Building Greener Buildings with No Increase in Budget

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Significant events are changing the way we need to think about the design of energy features and systems for new UC Irvine buildings. The Regents' Green Buildings and Sustainable Energy Policy mandates that we strive for LEED "Silver" performance from our new buildings, and that we design to minimize carbon-based energy consumption and emissions. There is mounting pressure to pursue LEED Gold awards. These expectations entail an *unfunded* cost increment that we need to *find* through intelligent design tradeoffs and value-engineering. Various design concepts and tradeoffs are discussed below, from the perspective that the only feasible way to attain greener building designs is to make spending tradeoffs that move in the direction of cost-effective sustainability.

Much of the discussion that follows pertains to laboratory buildings, since these buildings are the campus' largest energy consumers and thus represent a considerable energy savings opportunity. Nonetheless, many of the ideas discussed below apply to all types of academic buildings.

Electric Heating in a "Green" Building?

UC Irvine's combined heat and power (CHP) plant, with its 53,000 ton-hour thermal storage system and six ways to use recovered heat, is remarkably clean, efficient, and robust. With the advent of CHP, some of the "ground rules" can change regarding how we distribute thermal energy.

We are so conditioned to think "electric heat = inefficient" that the idea of electric resistance heat in a University building initially seems nonsensical. However, the reasons for that accepted view stem from *utility-provided*, *grid-transported* power, where long-distance transmission and generation plant thermal losses degrade the overall system efficiency of electric power.

With campus CHP, this assumption can change for three reasons: First, most of the heat lost by conventional generating plants is recovered for use in appropriate applications, as discussed below. Thus, recovered heat has economic value; it is no longer regarded as "waste heat." Second, transmission distances are short compared to grid-transported electricity, thereby reducing transmission losses. Third, the alternative of small, local, gas-fired, hydronic boilers involves significant standby losses. Therefore, when the CHP plant is operating at less then full electrical load (no grid purchase), and there is capacity to absorb the exhaust heat for other useful purposes, the overall fuel utilization efficiency can be greater than that of small, local, gas-fired, hydronic boilers. This situation most commonly occurs at night and on weekends. Thus, heating some student housing with electric baseboard units could be an efficient alternative to hydronic baseboard heating. Using ground-source heat pumps could be even more efficient.

Since the use of exhaust gases (waste heat) from the combustion turbine generator is what makes CHP thermally efficient, the campus must maximize the use of high temperature water (HTW)

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from the central system. Efficient use of HTW is best accomplished where large heat loads demand massive quantities of industrial and potable hot water. For example, vivariums have the largest heating loads per square foot of space and should always be served by the HTW system. Similarly, gymnasiums have large potable hot water loads. On the other hand, it makes little sense to provide a HTW heat exchanger to serve a few sinks and a janitor's closet in an office building where small, local, electric water heaters can be economically provided. Buildings should use HTW for *sizable* heating water requirements, such as central heating coils at air-handlers in mechanical rooms and where significant reheat loads exist (e.g., fume-hood dominated laboratories).

In summary, where and whether HTW, electric resistance heating, or heat pumps are used depends on large vs. small quantities, centralized vs. decentralized locations, and time-of-use expectations.

A New Paradigm for Emergency Power

The primary driver of generator sizing in recent projects has been the assumed loads on the generator. Due to growing concerns about reliable power, researchers have been demanding increased capacity in emergency circuits. However, we need to recognize that *emergency* generators are *life-safety* devices that should not be confused with *standby* sources. Provision of life-safety devices is mandatory. Provision of standby power is an elective decision with benefits that need to be weighed against costs and alternatives.

Although newer building codes place increasing requirements on emergency power, we need to use resourceful approaches, such as sharing emergency generators among neighboring buildings, and new technologies, such as photo-luminescent emergency exit lighting, rather than simply up-sizing emergency generators and circuits. Further demand side reductions can be achieved by requiring that all motors powered by the generator have soft and staged starting upon loss of power and switchover to life-safety or standby power. In addition, new building projects in proximity to existing emergency generators may be able to replace and up-size the existing generator rather than purchase a new one.

By installing automated load-shedding (shunt trips) for standby loads that can withstand a 15-minute power outage stemming from glitches in the SCE system (typically, of short duration), we could accommodate longer-term, single-building outages that could have the potential to negatively impact research processes or materials. When operating in this mode, the generator would still be available to support the life safety systems of other buildings. In effect, this creates three classes of power: normal power from the CHP supplemented by SCE, life-safety power, and standby power. The "orange" plugs would become *standby* power and the existing, hard-wired, life-safety power would remain so.

