



GSA Public Buildings Service

# GREEN BUILDING PERFORMANCE

A POST OCCUPANCY EVALUATION OF 22 GSA BUILDINGS



WHITE PAPER

1



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The Office of the PBS Chief Greening Officer drives the implementation of sustainability practices and customer facing solutions to enhance the environmental performance of GSA's real estate portfolio and provide healthy and productive workspaces. The Office also leads GSA's Green Proving Ground, a program that aims to accelerate sustainable real estate through testing, evaluation, and adoption of "proven" innovative technologies and practices.

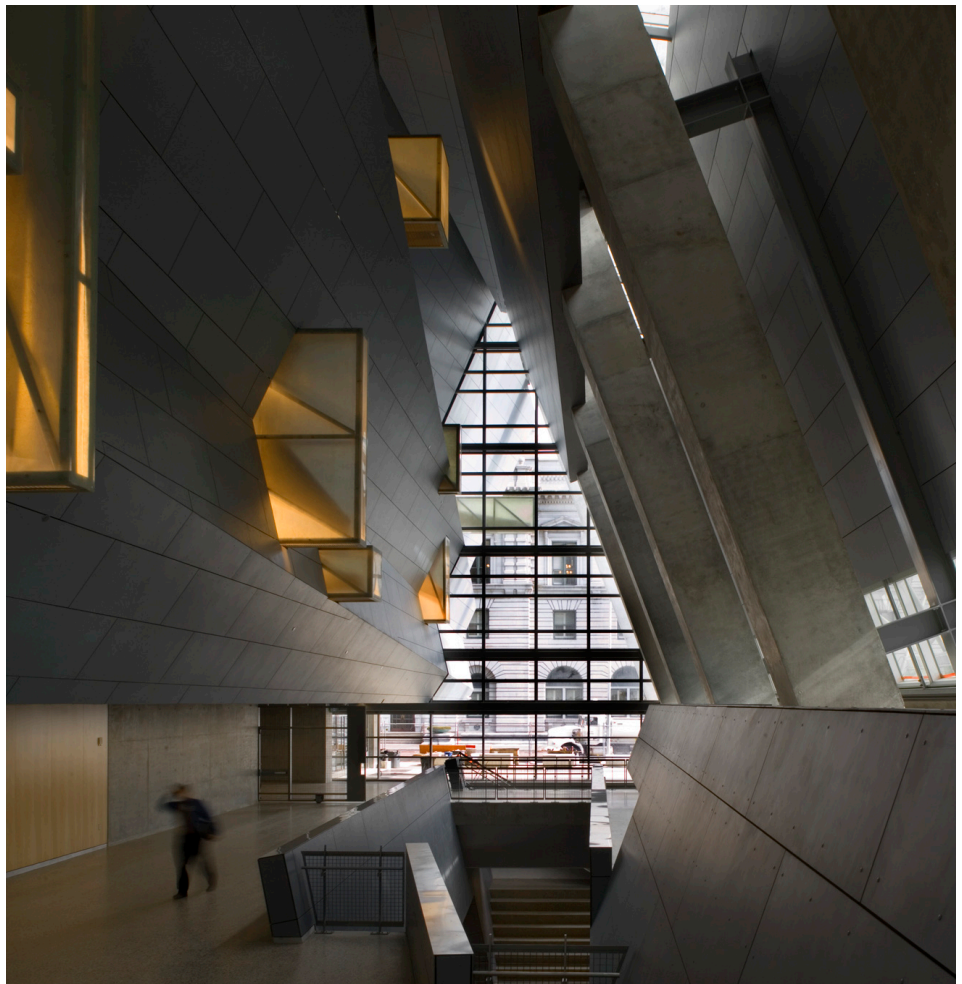


photo: Nic Lehoux

*“Greening federal buildings makes good business sense: GSA’s sustainably designed buildings deliver through reductions in energy and water consumption, decreased CO<sub>2</sub> emissions, higher tenant satisfaction and lower operating costs.”*

ROBERT A. PECK  
Commissioner, GSA Public Buildings Service

## INTRODUCTION

### SUSTAINABLE DESIGN DELIVERS

Do “green” buildings deliver the performance they promise? To answer this question, the General Services Administration (GSA) selected 22 representative green buildings from its national portfolio, including 12 buildings whose performance was assessed initially in 2007<sup>1</sup>. The evaluation was comprehensive, measuring environmental performance, financial metrics, and occupant satisfaction. Results were compared to both industry and GSA baselines. All buildings in the study incorporated sustainable design practices. Sixteen were LEED-NC certified or registered, representing more than one-third of the LEED buildings in GSA’s inventory at the time of the study. The remaining six buildings implemented a suite of sustainability strategies to enhance building performance.

The results of the study confirmed that, on average, GSA’s sustainably designed buildings use less energy and water, emit less CO<sub>2</sub>, cost less to maintain, and have occupants who are more satisfied than those working in typical buildings. In short, the GSA’s 12-year commitment to green building practices is paying off.

# RESEARCH OVERVIEW

## MOTIVATIONS AND METHODS

For more than a decade, the Federal Government has committed itself to demonstrating that sustainably designed commercial buildings save energy, cost less to operate, have smaller carbon footprints, and more satisfied occupants. This commitment is reflected in executive orders and congressional legislation. GSA, which provides real estate for more than one million federal employees, has adopted policies to realize this commitment to sustainability. The intention of this study was to evaluate the effectiveness of those policies.

The study was conducted in two phases. The first phase, completed in 2008, developed a repeatable, cost-effective, post occupancy evaluation (POE) methodology and piloted that methodology across a representative sample of 12 sustainably designed buildings in GSA's portfolio. The study's second phase re-examined the first set of buildings to verify that measured results persisted. When ten additional buildings were added to the sample, results obtained from the second set were consistent with results obtained from the first. In all cases, "whole building performance" was evaluated—energy and water use, carbon emissions, operations and maintenance, waste generation and recycling, and occupant satisfaction.

Because all buildings constructed by GSA for the past decade have incorporated sustainable design, key performance indicators were judged against comparable, industry-accepted benchmarks that measured performance of the broader building stock constructed during the same period. Data summarized in this study were provided in mid to late 2009 and are primarily for calendar year 2008. Evaluated in this way, green buildings outperformed national averages in all measured performance areas. Comparisons were based on the following sources of data:

<u>Measurement</u>	<u>Data Source</u> <sup>2</sup>
EUI	CBECs National Survey of Commercial Buildings constructed between 1990 and 2003 <sup>3</sup>
Energy Cost	BOMA <sup>4</sup> 2008 All Sector Total Building Rentable Area – Utility (less water)
CO <sub>2</sub>	ENERGY STAR baseline <sup>5</sup> , late 2009/early 2010
Maintenance Costs	IFMA <sup>6</sup> facilities less than 5 years old and BOMA <sup>4</sup> 2008 All Sector Total Buildings Rentable Area - Roads/Grounds
Water Use	IFMA <sup>6</sup> 50th Percentile, 2009
Occupant Satisfaction	Center for the Built Environment, UC Berkeley, 2009 <sup>7</sup>



### KEY FINDINGS:

Compared to national averages, buildings in this study have:

**25%**

Less energy use  
(66 kBtu/sf/yr vs. 88 kBtu/sf/yr)

**19%**

Lower aggregate operational costs  
(\$1.60/sf vs. \$1.98/sf<sup>8</sup>)

**27%**

Higher occupant satisfaction

**36%**

Fewer CO<sub>2</sub> emissions

# RESEARCH CONTEXT

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*“By looking critically at real world performance, this report demonstrates that GSA, in support of its zero environmental footprint vision, delivers high performance, sustainable workplaces.”*

MARTHA JOHNSON  
GSA Administrator

## A COMPREHENSIVE EVALUATION

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GSA commissioned the Pacific Northwest National Laboratory (PNNL) to evaluate 22 of GSA's sustainably designed buildings. It wanted to know whether its green buildings were delivering the performance they promised.

