking for carpools. All three measures are included in the base design—although the carpool parking is not called out. To achieve the LEED credit, documentation showing the carpool parking stalls will be required.

Like 4.1.4, this measure encourages use of alternative transportation, reducing the use of private automobiles.

#### 4.1.6 Additional Trees

The Bren School has received a donation of *Platanus racemosa* (California Sycamore) trees, in 36-inch boxes. This native tree would work well with the landscaping intent of the campus master plan. 19 sycamores have been added as an addendum to the base bid documents. The goal of this measure is twofold: to reduce the heat island effect, and to shade the west facing labs.

Given the building orientation, no satisfactory architectural solution has been found to provide shade at the labs on the west facade of the Bren School. The heat gain and glare at these labs will be considerable when the sun is low in the western sky. We can minimize this effect by placing tall trees in the planters to the west of the building. The Sycamores will grow to 50-90 feet tall, with a spread of 30-50 feet.

LEED Site Credit #2 requires the planting of at least one tree within every 1,000 square feet of impermeable grade surface on the building lot, including parking, walkways, plazas, etc. The goal of this measure is to reduce the heat island effect created by the use of dark, non-reflective surfaces at parking, walkways, and roofs, thus reducing disturbance of the local microclimate and the energy required for cooling. This reduces the environmental impact of energy production and transmission. This measure also mitigates the effects of paving on surface runoff and groundwater recharge.



*California Sycamore*



In order to fully meet this requirement, nine additional trees would be added at the parking area. Because the parking lots are due to be removed for future construction, the decision was made not to add the trees here, and an appeal put in to the LEED committee.

In the addendum, five trees have been added at the west side of the building, three replacing the stone pines that were in the original design. The seven *Arbutus "marina"* (Madrone) in the courtyard are replaced by sycamores, and an additional seven sycamore trees have been added between the Bren School and Engineering 1.

#### 4.1.7 Increased Roof Reflectance Factor

A reflective white roof will reduce cooling loads significantly. Temperatures of a typical built up roof (even a "white" mineral cap sheet – such as in the current design) exceed 150°F on a sunny day, while a smooth white surface will remain around 100°F. Gravel also gets very hot in the sun, and even light-colored gravel will not provide much cooling benefit.

An elastomeric coating can be added to the roofing at the lab wing, increasing the reflectance and durability of the material. This coating is best added a year or more after initial roof installation. The elastomeric seals the roofing, approximately doubling its life expectancy. Reflectance would be increased to 85%. Gaco and Celotex both make a coating that is inexpensive and easy to install. The coating will have to be reapplied periodically.

Note that an aluminized silver-colored coating does not provide as much cooling benefit. While it is more reflective than a typical built-up roof, it also has a low emissivity and does not reradiate heat to the sky as freely as other types of surfaces.

#### 4.1.8 Alternative Fueling Facilities

This measure recommends the installation of a refueling facility for alternative-fuel vehicles, for LEED Site Credit #8. Examples of fuel sources include methanol/ethanol, electricity, fuel cells, and natural gas. Such a facility could be constructed in the parking area adjacent to the service enclosure. Innovative technologies could be showcased: for example, electric cars can be refueled at a photovoltaic powered refueling station.

This strategy encourages the development of alternative fuel vehicles by providing the infrastructure to support them.

The decision was made not to include this strategy in the current building design; alternative fuel technologies are developing rapidly enough that it is worth waiting to see what develops. And a fueling station can be designed to stand alone; this measure can readily be implemented at a later date.

Costs to design and build a fueling station powered by photovoltaic cells would be approximately \$30,000 for two parking stalls.

Similarly, the backup power generator is currently specified as diesel, but a fuel cell will be considered at the appropriate time.



*Solar powered refueling station*



*Fuel cell powered mass transit*



## **4.2 Improving Energy Efficiency**

### **4.2.1 Energy Efficiency**

LEED Energy Prerequisite #2 requires that the design comply with state and local energy codes, or ASHRAE 90.1– 1989, and subsequent revisions, whichever is stricter. This project de facto complies with California Title 24, which is stricter than the ASHRAE standards.

### **4.2.2 Daylighting**

Offices and labs are designed to receive an abundance of natural light, predominately by windows. The fourth floor conference room is daylit by three roof monitors that capture north light and bounce it down into the space.

Additional measures such as architectural features (light shelves, etc.) and electronic daylight controls are discussed in section 5.

### **4.2.3 Variable Frequency Drives**

All of the motors over 5 horsepower are provided with variable frequency drives to conserve electrical energy. SCE estimates that there will be some incentive funding available for this measure, totalling over \$3,000.

### **4.2.4 Energy Efficient Lighting**

Lighting for the building is provided by direct/indirect fixtures utilizing T8 lamps. Site lighting is provided using high-pressure sodium fixtures. Title 24 allowable design for this building is 1.4 Watts/SF. The proposed design uses 1.126 Watts/SF. SCE estimates that there will be incentive funding available for this measure, totalling over \$7,000. This number will increase with the implementation of further efficiency measures as addenda and change orders.

### **4.2.5 Outside Air Economizer**

Areas of the building that are air-conditioned (labs, colloquium, seminar, interior offices) are provided with an outdoor air economizer. As the outside air temperature decreases, the quantity of outside air is increased. This measure reduces air conditioning load and electrical usage.

### **4.2.6 Variable Volume Lab Exhaust System**

This system will minimize the exhaust rate for each lab, based on hood position, cooling load and minimum ventilation rate. By minimizing the exhaust flow rate, cooling energy and electricity are conserved.



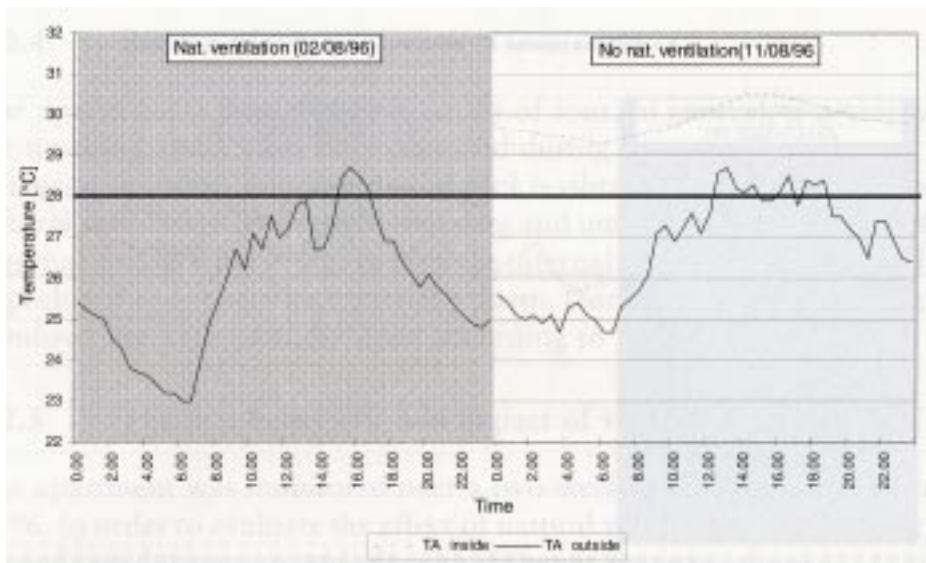
*Natural daylight and ventilation will be provided at all Bren Hall offices.*



#### 4.2.7 Reduce Lab Air Change Requirements

Required minimum ventilation rates have been reduced to 6 air changes per hour (ACH) at the 1<sup>st</sup> Floor and 8 ACH at the 2<sup>nd</sup> Floor lab spaces. While various other energy saving measures that could lower these rates were considered, such as night setbacks, campus Environmental Health and Safety (EH&S) set these to be the lowest allowable rates. These limits set a bottom floor on the overall exhaust airflow and the limits the savings possible from variable flow exhaust fans. See 4.2.24 for a discussion of ways to further reduce energy usage.

Based on a rough simulation analysis, switching from 10 ACH minimum to 6 ACH minimum will save up to 20% of total energy consumed in the labs, or about \$30,000/yr.



*Comparison between a day with natural ventilation and one without, Apartment Building in Catania, Italy*

#### 4.2.8 Natural Ventilation

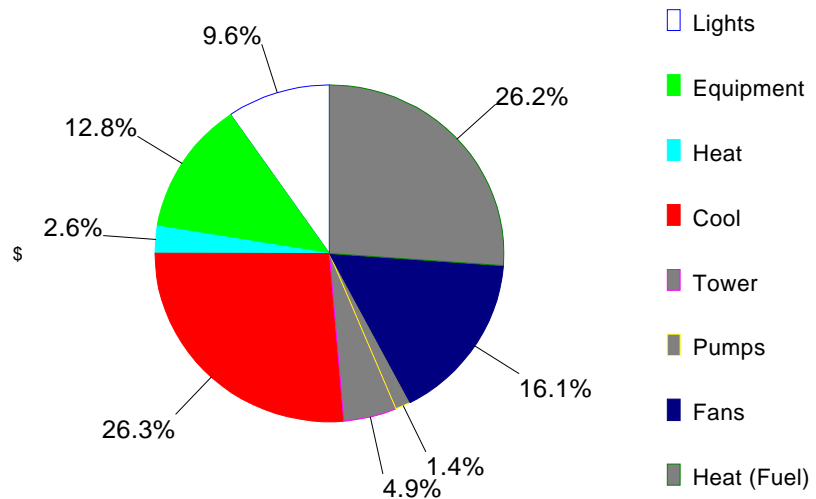
LEED Energy Credit #2 requires that natural ventilation and passive energy design be used to fulfill all heating and cooling requirements of a building for at least 8 months out of a year. The intent of this measure is to reduce the energy usage and therefore environmental burdens associated with mechanical heating and cooling.

In the current design, offices are cooled using natural ventilation. The building has been designed to maximize opportunities for natural ventilation; the office wing and fourth floor lab wing are all ventilated via operable windows. However, the need for carefully controlled exhaust of toxic substances prevents the use of natural ventilation in the laboratories.

Although it will not be possible to achieve this LEED credit, the principle behind it has been applied.



## Electricity and Fuel End Uses



*A simulation model provided these rough energy consumption estimates for Bren Hall, showing the breakdown by end use.*

### 4.2.9 Energy Efficiency

LEED Energy Credit #1 provides the opportunity to achieve up to 5 credits, based on reducing energy consumption by specified increments.

Most of the measures in the energy section address this credit. System efficiency, siting and massing, materials choices, daylighting, natural ventilation, and glazing choices are just some of the strategies used to maximize energy efficiency. Many of these are described in detail in the following sections.

Energy efficiency translates into operating cost savings. In some cases, measures had a higher first cost, in others the first cost itself was reduced. In general, payback periods for energy efficiency measures are short, five years or less. The table in section 3.2 lists estimated energy savings in thousands of dollars per year for each item.

One credit is awarded for complying with California Title 24 lighting requirements. This was achieved in the base design.

Subsequent credits require energy modeling to determine compliance with credit criteria. Two credits are available for exceeding ASHRAE/IES Standard 90.1-1989 by 20% or by achieving a score of 80 using the EPA/DOE Energy Star Benchmarking Tool. Three credits are achieved by exceeding ASHRAE by 30% or getting 85 on the Energy Star.



It is our estimation that the design as amended by addenda stands a good chance of achieving level 2, or 20% better than ASHRAE; with the proposed change orders, level 3 may be reached.

To help achieve energy efficient goals, Southern California Edison has introduced UCSB to Savings By Design. Savings By Design is California's new state wide non-residential New Construction Incentive Program. Savings By Design is sponsored by the three largest California Utilities: Southern California Edison, Pacific Gas and Electric Company, and San Diego Gas and Electric. Savings By Design encourages high-performance design which results in greater occupant comfort, reduced operating costs, higher productivity, and more valuable property. New construction incentives offered through Savings By Design are offered on a limited time and limited funds basis. Incentives are paid upon verification of installation of qualifying energy efficient measure. Generally speaking, Savings By Design program requirements are 10% beyond Title 24 requirements.

