



LABORATORIES FOR THE 21ST CENTURY: CASE STUDIES

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Timothy Hursley/PIX12820

DONALD BREN HALL, SANTA BARBARA, CALIFORNIA

Introduction

The Donald Bren School of Environmental Science & Management at the University of California, Santa Barbara (UCSB) “walks the talk” and exemplifies its mission. Because of its many energy-efficient and environmentally sound features, Donald Bren Hall has received a Platinum rating—the highest—under the U.S. Green Building Council’s Leadership in Energy and Environmental Design (LEED)TM rating system (Version 1.0). In October 2003, this building was one of only two certified Platinum in the nation, and it is the only laboratory to achieve this level of recognition.

The mission of the Donald Bren School is “to play a leading role in researching environmental issues, identifying and solving environmental problems and training research scientists and environmental management professionals.” The school trains graduate students in rigorous,



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interdisciplinary approaches to environmental problem-solving in a curriculum that blends natural science, social science, law, and policy. It can accommodate about 100 master's degree students and 50 doctoral students annually.

During the development of construction documents for the school's new building in the late 1990s, and following an endowment from the Donald L. Bren Foundation, the advisory board decided that it should be a "living laboratory" for the technologies and design approaches that it advocates. The school then commissioned reviews by various outside experts and, midway through the design process, began moving toward being the "greenest" building on the UCSB campus. *The Greening of Bren Hall*, a report issued in October 1999, described how the building could set an example of what can be achieved through the conscientious application of sustainable design principles.

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"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." The Greening of Bren Hall, October 1999

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Ultimately, Bren Hall was designed to surpass California Title 24's required standards for energy efficiency by more than 31%, through its many energy-efficient features. These include naturally ventilated rooms in the office wing of the building, premium-efficiency equipment motors, variable-volume pumps, variable-air-volume (VAV) laboratory exhaust and supply systems, and daylighting controls. Staff also obtain real-time building performance data as part of an extensive energy-use monitoring and management system.

The university's experience with Bren Hall has prompted it to adopt sustainable design guidelines for all UCSB projects. These guidelines include mandating the attainment of a LEED Silver certification and establishing a campus-wide approach to LEED.

This case study of Bren Hall is one in a series produced by *Laboratories for the 21st Century* ("Labs 21"), a joint program of the U.S. Environmental Protection Agency (EPA) and the U.S. Department of Energy (DOE). It is geared toward architects and engineers who are familiar with laboratory buildings. This program encourages the design, construction, and operation of safe, sustainable, high-performance laboratories.

Project Description

Donald Bren Hall is a four-story classroom, office, and laboratory building that houses the Donald Bren School of Environmental Science & Management at UCSB. Bren Hall contains three floors of teaching and research laboratories and four floors of offices. The architect was Zimmer, Gunsul, Frasca Partnership of Los Angeles, California. The mechanical and electrical engineer was Flack + Kurtz Inc. of San Francisco.

The building contains 84,672 gross square feet (ft²) (46,304 net ft²) of space (see Table 1). The construction cost was \$22 million (\$260/gross ft²), and the total project cost was \$26 million.

The design goal was for Bren Hall to be the best-performing sustainable building to date—one of the very best of UCSB's teaching and research buildings—and a model not just for other UC buildings but for all those in California. Dennis J. Aigner, Dean of the Bren School, said, "What we want to do is create a new standard for construction, not just at UCSB but throughout the whole university system."

Layout and Design

Bren Hall includes faculty and administrative offices, research and teaching laboratories, and seminar rooms for applied and quantitative ecology, earth sciences, environmental engineering, environmental microbiology and toxicology, and environmental policy and resource management programs. An open courtyard unites the laboratory wing and the office wing. Upper-level walkways provide access to offices as well as spaces for planned and spontaneous interdepartmental interactions. A floor plan is shown in Figure 1 and the courtyard in Figure 2.