Because of GSA's commitment to real-world results, the study evaluated actual, not modeled, building performance. Successes and shortcomings were identified, along with areas requiring further research. The 22 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. Sixteen of these buildings were designed to meet or exceed basic LEED certification. The other six 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 understand how GSA's green buildings measured up to commonly accepted national benchmarks, the team compared each performance metric with the national average for US commercial buildings. The latest available benchmark data come from widely accepted industry and government standards.<sup>9</sup>

## 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. 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.

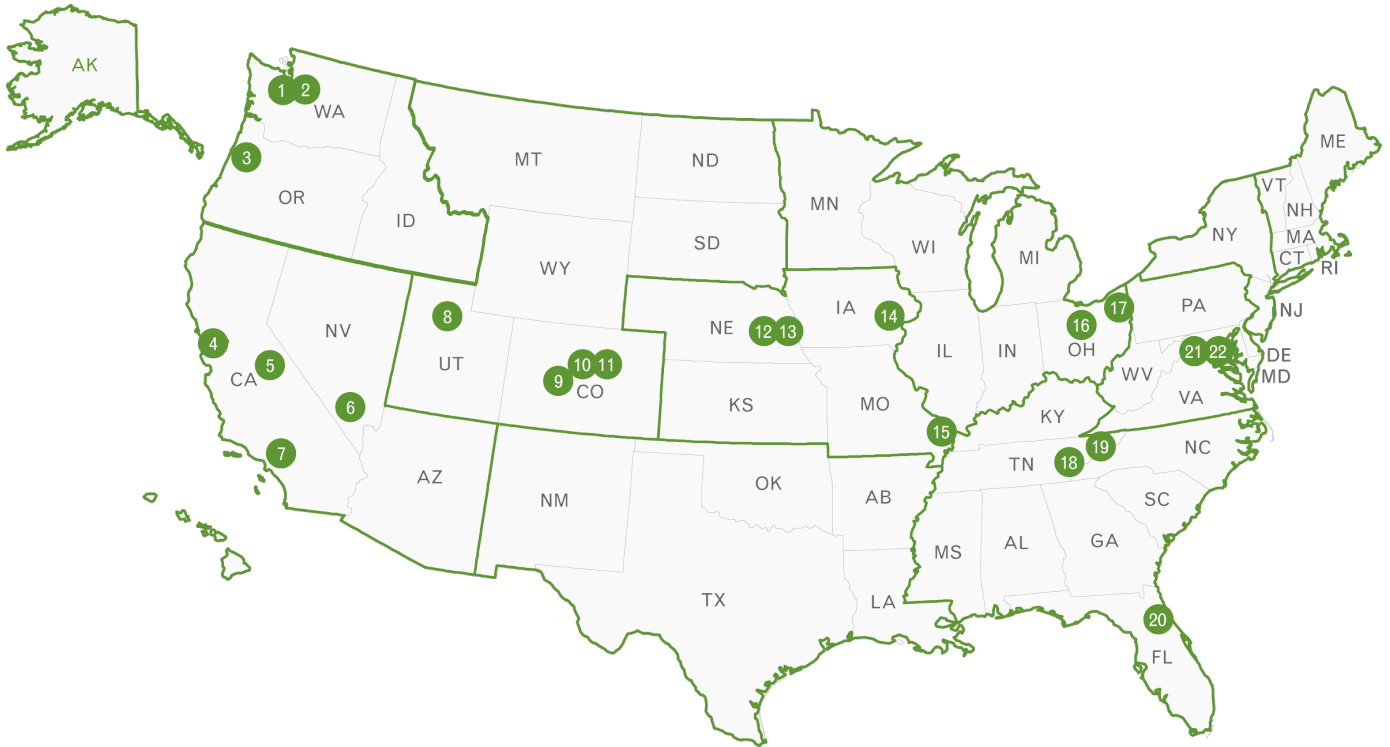
LEED provides four measures of performance: basic certification, Silver, Gold, and Platinum, based on a set of prerequisites and credits in the five major categories listed above. Each measure represents an incremental step toward integrating the different components of sustainable design, construction,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

For more information on the LEED Rating System: [www.usgbc.org](http://www.usgbc.org)

# GSA STUDY BUILDINGS

Figure 1: A Representative Sampling

To achieve a representative sampling, GSA chose 22 buildings from 7 of its 11 national regions.