#### **4.2.10 Carbon Dioxide (CO<sub>2</sub>) Controlled Ventilation**

Peak air flows in conference rooms, auditoria, classrooms, and lobbies are based on high occupant densities. The minimum airflows are simply 30% of the peak flows (about 0.6 cfm/ft<sup>2</sup>). When these rooms are unoccupied or lightly occupied this minimum will lead to wasted fan and reheat energy. Using CO<sub>2</sub> sensors in these spaces will allow the minimum airflow to be reduced to the Title-24 minimum of 0.15 cfm/ft<sup>2</sup>. In addition to reducing the minimums on the variable air volume (VAV) boxes, the minimum outside airflows on the air handlers can be reduced as well. A possible limitation on this strategy is the ability of the VAV boxes to control low minimum airflows. However, according to the Titus literature (Titus PESV boxes have been specified), the cubic feet per minute (CFM) range for all box sizes starts at 0 CFM and "...All Titus products operate extremely well within the published cfm ranges. Therefore, low velocity control concerns can be eliminated." Therefore, CO<sub>2</sub> sensors can be implemented as follows:

- Minimum outside air (OA) CFM for air handling units (AHU) 3, 4, and 5 are set to 0.15 cfm/sf.
- CO<sub>2</sub> sensors are installed in the mixed air inlet to AHU-3, 4, 5.
- Min flow on all VAV boxes served by AHU-3,4,5 are set to 0.15 cfm/sf. A separate heating-mode min flow may be required for the boxes.
- If the CO<sub>2</sub> concentration exceeds 800 parts per million (ppm), then minimum OA is modulated to maintain CO<sub>2</sub> concentration below 800 ppm.
- If minimum OA - supply CFM, and CO<sub>2</sub> concentration is still greater than 800 ppm, then minimum flow on all boxes served by that AHU is modulated to maintain acceptable CO<sub>2</sub>. (Of course, the boxes will also open up automatically based on the thermostat).

This control strategy has been implemented for AHU-5, reducing the minimum OA flow from 3,300 CFM to 630 CFM (80% reduction) resulting in substantial energy savings.



#### **4.2.11 Reduce Ambient Lighting Levels in Offices**

The original building program called for 50 footcandles of illumination in office spaces, meaning that the typical office used two fixtures with 3 lamps each for a lighting power density of 1.4 watts per square foot (WSF). By comparison, the Title 24 area method maximum is 1.3 W/sf for office space, and installed lighting power densities of less than 1.0 W/sf are now common in new office buildings.

As part of an Addendum to the bid documents, the lighting within the offices has been revised to 2 lamp fluorescent fixtures. The illumination level will drop from the 50-60 footcandle range to around 35-40 footcandles. However, a lower illuminance requirement in exterior offices is acceptable because these offices will be receiving natural light during the day and at night occupants' eyes adjust to lower light levels. Task lighting such as a desk lamp is appropriate for specific tasks requiring higher illumination.

The design criterion for lab spaces is 80 to 100 footcandles. The design uses direct/indirect suspended fixtures with two lamps for each 4-foot length, and the lighting power density ranges from around 1.3 to 1.5 W/sf. This design criterion is appropriate for lab function, and has not been reduced.

#### **4.2.12 Electronic Ballasts**

More efficient electronic ballasts are standard design practice, instead of the magnetic ballasts that are currently specified. For a two lamp fixture, savings are roughly 15% of power consumption. Fixture input power is 60 W instead of 72 W. This has been included as part of an Addendum to the Bid documents.

#### **4.2.13 Lighting Controls**

The following controls are recommended by room type.

- Private offices have occupant sensors and dual switching for outer and inner fixtures. The dual switching allows the fixture closer to the window to be turned off by the occupant when ambient light is adequate. This was provided by addendum. Occupant sensors at offices may be wall box types as long as they are not blocked by furniture. Occupancy sensors are provided at each private office to automatically turn lights off when the office is unoccupied.
- Labs should also have multilevel switching for separate control of the fixtures closest to the window. With the current fixture orientation (perpendicular to windows), redesign of wiring will be required to run at least two circuits in each pendant. If the fixtures are reoriented parallel to the window, then simple daylight switching is possible. It was decided that to reorient the lights would result in uneven lighting. Users are in labs for very long periods of time: good lighting is essential. Bilevel switching is provided as a part of the base design.



- Occupancy sensors in the labs are also recommended, but several sensors would be necessary in each room to cover the area between lab benches. The sensors help in rooms such as labs with multiple occupants, because it is common that no one takes responsibility to turn the lights off. Occupant sensors also eliminate the need for a central time control system on the lighting. The lab users chose not to use occupancy sensors at the labs.

#### **4.2.14 Enhanced EMCS**

The key to efficient building operation is an electronic monitoring control system (EMCS) that collects and stores information and can graph that information quickly in an extremely user-friendly way.

##### **Monitoring Points**

The EMCS specification includes a minimum list of specific points to be monitored. A high sampling rate (e.g. every minute) should be stored short-term (e.g. for 1 day) and hourly data should be permanently stored. This list should include but not be limited to the points listed in Appendix A.

##### **Graphing Capabilities**

The EMCS should be required to have at least the following graphing capabilities:

- At least six columns of data can be viewed on the screen at once and can be graphed using a graphing program integral to the control system, with at least four parameters graphed against time on the same graph. The columnar format shall have time down the left column with columns of data to the right (one column for each parameter).
- The system shall have the ability to graph real-time data of up to four points on the EMS at once, giving each point its own scale. The user should be able to easily set the time interval (e.g. last 24 hours of 1 minute data or last week of hourly data) and dates (e.g. from June 15 to July 7).
- Without any special or difficult conversions, this data shall be able to be designated to be stored as an ASCII delimited file in the same columnar format for use in graphing with normal commercial spreadsheet software.
- The system shall have the capability to graph one or more points against another, rather than just against time (e.g. kw vs tons).

All of the graphing capabilities should be accessible over the internet via standard internet browsers (Netscape or Internet Explorer).



An outside agent, Johnson Controls (JCI), has been hired by the University to install and monitor EMCS systems at all campus buildings. Rich Beddie of Johnson Controls has reviewed the above points list and graphing capabilities and confirms that they are all achievable and in fact fairly standard features. He pointed out two items that are not standard and that are fairly costly: (a) chilled/hot water supply and return temperatures at each air handler and (b) CO<sub>2</sub> sensors at each air terminal unit. We think that the water temperatures at each air handler are not critical and can be omitted. The CO<sub>2</sub> sensors are only needed if the CO<sub>2</sub> OSA strategy is approved by F&K and UCSB and would only be needed in a few VAV boxes in high occupant density areas: auditorium, large conference rooms, and perhaps some classrooms. Depending on how the CO<sub>2</sub> strategy is implemented, it may be possible to only put CO<sub>2</sub> sensors in the return air to the AHU's with economizers. Rich also said that the only graphing capability that could be a problem is the internet access. There is a new product (M-Web) being developed by JCI that can do this but he does not know the release date.

Required changes to the specifications have been made by addendum.

#### **4.2.15 Building Commissioning**

Commissioning is a systematic process of ensuring that building systems perform interactively according to the design intent and the owner's operational needs. This is achieved beginning in the design phase by documenting the design intent and continuing through construction, acceptance, and the warranty period with actual verification of performance, operation and maintenance (O&M) documentation verification and the training of operating personnel.

##### **Commissioning Results**

- Reduced number of occupant complaints
- Dramatically reduced staff time required from building operator during early occupancy period
- Lower energy costs
- Improved indoor air quality
- Fewer warranty claims
- Fewer change orders

##### **Commissioning Objectives**

- System performance monitoring system installed and calibrated for accuracy
- Systems tested for proper operation and tuned for optimal efficiency
- Improved system documentation that is useful to building operators
- Improved operator training

##### **Commissioning Key Elements**

- An individual (commissioning authority) responsible for oversight of commissioning activities.
- Early kickoff meetings during design phase and construction phase to inform design team and contractors of commissioning process.



- Adequate specification of measurement points to test and monitor system performance through the facility management system (and via internet).
- Calibration of those measurement points to verify accuracy.
- Complete tests of system operation in all modes, verifying that the sequence of operations is implemented as intended.
- Clear specification of contractor responsibilities for participation in commissioning tasks.
- Regular coordination meetings attended by all trades.
- Financial penalty for failure to complete commissioning tasks.

There are several models for structuring the commissioning process.

- The University hires an independent commissioning agent that oversees and/or performs system tests and coordinates scheduling. The agent develops a commissioning plan.
- The University requires the contractor to be responsible for all commissioning tasks and coordination. The University reviews commissioning documentation for acceptance.

Measure 4.2.14 discusses contractor implementation of commissioning, agent commissioning is covered in 4.2.15.

The University intends to hire Johnson Controls as commissioning agent, if the budget allows.

In either case, we recommend that commissioning language be added to the specifications so that the contractor understands the responsibilities to either perform the commissioning tasks or assist with those tasks. Our experience has shown that proper system testing and documentation will not occur without specific requirements in the construction documents. Some commissioning language is currently in the specifications, more will be added, depending on the method of commissioning decided upon.

### **Commissioning by GC**

If Commissioning is to be successfully performed by the Contractor, the specifications must be expanded. In several places the specifications call for commissioning and testing of mechanical and electrical equipment in order to show proper operation and compliance with all sequences of operation. However, the specification is lacking in specific required tests and reports. Moreover, the sequence of operation documentation lacks sufficient detail for efficient operation of equipment, particularly at part-load. The specifications need to tell exactly how the Contractor is to program the system and how to verify that it is operating according to the design intent. The following is a small sample of the sequences that should be described and the tests that should be required.

**Economizer Tests.** Testing of the economizers should include manually setting the outside air temperature to be above the return air temperature and then measuring outside air and supply air flows under various load conditions.



**Minimum Zone Flows.** Tests should insure that airflows are minimized under a wide variety of conditions. For example, the thermostat setpoint can be manually set to 90F, and the exhaust hoods turned off. The tester should then verify with a flow hood that SAV, EAV, and VAV terminal unit flows are at minimum. If CO<sub>2</sub> sensors are used, these minimum flows should be no more than 0.2 cfm/ft<sup>2</sup>.

**Air Handlers: Supply Air Temperature Reset.** A number of the sequences of operation for the air handlers could be better specified. For example, the supply air temperature reset sequence is not clear. There are a number of algorithms for automatically resetting the supply air temperature. One method is to use outside air temperature to reset supply air temperature. This can then be tested by manually setting the outside air temperature and recording changes in the supply air temperature. A more efficient reset algorithm is reset by warmest zone. Test should be included for documenting that this algorithm is implemented correctly.

**Tower Control.** The control algorithm for the cooling tower is unclear. There are a number of ways to stage condenser water pump (variable speed), the tower circulation pump, and the tower fan (variable speed) such as fixed CW temperature control or wetbulb reset control. The specifications need to include the most efficient algorithm and test for verifying proper implementation.

**Variable Speed Pumps.** The plans call for variable speed drives on the chilled water, condenser water, and hot water pumps, but the specifications do not describe how these pumps are to be controlled for optimum energy efficiency.

#### **4.2.16 Building Commissioning - Agent**

Rather than having the Contractor solely responsible for commissioning, we recommend that the University (1) hire an independent commissioning agent to oversee the process and (2) clarify in the specifications the role of the Contractor in the commissioning process. Eley Associates has prepared “Energy Efficiency Commissioning Guidelines for The Donald Bren School Building” which is intended to assist the University in achieving these two objectives. Below is the executive summary from this document:

The purpose of these guidelines is to verify that the HVAC system is operating according to the design intent and as energy efficiently as possible. The focus is on energy efficiency and not other issues such as system capacity, indoor air quality, maintenance or training. These guidelines and the involvement of the Commissioning Agent do not in any way excuse the Contractor from the responsibilities described in the plans and specifications, which includes the requirement to “...completely checkout, calibrate, and field test all connected hardware and software to assure that the complete system performs in accordance with the approved sequence of operation.” (See Specifications Section 13810 Part 3.10)

The Commissioning Agent (Cx Agent) has three basic responsibilities:



**Sensor Verification.** After the Contractor has fully calibrated all required sensors, the Cx Agent shall independently verify, using stand-alone sensors, that a sample of the installed sensors are accurately calibrated and that the EMS is recording the correct information. The Cx Agent will report any problems to the Owner and Contractor and the Contractor will take appropriate corrective action in a timely manner.

