GSA Public Buildings Service
Office of Applied Science
Applied Research

ASSESSING GREEN BUILDING PERFORMANCE

A POST OCCUPANCY EVALUATION OF 12 GSA BUILDINGS

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SUSTAINABILITY

The Office of Applied Science supports GSA's Public Buildings Service by generating research findings and recommending business improvements that can be directly applied to real world situations. The mission of the Public Buildings Service is to provide superior workplaces for federal customer agencies at the best value to the American taxpayer.

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National Park Service,
Omaha, Nebraska

Photo Credit: Kessler Photography

INTRODUCTION

SUSTAINABLE DESIGN DELIVERS

To answer the question, 'does sustainable design deliver?' GSA evaluated 12 sustainably designed buildings in its national portfolio. The evaluation of these buildings was comprehensive—measuring environmental performance, financial metrics, and occupant satisfaction. No previous analysis has taken such a holistic view. The buildings studied all incorporated sustainable design criteria to varying degrees, with seven receiving LEED ratings. The results of GSA's evaluation show that sustainably designed buildings outperform the national average for buildings of their type by a substantial margin.

INTEGRATED DESIGN YIELDS EVEN BETTER PERFORMANCE

The best performing buildings in the study were those that took a fully integrated approach to sustainable design—addressing site development, water savings, energy efficiency, materials selection, and indoor environmental quality. As America's largest public real estate organization, GSA has a special responsibility to lead in building sustainably and meet federal mandates, including energy policies and Executive Orders. What the evaluation shows is that a fully integrated approach to sustainable design is helping GSA to meet its mandates by delivering buildings that use substantially less energy, cost less to operate and maintain, and lead to greater occupant satisfaction.

NEEDED NEXT: NATIONAL SUSTAINABLE BUILDING DATA

This study is an important first step in a much-needed national assessment of sustainable building performance in the public, private, and institutional sectors. GSA's evaluation establishes a new benchmark for comprehensiveness using a protocol that others can follow, both in the federal and private sectors.

RESEARCH OVERVIEW

Integration Means High Performance

"This study breaks new ground by comparing GSA's sustainably designed buildings against US commercial buildings, using the latest performance data. Its findings will be relevant to building owners and developers, public and private, across the country."

-DAVID WINSTEAD
Commissioner, Public Buildings Service

The US General Services Administration (GSA) commissioned a comprehensive post-occupancy evaluation of 12 of its sustainably designed buildings.[1] The measures studied included environmental performance, financial metrics, and occupant satisfaction. No previous US study has taken such a holistic approach to building performance. The LEED buildings evaluated represented one-third of the total LEED buildings in GSA's national portfolio at the time the study was conducted.

The study compared the energy performance, operating cost, and water use of the 12 GSA buildings against the average performance of US commercial buildings, using the following sources of data:

Measurement	Data Source[2]
Energy Performance:	CBECS National Survey of Commercial Buildings constructed between 1990 and 2003[3]
	ENERGY STAR[4]
Maintenance Costs:	IFMA[5] and BOMA[6] 2006/2007 Surveys reporting 2003-2005 data
Water Use:	Federal Water Use Index[7]
Occupant Satisfaction:	Center for the Built Environment, UC Berkeley[8]

The study found that GSA's green buildings outperform national averages in all measured performance areas—energy, operating costs, water use, occupant satisfaction, and carbon emissions. The study also found that GSA's LEED Gold buildings, which reflect a fully integrated approach to sustainable design—addressing environmental, financial, and occupant satisfaction issues in aggregate—achieve the best overall performance.

KEY FINDINGS:

Compared to national averages, buildings in this study have:

26%
Less energy use
(65 kBtu/sf/yr vs. 88 kBtu/sf/yr).

13%
Lower maintenance costs
($2.88/sf vs. $3.30/sf)

27%
Higher occupant satisfaction

33%
Fewer CO_2 emissions
(19lbs/sf/yr vs. 29lbs/sf/yr)

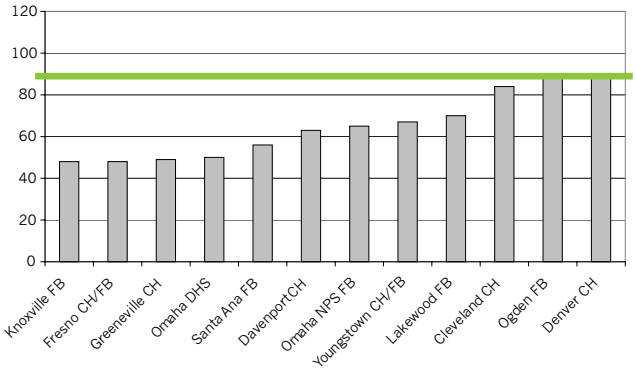
GSA STUDY BUILDINGS

Figure 1: Performance Metrics

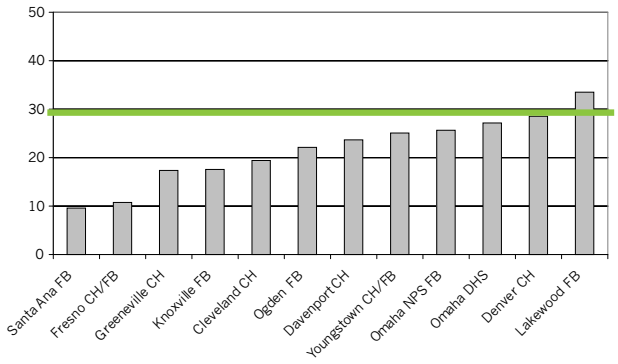
On average the 12 sustainably designed buildings in the study outperformed US commercial buildings.

