

NEW BUILDING ENERGY STANDARDS FOR UCSD:
INSTITUTIONAL BARRIERS, CURRENT IMPACTS AND FUTURE PITFALLS

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ABSTRACT

In response to a large building program commencing in 1984, an energy standard for new buildings was developed by the campus energy committee and approved by all administrators at UCSD. The standard now applies to all new campus buildings regardless of funding source. The standard deals with all aspects of energy consumption in new buildings including building layout, allowable spaces for air conditioning, building equipment efficiency, zone separation and building HVAC control systems. It specifies mandatory consumption metering in all new buildings. It also enhances habitability.

This paper surveys energy standards for other universities. It compares the UCSD energy design situation before and after implementation of the standard (including a detailed description of energy provisions in the standard). The process by which the standard is imbedded in the actual design/construction process is described. The paper discusses the financial and institutional barriers to energy efficient design in university buildings and to implementation of a standard. It discusses the predicted effects of the new standard in Engineering I (the only completed design to date). The other new buildings to which it has already been applied are listed.

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I. HISTORY

After a long hiatus, UCSD began a large building program in early 1984. The campus energy committee determined that new building design and construction was not sensitive to energy considerations.

The University of California at San Diego (UCSD) is a mid sized institution with a very large research program. It occupies 1200 acres near the ocean in San Diego (climate: 800 Heating Degree Days and 1500 Cooling Degree Days; both base 65). In spite of its mild climate, energy consumption per square foot is substantial¹. Energy prices have also increased dramatically².

As a result, UCSD has been pursuing an aggressive energy conservation program since 1973 with outstanding results. Excluding energy increases due to growth in occupied space, this program has reduced campus energy consumption by 46% since 1974. Approximately \$32 million in energy costs have been avoided in the period 1973 through 1985. Savings due to these actions will of course continue to accrue. This is a remarkable achievement. Only UC Santa Cruz has exceeded that record. They have achieved 50% in the same period but their building mix includes fewer laboratories and is therefore much less energy intensive than ours.

These efforts concentrated on relatively low cost, high payback, retrofits like delamping and rebalancing entire buildings including: reduction of building air change rates in labs and offices, and installation of two speed fans to reduce off-hour ventilation rates. However, the exceptional campus conservation success before 1985 had been achieved by eliminating the easy targets.

This is not to denigrate the amount of effort or commitment involved in such a complex and useful endeavor. The fact remains, however, that previous efforts had concentrated on increasing the efficiency of energy delivery systems under severe capital restrictions. In 1984, we found ourselves at a

¹ In fiscal 1972/73, UCSD consumed 9.8 million therms over 2.6 million ft² (377kbtu/ft²). In 1984/85, the consumption was 7.5 million therms over 3.4 million ft² (220k Btu/ft²).

² In 1979/80, electricity at UCSD cost \$0.057/kwh and gas/oil cost \$0.328/therm. Today, the prices are \$0.125 and \$0.36 respectively.

turning point in the process. Further gains in efficiency would require more aggressive attention to new areas.

There is substantial opportunity for improvement. UCSD currently spends about \$11.6 million per year on energy. Between 1982 and 1984, campus utility bills increased from \$9.6 million to about \$11 million. In the period 1979/1980 through 1983/84, total campus energy costs increased 110% while space increased 3%.³ Although energy use per square foot has been dropping, there is great opportunity for increased efficiency to compensate for rising prices. In many ways, the current state energy financing system is rooted in the traditional view of energy as a free good. For example, at UCSD, we don't even measure the space conditioning energy delivered to campus buildings.

New Buildings

Prior to the 1982-83 academic year, UCSD had a very small building program involving only structures funded by non-state money. Consequently there was no formal energy regulation governing design practices beyond the state standard, Title 24. Essentially, each building was designed by an outside executive architect and the energy performance was left to this architect. The emerging design was strongly influenced by a consensus generating process involving a building advisory committee (BAC) composed of students, staff and faculty slated to occupy the new building. The campus architect was also a member of the committee. The executive architect and his staff worked closely with this committee. Except for the campus architect, future occupants were mostly concerned with the functional layout and getting as much useful space as possible within budget constraints. Energy considerations were, for the most part, left to the executive architect and Title 24. This process is heavily dominated by the building's first cost. The state is understandably very careful of first costs. However, the zeal to hold down first costs has resulted in a state policy that, beyond Title 24, investments in energy conserving features of new buildings are funded only if they have a payback of less than two years.