**Functional Testing.** After the Contractor has corrected any sensor calibration problems and has completed Test and Balance and Start Up and before the building is occupied, the Cx Agent shall conduct functional tests, with the assistance of the Contractor, that verify systems are operating efficiently under a range of possible operating conditions. The Contractor (HVAC and Controls subcontractors) shall provide skilled technicians for the duration of the functional testing who will operate the HVAC equipment according to the instructions of Cx Agent.

For each piece of equipment there is a series of test conditions (e.g. min load) and for each set of test conditions there is a series of parameters that must be recorded (e.g. CFM). Prior to functional testing, the Cx Agent shall calculate the expected value of each parameter for each set of test conditions. The Design Engineer shall confirm all expected values before functional testing.

The Cx Agent will immediately report any failed tests to the Owner and Contractor and the Contractor will take immediate corrective action. A test is considered failed if in the judgement of the Cx Agent the observed value is substantially different from the calculated or expected value such that the system is clearly not operating according to the design intent. Any tests that are failed will be re-performed, at the Contractor's expense, prior to occupancy. We recommend that the Contractor have a strong financial incentive to pass all functional tests, i.e. a significant portion of the Contractor's compensation be withheld, pending successful completion of all functional tests.

**Post-Occupancy Testing.** After 12 months of occupancy, the Cx Agent shall review the recorded EMS data to find points in time that most closely represent all of the test conditions described in functional testing (e.g. peak load, low load, OA temp > RA temp, OA temp < RA temp, etc.). As with the functional tests, the Cx Agent shall compare recorded and calculated values for parameters under all test conditions and shall make a full report.



#### 4.2.17 Convert Lab Exhaust Fans to Variable Flow

As lab usage changes over the course of a day or over several years, the ventilation requirements will also change. Airflow through fume hoods will vary with sash position, and lab equipment changes will lead to new ventilation requirements. The exhaust system needs to be capable of handling peak flow, but most of the time it will operate at less than peak flow. Therefore, it is important that the system operates efficiently at partial as well as peak load. For fans, part load efficiency is best achieved by slowing the fan rotation speed when airflow drops. The special constraint for this exhaust system is that air velocity leaving the rooftop stacks must not drop below a limit set by health codes.

In this measure, the rooftop exhaust fans will be controlled with variable speed drives to maintain adequate negative pressure in the exhaust ducts. The two makeup air louvers on the lab exhaust plenum will be eliminated. Velocity of air leaving the stacks will be controlled by either staging stack usage, smaller diameter stack nozzles or with variable aperture stacks.

This measure has potential to save a large fraction of the exhaust fan energy consumption, and provides the indirect benefit of quieter fans when they are running at reduced speed. This measure may be implemented as a future change order.

#### 4.2.18 Daylighting Controls

Both labs and offices are candidates for automatic dimming controls (stepped controls are not recommended because occupants perceive them as too disruptive). This measure will be especially effective if building shell measures are also employed to control glare and improve daylight distribution in these spaces. With those measures in place, window blinds are more likely to be left open and daylight savings can be captured. Without glare control, daylighting controls are less likely to have an impact.

Savings from dimming daylight controls can be on the order of 30% annually for the spaces with controls.

Options include:

- Closed-loop controls with a photosensor in each space controlling the lamps in their own spaces. This system adapts when blinds are closed.
- Open loop control with one photocell (or a small array of photocells) providing control for the whole building or for each facade. This approach has the advantage of having fewer sensors and requires less time for sensor adjustments. A disadvantage is that it would not adjust lights when blinds are closed in a space.



*The light fixtures in this atrium are controlled by photosensors.*



Ceiling, wall and floor reflectance will have a significant impact on daylight penetration, and light colors are recommended. However, deep daylight penetration requires controls that reduce the illumination close to the window and redirect light towards the back of the room. Some options for improving daylighting are light shelves; higher ceilings; overhangs; sidefins; reorienting lights parallel (not perpendicular) to windows; more/deeper open perimeter spaces; additional roof monitors.

It is too late in the project schedule to implement the architectural daylighting controls. Except for finish colors, these design changes should have been incorporated in early design.

#### **4.2.19 Reduce Cooling System Capacity**

Reduce cooling system capacity to account for lower lighting power, lower lab ventilation rates and revised internal gain assumptions if appropriate. Also consider diversity in lab loads (not all at peak at same time).

Reduced system size can lead to both initial cost savings and operating cost savings. Since the assumptions of equipment heat gain based on the project program in the labs is fairly high, and the ventilation loads are high as well, it is possible that there are opportunities to reduce system sizes with little risk. A review of the design criteria based on final lab design can be undertaken to more closely calculate the cooling loads. A reduction in the cooling airflow may be possible, leading to energy savings; a reduction in equipment cost is not expected.

#### **4.2.20 High Efficiency Condensing Boiler**

Change the boiler specification from a standard powered combustion air unit (about 80% efficient) to a more efficient condensing unit (around 95%). The gas savings would be partially offset by increased pumping energy because the output of the condensing boiler will be at a lower temperature. However, the lower temperature also reduces heat loss in the piping system. The lower temperature may also lead to requirement for different type of baseboard radiator (with larger surface area) that might increase initial cost.

#### **4.2.21 Operable Windows/HVAC Interlock**

Since the offices will have operable windows, there is potential for occupants to leave them open during heating season and waste energy. An interlock would shut off heating to a space when its window is open. Based on a rough calculation, the wasted heating cost for a single office could be as high as \$200-\$500/year. The cost per zone for window interlock is between \$500 and \$1200, for a payback of between one and six years.



#### **4.2.22 Chilled Water Loop Integration/Elimination of Chiller**

We cannot comment on this issue without additional information about the other buildings/loads and chiller plants on the loop. The type of information necessary is the hourly cooling load for buildings on the loop and the performance specifications of all the chillers and pumps. It is likely that a new efficient chiller added to the loop would increase the overall loop efficiency, but we cannot say without analysis whether the addition is necessary or cost effective.

There may be an opportunity to reduce the chiller size if lighting loads, ventilation loads, and plug load assumptions are reduced. The piping is configured so that the campus chilled water loop can be connected directly to the building loop without going through the chiller, hence it is possible, but perhaps not advisable, to eliminate the chiller altogether.

#### **4.2.23 High Efficiency Chiller**

Specify a high-efficiency chiller with variable speed drive.

There may be opportunities to improve both full load efficiency (kW/ton) and part-load efficiency. For example, chiller part-load performance will be improved by using variable speed drive rather than inlet vanes. Part load performance of several machines should be compared. It may also be possible to reduce the minimum flow through the evaporator below 50%.

Implementing this measure requires specifying a larger chiller with more surface area for heat transfer. This can be implemented as a change order early in the construction.

The Savings By Design requirement for chiller efficiency is 0.753 kW/ton for a 300 ton unit. The current design calls for Trane CVHE with efficiency of 0.587 kW/ton. The estimated incentive funding available for this measure is over \$2,000.

#### **4.2.24 HVAC Control Additions**

HVAC controls, including supply air temperature reset, supply air pressure reset, night thermostat setback and night ventilation setback, are part of the building design.

Due to the large ventilation air demand in the labs, a large amount of energy may be required to reheat the air before it enters each zone to avoid overcooling. To help minimize the reheat energy, the supply air temperature shall be controlled (reset) so that it is just cold enough to provide enough cooling to the warmest zone.

It would also be beneficial to vary the static pressure control setpoint in the supply duct depending on the amount of air required by the most demanding zone. Lower pressure leads to lower fan energy, and the savings potential is large because these fans are likely to run 24 hours per day.



Considerable energy savings are achievable by setting the heating thermostat setting back to 50F at night and by reducing the minimum ventilation requirements in the labs at night. Night ventilation setback could be linked to occupancy sensors so that normal ventilation rates are restored if labs are occupied during after hours. Night setback for ventilation rates would have to be approved by the University EH&S.

#### **4.2.25 HVAC Component Sizing**

Design HVAC component sizing to reduce pressure loss in duct and pipe systems.

Fan savings are achieved when pressure drop through the air distribution system is minimized. One way to reduce pressure drop is to increase the area of components like cooling and heat coils or filters so that the air moves more slowly through them. Increasing duct size can also be cost effective.

Similarly, pumping energy is reduced when careful attention is paid to pipe sizing, valves, and other fittings.

The heating and cooling systems are currently designed to conserve energy while adhering to a very tight budget.

#### **4.2.26 Hood Controls**

This measure saves energy by reducing hood air volume, either by sash position or air volume controls.

In a VAV system, air volume through the sash increases as the opening size increases; energy use can be reduced by keeping hood sashes down as much as possible. Alarms could be installed that would sound when the sash is opened beyond a certain point. Catches could be installed to make it difficult to open the sash beyond a certain point.

Motion sensors can determine whether a hood is in use and lower the air volume accordingly.

This measure would require coordination between EH&S and the users to ensure optimal and safe hood function.

#### **4.2.27 Increase Cooling Tower Efficiency**

The cooling tower as designed will provide 85°F condenser water at design outdoor conditions (70°F wet bulb temperature). An increase in cooling tower size compared to the current specification will allow the chiller to operate more efficiently by providing lower condenser water temperatures. Two-speed motors are generally more efficient than parallel staged fans, thus the cooling tower has been specified with its own variable fan drive (VFD)..



*The volume of air exhausted through a fume hood is determined by the sash opening. Sash controls can save a considerable amount of energy.*



#### **4.2.28 Performance Contracting for Energy Efficiency**

Performance contracting for new buildings is a fairly new concept that has been tested in several pilot projects (although it is a mature industry in the building retrofit business). This project may be eligible for free modeling and other performance contracting assistance under a grant from the Energy Foundation to Eley Associates.

There are several issues to consider in developing a performance contract

- Who is performance contractor? General contractor, designers, commissioning agent?
- What is covered: systems (such as lighting, or chilled water) or whole building
- How to set performance target
- How to evaluate actual performance

As an example, there are several options for whole building or central plant performance contracts.

##### **Whole Building Option A:**

- Eley Associates will build a model to determine expected energy use target.
- Monitoring equipment installed to measure HVAC, lighting, plug loads + misc.
- After 1 or 2 years of occupancy the model is adjusted based on actual weather, schedules (people, lights, etc.) and plug loads to determine adjusted expected target (i.e. Contractor is only accountable for HVAC and lighting efficiency, not for schedules, weather, plug loads, etc.).
- If the actual energy use (utility bills) is less than or equal to adjusted target then the Contractor is paid a bonus. If actual energy use is greater than adjusted target then Contractor pays a penalty.

##### **Whole Building Option B:**

- The Contractor is required to pay the utility bills for the first two years.

##### **Whole Building Option C:**

- The Contractor could be eligible for a bonus based on results of commissioning functional tests and/or recommissioning. If the Contractor can prove that all systems are operating efficiently and according to the design intent after construction or after Year 1 or 2 then a bonus could be given.

##### **Central Plant Only Option:**

- Eley Associates would develop a model of the central plant for the building (chiller, pumps, tower, boiler, etc)
- The heating and cooling loads would be measured for a year (CHW, HW gpm and delta T)
- Based on actual loads and actual weather, the model would estimate optimal energy consumption by the central plant.



- Model output would be compared to actual measured central plant energy consumption (kWh, therms).



#### **4.2.29 Renewable/Alternative Energy**

LEED Energy Credit #4 requires that a certain percentage of the building's total energy load be supplied through building-integrated or directly connected energy systems. One credit is achieved for each 10% of the total energy load supplied by renewable/alternate energy, for a maximum of three credits.

The intent of this credit is to encourage the use of renewable and alternate energy sources, thus reducing the environmental burdens associated with energy production.

