Getting to 50: Drivers and Data of Measured Energy Performance

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ABSTRACT

The mainstreaming of zero-energy buildings has become the long-term goal of strategic energy planners seeking climate stabilization. Such planning requires intermediate milestones and near-term examples. A good first milestone is the halving of building energy use using smart design and state-of-the-shelf technology.

The *Getting to 50* (GT50) database has compiled information on over 100 U.S. commercial buildings with stated energy savings at least 30% beyond comparable or code buildings. While many of the buildings identified in this database have been evaluated as designed, the number of buildings that offer as-operated data is over 60 and growing. What is needed is greater measured performance data linked to information about the design and operation of high-efficiency buildings.

This paper presents 1) an overview of current policy drivers for increased information on low-energy buildings, 2) the case for the value of increased data to support that direction, 3) a summary of the sizes, types and measures used by buildings striving for low energy from the GT50 dataset and 4) the approach and results on a pilot measured performance case study. The case study building is a part of a major university working toward a net-zero energy campus and serves as an example of the evaluation and documentation needed for promulgating high-efficiency buildings.

The New Framework

"Lead by example" is a long-time adage to create change. The ground is set for the growth of low-energy buildings and for the potential of data and case studies of low-energy buildings to be seeds of change. It is now commonplace for mainstream media sources to feature stories that include information on the relationship between the energy use of buildings and associated greenhouse gas (GHG) emissions. Since buildings account for approximately 40% of total U.S. energy consumption and GHG emissions, the drive to demonstrate the potential for reduced energy use has never been stronger (EIA 2009).

The following presents some of the policy framework that is driving an increased need and value for examples of buildings striving for, and accomplishing, low-energy use.

Emission Reduction Policies

Emission reduction policies contain building energy use targets that need to be supported by valid information on actual performance. In 2006, Architecture 2030 proposed the 2030 Challenge promoting that new buildings and major renovations be carbon neutral – using no energy from GHG-emitting sources – by the year 2030. The Challenge has been adopted by many leading industry organizations including the U.S. Conference of Mayors, American Institute of Architects, the U.S. Green Building Council (USGBC), the Environmental Protection

Agency (EPA) and the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) (Architecture 2030 2010).

The U.S. Energy Independence and Security Act of 2007 has a net-zero energy target for 50% of the U.S. commercial buildings by 2040, and for all U.S. commercial buildings by 2050. This Act authorized major moves within the government agencies associated with managing public buildings and increasing building energy efficiency. The U.S. Department of Energy (DOE) launched a Net-Zero Energy Commercial Buildings Initiative supported by a national steering committee (www.zeroenergycbc.org) that began work in 2009. The U.S. General Services Administration is reducing federal building energy use toward a carbon neutrality target by 2030 (CBE 2008).

Internationally, measured building energy use is coming to the forefront through such efforts as the Climate Reduction Commitment in the U.K. (Carbon Trust 2010). Annual reporting was slated to begin in April 2010 with documented improvements in building energy efficiencies a major strategy to meet targets. The National Australian Built Environment Rating System measures an existing building's environmental performance during operation and rates a building on the basis of its measured operational impacts on the environment (NABERS 2010). Their public database contains measured performance of almost 400 commercial buildings providing a rare and valuable resource of actual energy use of buildings.

At the state level, Massachusetts developed the first statewide net-zero energy plan in 2009, encouraging adoption of net-zero energy targets for all new construction by 2030. California is also in the process of a state roadmap to zero-energy buildings. The Global Warming Solutions Act of 2006 requires California to reduce GHG emissions to 1990 levels by 2020, with later reductions of 80% by 2050 (AB 32). Both the California Public Utilities Commission and the California Energy Commission have adopted policies for all new commercial construction to meet zero energy by 2030 (CBE 2008). Policies also target specific measures such as reducing California commercial building lighting by 20% by 2018 (AB 1109). These policies all presume three key assumptions: 1) information on the measured energy use of buildings will be available, 2) significant reductions in building energy use are achievable now and will progress and 3) steps to net-zero are or will be feasible.

