Higher Education

Higher education uses less energy per square foot than most commercial building sectors. According to the international energy company National Grid, higher education campuses spend, on average, about $1.30 per square foot on energy each year. However, higher education campuses house energy-intensive laboratories and data centers that may spend more than this average; laboratories, in particular, are disproportionately represented in the higher education sector. Despite a concentration of energy-intensive buildings, many campuses have only a single meter for their entire sites.

The Commercial Building Partnership (CBP), a public/private, cost-shared program sponsored by the U.S. Department of Energy (DOE), paired selected commercial building owners and operators with representatives of DOE, its national laboratories, and private-sector technical experts. These teams explored energy-saving measures across building systems – including some considered too costly or technologically challenging – and used advanced energy modeling to achieve peak whole-building performance. Modeling results were then included in new construction or retrofit designs to achieve significant energy reductions.

CBP design goals aimed to achieve 50 percent energy savings compared to ANSI/ASHRAE/IES Standard 90.1-2004 for new construction, while retrofits are designed to consume at least 30 percent less energy than either Standard 90.1-2004 or current consumption. After construction and commissioning of the project, laboratory staff continued to work with partners to collect and analyze data for verification of the actual energy reduction.

CBP projects represent diverse building types in commercial real estate, including lodging, grocery, retail, higher education, office, and warehouse/storage facilities. Partners also commit to replicating low-energy technologies and strategies from their CBP projects throughout their building portfolios.

As a result of CBP projects, five sector overviews (Lodging, Food Sales, General Merchandise, Higher Education, Offices) were created to capture successful strategies and recommended energy efficiency measures that could broadly be applied across these sectors. These overviews are supplemented with individual case studies providing specific details on the decision criteria, modeling results, and lessons learned on specific projects. Sector overviews and CBP case studies will also be updated to reflect verified data and replication strategies as they become available.

Projects at a Glance

The experiences of campuses that have implemented measures to achieve CBP goals demonstrate the extent of possible savings as well as practices and lessons that can be applied across the higher education sector. Case studies from six higher education institutions – University of California (UC) Merced, the University of Hawaiʻi at Mānoa, Loyola University, Grand Valley State University, Massachusetts Institute of Technology (MIT), and Fort Bragg – illustrate how energy efficiency strategies, technologies, and measures have been implemented at a range of public and private institutions. The case studies describe the decision criteria, modeling results, and lessons learned from both retrofit and new construction projects.

The universities features in the case studies range in size. UC Merced owns and operates just over 1 million square feet, and MIT owns and operates more than 12 million square feet. The floor area affected by the measures described in the higher education case studies is 1.6 million square feet, with individual projects ranging from 50,000 to over 800,000 square feet. Because CBP partners commit to replicating low-energy technologies and strategies from their projects throughout their building portfolios, there is the potential for the efficiency improvements at these campuses to be extended to to the six institutions' total floor area, which is over 29.5 million square feet.

The universities described in the case studies own, occupy, and operate most of the space on their campuses; all of the projects described are owner-occupied. Each university has laboratory and data center space. The case studies focus on classroom, office, and data center projects.

Two of the campuses featured here, MIT and Loyola, are private universities; the others are public institutions. All have their own methods for financing campus efficiency projects. UC Merced uses on-bill financing for its central plant retrofit, and MIT is partly financing lighting and data center retrofits through utility incentive payments. Loyola is financing its project incrementally as funds are available in the capital projects budget, and the University of ‘Hawai‘i at Mānoa is financing classroom and office building retrofits from tuition revenue and a capital projects bond. Grand Valley State University's new construction projects are funded by private donations, tax credits, university-issued bonds, and university capital projects funds. Fort Bragg's projects are funded from the Military Construction (MILCON) budget, which is typically used for larger construction projects and required to meet a specific life-cycle cost hurdle to proceed.

Each institution has its own near-term practical and long-term strategic priorities to consider when implementing energy efficiency measures. For example, the University of Hawai‘i at Mānoa is planning for rapidly escalating energy costs while meeting challenging institutional sustainability targets. MIT looks to strategically select projects that can be replicated throughout its buildings portfolio. Design of the non-energy elements of efficiency projects is also important, including ensuring occupant and acoustical comfort, maintaining reliability of services (particularly in data centers), and attending to design aesthetics. The CBP partner projects presented in the case studies demonstrate that it is possible to meet this diverse range of objectives while saving substantial energy in existing buildings as well as new construction.

Successful Strategies

Colleges and universities that value and commit to energy efficiency have developed and implemented strategies that take advantage of existing market drivers or overcome barriers to saving energy and achieving sustainability goals. Successful strategies include:

- **Commit to campus-wide sustainability –** Leveraging the economy of scale in campuses' large single-owner building portfolios significantly reduces energy use and offers opportunities to engage the student population in energy saving and sustainability activities, which may attract new students.

