University of California, Irvine

Life-Cycle and Sustainability Design Standards and Costs

The University of California, Irvine pursues performance goals in new construction and applies quality standards that affect the costs of capital projects. Construction costs are not "high" or "low" in the *abstract*, but rather in relation to specific quality standards and the design solutions, means, and methods used to attain these standards. Thus, evaluating whether construction costs are appropriate involves determining whether:

- quality standards are excessive, insufficient, or appropriate;
- resultant project costs are reasonable compared with projects that employ essentially the same quality parameters.

"Quality" encompasses the durability of building systems and finishes; the robustness and life-cycle performance of building systems; the aesthetics of materials, their composition, and their detailing; and the resource sustainability and efficiency of the building as an overall system.

Overall Goals and Life-Cycle Performance Sustainability Standards

UCI, in order to support distinguished research and academic programs, builds facilities of high quality. As such, UCI facilities are designed to convey the "look and feel," as well as embody the inherent construction quality, of the best facilities of other UC campuses, leading public universities, and other research institutions with whom we compete for faculty, students, sponsored research, and general reputation.

Since 1992, new UCI buildings have been designed to achieve five broad goals:

1. New buildings must "create a place," rather than constitute stand-alone objects – forming social, aesthetic, contextually sensitive relationships with neighboring buildings and the larger campus.
2. New buildings reinforce a consistent design framework of classical contextual architecture, applied in ways that convey a feeling of permanence and quality, and interpreted in ways that meet the contemporary and changing needs of a modern research university.
3. New buildings employ materials, systems, and design features that will forestall the expense of major maintenance (defined as >1 percent of value) for at least 20 years. Accordingly, many of the quality standards that follow derive from an exhaustive analysis of premature major maintenance that was actually incurred for UCI buildings constructed 1976-1991.
4. New buildings attain exemplary sustainability performance – LEED Gold (2005) or Platinum since 2009 and outperforming California's Title 24 energy efficiency standards by as much as 50 percent.
5. Capital construction projects are designed and delivered within the approved project budget, scope, and schedule.

UCI capital construction budgets are not augmented to accommodate the additional costs for exemplary sustainability performance or enhanced life-cycle performance. The reason this document interweaves cost management strategies with sustainability and life-cycle standards is that these latter goals would not be attainable without considerable savings from the cost management strategies that will be discussed in detail.

UCI's goals for sustainable materials and energy performance were adopted partly for environmental reasons and partly to reverse substantial operating budget deficits. The latter problems include a multimillion-dollar utilities deficit that was growing rapidly in the early '90s, and tens of millions of dollars in unfunded major maintenance that was emerging prematurely in buildings only 10-20 years old. Without the quality and performance standards adopted in 1992, utilities deficits and premature, unfunded major maintenance costs would have exceeded $150 million during the past three decades, and these costs would still be rising out of control.

The campus' materials standards, building systems standards, sustainability and energy-efficiency criteria, and site improvements all add cost increments that can only be afforded through aggressive cost management. Institutions that cannot manage capital costs tend to build projects that consume excessive energy, cost a lot to maintain, suffer premature major maintenance costs, and require high costs to modify. Such problems tend to compound and spiral in a pattern of *increasingly costly* consequences. Every administrator with facilities experience understands this dynamic. Without effective construction cost management, quality would suffer and UCI would experience all of these problems.

The balance of this document expresses the building performance criteria and life-cycle performance standards generally outlined above, organized according to building systems classes. Each section discusses key cost-drivers, cost-control strategies, and important cost trade-offs. The implicit underlying premise is that life-cycle performance is attained through consistent application of building system quality standards rather than a project-by-project exercise. The focus which follows centers on laboratory buildings because of their complexity and cost, although many standards that follow apply equally to non-laboratory projects.

Building Organization and Massing

Construction cost management starts with the fundamentals of building organization and massing. UCI's new structures' floorplates have length-to-width ratios <1.5 to avoid triggering disproportionate costs of external cladding, circulation, and horizontal mechanical distribution. Our new buildings tend to be at least five floors high; other key design ratios are observed, such as exterior cladding area/floor area <0.5 and roof + foundation area/floor area <0.4.

Architectural articulation is preferably achieved through textured or enriched materials, integral material detailing (such as concrete reveal patterning), and applied detailing (e.g., window frames and sills). Large-scale articulation is concentrated at the roofline (e.g., shaped roof forms) and at the pedestrian level (e.g., arcades), where it will create the "biggest bang for the buck," rather than through modulating the larger building form itself. This is more than a subtle design philosophy, as the cost impact is substantial.