Table 1. Bren Hall Space Breakdown

(In net ft², unless otherwise noted)

Function	Size (ft ²)	Percentage (1)
Labs (BL-1)	21,058	45%
Administration (offices, classrooms, conference)	25,246	55%
Total net ft ²	46,304	100%
Other (2)	38,368	
Total gross ft ²	84,672	

Notes:

1. The percentage shows a breakdown of the net square feet only. Net ft² equals gross ft² minus "other."
2. *Other* includes circulation, toilets, stairs, elevator shafts, mechanical and electrical rooms and shafts, and structural elements like columns. The net-to-gross-ft² ratio is 0.54.

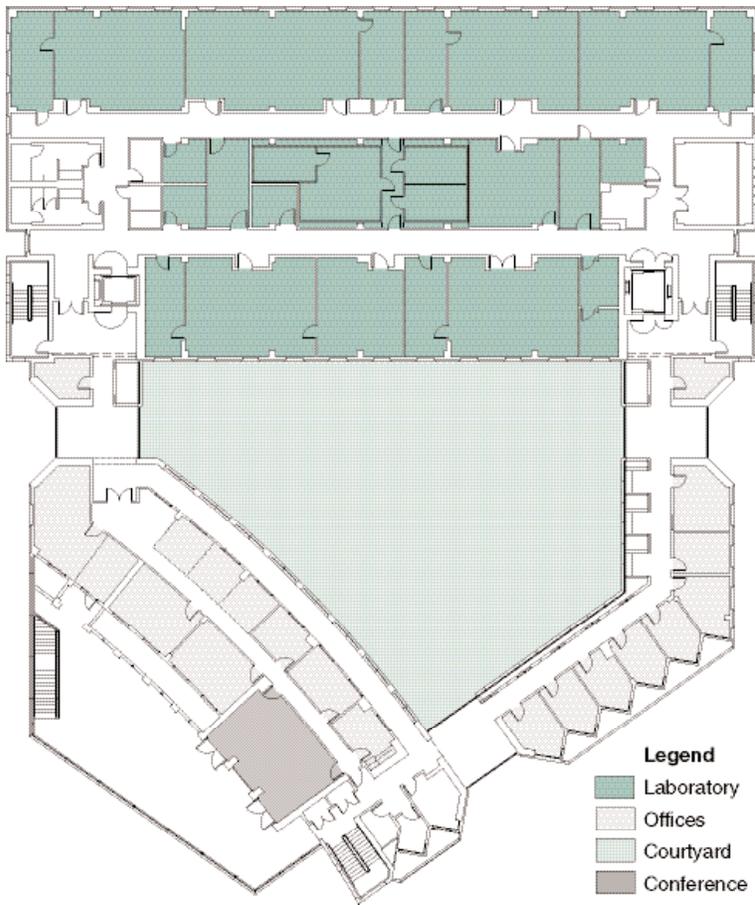


Figure 1. Bren Hall second floor plan

The form of the building serves to mediate between the campus and its coastal location, taking advantage of the site's sea air and views. On the eastern side of the building is a four-story, rectangular laboratory wing with east-facing exterior terraces on the third and fourth floors. On the ocean side of the campus, a less formal, "organic" curve defines the office wing.

A sawtooth pattern along the office wing's façade is designed to maximize views and provide natural light for offices. The ground floor of the office wing houses spaces dedicated to teaching; it includes a lecture hall that can seat 100 people and several 1,200-ft² classrooms and breakout rooms. The first floor also includes "wet" teaching labs with fume hoods for watershed science. Figure 3 shows the interior of a teaching laboratory.

The prefunction space for the rooms is an interior courtyard that can be accessed via three portals at north, south, and northeast points of the building. Stairs near the portals lead to a large, second-level terrace offering panoramic ocean views. The second floor contains both "wet" and "dry" labs for teaching environmental

microbiology, chemistry, and geography. It also houses departmental administrative offices, support facilities, and a conference room. On the third floor are the computer science labs.

Interior terraces (see Figure 4) at the second and third levels overlook the courtyard below. The courtyard's open walkways are lined with a two-story vertical trellis that will be covered with green vines when they are fully grown.