Although CHP is not a substitute for life-safety emergency generation, as funding becomes available to improve the system, CHP, in tandem with a "smart" and robust primary distribution system and continuous grid backup, should provide even more reliable power for all user loads. This approach represents an improvement for three reasons: First, the savings from eliminating or downsizing new emergency generators and circuitry could be reallocated to unfunded "green" building features. Second, valuable, grade-level space freed from generator footprints could be reallocated. Third, emissions are reduced.

Fine-Tuning the Way We Use Glazing

Our glazing choices -- in terms of product specifications, window shapes, and window sizes -- need to shift strategically as we pursue LEED "Silver" performance for our new building designs. And we need to manage and steer these choices, rather than rely on others to make green decisions *for* us.

For windows that receive direct sun most of the year, we need high-performance glass that is wavelength-selective, such that heat transmission is reduced (<0.3 shading coefficient) while useful, visible daylight is transmitted at >1.5 times the shading coefficient, i.e., >.45 transmittance for visible light. Such glazing is expensive, and project managers need to ensure that we are not specifying high-performance glass in locations that are predominantly shaded. For example, all glass that faces north, plus or minus 60 degrees east/west, should be clear, double-glazed with no tint whatever, in order to maximize daylighting. Similarly, glass that is under an arcade, shaded by a recess in the exterior wall, behind trees (even within a few years), or in the shadow of neighboring buildings should also be clear, double-glazed. With the tight spacing of many of our infill sites, even south-, east-, and west-facing glass low on the building may be shaded by neighboring structures or mature trees most of the time, and thus it should *not* be high-performance glazing. Even if contractors prefer to install high-performance glass throughout a project in order to simplify field coordination, our requirement is clear, double-pane glass -- to maximize day-lighting -- in all locations that are predominantly shaded.

It is worth creating a simple computer or block model (including shade trees and neighboring structures) in order to understand which windows will be shaded and which ones require high-performance glazing, for the cost of the latter product is only warranted in specific locations that receive direct sun. A solar study does not need to model every hour of every day of the year, but can interpolate the desired information by looking at seasonal maxima and minima sun angles mid-morning and mid-afternoon. Even simple analysis such as this will result in considerable savings, typically reducing by *more than half* the quantity of expensive, high-performance glass.

For north-facing glass and exterior elevations that are mostly shaded, we want windows to be large and tall -- bigger to admit more daylight, and taller so that daylight can penetrate deeper into perimeter spaces. In cases where a tradeoff exists between larger *or* taller windows, taller windows -- extending all the way to the ceiling -- may be the best choice for getting useful daylight into deep spaces. In naturally ventilated offices, it helps to have tall windows with operable panes at both the top and bottom of the window opening, so that convection draws in fresh air via the lower opening and vents out warm air at the upper one. Making external windowsills and the recesses around windows deep and light-colored captures indirect daylight that bounces into interior spaces.

New Thinking about Laboratory Air-Change Rates

Due to the influence of the University of California and other major research universities, the manufacturers of laboratory-grade refrigerators and freezers are introducing ENERGY STAR products. Since freezers and refrigerators contribute a major fraction of the heat load that must be removed from research laboratories, we may be able to reduce lab air exchange-rates substantially by installing ENERGY STAR refrigeration equipment.

If heat loads and minimum fume hood exhaust can be minimized, our laboratory designs should use real-time air quality monitoring to provide four air-changes when occupied, and two air-changes when unoccupied. This should be our design goal unless tangible safety reasons (as distinguished from unsubstantiated fears) warrant higher ventilation rates. Design air-change rates will be based on the actual space volume, subtracting out fixed casework and equipment rather than using an assumed dimensional volume. When occupancy sensors indicate the presence of no people in the lab, the night setback will take effect. Ventilation rates will also vary based on real-time measured levels of air contaminants of interest such as CO_2, particulates, and total volatile organic compounds. Such systems enable reduced ventilation rates during normal operation while permitting the system to ramp up in response to a chemical spill. In summary, with real-time air quality monitoring a "baseline" of 4 air-changes per hour (ACH) may be reduced to a 2 ACH setback rate when no occupancy is sensed, but increased to 10-12 ACH when threshold levels of contaminants are sensed or when a red "spill button" is activated as a user exits the laboratory. Recirculated filtered or ventilated chemical storage cabinets will help to maintain lab air quality at low air-change rates.