Mandating Measurement: Benchmarking and Disclosure Policies

In addition to the emission policy objectives are more near-term regulations to increase measured building energy use data. Adoption of mandated benchmarking and energy-use disclosure has grown substantially in the past two years. Benchmarking is gaining traction among lawmakers, environmentalists and landlords as a viable first step toward systematically reducing energy use in buildings (Greenspan 2010). Table 1 summarizes the currently adopted energy use disclosure requirements in the U.S.

Table 1: Summary of Disclosure Mandates

Jurisdiction	Name	Building Type	Effective
California	AB 1103	Comm'l	January 2011*
DC	Energy Act of 2008	Comm'l	2010*
Austin, TX	Energy Cons. & Audit Disclosure Ordinance	Comm'l & Multi-Family	June 2011
Washington	SB 5854	Comm'l	January 2011*
New York City	No. 476-A	Comm'l & Multi-Family	May 2011
Seattle	CB 11673	Comm'l & Multi-Family	April 2011*

** has a phase-in provision. Source IMT 2010: Details at: http://imt.org/benchmarking-and-disclosure.html*

These six regulations are the start of a turning point in the public gathering and comparison of building energy use that can enable better decisions by architects, engineers, owners, tenants, policymakers and energy researchers.

Voluntary efforts. Voluntary efforts toward benchmarking have been almost singularly driven by private-sector participation and utility support in the 10-year effort of EPA's Energy Star Portfolio Manager Program. This largest collection of actual building energy usage information contains data on 130,000 Energy Star participant buildings totaling almost 15 billion square feet of commercial building space. Nearly 9,000 top performing buildings - representing close to 1.6 billion square feet - earned the Energy Star label[1] through December 2009 (EPA 2010).

There are over 3,000 Energy Star partners in this program, with the top 15 representing some of the largest and leading real estate management companies in the U.S. These 15 alone collectively represent 44% of the total Energy Star rated square footage in the Program.
Energy Star participation reflects a growing interest in benchmarking. In 2009, there was a 25% increase over 2008 in the amount of commercial floorspace that was rated. About 60% of this space is being repeatedly rated for its energy use, which indicates that regular assessment is becoming a standard practice for many (EPA 2010).

This documented level of market participation and rating information will help support energy use policy development. For example, the District of Columbia's healthy market for LEED[2] buildings and wide use of EPA's Portfolio Manager allowed them to reject the argument that "green" building is too costly when adopting their disclosure policy (Rahim 2009).

The Case for More Case Studies

In February 2009, the Commercial Real Estate Development Association published findings showing that reaching a 30% reduction beyond the ASHRAE 09.1-2004 Standard is not feasible using common design approaches and would exceed a 10-year payback. The study concluded that achieving a 50% reduction beyond the standard is not currently reachable (ConSol 2008). These results were quickly and widely refuted, but they fueled the need to document and make available greater information on the actual results of buildings and the market entities electing to pursue low-energy buildings.

Rebuttals to the study cited numerous projects that not only demonstrate actual savings beyond the study parameter but, more importantly, show that these buildings met financial criteria reasonable to the owner. For example, the BetterBricks Integrated Design Lab directors provided a list of over 50 buildings that have achieved levels better than 30% over Washington or Oregon code (which are slightly better than the levels of ASHRAE 90.1-2004). A study of 121 LEED buildings found that on average LEED buildings were achieving savings of 28%[3] with one-quarter above 50% and some as high as 75%, while 21% of the buildings studied had actual energy use greater than the code comparison (NBI 2008). A recent post-occupancy evaluation of the Oregon Health Sciences University building in Portland, Oregon, found the building savings to be close to 50% over ASHRAE 90.1-2004, with an incremental cost for energy efficiency measures of less than 1% of total cost (Jennings 2009).

[1] Buildings earn the Energy Star label by achieving a score of 75 or higher on EPA's energy performance rating system. These buildings typically use 35 percent less energy than average buildings.
[2] Leadership in Energy and Environmental Design
[3] Savings compared with code baseline. Most study buildings used ASHRAE 90.1-1999.