This credit can be achieved in two ways in this design. The first would be to purchase renewable energy through the power company. If the Bren School can provide proof (a contract) that at least 10% of the building's energy is being supplied by renewable sources, one credit will be awarded. Since the school gets its power off the university grid, this means the campus as a whole would be making a commitment to renewable energy.

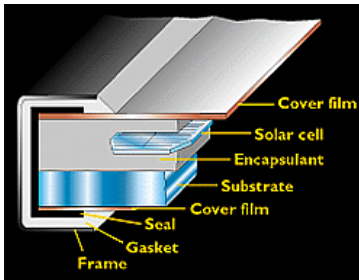
The second method would be to install a photovoltaic system on the roof. See 4.2.30.

#### **4.2.30 Photovoltaic Panels**

Install photovoltaics panels at the roof.

An initial rough estimate gives the following information: Using all of the available and practical flat roof surfaces, there is about 5,800 square feet that could hold flat interlocking photovoltaic solar modules.

- @ 10 watts per SQ, this would amount to about 58,000 watts or 58 kW.
- @ 1,800 kWh per year per installed kW, this system would produce about 104,400 kWh of electricity annually. The building is estimated to use roughly 1 million kWh annually, so the roof would generate 10% of the building's electricity consumption.



*Section through photovoltaic cell*

- @ \$9.00 per watt total installed cost, the system would cost about \$522,000. The available California Energy Commission rebate, federal tax rebate, and accelerated five-year depreciation schedule would bring the net cost down to about \$230,000.
- The system would produce energy worth \$13,572 per year. Payback period is about 17 years. This values the electricity only, and does not take into account the value of the air emission reductions. Carbon dioxide credits, Nox credits, etc are just starting to take form and offer some additional value although it is difficult to put a price on them today.
- Using EPA figures, this project would offset the emission of over 1,600 tons of harmful carbon dioxide, nitrogen oxide and sulfur dioxide over its 25-year life. This is by offsetting utility generation that uses gas, oil, coal and nuclear fuel. It would take 21 acres of new rain forest to accomplish that emission reduction.
- Solar modules have a 20-year warranty, the remainder of the system including installation carries a 5-year warranty.
- The system would be grid-connected and would backfeed an electrical distribution panel in the building to reduce electrical consumption and sell any excess back to the electric utility

No provisions have been made in the base design for photovoltaics. To keep open the option to pursue this measure, it would be prudent to issue a change order to install the infrastructure for a future array. This would consist simply of three empty 3-inch conduits running from the electrical distribution room and stubbing out at the roof.

#### **4.2.31 International Performance Measurement and Verification Protocol**

LEED Energy Bonus Credit # 1 requires the implementation of International Performance Measurement and Verification Protocol, or IPMVP.

IPMVP establishes a method for measuring the use of energy and water in existing buildings before and after remodeling. It can be used to qualify for economic incentives for utilities and other government agencies. The greater the energy reduction the greater the potential for the incentive. To use this protocol a qualified IPMVP specialist should be hired to determine the energy use of the building before and after it's remodeling.

The cost effectiveness of using IPMVP depends on the building it is applied to, and the function it is serving. The greater the size and the greater the energy use per square foot, the greater the opportunity.

Some utilities may provide economics incentives for measurable energy reductions in buildings following IPMVP procedures.

It is possible that the EMCS will cover this credit.



### **4.3 Conserving Materials and Resources**

#### **4.3.1 Elimination of CFCs/Halons**

LEED Materials Prerequisite #1 requires that there be no CFC refrigerants and no halon fire suppression systems in new construction.

CFCs (chlorofluorocarbons) and halons are known ozone-depleting substances. HCFCs (hydrochlorofluorocarbons) are now substituted for CFCs, but they too are ozone-depleting substances. The United States contributes a lion's share of the ozone depleting substances emitted around the world. Under the "Montreal Protocol on Substances that Deplete the Ozone Layer", 140 countries have phased out CFCs and halon, and have pledged to phase out HCFCs entirely by the year 2030.

There are no CFC refrigerants or halon fire suppressant in this design. LEED Materials Credit #requires the elimination of CFCs, HCFCs, and Halon at new mechanical equipment and building materials—see 4.3.19, 4.3.28, and 5.4.3.

#### **4.3.2 Storage and Collection of Recyclables**

LEED Materials Prerequisite #2 calls for a centralized location for the collection and storage of sorted recyclable materials, including newspaper, glass, metal, plastic, organic waste, and dry waste. This measure diverts usable materials from landfills, and provides materials for many future products.

The base design includes recycling bins at the service enclosure. To qualify for a LEED rating, documentation of campus recycling procedures may be required.

#### **4.3.3 Recycled Aggregate Base Course**

Specify recycled aggregate @ asphalt and walkway base courses per the Greenbook (Standard Specifications for Public Works Construction.)

In Southern California, recycled aggregate tends to be of better quality and cheaper than available native material. Many contractors prefer to work with recycled aggregate; it tends to adhere to itself in a way that makes it more workable.

If the project site were big enough, the contractor could have crushed demolished materials on site for reuse as aggregate. This method requires adequate space for the machinery required.

This measure conserves virgin resources and diverts materials from landfills, and was implemented as a part of the base bid.

#### **4.3.4 Recycled Glass in Concrete Paving**

Use recycled post-consumer glass to replace a portion of aggregate in concrete paving. This measure was implemented in the base design.



The process for incorporating recycled glass (hand seeded and floated on the surface of the concrete, and then water blasted to expose the seeded material) takes greater skill and time than a standard broom finish. Since this is already specified for this job, there will be no schedule or cost impact.

This strategy conserves natural resources and diverts materials from the waste stream. A highly visible and beautiful material, this can be used as an educational tool.

#### 4.3.5 Recycled Glass Mulch

Recycled glass has been specified for use as mulch at interior courtyard and terrace planters. The glass specified matches that used in the concrete paving.

This strategy conserves natural resources and diverts materials from the waste stream. A highly visible material, this paving can be used as an educational tool.

#### 4.3.6 Recycled HDPE Porous Paving



*Porous paving made from 100% post-consumer recycled content*

Specify a porous paving system at occasional use vehicular surfaces; in this case the fire lane that runs between the Bren School and Engineering 1. Porous paving systems reduce runoff by allowing ground water to soak into the ground through the pavers. In this case, a honeycomb paver system made of post-consumer plaster has been specified as part of the base design.

Other porous paving systems include cement unit pavers (up to 75%), porous asphalt, and decomposed granite.

This product should not take longer to install than a cement unit paver system. The product itself is simply unrolled and so saves time and labor. Turf seeding and initial maintenance must be carefully done to ensure success.

This product allows infiltration of rainwater, and diverts water from the stormwater system. 100% post-consumer HDPE plastic is used in its manufacture. Recycled aggregate can be used as the base course.

#### 4.3.7 Recycled Content Tree Grates

100% post-consumer iron tree grates have been specified as a part of the base design.

This is an example of market forces creating sustainable products. The manufacturer of this product has found that iron from used car engine blocks and scrap iron yards is less expensive than virgin iron. This measure helps to divert material from the waste stream and reduce energy used in production.

#### 4.3.8 Organic Compost

Organic compost within the planting medium has been specified as a part of the base design. Organic fertilizers have also been specified.

The native plant materials have a greater chance of survival and sustain long-term growth when a low percentage of organic composting materials and fertilizers are blended within the planting backfill mixture.



#### 4.3.9 **Recycled Content Steel**

Require minimum recycled content at steel.

The North American steel industry annually recycles millions of tons of steel scrap from recycled cans, automobiles, appliances, construction materials, and other steel products. This scrap is recycled to produce new steel. The industry's overall recycling rate is 64%. Every ton of steel recycled saves 2,500 pounds of iron ore, 1,400 pounds of coal, and 120 pounds of limestone. – Steel Recycling Institute. (This project has been estimated to require 95 tons of structural steel. Given recycling rates, 150,000 pounds of iron ore and 90,000 pounds of coal will be saved in the steel production)

Market forces have determined that steel commonly includes a high recycled content. Exact percentages are determined by the availability of post-consumer steel and by the manufacturing process used. Framing steel typically has about 28% recycled content, while structural shapes are commonly 98% recycled.

If a LEED rating is desired, the amount of recycled steel will help to achieve Materials Credit #3. Therefore, the addendum requires the contractor to document the recycled content of steel rebar, structural shapes, framing, decking, door frames, and miscellaneous steel items. In some cases, a minimum recycled content is specified.

#### 4.3.10 **Wood from Certified Forests**

The specifications currently require all trim and veneer hardwoods to be certified as having been harvested from sustainably managed forests. In this design, maple trim and veneer are used at the colloquium room. Exterior benches will be made from ipe, a certified hardwood similar in quality to teak.

There are many wood products available that claim to be from sustainable managed forests. To be sure of the quality of that claim, certification by the Forest Stewardship Council (FSC) is required. FSC focuses its review on three areas: sustainability of the timber resource, maintenance of the forest ecosystem, and socioeconomic benefits provided to the local and regional community.

FSC tracks products from harvesting through to the final production; this is called “chain-of-custody” certification. Very few wood products have received this certification. By specifying FSC certified wood, demand is increased; helping to open up the market for sustainably harvested products.

The base bid calls for interior trim and veneer to be certified maple, grown in North America. Maple is, however, an increasingly overharvested wood: it would be a good idea to consider alternate, lesser used species, as a change order. (This change was not possible as an addendum item – other woods will cost more.)



**Ecology:** the wood used to make these site benches is sustainably harvested.

**Equity:** Rather than exporting the raw materials elsewhere, the benches are fabricated at the source.

**Economy:** these benches cost a fraction of the ones originally specified.



Exterior benches were originally specified to be of teak. The specified Smith and Hawken benches were made of certified wood. However, it was decided to specify a lesser known species in Addendum #1. Ipe is a tropical hardwood grown in Bolivia. The wood is processed and the benches manufactured there – providing for the social equity that is one of the goals of sustainable development. Ipe is similar to teak in durability and quality, with a lovely reddish cast to the color.

#### **4.3.11 Recycled Content Ceiling Tile**

The acoustical ceiling tiles specified in the base design include 69% recycled content, consisting of slag wool from steel mills, and newsprint. Other ingredients are perlite, an abundant naturally occurring mineral, and starch from agricultural sources. Some manufacturers (Armstrong) offer a reclamation program, whereby they will remove and recycle used ceiling tile at the end of its life. (Because this is a public bid job, the reclamation program was not required.)

The option of deleting ceilings altogether was considered – the less material the better. However, this would increase the volume of conditioned space: the environmental costs associated with increased energy usage outweigh the benefits of using fewer materials.

#### **4.3.12 Recycled Content Asphalt Paving**

Recycled asphalt concrete can replace a percentage of virgin asphalt in paving applications. Recycled asphaltic concrete normally contains up to 15% reclaimed asphalt pavement but can go much higher in experimental applications.

The asphalt plant must be set up to produce recycled asphalt: separate stockpiles and feeders would be needed. According to a Santa Barbara plant, local plants are not yet set up for this but they expect to do so in the next few years as this process becomes standard. There is an initial setup cost to ready a plant to produce recycled asphalt; however, this should be offset by the lower cost of materials (50 to 75 cents less per ton).

This measure was implemented as an addendum. Recycled content was specified per the Standard Specifications for Public Works Construction (Green book) Sections 203-7, which allows up to 15% recycled content.

Use of recycled asphalt concrete conserves diminishing aggregate and petroleum. It also reduces construction and demolition disposal, which are currently 28% of California's waste stream.

**4.3.13 Fly Ash Content at Concrete**

Replace a percentage of cement in concrete with fly ash. Types C and F fly ash from coal-fired power plants can be used to replace a portion of cement in concrete in most applications. Concrete made with fly ash is more workable, cures to a higher strength, and is less permeable. Ground granulated blast furnace slag is a waste product of iron manufacture and may also partially replace Portland cement. Cinder block uses fly ash for up to 100% of sand aggregate.