## Northwest/Arctic

- 1 Seattle CT
- 2 Auburn FB
- 3 Eugene CT

## Pacific

- 4 San Francisco FB
- 5 Fresno CT & FB
- 6 Santa Ana FB
- 7 Las Vegas CT

## Rocky Mountain

- 8 Ogden FB
- 9 Lakewood FB
- 10 Denver CT
- 11 Denver FB

## Heartland

- 12 Omaha DHS FB
- 13 Omaha NPS FB
- 14 Davenport CT
- 15 Cape Girardeau CT

## Great Lakes

- 16 Cleveland CT
- 17 Youngstown CT & FB

## Southeast

- 18 Knoxville FB
- 19 Greenville CT
- 20 Jacksonville FB

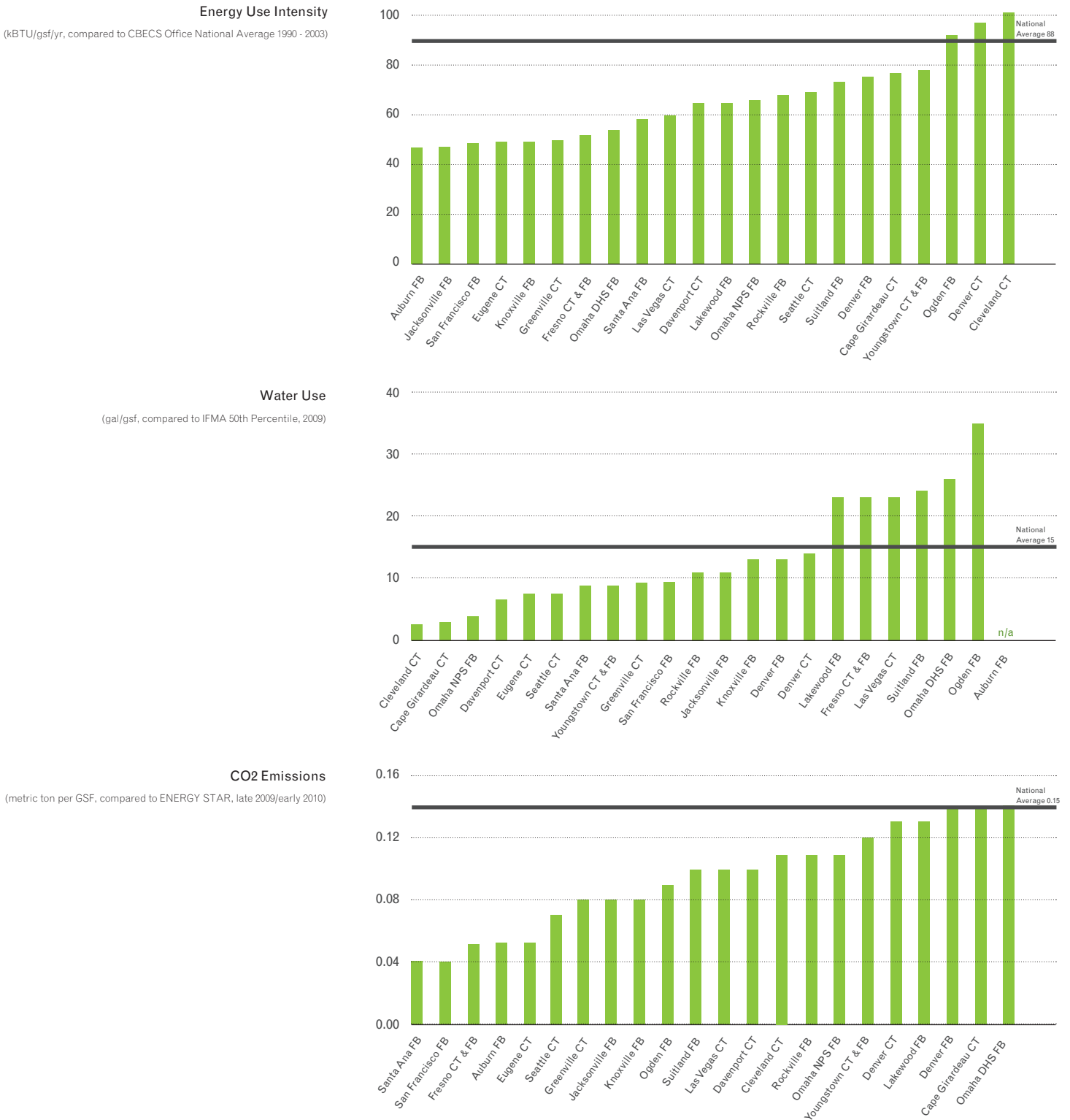
## National Capital

- 21 Suitland FB
- 22 Rockville FB

# GSA STUDY BUILDINGS

Figure 2: Performance Metrics

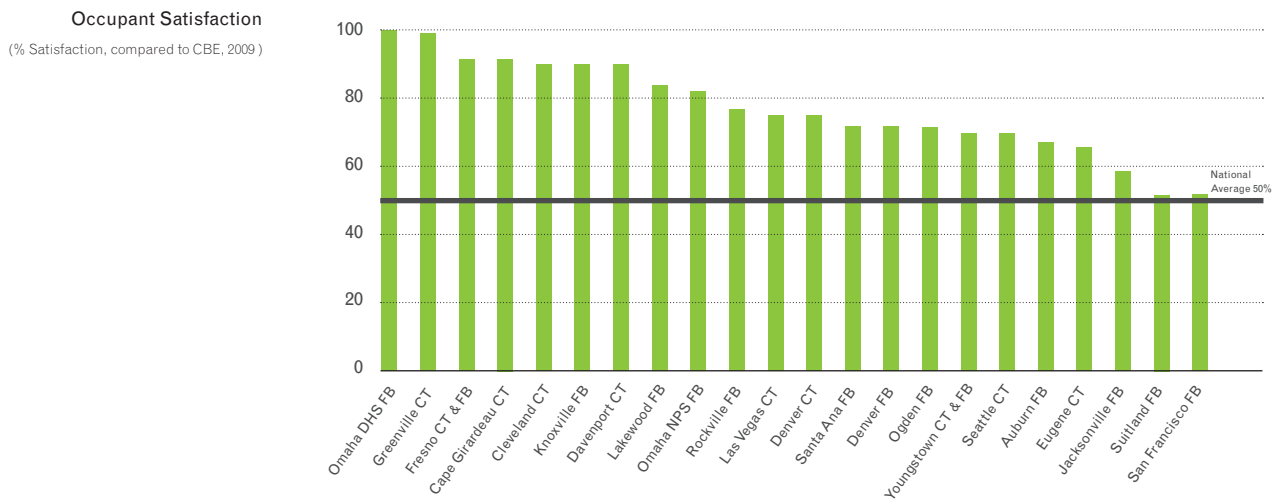
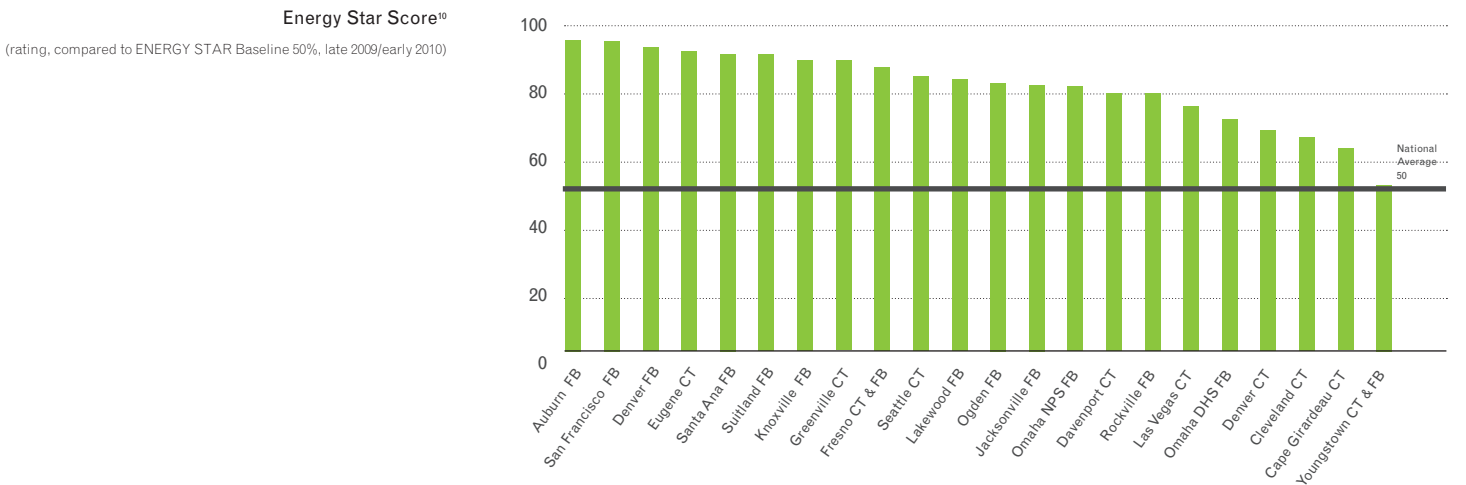
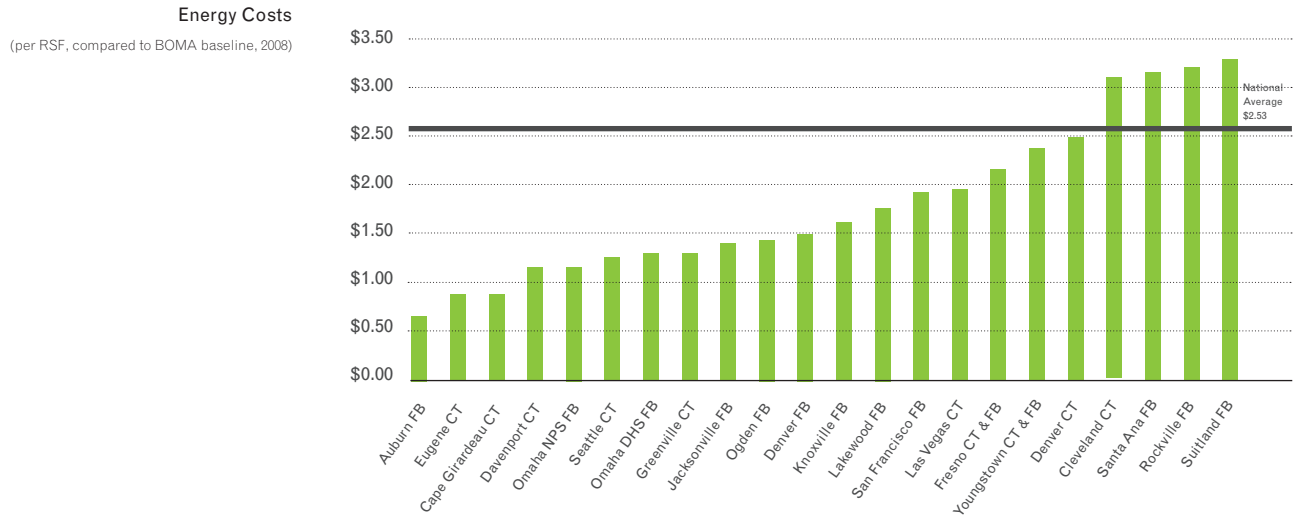
On average the 22 sustainably designed buildings in the study outperformed US commercial buildings.



# GSA STUDY BUILDINGS

Figure 2 (continued): Performance Metrics

On average the 22 sustainably designed buildings in the study outperformed US commercial buildings.





# GSA STUDY BUILDINGS: FAST FACTS

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## AUBURN

BUILT: 1944  
RENOVATED: 2006  
SQ. FT: 205,354  
OCCUPANTS: 675  
ENERGY STAR: 96  
LEED-SILVER



Converted from a warehouse to office space in 2006, this adaptive reuse project earned a LEED Silver rating. Sustainable design features include an underfloor air distribution system, use of low-emitting materials, and increased ventilation.