An important measure that will help enable reduced laboratory air-change rates is to reduce the minimum (sash closed or nearly closed) fume hood airflow from 25 CFM per square foot of working surface to 12 CFM/SF, based on the evaluation, "Solvent Vapor Concentrations Following Spills in Laboratory Chemical Hoods."[1]

Air quality sensing should also enable general lab exhaust and lab support spaces' exhaust to be recirculated (or dumped into the fume hood exhaust system if/when contaminants are sensed). Hot exhaust, such as collected at equipment corridors lined with freezers, may not be economical to recirculate except during heating season. The design concept outlined here will require exhaust segregation for fume hoods vs. lab support and general lab exhaust, as well as real-time air quality sensing. However, head-end HVAC sizing will benefit from reduced air-changes and return air recirculation.

Nonmetallic Exhaust Duct

Plastic exhaust duct may free up savings for energy-saving features. Moreover, this product can be procured with a high recycled content.

[1] *Chemical Health and Safety,* March-April 2004.

Energy-Efficient Fume Hoods

UC is pursuing CalOSHA certification of high performance, energy-efficient fume hoods that will function safely at face velocities of 60 FPM. This will add an important tool to our arsenal as we pursue additional energy savings, in pursuit of LEED Silver. In some cases, a low-flow fume hood may negate the need for variable-volume HVAC supply and exhaust systems for laboratories, although analysis of the program -- not a “one size fits all” approach -- will become increasingly important.

In some cases, low fume hood density in relation to minimum ventilation requirements may enable the use of conventional, 100 FPM bypass hoods with fixed-volume HVAC. Where fume hood density is high, the use of high performance (low-flow) fume hoods may also enable the use of fixed-volume HVAC to satisfy the air-change requirement. Another alternative that warrants a cost/benefit evaluation is automatic sash closures. Automatic sash closures are especially cost-effective for large fume hoods and double-width units and in labs with a high density of fume hoods. Auto-sash fume hoods are safer for laboratory users, in addition to their energy-efficiency advantages; in some circumstances they also offset the need for low-flow fume hoods.

Clearly, numerous HVAC and exhaust system permutations stem from the array of tools available (VAV, presence sensors, low-flow hoods, and auto-closure sashes) juxtaposed against varying laboratory parameters (hood density, heat load, types of possible spill hazards, etc.). Whether the expense of variable-volume HVAC and/or high performance fume hoods and/or automatic sash closures (or various combinations thereof) is used in a laboratory design should take into account both operating and capital costs, and the most robust HVAC solution that attains our energy-efficiency objectives should be employed.

“Smart” Laboratory Exhaust Systems

Manifolded laboratory exhaust fans/stacks should be designed to all run simultaneously (in-parallel), thus minimizing stack discharge airspeed, when *either* (A) sensed wind velocity is below the threshold condition when re-entrainment becomes problematic, *or* (B) sensed exhaust contaminants are below a critical concentration level. The design objective is a safe discharge velocity based on *measured conditions*. When the system is designed for pathogens as well as chemical exhaust, only condition A will be used as a control parameter. When wind conditions or contaminant concentrations require higher stack airpseeds the exhaust flow will be channeled into fewer stacks operating at sufficient discharge velocity to prevent re-entrainment.

"Smart" Laboratory HVAC System Parameters

The following table illustrates the changes in HVAC system parameters we need to consider, in contrast to the (fairly resourceful) criteria we have been applying in recent years:

Laboratory HVAC, Exhaust, and Ventilation Performance Parameters

	Typical Recent	**Green Goal**
• Maximum air-handler/filtration airspeeds	~400 ft/min	300 ft/min
• Total system pressure-drop	~6 in.w.g.	< 4 in.w.g.
• Expected system lifespan	> 30 years	>30 years
• Oversized for economical future expansion	20%	10%
• Duct noise attenuators	Few	None
• Occupied lab air-changes/hr.	6	4x/hr. w/real-time contaminant sensing
• Night air-change setback	None	2x/hr. w/occupancy and contaminant sensing
• Minimum fume hood flow rate	25 CFM/SF	12 CFM/SF
• Spot heat loads	More VAV supply air	Chilled beam or local 55ºF fan-coil unit
• Fume hood face-velocities	100 FPM	60 FPM and/or auto-closure
• Fume hood face-velocities when lab unoccupied	100 FPM	40 FPM or auto-closure
• Fume hood auto-closures	None	Use where hood density high and/or heat load is low and/or as needed to attain ACH goal.
• Exhaust stack discharge velocity	3,000 FPM	"Smart" controls run stacks/fans at minimal airspeeds when wind conditions *or* contaminant concentrations allow.
• Exhausted to outdoors	100%	100% for fume hoods; recirculate lab support and general lab exhaust
• Out-perform Title 24	20%	>> 20%

