LEARNING FROM PERFORMANCE

BY CATHY HIGGINS AND KARL BROWN

Achieving net zero energy buildings requires knowledge of best real-world strategies. A dataset from New Buildings Institute includes about 70 buildings that, on average, use half of the energy required by comparable buildings and identifies commonalities of design and technology decisions to provide insight into the results of energy efficiency strategies.[1] This national, geographically diverse dataset includes a California university campus building whose design process achieves aggressive energy savings on the way to net zero performance.

Data Overview

Offices comprise 31% of the dataset, and K–12 and higher education make up a combined 27% of the buildings. Public assembly follows with 22% and medical/lab represent 11%. All buildings were constructed or renovated within the past five years, with 77% identified as strictly new construction and occupied for a minimum of one year.

In addition to a variety of building types, the dataset includes a broad geographic distribution. Although these buildings are found across the country, more were located in states with strong energy efficiency programs, and fewer buildings were located in hot, humid climates.

Common Technologies

Twelve technologies (*Figure 1*) are most commonly identified as part of the buildings' designs or efficiency upgrades. Measures for these projects were either self-selected from a larger list or derived from project notes. Definitions may vary depending on the submitting party. Key findings for common technologies include:
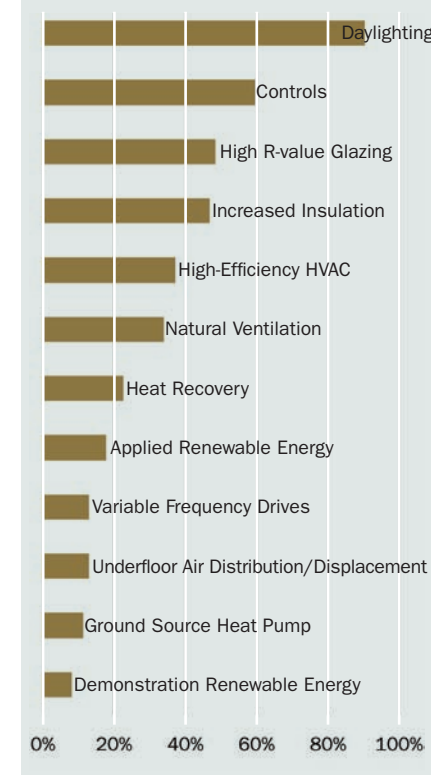
- Daylighting appears in nearly all buildings and includes the control of electric lighting through dimming or step relay controls. Given the double benefit of reduced watts per square foot and reduced cooling load, these make sense as major contributors to low energy use.
- Automated controls of HVAC and lighting, such as through occupancy sensors, are found in most projects.
- Mechanical systems usually incorporate high-efficiency equipment.
- High performance glazing is the most frequently mentioned shell element.

Above The UC Merced Classroom and Office Building's primary features contributing to low energy use are high performance HVAC and lighting designs and an energy management control system.

Opposite The Classroom and Office building was completed in January 2006 and received LEED Gold certification. The building provides multidisciplinary instructional space and research office space for the Merced, Calif., campus. Its three stories include 103,006 gross ft².

FIGURE 1
TECHNOLOGIES IN HIGH PERFORMANCE DATASET

Technology	
Daylighting	
Controls	
High R-value Glazing	
Increased Insulation	
High-Efficiency HVAC	
Natural Ventilation	
Heat Recovery	
Applied Renewable Energy	
Variable Frequency Drives	
Underfloor Air Distribution/Displacement	
Ground Source Heat Pump	
Demonstration Renewable Energy	

0% 20% 40% 60% 80% 100%

- Natural ventilation and underfloor air displacement ventilation appear to be growing trends, having increased in usage from a previous review.
- PV systems tend to be found on public buildings as a demonstration or on larger corporate buildings where the extra expense is more cost effective.
- While a few technologies such as insulation and cool roofs are more common in certain climates, the majority seem independent of climate.

Average energy use by building type was compared with the averages in the Commercial Buildings Energy Consumption Survey (CBECS) 2003. The buildings are performing near or beyond 50% of this national baseline of building energy use. Some outperformed CBECS averages by more than 70%. Several have energy use intensities (EUIs) of less than 25 kBtu/ft² · yr, placing these projects potentially in reach of net zero energy, depending on options for on-site renewable energy.

This dataset demonstrates that low-energy buildings can be constructed today in most climates, for all common building uses and in new and retrofit scenarios. The sites involve a mix of owners and design teams and provide valuable technical references for other projects.

Real-World Example

The University of California (UC) Merced Classroom and Office Building (COB) offers lessons in design process and outcome.[2] UC Merced, informed by measured energy performance of the COB, has

set a goal of net zero energy use by 2020 for main campus buildings and vehicle fleets. Climate neutrality and elimination of landfill waste are the other components of a triple-zero commitment (zero net energy, zero new carbon, and zero landfill waste) for the same timeframe.

UC Merced set its goals based on two advances in methodology

The University of California at Merced is the first new UC campus in 40 years. The campus, which opened in 2005, set a goal of using 50% less energy than other California state campuses.