## CAPE GIRARDEAU

BUILT: 2008  
SQ. FT: 173,392  
OCCUPANTS: 45  
ENERGY STAR: 64  
LEED-SILVER



This courthouse is one of the first LEED buildings in Southeastern Missouri. The facility features advanced building HVAC and lighting controls, irrigation rain sensors, and low-flow fixtures. Carbon dioxide sensors and low-emitting materials contribute to improved indoor environmental quality.

## CLEVELAND

BUILT: 1910  
RENOVATED: 2005  
SQ. FT: 251,314  
OCCUPANTS: 105  
ENERGY STAR: 69  
LEED-CERTIFIED



The Metzenbaum Courthouse is on the National Register of Historic Places. The renovations preserved 96% of the existing shell and a majority of the interior non-structural elements. The courthouse won GSA's Environmental Award for recycling because of its seven-material collection system and green housekeeping practices.

## DAVENPORT

BUILT: 1933  
RENOVATED: 2005  
SQ. FT: 79,872  
OCCUPANTS: 45  
ENERGY STAR: 80



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 maximize daylight. The HVAC system consists of water-cooled chillers, boilers, and air-handling units with variable speed drives.

## DENVER CT

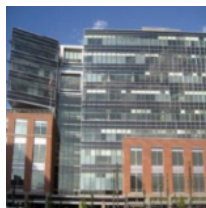
BUILT: 2002  
SQ. FT: 327,103  
OCCUPANTS: 170  
ENERGY STAR: 70  
LEED-SILVER



The Arraj Courthouse was designed as a green courthouse prior to the completion of the LEED rating system. It has since earned Silver certification under LEED for Existing Buildings. The Arraj Courthouse employs a hybrid underfloor air distribution system, extensive HVAC and lighting sensors, as well as photovoltaic panels.

## DENVER FB

BUILT: 2006  
SQ. FT: 301,292  
OCCUPANTS: 922  
ENERGY STAR: 94  
LEED-GOLD



The EPA Region 8 Headquarters building, located in a redeveloped area of downtown Denver, earned LEED Gold certification. The building is designed to maximize daylight and has an underfloor air distribution system, a vegetated roof, and photovoltaic panels.

# GSA STUDY BUILDINGS: FAST FACTS

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## EUGENE

BUILT: 2006  
SQ. FT: 270,322  
OCCUPANTS: 120  
ENERGY STAR: 92  
LEED-GOLD



The Morse Courthouse was the first LEED Gold Courthouse in the US. Sustainable design features include an underfloor air distribution system, daylight sensors, and low-flow fixtures. Indoor Environmental Quality (IEQ) is improved through the use of low-emitting materials.

## FRESNO

BUILT: 2005  
SQ. FT: 495,914  
OCCUPANTS: 235  
ENERGY STAR: 87



The Coyle Courthouse and Federal Building houses 14 courtrooms and is the tallest building in the city (11 floors). Designed under California's Title 24 Energy Standard, the building includes high-efficiency lighting, an underfloor air distribution system, water-cooled chillers, and natural gas boilers.

## GREENVILLE

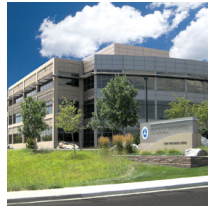
BUILT: 2001  
SQ. FT: 160,975  
OCCUPANTS: 85  
ENERGY STAR: 90



Energy-efficiency features in the Quillen Courthouse include a well-insulated white roof and an Energy Management Control System that integrates lighting and occupancy sensors. It also scores the highest occupant satisfaction rating for air quality, acoustics, and lighting of any building in this study.

## JACKSONVILLE

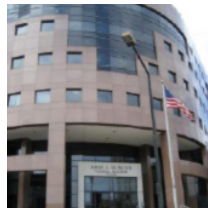
BUILT: 1967  
RENOVATED: 2004  
SQ. FT: 338,008  
OCCUPANTS: 1,000  
ENERGY STAR: 82



Renovations to this federal building improved operations and occupant satisfaction. The building earned an Energy Star rating in 2007 and incorporates high-efficiency lighting and recycled materials in the interior.

## KNOXVILLE

BUILT: 1986  
RENOVATED: 2005  
SQ. FT: 172,684  
OCCUPANTS: 285  
ENERGY STAR: 90  
LEED-CERTIFIED



Located in downtown Knoxville, the Duncan Federal Building incorporates high-efficiency lighting, enhanced metering techniques, and low-flow fixtures. The cool roof reduces the heat island effect and supports photovoltaic panels.

## LAKESWOOD

BUILT: 2004  
SQ. FT: 128,342  
OCCUPANTS: 318  
ENERGY STAR: 84  
LEED-SILVER



The LEED Silver facility at Lakewood features daylight and exterior views in 91% of its regularly occupied spaces. In addition, all building occupants receive a booklet about the design and operations of the building enhancing tenant engagement

# GSA STUDY BUILDINGS: FAST FACTS

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## LAS VEGAS

BUILT: 2000  
SQ. FT: 495,877  
OCCUPANTS: 321  
ENERGY STAR: 77



The George Courthouse creates a federal presence in downtown Las Vegas, with a large column supporting the sun-screen entry canopy. The courthouse received an Energy Star Label in 2007 and includes high-efficiency lighting and HVAC systems.

## OGDEN

BUILT: 1900  
RENOVATED: 2001  
SQ. FT: 105,000  
OCCUPANTS: 514  
ENERGY STAR: 83  
LEED-SILVER



Renovations transformed the historic Scowcroft Building into office space that meets the IRS's specific needs. The space incorporates earthquake upgrades, improved roof insulation, radiant baseboard heating, and an underfloor air distribution system coupled with indirect/direct evaporative cooling.

## OMAHA DHS

BUILT: 2005  
SQ. FT: 86,000  
OCCUPANTS: 65  
ENERGY STAR: 74  
LEED-GOLD



This federal building won the 2007 American Council of Engineering Award for its design. It is a LEED Gold building that incorporates daylight- and rainwater-harvesting systems and a ground-source heat pump system.

## OMAHA NPS

BUILT: 2004  
SQ. FT: 68,000  
OCCUPANTS: 125  
ENERGY STAR: 82  
LEED-GOLD



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 include green housekeeping practices.

## ROCKVILLE

BUILT: 2004  
SQ. FT: 232,000  
OCCUPANTS: 720  
ENERGY STAR: 80



This leased building incorporates many sustainable design features, including a reflective white roof, low-water landscaping, and use of renewable materials in both interior finishes and furniture.

## SAN FRANCISCO

BUILT: 2007  
SQ. FT: 652,433  
OCCUPANTS: 1,314  
ENERGY STAR: 96  
LEED-SILVER



Located in the South of Market district, the building was constructed on a brownfield as part of the city's urban revitalization. Unique features include natural ventilation in tower offices, an underfloor air distribution system, and extensive daylighting.

# GSA STUDY BUILDINGS: FAST FACTS

**SANTA ANA**  
BUILT: 1975  
RENOVATED: 2005  
SQ. FT: 280,365  
OCCUPANTS: 409  
ENERGY STAR: 91



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.

**SEATTLE**  
BUILT: 2004  
SQ. FT: 658,392  
OCCUPANTS: 500  
ENERGY STAR: 85



Located in downtown Seattle, this courthouse features radiant floor heating, a well-utilized Energy Management Control System (EMCS), waterless urinals, and photovoltaic panels. The lighting controls operate both on occupancy and time-of-day routines.

**SUITLAND**  
BUILT: 2006  
SQ. FT: 2,340,988  
OCCUPANTS: 5,360  
ENERGY STAR: 91  
**LEED-GOLD**



The curved shape of the Census Bureau Headquarters building takes advantage of natural daylight. Other features include an underfloor air distribution system, vegetative roofs, and bioswales.

