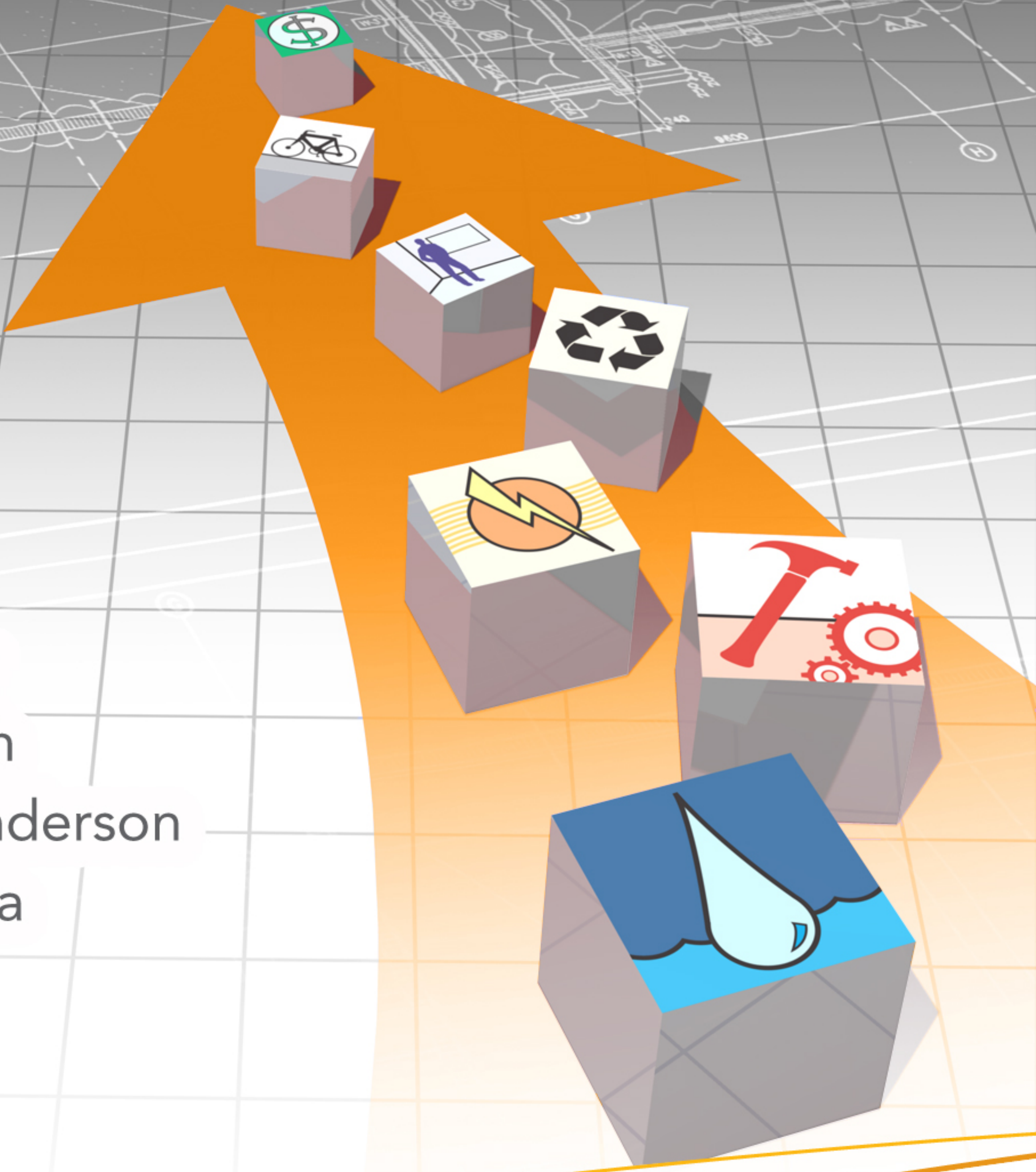
RE-ASSESSING GREEN BUILDING PERFORMANCE

A Post Occupancy Evaluation of 22 GSA Buildings



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Emily Rauch
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June 2010 – *Published September 2011*

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Re-Assessing Green Building Performance:
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Because of the need for a large quantity of data for each building, the GSA buildings' site contacts were generous with their time and data. The site contacts offered their time to host site visits, provided data for the building performance metrics, and promptly responded to our requests for clarification. Twenty-two of the buildings of the twenty-five pursued in this study lent themselves to assembling comparable data sets for analysis. The site contacts that helped make this study possible include the following (in alphabetical order)

Laura Anderson, Rockville FB

Paul Anderson, Davenport CT

Danielle Bogni, Las Vegas CT

Alex Bonaparte, Rockville FB

Jonathan Bringewatt, Lakewood FB

Jim Brown, Ogden FB

Gina Carter, Ogden FB

Steven Casey, San Francisco FB

Diana Ciryak, Cleveland CT

Chris Cockrill, Cape Girardeau CT, Manhattan FB

Pamela Coleman, Ogden FB

Scott Crews, Ogden FB

Mike Daniels, Rockville FB

Tim Essebaggers, Seattle CT

Dan Fenner, Sault Ste. Marie Port

John Garner, Omaha NPS FB and Omaha DHS FB

Christopher Grigsby, Denver CT

Angel Gonzalez, San Francisco FB

Richard Gordan, Auburn FB

Scott Hawkins, Greeneville CT and Knoxville FB

Sue Heeren, Davenport CT

Tina Hingorani, Santa Ana FB

Richard Hosey, Jacksonville FB

Jason Hunt, Fresno CT & FB

Nicholas Infantino, Youngstown CT & FB

Mary Ann Kosmicki, Omaha NPS FB and Omaha DHS FB

Kristina Lee, Omaha NPS FB

Chris Litsey, Auburn FB, Eugene CT, Seattle CT

Jill McCormick, Omaha DHS FB

Donald Murphy, Eugene CT

William Murphy, Auburn FB

Lorento Neequaye, Suitland FB

J. Michael Ortega, Denver CT

Peter Pocius, Sweetgrass Port

Sharon Schuler, Cape Girardeau CT

Wendy Schuman, Lakewood DOT FB

Warren Sitterley, San Francisco FB

Sandy Sitton, Fresno CT & FB

C. Johnathan Sitzlar, Greeneville CT and Knoxville FB

Amy Smith, Denver FB

Don Smyth, Omaha NPS FB

Mark Stanford, Sweetgrass Port

Joni Teter, Denver FB

Tim Trubey, Manhattan FB

Steven Underhill, Las Vegas CT

Christopher Wentzell, Sweetgrass Port

Stephen West, Scowcroft FB

Ryan Wilcoxen, Denver FB

Bruce Williams, Las Vegas CT

Thank you to these and all others that contributed to this research effort.

Executive Summary

The General Services Administration (GSA) sustainably designed buildings investigated under this study use less energy and water, cost less to maintain, and have occupants that are satisfied when compared to typical buildings. Additional findings from the building performance analysis include:

- Aggregate operations costs are 19% lower than industry average
- Carbon dioxide equivalent emissions are 34% lower than typical buildings
- U.S. Green Building Council Leadership in Energy and Environmental Design (LEED) Gold rated buildings generally perform better when compared to industry baselines.

Figure S1 represents the energy, water, and aggregate maintenance for each of the 22 buildings investigated. All of the Energy Star Portfolio Manager values were better than or equal to the industry baseline. Two-thirds of the water use intensity values (WUI, water use per gross square foot) and aggregate maintenance costs were better than the industry baseline. The buildings performing the best in all categories are located in the top right quadrant and have lighter colored circles.

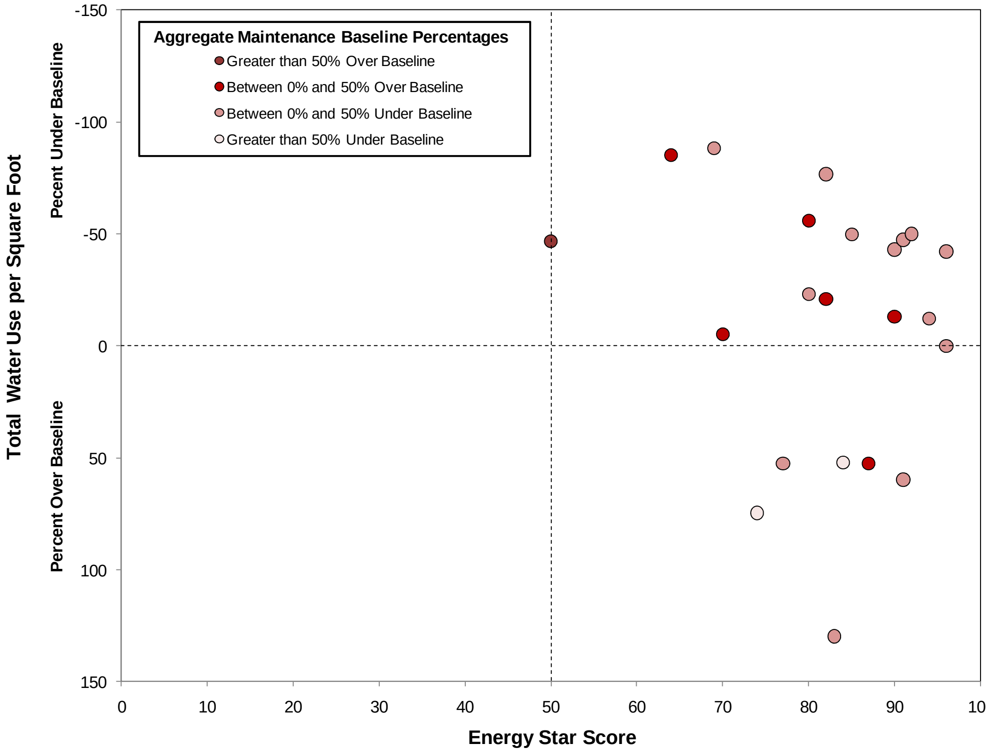


Figure S1. Energy performance is better than or equal to the baseline for all of the buildings, water performance and maintenance costs are better for two-thirds of the buildings.

This whole building performance measurement study uses the data collected for Assessing Green Building Performance: A Post Occupancy Evaluation of 12 GSA Buildings, includes 10 additional buildings, and includes updated data for the original buildings set, resulting in measured building performance data for twenty-two GSA buildings, located in seven of its national regions (Figure S2). The intent of the analysis is to inform GSA on how its sustainably designed buildings are performing in comparison to industry and GSA baselines of typically designed buildings for energy, water, maintenance and operations, waste, recycling, occupant commute, and occupant satisfaction. Thirteen of the buildings are LEED-certified, three are LEED-registered, one won the International Facility Managers Award for Sustainable Design and Energy Efficiency, while another five buildings emphasized energy efficiency during design.