Lab buildings completed in the past several decades separate laboratory and non-laboratory functions into distinct, adjoined structures (although such a building may *look* like one structure). Consolidated non-laboratory functions include faculty, staff, operational support, and departmental offices; restrooms; circulation (elevators, lobbies, primary stairways); classrooms, seminar rooms, conference rooms, and social areas designed to foster interaction and to provide safe areas for eating and drinking; dry labs and dry lab-support functions; and general administrative support. Consolidating these functions into a separate structure yields considerable cost savings. The non-laboratory structure has a lower-cost HVAC (heating/ventilation/air-conditioning) system, wider column-spacing, reduced floor stiffness, lower floor-loading, fewer fire-control features and related code requirements, possibly steel-framed or steel/concrete hybrid structural system with concrete flat-slab flooring system, smaller footings, and possibly curtain-wall fenestration.

This two-structure approach can be seen clearly at the Gillespie Neuroscience Research Facility, Sprague Hall, Hewitt Research Hall, Sue & Bill Gross Hall, Natural Sciences I and II, Biological Sciences III, Engineering Hall, Interdisciplinary Science & Engineering, and UCI Medical Center's Shanbrom Hall. Consolidating and separating non-laboratory functions saves 8-10 percent in overall construction costs and 15 percent/year in energy expense and greenhouse gas emissions.

Life-Cycle Design Concepts that Work Synergistically for Laboratory Buildings

These design strategies, applied in combination, have proven effective in controlling the cost of laboratories:

- Utilizing a consistent lab module
- Using 22 ft. x 22 ft. column spacing in the laboratory structure
- Utilizing a reasonable vibration criterion and locating ultra-sensitive conditions at-grade or employing benchtop vibration isolation
- Concentrating fume hoods and utility risers into a central "wet zone," thus limiting horizontal mechanical distribution
- Concentrating laboratory support areas into the central core of a laboratory structure, where utilities are available but daylight is not needed, thus enabling lab structures to be 110-154 feet wide
- Utilizing dual-usage circulation/equipment cross-corridors through this central lab support zone, with sufficient width (11.5-12 feet) to load both sides of the corridors with shared equipment while providing cross-circulation through lab support zones
- Utilizing open laboratory layout with one or more "ghost" corridors for intra-lab circulation
- Polished, sealed concrete floors in lab areas
- And, most importantly, concentrating non-laboratory functions into an adjoining, lower-cost structure (as discussed above).

In addition, UCI requires the use of the BIM (Building Information Modeling) system at both the schematic design stage and construction document stage for all new construction, however the resultant cost and sustainability benefits are especially significant for science buildings. This 3-D design-assistance system models the precise coordination, sizing, routing, and density of above-ceiling mechanical components. This has yielded cost reductions in the vertical structural system (~15% reduction in floor-to-floor height); in HVAC materials and fabrication costs; and in field installation of all above-ceiling trades. Moreover, these reduced materials costs also represent a significant reduction in embedded carbon.

To further control laboratory construction costs, non-standard fume hood sizes are minimized, “generic” lab casework is specified, laboratory-grade movable tables typically alternate with full casework in every other lab bay, building DI systems provide intermediate quality water (with localized water purity polishing in the lab rather than building-wide), facility-wide piped services do not include gases that can be cost-effectively provided locally via canisters, natural gas is not piped throughout, and glass-wash facilities are consolidated – typically, one glass-wash facility for an entire laboratory building.

Finally, our design philosophy favors generic, modular laboratories with movable casework and overhead flex-connections for benchtop services, supported by a robust building infrastructure, rather than highly customized spaces with limited capacity to make later changes. This is an important tradeoff. Although some post-occupancy expenses may be necessary to “fine-tune” a laboratory to a principal investigator’s requirements, building infrastructure elements – intentionally oversized 20 percent, including HVAC supply ducts, exhaust system capacity, and electric risers and service capacity – seldom limit the ability to modify labs to meet future researcher needs. And the cost premium for a modular/movable casework system is recovered many-fold over the life-cycle of a building.