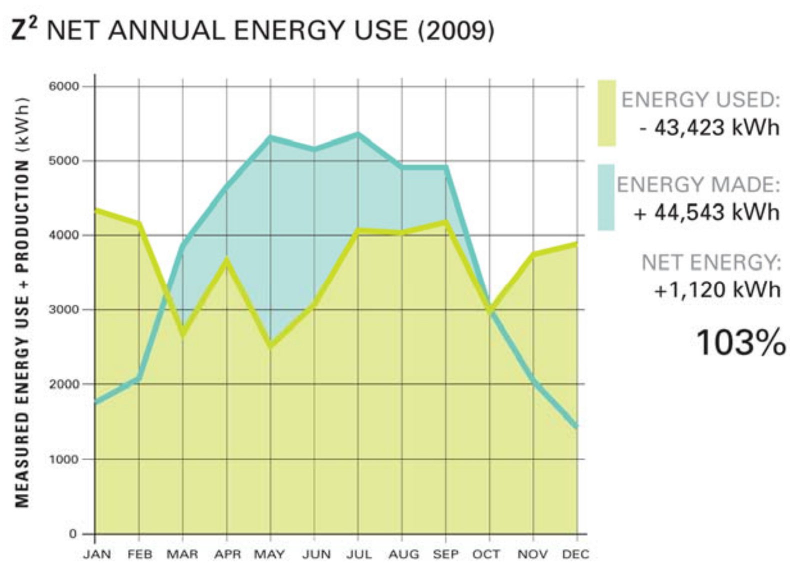
Examples like these validate the potential for achieving low-energy buildings. In searching for measured energy results of commercial buildings just two public sources with large samples can be easily found: the Commercial Building Energy Consumption Survey (CBECS 2003) with approximately 5,200 buildings and the California Energy Use Survey (CEUS 2006) with 2,790 buildings. These resources together represent data on less than 1% of the U.S. commercial building stock - and even if the EPA data were made available the total would still be only 3% of all buildings in the U.S. A literature search for case studies on buildings with actual measured energy performance requires extensive time at approximately 30 sites resulting in less than 1000 project examples. Larger data sets on building characteristics, energy use and case studies would be highly valuable as a comparative design and performance resource.

Getting to Zero

If 30-50% reduction in energy use is the intermediate, and immediate, target for buildings toward these policy goals, then the progress of buildings designing for or achieving full net-zero energy is proof of the possible for the next steps.

The IDeAs "Z^2" (net-zero energy and zero carbon emissions) building in San Jose, California, is designed to demonstrate how thoughtful design and a full complement of sustainable design techniques can merge to achieve ultra high energy at 60% below ASHRAE (IDeAs 2010). According to principal Mark Fisher "We didn't do anything that other people can't do, we just decided to do now what many people will be doing ten years from now." (CBE 2008). This 7,000 square foot office building has actual energy use of just 6.2 kWh/sf/yr (21 kBtus/sf/yr) as shown in Figure 2 and produced more energy than it used in 2009.

Figure 2: Monthly Energy Use and Solar Production[4] - IDeAs Z^2 Building



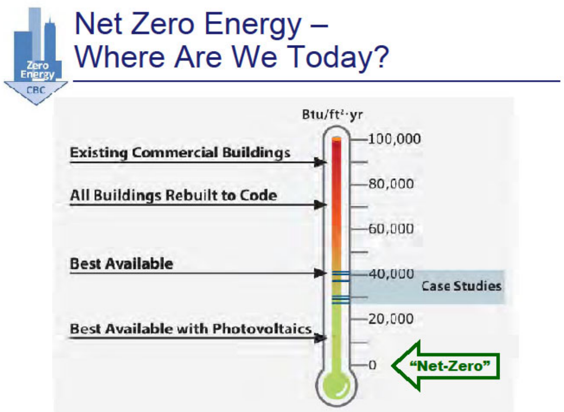
Source: EHDD Architects

On the other end of the size scale, the National Renewable Energy Laboratory (NREL) is under construction on their Resource Support Facility (RSF) in Golden, Colorado, with an

[4] Energy Made in the Figure refers to solar energy produced on site

ambitious goal of a zero-energy building based on a requirement for an energy use intensity (EUI), including the data center, of just 35 kBtus/sf/year. By comparison, conventional office buildings built over the past 30 years typically use *three times* more energy than this without the large data center of the RSF. The NREL requirement is 50% more energy efficient than the new 2004 ASHRAE commercial energy code (ASHRAE 2009). The building is, as expected, being highly monitored and documented and will become a significant case study on very low-energy-use buildings and net-zero achievements. Figure 3 shows how case studies on the "Best Available" buildings are a core part of the transition toward net-zero buildings.