While fly ash has been specified in quantities of up to 70% of cement, mixes such as these are still considered experimental. We have chosen to specify up to 30% fly ash at hardscape, 25% at structural foundations, and 20% elsewhere. Specifications were modified by addendum.

Local concrete ready-mix plants routinely use fly ash, so there should be no negative schedule or methods impacts. In every case, maximum fly ash contents only are given; this allows the contractor to use a quantity with which they are comfortable and familiar.

This strategy conserves natural resources, diverts material from the waste stream, and reduces energy used at CO<sub>2</sub> produced in cement production.

**4.3.14 Mulch from Site Demo/Trimming**

Require the contractor to make mulch from the trees removed or trimmed in the work of this contract, rather than exporting the trees to landfills and importing mulch. This measure diverts materials from the waste stream.

This measure would require the Contractor to find a place to store this site-manufactured mulch until it could be used. Rather than require the mulch to be reused specifically on this project, the University will undertake the effort to use the mulch elsewhere on campus. When the project is ready to receive mulch in the planting areas, the University will supply the mulch created from other locations on the campus. This would mean deleting from the project the mulch made from recycled wood products currently specified.

It is hoped that this effort will encourage similar methods at other campus projects.

This measure has been implemented by addendum.

**4.3.15 Recycled Content Trash Receptacles**

Specify recycled content site trash receptacles.

The base design included precast concrete trash receptacles. High-recycled content precast trash receptacles have been specified by addendum. The manufacturer of the precast concrete trash receptacles offers the option to use 93% post consumer recycled concrete in the manufacturing of new receptacles

**4.3.16 Certified Wood Benches**

See 4.3.10



#### **4.3.17 Recycled Content Casework Substrate**

Base design specifications call for plywood at architectural cabinetry casework and paneling, and for particleboard at laboratory casework. As an addendum, recycled content medium density fiberboard (MDF) replaces plywood, and recycled content particleboard made from agricultural waste replaces particleboard. Where possible, the substitute products use no urea-formaldehyde as binders, and so help to improve indoor air quality.

Plywood is specified for use at architectural casework substrate and at paneling in the base design. The use of virgin wood in the production of plywood depletes a valuable natural resource. There are several products now available that incorporate agricultural waste or post-consumer goods, and that perform as well as plywood. AllGreenMDF is made from 100% post-consumer waste, costs about half as much as plywood, and is locally manufactured (Riverside.) Medite and Medite II are made from sawmill waste, use no urea-formaldehyde, and are made in California. They cost more than standard MDF but considerably less than plywood. These two products have been specified for use in lieu of plywood at architectural casework.

Melamine liners are no longer called for at architectural casework. We Plain MDF provides a suitable finish that is arguably more attractive than the customary melamine.

Medium density particleboard is called for at laboratory casework. Some particleboard manufacturers include virgin wood in their product, others use sawmill scraps. The addendum specifies compressed straw particleboard. It is estimated that 140 million tons of straw is produced annually in North America, most of which is incinerated or plowed back into the soil. This includes straw from wheat, rice, rye, oats, and barley . Manufacturers of products such as Isobord and Wheatbord use finely chopped straw in a non-urea-formaldehyde binder (in this case methyl diisocyanate) to make a product that outperforms traditional particleboard and is competitive in cost. Straw particleboard has been specified to replace medium density particleboard at laboratory casework.

#### **4.3.18 Recycled Content Wall Insulation**

Insulation is one of the most important components of any environmentally responsible design because it reduces energy consumption and the resultant pollution. In this sense, any insulation is a “green” product.

This measure replaces fiberglass batt thermal and sound insulation with recycled content mineral wool batt insulation, thus diverting material from the waste stream. This measure was implemented by addendum.

Mineral wool insulation has a much higher recycled content than does the more commonly used fiberglass batt insulation. The product specified for the Bren School is made from 90% post-industrial blast furnace slag. The process used to make mineral wool is virtually waste-free; all the scrap is reusable. The installed product also is recyclable. And the embodied energy is about half that of fiberglass.



Mineral wool insulation was the standard until the advent of fiberglass; it is a familiar and proven material. Mineral wool insulation has excellent fire-resistant capacities and is typically used for fire-safing. It has good insulation value, R=4 per inch. It is simple to install, and is sized to be press fit into typical stud spacing. (It is actually more like a board, though it is called batt insulation.) Moreover, mineral wool has excellent acoustic properties.

In some ways, mineral wool is similar to fiberglass. The International Agency for Research on Cancer (IARC) lists mineral wool as a possible carcinogen; it should not be exposed to airstreams (in this design it is always enclosed). It may act as a sink for VOCs, again meaning that it must be enclosed. Both products use phenol-formaldehyde (still less dangerous than urea-formaldehyde).

Spray-on cellulose insulation and cotton batt insulation were also considered. Cotton batt insulation is commonly used in low-toxicity buildings and requires 25% as much energy to produce as fiberglass or mineral wool. It was not chosen for this project because of its cost (10% more) and because of concerns about fire-resistance. Sprayed cellulose insulation is made from recycled newspaper, mixed with a binder, and spray applied. Embodied energy is very low. Questions have been raised about the use of boron products as a fire retardant; boron is a nonrenewable resource and a known toxin. Cellulose is not readily reusable, so it is usually consigned to incinerators or landfills. While it decomposes easily, the borate and ammonium sulfate fire retardants remain, and eventually permeate the soil. Given these drawbacks, cellulose is still considered an environmentally friendly product. However, for reasons of constructability and cost, it was not chosen for this project. Had the question of insulation choice been considered early in design, different choices might have been made.

**Estimated Embodied Energy of Various Insulation Materials**

Material	Embodied Energy in Btu/lb	Weight per insulating unit in lbs.	Embodied Energy per insulating unit in Btu
Cellulose	750	0.812	600
Fiberglass	12,000	0.379	4,550
Mineral Wool	6,500	0.458	2,980
Polyisocyanurate	30,000	0.476	14,300

#### **4.3.19 Delete Polyisocyanurate Roof Insulation**

Polyisocyanurate insulation (iso) has been deleted from the roofing system and replaced with mineral wool batt insulation under the roof structure.

Polyisocyanurate board is a rigid foam insulation widely used in the construction industry. Iso contains 12-15% CFC-11, an ozone-depleting substance. It has no recycled content, is not recyclable, and has a high embodied energy.



Rigid fiberglass board contains no CFCs and is reportedly a good product, but is not readily available in North America. Atlas Roofing Co. is now producing an iso board that uses pentane instead of CFCs as a blowing agent. However, pentane is a VOC, so there are questions about pollution control during manufacture.

Mineral wool batt insulation can easily be installed with mechanical fasteners under the roof deck. This is a standard system; the insulation has high recycled content (see 4.3.18) and is quite a bit cheaper than iso. This measure was implemented by addendum.

**4.3.20 Steel instead of Aluminum Door Frames**

Replace interior aluminum door frames with painted steel door frames. This measure reduces the use of natural resources and other environmental costs of aluminum production, and provides a more durable building element.

Most aluminum building products contain virgin material: although aluminum cans are recycled, most are made into new beverage containers. A major reason for the clearcutting of tropical rainforests is to gain access to bauxite mines. Bauxite is the material used to fabricate aluminum. The manufacture of aluminum is water intensive and produces wastewater contaminants such as aluminum, fluoride, nickel, cyanide, and antimony.

Aluminum, though aesthetically pleasing, is not as durable as steel. Aluminum door frames would dent easily, and are not easily repaired.

Painted hollow metal door frames typically include recycled content, (see 4.3.9).

**4.3.21 Recycled Content Ceramic Tile**

Provide ceramic tile with recycled content. This measure helps to divert materials from the waste stream, and reduces the use of raw natural resources and the environmental degradation caused by mining.

By addendum, tile containing a minimum 55% recycled glass was specified where tile occurs (toilet rooms.) The glass is typically from postindustrial waste, such as windshield and lightbulb manufacturing waste.

The products are competitive in cost, and the same in quality and construction methods as standard ceramic tile.

**4.3.22 Recycled Content Carpet Tile**

As an addendum item, recycled carpet tile was specified at one office (4404) in lieu of VCT. For a discussion of VCT, see 4.3.30.



The carpet tile recommended, Earthsquare by Milliken, is the only carpet available that is actually reused rather than recycled carpet. Most carpets that advertise recycled content actually use most of their recycled content in the backing; the face of the carpet is at least 90% virgin material. (This may change, at least one other carpet manufacturer is now reusing carpet, and a major chemical company is building a plant in North America to recycle carpet yarn, see 4.3.37) For Earthsquare, used carpet is cleaned and dyed for reuse. This saves a considerable amount of energy in manufacturing.

When the carpet needs replacing, Milliken will recover it, free of charge, for reuse.

The intent of the addendum change is to make it easier to substitute carpet tile at all offices in lieu of VCT. Because the carpet tile is in the bid, the contractor will have priced it theoretically at a lower bid-phase price, rather than at a higher change order price.

While carpet is preferable to VCT, it does not last as long, requires more maintenance, and is not as easily recycled as other recommended floor finishes such as linoleum or rubber. Carpet also tends to harbor mold and other sources of poor indoor air quality.

#### **4.3.23 Recycled Content Rubber Flooring**

By addendum, recycled rubber flooring has been provided at Interaction Area 3328 , replacing VCT. It is a candidate for use at other areas currently showing VCT.

The specified product, EcoEarth by Dodge-Regupol, is made from 100% post-consumer content recycled rubber, primarily tires and EPDM. The product meets State of Washington's VOC Requirements.

This product is much more resilient than VCT, making it far more comfortable for long periods of standing. The installation process is similar to that of any sheet product. It requires several coats of sealer before use.

Recycled rubber flooring may also be used at labs, pending study of its resistance to the chemicals that may be used.

Recycled rubber flooring has a higher initial cost than VCT, but a lower life-cycle cost when durability and maintenance are factored in.

#### **4.3.24 Linoleum**

The base design shows VCT at lab, corridor, and office floors. This measure would replace VCT at lab and corridor floors with linoleum. A low or zero-VOC adhesive should be specified. Other substitutes for VCT at offices would be carpet tile or recycled rubber flooring (see 4.3.22 and 4.3.23)



Linoleum is composed of organic materials - cork, linseed oil, wood flour and pine resin, with a jute or polyglass backing. Manufacture generates very little waste because nearly all manufacturing waste is recycled back into the product. Linoleum is biodegradable and may be shredded and composted. While it often has a distinctive odor, it emits no dangerous VOCs.

Unfortunately, linoleum is only made in Europe, because of low demand in the United States: an undesirably large amount of energy is therefore spent in transportation.

While linoleum costs up to three times as much as VCT, it has a long life, typically lasting for 40 years or more, versus a life expectancy of 8-10 years for VCT. It is much more resilient than VCT (which is not much more resilient than exposed concrete.), and therefore more appropriate where the users will be standing for long periods of time..

Linoleum can be maintained with a dry maintenance system and periodic buffing. It does not require (and may be damaged by) the periodic wet maintenance and refinishing that is typical on vinyl flooring. In areas where the linoleum is likely to come into contact with water and where aggressive maintenance is expected, heat-welded seams should be specified.

As an addendum, linoleum has been specified at one lab (Fluid Mechanics 1027), and a unit price requested as a part of the bid. Should the university decide to issue a change order to install linoleum at all labs and corridors, a cost basis will already have been established. This measure counts toward LEED Credits M-C3 and IAQ-C6.

Sheet rubber flooring could also be considered as a replacement for VCT. This product is similar to linoleum in appearance, durability, and comfort. It costs less than linoleum and is made in the United States. It contains no recycled content but is recyclable.

#### **4.3.25 Recycled Content Toilet Partitions**

Replace stainless steel with recycled content plastic toilet and urinal partitions. This measure has been implemented as an addendum.

Single polymer plastic partitions have been specified, with a recycled content of 90% post-consumer plastics. (Co-mingled plastic is also available, but is not as durable.) This product diverts material from the wastestream, and uses fewer natural resources and energy in manufacture than the stainless steel it replaces. It is durable, available in a variety of colors, and is installed with the same hardware and methods. Initial cost is considerably lower than that of stainless steel.