Generally, our approach is to slow down airspeeds and air-changes, reduce fan energy, make labs "smarter" by sensing occupancy and measuring air quality in real-time, and recirculate uncontaminated return air from general lab exhausts and lab support spaces. However, not all performance parameters summarized in the table, above, will apply to all laboratory designs.

Modeling will be required to determine the best *combination* of energy features that will achieve exemplary efficiency in a cost-effective manner. Design-build proposals need to demonstrate that modeling has evaluated and optimized all feasible measures to reduce ACH and fan power. In addition, design-build scoring incentives should reward proposals that further reduce fan and thermal energy through application of chilled beams, induced chilled beams, tempered floor/ceiling slabs, LED task lighting, or other innovative design-features. The engineers involved in our projects need to be active in Labs21 studies that challenge status quo design practices, and they need to seize the opportunity to down-size equipment wherever possible to help offset the cost of desired energy features. For example, head-end equipment can be down-sized and duct and plenum sound attenuators should be eliminated on both supply and exhaust side (however, install a duct segment where an attenuator can be readily retrofitted if fan noise proves problematic post-occupancy).

Design-build proposals do not need to employ all, or any specific combination, of the design approaches or technologies discussed above. Rather, designs need to evaluate the most cost-effective design responses for the particular program, and scoring will be based on the lowest energy consumption, operating expense, and carbon emissions attainable within the project budget.

ENERGY STAR Ratings for Lab Refrigeration Equipment

DOE ENERGY STAR products are now being introduced to the market for laboratory-grade and medical-grade refrigerators and freezers, as well as cold room compressors, office refrigerators and, of course, all types of office equipment. In order to meet the Regents' Policy for Green Buildings and Sustainable Energy, new and renovated buildings will install ENERGY STAR equipment throughout (now required by UC Irvine procurement policy). The savings extend well beyond direct kilowatt-hours, resulting in lower building cooling expenses; making reduced air-changes feasible in many labs; and lowering plug loads, electric distribution costs, and emergency power system costs.

Speaking of plug loads, in laboratories we need to specify plug loads and size mechanical systems based on actual measurements of similar, recently constructed UC Irvine facilities, taking into account that more efficient refrigerators and freezers will reduce these loads.

Keep Concrete Walls *Exposed*

Occasionally, we make the mistake of installing furring, sheetrock, and even insulation on exterior concrete walls. However, an energy study performed for UC Irvine about ten years ago showed that -- in our climate with its moderate day/night temperature swings -- an exterior concrete wall of twelve inches or greater thickness is more energy-efficient if left *un*-insulated, exposed to the interior space. The thermal massiveness of an exposed exterior concrete or masonry wall in our mild climate moderates outdoor temperature variations, cooling the interior during the day and keeping it warm during the night. Of course, during extended hot or cold spells this exterior thermal envelope will heat up or cool down and require more energy to make the interior comfortable than, say, a conventionally insulated room. But energy modeling has shown that, aggregated over an average seasonal pattern, it makes sense to keep thick, exterior masonry or concrete walls exposed and uninsulated. This pertains to exterior walls on all sides of the building, whether or not the wall receives direct sun. Generally, interior concrete walls (such as shear walls) should also be left exposed (rather than sheetrock-faced) in order to benefit the overall thermal mass of a building. If an exposed concrete wall requires a conventional interior finish for aesthetics, it can be primed, textured, and painted to look like painted drywall.

Occupancy Sensors in Stairwells and Corridors

Using occupancy sensors in corridors has proven a big success, particularly where an occupancy sensor near the elevator can also “see” the main stairwell door. When occupancy is sensed, all corridor lights go “on”; when no occupancy is sensed for fifteen minutes, three-quarters of the corridor lights go “off,” leaving a handful of lamps illuminated full-time. Thus, a solitary occupant leaving his/her office after fifteen minutes will still have sufficient light for safe egress. Similarly, occupancy-sensing lighting fixtures in stairwells should be our standard for new construction and renovation.