Structural and Foundation Systems

For both cost-benefit reasons and past seismic performance (in California’s most damaging earthquakes over the past century), UCI requires concrete shear wall or steel braced-frame structural systems. The correlating foundation systems depend on site-specific soil conditions. Past problems with undiscovered substrates and uncharacterized soil conditions are minimized through extensive, pre-design soil testing (drilling test holes on a 20x20 ft. grid). This minimizes risk for both the University and the design/build contractor.

External concrete shear-walls provide savings *and* energy benefits. This stems from an LBNL study in ~1994 (supported by Southern California Electric) which demonstrated that exterior wall insulation is not needed in the UCI climate zone provided that exterior concrete or masonry thickness is 12 inches or greater and exposed to perimeter interior spaces. Buildings that employed this exposed thermal mass design proved 8 percent more efficient than conventional insulated exterior wall construction.

When feasible, design/build contractors are allowed flexibility to propose either concrete or steel structural or seismic-force systems. All structural system designs must pass an independent peer review, in accordance with UC's Seismic Safety Policy. The seismic performance of University of California buildings constructed since this policy went into effect in 1975 appears to substantiate the policy's value.

Structural vibration is carefully specified in research buildings where vibration-sensitive protocols and conditions must be maintained on above-grade floors. The most cost-effective tools to control vibration are generally employed: first, to program vibration-sensitive procedures at on-grade locations or to isolate them at the bench; second, to space columns at a distance that does not entail excessive structural costs. In laboratory buildings, we normally require 22 ft. x 22 ft. column spacing. Conversely, where vibration is not problematic, a beam/column system can be cost-optimized and lighter floor loading tolerated. Design/build contractors are, accordingly, allowed more flexibility under such conditions.

To control structural costs, UCI avoids use of moment-resisting structures; unconventional seismic systems; non- standard structural dimensions; inconsistent, unconventional, or non-stacking structural modules; non-standards means and methods; and requires BIM to reduce structural (and mechanical system) costs.

Building Mechanical Systems

For three decades, UCI's new buildings have been designed to outperform California's Title 24 energy efficiency standards by 20-50 percent (~50 percent for all new construction since 2008). UC Irvine's "smart" laboratory buildings lead the nation in terms of energy efficiency. This comprehensive approach to laboratory energy efficiency is summarized in a paper describing UC Irvine's Smart Labs Initiative:
www.ehs.uci.edu/programs/energy/UCISmartLabsInitiative_Feb222016.pdf.

Energy-efficient mechanical systems do entail a significant cost premium financed by savings realized *elsewhere* throughout the project. These intentional costs include premium-efficiency materials and components; increased duct, plenum, fan housing, and filter sizes to slow HVAC airspeeds (a primary factor in reducing HVAC energy consumption and operating costs); increased building volumes in terms of riser sizes, mechanical room sizes, and above-ceiling volume as needed for oversize HVAC distribution components; digital controls and sensors; and multiple, smaller, demand-controlled HVAC zones for precision control, efficiency, and comfort.

Precision energy design objectives apply to laboratory mechanical systems, in particular. Safety is of paramount concern, and reliability and robustness are important to a first-rate research infrastructure. Avoidance of major maintenance for at least 20 years is necessary given the University's backlog of deferred maintenance and its limited funding for major and deferred maintenance. In addition to specifying premium-quality mechanical equipment, we desire a weather-protection canopy (which can constitute a solar photovoltaic canopy) over roof-mounted equipment, which adds years to the useful life of such equipment (even if equipment is rated for outdoor use).

MECHANICAL SYSTEM ENERGY PERFORMANCE REQUIREMENTS	
Overall building energy performance	U.S. Green Building Council LEED Platinum
Air-handler face velocity / air-speed through filtration	300 ft. (91.4 m.)/minute maximum
Total HVAC pressure drop (supply+filtration+distribution +exhaust)	Labs: < 5 in. W.G. (1,250 pascals) Non-lab spaces: < 3.5 in. W.G. (875 pascals)
Static pressure setpoint reset (supply and exhaust)	Reduce static setpoints based on zone voting
Supply temperature setpoint reset	Raise supply setpoint based on zone voting
Air-handler and duct sound-attenuators	None
Minimum occupied lab air-changes per hour	4 air-changes/hour with contaminant sensing (Aircuity backed up by Smart Labs risk-banding)
Minimum unoccupied lab air-changes per hour)	2 air-changes/hour with contaminant sensing and reduced thermal conditioning during setback
“Purge” laboratory air changes per hour	10-12 air-changes/hour when contaminants sensed
Laboratory exhaust stack discharge velocity	Requires wind study; design goal ~1,500 FPM; > 1,500 FPM when necessary during re-entrainment conditions
Exhaust stack height (labs)	As determined by wind study, minimum 10 ft.
Exhaust bypass damper (outside air into exhaust header)	Only activated by adverse wind conditions
Laboratory illumination power density	< 0.5 watt / sq. ft. including bench task lighting
Fume hoods	Occupancy controlled, low-flow/high performance
Heat-generating equipment exhaust	Exhaust grilles directly over equipment such as freezers, etc.
Non-laboratory (recirculating) HVAC delivery and outside air	HVAC delivery occupancy-based w/relief air CO_2-controlled