No aggressive consideration was given to the future building's operation and maintenance costs since those costs are borne by other administrative units not significantly represented in the design process. Energy use was particularly under represented because of the state system for funding energy bills. The campus receives state funds for energy in the amount of a budgeted base consumption per square foot of occupied space multiplied by the energy price at the campus. Provided the campus meets this target, there is really no incentive to reduce consumption. Essentially no viable mechanism exists for either investing savings in current conservation retrofits or increasing first cost of a building to pay for conservation equipment in the new building.

³ Two factors are at work here. Energy use per square foot has declined dramatically while energy prices have increased dramatically.

Beginning in 1984, the situation changed dramatically. For the first time since its inception, UCSD was entering an intensive building program of public and privately funded buildings. Although there had been a Chancellor's Energy Committee composed of faculty and staff for a number of years, in 1984 the committee began an aggressive study of the system for designing and constructing new buildings.

II. THE APPROACH FOR EVALUATING THE DESIGN SYSTEM

The committee studied the current system from within by participating in the Building Advisory Committee for the first state funded building, Engineering I (210,000 square feet). Information from outside the campus was also sought via consultants: Hal Levin, Past Chairman of the California Architectural Licensing Board; Barry Wasserman, Former State Architect; and Malcolm Lewis, President of Malcolm Lewis Associates, a mechanical engineering firm in Los Angeles. Each of these men is a recognized innovator in aggressive energy management. Mr Levin is an expert on habitability and air quality considerations in energy efficient buildings. Mr. Wasserman presided over the design of many very efficient state office buildings. Mr. Lewis is well known for his innovative work in energy efficient mechanical design. We also visited the Stanford University Architect's office, the architect at UC Irvine, and GA Technologies in La Jolla. Finally, telephone interviews were done with appropriate people at Berkeley, Princeton and Ohio State.

The New Design Philosophy at UCSD

Our first focus was UCSD's design process; next, specific design measures were considered. Regarding the process, three points were paramount in other successful design programs. First, new university buildings would be with us for a long time and, within reason, we should strive for designs which make economic sense over the long haul. Second, although energy conservation and habitability are both extremely important design considerations; there is ample evidence that these are not conflicting goals. Third, decisions made by architects and engineers early in the design of a new building have great impact on the habitability and total cost of operating and maintaining the building over its life. The message from our contacts outside UCSD was clear. Habitability and energy consumption in a building, especially in relation to the operating habits of its eventual occupants, are strongly affected by five factors: 1)the layout of the building, 2)office access to natural lighting and ventilation, 3)whether the building's mechanical equipment permits good zone control of lighting and space conditioning, and 5)whether the building can efficiently handle changes in occupancy over time.

Work on the building advisory committee convinced us that the principal impediment to advancing the campus energy efforts in the area of new buildings was a virtual total lack of mandatory consideration for energy implications beyond Title 24. Building committees are understandably consumed with programmatic issues. Both the campus architect and an outside contract architect play key roles in the process. The contract architects were striving to satisfy programmatic needs on a stringent capital budget. There was no explicit motivation (financial or otherwise) for them to go beyond Title 24.

There seems to be incredible pressure not to exceed the budgeted first cost. This pressure seemed to be mostly founded on a visceral fear of delaying and risking cancellation of the building.

From the outset, the Chancellor's Energy Committee was sensitive to the financial realities in new buildings. Our approach was based on the view that conservation and habitability are most cost effectively achieved if the building's basic concept is sound. In fact, the new standard explained below has not substantially increased the first cost of any new building. It is not our intent to build energy efficient buildings at any cost. We are ultimately interested in buildings whose life cycle cost is low. We are interested in buildings whose ambience permits occupants to be more productive, and this implies buildings whose occupants have a healthful working environment.