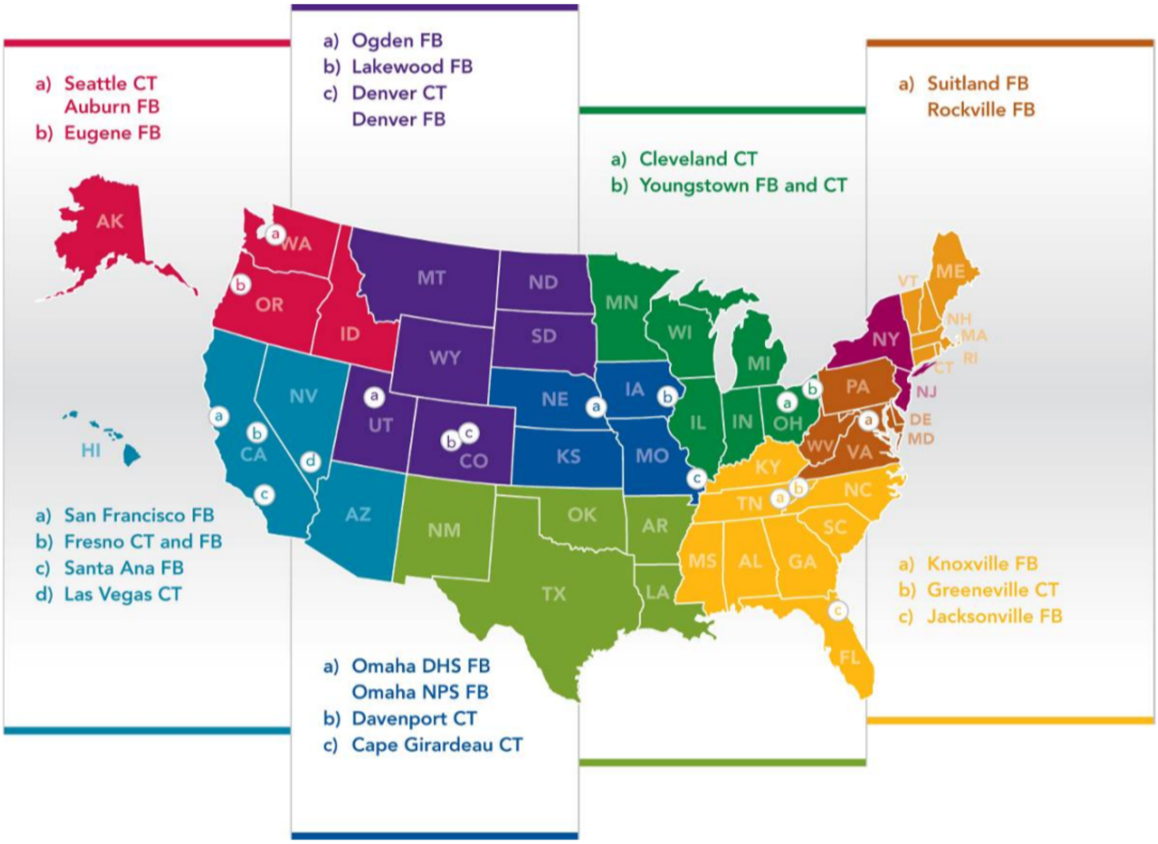


Figure S2. Twenty-two sustainably designed buildings from seven of the GSA regions are analyzed in this study.

As of the winter of 2009, GSA had 40 LEED-certified buildings. Many of these buildings are newly constructed and thus did not have performance data available for participation in the study. Although this study involved a small number of buildings, especially when considering the size of the GSA portfolio, it includes approximately one-third of GSA's LEED-certified buildings. LEED certification levels and Energy Star scores are shown in Table S1. If a building had received an official Energy Star rating, the score is in parentheses in the Certification Level column. The Energy Star Score column has unofficial scores calculated from the data provided by the sites. All of the buildings were at or above the 50th percentile of the Energy Star Portfolio Manager database, and all but 4 of the buildings scored above the 75th percentile, which means they could potentially qualify for an Energy Star rating.

Table S1. Documentation of "green-ness" of study buildings.

Building Name	Certification Level	LEED® Total Credits	Energy Star® Score
Greeneville CT	Energy Star 2007 (89)	N/A	90
Jacksonville FB	Energy Star 2007 (88)	N/A	82
Knoxville FB	LEED-EB Certified, Energy Star 2007 (88)	28	90
Cleveland CT	LEED-NC Certified	29	69
Youngstown CT & FB	LEED-NC Certified	27	50
Cape Girardeau CT	LEED-NC Silver	33	64
Davenport CT	LEED-NC Registered	N/A	80
Omaha DHS (L) FB	LEED-NC Gold	42	74
Omaha NPS (L) FB	LEED-NC Gold	40	82
Denver CT	Green Building Challenge, LEED-EB Silver	33	70
Denver (L) FB	LEED-NC Gold, Energy Star 2008 (96)	40	94
Lakewood (L) FB	LEED-NC Silver	35	84
Ogden (L) FB	LEED-NC Silver	34	83
Fresno CT & FB	California Energy Standard Title 24	N/A	87
Las Vegas CT	Energy Star 2007 (77)	N/A	77
San Francisco FB	LEED-NC Silver	34	96
Santa Ana FB	California Energy Standard Title 24	N/A	91
Auburn FB	LEED-NC Silver	36	96
Eugene CT	LEED-NC Gold, Energy Star 2009 (94)	39	92
Seattle CT	IFMA Sustainable Design and Energy Efficiency Award	N/A	85
Rockville (L) FB	LEED-NC Registered (Silver), Energy Star 2009 (76)	33	80
Suitland FB	LEED-NC Registered (Gold)	41	91

Table Notes

FB is the abbreviation used for Federal Buildings
CT is the abbreviation used for Courthouses
(L) identifies the leased buildings
LEED-NC is LEED for New Construction and Major Renovations and EB is for Existing Buildings

Performance metrics collected, normalized, and analyzed for the buildings include

- Water
- Energy
- Maintenance and operations
- Waste generation and recycling
- Occupant satisfaction
- Occupant commute.

These performance metrics were chosen to evaluate the intent of sustainable design - reduced environmental impact while keeping operational costs low and occupant satisfaction high.

Building contacts provided utility bills, maintenance budgets and schedules, and supported the administration of an occupant survey. Twelve consecutive months of data were collected for each performance metric and the data were normalized using building and site characteristics. The performance data were compared to industry baselines developed from GSA building data, the U.S. 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.

Aggregate Operational Cost is Lower than Baseline

The "aggregate operating cost" metric includes water utilities, energy utilities, general maintenance, grounds maintenance, waste and recycling, and janitorial costs. On average the study buildings have an aggregate operational cost 19% lower than the baseline. Four of the five buildings that cost more than the baseline in Figure S3 have higher general maintenance costs and two have higher energy costs.

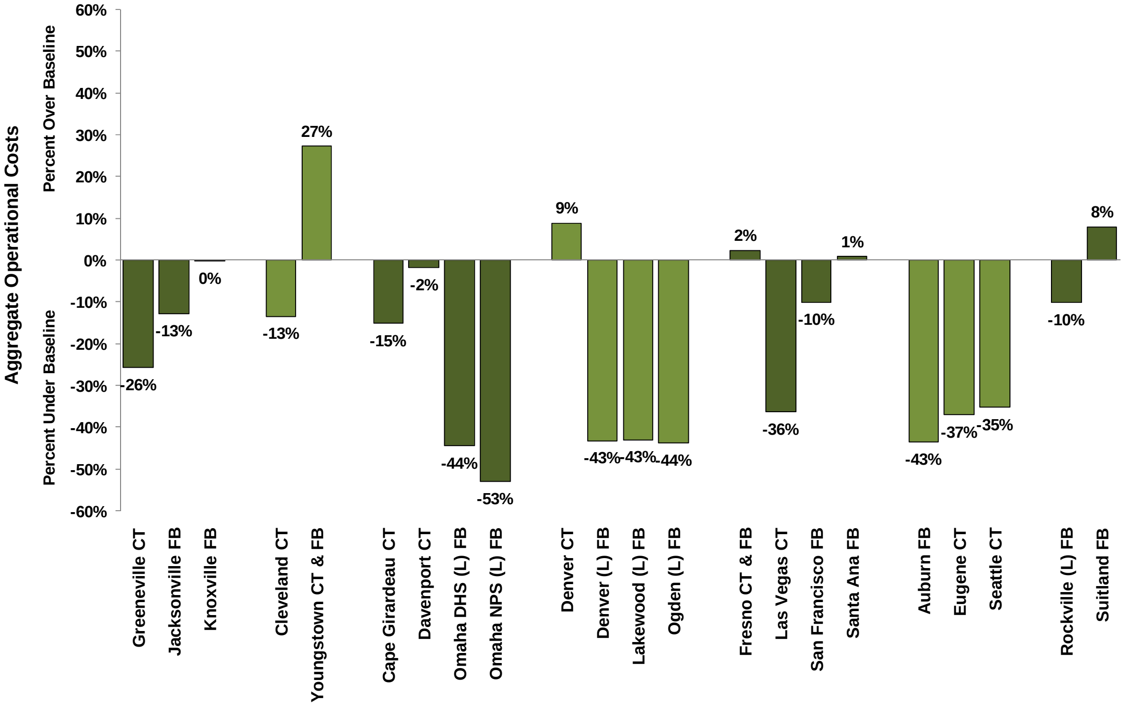


Figure S3. Aggregate operational costs are lower for most buildings.

Three different types of maintenance data were collected: general, janitorial, and grounds. Considering the calculated GSA 'general maintenance' cost baseline, half of the buildings cost less to maintain than the baseline. The janitorial maintenance costs were higher than the GSA baseline for more than half of the buildings. The grounds maintenance was within or below the normal industry baseline range for all but one building.

Energy Performance is Better than Baseline

The buildings' energy use intensity (EUI) was compared to multiple different baselines (Figure S4), with the most commonly referenced baseline being the Commercial Building Energy Consumption Survey (CBECS) average EUI for office buildings. The energy performance average of the buildings in the study was 25% better than CBECS, 10% better than fiscal year 2009 GSA Regional Averages, 13% better than fiscal year 2009 GSA Target values, and 18% better than CBECS regional averages. The CBECS national average is for office buildings built from 1990-2003, while the regional averages are for all building types. The GSA Target is the Public Buildings Service goal for energy performance across the agency.

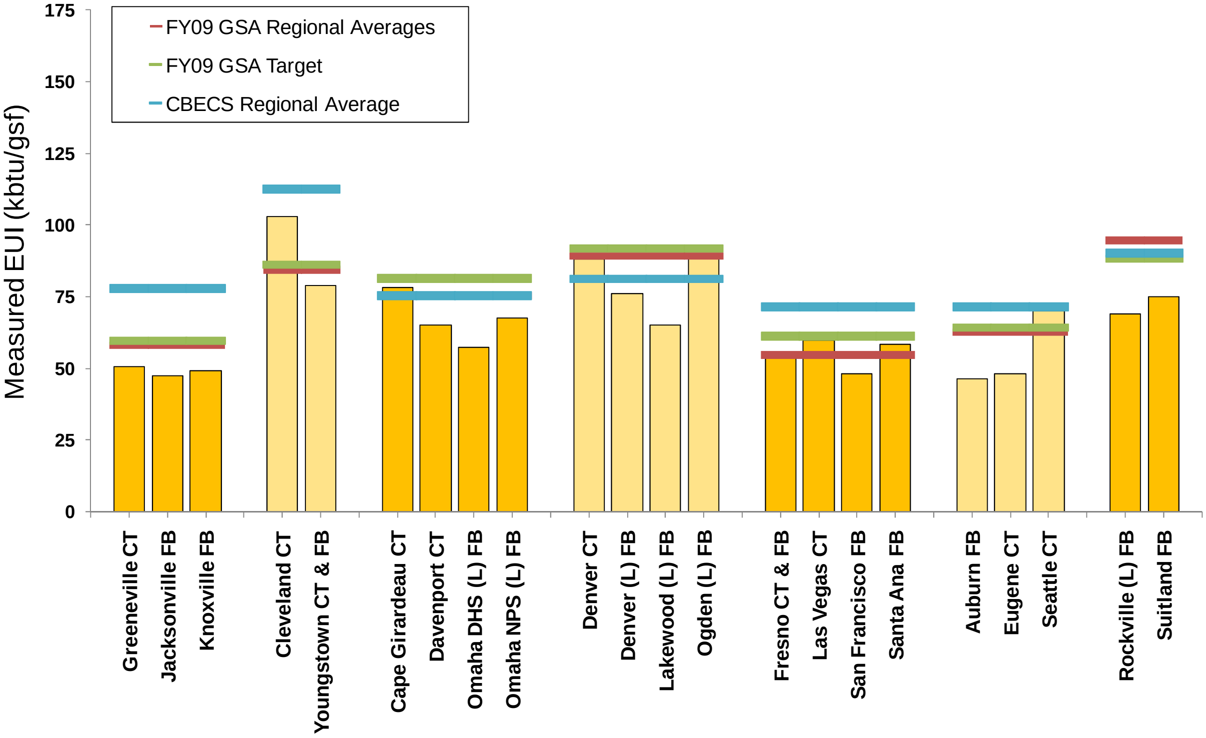


Figure S4. Energy performance of GSA buildings is strong when compared to industry averages.

Water Use is Lower than Baseline

GSA's metric for assessing the water use of its buildings is water use per gross square foot (WUI). This metric offers a simple way to compare building water use and shows that two-thirds of the buildings in this study use less water than the GSA baseline (Figure S5) with the average water use 11% below the baseline. Of the six buildings using more water than the baseline, all but one of them has cooling towers or evaporative cooling, two have exterior fountains in a hot, dry climate, and three have non-typical operating schedules.