Another important dimension of mechanical system robustness is the extra 20 percent capacity that is typically designed into primary, core HVAC distribution systems and risers, fans, conduits, and mechanical rooms. That is, the elements that are practically impossible to expand later are intentionally oversized.

Lighting Design Standards

Illumination 100% LED; 2,700-3,000 degrees Kelvin for exterior lighting; 3,500-4,000 degrees Kelvin for interior lighting; and CRI > 90 (including task lighting and specialized fixtures). Lighting design should employ an integrated set of solutions to minimize overall lighting direct load, indirect load, and overall building energy consumption. Lighting design solutions may employ track lighting in combination with low overhead illuminance, wall-washing in combination with low overhead illuminance, bi-level stair and corridor lighting, and whole-building lighting control technologies.

Management of Solar Heat Gain

Highly effective design solutions are needed to manage sunlight – both in terms of harvesting its positive benefits, and in minimizing heat gain that penetrates the building envelope and then requires mechanical removal. This is considered a key, high priority factor toward attainment of exemplary, energy performance.

Performance expectations:

- For glass that does not receive intense, direct sun, clear glass (double-pane) with high visible light transmittance is desired, to maximize daylighting. This includes glass facing north, northeast, and northwest; glass that is nearly fully shaded by mature landscaping or neighboring structures; and glass that is shaded by deep overhangs or recesses that effectively prevent 85 percent of the 365-day cycle of direct sun from reaching the building interior.
- For sun-exposed glass that does not meet the general conditions stated above, three general design approaches are acceptable:
    - Exterior sun-shading devices that prevent 85% of the full-year's direct sun from reaching the interior, in combination with interior window coverings for sun and glare control of the 15% of seasonal sunlight that does enter. (Note that this option allows clear glass.)
    - Exterior sun-shading devices in combination with high-performance glass that, in combination, prevent 85% of annual insolation from reaching the building interior. For example, a shading system that is 40% seasonally effective in combination with a glass product with a shading coefficient of 0.25 would yield an overall 85% year-round reduction in direct sun reaching the interior.
    - For glass that will be 85% shaded by existing or project-based tree canopies within ten years, any combination of physical solutions that attains 70% reduction in solar impact in years 1-10 will be considered acceptable. This constitutes an intentional preference for tree shading over physical solutions due to the multiple sustainability benefits of urban forestation, consistent with UC Irvine's "Green and Gold Plan."

  Because some sun-shading computer models are not reliably accurate, S/E/W mock-ups are required for performance validation prior to complete system installation.
- Interior window coverings, where required, need to be perforated to provide daylighting with glare control benefits when the coverings are *closed*, including at times when users forget to open their shades after the direct sun is no longer problematic. A thermally-reflective coating (e.g., foil-faced) is required on the outward-facing surface of window coverings.
- To clarify, it is understood that preventing 85% of seasonal direct sun from entering the building interior will achieve >85% reduction in seasonal solar *energy*, since sun-shading devices' reduced effectiveness occurs during seasonal conditions with lower sun intensity. Thus, the three design options outlined above are considered equivalent in performance value to the University.
- Finally, any other design solution (such as a dynamic electrochromic system for sun-exposed glass) that attains the same overall seasonal solar energy performance as the three concepts outlined above will be considered, and likely judged acceptable.