Although energy is now a substantial cost item, state procedures for dealing with it have not deviated much from the old, "free good" mode. We believe that, sooner rather than later, the legislature will revise energy funding procedures to reflect the new reality. Some sort of pay-your-own-bill scheme is likely to emerge. The new buildings we build today will be around at that time. We feel that it is in our own best interests to recognize the new reality in our current building specifications. One final point needs to be mentioned. The purpose of UCSD is to educate. The committee strongly feels that UCSD doesn't simply educate our enrolled students. We also educate ourselves (faculty and staff) and the community at large through experiencing the physical reality of the campus. We strongly believe that we have an opportunity, indeed an obligation, to educate ourselves and others in the promise for increased humanity and productivity in buildings which conserve resources. Our new buildings will make a statement in this regard. The committee strongly urges that the statement be optimistic, even exciting.

III. A Description of the Resulting Standard

It was decided that the Stanford model of a tight, cost effective energy standard for new buildings would be of great help. It would eliminate the need to fight design battles in each and every building advisory committee. It would also transmit to bidders on future buildings our firm commitment to energy conservation and habitability in new buildings. The UCSD standard is much tighter than Title 24. The latter, for example, does not require metering of energy consumption in buildings. It also says nothing about the types of spaces which can be air conditioned. The UCSD standard is philosophically very close to the Stanford standard but regional differences exist. Our standard is also considerably shorter. The UCSD standard does essentially four things. First, it enforces an overall design philosophy in all new buildings. Second, it requires certain energy conservation measures in all new buildings. Third, it specifies certain energy related submittals at critical stages in the design process. Finally, it discusses post construction verification of system performance. In this section, we briefly discuss each of these areas.

Fundamental Design Features

The following apply to all new buildings (quotes are from the standard).

1) Life cycle cost analyses must be provided at appropriate stages of the building design process (details below).

2) "Mechanical cooling shall only be provided to the following spaces requiring controlled temperatures and relative humidity: Major computer facilities, Libraries, Patient Care Facilities, certain types of Laboratories, Animal Handling and certain other facilities where such need is clearly demonstrated."

3) "Non air conditioned spaces shall be designed to provide maximum comfort using operable windows, appropriate shading and thermal flywheel effects, and where required, mechanical ventilation."

4) "Buildings shall be designed to separate areas requiring conditioned air from those requiring only ventilation, and mechanical systems shall be separated accordingly".

5) Each floor will be served by at least one separate air handling system in order to provide efficient control and the ability to follow use patterns on weekends and after hours.

6) The building's zoning and energy control system will be designed to easily provide off hour support (lights, heating, cooling and ventilation) at minimum levels consistent with energy conservation and safety. The desire is to avoid turning on large parts of the building to accommodate a single use area.

7) "Metering:

a) All energy consumption (electricity, natural gas, chilled water and high temperature water) will be measured at the building level. Meters capable of being monitored by computer are required.

b) Electricity consumption will be metered by load type (lighting, building systems, and plug-in outlets), with meters capable of being read by computer. This requires that both building wire layout and meters will be provided to accommodate this requirement."

Specific Measures

The following energy conservation measures shall be used on all new buildings unless specifically exempted in writing by the Office of Design and Construction:

1. Natural ventilation of offices.
2. Variable Air Volume Systems
3. Economizers
4. Energy Efficient Motors
5. Direct Digital Control of environmental equipment and lighting systems tied to Central Control.

6. Lighting systems must incorporate day lighting, task lighting energy efficient lamps and ballasts, local temporary override, stumble lighting and multiple circuiting.

Submittals

Energy impact must be evaluated in each part of the project development process as follows.

1)Project Planning Guide: Preliminary analysis of project siting and orientation will include maximization of passive solar heating, cooling and ventilation effects as well as natural lighting. Furthermore, statements will be made regarding particular zoning or air conditioning requirements for the project.

2)Detailed Project Program: More complete analysis of the project siting and a preliminary zoning analysis of occupant HVAC and lighting needs.

3)Architect Selection : Consideration of architect and consultants with energy conservation design experience.

4)Schematic Design

50% Schematic Submittals:

"a)Preliminary selection of candidate concepts for environmental control in non air conditioned spaces. These concepts include glazing area, orientation, shading, daylighting, natural ventilation processes etc.

b)Preliminary evaluation of various strategies for HVAC and lighting to take full advantage of architectural decisions and building use considerations.

c)Building Envelope: Preliminary analysis including evaluation of type of materials necessary to take full advantage of the results of 1) above (e.g. wall and roof insulation, type of windows).

d)Life Cycle Cost Analysis: Life Cycle Cost (LCC) Analysis shall be the basis for evaluating the financial viability of alternative energy conservation measures. In all cases, consultants shall use current standard UCSD parameters and calculation procedures in accordance with Appendix B of the standard." There is a list of required comparisons and the campus architect can require more.