Indicates National Average

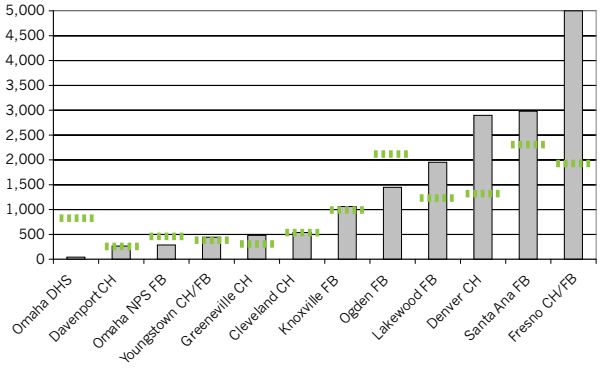
Indicates Building Baseline



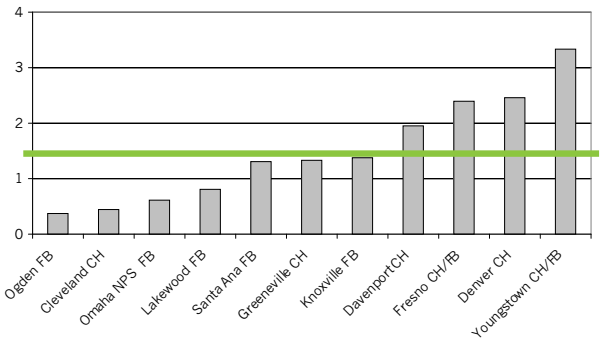
ENERGY USE INTENSITY
(kBtu/sf/yr)



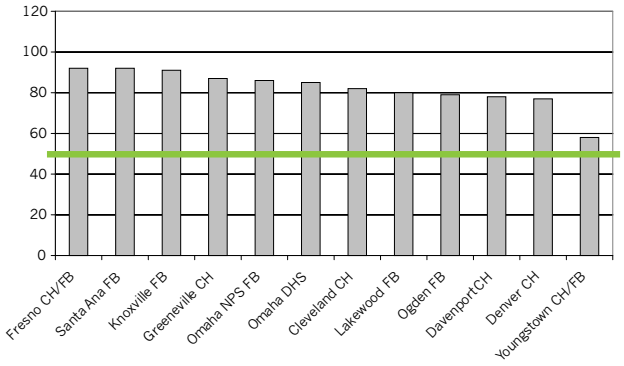
CO_2 EMISSIONS
(lbs/sf/yr)



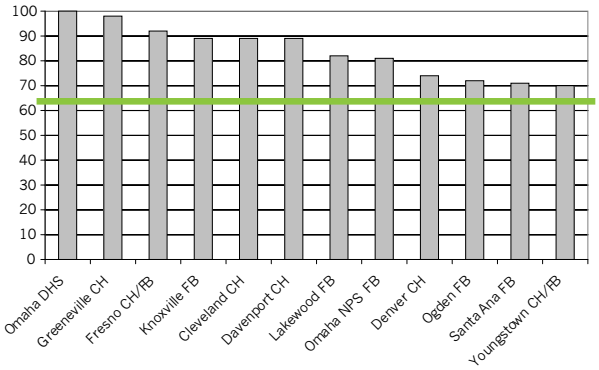
WATER USE
(Thousand gallons/yr)



MAINTENANCE COSTS
($/sf)



ENERGY STAR
SCORE



OCCUPANT SATISFACTION
(% Satisfaction)

RESERCH CONTEXT

A Comprehensive Evaluation

"We believe that 'green' building and sustainable design and operation has a very positive impact on the people that work in our buildings, in terms of their morale and productivity. 'Green' building is the right thing to do, and it's also the right business thing to do."

DAVID BIBB
Acting Administrator, GSA

GSA asked Pacific Northwest National Laboratory (PNNL) to evaluate 12 of GSA's sustainably designed buildings, and answer this question:

While sustainably designed buildings promise higher performance, do they deliver?

The study evaluated actual, not modeled, building performance, so the results are reliable and objective. Successes and shortcomings were identified, along with areas requiring further research, to provide best practices to emulate and actions to take to improve performance.

The 12 buildings selected reflect different US regional climates, a mix of uses (courthouses and offices), and a mix of build-to-suit leases and federally owned buildings. Land ports of entry were excluded because, as a building type, they are too different to allow meaningful comparisons. Eight of these buildings were designed to meet or exceed basic LEED certification. The other four were designed to meet the requirements of other programs, including ENERGY STAR and the California Title 24 energy standard.

The research team used a consistent evaluation process for every building studied:

- Obtaining and reviewing one year of operating data
- Surveying building occupants
- Interviewing the building manager
- Conducting an expert walkthrough

To make the study useful to a larger audience, the team compared each performance measure with the national average for US commercial buildings. The latest available benchmark data comes from widely accepted industry and government standards.