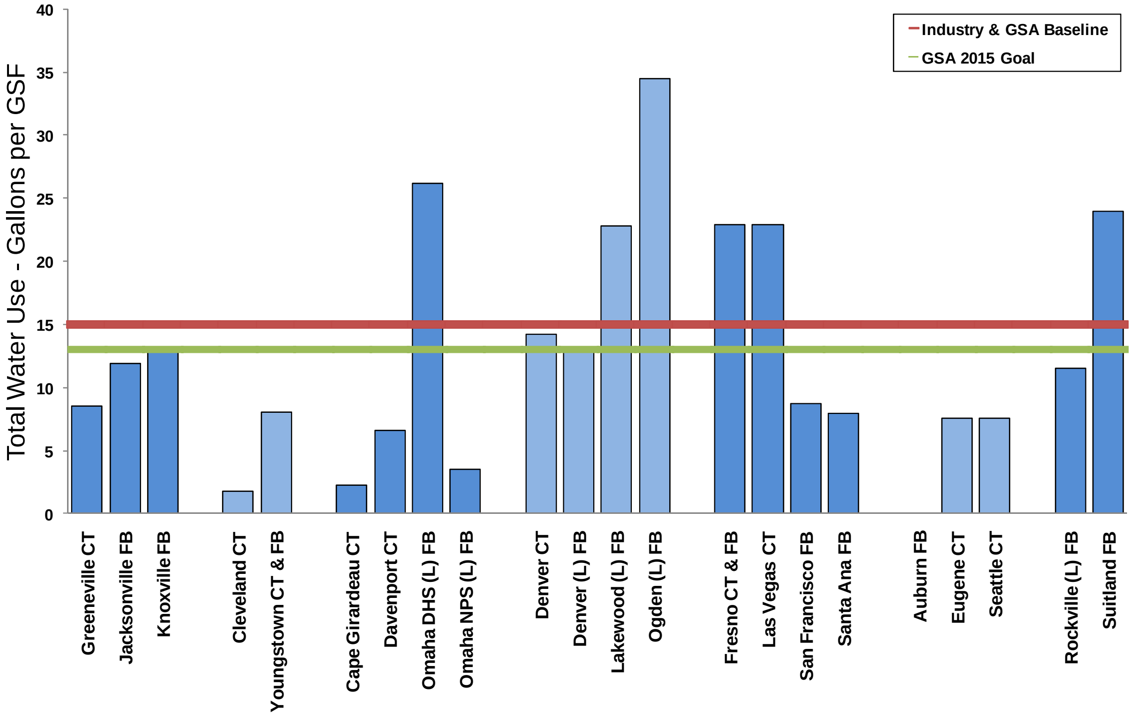


Figure S5. Two-thirds of the GSA buildings use less water than the GSA baseline.

As with energy, there are multiple baselines with which the buildings' water use can be analyzed. The water cost per rentable square foot is within or below the typical baseline range for all but one building. In the first assessment of GSA buildings the water use was analyzed as the quantity of domestic water use and the number of building occupants and visitors. This metric was examined however the comparison was erratic because of the variety of water uses in the buildings, with most buildings using more than the calculated baseline.

Occupants are Satisfied with the Buildings

The Center for the Built Environment (CBE) indoor environmental quality survey was tailored for the study participants with the addition of a few questions, and is referred to as the Sustainable Places and Organizational Trends (SPOT) survey. The core CBE survey has been given to the occupants of over 500 buildings, which offers a valuable baseline for comparing occupant satisfaction scores. Figure S6 shows the average scores from the SPOT survey were higher than the average scores in the CBE database, except for Lighting questions where the average survey responses were essentially the same. When compared to the LEED certified buildings in the CBE database, the SPOT survey responses were better for all questions except for air quality.

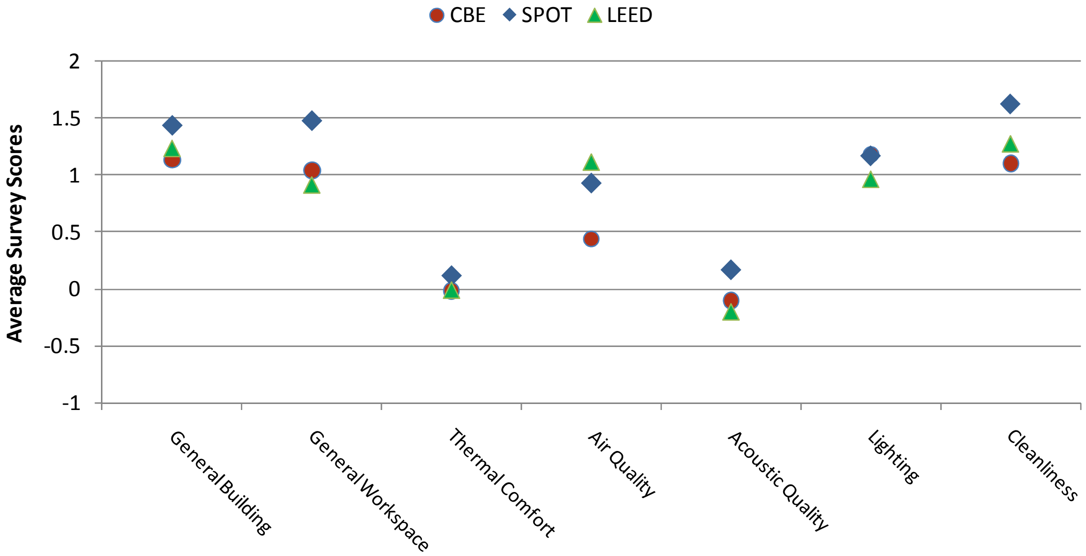


Figure S6. On average, the study building occupants are more satisfied with the buildings than those in the CBE database.

The average survey response rate was 47%. All of the general building satisfaction scores are positive, however, five are below the CBE database 50th percentile (i.e., below average). The average general building satisfaction levels are 27% higher than the CBE database 50th percentile (Figure S7).

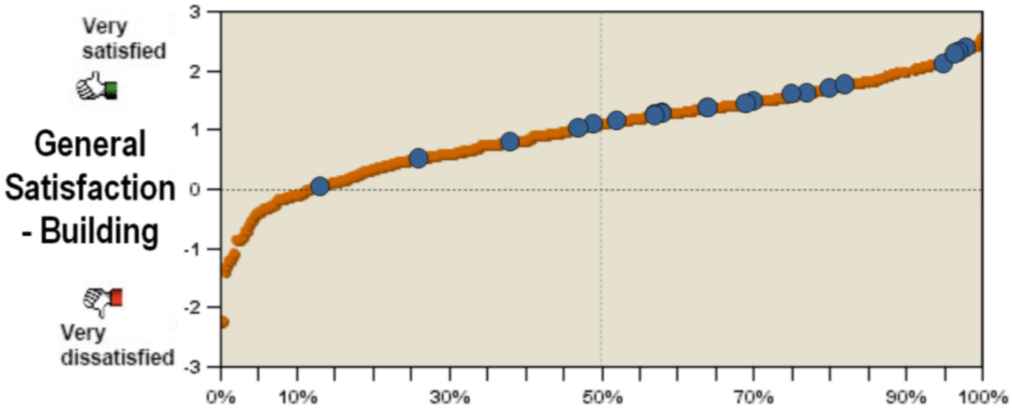


Figure S7. GSA building occupants are satisfied with their buildings overall.

Buildings and Occupants Contribute Less to Global Climate Change

Based on the occupant response to SPOT survey commute questions, the emissions from identified transportation modes result in 29% lower average carbon dioxide equivalent emissions when compared to the average commute (Figure S8). This could be the result of federal agency commute policies, building location, community culture, or sustainable design related decisions, such as preferred parking for carpools and alternative vehicles, showers and bike racks, or intentionally locating a building near mass-transit options.

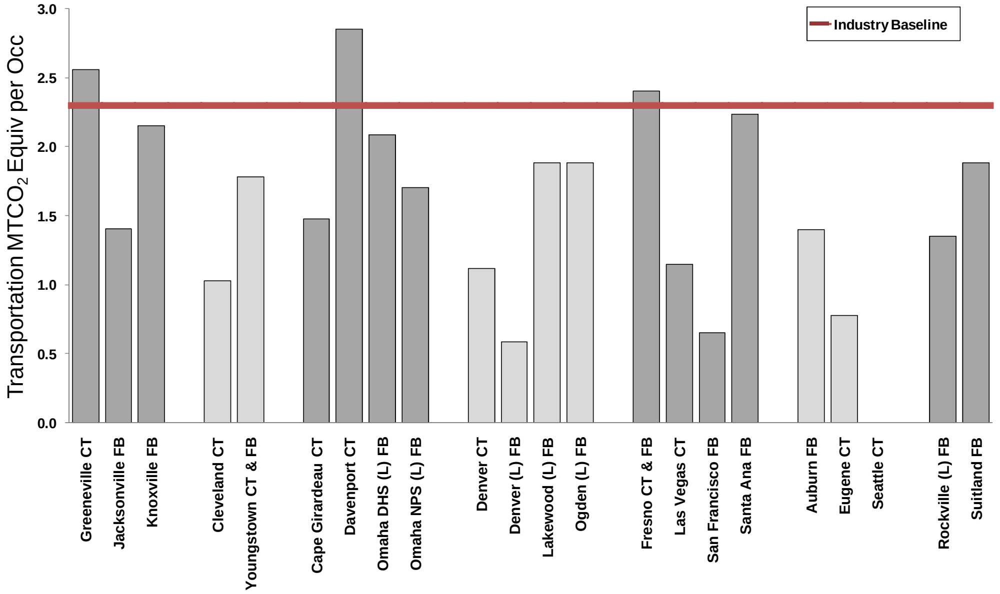


Figure S8. Lower emissions as a result of building occupant commute for most buildings.

Combining the emissions avoided from the occupant commute and the building energy performance shows that the average is 34% lower carbon dioxide-equivalent emissions than a typical building (Figure S9).

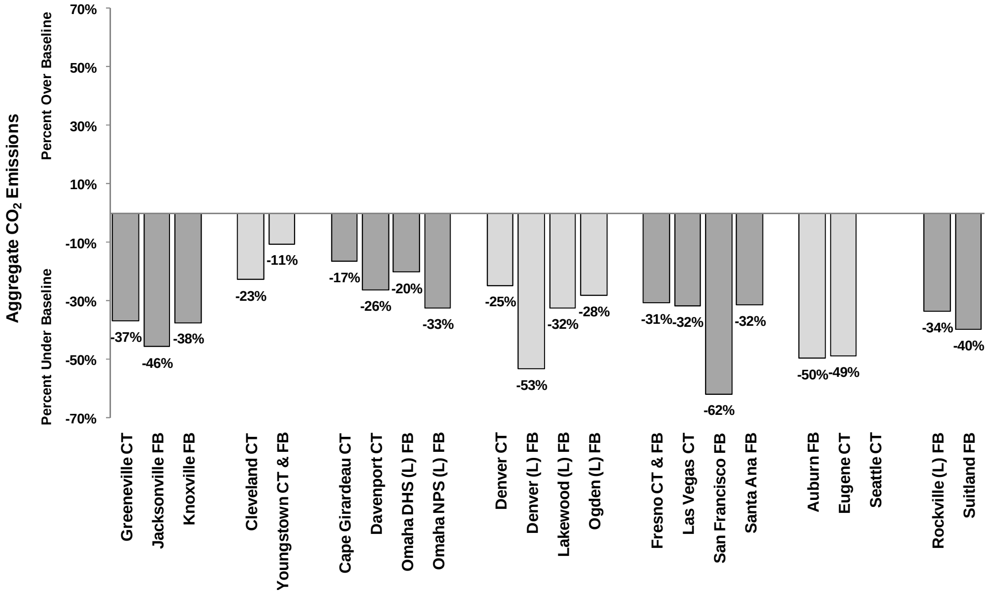


Figure S9. Emissions as a result of building energy performance and occupant commute.

LEED Gold Buildings are Top Performers

Figure S10 shows that overall the four LEED Gold buildings in the study performed better than the industry baselines. Water use for the Omaha DHS building is not only higher than the industry baseline, but also significantly higher than it was during the first assessment of this building. This change in water use should be investigated to understand if it is a data measurement error, a leak, an unintended use, or an increase in the building occupant related water use. The waste to recycle ratio is worse than the industry baseline for both of the Omaha buildings as well.