Utility Servicing

Utility servicing is provided by a horizontal piping distribution system. Laboratory piping utility racks are located in the corridor. Each room has an isolation valve for each service. Access to each lab's mechanical equipment, ductwork, laboratory waste piping, and ventilation piping is above the ceiling.

Design Approach

In 1997, the school received a sizable endowment from the Donald L. Bren Foundation, established by Donald Bren, a California real estate developer who strongly supports sustainable design. Although the design process for a new building had already begun, the school advisory board decided at that point that a School of Environmental Science & Management should be a living laboratory. So, the project moved from simply constructing a building in which environmental science is taught to creating a structure that is itself an example of environmental sensitivity.



Figure 2. Bren Hall features an open courtyard between laboratory and office wings.





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Figure 3. Interior of a teaching laboratory in Bren Hall

UCSB then commissioned the architect to prepare a feasibility study that would show how the building could achieve the greatest level of sustainability. Many recommendations from the resulting *Greening of Bren Hall* report were implemented in the new building, which was completed in 2002. In addition, Bren Hall is the first UCSB building to have been fully commissioned by a third party. In this case, an independent commissioning authority conducted a review of the design and construction documents at multiple phases throughout the design process.

Technologies Used

Among the sustainable technologies used in Bren Hall are numerous recycled materials, natural ventilation, daylighting, and energy-efficient motors and fans. A solar electric system has also been installed to generate some of the building's power.

Recycled Materials

Recycled, sustainable materials were very important in the design and construction of Bren Hall. The original site was a parking lot; all the old asphalt and concrete curbing were ground up and reused as base. Contract specifications required the builder to separate and reuse waste and to minimize debris taken from the site. Desilting facilities were placed at each drainage outlet, and hay bales and fencing helped to control soil erosion and sediment. After each rainstorm, silt and debris were removed and the hay bails were replaced. One hundred percent of the demolition waste and 93% of the construction waste were recycled.

In the structural construction, a 20% fly-ash mix in the concrete was used in the first two floors, and a 17% mix was used in upper floors. The building's structural steel is

80% recycled material, and rebar has 80%–100% recycled content. The pan deck is constructed of 30% recycled material, and fireproofing is 20% recycled material containing gypsum, polystyrene, common cellulose, and recycled newsprint.

Recycled materials are also in carpets, lab casework, rubber flooring, fabrics, wallboard, tiles, ceiling tiles and grids, insulation, and furniture. Wood paneling and cork flooring are from certified sustainable harvests. Bathroom partitions are made of 90% recycled plastics. And restroom countertops contain 80% post-consumer recycled tumbled glass.

Linoleum, a biodegradable product, is one of the main flooring materials used in the hallways. In addition, a room on the third floor that houses lockers, a kitchenette, and vending machines has a 100% recycled rubber floor made of recycled tires. For every 100 square feet of this rubber flooring, as many as 7.5 tires are diverted from landfills. Another room has a cork floor.

Other floor areas are covered with “renewed” carpet—10-year-old carpet tiles that are “super-cleaned” and redyed. This carpet is free of polyvinyl chloride (PVC) and is off-gassed before installation to enhance air quality. In all, 14 tons of used carpeting were recycled rather than placed in landfills.

Outside, grids around the bases of trees are made of 100% recycled metals. The fire road around the structure consists of permeable turf-block with a grass overlay.

The building footprint was carefully designed to preserve the site's landscape and its habitats. Original trees were protected throughout the project, and native trees were added to provide shade at the west façade. Small plants on the old site were ground up and reused as mulch on campus. All native soil from the site was retained and reused.

Natural Ventilation, Daylighting, and Lighting

Because it faces the ocean, the office wing needs no air-conditioning. It relies instead on flow-through ventilation, using operable windows and transoms. Windows in the office wing have a mechanical interlock (a small sensor in the frame); when the windows are opened, hot water convectors (radiators) automatically turn off.

Daylighting is featured in the offices. Photosensor controls detect the amount of natural lighting in a room and dim the artificial lighting accordingly. The offices also have on/off light switches for the electric lighting, which incorporates energy-efficient fixtures and bulbs and motion controls.