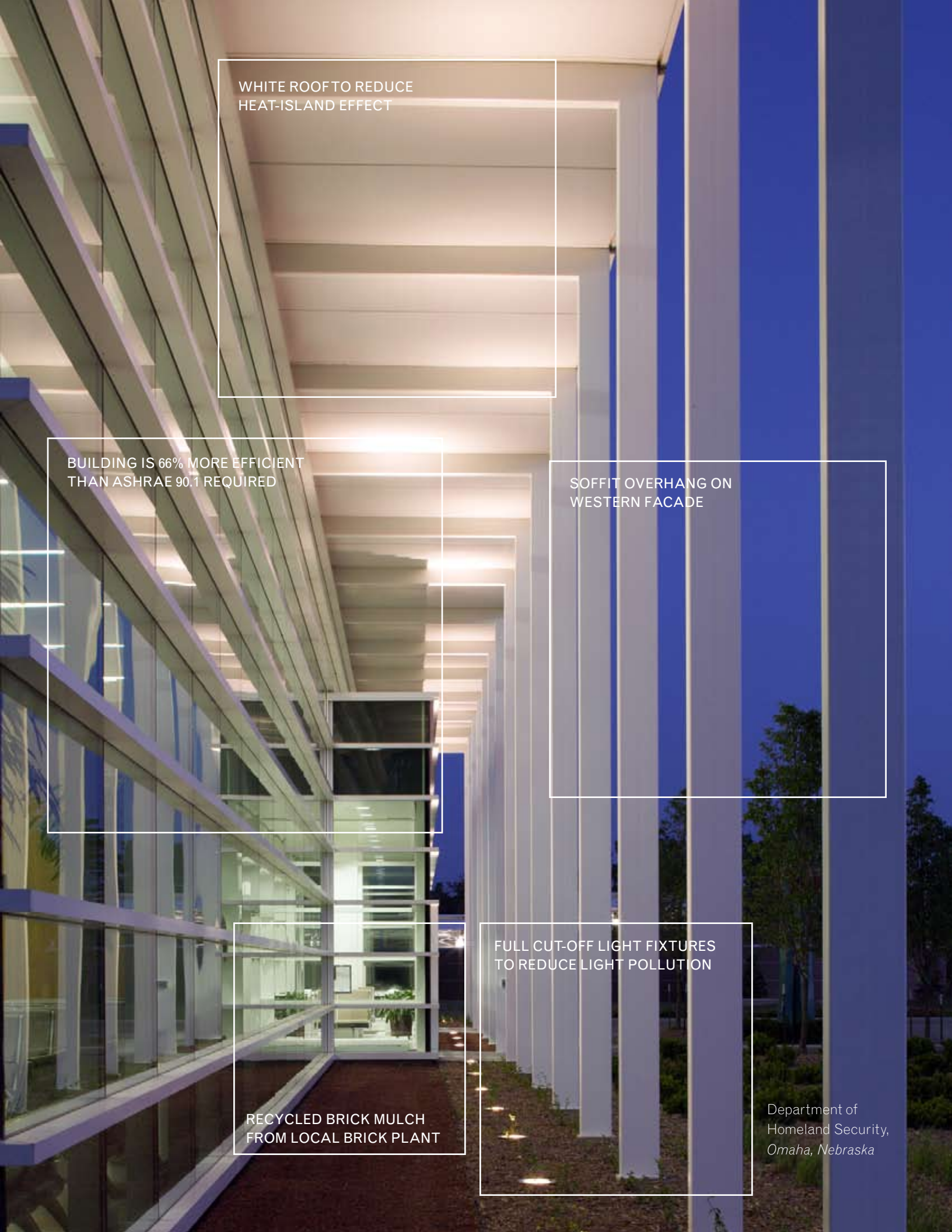
ABOUT THE LEED GREEN BUILDING RATING SYSTEM

The US Green Building Council's (USGBC) Leadership in Energy and Environmental Design (LEED) Rating System is a nationally accepted third party certification program for green building design, construction, and operation. As the USGBC puts it, "LEED promotes a whole-building approach to sustainability by recognizing performance in five key areas: sustainable site development, water savings, energy efficiency, materials selection, and indoor environmental quality." LEED closely approximates GSA's holistic approach to sustainable building development and operation.

The LEED Rating System addresses new construction and renovation, operations and maintenance of existing buildings, design of commercial interiors, building core and shell development, as well as neighborhood development and homes.

LEED provides four measures of performance: basic certification, Silver, Gold, and Platinum, based on a set of prerequisites and credits in the five major categories listed above. Each measure represents an incremental step toward integrating the different components of sustainable design, construction, and operation to achieve optimal performance.

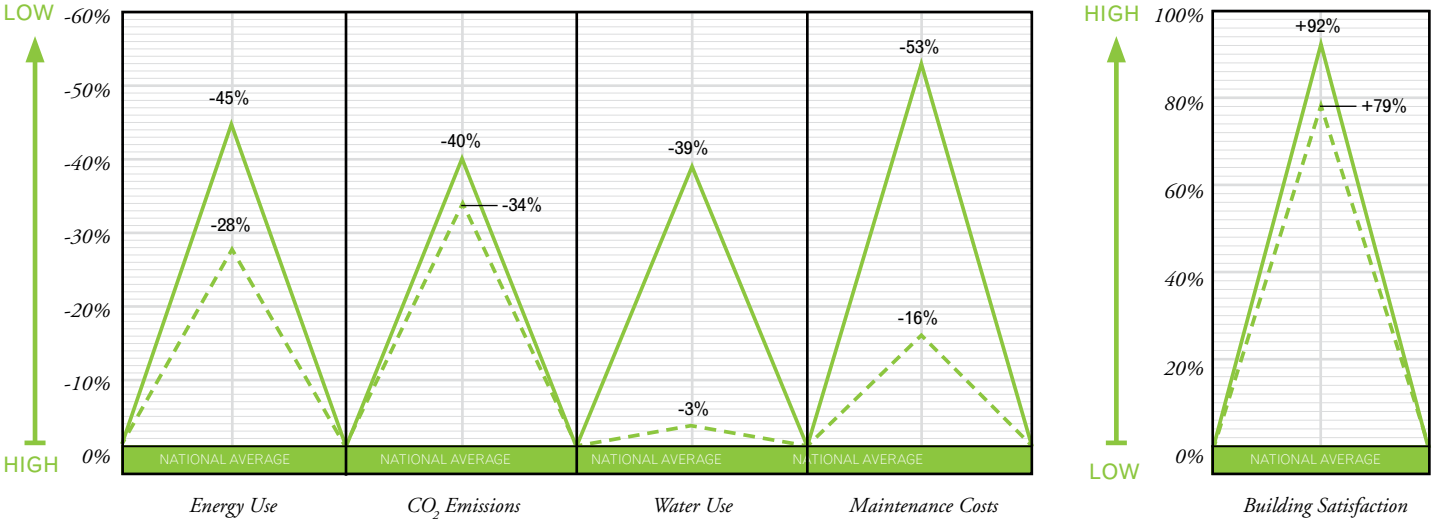
Learn more:
For more information on the LEED Rating System: www.usgbc.org



Department of
Homeland Security,
Omaha, Nebraska

HOW THE GSA STUDY BUILDINGS PERFORM

Figure 2: Comparison Against National Averages



THE TOP PERFORMING BUILDINGS IN EACH METRIC DELIVER SIGNIFICANTLY BETTER RESULTS THAN THE NATIONAL AVERAGE.