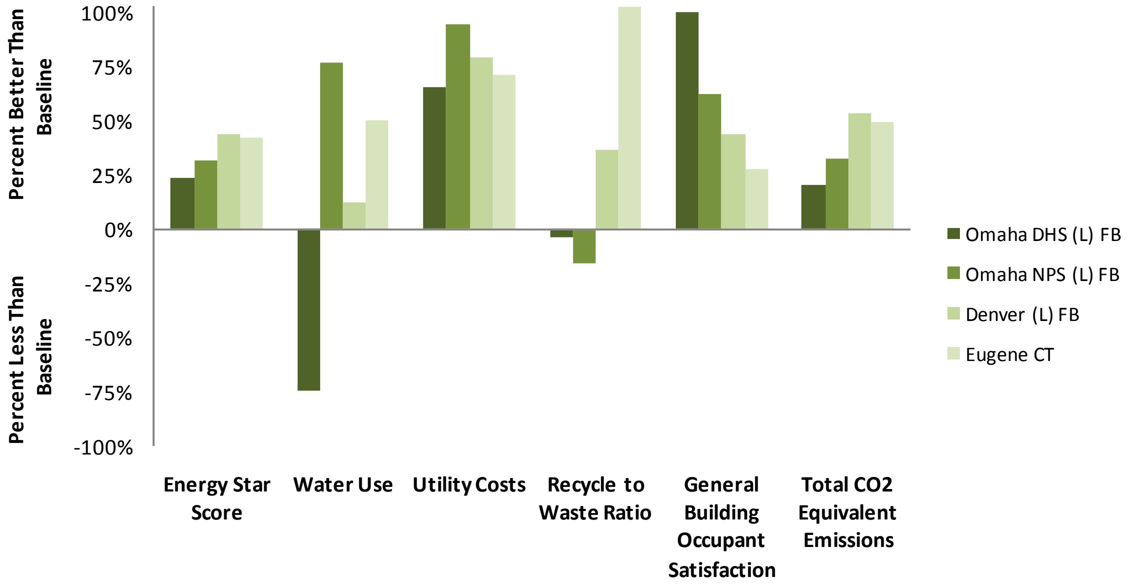


Figure S10. LEED Gold buildings show exceptional performance on all of the key performance metrics.

Baselines and Operations Make a Difference

One of the more important lessons learned with respect to whole building performance measurement and assessment is that the baselines selected for performance comparison are what define the study findings. When agency specific baselines are available, they offer a comparison of how a building meets an agency's expectations, but they make the assessment results less comparable to the general building industry. For this study GSA baselines were used whenever they were made available, however, industry baselines are also provided in order to offer another basis for comparison.

Do Sustainably Designed Buildings Perform Better?

The results from this study of 22 buildings are generally consistent with the findings from the original study of 12 buildings. For individual buildings the response to the question "Do sustainably designed buildings perform better when compared to an industry average?" is still "it depends." The results from this study should not be assumed to represent all sustainably designed buildings. When examining the average performance values for buildings the in this study, the aggregate operational costs are 19% lower, the energy performance is 25% better, and water performance is 11% better than comparable baselines. The LEED Gold buildings are performing well and the carbon emissions associated with the buildings are significantly lower than an average building. Given this portfolio analysis of building performance, it appears the sustainably designed buildings in the GSA portfolio are performing well and helping GSA to meet its mandated goals for reduced environmental impact.

The whole building performance measurement method used in this and the previous GSA study offers a replicable tool for assessing building performance. This portfolio analysis of 22 buildings offers an indicative assessment of building performance, identifying major strengths and weaknesses. When a diagnostic type of analysis is needed for a particular building, a detailed post occupancy evaluation or re-commissioning report may be needed to provide the necessary information on why a building is operating in a particular way.

Acronyms

ASHRAE	American Society of Heating, Refrigerating, and Air-Conditioning Engineers
BOMA	Building Owners and Managers Association International
Btu	British thermal unit
CBE	Center for the Built Environment
CBECS	Commercial Buildings Energy Consumption Survey
CO_2	Carbon dioxide
CT	courthouse
DHS	Department of Homeland Security
DOE	U.S. Department of Energy
EAc1	Energy and Atmosphere Credit 1 (Optimize Energy Performance)
EMCS	Energy Management Control System
EUAS	Energy Usage and Analysis System
EUI	energy use intensity
FB	federal building
FEDS	Federal Energy Decision System
FEMP	Federal Energy Management Program
ft^2	square feet
ft^3	cubic feet
FY	fiscal year
GSA	General Services Administration
gsf or GSF	gross square feet
HVAC	heating, ventilation, and air-conditioning
IAQ	indoor air quality
IEQ	indoor environmental quality
IFMA	International Facility Management Association
kBtu	one thousand British thermal units
kw	kilowatt
kwh	kilowatt hour
L	leased facilities
LBNL	Lawrence Berkeley National Laboratory
LEED	Leadership in Energy and Environmental Design
LEED-EB	LEED for Existing Buildings
LEED-NC	LEED for New Construction and Major Renovations
mBtu	one million British thermal units
$MTCO_2e$	metric tons carbon dioxide equivalent
N/A	not available
NPS	National Park Service
NREL	National Renewable Energy Laboratory
O&M	operations and maintenance
Occ	occupants
PBS	Public Buildings Service

PNNL	Pacific Northwest National Laboratory
POE	Post Occupancy Evaluation
R1	Round 1
rsf or RSF	rentable square feet
SVOC	semivolatile organic compound
SPOT	Sustainable Places and Organizational Trends (survey)
UFAD	Under floor air distribution
U.S.	United States
Vis	visitors
VOC	volatile organic compound
WBPM	whole building performance measurement
WEc3	Water Efficiency credit 3 (Water Use Reduction)
WUI	water use intensity

Contents

Figures

Tables

Introduction

The U.S. General Services Administration (GSA) has been applying sustainable design principles to its building design projects since 1999. In 2003, GSA set its target for certification at the Silver level of the U.S. Green Building Council's (USGBC) Leadership in Energy and Environmental Design for New Construction (LEED®-NC) green building rating system for new building design starts. In 2007, GSA evaluated the performance of a dozen sustainably designed buildings with the results documented in Assessing Green Building Performance: A Post Occupancy Evaluation of 12 GSA Buildings.[1] This is an updated study that involves the analysis of an additional ten GSA buildings for a total of 22 to determine the potential benefits and challenges of sustainably designed buildings.

GSA engaged several key stakeholders, including its own representatives, a research team from Pacific Northwest National Laboratory (PNNL), the University of California Berkeley's Center for the Built Environment (CBE), and site building managers and engineers to measure whole building performance in order to evaluate how well GSA's sustainably designed buildings are performing compared to industry norms and GSA comparative baselines. In contrast to LEED-NC, which is focused on the design of new construction projects; "whole building performance measurement" (WBPM) assesses how well sustainably designed buildings are actually operating. Thus, the primary intent of this WBPM study is to demonstrate the impact of investing in sustainably designed buildings, thereby enabling GSA to better document how its buildings are performing compared to a variety of building performance baselines. Ideally, the information derived from this study will be used to inform the design, construction, and operation of GSA's building portfolio.

Background

GSA buildings are typically built for a 100-year life and follow robust guidelines to enhance their asset value. The federal government owns or leases approximately 725 million square feet of office space and employs 2.7 million workers.

USGBC membership developed the LEED® green building rating system to provide a system for defining "green buildings." The rating system is organized by five aspects of building design

- Sustainable Sites
- Water Efficiency
- Energy & Atmosphere
- Materials & Resources, and
- Indoor Environmental Quality.

LEED ratings can be achieved for new construction and major renovation (LEED-NC), existing buildings (LEED-EB), and several other building products.

Points are earned for meeting the intent of specific design criterion in each of the above categories. A LEED rating is awarded based on the total number of points earned by a building design. Prior to LEED version 3.0, LEED-NC had a total of 69 possible points and LEED-EB had a total of 85 points. LEED version 3.0 has a 110 point scale. The Buildings are rated, depending on the number of points as

- Certified
- Silver
- Gold
- Platinum

GSA houses 1.1 million workers in 354 million square feet of office space (45% of federal government space).[2] Of the more than 4,000 LEED certified projects, 29% are owned by federal, state, or local governments.[3]

It is commonly recognized that a whole building, integrated design approach is essential to creating a sustainable or green building design. This design is assumed to result in optimal building performance based upon the product and equipment specifications. Several studies have documented the **projected benefits** of sustainably designed buildings.[4,5,6,7,8] Often these studies projected savings based on design intent or measured performance of a single metric, such as occupant productivity. The measured whole building performance of sustainably designed buildings has rarely been documented. To fully measure the operational impact of sustainably designed buildings, multiple occupant and operational measures, more than energy use, need to be considered.

Although energy modeling of a building's performance is a very useful tool during the design process, it does not always accurately predict how a building will perform. Studies have shown that although modeled data can predict average, relative performance, the models do not consistently predict actual performance of an individual building.[9,10] The National Renewable Energy Laboratory (NREL) technical reports have highlighted that building energy models assume the buildings will function under ideal operating conditions, which results in measured building performance being different and typically higher than modeled energy use. NREL also estimates that when an energy simulation is calibrated to the as-built design, weather, and current operating conditions, it would generally be within 12% of the measured performance. This is one reason why more measured performance data are needed to better predict the performance of design strategies, rather than design simulations.

In 2007 the New Buildings Institute led a study focused on energy performance in LEED buildings.[11] This study noted that the energy performance for individual projects is highly variable and more building performance data need to be gathered and analyzed to compare design performance with design intent. It also documented that the energy performance of LEED-NC buildings in their study performed 24% better than the Commercial Buildings Energy Consumption Survey (CBECS) average for all commercial building stock and 33% better than the CBECS average for office buildings.[12]

Scope and Approach

The scope of this WBPM study is to evaluate the impact of GSA's sustainably designed buildings by collecting and analyzing actual performance data from operating buildings for comparison to industry baselines for building performance. As study collaborators, the PNNL research team was responsible for data collection, data management, data synthesis, analysis, and report development. The GSA representatives provided building and site contacts, building data derived from existing GSA systems—such as the Energy Usage and Analysis System (EUAS), the Asset Business Plan, and Project Information Portal—and coordinated the completion of the study's version of the CBE survey to assess occupants' satisfaction with their buildings (also known as GSA's Sustainable Places and Organizational Trends [SPOT] survey). The CBE team was responsible for preparing, distributing, and summarizing the data from the SPOT building occupant satisfaction survey. The building managers and engineers hosted the site visit(s), provided data as requested, and deployed the SPOT survey. The quantity and quality of data were enhanced by the engagement of multiple stakeholders.

As of the end of 2009, GSA had 40 LEED-certified buildings that were either leased or owned.[13] At the start of this project in the summer of 2009, there were 34 GSA LEED certified projects with many those having recently been occupied. The selection criteria for the buildings in the study included the following

- Buildings built or remodeled in the last 10 years that included sustainable design or energy efficiency as a key design consideration.
- Ability to collect a minimum of 12 months of operations data, at least 6 months after the building occupancy date and from timeframe when the building is operating without major deficiencies.
- Data availability of calendar year 2008 performance data for the key performance metrics.
- Occupants' willingness to participate in the SPOT survey.
- Building performance comparability considerations, which included
    - selecting GSA building types (office and courthouse) that align with commercial building industry baselines
    - co-location of buildings by region
    - building ownership – leased or owned.

Using the above criteria helped to narrow the GSA portfolio of buildings to a list of 10 additional buildings for this update and 22 overall.

- eight are courthouses
- twelve are federal buildings
- two are courthouses and federal buildings

Three buildings were visited and performance measurement data were collected before it was understood that they did not meet all of the above criteria. Those buildings included two port of entry facilities and one federal building. The two port of entry facilities did not have comparable commercial building baselines. The federal office building was experiencing notable equipment problems that needed to be addressed before performance measurement would offer a comparable story. Site summaries for all of the buildings can be found in Appendix A. Additional detail on the excluded buildings can be found in Appendix B. A list of the buildings considered for this round of WBPM and why there were not included in the study can be found in Appendix C.

The buildings included in the report are listed in Table 1. Throughout the report the buildings are organized by region, then alphabetically. Federal buildings (FB) are typical office buildings. For the most part, courthouses (CT), include bankruptcy and criminal courtrooms and related offices. The combined courthouse and federal building (CT & FB) type includes significant courtroom space and significant typical office space. Six of the buildings are leased facilities, and the rest are GSA-owned.