Occupancy Sensors for Restroom Ventilation

Restroom exhaust fans do not need to operate day and night, every day. A restroom exhaust fan typically serves the ducted exhaust from a number of stacked restrooms. If these restrooms have occupancy sensors (separate from lighting occupancy sensors) wired in parallel, the exhaust fan will shut off fifteen minutes after no occupancy is sensed in *any* of the restrooms. With such a configuration, the restroom exhaust will seldom shut down, even with low building occupancy, since occupancy in any of the restrooms will activate the fan. However, the savings that accrue overnight and during vacation breaks will be substantial.

Alternatively, restroom occupancy sensors can be interlocked with building HVAC, as follows:

- When building HVAC is “off,” restroom exhaust fans are also “off.”
- When building HVAC is “on” but no restroom sensors detect occupants for one hour, the building fans can be shut down.

Efficient Illumination

Our design goal for most spaces will be <1.0 watt/SF. Lighting fixtures near windows should have daylight sensors. Most spaces do not warrant dual-level lighting circuits if daylight sensors are installed. However, an alternative to daylight sensors is to install two lighting circuits (zones), where the primary zone is controlled by an automatic-on/automatic-off occupancy sensor and illuminates the interior part of the room; while the perimeter zone is controlled via a manual-on/auto-off sensor and illuminates the part of the room near the window(s). These two, general options can be allowed as design-build alternatives.

In laboratories where LED strip lighting can be installed on the underside of over-bench shelving, general illumination in lab bays can be reduced. Lab bay illumination should be controlled via occupancy-sensors that can "see" down bench corridors, and some lighting should always remain "on" for safety in case occupancy sensors "time-out." (LED task lighting could serve this always-on function.)

Showers for Bicyclists

Rather than install showers for bicyclists in all new buildings, our campus strategy is to install a shower stall in one unisex restroom in each academic quad, at ground level and close to bicycle parking. What we need is one shower stall with a changing bench -- not a complete locker room.

Protection of Trees

Saving trees at the outset of construction and protecting them during construction is important to the campus. The campus community is not impressed when we clear-cut trees on a building site (except for eucalyptus trees, which are *good* to remove). We need to protect established trees that are more than thirty feet from a new building's perimeter by installing fencing at the drip line; trees closer to the footings should be boxed and saved if they are of specimen quality. These practices are increasingly important in terms of our new, greener construction ethic.

Architectural and Exterior Lighting

An important green principle is to waste no illumination energy by directing it to places where it will not benefit people's safety. Thus, up-lighting that illuminates the atmosphere is definitely not a green design feature, although lighting designers have not gotten the message. Another green lighting principle emphasizes recessing the source of illumination to eliminate glare, so that one cannot see the light source from normal viewing angles.

Materials, Finishes, and Furnishings

To attain LEED Silver or Gold performance, our selections and specifications for materials, finishes, and furnishings need to be "green" in terms of both emissions and recycled or rapidly renewable content. There are other green aspects to consider, but emissions and content are the big issues that warrant the most attention on the part of building planners and designers. Carpeting should be procured from UC's strategic sourcing contract with Interface Americas, Inc., a carbon-neutral supplier. (UC contract prices flow through to our contractors.) Carpet tiles should be installed in areas where different wear patterns are likely to occur. Incidentally, some materials hyped as "green" may not really be *sustainable* due to short service life. Harry Gunther can help track down factual information in this regard.

Water Conservation Improvements

Our projects routinely install reclaimed irrigation systems, faucet flow-restrictors, and low-flow urinals and water closets. Nonetheless, we need to make additional water-efficiency gains in order to reach LEED Silver or Gold performance. In academic buildings, we need to install 1/8 GPF urinals and dual-flush women's toilets (with upward lever action for full volume flush) throughout buildings. In new housing we need to install dual-flush toilets, ENERGY STAR laundry equipment, and distributed, "mini" water heaters, tankless heaters, or circulating hot water piping.

Finally, we need to minimize the use of trap primers. Where we do install them, we should use tailpiece primers from toilets, direct condensate from fan coils, or reclaimed water.

Planning Ahead for Photovoltaics

Our new buildings need to earmark roof areas that are unshaded, free of equipment, and provided with a conduit to an electrical-mechanical room in order to minimize the expense of future photovoltaic installation.