TOP THIRD OF STUDIED BUILDINGS

MIDDLE THIRD OF STUDIED BUILDINGS

GSA STUDY BUILDINGS: FAST FACTS

Year Built: 1910
Year Renov: 2005
Employees: 105
Energy Star: 82
CO_2e: 2,440 mt
LEED-NC Certified

CLEVELAND

The Metzenbaum Courthouse is on the National Register of Historic Places. The renovations preserved 96% of the existing shell and 59% of the interior elements.

The courthouse won GSA's Environmental Award for recycling because of its seven-material collection system and green housekeeping practices.

Year Built: 1933
Year Renov: 2005
Employees: 45
Energy Star: 78
CO_2e: 945 mt
LEED Registered

DAVENPORT

The Davenport Courthouse is on the National Register of Historic Places. The renovation maintained the integrity of the historic space, while updating the mechanical systems in the building.

The courtrooms incorporate techniques to bring in daylight and the mechanical systems use variable speed drives. The HVAC system consists of water-cooled chillers, boilers, and air handling units.

Year Built: 2002
Employees: 170
Energy Star: 77
CO_2e: 4,668 mt

DENVER

The Arraj Courthouse was designed as a green courthouse prior to the completion of the LEED rating system. It is currently seeking LEED for Existing Buildings Certification.

Denver employs a hybrid underfloor air distribution system, HVAC and lighting sensors, as well as photovoltaic panels.

Year Built: 2001
Employees: 85
Energy Star: 92
CO_2e: 2,666 mt
CA Energy Standard Title 24

FRESNO

The Coyle Courthouse and Federal Building houses 14 courtrooms and is the tallest building in the city (11 floors high).

Designed under California's Title 24 energy standard, the building includes high efficiency lighting, underfloor air distribution systems, water-cooled chillers, and natural gas boilers.

Year Built: 2001
Employees: 85
Energy Star: 87
CO_2e: 1,397 mt

GREENEVILLE

The Quillen Courthouse replaced a smaller courthouse from which the occupants reclaimed quality historic furniture.

Some of the energy-efficiency features include a well-insulated white roof and an Energy Management Control System of lighting and occupancy sensors. It also scores the highest occupant satisfaction for air quality, acoustics, and lighting.

Year Built: 2001
Employees: 252
Energy Star: 80
CO_2e: 2,150 mt
LEED-NC Silver

LAKEWOOD

The facility at Lakewood for the Department of Transportation is a LEED Silver-leased building.

Some features include low-emitting material selection, and daylight and views in 91% of regularly occupied spaces. In addition, all building occupants receive a booklet about the design and operations of the building.

Year Built: 2001
Employees: 252
Energy Star: 85
CO_2e: 1,168 mt
LEED-NC Gold

OMAHA DHS

The Omaha Department of Homeland Security was designed to house multiple DHS agencies, and recently won the 2007 American Council of Engineering Award for its design.

As a LEED Gold building, the facility incorporates daylight and rainwater-harvesting systems, a ground source heat pump, and Green Seal janitorial products.

Year Built: 1975
Year Renov: 2005
Employees: 409
Energy Star: 92
CO_2e: 1,344 mt
CA Energy Standard Title 24

SANTA ANA

Renovated in 2005, the Santa Ana Federal Building lies in the heart of the civic center district and accommodates a large flow of visitors to the building each day.

This building features high-efficiency lighting and HVAC systems, a new roof, energy-efficient elevators, and lighting sensors.

Year Built: 1986
Year Renov: 2005
Employees: 285
Energy Star: 91
CO_2e: 1,516 mt
LEED-EB Silver

KNOXVILLE

Located in downtown Knoxville, the Duncan Federal Building currently houses a range of services including the FBI, US Customs, and HUD.

Alterations to the building incorporate high-efficiency lighting, enhanced metering techniques, and low-flow fixtures. The roof reduces the heat island effect, as well as housing photovoltaic panels.

Year Built: 2001
Employees: 252
Energy Star: 79
CO_2e: 1,161 mt
LEED-NC Silver

OGDEN

Renovations transformed the historic Scowcroft Federal Building into usable office space meeting the IRS's specific needs.

The space incorporate earthquake prevention upgrades, improved roof insulation, radiant baseboard heating, and an underfloor air distribution system coupled with indirect/direct evaporative cooling.

Year built: 2004
Employees: 125
Energy Star: 86
CO_2e: 872 mt
LEED-NC Gold

OMAHA NPS

The Curtis National Park Service building was built on a brownfield as part of an urban redevelopment effort.

The building showcases passive solar design, daylight harvesting and HVAC sensors, as well as underfloor air distribution. Use of native and adaptive vegetation eliminated the need for irrigation. Operations also include green housekeeping practices.

Year Built: 2002
Employees: 45
Energy Star: 58
CO_2e: 655 mt
LEED-NC Certified

YOUNGSTOWN

The Jones Federal Building and Courthouse facility was built on a brownfield, and was part of the city's urban revitalization.

Youngstown incorporates building controls and daylighting to over 75% of occupied spaces. Unique features include a storm water management demonstration, a white membrane roof, and light-colored pavement.

FINDING 1:

Fully Integrated Design Delivers Higher Performance

GSA's sustainably designed green buildings have 26% lower energy use compared to the National Average.