Table 1. GSA buildings studied

Building Type	Building Full Name	Abbreviation
Region 4		
Courthouse	James H. Quillen U.S. Courthouse	**Greeneville CT**
Federal Building	Chas. E. Bennett Federal Building	**Jacksonville FB**
Federal Building	John J. Duncan Federal Building	**Knoxville FB**
Region 5		
Courthouse	Howard M. Metzenbaum U.S. Courthouse	**Cleveland CT**
Courthouse & Federal Building	Nathaniel R. Jones Federal Building and U.S. Courthouse	**Youngstown CT & FB**
Region 6		
Courthouse	Rush H. Limbaugh U.S. Courthouse	**Cape Girardeau CT**
Courthouse	Davenport U.S. Courthouse	**Davenport CT**
Federal Building	DHS Citizenship & Immigration Services	**Omaha DHS (L) FB**
Federal Building	Carl T. Curtis NPS Midwest Regional Headquarters	**Omaha NPS (L) FB**
Region 8		
Courthouse	Alfred A. Arraj U.S. Courthouse	**Denver CT**
Federal Building	EPA Region 8 Headquarters	**Denver (L) FB**
Federal Building	DOT Colorado Field Office	**Lakewood (L) FB**
Federal Building	Scowcroft IRS Utah Field Office	**Ogden (L) FB**
Region 9		
Courthouse & Federal Building	Robert E. Coyle U.S. Courthouse and Federal Building	**Fresno CT & FB**
Courthouse	Lloyd D. George U.S. Courthouse	**Las Vegas CT**
Federal Building	San Francisco Federal Building	**San Francisco FB**
Federal Building	Santa Ana Federal Building	**Santa Ana FB**
Region 10		
Federal Building	Auburn SSA Teleservice Center	**Auburn FB**
Courthouse	Wayne L. Morse U.S. Courthouse	**Eugene CT**
Courthouse	New Seattle U.S. Courthouse	**Seattle CT**
Region 11		
Federal Building	SAMSHA Metropolitan Service Center	**Rockville (L) FB**
Federal Building	Census Bureau Office Complex	**Suitland FB**

The buildings were located in seven different GSA regions (Figure 1)

- three in the Southeast Region 4
- two in the Great Lakes Region 5
- four in the Heartland Region 6
- four in the Rocky Mountain Region 8
- four in the Pacific Region 9
- three in the Northwest/Arctic Region 10
- two in the National Capital Region 11.

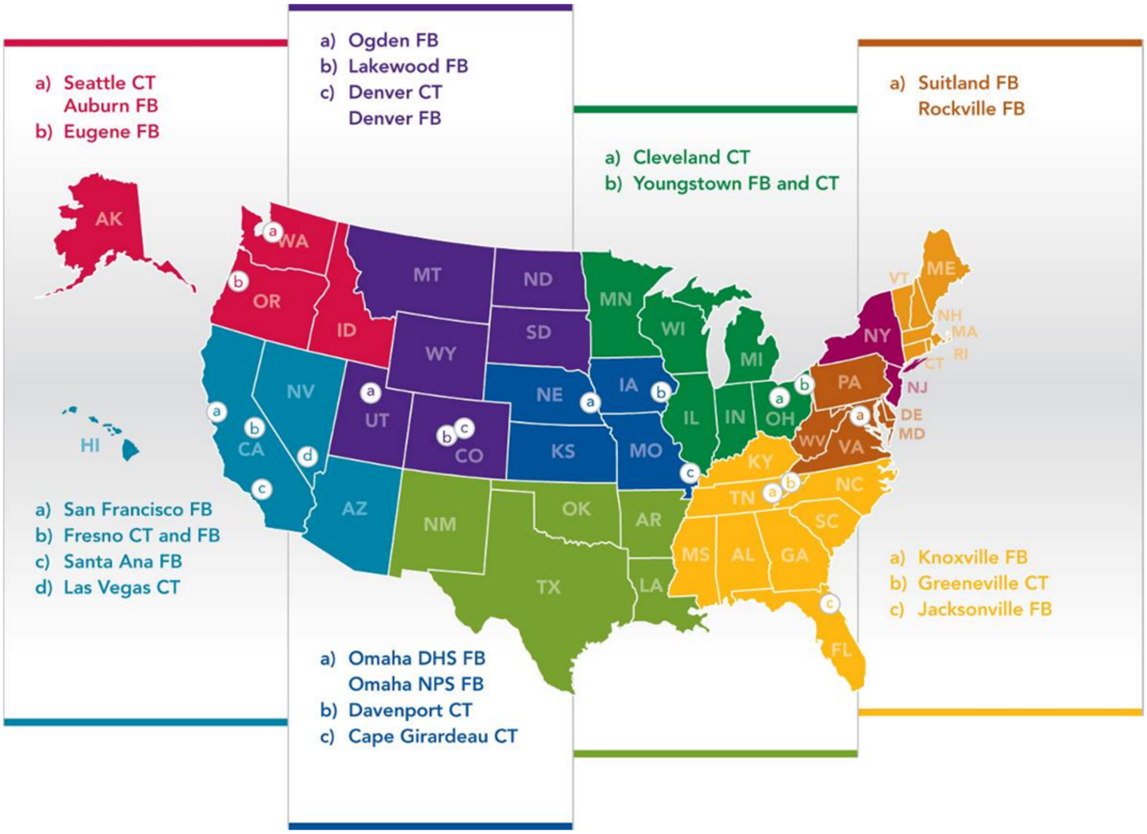


Figure 1. Study buildings by region

Many of these buildings have won sustainable design related awards, thirteen of the buildings are U.S. Green Building Council LEED-certified buildings, three are LEED registered, one won the International Facility Managers Award for Sustainable Design and Energy Efficiency, and five buildings emphasized energy efficiency during design. It is assumed GSA design expectations have resulted in a number of undocumented sustainably designed buildings. Given the number of GSA owned or leased LEED-certified buildings, LEED offers the most consistent way to track sustainably designed buildings within the agency. Brief descriptions of the buildings can be found on the next few pages.

Year Built: 2001
GSF: 160,975

Greeneville CT

The Quillen Courthouse replaced a smaller courthouse, from which the occupants reclaimed quality historic furniture. Some of the energy-efficiency features in the building include a well-insulated white roof and EMCS of lighting and occupancy sensors.

Year Built: 1910
Year Renovated: 2005
GSF: 251,314

Cleveland CT

The courthouse is on the National Register of Historic Places. The renovation preserved 96% of the existing shell and 59% of interior elements. It won GSA's Environmental Award for recycling because of its seven-material collection system.

Year Built: 1967
Year Renovated: 2004
GSF: 338,008

Jacksonville FB

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

Year Built: 2002
GSF: 52,240

Youngstown CT & FB

The building was built on a brownfield, as part of the city's urban revitalization. The facility incorporates daylighting to over 75% of occupied spaces, a stormwater management demonstration, a white membrane roof, and light-colored pavement.

Year Built: 1986
Year Renovated: 2005
GSF: 172,684

Knoxville FB

Located in downtown, the federal building currently houses a range of services. Alterations include enhanced metering techniques, and a rainwater system. The roof reduces the heat island effect, as well as housing photovoltaic panels.

Year Built: 2008
GSF: 173,392

Cape Girardeau CT

This courthouse is one of the first LEED buildings in the area. The facility features building HVAC and lighting controls, irrigation rain sensors, and low-flow fixtures. Carbon dioxide sensors and low-emitting materials add to the enhanced IEQ design.

Davenport CT

The Davenport Courthouse renovation maintained the integrity of the historic space, while adding more courtrooms, incorporating techniques to bring in daylight and the HVAC system utilizes high efficiency equipment.

Year Built: 1933
Year Renovated: 2005
GSF: 79,872

Denver CT

The Arraj Courthouse was designed sustainably and earned LEED for Existing Buildings Certification. The building is located downtown and uses an underfloor air distribution system, lighting sensors, as well as photovoltaic panels.

Year Built: 2002
GSF: 327,103

Omaha DHS FB

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

Year Built: 2005
GSF: 86,000

Denver FB

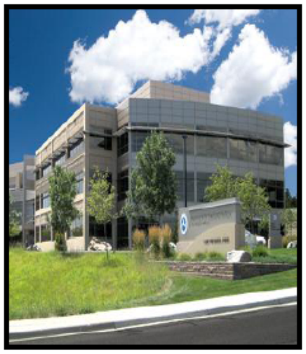
The EPA Region 8 Headquarters building located in a redeveloped area of downtown Denver is rated with LEED Gold certification. The building uses daylighting, an underfloor air distribution system, a vegetated roof, and photovoltaic panels.

Year Built: 2006
GSF: 301,292

Omaha NPS FB

The building was built as part of an urban redevelop-ment effort. This building showcases passive solar design, daylight harvesting, and an underfloor air distribution system. Use of adaptive vegetation eliminated the need for irrigation.

Year Built: 2004
GSF: 68,000



Lakewood FB

This facility is a LEED Silver leased building. Features include low-emitting materials, and daylight and views in 91% of regularly occupied spaces. All building occupants receive a booklet about the design and operations.

Year Built: 2004
GSF: 128,342

Year Built: 1900
Year Renovated: 2001
GSF: 105,000

Ogden FB

Renovations transformed this historic building into usable office space for the IRS. The design incorporated an underfloor air distribution system which was coupled with indirect/ direct evaporative cooling.

Year Built: 2007
GSF: 652,433

San Francisco FB

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 naturally ventilated and underfloor air distribution HVAC systems, and extensive daylighting.

Year Built: 2005
GSF: 495,914

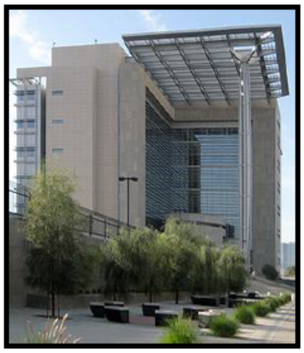
Fresno CT & FB

The Coyle Courthouse and Federal Building houses 14 courtrooms and is the tallest building in the city. Designed under California's Title 24 energy standard, the building includes high-efficiency lighting and underfloor air distribution.

Year Built: 1975
Year Renovated: 2005
GSF: 280,365

Santa Ana FB

Renovated in 2005, this Federal Building lies in the heart of the civic center and accommodates a large flow of visitors each day. This building features high-efficiency lighting and HVAC systems, occupancy temperature control, and energy efficient elevators.



Year Built: 2000
GSF: 454,877

Las Vegas CT

The Lloyd George Courthouse creates a federal presence in downtown with a large column supporting the sun-screen entry canopy. The courthouse was rated under Energy Star in 2007 and includes high-efficiency lighting and HVAC systems.

Year Built: 1944
Year Renovated: 2006
GSF: 205,354

Auburn FB

Renovated from a warehouse in 2006, the open plan office space earned a LEED Silver rating. Unique features include underfloor air distribution system, use of low-emitting materials, and increased ventilation.

Eugene CT

This was the first LEED Gold Courthouse in the US. Notable features include underfloor air distribution system, daylight sensors, and low flow fixtures. IEQ is improved through the use of low-emitting materials.

Year Built: 2006
GSF: 270,322

Rockville FB

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.

Year Built: 2004
GSF: 232,000

Seattle CT

Located in downtown Seattle, this court-house has been deemed one of the safest structures ever built. It features radiant floor heating, a well-utilized EMCS system, waterless urinals, and photovoltaic panels.

Year Built: 2004
GSF: 658,392

Suitland FB

The Census Bureau Headquarters building's curved rectangular shape takes advantage of natural daylighting. Other features include the under-floor air distribution system, vegetative roofs and bioswales.

Year Built: 2006
GSF: 2,340,988

The PNNL research team collected the building and site characteristics data listed in Table 2 to normalize the building performance metrics. For example, gross interior floor area (gsf) is the total building square footage value used to estimate costs per square foot, energy use per square foot, and more. The Department of Energy (DOE) Federal Energy Management Program (FEMP) *Building Cost and Performance Metrics: Data Collection Protocol*[14], developed by PNNL, was the tool used to identify, normalize, and analyze the performance data collected for each building.