UC Irvine Leadership in Pursuing this New Green Building Ethic

For years, Irvine has been a leader in terms of energy-efficiency and energy infrastructure innovations, even before the "green movement" took hold. We have pursued a number of other green design features as well, such as operable windows, long-life durability of materials, reclaimed irrigation water, native and drought-tolerant plant materials, generous daylighting, a no-smoking policy once buildings under construction are enclosed, no use of rain forest woods, and many other green practices and design features.

Maintaining a leadership position in the green building movement will require us to challenge status quo beliefs and design practices. We need to inspire and push our project planners and designers to re-evaluate practices and assumptions that have been considered best practices for years or even decades. Under rigorous value-engineering evaluation, some of the ideas in this "white paper" may not prove cost-effective. But the goal of LEED Silver or Gold compels us to look for areas where we can save money -- such as more selective use of high performance glazing, down-sizing HVAC head-end equipment, eliminating or sharing emergency generators, removing furred sheetrock from exterior masonry walls, eliminating mechanical ventilation in perimeter offices, and lowering air-changes and eliminating attenuators to reduce the costs of HVAC systems -- so that we can invest the savings in higher overall energy-efficiency; more daylighting; "smarter," use-sensitive building controls; bicycle showers in each academic quad; low-emission materials, finishes, and furnishings with high recycled or renewable content; and other green features that will become evident in our pursuit of LEED awards. This is an exciting challenge, and the winners will be our students, staff, and faculty, who will benefit in many ways from greener buildings -- as well as the environment, itself.

The leadership role we envision for UC Irvine in designing green buildings will require commitment, sophistication, and cooperation that extends beyond Design & Construction Services, Facilities Management, Campus & Environmental Planning, Campus Housing, Parking & Transportation Services, Procurement, and EH&S, to inspire and motivate project stakeholders and building users to share in this pursuit. The first step is to understand the overall goal we are pursuing, and to re-think past practices and assumptions as we have outlined in this paper. The reason this paper is a *draft* is to encourage everyone to think of more and better ideas that will make our buildings greener -- especially value-engineering tradeoffs that yield savings that can be redirected into green features, for which there is no new funding apart from our own ingenuity and value-engineering.

We can meet this challenge.

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	Savings from…	Reallocated to…
Mechanical/Electrical/Plumbing	Downsize HVAC head-end equipment and duct work by reducing laboratory air-changes and utilizing design alternatives to VAV + reheat Lower plug load design capacity Simpler HVAC controls, viz., fixed-volume where feasible No forced-air ventilation or HVAC in offices Electric heating for low quantities of distributed hot water rather than hot water distribution piping Electric baseboard heating where 90% of its usage will be at night (see discussion) Plastic exhaust duct Do not install VAV hoods where fume hood density does not exceed minimum air-change requirement Eliminate duct and plenum sound attenuators in both supply and exhaust systems	Design HVAC to meet best practice energy design criteria (slower airspeeds, less static resistance, larger filters, etc.) "Smarter" controls with occupancy sensing, real-time air quality sensing, night setbacks, and exhaust stack discharge airspeed based on measured wind and contaminant conditions. Recirculate general lab exhaust and lab support return air (with real-time contaminant sensing) Low-flow or auto-sash fume hoods Ultra-low flow (1/8 GPF) urinals and dual-flush women's toilets Conduit to roof for future solar Operable windows with radiant heating and cooling for offices Radiant cooling (chilled beams, induced chilled beams, or tempered slabs) for labs Occupancy sensors for restroom exhaust fans (or interlocked with building HVAC) Occupancy sensors in corridors and stairwells High performance lighting <1 watt/SF with more task lighting LEDs for any required 24x7 illumination Bicycle shower stalls (one per Quad)
Emergency Generators	Reduce size of "emergency" generators to that needed for life-safety equipment only. Reduce life-safety electrical circuitry to minimum necessary.	Campus primary grid components (high speed switching, redundant feeds, etc.) necessary to provide robust power reliability via cogen + grid backup
Building Shell	Limit the use of high-performance glass (see discussion) Expose thermally massive walls (no furring, insulation, or drywall)	Very high performance glass where sun-exposed Generous use of glass on north and other shaded exposures Thicker window sills and surrounds as well as deep, white mullions to reflect indirect daylight into interior spaces External thermal mass walls 12 inches or thicker High-reflectance roof surfacing Clerestory windows or skylights for top floor interior spaces