100% Schematic Design Submittals

"a) Preliminary HVAC system selection. Submittal shall include criteria and calculations for selection of HVAC system type, estimated energy demand (including lighting) in Btu/hr/sq. ft. and watts/sq. ft. broken down into heating, cooling (including percentage of load resulting from solar gain through fenestration), ventilation, installed user equipment and lighting.

b) Provide estimated operating costs, and life cycle cost analysis leading to above systems selection.

c) Preliminary analysis of performance of non-air-conditioned spaces. Quantitative results on interior air temperatures and mean radiant temperatures are required.

d) Preliminary initial cost estimates of the building in terms of unit cost (dollars per square foot of gross building floor space, dollars per system or component or similar).

e) Location of mechanical equipment rooms and major equipment.

f) Major zoning and airflow schematics."

5) Design Development

100% Design Development Submittals:

"a) Location of all HVAC Equipment

b) Single line layout of all major air distribution and hydronic systems.

c) Major air and hydronic flow diagrams.

d) Sequence of operations for controls.

e) Design calculations including

(i) Revised system energy use broken down into: heating, cooling (including percentage of load resulting from solar gain through fenestration), ventilation, lighting, and

(ii) Revised LCC analysis for final mechanical and electrical systems.

f) Written evaluation of the lighting design approach. The evaluation should include an economic analysis considering installed costs, energy use, energy costs, lighting efficiency, maintenance cost, lamp life, footcandle levels, watts per square foot connected load, and the effect on the HVAC system. Typical manufacturers' literature and photometric data for each fixture shall also be provided.

g) Written evaluation of the lighting system controls and wiring designs. Typical manufacturers' literature and specifications for digital controls shall be provided. An economic and energy analysis of the control alternatives shall be provided along with specific details of the system.

h) Final quantitative habitability analysis including interior air and mean radiant temperatures of non air conditioned spaces as well as natural ventilation patterns.

j) Preliminary system cost estimate.

k) Life Cycle Cost analysis on optional systems as directed by the UCSD project engineer."

6) Construction Documents Submittals:

50% Construction Documents submittals:

"a) Final selection of equipment and systems options considered under design development.

b) Design Calculations.

c) Revised system cost estimates based on 50% construction documents.

d) Revised description of systems and equipment.

100% Construction Documents submittals:

a) Final Contract Drawings and specifications.

b) Final Description of systems and equipment.

c) Final cost estimate.

d) 100% design calculations."

Installation and Balancing

All systems must be completed and tested early enough to enable completion of balancing prior to occupancy. Performance and capacity testing is required on all pumps, air handling equipment, coils and VAV fans. Control set points for fans must be verified. Data indicating how the above readings compare with manufacturers published ratings shall be provided and the equipment performance shall be made to meet the manufacturer's specification without cost to UCSD. The above readings shall be taken by the balancing contractor who will submit a certification of performance to UCSD.

IV. RESULTS TO DATE

The first building (Engineering I) governed by these standards is scheduled to start construction in June 1986. It meets the standard but does not provide a complete test of the standard's independent influence on design since energy committee members were watching the process closely. Engineering I is estimated to require 7820 Btu/conditioned square foot per year as compared with 78344 for Title 24 design. These figures include only building systems without lights and user equipment. The buildings in Table I were designed with the standard in effect, and without energy committee participation.

Furthermore, two buildings nearing completion at the promulgation of the standard (Center for Magnetic Recording Research and the Molecular Biology building; each 43,000 ft²) were substantially impacted by changing their HVAC systems from pneumatic to Direct Digital Control. The supercomputer building also provided an interesting test of the administrative will to enforce the fledgling standard. This is a high visibility building funded by NSF and operated by GA Technologies on UCSD property. There was intense pressure to

Table I: Buildings designed with the standard in effect

Building	Gross square footage
University Center (Student Center)	175,000
Supercomputer Building	58,000
Instruction and Research Building	130,000
Howard Hughes Medical Institute	70,000
Total	<u>433,000</u>

air condition offices in the building (which violates the standard). The decision to enforce the standard was made personally by the chancellor. Therefore, the supercomputer building will have offices separate from the conditioned zone to permit use of natural ventilation.