Table 2. Building and site characteristics metrics

Metric Categories	Characteristic
Building Specifications	**Building Location** *address, city, state, zip code*
	Building Function *Federal building, courthouse*
	Key Building Features *LEED checklist and design highlights*
	Building Occupancy Date *Year*
	Gross Interior Floor Area (gsf) ft^2
	Rentable Floor Area (rsf) ft^2
Occupancy	**Hours of Operation** $\frac{hours}{week}$ *# of Computers*
	Total Number of Regular Occupants and Visitors $\frac{\text{Occupant}}{\text{work day}}$ $\frac{\text{visitors}}{\text{work day}}$
	Occupant Gender Ratio *Number of female & male occupants*
First Costs	**Total Building Cost** ***Design and Construction Cost*** $\frac{\$}{ft2}$

For each of the buildings, data were collected and analyzed for the key performance metrics provided in Table 3. The PNNL research team collected a minimum of 12 consecutive months of data and documented an industry baseline for each metric. When available, the study also used GSA baselines for performance analysis. Site and building contacts provided utility bills, maintenance budgets and schedules, and supported the distribution of the occupant satisfaction survey.

Table 3. Whole building performance metrics

Metrics	Performance Measurement	Reporting Metrics
Water	**Total Building Potable Water Use** $\frac{\text{gal}}{\text{year}}$ $\frac{\$}{\text{year}}$	**Annual Domestic Water Use** $\frac{\text{gal}}{\text{occupant}}$ $\frac{\$}{\text{occupant}}$ $\frac{\text{gal}}{\text{gsf}}$ $\frac{\$}{\text{rsf}}$
	Indoor Potable, Outdoor, and Process Water Use $\frac{\text{gal}}{\text{year}}$ $\frac{\$}{\text{year}}$	
Energy	**Total Building Energy Use** $\frac{\text{Btu}}{\text{year}}$ $\frac{\$}{\text{year}}$	**Annual Energy Use** $\frac{\text{Btu}}{\text{gsf}}$ $\frac{\$}{\text{rsf}}$ $\frac{\text{Gkg } CO_2}{\text{year}}$
Maintenance & Operations	**Building & Grounds Maintenance** $\frac{\text{Service Calls}}{\text{year}}$ $\frac{\$}{\text{year}}$ $\frac{\text{Preventative Maintenance}}{\text{year}}$	**Annual M&O** $\frac{\text{Service Calls}}{\text{Preventative Maintenance}}$ $\frac{\text{Maint }\$}{\text{rsf}}$ $\frac{\text{Grounds }\$}{\text{rsf}}$ $\frac{\text{Janitor }\$}{\text{rsf}}$
Waste Generation & Recycling	**Solid Sanitary Waste** $\frac{\text{ton}}{\text{year}}$ $\frac{\$}{\text{year}}$	**Annual Waste & Recycled** $\frac{\text{lb}}{\text{occupant}}$ $\frac{\$}{\text{rsf}}$ $\frac{\$}{\text{occupant}}$ $\frac{\text{lb Recycled}}{\text{lb Sanitary Waste}}$
	Recycled Material $\frac{\text{ton}}{\text{year}}$ $\frac{\$}{\text{year}}$	
Occupant Satisfaction	**Building Occupant Self-Reported Satisfaction** $\frac{\text{Occupant Rating}}{\text{Survey Metric}}$	**Building Occupant Satisfaction** *CBE Baseline Percentile - Total Building Occupant Satisfaction*
Transportation	**Regular Commute (from survey data)** $\frac{\text{miles}}{\text{gallons}}$ $\frac{\text{miles}}{\text{week}}$	**Annual Transportation Impacts** $\frac{\text{Gkg } CO_2}{\text{year}}$

Baseline Summary

One of the more important lessons learned with respect to whole building performance measurement and assessment is that the baselines selected for performance comparison are what define the study findings. When agency specific baselines are available, they offer a comparison of how a building meets an agency's expectations, but they make the assessment results less comparable to the general building industry. Ideally performance measurement data should be compared to other measured building performance data. Comparing measured values to modeled or estimated values does not offer a valid comparison, and should be avoided whenever possible. For this study GSA baselines were used whenever they were made available, however, industry baselines are also provided in order to offer another basis for comparison.

In addition to the baselines needing consistency to make the performance measurement and assessment data useful, the buildings being studied need to be working properly to be representative of sustainably designed building performance. If a building is not operating well because it has not been properly commissioned, has had an equipment failure, or occupancy settings have not been configured, it is not useful to include in a portfolio analysis of sustainably designed buildings. In the case of a building that is not working properly, it would be difficult to parse out what aspect of the performance data is related to the design rather than the insufficient operations, and it would be more effective to perform a detailed post occupancy evaluation to identify where changes could be made in the building to improve building performance. For example, one of the buildings originally included in the study was found to have heating, ventilation and air conditioning equipment that was not functioning properly to meet the needs of the occupants. The equipment challenges were not related to the sustainable design features of the building, so the building could not be included in the study until the building was operating normally. The building managers have been working to improve the building's operations so that its equipment is performing as expected. This building could be included in future performance measurement studies when the equipment issues have been resolved.

Comparable baselines were identified for each of the metrics. Where available, GSA, regional, and industry baselines are shown together throughout the report to offer multiple points of view to assess the buildings within the study. The following tables are summaries of the baselines used in the study. Table 4 includes the baselines that apply to all of the buildings, regardless of location, size, or number of occupants. Table 5 includes baseline values that applied to specific GSA regions. Some of the baseline values were calculated specifically for the building because of occupancy and/or location. Building specific baselines are in Table 6. Additional details regarding the baselines, especially the water baseline, are provided in Appendix D.

Table 4. Baseline Values and References

Metric	Value	Units	Source
Water	15	gal/gsf	IFMA # 32 50th Percentile (2009 pg 59)
	13	gal/gsf	GSA FY2015 Target
	0.19	$/rsf	BOMA 2008 All Sector Total Building Rentable Area - Utility Water/Sewer
Energy	2.53	$/rsf	BOMA 2008 All Sector Total Building Rentable Area - Utility (less water)
	88	kBTU/gsf	EIA CBECS Table C12 Office 1990-2003
Maintenance - Grounds	0.45	$/rsf	BOMA 2008 All Sector Total Building Rentable Area - Roads/Grounds
Maintenance - Preventative	0.75	Ratio	IFMA #32 Facilities less than 5 years old (2009 pg. 47)
Maintenance - Service	0.25	Ratio	IFMA #32 Facilities less than 5 years old (2009 pg. 47)
Waste	0.05	$/rsf	IFMA #25 (2004 pg. 27)
Recycling	0.01	$/rsf	IFMA #25 (2004 pg. 27)
Occupant	1.13		CBE 2009 Survey Average Score - General Building Satisfaction
Satisfaction	1.23		CBE 2009 Survey Average Score - LEED General Building Satisfaction
Transportation	2.3	MTCO2e/ occ/year	EPA Climate Leaders Guidance (2008) and DOT Travel Survey (2001)

Table 5. Regional Baseline Values

	Regional Baselines						
	Energy kBTU/gsf			Maintenance $/rsf			
GSA Region	GSA FY09 Regional EUI	GSA FY09 Regional Target	CBECS Regional EUI	GSA General Maint	Adapted BOMA General Maint	GSA Janitorial Maint	Adapted BOMA Janitorial Maint
4	58	60	78	$1.25	$1.23	$1.32	$1.25
5	84	86	113	$1.23	$1.81	$1.91	$1.60
6	75	81	75	$1.33	$1.60	$1.55	$1.39
8	89	92	81	$1.79	$1.50	$1.33	$1.32
9	55	61	71	$1.83	$2.15	$1.71	$1.98
10	63	64	71	$1.37	$1.80	$1.34	$1.66
11	95	88	90	$2.24	$2.23	$1.93	$2.12

For the energy baseline in Table 6, the Energy Star Portfolio Manager energy use intensity value for the 50th percentile is shown. This value is used to represent the industry average energy use.

Table 6. Building Specific Baseline Values

	Energy	**CO_2**		**Water**
	kBTU/gsf	**$MTCO_2e$/gsf**		**gal per Occ-Vis Equiv**
Building Name	Energy Star Baseline-50%	Industry Average - 50%	Energy Star - 75%	FEMP Water Use Intensity
Greeneville CT	87	0.014	0.010	3750
Jacksonville FB	93	0.016	0.012	3750
Knoxville FB	91	0.015	0.011	3750
Cleveland CT	129	0.014	0.010	3160
Youngstown CT & FB	80	0.012	0.012	3750
Cape Girardeau CT	92	0.016	0.012	3645
Davenport CT	96	0.015	0.011	3750
Omaha DHS (L) FB	77	0.019	0.014	4323
Omaha NPS (L) FB	103	0.017	0.013	3698
Denver CT	123	0.016	0.012	3750
Denver (L) FB	144	0.026	0.019	3750
Lakewood (L) FB	103	0.021	0.015	3645
Ogden (L) FB	139	0.014	0.011	4170
Fresno CT & FB	91	0.008	0.006	3750
Las Vegas CT	84	0.014	0.010	3750
San Francisco FB	112	0.010	0.007	3855
Santa Ana FB	109	0.007	0.005	3791
Auburn FB	108	0.011	0.008	3908
Eugene CT	90	0.009	0.007	3855
Seattle CT	111	0.010	0.008	3750
Rockville (L) FB	99	0.016	0.012	3908
Suitland FB	140	0.018	0.013	3960

Report Contents and Organization

The observations for each of the key performance metrics addressed under this study are provided in the Summary Analysis section of this report. The values used for comparison include the following

- water use per gross square foot
- estimated domestic water use per occupant-visitor equivalent
- water cost per rentable square foot
- Energy Star rating
- energy use per gross square foot
- energy cost per rentable square foot
- general maintenance cost per rentable square foot
- grounds maintenance cost per rentable square foot
- janitorial maintenance cost per rentable square foot
- aggregate operational cost per square foot
- ratio of quantity recycled to total waste generation
- waste cost per square foot
- occupant satisfaction scores
- occupant commute greenhouse gas emissions per occupant.

General observations from the study are provided in the Conclusion section. Site-specific observations are provided in the site summaries in Appendix A. Details on excluded buildings can be found in Appendix B and Appendix C has a list of buildings considered for this study and why there were not included at this time. A summary of how the comparative baselines were developed can be found in Appendix D. Appendix E is a sample Indoor Air Quality assessment performed on one of the study buildings. Example occupant satisfaction survey questions can be found in Appendices F and G. Appendix H, I, and J contain the conversion factors, site contacts, and references respectively.

Summary Analysis

This section is organized by metric type. First, the key building and site characteristics are provided as a reference for the analysis. Next, the building performance data are analyzed for each performance metric, with the information provided in the following order

- Water
- Energy
- Maintenance and operations
- Waste generation and recycling
- Occupant satisfaction
- Transportation.

The discussion for each metric includes performance data, costs, and operational, occupant, or environmental impact, as available.

The data represented in this section were provided by GSA representatives, site contacts, and CBE. Data summarized in this study were provided in mid to late 2009 and are primarily for calendar year 2008. Where multiple years of data were available they were examined for significant differences and similarities. In the few times the differences were significant, they are noted in the text.

The building and site characteristics data collected for each building are used to normalize the performance metrics (Table 7). The gross square footage (gsf) and rentable square footage (rsf) are the primary building geometry characteristics used for normalizing the performance metrics. The building geometry metrics are needed as part of the water, energy, and maintenance and operations metrics. The number of regular building occupants (Occ) and visitor (Vis) estimates are needed as part of the water, energy, waste and recycling, and transportation metrics. The number of computers (# Comps) is needed as part of the energy metric.