#### **4.3.26 Recycled Content Acoustic Wall Panel Fabric**

Provide recycled content fabric at colloquium room acoustic wall panels. Several fabrics are now available that are made from recycled soda bottles. Guilford of Maine makes a fabric is cost competitive with the number used in the estimate. This material was specified by addendum.



Designtex also makes a recycled content fabric, at a slightly higher cost. This could be considered as a change order.

**4.3.27 Construction Waste Management Plan**

The contractor is required to recycle construction materials, and to document the process and results.

This measure drastically reduces the amount of waste materials going to landfills, and reduces the depletion of natural resources. This measure typically saves the contractor a fair amount of money, but requires up-front planning and training, and diligence throughout construction.

A construction waste management plan was specified in the base design. By addenda, the process was more fully described and sample plans included, in an effort to make implementation of this measure as straightforward and simple as possible.

Wood	27.4%
Asphalt, concrete, dirt	23.3%
Drywall	13.4%
Roofing	12.0%
Metal	8.8%
Cardboard, paper	2.7%
Miscellaneous mixed	11.9%

*Average composition of the construction waste stream. The implementation of a construction waste management plan can dramatically reduce the volume of materials going to landfills.*

**4.3.28 Elimination of CFCs, HCFCs, and Halon**

LEED Materials Credit #6 offers two credits. For one credit, CFCs, HCFCs and halon are eliminated from mechanical equipment and fire suppression systems. See 5.3.8 for further discussion. For the second credit, building materials that use CFCs or HCFCs are eliminated.

This measure reduces the amount of ozone depleting substances produced, and encourages manufacturers to develop alternate materials.

By addendum, all carpet pads and insulation that use CFCs or HCFCs were deleted. See 4.3.19 for roof insulation.

**4.3.29 Verify Centralized Recycling**

See 4.3.14

**4.3.30 Delete all Vinyl Composite Tile (VCT)**

This measure would delete VCT where currently shown at labs, corridors, and offices. Vinyl composite tile is made from a number of hazardous chemicals and petroleum-based resources, including ethylene dichloride and polyvinylchloride (PVC). The manufacture of PVC results in the production of highly toxic by-products, including dioxins, PCB's and organochlorines. Substances known or suspected of causing cancer and disrupting immune and reproductive systems are produced during the manufacture of vinyl chlorides. Some European countries are implementing restrictions against vinyl use and manufacture, and the EPA is reassessing dioxin.

VCT is generally not recycled, and usually ends up in landfills or incinerators. When VCT is incinerated, dioxins, metal chlorides, and hydrogen chloride are released. Because of the heavy metals that remain after burning, the ashes must be treated as hazardous waste. Standard VCT adhesive contains VOCs, though some low VOC and zero-VOC products are available.

Several alternate materials are proposed to replace VCT, see 4.3.22, 4.3.23, and 4.3.24.



#### **4.3.31 Resource Reuse**

LEED Materials Credit #2 requires the use of salvaged or refurbished materials for 5% of total building materials. Reuse of materials is an extremely effective way to mitigate the environmental damage caused by new construction. Materials are diverted from the waste stream, and less energy is expended in the manufacture of new materials or recycling of old.

It can be difficult to specify resource reuse on a project of this size and budget constraints; it is unlikely that the quantities of materials needed could easily be found, and extremely unlikely that they would not cost significantly more than virgin or recycled materials.

The Bren School should consider using salvaged or refurbished materials for furnishings.

#### **4.3.32 Recycled Content**

LEED Material Credit #3 awards up to two credits for the use of recycled content materials. This measure avoids the detrimental effects of extracting and manufacturing virgin resources, and it diverts materials from the waste stream.

Many of the recommended measures in this report have to do with using recycled materials. This is in part because there are so many good and cost-effective products available, and because at this late point in the design, materials substitutions are the measures least likely to cause untenable budget and estimate impacts.

Recycled content is measured by post-consumer and post-industrial content. We have attempted to achieve the level that brings one credit: 20% of building materials contain at least 20% post-consumer or 40% post-industrial recycled content. Quantities are calculated using the total estimated cost of the materials alone, exclusive of labor, soft costs, and building system costs.

The research for this measure confirmed the effects the dwindling of virgin materials sources has had on the market. Many materials, such as steel, are now routinely recycled, for economic, not environmental reasons. Other materials, formerly waste products, have found use as building materials, including particleboard and linoleum, among others.

If the LEED rating is actively pursued, the contractor will be required to provide proof that the minimum recycled content has been achieved.

#### **4.3.33 Alternate Concrete**

Mitsubishi has offered to donate cement manufactured using sludge and tires instead of coal as fuel. The cement would be type 5 cement, replacing the specified types 1, 2, and 3. The cement would be delivered to local readymix plants as needed.



While the savings on material costs should be considerable ( a rough estimate puts the worth of total cement on the job at between \$150,000 and \$200,000), other factors would reduce that potential savings. Type 5 cement, while suitable in strength, takes longer to reach its required strength. While the added time is probably only a few days per pour, it could adversely affect the construction schedule and therefore cost.

Type 5 cement will not be allowable at architecturally exposed concrete, for aesthetic reasons.

This measure should be implemented as a change order.



*Ground glass waiting to be recycled*

#### **4.3.34 Recycled Content Countertops**

Currently, countertops at the toilet rooms are specified to be a solid polymer, typically Corian. This measure would replace this virgin material product with a recycled content product, and could be implemented as a change order.

Two products have been researched and appear suitable for this application. Syndecrete is a cement based, precast product that incorporates a variety of recycled goods from bottles to electronic components to plastic regrind. It is available in 11 standard solid colors, and a host of custom colors and patterns. The cost of the standard colors is competitive with that of Corian.



Vetrazzo makes a precast product that has a cement-based matrix with recycled glass aggregate, very similar in appearance to terrazzo. This product also is competitive with Corian.

Either of these products could provide an attractive and effective example to the public of the possibilities of recycling everyday consumer goods. These products could be considered for use not only at the toilet rooms, where Corian is currently specified, but also at more public spaces, such as the interaction room or dean's suite.

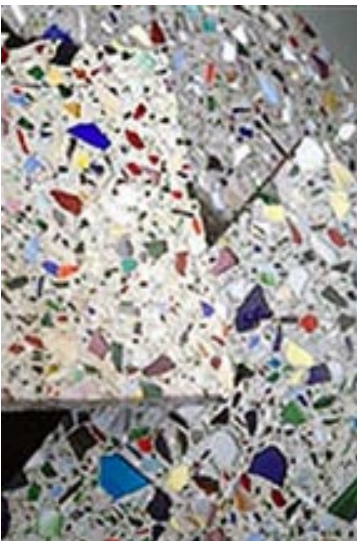
#### 4.3.35 Alternatives to Wood Veneer

There is a number of intriguing alternatives to virgin wood available.

For a traditional wood appearance, consider using bamboo. This fast growing wood can be harvested in four years from planting. It has warm, pleasing color and grain, and is as hard as traditional flooring woods. It is produced laminated, tongue and groove lumber, or on a flexible backing. It is cost competitive. There would be a significant design cost to modify the existing design for bamboo.

Other alternatives include EcoColor, made by Architectural Forest Enterprises in Northern California. EcoColors is a sheet product produced from particleboard made of recycled or certified fiber, or wheat straw, finished with water-based dyes and a zero-emission finishing process. The product is durable and repairable. EcoColor might be a great teaching product. This material does not deceive: hardwood veneer and trim are typically designed to appear as solid wood, denying the substrate beneath. EcoColor looks like what it is – substrate. Some design work might be needed to incorporate this product. A product similar to this might be used at interior wood doors.

The specified material, certified wood veneer over a recycled content substrate, is already fairly “green”. However, maple is a very popular wood and is overharvested. It is worth considering other lesser known species of certified woods.



*Recycled glass countertop*

#### 4.3.36 Alternate Upholstery Fabric

Specify DesignTex's William McDonough fabric for use at colloquium room fixed seating.

The new fabric is a blend of wool and ramie. The wool comes from free-ranging New Zealand sheep. Sheepfarmers are reducing adverse environmental impacts by addressing issues such as low-impact grazing and alternatives to the toxic “flea-dips” that sheep typically get. . Ramie is made from plant fibers. The ramie for this fabric is grown organically in the Philippines. Work is underway to minimize any impacts from this process as well.



Working with chemical giant Ciba-Geigy (the only chemical company willing to cooperate at the level they required), the designers identified only sixteen chemicals—from a list of 4,500—that met their environmental criteria. Using the sixteen approved chemicals, DesignTex is now able to produce every color except black. The resulting fabric is 100% biodegradable, according to the company. The textile mill has contracted with local strawberry growers to use their scrap material as mulch, allowing the nutrients to return to soil.

#### **4.3.37 Recycled Content Carpet**

Until recently, recycled content in carpet has occurred primarily in the backing or pad. Allied Signal is building a plant that will have the ability to manufacture 100% post-consumer recycled content carpet yarn. It may be worth keeping an eye on the progress of this material, with the thought if specifying it as a change order. See 4.3.22.

#### **4.3.38 Recycled Content Signage**

As a change order, specify recycled content single polymer plastic at interior and exterior signage. Select a material that requires no coatings or preservatives. There are a number of companies in California that make this product. It should be cost-competitive.

#### **4.3.39 Construction Waste Management Plan - Second Credit**

Achieve a second point for LEED Materials Credit #4 by implementing an advanced construction waste management plan. This would include the recycling of additional materials such as clean dimensional wood, plastic, glass, gypsum board and carpet. And the cost-effectiveness of recycling rigid foam insulation, engineered wood products, and other materials must be evaluated.

While this would be considered additional work for the contractor, experience shows that construction waste management usually saves money for the contractor by reducing tipping fees. In addition, the required evaluation would fit nicely with the idea of this project as a “building that teaches”. Data gained from the required cost evaluation could be published and so add to the wider sustainable design discussion.

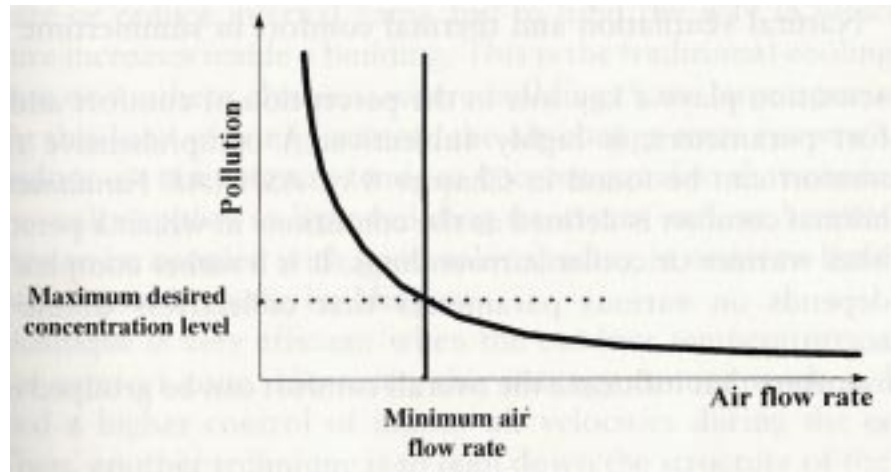
#### **4.3.40 Use of Local Materials**

This measure encourages the use of local materials. If a certain percentage of building materials are locally produced, one credit can be achieved (LEED Materials Credit #5). Use of local materials reduces the pollution caused by transportation, and reduces use of fossil fuels.

Effort has been made to specify materials that are of local origin. Should the user decide to apply for a LEED rating, documentation will be required.



*100% biodegradable fabric*



*The indoor air quality at the Bren School will be improved by natural ventilation*

#### **4.4 Enhancing Indoor Environmental Quality**

##### **4.4.1 Fresh Air Intakes**

LEED IEQ Prerequisite #2 requires that ASHRAE Standard 62-1989 for minimum ventilation rates and indoor air quality be used in designing the building systems, and that fresh air intakes be located away from exhaust sources.