Financially, the standard appears to decrease the first cost over conventional UCSD designs as well as dramatically decrease the utility bills and life cycle cost of the buildings. In Engineering I, for example, the standard decreases the first cost by about \$328,000 over conventional UCSD designs and reduces first year utility costs from about \$367k to about \$43.6k, resulting in a life cycle cost savings of about \$9 million (present value). This amounts to a present value savings of \$42/square foot and an annual savings of about 13 billion Btu. See Table II for a comparison. These calculations were provided by the building architect using economic parameters provided by the UCSD Campus Architect pursuant to the standard. The life cycle cost was computed over a 30 year time horizon.

IV. FUTURE NEEDS

Two major areas of work remain. First is the issue of sufficient staff to ensure the standard is being adhered to. The submittals required by the standard force the contract architects and engineers to consider energy early in the project. We feel that great benefit will be derived by convincing the contract architects of our interest in the energy and habitability aspects of the building. Further, mandating energy submittals early in the process is expected to permit competent architects and engineers the opportunity and backing to do a good job in these areas. However, some degree of in-house oversight must be provided. Staff has been increased to handle the increased building activity. Thankfully, the new staff has been uniformly excellent. They have already done a very aggressive job in the area. Time will tell if

the internal staff is adequate. The energy committee has agreed to a couple of reviews of the first new buildings coming off the process to gauge how well the standard has been working.

Table II: Summary of life cycle costs for Engineering I. Alternative 1 denotes air conditioning the entire building with a constant volume system (most common campus system). Alternative 2 denotes air conditioning the entire building with a variable air volume system. Alternative 3 denotes a design with office pods having heating and operable windows with a variable volume system for the laboratory part of the building (that required by the standard).

Summary of Economic data: (\$k)	alternative		
	1 (most common existing system)	2	3 (New Standard)
Installed cost	2910	3407	2583
Utility cost (first year)	367	56	44
Utility cost (final year)	4485	679	532
Maintenance cost (first year)	63	59	57
Life cycle cost	15810	8305	6451

Comparison of economic data:

alternatives	First cost Difference (\$k)	Payback Period (yr)	Net Present Value (\$k)
1 vs 3	327	0	-9359
2 vs 3	824	0	-1854
2 vs 1	496	2	7506

Second, one needs a quantitative way to determine how well the completed buildings are performing. This would involve a quantitative comparison of the building's actual consumption with both theoretical analyses and existing buildings. The comparison would necessarily deal with variations in weather, type and density of occupancy etc. The authors believe that there exists a technically sound way to attack this problem and initial work is under way.

V CONCLUSIONS

1) A building energy design standard is a very effective way to communicate detailed requirements on energy efficiency and habitability. It has been of enormous help to the campus design and construction group.

- 2) The fact that the UCSD energy committee is a chancellor's committee made an enormous difference in the committee's ability to develop these standards in a timely manner.
- 3) We went into the process believing that life cycle cost analysis would be needed to justify increases in first cost for increased energy efficiency and habitability. It turned out that the building as designed actually cost less than a building with a standard design would have.
- 4) Life cycle cost analysis plays a very important role in achieving energy conservation, not because everyone can agree on its accuracy, but because it forces participants in the design to think quantitatively about the problem of increasing energy efficiency.
- 5) Enormous energy savings can be achieved with reasonably careful design in new buildings.
- 6) Although UCSD is in a very favorable climate, commercial buildings containing extensive laboratory facilities consume enormous amounts of energy. Before the standard, buildings were perceived as homogeneous entities in which offices and laboratories shared the same ventilation rates. In other words, operable windows were excluded from both laboratories and offices alike. The standard provides enormous savings in both first cost and operating expenses by excluding air conditioning from offices. The initial push for operable windows came from occupants of the current engineering building which is mechanically ventilated and provides very poor occupant comfort.
- 7) Over 500,000 square feet of new building space is being designed under the new standard.

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REFERENCES

- [1]University Of California, San Diego Facility Design Standard, Energy Section, 1985.
- [2]Stanford University Facility Design Standards, 1984