Figure 3: Case Studies Support Moving from Today to NZE



Source: P. Torcellini, NREL

The Getting to 50 Database

The GT50 database is a searchable collection of information and case studies on over 100 buildings targeting low energy use. The database was launched in 2007 and is freely available on the web at www.newbuildings.org/advanced-design/getting-50-beyond.

Background

In Atlanta in March 2007, a group of 60 experts in energy efficiency joined the two-day *Getting to 50* (GT50) Summit. *Getting to 50* was selected as the name partly in reference to the Energy Policy Act of 2005 (EPACT 2005) which provides tax incentives for buildings designed to use 50% or less of the energy of the Standard in place at that time (ASHRAE 90.1-2001). The name also implies a critical milestone on the path to zero-energy buildings.

The GT50 Summit was a working meeting, designed to develop concepts and networks that would progress toward solutions to reduce energy use in new and renovated commercial buildings. In preparation for this Summit, a review of new U.S. commercial buildings designed to be significantly more energy efficient than typical construction was undertaken. Only 1 in 1,000 was found to meet the EPACT 05 standard (NBI 2007). Yet the types of energy efficiency strategies adopted by designers and/or owners of these low-energy buildings were seen as informative with the potential to transform the market.

There was strong consensus on the power of example. One of the outcome recommendations from the Summit was to increase the amount of easily accessible and public information and case studies on the design, technologies and energy data from buildings striving for very low energy use. The initial research became the basis for the GT50 database and continues as an ongoing effort toward this goal.

Database development. The first step in the development of the GT50 database was to gather building data gleaned from a number of national databases of energy efficient or green commercial new construction buildings. Additional buildings from research efforts were also solicited. Buildings with stated energy use (modeled or measured) were screened to determine whether they approached a threshold of 30% or better than ASHRAE 90.1-2001 as an indication of pursuing low energy use and being on a path to fifty-percent savings. Often the savings were not given in reference to ASHRAE 90.1-2001 specifically but were defined as "better than a code-minimum building." Finally, a few buildings that did not meet this threshold were included if they had a unique approach or were good illustrations of a technology.

The second step was to characterize the project by type, climate zone, size, cost-per-square foot (if available), LEED level, EUI and location. The types of technologies and systems most responsible for the savings were identified. Where possible, links to the best articles or additional case studies on each project were provided.

The GT50 database is built as a portal from the DOE National High Performance Building (HPB) database. Being a portal allows the GT50 site to be discrete and filter buildings in the National HPB database for parameters aligned with the GT50 site objectives and allows the ability to input additional building information. The GT50 database site also has an additional search feature for those studies with actual energy data.

Review Results

As of May 2010, there are 91 buildings online in the GT50 database; 32 more are under review. All of these 123 buildings have information on the building characteristics, design features, energy technologies, and energy use information. For the purpose of this study and paper, buildings with estimated or predicted energy use were removed resulting in a subset of 62 buildings with actual measured building energy data[5]. Currently only 39 of these buildings are on line due to the time and process necessary to get permissions to post each building's information by name. All buildings were built or had a major renovation in the past five years. These 62 buildings were screened against the CBECS 2003 dataset as a common baseline due to the variability of codes and references in the building documentation.

Key Findings

Key findings of the review of these buildings include:

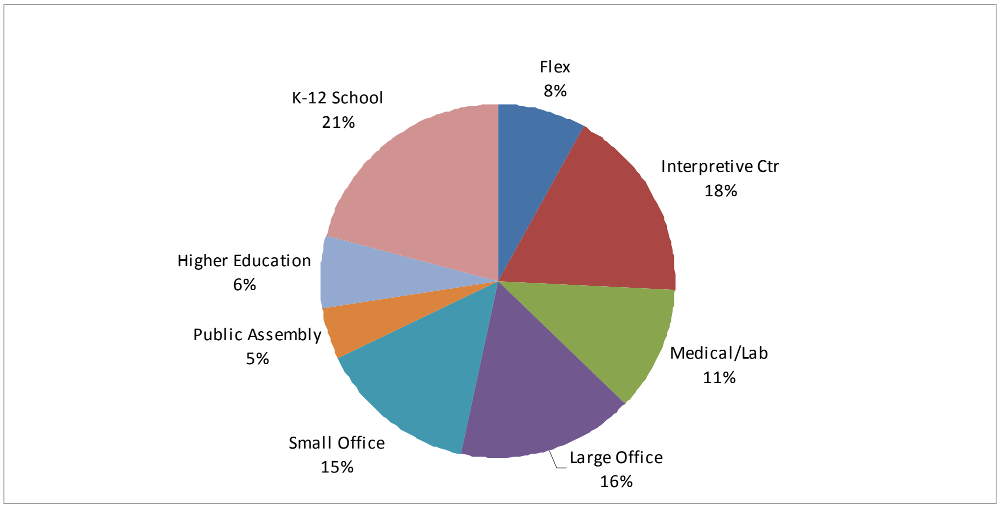
- It is rare to achieve low energy use without integrated daylighting control. Daylighting and advanced control strategies were referenced in nearly all buildings.
- Features previously considered as innovative, such as natural ventilation and underfloor air/displacement ventilation, were present in 20-40% of the buildings and appear to be growing trends.

[5] All data is self-reported. No independent validation is required for input to the database but all input is reviewed for clarity and reasonableness prior to acceptance.

- Low-energy buildings were found across the country, but more were located in states with strong energy efficiency programs; fewer buildings were located in hot, humid climates.
- The average energy use was 50% or less than CBECS 2003.
- Several buildings reduced designed energy use by 70-80%, a level that could easily lead to a zero-energy building with a moderate size photovoltaic array.

Project types and locations. Figure 4 shows the breakout of the project types. Large and small offices are the largest use type in this selection of the GT50 database (31% of the buildings). The K-12 and Higher Education buildings combined represent 27% of the GT50 buildings with actual energy use data. Interpretive Centers follow with 18% and Medical/Lab with 11%. Although retail is a large part of the commercial sector, the only retail buildings in this data set were mixed-use with office and are included under "Flex."

Figure 4. GT50 Buildings with Energy Data by Type



In addition to a good variety of building types, there is a broad geographic distribution, representing a wide range of national locations and climates as shown in Table 2. Although these buildings were found across the country, more were located in states with strong energy efficiency programs, and fewer buildings were located in hot, humid climates

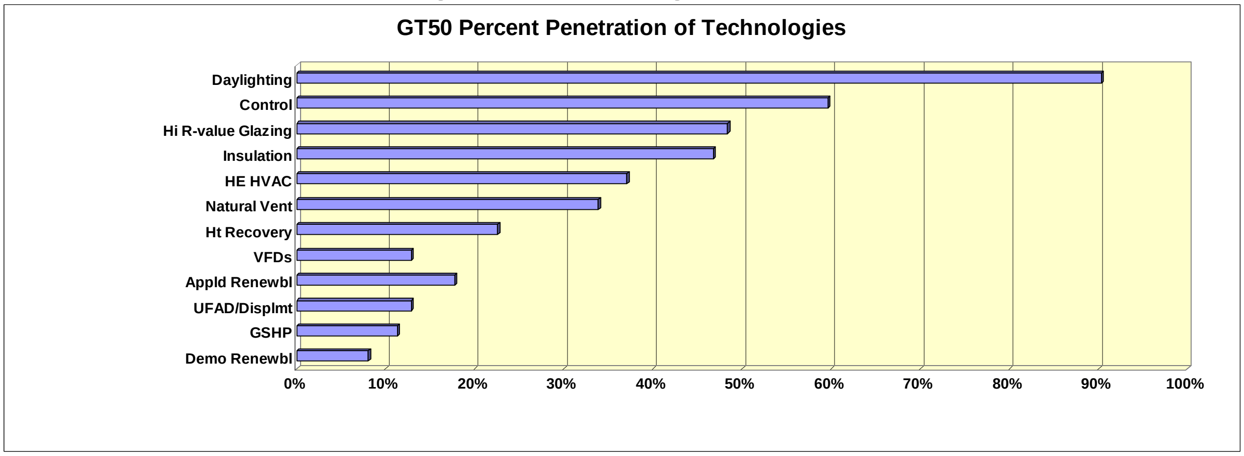
Table 2: Geographical Diversity of Buildings