TABLE 1 BENCHMARKS AND ENERGY PERFORMANCE OF CLASSROOM AND OFFICE BUILDING
JULY 2007–JUNE 2008

	Comparable Buildings Benchmark	Actual Energy Use	Percent of Benchmark
Annual Site Electricity (1)	15 kWh/ft^2	9 kWh/ft^2	60%
Annual Site Gas (2)	0.2 therms/ft^2	0.15 therms/ft^2	75%
Annual Site EUI	71 kBtu/ft^2	46 kBtu/ft^2	64%
Annual Source EUI (3)	159 kBtu/ft^2	98 kBtu/ft^2	62%

Notes: (1) Includes prorated central plant chiller energy use and distribution losses. These figures include approximately 5% transformation/distribution losses and exterior site lighting, which is not typically included in metered usage for stand-alone buildings.
(2) Including prorated central plant heating efficiency and loop distribution losses.
(3) Site-to-source conversion factors from CalArch: 2.7 for electricity, 1 for natural gas.

for evaluation of building performance. First, the campus' energy performance targets account for whole building performance, not just regulated systems, as is the case with building code-based targets (such as California's Title 24 and earlier versions of LEED). Second, performance is regularly assessed relative to targets as operated (measured), in addition to as designed (modeled). UC Merced uses the measured performance data to support future improvements in modeling and goal setting.

Setting a Benchmark
The campus established an initial goal of using 50% less energy than comparable university buildings circa 1999 by the third phase of construction (after approximately 1 million ft^2), based on data (adjusted for building type and climate) from eight other California campuses. By assessing the real-world energy use of similar buildings to set targets and inform modeling, UC Merced created a data-driven design process that enabled more complete and accurate performance estimates—forecasts that allow meaningful comparison with actual continuous measurements of building operation.

A progressive set of energy efficiency targets enables the campus to work toward the 50% goal, learning from its experience with each building. Performance targets were set as a percentage of benchmarks.

The target for COB and other buildings in the first major phase of construction (600,000 gross ft^2) is to operate at or below 80% of benchmark (a 20% reduction in energy consumption). Incremental targets for future phases move toward 50% of benchmark, aligning with a path-to-zero scale. This methodology is similar to a recently developed building performance index based on net zero energy (see http://tinyurl.com/netzeroindex).

Performance
Completed in January 2006, the COB is three stories and 103,006 gross ft^2, with multidisciplinary instructional and office space. On an as-operated basis, COB surpasses its target performance for all annual energy consumption metrics. Source energy use
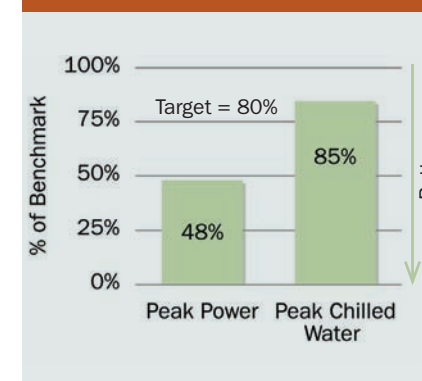
(gas and electricity combined) was only 62% of the benchmark, already better than the 65% target for the next phase of campus build-out.

For peak power, the target benchmark was adjusted to incorporate the shift of cooling to off-peak times based on a district chilled water thermal energy storage system. The as-operated peak power, at just 48% of benchmark, primarily represents the effectiveness of reduced lighting, fan and plug loads in the building.

With a site EUI benchmark of 71 kBtu/ft^2 · yr, and as-operated energy use measured of 46 kBtu/ft^2 · year, this building puts the campus on track for reaching 50% of benchmark sooner than anticipated. The monitoring-based feedback provides for continuous improvement at building and plant levels.

Energy efficiency technologies and strategies used in the COB include:
- Low-pressure drop design for air systems;
- Variable air volume, dual-fan, dual-duct HVAC;
- No reheat for HVAC;
- CO_2 sensors to minimize airflow during low occupancy;

- Low-power-density lighting with occupancy sensors;
- Double-pane low-e windows with a low solar heat gain coefficient;
- Controls to disable space conditioning when windows are open;
- Solar shading on all but the north façade;
- Direct digital controls at the plant, system and zone levels; and
- Meters for all energy types, including hot/chilled water.

The energy savings realized from these efficiency measures contributed to establishment of the whole-campus goal of net zero energy by 2020. The efficiency success also led the campus to consider moving beyond the 50% goal to a target of reducing energy use to just 25% of benchmark, which would require less renewable energy to achieve net zero.

Monitoring-based feedback is a key to continuously improving current operations and future designs as the campus moves along a path of more advanced, but surmountable, steps.

Data Demand
Essential to progress is information, which links design to performance and operations to objectives. Nothing makes the case as eloquently as real buildings backed by real data. As the transition is made from energy-wasting to high-efficiency buildings, performance must be measured and used as a yardstick for success and course corrections.

This small dataset reflects the scarcity of information on actual energy performance and highlights the value and need for additional examples of high performing buildings. Barriers

ABOUT THE AUTHORS

Cathy Higgins is program director for New Buildings Institute, a national non-profit with offices in Washington state that assesses technologies, promotes advanced design approaches and helps guide policies and programs to improve the energy efficiency of commercial buildings. Its funders and project partners include the U.S. Green Building Council, American Institute of Architects, U.S. federal agencies and electric utilities and benefits administrators.

Karl Brown is deputy director of the California Institute for Energy and Environment (CIEE), a branch of the University of California Energy Institute. CIEE supports public-interest energy research in California through research planning, research project administration and technical coordination of research projects.

to widespread design and construction of low-energy buildings are not technical in nature; more likely they are related to the motivation of owners, the skill set of design and construction teams, and a common understanding of what is possible. A critical bridge to that understanding is more easily accessible data and case studies of measured performance.

NBI is collecting performance data on existing building energy efficiency improvements and building characteristics. Share examples at http://newbuildings.org/existing-buildings-retrofit-examples. ●

References
1. New Buildings Institute. 2010. Data derived from buildings in NBI's "Getting to 50 (GT50) Buildings Database," http://tinyurl.com/nbigt50, and other NBI measured performance research projects.

2. California Institute for Energy and Environment, New Buildings Institute. 2009. "Classroom and Office Building, UC Merced." http://tinyurl.com/UCM-COB.