UCI SUNLIGHT MANAGEMENT PERFORMANCE REQUIREMENTS

Condition	Shading Requirement	Glazing Type	Interior Window Covering / Glare Control	Comments
North, northeast, and northwest exposures	No exterior or glass shading required for facades > 30° N of E or W	Clear insulated glass	Perforated blinds or shades for glare and sun-control (except lobbies, stairwells, other public spaces)	Not tinted
N / E / W exterior sun-shading devices	Reduce 85% of annual direct sun impact	Clear insulated glass		Include shade from adjacent buildings, mature trees, building overhangs, recesses, and fins
N / E / W exterior sun-shading + high performance glass	Reduce 85% of annual direct sun impact	High performance glass		Example: 40% effective seasonal shading system with 0.25 shading coefficient would attain 85% annual performance requirement
S/E/W glass with tree-shading	Reduce 85% of direct sun impact by year 11; reduce 70% of direct sun impact years 1-10 using any method or means discussed above.			

Roofing and Flashings

UC Irvine specifies 20-year roofing systems and stainless steel flashings. Occasionally, we allow hot-dip galvanized flashings (no electro-galvanized flashings). Why this emphasis on flashings? Our roof replacement projects typically double in cost when the old roofing is torn off only to reveal that the flashings have deteriorated. Many roof leaks of recent years have been due to faulty flashings rather than roofing membranes or coatings, per se.

A desirable alternative to a high-albedo roof surface is a solar canopy that shades the entire roof, with cutouts for ventilation stacks and other mechanical considerations. Since the roof is fully shaded, it can be of any conventional roofing type so long as it meets our warranty requirement.

Site Development

In accord with the design goal of “creating a place,” most UCI projects include exterior landscape and hardscape elements such as plazas, walkways, seat walls, site lighting, and landscape materials that may extend to neighboring buildings. Since there is no capital budget for site development, per se, a new building project provides the “now or never” opportunity to fund site improvements.

We require interlocking, glazed (*not* porous), heavy-duty concrete or clay pavers rather than a poured monolithic material for plazas, for two reasons: aesthetics and cost. The latter reason centers around long-term costs, as pavers initially cost more than asphalt or concrete. However, pavers cost less on a life-cycle basis, because in a growing research campus practically every walking surface will need to be excavated sooner or later in order to install new utilities or to fix underground utilities problems.

The campus uses reclaimed water for landscape irrigation, and landscape materials are specified in UCI's "Green and Gold Plan" (*www.ceplanning.uci.edu/PhysicalPlanning/Greengold.html*). These practices have been in effect for 27 years and are consistent with the University of California's Policy on Sustainable Practices. Site lighting is provided by concealed-source fixtures, consistent with green building standards. Projects' site development costs include extension of utilities to the project as well as infrastructure capacity upgrades necessary to support a new building.

Exterior Cladding and Interior Finishes

Exterior materials and their application in recent buildings are consistent with a campus design philosophy that has been affirmed by the Regents, UC and campus leaders, and by many members of the UCI campus community. "Classical contextual architecture" derives partly from building forms and detailing, and partly from the consistent use of materials that reinforce a feeling of permanence and quality – architecture that is "institutional" in the best sense of that term.

Buildings completed since 1992 use notably different exterior materials than those completed during the 1980s. Due to stringent capital budgets, many of the 1980s projects used exterior stucco cladding (including Social Ecology, the Paul Merage Graduate School of Management, the Science Library, and the Physical Sciences Annex). Buildings completed since 1992 are clad with masonry, poured-in-place concrete, and other permanent materials that do not require initial and periodic painting or patching. Exterior plaster (stucco) is used only as a surface coating over a masonry substrate (as distinct from a lightweight stucco system) or in weather-sheltered areas, such as areas recessed under an overhang and behind an arcade. We do use stucco exteriors in student housing in combination with generous eave overhangs and ample expansion joints.

Interior finishes are typically conventional and employ standard materials, detailing, and means and methods of construction in order to control building costs. Durability is an important goal that leads to such features as quality hardware (e.g., locksets); corner-guards, plasticized coatings, chair-rails, and wall coverings in heavily trafficked corridors; full-height ceramic tile in restrooms; welded door jambs; and institutional quality doors and hinges. We require more acoustical isolation between adjacent offices than is conventional (but do not waste money on acoustical isolation in partial-height partitions or partitions containing a door or window), and more bedroom and bath sound isolation in residential facilities (although we specify generic acoustical finishes and materials rather than specialized products). New classroom designs apply an extensive set of design standards and criteria in order to attain excellent seeing and hearing conditions as well as modern instructional resources. See "Design Criteria for Effective Classrooms" in the Society for College and University Planning publication, *Special Planning for Special Places*.