(65 kBTu/sf/yr vs. 88 kBtu/sf/yr)
Source of National Average: CBECS

To achieve LEED Gold certification, credits must be obtained in all five rating areas, requiring a completely integrated approach to sustainable building design. The two LEED Gold buildings in this study clearly show that a comprehensive approach yields broad, holistic performance benefits. While neither building led in every category, these two buildings were the only ones studied that achieved consistently high levels of performance on all measures.

The **Curtis National Park Service (NPS) building,** Omaha, Nebraska, performed well in all categories. Its ENERGY STAR rating (86) is in the top third for the group. Its water costs are 91% below the BOMA/IFMA baseline. Its domestic water use is 50% below baseline. Its CO_2 emissions are 34% under baseline, putting it in the top half. Its emissions from occupants' commutes, 1.7 metric tons per person, put it in the top one-third.

The **Omaha Department of Homeland Security (DHS) building,** Omaha, Nebraska, performed well across all categories. Its ENERGY STAR rating (85) is also in the top third for the group. Its water costs are 66% below the BOMA/IFMA baseline, achieved using rainwater harvesting and low-flow and auto-flow lavatory fixtures to offset its greater public use. DHS has 65 regular occupants and 360 occupant visitors while NPS has 125 regular occupants and 134 occupant visitors. DHS's domestic water use is 58% below baseline.

LESSON LEARNED

Across all buildings studied, building performance tracks design intent. Buildings designed with a strong energy focus—compliance with California's demanding Title 24 energy code or ENERGY STAR—had outstanding energy performance, although with a lesser achievement in terms of water use intensity. One LEED certified building did not pursue energy efficiency during design. As a result, it achieved no LEED energy optimization credits, and had the lowest ENERGY STAR rating in the study.

NATIONAL BUILDING FACTS

31%
projected increase in energy consumption by the year 2030 despite dramatic gains in energy efficiency.[9]

20%
of U.S. drinking water supply is consumed by commercial buildings.[10]

2 trillion
gallons of water a year would be saved if commercial buildings reduced their water consumption by 10%.[11]

Figure 3: Top Performers by CO_2 Emissions (lbs/sf/yr)

Source of National Average: Energy Star

ALL BUILDINGS IN THIS STUDY PRODUCE A SMALLER CARBON FOOTPRINT THAN THE NATIONAL AVERAGE.

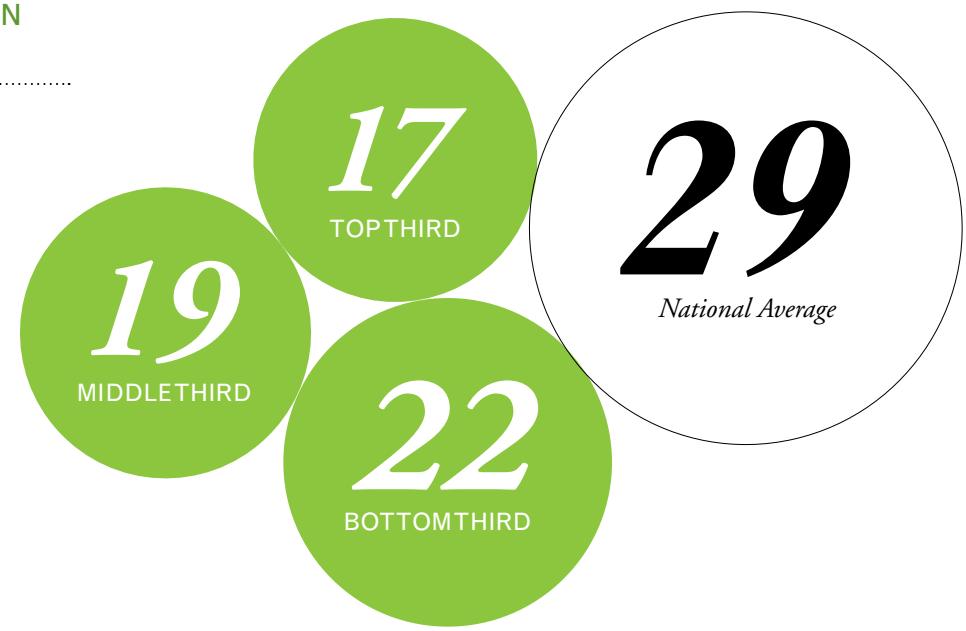
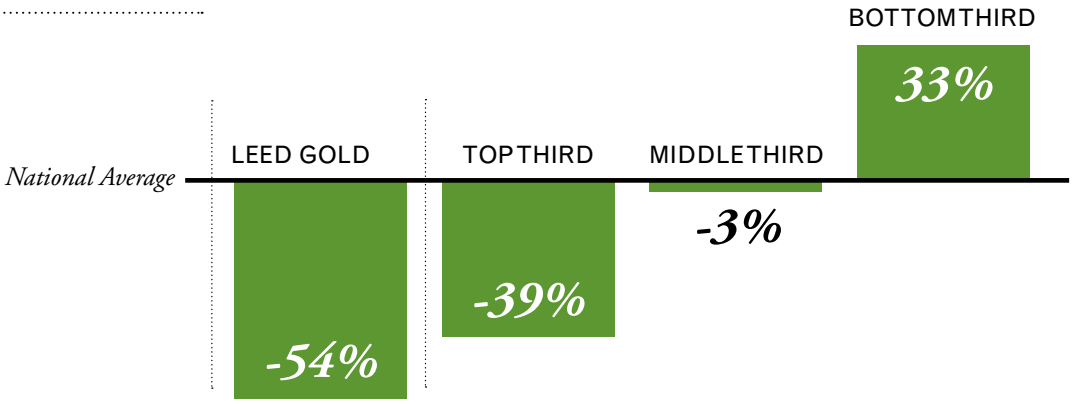


Figure 4: Top Performers by Water Use (thousand gallons/yr)

Source of National Average: Federal Water Use Index

LEED GOLD BUILDINGS IN THIS STUDY HAVE SIGNIFICANTLY LOWER WATER USE COMPARED TO THE NATIONAL AVERAGE.