Alabama	Illinois	Montana	Tennessee
CA - South	Iowa	New Hampshire	Texas
CA - Central	Maryland	North Carolina	Utah
CA - North	Mass	Ohio	Vermont
Georgia	Michigan	Oregon	Washington
Hawaii	Missouri	Penn	Wisconsin

Technology characteristics. Twelve commonly used technologies have been identified by frequency of use. Figure 5 shows the percent of the buildings that utilized these technologies.

Note that these results are based on this very small sample of 62 and are provided here to characterize the sample, not buildings in general.

Figure 5. Technologies in GT50



Technology specifics. Some of the findings and conclusions in reviewing the technologies selected by these leading buildings are:

- Daylighting and controls appear in nearly all buildings. Given the double benefit of reduced watts/sf and reduced cooling load, these make sense as major contributors.
- Daylighting typically included controlling electric lighting through dimming or step relay controls, with many systems including occupancy control.
- Control of lighting and HVAC was mentioned as important in most cases.
- High-efficiency equipment was usually called out in the mechanical systems.
- High-performance glazing was the most frequently mentioned shell element.
- PV systems tended to be on public buildings as a demonstration or on larger corporate buildings where the extra cost could be more cost competitive.
- While a few technologies, such as insulation and cool roofs, demonstrate a climatic tendency, the majority seem independent of climate.
- High performance is not limited by size, per-square-foot cost or geography.

Size and energy use. The average energy use by building type was compared with the averages in CBECS 2003 and is shown in Table 3. The GT50 subset is performing near or beyond 50% of this national baseline of building energy use. Some buildings exceeded CBECS by more than 70% with several having EUIs less than 25 kBtu/sf/yr. These projects are potentially in reach of net-zero energy depending on options for site renewable energy.

Table 3. Size and EUIs for GT50 Buildings by Type

GT50 Projects with Energy Data					CBECS 2003 Reference		
Building Type	Quantity (n)	Avg. Bldg. Size (000s SF)	Avg. Measured EUI (kBtu/SF/Yr)	Standard Deviation (σ)	CBECS type	CBECS Avg. EUI (kBtu/SF/Yr)	GT 50 group % better than CBECS avg.
Flex	5	34	33	13	*	75	56%
Interpretive Center	11	12	33	9	Public Assembly	66	50%
Medical/Lab	7	112	141	73	Laboratory	360	61%
Large Office	10	365	54	16	Office (>50k sf)	106	49%
Small Office	9	28	41	11	Office (<50k sf)	77	47%
Public Assembly	3	41	35	3	Public Assembly	66	47%
Higher Education	4	47	30	12	Education- general	76	61%
K-12 School	13	121	33	12	Education- K-12 School	75	57%
Total:	62						

** For Fex building types, an average between Office and Retail Store CBECS average EUI was used*

UC Merced – Got to Fifty

Pilot GT50 case studies were developed on two new buildings at the University of California Merced (UC Merced) to provide examples of evaluation and documentation of high-efficiency buildings. The information in the case studies is intended to allow replication of results, and eventually extension of the results to the design of even higher efficiency buildings. The full case studies and other papers on the policies, construction and continuous commissioning process are available through the California Institute for Energy and the Environment (CIEE 2010). Here a snapshot of the benchmarks and performance results of the Classroom and Office Building (COB) is given to provide an example of a GT50 case study.

Classroom and Office Building Energy Performance

The COB is one of five buildings in the initial phase of development at UC Merced. It is three stories tall, 103,006 gross square feet, and was completed in January 2006. The building provides multi-disciplinary instructional and research office space for the Merced campus. The energy measurements occurred from July 2007 through June 2008.

Performance targets. The campus established a goal of using 50% less energy than comparable university buildings. To meet this target, the project team developed energy-use benchmarks for the campus and each building based on data, adjusted for building type and climate, from eight other UC and California State University campuses (Brown 2002).