**YOUNGSTOWN**  
BUILT: 2002  
SQ. FT: 52,240  
OCCUPANTS: 45  
ENERGY STAR: 50  
**LEED-CERTIFIED**



The Jones Federal Building and Courthouse facility was built on a brownfield as part of the city's urban revitalization. The building provides daylight to over 75% of occupied spaces. Sustainable design features include an advanced storm water management system, a white membrane roof, and light-colored pavement. This was GSA's second LEED-Certified building.

## NATIONAL BUILDING FACTS

**31%**

projected increase in energy consumption by the year 2030 despite dramatic gains in energy efficiency.<sup>11</sup>

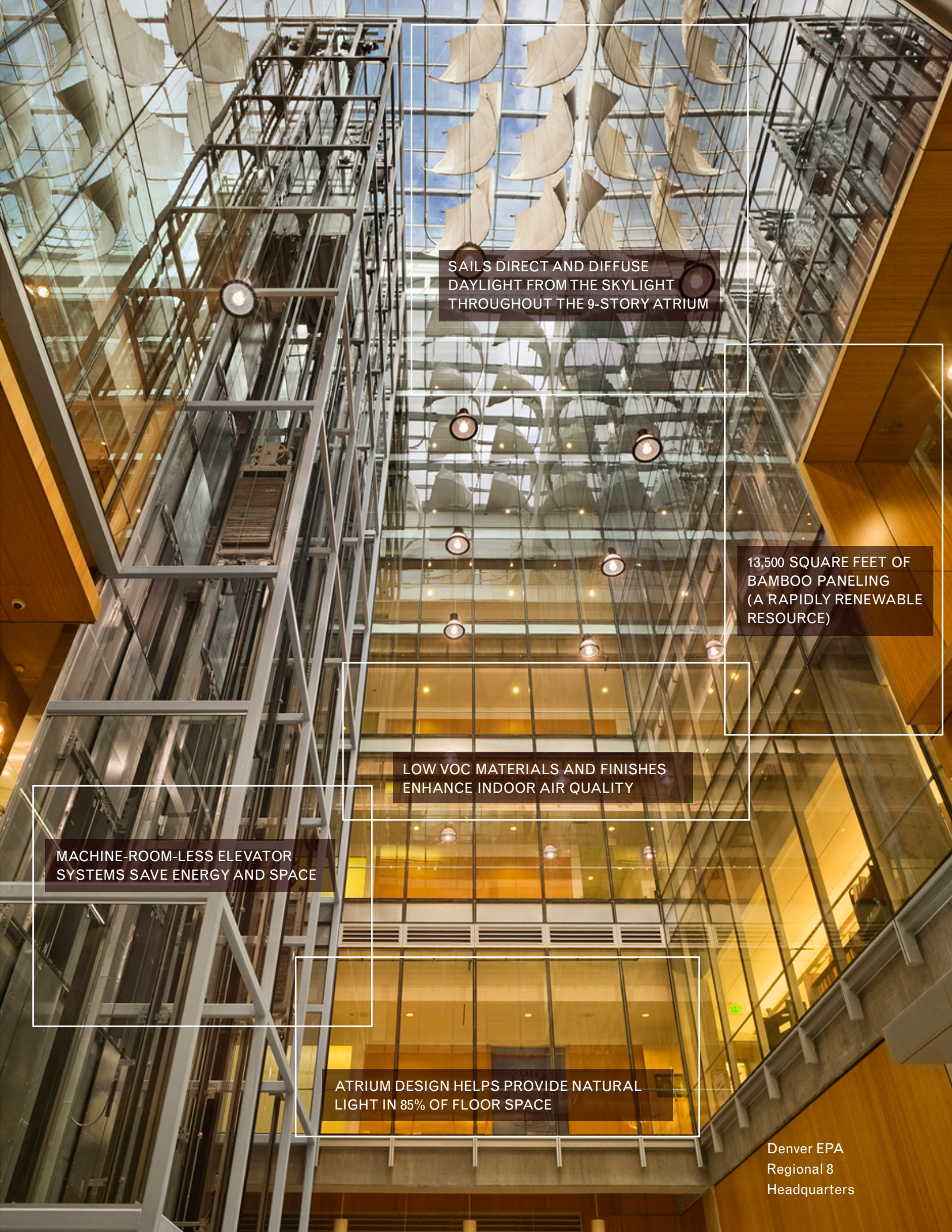


**20%**

of U.S. drinking water supply is consumed by commercial buildings.<sup>12</sup>

**2 trillion**

gallons of water a year would be saved if commercial buildings reduced their water consumption by 10%.<sup>13</sup>



SAILS DIRECT AND DIFFUSE DAYLIGHT FROM THE SKYLIGHT THROUGHOUT THE 9-STORY ATRIUM

13,500 SQUARE FEET OF BAMBOO PANELING (A RAPIDLY RENEWABLE RESOURCE)

LOW VOC MATERIALS AND FINISHES ENHANCE INDOOR AIR QUALITY

MACHINE-ROOM-LESS ELEVATOR SYSTEMS SAVE ENERGY AND SPACE

ATRIUM DESIGN HELPS PROVIDE NATURAL LIGHT IN 85% OF FLOOR SPACE

# FINDING 1

## Fully Integrated Design Delivers High Performance

*GSA's LEED Gold buildings have 27% lower energy use compared to the national average.*

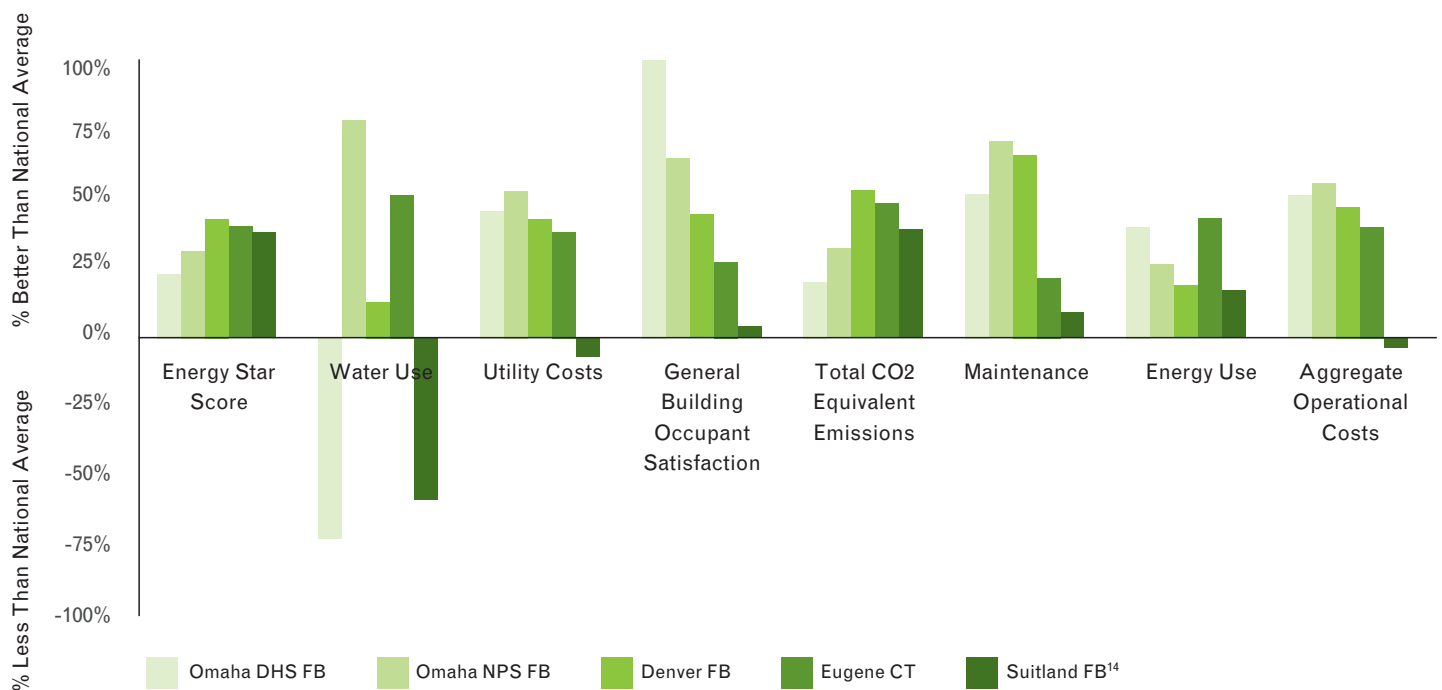
(62 kBtu/sf/yr vs. 88 kBtu/sf/yr)  
Source of national average: CBECS