Domestic Water Usage Index Compared to the National Average

FINDING 2:

GSA's Green Buildings Cost Less to Operate

The five top-performing buildings studied spent 14% to 45% less on energy than the National Average.

Source of National Average: BOMA/IFMA

Why do operations and maintenance (O&M) costs matter? Considered in aggregate, they approximate the consumption side of overall sustainable performance. As a group, the 12 buildings studied performed only slightly better than the national average for US commercial buildings: 7% below that baseline. However, the top-performing one-third of the group did much better, at 41% below.

The two LEED Gold buildings were among the best performers from an O&M cost perspective. Lower utility and janitorial costs and savings from recycling resulted in top scores for the Curtis National Park Service building and the Omaha Department of Homeland Security building. The use of green cleaning practices enhanced their performance.

On average, the bottom quartile of the buildings studied had considerably higher costs than the industry baseline: 45% above the national average for US commercial buildings. These buildings had unusually high maintenance costs and, in one case, an operating emergency.

LESSON LEARNED

The best practice lesson here is that O&M costs are lowest when sustainability is integral to every aspect of a building, including cleaning and recycling. Building and systems efficiency alone isn't enough. Upfront investments in sustainable measures need to be matched by sustainable O&M practices.

NATIONAL BUILDING FACTS

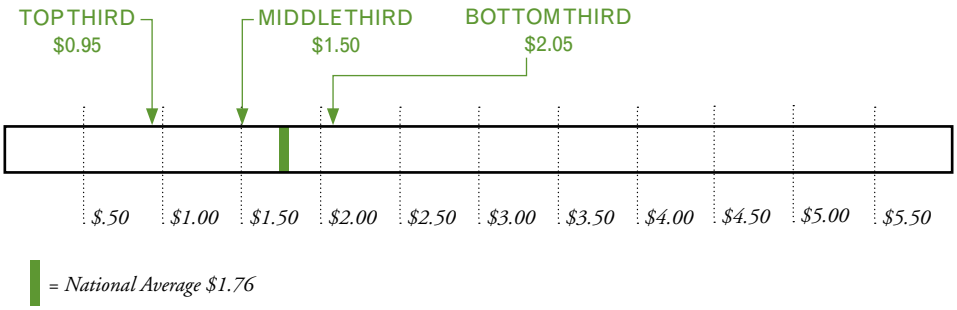
18%
of total U.S. energy use consumption comes from commercial buildings.[12]

Why water efficiency?
Between 1950 and 2000, the US population nearly doubled. In that same period, however, public demand for water nearly tripled. Americans now use an average of 100 gallons of water per day—enough to fill 1,600 drinking glasses![13]

Figure 5: Top Performers by Energy Cost ($/sf/yr)

Source of National Average: BOMA/IFMA

THE TOP-PERFORMING SUSTAINABLE BUILDINGS STUDIED SHOWED CONSISTENTLY LOWER ENERGY COSTS THAN NATIONAL AVERAGES.



Buildings in this study, on average, spend 15% less on energy than the National Average.

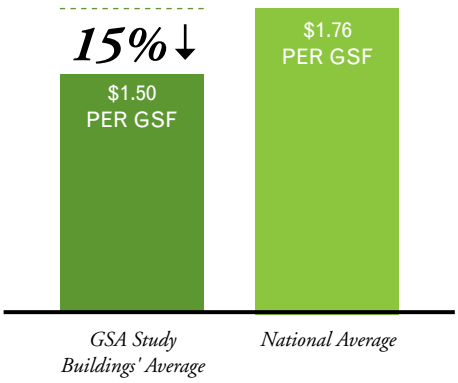
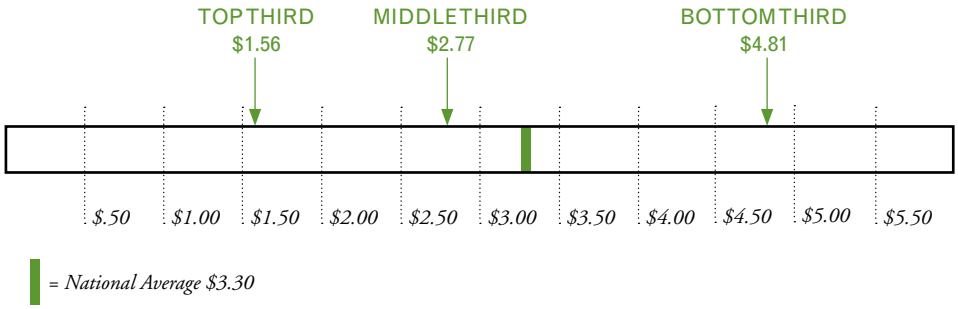


Figure 6: Top Performers by Maintenance Cost ($/sf)

Source of National Average: BOMA/IFMA

THE TOP-PERFORMING SUSTAINABLE BUILDINGS STUDIED SHOWED CONSISTENTLY LOWER MAINTENANCE COSTS THAN THE NATIONAL AVERAGE.



Buildings in this study, on average, spend 13% less on maintenance than the National Average.

FINDING 3:

GSA's Green Buildings have Satisfied Occupants

GSA's sustainably designed green buildings demonstrate a 29% higher occupant satisfaction than the National Average.

Source for National Average: CBE, UC Berkeley[3]

This study provides important new evidence that occupant satisfaction is higher in sustainably designed buildings. Occupant satisfaction is important because it correlates with personal and team performance. That often means higher productivity and creativity for an organization.