Priorities and Trade-Offs

UCI's building designs intentionally trade-off particular design choices and the associated costs in order to achieve priority performance goals and life-cycle quality standards. These goals and standards would not be attainable within established capital budgets without rigorous cost-control in the areas targeted for intentional trade-offs.

This entire decision-making system and its precepts warrant review, fine-tuning, and affirmation to ensure that capital investment decisions are cost-effective, both initially and on a life-cycle basis. This is not only sound campus policy, but also an inherent part of the UC Policy on Sustainable Practices.

Benefits and Cost-Control Strategies

Quality practices and sustainability standards applied to new buildings' designs at UC Irvine are enabled (funded) by cost-control savings summarized in the following table. There is no way to realize the benefits in the right-hand column without the cost-control summarized in the left-hand column.

Cost-Control & Savings Opportunities	**Areas Into Which Savings are Redirected**
Sensible ratios for floorplates & exterior skin Cost-effective architectural detailing and articulation strategies Consolidate non-laboratory functions into adjoining structure Generic, modular laboratory design Moderate column-spacing in laboratory structures for cost-effective vibration control No unconventional structural, seismic, or foundation design systems Unconditioned exterior stairways No custom-fabricated, specialized materials Conventional interior finishes No floor coverings in laboratories Generic acoustical materials No sound absorption in partial-height partitions or walls w/doors Downsize HVAC due to sun shading Eliminate window coverings if electrochromic glass is used Eliminate exterior wall insulation, furring, sheetrock, and paint (due to thermal mass) BIM-produced savings in structural and mechanical systems Exterior walls ≥ 12 in. concrete integral color, exposed both sides Conventional rather than high-albedo roofing when weather-protection canopy covers rooftop equipment	Smart Labs energy design criteria Smart Lab co-benefits including longer lifespans for building mechanicals, improved minute-by-minute fault detection for improved safety, and ~6 other co-benefits Small, demand-controlled HVAC zones for comfort and efficiency LEED Platinum sustainability standards Outperform Title 24 by 50% or more Robust laboratory core infrastructure to support inexpensive future modifications Durable materials and system quality to avoid major maintenance expenses Long-life/low maintenance exterior finishes High-quality teaching spaces Stainless steel flashings Durable hardware and interior finishes Operable office windows (w/HVAC interlocks) Quality hardscape and landscape materials and features Sound isolation where needed (e.g., offices) Weather-protection canopy to extend life of roof-mounted equipment Sun-shading 85% overall annual effectiveness

The priorities, trade-offs, and underlying assumptions inherent in the table above should be discussed, understood, and reaffirmed or upgraded periodically to ensure that the University's construction standards are appropriate and that the capital program remains cost-efficient and responsive to academic needs and priorities. These standards and quality criteria need to be understood in order to arrive at valid capital cost comparisons.

Results

The broad goals and principles outlined in this document have been in place since 1993, although some refinements in the details have been updated based on experience and new technologies. Since this framework has been used consistently (with a few gaps due to inflexible project circumstances), it is now possible to assess the overall effectiveness of this program of life-cycle quality assurance.

- This program has realized consistent, exceptional sustainability and life-cycle performance results funded via savings realized by a system of cost-control principles and standards, with no budget augmentations for life-cycle or sustainability systems, features, or upgrades.
- No premature major maintenance has been experienced in these buildings.
- These buildings have all outperformed California's energy code (Title 24) by at least 20 percent since 1993 and as much as 50 percent for the past 15 years.
- Twenty-one of these projects were awarded LEED Platinum by the U.S. Green Building Council, and eleven have been awarded LEED Gold.
- A number of unexpected, valuable co-benefits have been realized, including improved safety (reduced airborne hazards and "smart" mechanical fault-detection), quieter buildings, cleaner indoor air quality, and improved lighting quality as well as efficiency, increased occupant satisfaction, operational productivity, longer service life for building mechanicals, and avoided/lower capital costs for Central Plant infrastructure (indirect effect of energy-efficient campus buildings).
- A consistent approach to quality standards has supported very high quality, competitive design-build proposals where the design-build teams were able to focus on the ratio of value to cost – the basis of project award.

Finally and most important, a consistent framework of life-cycle and sustainability principles, quality standards, and performance criteria -- rather than attributes developed on a project-by-project basis -- is understood by all professionals who manage the design process; review design submittals; inspect the work product; commission completed projects; and accept, operate, and maintain new capital assets. This consistency fosters a quality culture of immense institutional value that is broadly shared and clearly understood.

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