Project Name	University of Hawai'i	UC Merced	MIT	Grand Valley State University	Loyola	Fort Bragg
Project Type	Retrofit	Retrofit	Retrofit	New	Retrofit	New
Climate Zone	1C, Hot / humid	3B, Hot / dry	5A, Cold	5A, Cold	5A, Cold	3A, Cold
Ownership	Public	Public	Private	Public	Private	Public
Barriers Addressed	Conventional design practice, existing energy management practices, non-energy related campus policies	Funding, limiting campus policies, data quality issues	Existing energy management practices, lighting quality, lack of measured data	Funding	Funding, existing energy management approaches	Energy management planning, security requirements, design schedule
Square Footage of Project	76,000	860,000	300,000 (RMSC) 6,900 (BW91)	140,000(College Business Center) 140,000 (Mary Pew Library)	24,000	96,000
Expected % Energy Savings (existing energy use)	~49%	14% (Central Plant) 36% (Science/ Eng)	~71% (RMSC) 30% (BW91)	12% (College Business Center) 12% (Mary Pew Library)	~47%	36%
Expected % Energy Savings (average energy use)						
Expected % Energy Savings (ASHRAE)	N/A	N/A	~71% (RMSC) N/A (BW91)	41% (College Business Center) 51% (Mary Pew Library)	N/A	52%
Actual Energy Savings	~450,000 kWh/yr* electricity	720,000 kWh/yr electricity 140,000 therms/yr natural gas	2,100,000 kWh/yr electricity	TBD kWh/yr electricity TBD therms/yr natural gas	TBD kWh/yr electricity TBD therms/yr natural gas	680,000 kWh/yr electricity TBD therms/yr natural gas
Expected Cost Reduction	$170,000-530,000**	$180,000	$270,000	$240,000	$11,000	$46,000
Actual Cost Reduction	Not Available	Not Available	Not Available	Not Available	Not Available	Not Available
Project Payback	~7 years	< 3 years	4 years (RMSC) ~4 years (BW91)	< 5 years	~26 years	5 years

- **Assign responsibility for sustainability –** Coordinating sustainability and energy efficiency efforts among an institution's directorates and departments ensures that initiatives are effective and deliver maximum value. It is most successful when campus leadership sets the tone, identifies project goals, assigns responsibility for carrying out projects to achieve these goals, and provides resources for implementing and managing energy efficiency initiatives.
- **Engage the campus community –** Traditionally, facilities offices administer sustainability and efficiency programs, but institutions that have successfully implemented efficiency projects have found that input and involvement of other campus stakeholder groups is essential. Participation by the occupants and / or operators of the affected spaces, the financial planning office, and the communications office is critical. Campus leadership recognizing and rewarding individuals or groups for their work on sustainability and efficiency also encourages program success.
- **Measure to enable continuous energy management –** Detailed energy data on both the type of energy used and where it is used helps campuses identify efficiency opportunities and develop campus energy plans. Some successful programs have installed permanent meters at each campus building. If funding is not available for permanent metering, a successful interim strategy is to invest in portable, wireless metering devices that can be used strategically to benchmark or obtain spot measurements of key buildings or systems as well as to obtain measured details about a building's energy use prior to retrofit. As funds become available, permanent whole-building and subsystem meters can be installed.

Highlighted Technical Solutions

- ***Demand-responsive equipment and controls –*** Opportunities to ramp down equipment during periods of reduced demand (or during demand-response events if the local utility offers such a program) include using variable-speed HVAC supply fans and pumps, variable-speed chillers, demand-controlled ventilation, dimmable lighting ballasts, and relaxed temperature set points.
- ***Reduced air change rates in laboratories –*** The air change rate in laboratories is often set to a constant value; however, Labs21 studies show that, in most laboratories, air change rates can be optimized to vary depending on usage, which both improves safety and reduces costs and energy use. At a minimum, air change rates can be reduced during hours when a laboratory is unoccupied.
- ***Increased data center temperature –*** As IT equipment improves, so does its ability to operate at higher temperatures. ASHRAE Technical Committee 9.9 on Mission Critical Facilities states that data centers can operate safely at temperatures above 90°F. Data center design advances, such as alternating hot and cold aisles, can support energy efficiency.
- ***Metering and monitoring –*** As market costs of metering equipment go down, campuses can cost effectively install system-level energy meters in buildings, which allows for monitoring-based, continuous commissioning of targeted systems; student competitions to save energy; and, in some cases, detection of faults. Energy consumption reduces when campuses are able to diagnose how and where energy is consumed.