As a group, the 12 sustainable buildings studied scored better in occupant satisfaction than the national average for US commercial buildings. Half of the buildings studied scored in the top quartile for occupant satisfaction. Significantly, their average scores in all categories were higher than those of LEED certified buildings in the private sector[14]. This suggests that GSA's integrated life cycle approach will be a valuable model for public and private organizations.

For the lower-performing buildings, the study found that occupant satisfaction is undermined by poor acoustics, lighting and maintenance problems. A low level of ambient noise, a lack of sound masking, and a perceived lack of privacy make acoustic quality worse. The poorly calibrated systems that turn lights on and off in response to daylight conditions may cause problems for some occupants. Mechanical failures and poor maintenance can drive down satisfaction scores.

LESSON LEARNED

GSA's sustainably designed buildings are scoring points with their occupants in terms of overall building and workplace quality, indoor air quality, cleanliness, and quality of maintenance. We also gained the following insights from the lower-performing buildings:

First, acoustic performance matters, and should be addressed by appropriate teaming and design criteria at the outset of every project.

Second, both change management and periodic fine-tuning may be needed to make automated systems work well for building occupants, at least until these systems are fully accepted.

Third, good building maintenance is a foundation stone of occupant satisfaction. Don't neglect it.

NATIONAL BUILDING FACTS

79%
of employees surveyed were willing to forgo income to work for a firm with a credible sustainable strategy.[15]

80%
of employees surveyed said they felt greater motivation and loyalty toward their company due to its sustainability initiatives.[16]

OCCUPANT SATISFACTION SURVEY

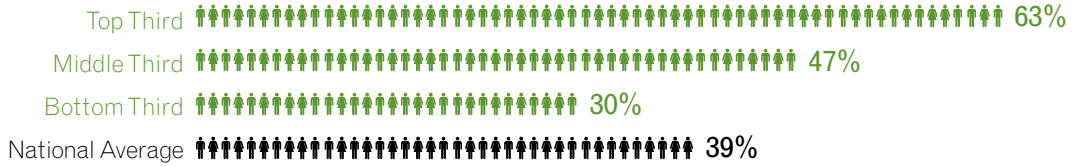
Figure 7: Comparison Against National Averages

Source of National Average: Center for the Built Environment, UC Berkeley

Air Quality Satisfaction

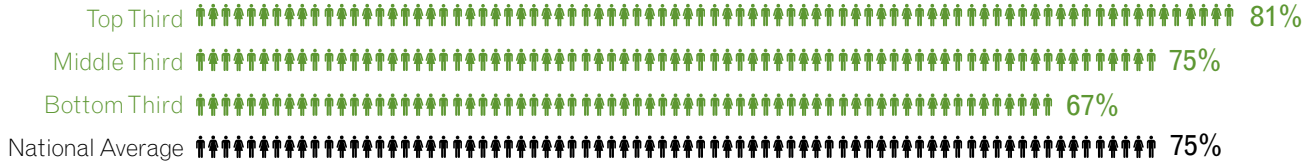
Cleanliness Satisfaction

Thermal Satisfaction



Acoustic Satisfaction

Lighting Satisfaction



FINDING 4:

Green Buildings Deliver on GSA's Mandates

New executive and legislative mandates raise the performance requirements for buildings in GSA's national real estate portfolio. (See chart to right)

To meet these new requirements, GSA will need to ensure that its future buildings, including both new construction and major renovation projects, achieve a consistently high standard of performance. The study found a strong positive correlation in that direction. Taken as a group, these 12 sustainably designed buildings use less energy and water, and have a smaller carbon footprint than the national average for US commercial buildings.

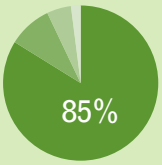
LESSON LEARNED

Although they were not designed to meet GSA's new legislative mandates, the top performing quartile of the buildings studied already meet 2015 requirements for reducing metered energy and water use. GSA can build on this strong foundation of achievable performance. GSA is and will continue to be an important benchmark for other public agencies and for companies and institutions as they plan and implement their building programs.

MANDATE	PERFORMANCE REQUIREMENT
EPAct 2005	• Modeled energy performance must be at least 30% better than ASHRAE 90.1-2004 by 2015
EO 13423	For entire GSA portfolio: • 3% per year metered energy use reduction • 30% metered energy use reduction by 2015 (an average of 54.6 kBtu per sf per year) • 16% metered water use reduction by 2015
EISA 2007	For new GSA buildings and major renovations, reduce fossil fuel generated energy consumption by: • 55% by 2010 • 100% by 2030

For additional information on EISA, EPAct 2005, and EO 13423: www.wbdg.org/references/federal_mandates

NATIONAL BUILDING FACTS



CO_2 EMISSIONS

In the year 2004, the United States emitted over 7 billion metric tons of greenhouse gases. Carbon dioxide accounted for the largest percentage of greenhouse gases **(83%),** followed by methane **(9%),** nitrous oxide **(5%),** and high global warming potential gases **(2%).**[17]

GSA ON THE GROUND

Green Elements of the Omaha Department of Homeland Security

Although designed in 2004, the Omaha Department of Homeland Security already meets the latest federal mandates.

Landscaping captures storm water run-off

Bike racks encourage people to leave their cars behind

The building features access to windows and daylight

Skylights provide daylight where needed

Rainwater is stored and reused for landscape irrigation

A ground source heat pump reduces energy costs

TEST YOUR KNOWLEDGE:

QUESTION 1
How much of US total energy is used by commercial buildings?

QUESTION 2
How much of US energy is generated by coal?

QUESTION 3
How much of US electricity is used by commercial buildings?

QUESTION 4
Over the 30 year life-cycle cost of a building, what percentage is dedicated to occupant salaries?

QUESTION 5
How much time does the average human spend indoors?

QUESTION 6
Compared to average US buildings, what is the aggregate reduction in energy use over the past year for the 12 buildings studied?