Table 7. Key building and site characteristics

Building Name	Building ID #	Region	Year Built/ Renovated	GSF	RSF	# Occ	Occ-Vis Equiv	Hours/ week	# Comps
Greeneville CT	TN0012ZZ	4	2001	160,975	136,104	85	103	70	100
Jacksonville FB	FL0067ZZ	4	1967/2004	338,008	299,941	1,000	1,150	71	1,080
Knoxville FB	TN0076ZZ	4	1986/2005	172,684	120,171	285	310	65	285
Cleveland CT	OH0033ZZ	5	1910/2005	251,314	185,105	105	143	60	120
Youngstown CT & FB	OH0302ZZ	5	2002	52,240	44,476	45	243	60	60
Cape Girardeau CT	MO0147ZZ	6	2008	173,392	138,548	45	100	60	90
Davenport CT	IA0027ZZ	6	1933/2005	79,872	68,391	45	63	70	60
Omaha DHS (L) FB	NE1430ZZ	6	2005	86,000	73,459	65	360	112	80
Omaha NPS (L) FB	NE1425ZZ	6	2004	68,000	62,772	125	134	70	140
Denver CT	CO0061ZZ	8	2002	327,103	256,718	170	370	70	185
Denver (L) FB	CO1977ZZ	8	2006	301,292	248,849	922	993	68	1,289
Lakewood (L) FB	CO1923ZZ	8	2004	128,342	122,225	318	336	70	383
Ogden (L) FB	UT1434ZZ	8	1900/2004	105,000	102,579	514	521	120	745
Fresno CT & FB	CA0309ZZ	9	2005	495,914	393,243	235	510	68	250
Las Vegas CT	NV0304ZZ	9	2000	454,877	368,969	321	428	55	242
San Francisco FB	CA0305ZZ	9	2007	652,433	523,208	1,314	1,444	70	1,400
Santa Ana FB	CA0200ZZ	9	1975/2005	280,365	205,378	409	459	70	424
Auburn FB	WA0102ZZ	10	1944/2006	205,354	201,003	675	675	70	675
Eugene CT	OR0053ZZ	10	2006	270,322	237,852	120	170	45	176
Seattle CT	WA0831KF	10	2004	658,392	557,077	500	600	53	550
Rockville (L) FB	MD0802ZZ	11	2004	232,000	228,020	720	760	60	800
Suitland FB	MD0778AG	11	2006	2,340,988	1,410,988	5,360	5,425	119	5,500

In addition to the building and site characteristics, the research team also captured the following information about the buildings that was of general interest (Table 8)

- Six of the buildings are leased, sixteen are GSA-owned.
- Seven of the buildings had major renovations, fifteen are new construction.
- Eight of the buildings are 4 stories tall or fewer.

- Ten of the buildings have GSA personnel co-located with the occupants.
- Nine buildings have underfloor air distribution systems.
- Five buildings purchase central steam.
- Three buildings purchase central chilled water.

Table 8. Additional building and site characteristics

Building Name	Owned or Leased	Project Type	# of Floors	GSA Personnel On Site	Underfloor Air HVAC Distribution	Purchased Steam	Purchased Chilled Water
Greeneville CT	Owned	New	4	No	No	No	No
Jacksonville FB	Owned	Renovation	11	**Yes**	No	No	No
Knoxville FB	Owned	Renovation	8	No	No	No	No
Cleveland CT	Owned	Renovation	6	**Yes**	No	**Yes**	**Yes**
Youngstown CT & FB	Owned	New	4	No	No	**Yes**	No
Cape Girardeau CT	Owned	New	4	No	No	No	No
Davenport CT	Owned	Renovation	4	**Yes**	No	No	No
Omaha DHS (L) FB	Leased	New	1	No	No	No	No
Omaha NPS (L) FB	Leased	New	3	No	**Yes**	No	No
Denver CT	Owned	New	13	**Yes**	**Yes**	**Yes**	**Yes**
Denver (L) FB	Leased	New	9	No	**Yes**	**Yes**	No
Lakewood (L) FB	Leased	New	3	No	No	No	No
Ogden (L) FB	Leased	Renovation	5	No	**Yes**	No	No
Fresno CT & FB	Owned	New	11	**Yes**	**Yes**	No	No
Las Vegas CT	Owned	New	8	**Yes**	No	No	No
San Francisco FB	Owned	New	18	**Yes**	**Yes**	**Yes**	No
Santa Ana FB	Owned	Renovation	10	No	No	**Yes**	**Yes**
Auburn FB	Owned	Renovation	1 + Mezz	No	**Yes**	No	No
Eugene CT	Owned	New	6	**Yes**	**Yes**	No	No
Seattle CT	Owned	New	25	**Yes**	No	No	No
Rockville (L) FB	Leased	New	9	No	No	No	No
Suitland FB	Owned	New	8	**Yes**	**Yes**	No	No

These items of general interest were analyzed and when they offered observable trends they are discussed within the report.

Water

Many communities periodically experience droughts and some are in the situation of an ever decreasing availability of potable water. Commercial buildings use 12% of potable water in the U.S.[15] Tracking water use offers opportunities for identifying possible strategies for water use reduction. In addition to the resource management benefits, there is a monetary incentive to track and decrease water consumption.

The ideal water metric for comparing domestic water use (i.e., toilets, urinals, and faucets) is indoor potable water in gallons per year. The potable water use data for some buildings included a combination of domestic water use, landscape water use, and/or process water use.[16] None of the GSA buildings had the indoor domestic water separately metered and reported, thus total building water use and cost were used. In addition to water use per square foot, water use per occupant was analyzed, using the U.S. Department of Energy's Federal Energy Management Program's water use indices. In this study, one building did not have metered water data. Sixteen of the buildings have water data that included process and/or landscape water use that needed to be excluded from the water use values in order for the buildings to be fairly compared to a water use per occupant baseline. The estimation of outdoor potable water and/or process potable water use is documented in Table 9 and described in more detail in Appendix D. In general the PNNL research team estimated the annual domestic water use for those buildings based on a review of monthly water use to identify a base water load.

Domestic water consumption depends on human operation and fixed equipment efficiency. Therefore, typical indoor water consumption is best expressed as per occupant.

Table 9. Process water use by building

		Water Use (gallons)				
Building Name	**Water Consuming Equipment**	**Total Water**	**Estimated Landscape**	**Estimated Process**	**Estimated Domestic**	**Total Water Cost**
Greeneville CT	Cooling Towers	1,376,320	275,264	371,606	729,450	$6,352
Jacksonville FB	Cooling Towers	4,007,860	0	1,082,122	2,925,738	$24,555
Knoxville FB	Cooling Towers	2,252,228	0	608,102	1,644,126	$16,061
Cleveland CT	-	450,295	0	0	450,295	$6,730
Youngstown CT & FB	-	418,880	0	0	418,880	$3,945
Cape Girardeau CT	Cooling Towers	385,170	77,034	103,996	204,140	$10,155
Davenport CT	Cooling Towers	530,250	0	143,168	387,083	$5,900
Omaha DHS (L) FB	-	2,252,228	0	0	2,252,228	$4,831
Omaha NPS (L) FB	-	238,629	0	0	238,629	$651
Denver CT	Evap Cooling	4,649,000	0	1,255,230	3,393,770	$20,390
Denver (L) FB	Cooling Towers	3,970,000	358,962	134,100	3,476,938	$9,882
Lakewood (L) FB	Cooling Towers	2,928,000	585,600	790,560	1,551,840	$10,617
Ogden (L) FB	Evap Cooling	3,619,100	0	977,157	2,641,943	$10,088
Fresno CT & FB	Cooling Towers	11,344,916	2,268,983	3,063,127	6,012,805	$42,150
Las Vegas CT	Cooling Towers	10,413,000	2,082,600	2,811,510	5,518,890	$64,381
San Francisco FB	Cooling Towers, Small Snack Bar	5,674,712	0	1,532,172	4,142,540	$88,562
Santa Ana FB	-	2,217,820	0	0	2,217,820	$12,724
Auburn FB	-	N/A	N/A	N/A	N/A	$8,448
Eugene CT	Cooling Towers	2,032,000	406,400	548,640	1,076,960	$13,208
Seattle CT	Cooling Towers	4,973,452	994,690	1,342,832	2,635,930	$74,016
Rockville (L) FB	Cooling Tower	2,680,000	0	723,600	1,956,400	$32,406
Suitland FB	Cooling Towers	56,110,000	0	15,149,700	40,960,300	$639,997

Total building water use per gross square foot includes the process water and irrigation water use. There are three different potential baselines for comparison. The GSA and industry baseline are the same value, and the GSA goal is slightly lower. Figure 2 shows six buildings use more water than the baselines, but all of those buildings have process water use, irrigation water, and/or other operational considerations that may impact water use.

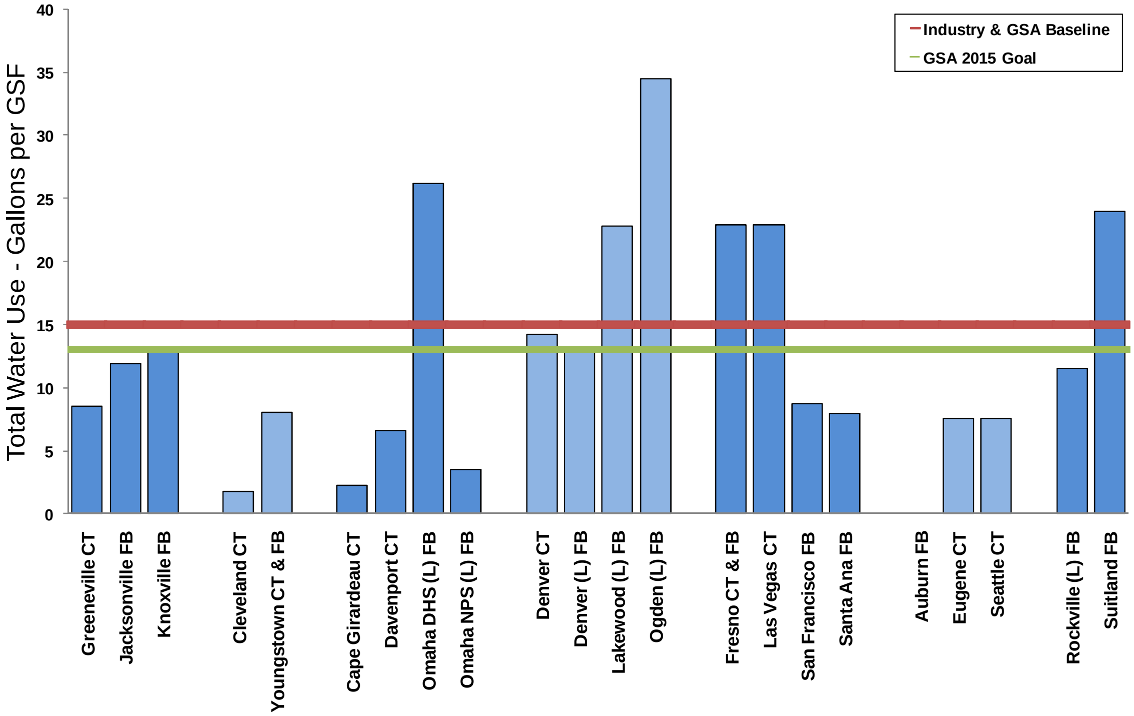


Figure 2. Water use per gross square foot

The Omaha DHS FB water use increased from the first assessment completed in 2008. It is possible this is because of an increase or change in the type of occupancy, however, given the significant increase, water use should be examined at the building to ensure there are no unexpected uses or leaks. The Fresno CT & FB and Las Vegas CT have significant outdoor water features, which could be separately sub-metered to understand what portion of the water use is building related. Ogden FB has a high level of occupancy, which contributes to it building related water use. Suitland FB is an extremely large building with a large cafeteria and fitness center. Further investigation and measurement of the water use in the buildings above the baseline is recommended to identify operational and design opportunities to reduce water use.

When considering the cost of water use, Figure 3 shows all but one of the buildings is within the typical range of water cost per rentable square foot. Water costs vary by location, which is especially noticeable when comparing the total water used per rentable square foot with the water cost per rentable square foot. For example, although Fresno CT & FB and Las Vegas CT use a similar amount of water per rentable square foot, the water costs are greater in Las Vegas. Low water costs decrease the likelihood of water use being a higher priority than other building operations, such as energy use and maintenance.