Though it may be good design practice, often the air intake guidelines are not followed. In some cases the fresh air intakes are located near loading docks or low to the ground along major streets, which can lead to noxious chemicals to entry a building's air supply.

The Bren Hall design was wind tunnel tested early in the design process to ensure that not only the Bren School, but also adjacent buildings, will not entrain noxious fumes.

##### **4.4.2 Smoking Ban**

LEED Prerequisite #3 requires that smoking be prohibited in all areas of the building. This would include banning smoking during construction, and smoking in close proximity to the building's air intakes. Smoking is detrimental not only to the health of the smoker, but to those around. Smoking indoors contributes to poor air quality and decreases the useful life of furnishings.

It is illegal to smoke in public buildings in California.

It is highly recommended that smoking be banned on the site during construction.

##### **4.4.3 Thermal Comfort**

LEED IEQ Prerequisite #4 requires that the building systems design comply with ASHRAE Standard 55-1992.



Any building meeting the minimum requirements of California's Title 24 will meet the requirements of this ASHRAE standard. This standard covers the requirements for what temperature ranges a building must be controlled to in order to keep people comfortable inside. The requirements vary depending on what the building's function is. Offices have a tighter range of temperature control than homes do, and homes a tighter range than warehouses do. The standard also regulates the amount of fresh air required to keep the air from becoming stale, and the amount of moisture required in the conditioning air to prevent people from feeling uncomfortable.

#### **4.4.4 IAQ Construction Management Plan**

Provide an Indoor Air Quality (IAQ) Construction Management Plan to meet LEED IAQ Credit #1. This measure requires the protection of the ventilation system equipment and ducts during construction, or the cleaning of system components exposed to contamination during construction. This measure ensures that the HVAC system will not be contaminated during construction.

This measure has been included in the base design. See 4.4.11 for a discussion of enhanced IAQ management to achieve a second LEED credit.

#### **4.4.5 Chemical Storage Area Design**

LEED Credit #4 requires that all housekeeping chemical storage and mixing areas are secure, are plumbed for water and drainage, are at negative air pressure, and have separate outside venting. This has been provided as a part of the base design.

Because this is a lab building, designed for toxic chemical use, careful attention has been paid to the protection of indoor environmental quality. Offices and labs are on separate air circulation systems. Chemicals are segregated and vented using storage cabinets and hoods. Janitor closets are locked, plumbed, and exhausted using negative pressure.

#### **4.4.6 Use of Low VOC Materials**

LEED IEQ Credit #2 requires that adhesives, architectural sealants, and paints and coatings comply with specified standards, as specified by the South Coast Air Quality Management District, the Bay Area Resources Board, and the New Jersey State Department of Environmental Protection. If two of the above are met, one credit is achieved; two credits are available for meeting all three.

Volatile organic compounds (VOCs) are chemical compounds that contribute to air pollution inside and out.

Materials specified in the base design certainly meet the California requirements, for one credit. During the LEED application process, compliance with the New Jersey requirements can be verified.



**4.4.7 Urea-Formaldehyde-Free Substrate @ Veneer**

Specify urea-formaldehyde free substrates at casework and veneer, see 4.3.17. This measure has been included in the addenda.

Used as a binder in most wood substrates, Formaldehyde is considered a probable carcinogen even at low levels. In the last decade, the amount of formaldehyde used has decreased considerably; current particleboard products have 80 to 90 percent lower emissions than they did ten years ago. Alternate binders are now available, often in combination with recycled materials.

**4.4.8 Reduced VOCs @ Carpet**

Specify carpet that meets either the State of Washington's guidelines, or the Carpet and Rug Institute's "green label" requirements. These set standards for total volatile organic compounds (TVOCs), styrene, 4-PC (4 phenylcyclohexene), and formaldehyde. This measure has been included by addendum.

Consider adhesive-free fastening systems. This is worth considering as a change order.

**4.4.9 Architectural Entryways**

Permanent architectural entryway systems installed at major entryways can dramatically reduce the amount of dirt and other contaminants brought in to the building. Mats, made of 100% post-consumer content HDPE with a textile insert, placed in a slab depression, will be installed at the three main lab entryways on the first floor. The grill can easily be rolled back for cleaning.

The goal of this measure is to reduce indoor air contaminants. It is estimated that 85% of soil ant particles that must be cleaned from buildings is tracked in via entryways. Grills capture much of this dirt, reducing the need for cleaning, and thus the indoor air contaminants that can result from the use of cleaning products. Reducing cleaning frequency can reduce the money spent on cleaning costs.

This measure is inexpensive, a conservative estimate is \$500 per entryway, and has been implemented as a bid addenda.

**4.4.10 Enhanced IAQ Construction Management Plan**

For a second credit under LEED IEQ Credit #1, reduce construction contaminants in the building prior to occupancy and provide a minimum of 85% filtration if the return side of the HVAC system is used during construction.

This measure could be implemented as a change order. Temporary ventilation would be required as a part of the general Conditions. 100% outside air ventilation with air exhausted directly outside during the installation of finishes and other VOC emitting materials would be required. Separate filters would be required during construction, and would be replaced prior to occupancy.



This measure would go a long way towards ensuring the building's indoor environmental quality, but could cost a considerable amount. The cost associated with implementing the LEED requirements for enhanced IAQ construction management makes this measure difficult to recommend.

#### **4.4.11 Duct Insulation**

Specify duct insulation to occur at the exterior of ducts, rather than as lining. This measure avoids the airborne fiberglass and microbial contamination that may occur with the installation of insulation at the interior of ducts. Where the void between suspended ceiling tiles and structure is used as a plenum, verify that all fibrous or soft insulation materials are encapsulated.

This measure may be worth considering as a change order, but may have considerable design and construction cost implications.

#### **4.4.12 Permanent Air Monitoring System**

Install a permanent air monitoring system to achieve LEED IEQ Credit #3. The system would monitor supply and return air and ambient air at fresh air intakes for carbon monoxide, carbon dioxide, total volatile organic compounds (TVOC's), and particulates. This measure would enable the owner to quickly detect problems, and ensures a consistent high standard of indoor air quality.

It may be worth investigating this recommendation.



*The United States uses 5 billion gallons of water per day flushing toilets. Annually, 1.4 billion pounds of nitrogen, 456 million pounds of potassium, and 194 million pounds of phosphorus are flushed down our toilets with the water. Sewage treatment plants try, with only moderate success, to remove those nutrients, then use 1.2 billion pounds of chlorine to “purify” the water.*

## 4.5 Safeguarding Water

### 4.5.1 Water Conservation

LEED Water Prerequisite #1 requires that the project design meet the Plumbing Fixture Requirements of the Energy Policy Act of 1992. This act imposes water conservation standards for water closets, showerheads, and faucets that should save the U.S. 6.5 billion gallons of water per day. This reduces the pressure on the streams, rivers, and aquifers that provide potable water.

This measure was written for renovation projects; the intent is that existing fixtures be replaced with newer, water conserving models. However, as this report is being written, a bill is being considered by the US House of Representatives that would repeal the water conservation requirements of the Energy Policy Act of 1992. Oddly enough, Bill H.R. 623 is not supported by either the plumbing fixtures industry or the National Association of Home Builders.

### 4.5.2 Lead in Drinking Water

The amount of lead allowed in drinking water is highly regulated in California and exceeds EPA requirements.

One way that lead can get into the drinking water of a building is if the plumbing contractor allows the use of lead based solder in copper piping. Though allowed in the past, this practice now is illegal in California and is generally not a problem with most contractors. In the past lead piping was used in plumbing, but its use has been banned for many years.

Buildings using copper plumbing and built before 1986 may have high content lead solder in them. Buildings built before 1930 may have lead piping or components in their plumbing systems. Disreputable contractors or building owners may have used banned materials after they were banned.

Building rehabs require a listing of all materials used in the plumbing system, not from old design drawings, but from direct observation. Testing of the water for lead is also required. Any sources in the plumbing system found to contribute to high lead levels must be removed, replaced or bypassed. The cost associated with reducing lead levels in existing buildings varies widely from project to project.

### 4.5.3 Reclaimed Water at Irrigation

LEED Credit #2 requires the installation of gray-water systems to reclaim non-sewage wastewater and ground water. The reclaimed water can be used to flush toilets and irrigate landscape. The intent is to reduce the demand for potable water and so reduce the strain on potable sources such as streams, rivers, and aquifers.



The base design includes the use of reclaimed water for irrigation purposes. Reclaimed water is supplied by the Goleta Water District and utilized throughout the campus landscape. Planters at the second and third floors use potable water: the pressure at the reclaimed water is not sufficient to provide water above ground level.

This measure should count toward the LEED credit. See 4.5.10 for the recommendation to provide reclaimed water for use at toilet rooms

#### **4.5.4 Water Conserving Cooling Towers**

LEED Water Credit #3 requires the installation of delimiters at cooling tower to reduce drift and evaporation. A delimiter is included in the induced-draft type cooling tower specified.

#### **4.5.5 Water-Efficient Landscaping**

LEED Water Credit #4 requires that plants are tolerant of the local climate, soil, and water availability, and that municipal potable water not be required after establishment.

All of the trees and shrubs specified on the plans in the base design are either native or drought-tolerant plant species. After a period of establishment, plants at ground level should not normally require additional water. Plants at the second and third floor terraces, because they are in a raised planter condition, may need periodic watering. During periods of extensive drought, additional water may be needed at all landscaping to sustain growth.

The plant material as specified is comprised of native and drought-tolerant plant species, except for the turf lawn. The designers were directed by the University to provide a lawn area across from the Engineering 1 Building. WRT has specified a low-water demand lawn species, but, as with all lawn areas, supplemental irrigation will be required to sustain growth. We are unaware of any lawn substitute that can be specified in lieu of the turf that will meet the performance requirements of durability, drought tolerance, and green aesthetics.

Plants at the ground level do not receive municipal potable water. It may be worth considering adding a pump to force reclaimed water to the second and third floor. It may be possible to share a pump with the toilet water system, if reclaimed water is to be used at the second and third floor toilet rooms. Further studies may need to be performed to analyze whether this may be feasible, considering the amount of potential harmful salts and metals that would exist in an enclosed planter condition.

To ensure that the irrigation system is correctly understood and used, a separate irrigation manual under separate cover will be provided to the Bren School and Facilities Management as a part of the work of this report, see 4.5.8.



*The native California plants used in Bren Hall landscaping are drought resistant and provide native fauna a habitat.*



**4.5.6 Surface Runoff Filtration**

LEED Water Credit #5 calls for oil-grit separators or water quality ponds to be installed at surface parking. Oil grit separators are included in the base design.

The purpose of this measure is to reduce the contaminant level contained in parking lot runoff such as oil, fuel, lubricants, combustion by-products, and tire material. These materials can contaminate streams and other bodies of water.

**4.5.7 Pervious paving at firelane**

See 4.3.6

**4.5.8 Irrigation operations manual**

An irrigation operation manual will be supplied to the university under separate cover from this report. It will outline specific irrigation practices that will need to be performed to heel-in and sustain the plant growth of the native and drought-tolerant plant materials. The manual will indicate proposed methods of watering, time of duration, application rates, soil permeability, rain day applications, etc.

**4.5.9 Automatic flush valves at toilet room fixtures**

Automatic flush valves at all of the toilet room fixtures have the dual benefits of reducing water use and increasing sanitation. This measure can be implemented as a change order for approximately. \$

3,000.

**4.5.10 Footpedals at lab sinks**

Provide footpedals at lab sinks to control water flow. This measure can reduce water use by allowing greater control of water flow when both hands are busy, and by making it hard to leave water flowing when one is not standing at the sink. This measure is commonly implemented in laboratories. The user should consider whether this is desirable. This could be implemented as a change order.

**4.5.11 Reclaimed Water at Toilets, Urinals**

Reclaimed water can be used at toilets and urinals, thereby conserving potable water. Implementing this item requires additional piping and pumps. The estimate to implement this measure for the whole building is \$12,000, and can be done as a change order.



#### **4.5 Improving the Design Process**

LEED Designer Bonus Credit #1 can be achieved by including on the design team at least one person who has satisfactorily completed a certified training course.