QUESTION 7
Compared to average US buildings, what is the aggregate reduction in domestic water use over the past year for the 12 buildings studied?

QUESTION 8
Compared to average US buildings, what is the aggregate reduction in carbon emissions over the past year for the 12 buildings studied?

QUESTION 9
Compared to average US buildings, how much did the 12 buildings studied save in aggregate maintenance costs over the past year?

ANSWERS

1. 18%
2. 49%
3. 35%
4. 88%
5. 90%
6. 616,000 BTUs
7. 313,000 gallons
8. 172,000 mt, equivalent to the annual emmissions for 28,667 cars.
9. $892,000

RESOURCES

LESSONS LEARNED FROM CASE STUDIES OF SIX HIGH-PERFORMANCE BUILDINGS
National Renewable Energy Laboratory
2006

Analyzed the design, construction, and energy performance of six commercial buildings. All of the low-energy buildings used more energy than predicted, but those designed with a whole building approach and with the "strongest" energy goals had the best energy performance. Monitoring buildings to provide feedback improves their energy performance.

THE ENERGY CHALLENGE: A NEW AGENDA FOR CORPORATE REAL ESTATE
Rocky Mountain Institute / CoreNet
2007

Buildings use two-fifths of the world's materials and energy and one-sixth of its fresh water. In the US, buildings make up 85% of all fixed US capital assets. In short, buildings are part of the problem and part of the solution. The Energy Challenge identifies barriers, documents successes, and recommends actions to achieve greater energy efficiency in US corporate real estate.

THE COST OF GREEN REVISITED
Davis Langdon
2007

Found no significant difference in the average costs between green and other buildings. The study also found that the construction industry has embraced sustainable design in most US regions, and no longer views sustainable design measures as an extra cost burden.

ENERGY PERFORMANCE OF LEED NC BUILDINGS
National Buildings Institute
2008

Compares design intent to energy performance in 121 LEED-rated buildings. Office buildings used 33% less energy and all buildings used 24% less energy than the CBECS average for US commercial buildings. Nearly half the buildings had an ENERGY STAR rating of at least 75; the average rating for all buildings was 68, with a quarter rated below 50.

GLOSSARY

BOMA
Building Owners and Managers Association International. This study used their research to obtain the national average for maintenance costs.

CBE
Center for the Built Environment. This study used their research as a basis for the occupant satisfaction surveys, as well as obtaining the national average for general building satisfaction, cleanliness, lighting, air quality, acoustic, and thermal satisfaction.

CALIFORNIA TITLE 24 ENERGY STANDARD
A California-specific building standard that compiles codes from three sources: standards from national model codes, adapted national model codes to meet California conditions, and new standards to address particular California concerns.

CBECS
Commercial Buildings Energy Consumption Survey. The survey gathers and compiles energy use and cost information for US commercial buildings. This study used their research to obtain the national average for energy use.

CH
Courthouse

ENERGY STAR
Energy Star is a rating to promote energy efficiency in products and buildings. This study used their research to obtain the national average for CO_2 emissions. It is a joint program between the US Environmental Protection Agency and the U.S. Department of Energy.

EUI
Energy Use Intensity.

FB
Federal Building

Federal Water Use Index
This study used the Department of Energy's research to obtain the national average for water use.

GSF
Gross square feet. Refers to a building's overall floor plate size, measuring from the outside of its exterior walls and including all vertical penetrations, such as walls and elevator shafts.

IFMA
International Facility Management Association. This study used their research to obtain the national average for energy costs.

kBtu
Kilo Btu

mt
Metric ton

NOTES

[1]This white paper summarizes research presented in the following report:

KM Fowler and EM Rauch: ***Assessing Green Building Performance: A Post-Occupancy Evaluation of 12 GSA Buildings,*** PNNL-17393, Pacific Northwest National Laboratory, Richland, WA, 2008.

www.gsa.gov/appliedresearch

[2]See glossary for abbreviations

[3]U.S. Department of Energy. Commercial Buildings Energy Consumption Survey (CBECS). 2003. Energy Information Administration. Washington, DC.

[4]ENERGY STAR Portfolio Manager. www.energystar.gov/index.cfm?c=evaluate_performance.bus_portfoliomanager

[5]IFMA. 2007. Space and Project Management Benchmarks #28. IFMA. Houston, Texas.

[6]Building Owners and Managers Association (BOMA) International Experience Exchange Report. 2006. Special Studies 2005, Agency Managed, Downtown all sizes, U.S. Government Sector. BOMA International, Washington, DC.

[7]Federal Water Use Index, Department of Energy, Federal Energy Management Program.

[8]IFMA. 2007. Space and Project Management Benchmarks #28. IFMA. Houston, Texas.

[9]Building Owners and Managers Association (BOMA) International Experience Exchange Report. 2006. Special Studies 2005, Agency Managed, Downtown all sizes, U.S. Government Sector. BOMA International, Washington, DC.

[10]Center for the Built Environment (CBE) Occupant Satisfaction Survey. UC Berkeley.

[11]www.yourenergyfuture.org/energyFacts.htm, (accessed 23.04.2008).

[12]www.energystar.gov/index.cfm?c=business.bus_water, (accessed 23.04.2008).

[13]ibid.

[14]goliath.ecnext.com/coms2/gi_0199-6408096/Section-2-Energy-consumption-by.html, (accessed 01.05.08)

[15]www.epa.gov/watersense/water/why.htm, (accessed 23.04.08)

[16]Center for the Built Environment (CBE) Occupant Satisfaction Survey. UC Berkeley.

[17]Survey of 800 MBAs from 11 Top International Business Schools; Stanford Graduate School of Business, 2002 GlobeScan International Survey, MORI.

[18]ibid.

[19]www.pewclimate.org/global-warming-basics/facts_and_figures/us_emissions/usghgemgas.cfm, (accessed 01.05.08)

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