- **Establish energy planning priorities** – Successful programs consider the whole-campus perspective, including overlaps and interactions, rather than focusing on periodic incremental improvements, such as upgrading single pieces of equipment. Energy management plans should also set specific short-, medium- and long-term sustainability and efficiency goals for individual buildings.
- **Explore innovative financing options, and emphasize value** – National Association of College and University Business Officers (NACUBO) guides to financing campus efficiency projects emphasize focusing on *value* rather than on cost in assessing options. These guides describe specific strategies, such as capturing incentives, bundling projects to capture additional efficiencies and leverage bulk purchasing power, using lease-purchase contracts, and employing revolving loan fund strategies to support efficiency projects.
- **Look for first-cost savings** – Reducing energy demand and increasing energy efficiency in buildings can lead to HVAC system downsizing, especially in new construction, though the design team must be explicitly charged with achieving this goal. The resulting first-cost savings can improve the business case for a package of energy efficiency measures that might appear uneconomic if evaluated individually.
- **Optimize existing system operational efficiency before retrofitting –** A retrofit that replicates the energy requirements of an inefficient building will not achieve the full potential benefit of the investment. Reviewing existing equipment and controls sequences to determine whether they are optimized for performance and operating as intended, and implementing corrections if they are not, ensures that a retrofit of the optimized building will produce maximum energy reductions.
- **Maintain energy performance** – Campuses that monitor energy performance reap the greatest energy savings benefits; measured data can be used to determine when buildings need tuning and to detect system faults as well as to support monitoring-based commissioning, a proven strategy for continuously improving performance. Staying up to date on the latest technological developments and best practices also helps sustain energy performance.
- **Ensure that campus policies support energy efficiency –** Institutional policies intended to create a safe and inspiring educational environment for students, faculty, and staff can have unintended energy impacts; new policies may be needed for some energy efficiency projects to be successful, such as to enable flexible air exchange rates in labs, higher temperatures in data centers, lower outdoor lighting levels or efficient fixtures with occupancy sensors, or prohibition on noisy outdoor activities such as leaf blowing if operable windows are to be installed in classrooms.

Energy Efficiency Measures

Many cost-effective energy efficiency measures on the market can save significant energy in higher education facilities. The list below is based on the experiences of leading campuses and institutions, as reflected in current literature published by DOE and others, such as the *Advanced Energy Design Guides* for new construction, *Advanced Energy Retrofit Guides* for existing buildings, *Laboratories for the 21st Century, Low-Energy Design Guide*, guidance on low-energy strategies for high-tech buildings and the CBP case studies presented here. These are low-risk measures that use off-the-shelf technology. When combined with best practices for integrated design, procurement, controls, and monitoring, the list of measures below cuts energy use across all building systems, adding up to significant whole-building savings.

Building Space Type	System	Energy Efficiency Measure Description
General (Office / Classroom / Library)	Envelope	Install wall and roof insulation appropriate for climate type
		Reduce or eliminate thermal bridging to avoid effects of unwanted heat loss / gain
		Install high-performance glazing appropriate for climate type and orientation, e.g., for hot climates to minimize southern exposure heat gain by use of double pane low-emissivity glass
		Install exterior shading to control heat gain and visual discomfort (without need for blinds to be pulled)*
		Install internal blinds to control daylight levels and glare and to limit direct solar heat gain; leave an air gap at top so overheated air rises to ceiling
		Reduce envelope air leakage impacts by installing vestibule doors or secondary glazing
	Lighting	Install lower-wattage, high-efficacy lighting such as compact fluorescent lamps (CFLs) and light-emitting diodes (LEDs)
		Install 0.75 watt-per-square-foot (W/ ft2) light power density, emphasizing ambient lighting systems and task lighting fixtures
		Install manual or automatic demand-based controls such as switches or occupancy sensors (motion or aural signal response) to reduce unwanted or unnecessary lighting use
		Install photosensors and electric dimming ballasts to dim lights when daylighting is sufficient
		Install reduced light power density for exterior lamps
		Install exterior lighting sensors and controls
	HVAC	Reset interior space temperature set points to reduce heating and cooling demand while meeting thermal comfort requirements
		Implement demand-controlled ventilation
		Install operable windows (or louvers) and ceiling fans to reduce operation of central mechanical cooling systems*
		Implement low-pressure-drop designs on air-side and water-side systems including ducts, air filters, pipes, and coils
		Install differential pressure sensors in ducts to control fan speed
		Install and commission 100% outside air economizers*
		Reduce economizer damper leakage*
		Consider installation of air-side heat-recovery systems
		Install high-efficiency motors
		Install variable frequency drives on pumps and fans on air-side and hydronic systems
		Implement water-side economizer on cooling towers*
		Implement a night-purge cycle
		Consider geothermal energy systems
	Hot Water	Consider instantaneous hot water heater
		Consider locating water heaters adjacent to point-of-use
		Utilize sources of 'free' heating such as heat recovery from cooling systems
		Install on-demand pumping with variable frequency drives
		Consider installing solar hot water panels
	Office Equipment	Consider power management options (software and hardware) to optimize energy performance of computers and other equipment
		Purchase equipment based on ENERGY STAR ratings
		Install occupancy controls on plug loads