Energy Efficiency

Bren Hall surpasses California's Title 24 requirements for energy efficiency by more than the estimated 31%. A computer simulation estimated annual energy use at 144,700 British thermal units (Btu) per square foot per year (144.7 kBtu/ft²/yr). Data based on actual measurements collected in 2003 from the building's energy monitoring system (Table 2) show that the building is using significantly less energy than the estimate—106.7 kBtu/gross ft²/yr for electricity and gas combined.

These are the building's primary energy efficiency and renewable energy features:

- Naturally ventilated offices
- Premium-efficiency motors on all equipment
- Variable-volume pumping systems
- Variable-air-volume laboratory exhaust and supply system
- Daylighting controls
- Maximized chiller and cooling tower efficiencies
- A 47-kilowatt (kW) photovoltaic (solar electric) system

There are 17 VAV fume hoods in the building. Measured data show that the labs use approximately 8 air changes per hour (ACH) when occupied, and about 4 or 5 ACH when unoccupied, such as at night and on weekends. (See page 7 for more details.)

The three exhaust stacks on the roof are each a different size. Each one has a different-sized fan: one for 16,000 cubic feet of air per minute (cfm), one for 23,000 cfm, and another for 30,000 cfm. The system design and controls ensure that only one of these fans or a combination of them is running at any given time, as required to maintain a minimum static pressure in the exhaust control loop. If the static pressure can't be maintained, then the next larger fan or combination of fans turns on as the fan that was previously running turns off. The exhaust fans use variable-frequency drives and a bypass damper to maintain the proper exhaust stack discharge velocity. Bren Hall received a LEED innovation credit for the design of this exhaust system.

The building is connected to a new, multi-building chilled water loop to provide cost-effective cooling for the laboratory wing. This loop connects Bren Hall's chiller to all other chiller plants on campus, so the loop is operated as if it were one large campus chiller plant. Bren Hall's chiller, which has a run time of about 15%, can thus take on a portion of the total campus load as needed. This allows other chillers to be fully loaded (and operating most efficiently) before bringing in the Bren Hall chiller.

Because of UCSB's "virtual central plant" control strategy, the Bren Hall chiller is sized at 300 tons—or about 25% larger than the building requires. The building has its own cooling tower. And to reduce the "heat island" effect, an Energy Star®-rated "white cap" roofing material reflects sunlight and helps to keep the building cool.

Bren Hall's 47-kW photovoltaic system was designed to meet about 7%–10% of the building's total electricity needs. In addition, 31% of Bren Hall's electricity is supplied by another renewable power source—methane landfill gas—through a contract with a "green power" provider that runs through 2004.

Indoor Environmental Quality

Products such as paint and carpeting had to meet stringent criteria for low amounts of volatile organic compounds, or VOCs. There are no asbestos or mineral fibers in the materials, and no hydro-fluorocarbons, hydro-chloro-fluorocarbons, or chloro-fluorocarbons (CFCs) were used. All paints, adhesives, and finishes exceed the new South Coast Air Management Air Quality Standards for 2005.

When the building was completed, all the mechanical systems were run for two weeks at full capacity. Then all the filters were changed before occupancy, which greatly improved indoor air quality. A carbon dioxide monitoring system also ensures fresh air in assembly spaces.

Water Efficiency

Reclaimed water is piped from the local water utility to meet 100% of the site's landscape irrigation needs. The landscaping also features drought-tolerant native plants.



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Figure 4. Both interior and exterior terraces overlook Bren Hall's courtyard.



Toilets on the first floor also use reclaimed water from the local utility. None of the urinals contain water, and each is estimated to save 45,000 gallons of water per year. All toilets have automatic flush valves, and low-flow fixtures are used throughout the building.

Measurement and Evaluation Approach

Bren Hall has a metering system to help operate the building efficiently; the system has an educational function for students and faculty, as well. Additional metering

monitors the actual loads of dry labs, wet labs, and offices. For ease of access, Web interface systems also monitor many of these items. The resulting data are being shared in “Labs 21” benchmarking efforts to assist others in the design of new laboratory buildings. The data will also help the University of California with designs for future sustainable buildings.