On average, buildings in this study surpassed national averages. This was particularly true of those with LEED Gold certification, which requires a fully integrated approach to sustainable design. LEED Gold's emphasis on site development, water conservation, energy efficiency, materials selection, and indoor environmental quality yielded broad holistic performance benefits and in most cases served as a valuable performance indicator. However, it was not foolproof. Of the five LEED Gold buildings evaluated for this study, three performed far better than industry baselines in all categories. Of the two remaining buildings, one, the Department of Homeland Security in Omaha, Nebraska, bested industry baselines in all categories except water use, where its score was not only much higher than the national average but also much higher than when the building was previously assessed, indicating the possibility of unexpected uses, leaks, or even measurement errors. The other remaining LEED Gold building, the Census Bureau office complex in Suitland, Maryland, earned inferior scores in three out of eight categories. These departures from anticipated performance warrant further investigation.

### LESSON LEARNED

Design intent does not always translate into real-world performance. In order to meet its executive and legislative mandates by delivering buildings that are truly sustainable, GSA must take into account the way its buildings perform on the ground, using all the methods and tools at its disposal.

Figure 3: LEED Gold Buildings Are Top Performers



# FINDING 2

## GSA's Green Buildings Cost Less to Operate

*GSA's sustainably designed green buildings have 19% lower operational costs compared to the national average.*

Source of national average: BOMA

Operations and maintenance are what keep properties in working order, and costs associated with them can be significant. As a group, buildings in this study outperformed national averages for O&M by substantial margins. On the whole, operating costs were 19% lower than the national average for US commercial buildings.

LEED Gold buildings were among the best performers from an O&M cost perspective. Lower water utilities, energy utilities, general maintenance, grounds maintenance, waste and recycling, and janitorial costs resulted in considerable savings.

Most buildings studied also realized savings in aggregate maintenance costs. Middle third and top third were all well below the national average. The performance of the bottom third of buildings studied, on the other hand, was less impressive. These buildings had unusually high aggregate maintenance costs and were 25% above the national average for US commercial buildings. Four of the five buildings whose maintenance costs exceeded the baseline had higher general maintenance costs and two had higher energy costs.

### LESSON LEARNED

O&M costs are lowest when sustainability is integral to every aspect of a building. Building and systems efficiency alone isn't enough. Upfront investments in sustainable measures need to be matched by sustainable O&M practices.

Figure 4: Aggregate Operational Costs: Performance of Study Buildings Compared to National Average

Source of National Average: BOMA

OPERATIONAL COSTS FOR BUILDINGS IN THE TOP THIRD ARE 43% LOWER THAN THE NATIONAL AVERAGE.

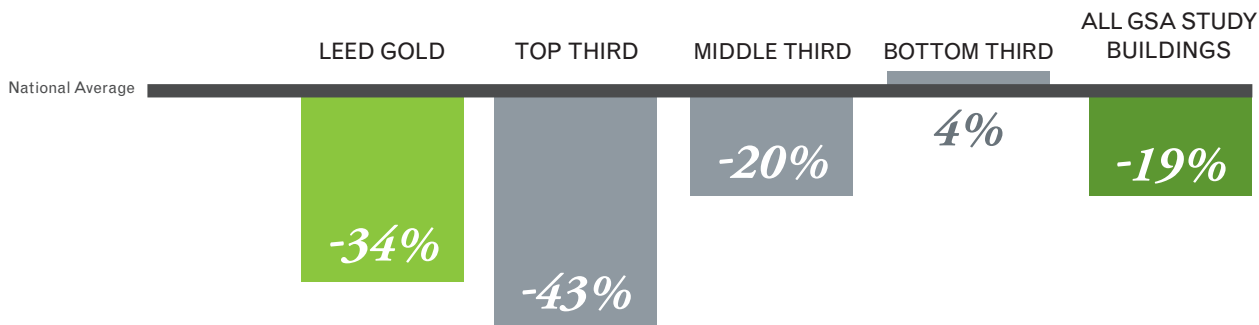


Figure 5: Energy Cost: Performance of Study Buildings Compared to National Average

Source of National Average: BOMA

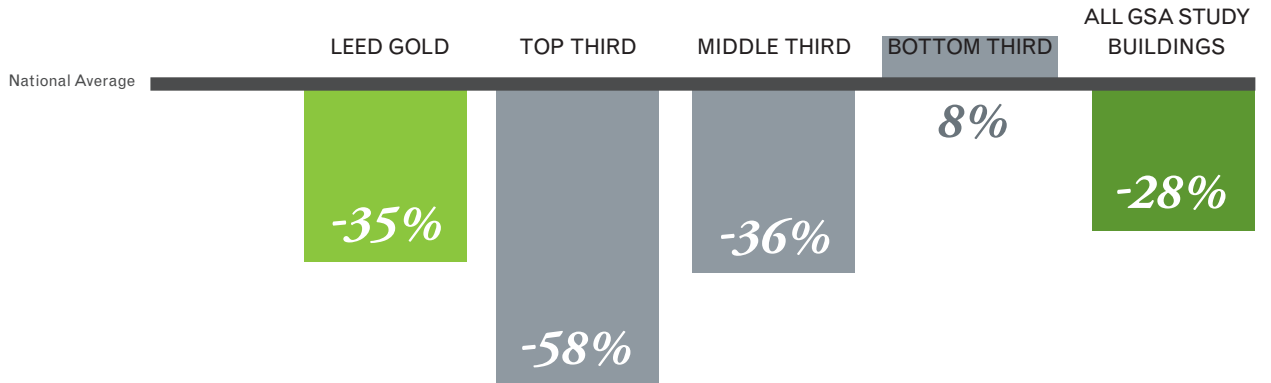
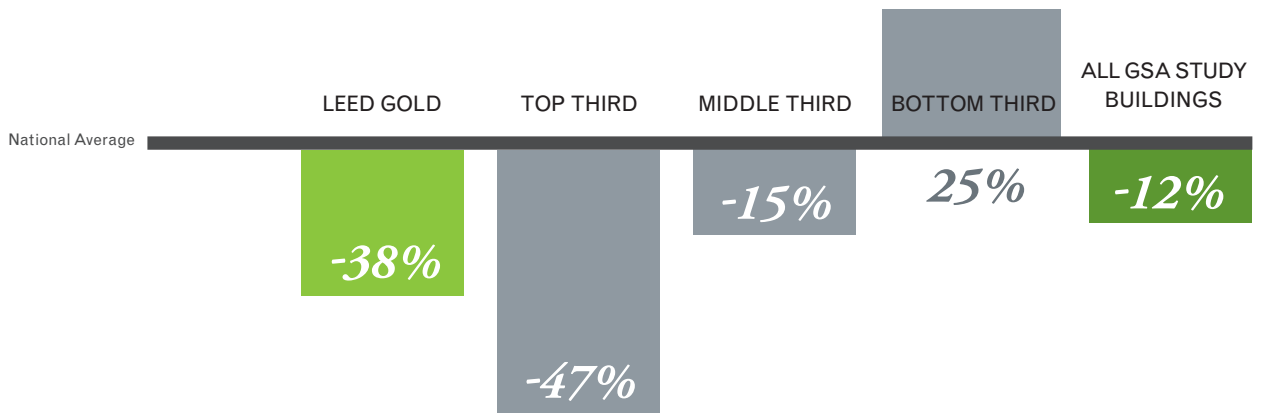


Figure 6: Aggregate Maintenance Cost: Performance of Study Buildings Compared to National Average

Source of National Average: GSA adapted industry baseline for General and Janitorial and BOMA for Grounds





# FINDING 3

## Sustainable Design Supports Occupant Satisfaction

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*GSA's sustainably designed green buildings demonstrate a 27% higher occupant satisfaction than the national average.*

Source for national average: CBE, UC Berkeley<sup>15</sup>

A primary goal of sustainable design is to maximize occupant comfort and satisfaction, while minimizing environmental impact and costs. Comfort and satisfaction are important for many reasons, not least of which is that they correlate positively with personal and team performance. The greater the satisfaction, the higher the productivity and creativity of an organization. It has also been demonstrated that occupant satisfaction impacts staff retention.