Building Space Type	System	Energy Efficiency Measure Description
Data Centers	HVAC	Implement air management e.g., hot and cold aisle air containment
		Widen humidity range allowable in data center, eliminate the need for humidifiers
		Raise inlet temperature to upper range of manufacturer’s standards, or per ASHRAE guidelines
		Maximize return air temperatures and delta T to control mechanical equipment load
		Raise chilled water temperature in operations to increase chiller plant efficiency
		Monitor and optimize control sequences to emphasize most efficient operation, including part-load conditions
		Install and optimize 100% outside air economizers*
		Install variable frequency drives for air handling units
		Consider variable speed chillers where loads are expected to vary significantly
		Implement water-side economizer on cooling tower*
		Install water-to-water heat recovery to remove equipment-generated heat for re-use in space heating
	IT Equipment	Virtualize computing functions to minimize server usage
		Specify low-energy servers
		Consider water-cooled racks and computing equipment
	Electrical	Right-size uninterruptible power supply (UPS), install bypass UPSs, and use UPSs only if an increase in voltage is required
		Consider direct current (DC) supply for equipment, to reduce multi-stage electrical losses
		Use high-efficiency power supplies and transformers (select at operating point)
Labs	HVAC	Assess and minimize ventilation air requirements for both occupied and unoccupied periods; refer to Labs21 standards for guidance on best practice air change rates for labs
		Reduce or eliminate simultaneous air-side heating and cooling
		Minimize duct system static pressure through low-pressure-drop ducts, coils, and extended surface low-velocity filters
		Install variable air volume systems and pressure controls
		Undertake fume hood sash management training for users
		Select plant equipment for part-load operation; modularize plant components as necessary
		Evaluate potential for heat-recovery options such as enthalpy wheels; refer to Labs21 for guidance on key factors
		Decommission unused lab hoods, or consolidate underutilized lab fume hoods and decommission
	Plug Loads	Purchase energy efficient lab and plug load equipment, e.g., freezers
		Assess plug load power consumption and plug load diversity
		Consolidate heat-generating equipment such as freezers into a common area, lowering intensity of cooling load in other spaces

* EEM is dependent on climate.

Lighting retrofits can be large contributors to energy savings, and many can even qualify for rebates from local utilities. Furthermore, lighting retrofits yield savings in any space type and in any climate, making them a good place to start.

With no new equipment to install or repair, proper fume hood management along with user training is an effective energy savings measure with a quick payback. Decommissioning and consolidating fume hoods can greatly decrease the amount of wasted energy due to open fume hood sashes.

Additional Resources

179D DOE Federal Tax Deduction Calculator
http://apps1.eere.energy.gov/buildings/commercial/179d/

2011 Thermal Guidelines for Data Processing Environments – Expanded Data Center Classes and Usage Guidance
http://www.eni.com/green-data-center/it_IT/static/pdf/ASHRAE_1.pdf

Advanced Energy Design Guide for Small and Medium Offices
http://apps1.eere.energy.gov/buildings/commercial/resource_database/

Advanced Energy Retrofit Guide for Office Buildings
http://apps1.eere.energy.gov/buildings/commercial/resource_database/

Brase, W., (undated). "Critical Path Issues on the Way to Carbon Neutrality – Presenting Thought Leaders' Points of View". Washington DC: DC. National Association of College and University Business Officers.
http://www.nacubo.org/Documents/business_topics/CriticalPathways_WendellBrase.pdf

CDW's 2009 Energy Efficient IT Report
http://newsroom.cdw.com/features/feature-08-31-09.html

Database of State Incentives for Renewables and Efficiency
http://www.dsireusa.org/

Laboratories for the 21st Century: An Introduction to Low-Energy Design
http://labs21.lbl.gov/docs/lowenergy.pdf

Mills, E., Mathew, P., 2009. "Monitoring-Based Commissioning: Benchmarking Analysis of 24 UC/CSU/IOU Projects." Berkeley: CA. Lawrence Berkeley National Laboratory.
http://evanmills.lbl.gov/pubs/pdf/MBCx-LBNL.pdf

Optimizing Laboratory Ventilation Rates, in Laboratories for the 21st Century: Best Practice Guide
http://www.i2sl.org/documents/toolkit/bp_opt_vent_508.pdf

Total Commercial Building Floorspaces by sector
http://buildingsdatabook.eren.doe.gov/TableView aspx?table=3.1.13

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