Building Metrics

The data in Table 2 compare design estimates to building energy performance estimates calculated from

Table 2. Donald Bren Hall Building Metrics

System	Key Design Parameters	Annual Energy Use (based on design data)	Annual Energy Use (based on measured data)
Ventilation (Sum of wattage of all the supply and exhaust fans)	Supply = 1.08 W/cfm Exhaust = 0.72 W/cfm Average = 0.9 W/cfm (1) (0.5 cfm/gross ft ² ; 1.0 cfm/net ft ² and 2.2 cfm/net ft ² for labs)(2)	7.8 kWh/gross ft ² (15.8 kWh/net ft ²) (3)	2.9 kWh/gross ft ²
Cooling plant	300 tons 0.54 kW/ton	4.1 kWh/gross ft ² (4)	1.1 kWh/gross ft ²
Lighting	1.6 W/gross ft ² in labs; 1.1 W/ft ² everywhere else	5.4 kWh/gross ft ² (5)	8.7 kWh/gross ft ²
Process/Plug	30.1 W/net ft ² of labs; 1.81 W/ft ² everywhere else	33.6 kWh/gross ft ² (6)	4.4 kWh/gross ft ²
Heating Plant	NA	NA	47 kBtu/gross ft ² /yr
Total		50.9 kWh/gross ft ² /yr (estimate based on design data for electricity only) 173.7 kBtu/gross ft ² /yr for electricity only (7) NA NA	17.5 kWh/gross ft ² /yr for electricity only 59.7 kBtu/gross ft ² /yr for electricity only (7) 106.7 kBtu/gross ft ² /yr for electricity and gas \$2.34/gross ft ² /yr estimated annual cost for electricity and gas

Notes:

1. W/cfm for supply air = (82.5 horsepower (hp) x 746 W/hp) / 56,900 cfm = 1.08 W/cfm; for exhaust air (45 hp x 746 W/hp) / 46,000 cfm = 0.72 W/cfm; average = 0.9 W/cfm.
2. 46,000 cfm (total cfm based on exhaust) / 46,304 net ft² = 1.0 cfm/net ft²; 46,000 cfm / 84,672 gross ft² = 0.5 cfm/gross ft²; 46,000 cfm / 21,058 net ft² of labs = 2.2 cfm/net ft² of labs.
3. 0.9 W/cfm x 0.5 cfm/gross ft² x 8760 hours x 2/1000 = 7.8 kWh/gross ft² (15.8 kWh/net ft²).
4. 0.54 kW/ton x 225 tons x 2890 hours / 84,672 gross ft² = 4.1 kWh/gross ft² (assumes cooling runs 33% of the hours in a year. Since the chiller was oversized by 25%, for the purpose of this estimate only 75% of the chiller plant size was assumed).
5. 1.2 W/gross ft² (weighted average) x 4534 hours / 1000 = 5.44 kWh/gross ft² (2.2 W/net ft² x 0.54 = 1.2 W/gross ft²) (assumes lights are on 87.2 hr/week).
6. 8.0 W/gross ft² (weighted average of 30.1 W/net ft² for the lab area of 21,056 ft² and 1.8 W/net ft² for the rest of that area) x 0.80 x 5256 hours / 1000 = 33.6 kWh/gross ft² (assumes that 80% of all equipment is operating 60% of the hours in a year).
7. Estimated data are presented in site Btu (1 kWh = 3412 Btu). To convert to source Btu, multiply site Btu for electricity by 3. *Note:* Santa Barbara has approx. 1458 heating degree-days and 727 cooling degree-days (based on Los Angeles, CA, weather data).

NA = not available.

How Bren Hall's Variable-Air-Volume Controls Work

First, as each fume hood sash is raised or lowered, the sash sensor signal to the fume hood's monitor changes proportionally. This signal prompts the fume hood monitor to generate another signal that controls the hood's exhaust valve, maintaining a constant average face velocity at each hood opening. Each fume hood exhaust valve thus sends a feedback signal (proportional to the cfm flow at the valve) to the make-up air control panel.