On average, the 22 buildings studied scored better in occupant satisfaction than the national average for US commercial buildings. With 76% higher occupant satisfaction, the top third of buildings scored significantly better than the national average. Despite the overall positive performance, however, the study found that occupant satisfaction was in some cases undermined by problems with lighting and acoustics. Lighting was the one area in which most of the buildings studied were no better than their non-green comparison set. While occupants in all buildings judged lighting to be "satisfactory," the scores for three-fifths of those buildings were below the national average. Acoustics were also problematic, but the problems did not necessarily have to do with noise level per se. Rather, an analysis of the data revealed that occupants were more dissatisfied with sound privacy than with noise level. Occupants in open office spaces and cubicles reported the highest levels of dissatisfaction.

### LESSON LEARNED

Lighting and acoustic performance matter greatly, even to occupants who are otherwise satisfied with building and workplace quality. Both should be addressed by appropriate teaming and design criteria at the outset of every project.

## NATIONAL BUILDING FACTS

**79%**

of employees surveyed were willing to forgo income to work for a firm with a credible sustainable strategy.<sup>16</sup>



**80%**

of employees surveyed said they felt greater motivation and loyalty toward their company due to its sustainability initiatives.<sup>17</sup>

# OCCUPANT SATISFACTION SURVEY

Figure 7: Compared to National Average

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



# FINDING 4

## Green Buildings Help GSA Meet Federal Mandates

In October, 2009, President Barack Obama issued an executive order establishing an integrated strategy toward sustainability in the Federal Government and making reduction of green house gas emissions a priority for federal agencies. To meet this and other sustainability mandates, GSA will need to ensure that an increasing percentage of existing buildings and all future construction and major renovation projects achieve a consistently high standard of performance. This study's findings suggest that that process is already well underway.

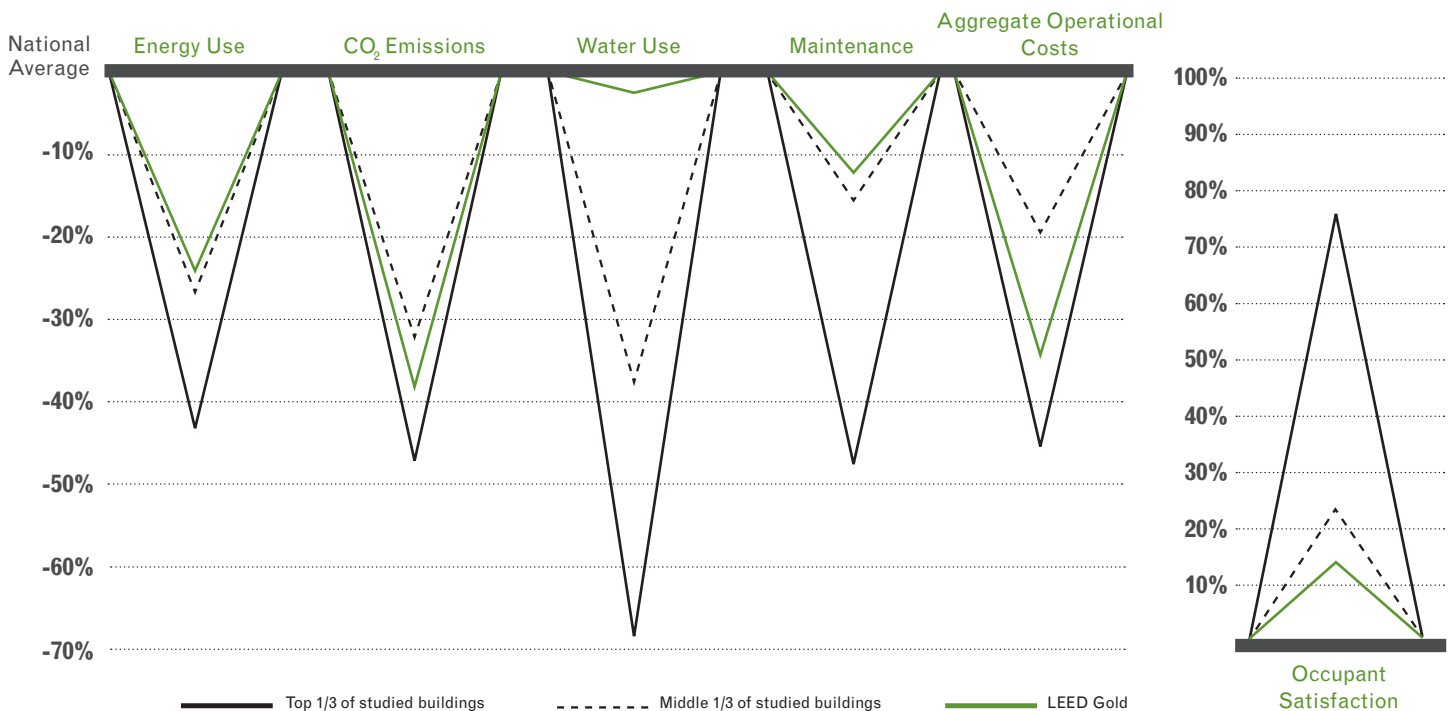
### LESSON LEARNED

The General Services Administration can build on this strong foundation. 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
EO 13514	Sets sustainability & GHG reduction goals for federal agencies
EPAAct 2005	Modeled energy performance targets must be at least 30% better than ASHRAE 90.1-2004
EO 13423	For an agency's portfolio: <ul style="list-style-type: none"> <li>• 3% per year metered energy use reduction</li> <li>• 30% metered energy use reduction by 2015 (an average of 54.6 kBtu per sf per year for GSA)</li> <li>• 16% metered water use reduction by 2015</li> </ul>
EISA 2007	New GSA buildings and major renovations must reduce fossil-fuel-generated energy consumption by: <ul style="list-style-type: none"> <li>• 55% in 2010</li> <li>• 100% in 2030</li> </ul>

For additional information on EISA, EPAAct 2005, and EO 13514 and 13423: [www.wbdg.org/references/federal\\_mandates.php](http://www.wbdg.org/references/federal_mandates.php)

Figure 8: GSA Buildings Compared to the National Average



# GSA ON THE GROUND

## Green Elements of the Denver EPA Regional 8 Headquarters

Built in 2006, the Denver EPA achieved LEED-Gold and demonstrates that integrated design is cost effective.



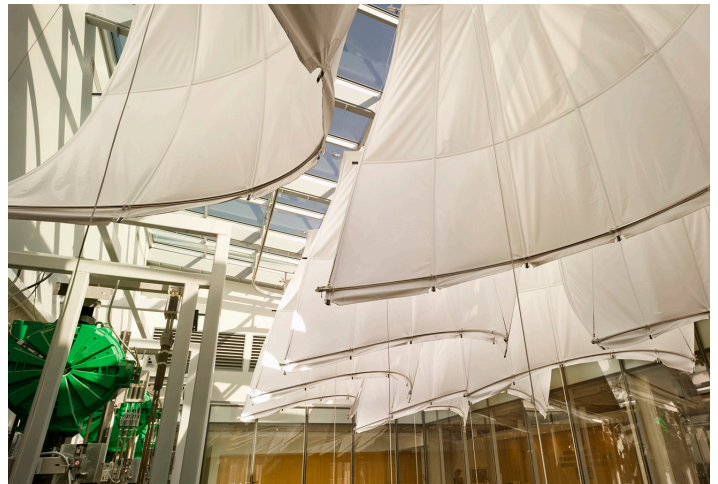
"Double-L" floor plan addresses solar and wind patterns.