It is probable that the design team will include one certified designer.



## 5. ADDITIONAL MEASURES

### 5.1 Planning Sustainable Sites

#### 5.1.1 Landscaping/Exterior Design to Reduce Heat Islands – second credit

LEED Site Credit # 2 offers two credits, of which the project has attained one. The second credit would require that high-albedo materials be used on at least 80% of non-parking impervious surfaces (walkways, plazas, etc.) The current design uses concrete at all hardscape, i.e. concrete plazas, sidewalks, paving, etc. Concrete typically has a reflectance factor of 0.3. To achieve higher, gravel or perhaps decomposed granite would be required. Given accessibility and maintenance issues, this measure was deemed inadvisable for this project. Instead, every effort was made to provide trees and high-albedo materials at exterior surfaces where the function and beauty of the design would not be compromised.

#### 5.1.2 Alternate Roofing System

An alternative to the built-up roofing with white cap sheet or white gravel currently specified would be to install a different roofing system altogether, as a change order. Many types of roof surfaces are available in white color. These include:

- Hypalon: Any roofing system, membrane that contains hypalon and is available in a white reflective color.
- EPDM: Any roofing system containing EPDM (Ethylene-Propylene-Diene-terpolymer Membrane) which is available in a white reflective color.
- PVC: Any roofing system, membrane that contains PVC (Poly-Vinyl Chloride) and is available in a white reflective color.
- Modified Bitumen: Any modified bitumen roofing system that is available in a white reflective color.
- Metal: Any metal roof that is available with a white reflective finish.
- Coatings and Paints: White coatings (elastomeric and ceramic) and white paints for various roofing types.
- Shingles: Any asphalt shingle that is available in white. Note that most “white” asphalt shingles are not very reflective and will not meet the 0.75 reflectance requirement. Check with the manufacturer.
- Tiles: Any ceramic or clay tile that can come in white and/or is barrel shaped. Many “white” tiles will also fail to meet the reflectance requirement.

For more information, see “Highly-Reflective Low-Slope Roofs”, <http://www.ornl.gov/roofs+walls/roof/coatings.html>.



### **5.1.3 Infill Development**

LEED Site Credit #3 requires that new construction be built in areas with an existing development density of 100,000 square feet per acre. This measure seeks to alleviate the damage caused by placing new construction in open space away from urban cores; increased reliance on transportation, loss of agricultural land and wildlife habitat, increased cost of infrastructure are avoided.

Although this project is replacing parking lots, and so is not destroying wildlife habitat or agricultural land, it does not meet the density requirement for this credit.

### **5.1.4 Reduced Habitat Disturbance**

LEED Site Credit #4 requires that the project's footprint be reduced to exceed the local zoning's open space requirement for the site by 25%. Limiting site coverage allows more room for wildlife and plant habitats and increases user well-being.

The site and its associated improvements cannot be classified as a restored "habitat" as discussed in the USGBC literature. Normally, habitats and corridors are defined as self-sustaining environments, and are usually measured in acres or miles. We are really pushing the envelope here to consider our small site as a specialized, stand-alone ecosystem, or as part of an overall ecological corridor or system that is entwined within the campus framework. We are, however, implementing a plan to preserve significant existing trees on the ESM site.



## **5.2 Improving Energy Efficiency**

### **5.2.1 Radiant Slab Heating for Offices**

Hot water pipes in the floor slab rather than the baseboard radiators could deliver heating to the offices. Advantages are greater comfort due to the radiant affect from the floor, energy savings due to potential for lower the thermostat setpoint while maintaining equal comfort, and lower heat loss through open windows. Another advantage is slightly increased usable floor space due to elimination of the baseboard heater. The radiant slab would be most effective with an exposed concrete floor rather than carpet. And an exposed floor provides additional energy benefits by improving passive solar heating and passive cooling performance (which is important in these uncooled rooms).

It is not feasible to implement this measure at this stage in the project.

### **5.2.2 Glazing and/or Shading Devices**

Improve comfort in uncooled offices by controlling solar gain with high performance glazing and/or shading devices. It has been determined that this measure would be prohibitively expensive and difficult to implement at this stage. See 4.1.6 and 4.2.18.

Many of the uncooled offices may be uncomfortably hot due to the unshaded glazing. This seems most likely to be a problem on the west-facing fourth floor offices. We support avoiding air conditioning where it is not absolutely necessary, but these spaces should probably be provided with solar gain control to improve comfort. There are several options, and a combination is likely to be most effective.

- Replace single-pane tinted glazing with a dual pane spectrally selective glazing. These coated glazings can reduce heat gain by 60% compared to clear glass while cutting visible light transmittance by only 20% and maintaining neutral color. They also dramatically reduce heat loss during winter and maintain a moderate indoor surface temperature to provide better comfort.
- Provide shading using overhangs or sidefins. This option helps significantly, but does not help in late afternoon.
- Operable exterior shades, such as louvers, shutters or roller blinds are much more effective than indoor shades at controlling heat gain.
- If interior shades are used for solar control, then they must be highly reflective (white) to reflect as much heat as possible.

### **5.2.3 Waste Heat Recovery System**

LEED Energy Credit #3 requires that 20% of total waste heat be captured for use in preheating water or incoming air. The purpose is to reduce energy use and thus the environmental burden associated with energy production.

Given the mild climate, this building's HVAC systems will most often be using outside air as is. This measure is therefore not appropriate to this design.



### **5.3 Conserving Materials and Resources**

#### **5.3.1 Rubberized Asphalt Paving**

Specify rubberized asphalt in lieu of standard asphalt. There are no direct impacts on design as a result of this strategy. Rubberized asphalt can be laid in a thinner section than conventional asphalt and can reduce road noise. Rubberized asphalt costs significantly more than conventional asphalt, and is difficult to work where tight corners and seaming with existing asphalt are required. It is not suitable to this project.

The environmental benefits of rubberized asphalt include: reduced scrap tire disposal, and less material (asphalt, aggregate, etc.) used because rubberized asphalt can be used in thinner sections to achieve performance that is equivalent to conventional asphalt.

#### **5.3.2 Replace Exterior Painted Steel with Stainless Steel**

This project specifies painted galvanized steel at exterior surfaces. This process works well, when done correctly.

An alternate method would be to use stainless steel. The goal would be to improve durability and maintainability. Stainless steel would probably cost four times as much as painted galvanized steel. In addition, at exterior marine conditions it is desirable to use high-grade 316 steel. Standard grade stainless steel can corrode because of the fabrication process: it is easy to contaminate the stain- less steel with regular steel via fabrication tools, in which case rust can occur. 316 steel does not have this problem but can cost 1.25´ as much as standard steel.

It may be worth considering using aliphatic paint in lieu of galvanized steel with alkyd paint. Because there will be a considerable amount of on site fabrication in this project, galvanized paint will have to be reapplied at many areas. In addition, the galvanized surface must be carefully prepped before painting. To ensure the protection of the steel, it would probably be more effective to use aliphatic paint only, which is applied after fabrication, on site. This process provides a durable finish, and is less susceptible to construction error than painted galvanized steel, and is less costly than high-grade stainless steel.

#### **5.3.3 Recycled Content Drain Pipe**

Require all HDPE pipe to contain recycled content.

HDPE is an environmentally expensive product, not easily recycled and involving toxic processes in the manufacture.

There are several companies on the East Coast that manufacture a high recycled content (97 %) HDPE pipe; these companies do not ship to California. Local manufacturers say they cannot use recycled content in drain pipes of the size required, that the product would not meet ASTM and AASHTO standards. However, the East Coast product does meet those standards.



This may be representative of a typical situation; the building industry as a whole is reluctant to change the status quo. As some manufacturers and builders forge ahead and make changes to better implement sustainable values, others initially balk and eventually catch up. Constant vigilance is needed to keep up with the changes; practices that were universally agreed to be impossible today will be standard tomorrow. Thus market forces can be used to further sustainable design.

As an addendum, the local product that does contain some recycled HDPE has been added to the specifications, as has wording requiring the maximum possible recycled content allowed by ASTM.

#### **5.3.4 Recycled Plastic Site Benches**

Recycled plastic wood benches were considered in lieu of certified wood. Plastic wood is a great product in many ways: it is made of 100% post consumer plastic, is strong and durable, and requires no maintenance. However, there is an unfortunate tendency to try to mimic the appearance of wood when making plastic lumber products. This leads the user to expect the warmth and softness of wood when touching the product – when in fact the product has an unpleasant slippery hardness to it. For this reason, plastic lumber benches are not recommended.

Instead, wood benches from a certified “Lesser Known Species” were specified by addenda, see 4.3.15.



## **5.4 Enhancing Indoor Environmental Quality**

### **5.4.1 Recycled Content @ Acoustic Panel Substrate**

The acoustic wall panels have rigid fiberglass substrate. There is a mineral wool substrate product available, which would provide a higher recycled content. However, the mineral wool product is not acoustically inferior and therefore nor recommended.

### **5.4.2 Exposed Concrete in lieu of VCT**

This measure would delete VCT currently shown at labs, corridors, and offices. No other finish would be used.

Obviously the best way to conserve resources is to use fewer resources. This measure avoids the environmental hazards that come with the various floor finishes listed in this document. Exposed concrete could be stained or integrally colored, and sealed, for an aesthetically pleasing, durable, and cleanable surface.

This measure was not pursued because the users felt that it would be undesirable to have such a hard and noisy surface in the labs and corridors.

### **5.4.3 Elimination of CFCs, HCFCs and Halon at Mechanical Equipment**

LEED Materials Credit #6 calls for the elimination of CFCs, HCFCs and Halon at new mechanical equipment. CFCs and Halon have already been phased out in the US, and have typically been replaced by HCFCs, which are less environmentally damaging. However, these are still ozone-depleting materials, and will be phased out by the year 2030, under the “Montreal Protocol on Substances that Deplete the Ozone Layer.”

HCFC-free mechanical equipment is not yet available in the United States.

### **5.4.4 Occupant Recycling**

LEED Material Credit #7 requires “a mechanical system that allows for floor to floor transportation and sorting of newspaper, glass, metals, plastics, organic waste, and dry waste for recycling and disposal in the ground floor of the building other than by labor.” Typically, this would mean installing chutes.

The University provides for the hauling of recycled materials by hand, and encourages awareness of the values of recycling, reuse, and waste reduction. Although this means that in spirit this credit can be achieved, the wording explicitly requires mechanical rather than manual sorting.

### **5.4.5 Elimination/Control of Asbestos**

LEED IEQ Prerequisite #1 requires the elimination and control of asbestos. This measure applies to existing buildings, and is not applicable to this project.



## **5.5 Safeguarding Water**

### **5.5.1 Surface Runoff Reduction**

In order to meet the criteria of providing 50% pervious paving materials of all non-landscaped areas (i.e. roadways, parking lots, plazas, courtyards, walkways, etc.) a total of approximately 36,000 SF of pervious pavement surfaces would have to be provided. Substantial design changes would have to be implemented to earn credit for this measure. For example, if all impervious concrete surfaces were changed to pervious decomposed granite, the design would still be deficient 9,000 SF of 50% pervious paving surfaces. Part of the parking lot would also have to be changed to meet this measure.

Aesthetic and functional issues need to be considered here. Decomposed granite walkways can result in increased indoor maintenance, because of the added dirt and sand that would be tracked into the building. Decomposed granite may not be considered accessible, as cement unit pavers certainly would not be.

Typically, the design strategies for reducing surface runoff are implemented in seldom used or in “overflow” parking situations. It would seem that the scale of the project, the intensity of use, and number of students using the ESM would warrant that this site would not be ideal for pursuing credit for this measure.

### **5.5.2 Pervious Paving**

Install asphalt paving with a large aggregate to provide drainage. This method is inappropriate to this project because of the rock shelf that exists 8 to 12 feet below the surface. Water can collect under the paving; pervious paving is especially susceptible to damage by standing water.

### **5.5.3 Biological Waste Treatment**

Install an on-site biological waste water treatment system. This measure should be included in the design from the beginning.

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