The make-up air controller card calculates total fume hood exhaust volume by summing the feedback signals from the hood exhaust valves and generating a total hood exhaust signal. The make-up air controller card maintains a constant, adjustable net negative offset between the control zone's total exhaust and the make-up air volumes. This offset should not vary with changes in the volume of the exhaust.

To maintain a negative room offset, the make-up air controller card resets the total hood exhaust signal by subtracting the quantity of offset desired. The result is a total fume hood make-up air signal; it represents the volume of supply air needed to satisfy fume hood demand with respect to the desired constant offset.

The make-up air controller card maintains a minimum volume of ventilation make-up air to the laboratory, because supply air to the space should not fall below this volume. The make-up air command signal is generated when the system compares the minimum ventilation signal to the total hood make-up air signal and selects the higher of these two signals as the command.

When the minimum volume of ventilation make-up air is being delivered to a room, and the fume hood exhaust valve is exhausting less than this minimum volume, the make-up air controller increases the command signal to the room's general exhaust valve. This valve opens inversely to the fume hood exhaust valve when the hood's sash is lower than it should be for the make-up air valves' minimum volume of ventilation.

When a control zone occupancy sensor indicates that the zone is unoccupied, the energy management control system (EMCS) resets the minimum ventilation air volume to the scheduled value for an unoccupied zone. If the signal is lost, either because the zone becomes occupied or the sensor fails, the control zone minimum ventilation air volume is reset to the scheduled value for an occupied zone.

On a call for cooling, the EMCS sends a signal to the make-up air control panel. This signal resets the minimum ventilation signal from the scheduled supply flow minimum to the scheduled flow maximum.

measured data collected in 2003. Data measurements taken for a shorter period of time were extrapolated for a full year, because the building was just completing its first year of operation.

The table shows that measured energy use for ventilation is lower than estimated. The estimate did not assume that all the exhaust and supply fans would be operating together. As noted earlier, the exhaust fans operate in stages, based on need. The design estimate assumes 2.2 cfm/net ft² for ventilation in the labs. Measured data show only about 1 cfm/net ft². The cause of this discrepancy could be that some planned lab equipment has not yet been installed, as well as that the innovative exhaust control strategy is working as designed. Because this mixed-use building has both classrooms and labs and not many fume hoods, ventilation loads will be lower than those of many other buildings in the Labs 21 benchmarking database.

Table 2 also shows a discrepancy between design estimates and measured data for plug loads. One reason is that Bren Hall plans to purchase and install significantly more new lab equipment. Given the measured data for plug loads, and assuming 1.8 W/ft² of plug loads in all spaces but labs (and other assumptions listed in Table 2, footnote 6) actual plug loads in labs are probably about 2.2 W/ft².

The design estimates in Table 2 indicate that the building would use 197 kBtu/ft²/yr for electricity only. This estimate is high because it doesn't account for usage schedules. The Bren Hall energy simulation predicted energy use in the "as-designed building" at 144 kBtu/ft²/yr for electricity and gas. Based on this simulation, the building was estimated to be 31% more energy efficient than the Title 24 base case at 209 kBtu/ft²/year. The measured performance is almost 50% better than this simulated base case. Measured performance is 107 kBtu/ft²/yr, however, or 25% better than predicted for this building in the simulation.

Summary

Bren Hall at UCSB's Donald Bren School of Environmental Science & Management is one of two LEED-certified Platinum buildings, and the only laboratory building to achieve this recognition. Once the decision was made to make this a high-performing, sustainable lab and classroom building, this goal was embraced by the school's leadership and accomplished. Its design incorporates many energy-efficient and sustainable features, making it a living laboratory for students and faculty. Its Web site carries this a step further by sharing information about greening product suppliers and the cost of





various measures (see www.bren.ucsb.edu/about/greening_information.html).



The building also includes a comprehensive real-time energy-use monitoring system. This system aids in managing the building's energy use and helps to identify more opportunities to save energy at the University of California and elsewhere. Bren Hall thus represents a great resource for teaching the next generation of policy and environmental management professionals and research scientists.



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