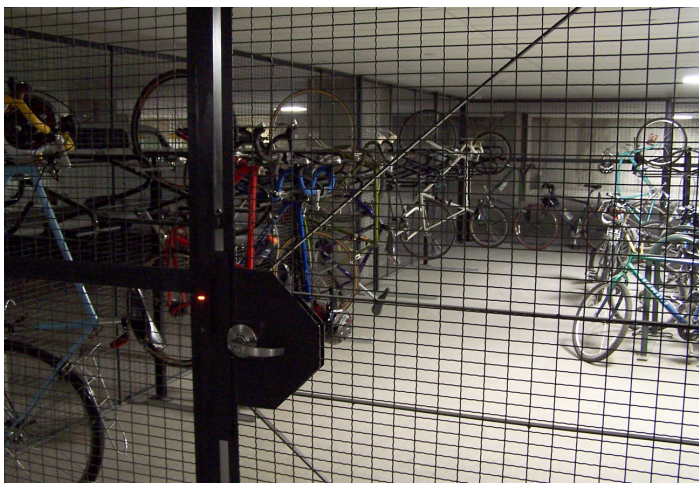
Green roof absorbs heat and CO<sub>2</sub> and reduces stormwater runoff.



Light shelf allows daylight to penetrate deep into building.



Sails in the building atrium help alleviate glare and control heat.



Bike lockers encourage people to leave their cars behind.



Forty-eight solar panels output 10kW at peak sun.

# RESOURCES

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## 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.

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## 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.

## 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.

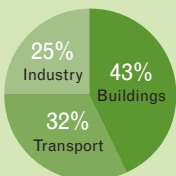
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## ENERGY PERFORMANCE OF LEED NC BUILDINGS

New 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.

## NATIONAL BUILDING FACTS



### 43% of CO<sub>2</sub> Emissions are from the Building Sector

Approximately 43% of U.S. carbon dioxide (CO<sub>2</sub>) emissions result from the energy services required by residential, commercial, and industrial buildings. Transportation accounts for 32% and industry for 25%<sup>18</sup>.

# GLOSSARY

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## **BOMA**

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

## **CBE**

Center for the Built Environment. This study used CBE 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 combines 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.

## **CB ECS**

Commercial Buildings Energy Consumption Survey. The survey gathers and combines energy use and cost information for US commercial buildings. *Green Building Performance* used their research to obtain the national average for energy use.

## **CT**

Courthouse

## **EMCS**

Energy Management Control System

## **ENERGY STAR**

Energy Star is a rating to promote energy efficiency in products and buildings. This study used Energy Star research to obtain the national average for CO<sub>2</sub> emissions. It is a joint program between the US Environmental Protection Agency and the US Department of Energy.

## **EUI**

Energy Use Intensity

## **FB**

Federal Building

## **Federal Water Use Index**

This study used the Department of Energy's research on federal buildings to obtain the national average for water use.

## **GHG**

Green House Gas

## **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.

## **IEQ**

Indoor Environmental Quality

## **IFMA**

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

## **kBtu**

1000 British thermal units, A BTU is the amount of heat energy needed to raise the temperature of one pound of water by 1° F.

## **RSF**

Rentable square feet. Usable SF + a percentage of the common areas of the building.

## NATIONAL BUILDING FACTS

**18%**

of total US energy use consumption comes from commercial buildings.<sup>19</sup>



### 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!<sup>20</sup>

# NOTES

- 1 This white paper summarizes research presented in the following report: KM Fowler, EM Rauch, JW Henderson, and AR Kora: *Re-Assessing Green Building Performance: A Post Occupancy Evaluation of 22 GSA Buildings*, PNNL-19369, Pacific Northwest National Laboratory, Richland, WA, 2010. For the original study of 12 GSA green buildings, see 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](http://www.gsa.gov/appliedresearch)
- 2 See glossary above for abbreviations.
- 3 US Department of Energy. Commercial Buildings Energy Consumption Survey (CBECS), 2003. Energy Information Administration. Washington, DC.
- 4 Building Owners and Managers Association (BOMA) International Experience Exchange Report. 2008. Special Studies 2005, Agency Managed, Downtown all sizes, US Government Sector. BOMA International, Washington, DC.
- 5 ENERGY STAR Portfolio Manager. [www.energystar.gov/index.cfm?c=evaluate\\_performance.bus\\_portfoliomanager](http://www.energystar.gov/index.cfm?c=evaluate_performance.bus_portfoliomanager)
- 6 IFMA. 2009. Space and Project Management Benchmarks #32. IFMA. Houston, Texas.
- 7 Center for the Built Environment (CBE) Occupant Satisfaction Survey, 2009. UC Berkeley.
- 8 Average percent better than baseline for Water, Energy, Maintenance, Janitorial, Grounds, Waste and Recycling costs per RSF as compared to BOMA industry baselines.
- 9 Industry baselines developed from GSA building data, the US Department of Energy, U.S. Environmental Protection Agency, International Facility Management Association, Building Owners and Managers Association International, University of California Berkeley's Center for the Built Environment, and the Energy Information Administration.
- 10 Energy Star scores are annual. Since the initial analysis, Cleveland CT and Youngstown have both improved their energy performance. The Cleveland Courthouse Energy Star score is 75 today, up from 69, and Youngstown is 77, up from 50.
- 11 [www.yourenergyfuture.org/energyFacts.htm](http://www.yourenergyfuture.org/energyFacts.htm). (accessed 23.04.2008).
- 12 [www.energystar.gov/index.cfm?c=business.bus\\_water](http://www.energystar.gov/index.cfm?c=business.bus_water), (accessed 23.04.2008).
- 13 *ibid.*
- 14 Suitland earned LEED Gold certification in 2011, two years after this study was conducted.
- 15 Center for the Built Environment (CBE) Occupant Satisfaction Survey, 2009. UC Berkeley.
- 16 Survey of 800 MBAs from 11 Top International Business Schools; Stanford Graduate School of Business, 2002 GlobeScan International Survey, MORI.
- 17 *ibid.*
- 18 Pew Center on Global Climate Change, *Towards a Climate-Friendly Built Environment*, June 2005, [www.pewclimate.org/publications/report/towards-climate-friendly-built-environment](http://www.pewclimate.org/publications/report/towards-climate-friendly-built-environment).
- 19 [goliath.ecnext.com/coms2/gi\\_0199-6408096/Section-2-Energy-consumption-by.html](http://goliath.ecnext.com/coms2/gi_0199-6408096/Section-2-Energy-consumption-by.html), (accessed 01.05.08).
- 20 [www.epa.gov/watersense/water/why.htm](http://www.epa.gov/watersense/water/why.htm), (accessed 23.04.08).

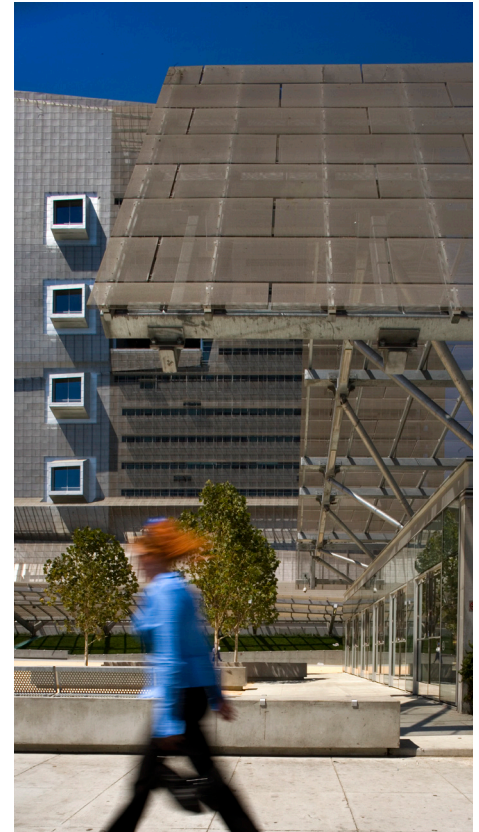


photo: Nic Lehoux



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