Performance targets were set as a percentage of benchmark metrics. The target for COB and other buildings in the first major phase (600,000 gross square feet) of construction is to operate at or below 80% of benchmark (a 20% reduction in energy consumption). Incremental targets for future phases moved towards a 50% of benchmark goal. UC Merced's energy performance targets are unique in that they account for the entire building performance, not just selected systems, as is the case with building code-based targets (such as California's Title 24 and the earlier versions of LEED). In addition to the benchmark-based performance targets, UC Merced set a goal of performing at least 30% better than California's Title 24 for all buildings in order to qualify for LEED ratings and utility incentives.

The project team incorporated the energy performance targets into the design specifications for each building. This ensured the design and construction team would make decisions within this constraint and reduced the risk of having energy efficiency measures compromised through value engineering.

Performance results. Table 4 shows that the COB has exceeded the 80% of benchmark energy performance target with all metrics, almost nearing the 50% of benchmark goal that is assigned to future phases. Note that the Annual Site EUI Benchmark established is 71 kBtu - 33% lower than the comparison CBECs site large offices EUI of 106 kBtu - so this building is performing well beyond large U.S. offices. By comparison, the as-operated energy use of 45.5 kBtu is almost 20% better than the office buildings in the GT50 data set.

The "best practice" plant efficiency levels are consistent with initial design expectations and should be achievable through a number of improvement measures under review. Thus, COB has the potential of performing even better in the future, as central plant issues are addressed. The UC Merced team plans to continue monitoring, comparing actual results to the "best practice" estimates.

Table 4. Benchmarks and Energy Performance of UC Merced COB Building

Metric	Benchmarks		Target	As-Operated		Best Practice Plant [4]	
	Value	Units	80% of benchmark	Value	% of benchmark	Value	% of benchmark
Annual Site Electricity [1]	15.1	kWh/gsf	12.1	9.03	60%	8.49	56%
Annual Site Gas [2]	0.20	therms/ gsf	0.16	0.15	75%	0.13	67%
Annual Site EUI	71.1	kBtu/gsf	56.9	45.5	64%	42.2	59%
Annual Source EUI [3]	159	kBtu/gsf	127	97.8	62%	91.4	58%

(1) Including pro-rated central plant chiller energy use and distribution losses. These figures include approximately 5% transformation / distribution losses and exterior site lighting not typically a part of metered usage for stand-alone buildings. (2) Including pro-rated central plant heating efficiency and loop distribution losses. (3) Site to Source conversion factors from CalArch: 2.7 for electricity, .1.0 for natural gas. (4) Best Practice Plant efficiency assumptions compared to As-Operated: Source: UC Merced COB Case Study at www.newbuildings.org

Based on the encouraging results from the first phase of construction, UC Merced expects to achieve their 50% of benchmark performance target. With confidence grounded in this initial success, UC Merced is already setting goals to achieve net-zero energy by 2020 through aggressive conservation efforts and development of onsite renewable power.

Conclusions

The long term view of strategic energy planners and policy makers is that we must significantly reduce the impact of our building stock on the planet and the economy. Net-zero buildings, initially seen as an environmental necessity, are being increasingly recognized as eminently doable and fiscally prudent. A key ingredient to progress is information – information linking design to performance, linking experiment to success, or failure. Nothing makes the case as eloquently as real buildings backed by real data. As we bootstrap our way from energy wasters to high efficiency, we need to measure performance and use it as our yardstick for success.

The *Getting to 50* data base is one such starting point for just such a resource. The broad conclusion drawn from this set of buildings is that very low-energy buildings of various types and sizes can be built today across the country, supported by a wide mix of owners and design teams. Owners, architects and engineers can clearly see for themselves that the GT50 goal is attainable in all climates, across all common building uses and in both new and retrofit construction.

So far, just a few buildings have attempted to reach this performance level. The barriers to widespread design and construction of low-energy buildings are not technical in nature, nor do they appear to be financial, but are more likely related to the motivation of owners, the skill set of the design and construction teams, and their common understanding of what is possible. Increasing easily accessible data and case studies of measured performance is a critical bridge to that understanding.

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