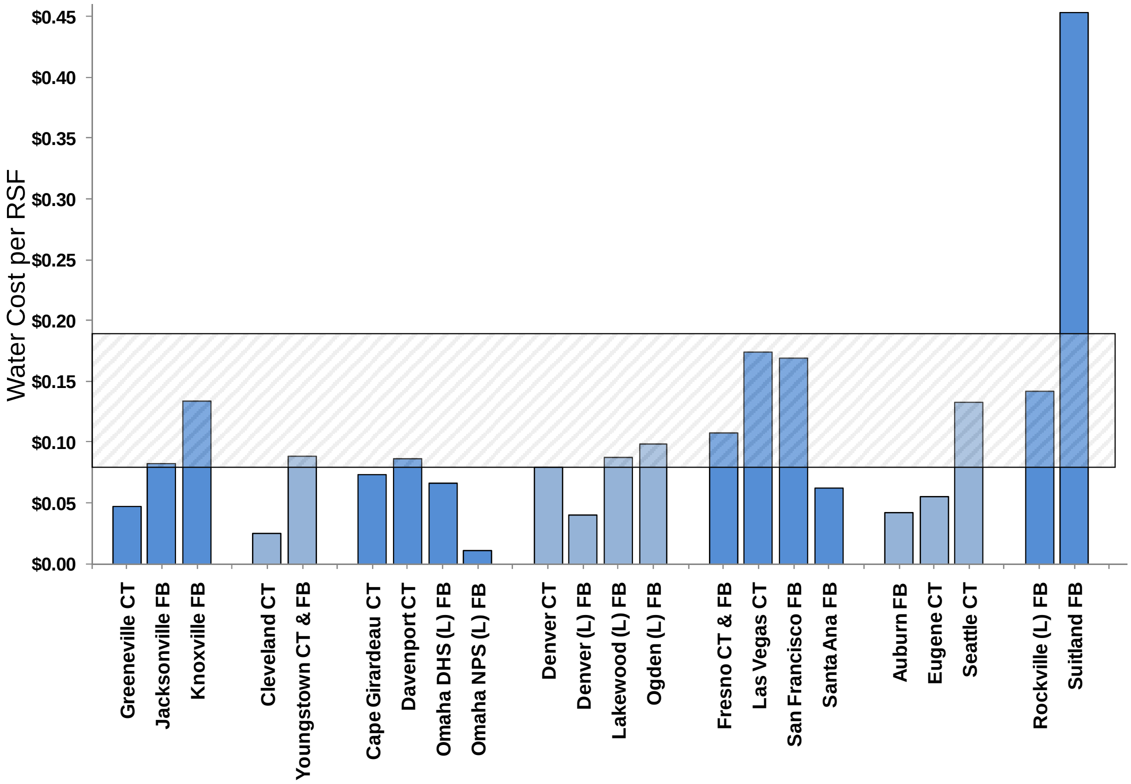


Figure 3. Water cost per rentable square foot compared to industry baseline

Table 10 shows the values of water use and cost by building. The domestic water use was estimated given the known water uses in the buildings. The water use per occupant equivalent is unique to the building. Water use is normalized to the number of building occupants and visitors. The ratio of female-to-male occupants and the number and type of visitors provides additional detail for understanding water use.

Table 10. Water use and cost by building

	Water Use (gallons/year)					
Building Name	**Total Water Use**	**Total Water Use per GSF**	**Total Water Cost**	**Total Water Cost per RSF**	**Estimated Domestic Water Use**	**Estimated Domestic Water Use/Occupant**
Greeneville CT	1,376,320	8.5	$6,352	$0.05	729,450	7,082
Jacksonville FB	4,007,860	11.9	$24,555	$0.08	2,925,738	2,544
Knoxville FB	2,252,228	13.0	$16,061	$0.13	1,644,126	5,299
Cleveland CT	450,295	1.8	$6,730	$0.04	450,295	3,160
Youngstown CT & FB	418,880	8.0	$3,945	$0.09	418,880	1,727
Cape Girardeau CT	385,170	2.2	$10,155	$0.07	204,140	2,041
Davenport CT	530,250	6.6	$5,900	$0.09	387,083	6,144
Omaha DHS (L) FB	2,252,228	26.2	$4,831	$0.07	2,252,228	6,256
Omaha NPS (L) FB	238,629	3.5	$651	$0.01	238,629	1,783
Denver CT	4,649,000	14.2	$20,390	$0.08	3,393,770	9,172
Denver (L) FB	3,970,000	13.2	$9,882	$0.04	3,476,938	3,500
Lakewood (L) FB	2,928,000	22.8	$10,617	$0.09	1,551,840	4,625
Ogden (L) FB	3,619,100	34.5	$10,088	$0.10	2,641,943	5,071
Fresno CT & FB	11,344,916	22.9	$42,150	$0.11	6,012,805	11,790
Las Vegas CT	10,413,000	22.9	$64,381	$0.17	5,518,890	12,905
San Francisco FB	5,674,712	8.7	$88,562	$0.17	4,142,540	2,868
Santa Ana FB	2,217,820	7.9	$12,724	$0.06	2,217,820	4,832
Auburn FB	N/A	N/A	$8,448	$0.04	N/A	
Eugene CT	2,032,000	7.5	$13,208	$0.06	1,076,960	6,335
Seattle CT	4,973,452	7.6	$74,016	$0.13	2,635,930	4,393
Rockville (L) FB	2,680,000	11.6	$32,406	$0.14	1,956,400	2,574
Suitland FB	56,110,000	24.0	$639,997	$0.45	40,960,300	7,550

Although the water use values in Figure 4 were adjusted in an attempt to represent indoor potable water use only, it is clear that the commonly used end use distribution of water use is not representative for some of these buildings, such as Fresno CT & FB and Las Vegas CT. Both of those buildings have exterior, decorative fountains and they are located in hot, dry climates. The FEMP water use indices offer the most consistently used industry baseline for water use per occupant-visitor equivalent. At the same time, the FEMP indices do not appear to work consistently with all of the buildings, and it is recognized in the area of building water use research that new values are needed. When the GSA buildings' water use is compared to the indices, at least eight of the buildings show a much greater water use per occupant than would be expected even with inefficient fixtures.

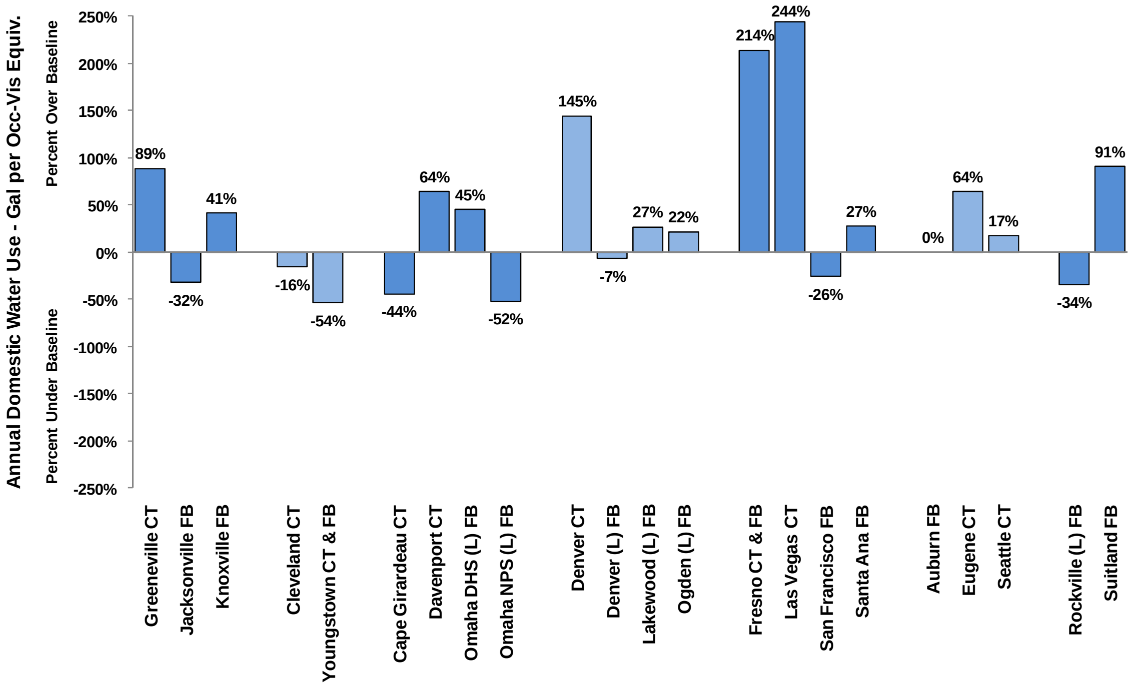


Figure 4. Water use per occupant compared to the water use baseline

The design intent of the buildings' water use can be represented by the LEED Water Efficiency credits. Table 11 shows the number of LEED points received for water efficiency credits by each building out of the five total points available. Thirteen of the buildings pursued indoor water use reduction strategies (WEc3). Twelve of the buildings attempted some water use reduction with either efficient landscape or innovative wastewater technologies.

LEED® Water Efficiency credit 3, Water Use Reduction, is achieved by reducing potable water use by 20% or more than a baseline design. Two WEc3 points can be achieved if potable water is reduced by 30%. An Innovation in Design point can be achieved for exemplary performance of potable water use reduction greater than 40%.

There are additional water credits that address water efficient landscaping and innovative wastewater management strategies.

Table 11. LEED Water Efficiency credits pursued

		LEED® Water Credits		
Building Name	**Total WE Credits**	**Efficient Landscaping WEc1**	**Innovative Wastewater Technologies WEc2**	**Water Use Reduction WEc3**
Greeneville CT	N/A	N/A	N/A	N/A
Jacksonville FB	N/A	N/A	N/A	N/A
Knoxville FB	2	N/A	N/A	2
Cleveland CT	4	2	0	2
Youngstown CT & FB	2	2	0	0
Cape Girardeau CT	2	1	0	1
Davenport CT	N/A	N/A	N/A	N/A
Omaha DHS (L) FB	3	0	1	2
Omaha NPS (L) FB	4	2	0	2
Denver CT	1	0	0	1
Denver (L) FB	4	2	0	2
Lakewood (L) FB	1	1	0	0
Ogden (L) FB	2	1	0	1
Fresno CT & FB	N/A	N/A	N/A	N/A
Las Vegas CT	N/A	N/A	N/A	N/A
San Francisco FB	3	1	0	2
Santa Ana FB	N/A	N/A	N/A	N/A
Auburn FB	3	1	0	2
Eugene CT	3	1	0	2
Seattle CT	N/A	N/A	N/A	N/A
Rockville (L) FB	3	2	0	1
Suitland FB	4	2	0	2

Graphically displaying the water use in comparison to the overall LEED score and the WEc3 points shows that water use is highly variable and there does not appear to be a correlation to the measured water use and the LEED credits.

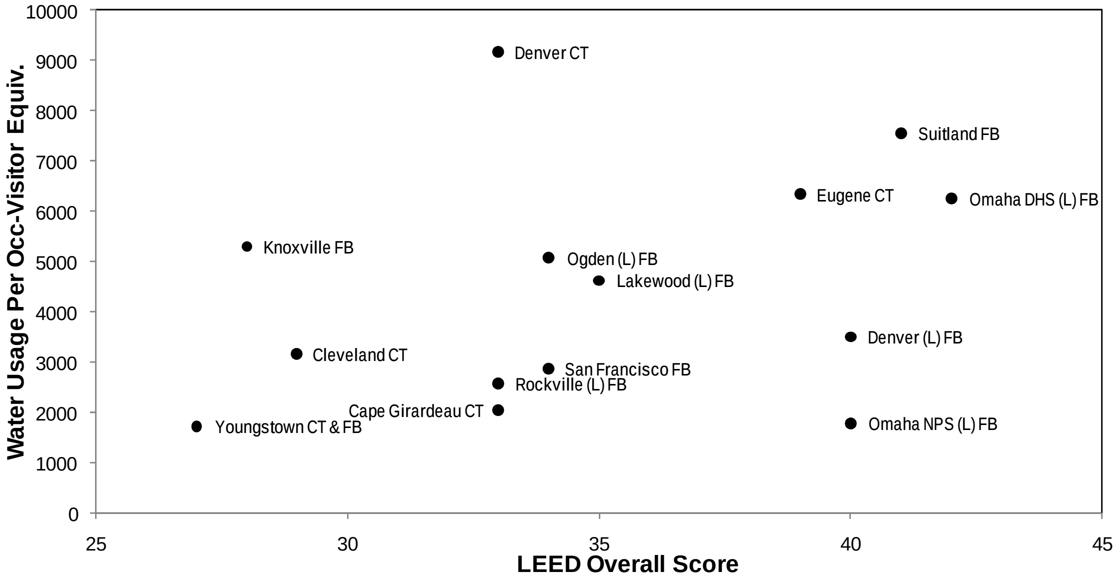


Figure 5. LEED overall score and water usage

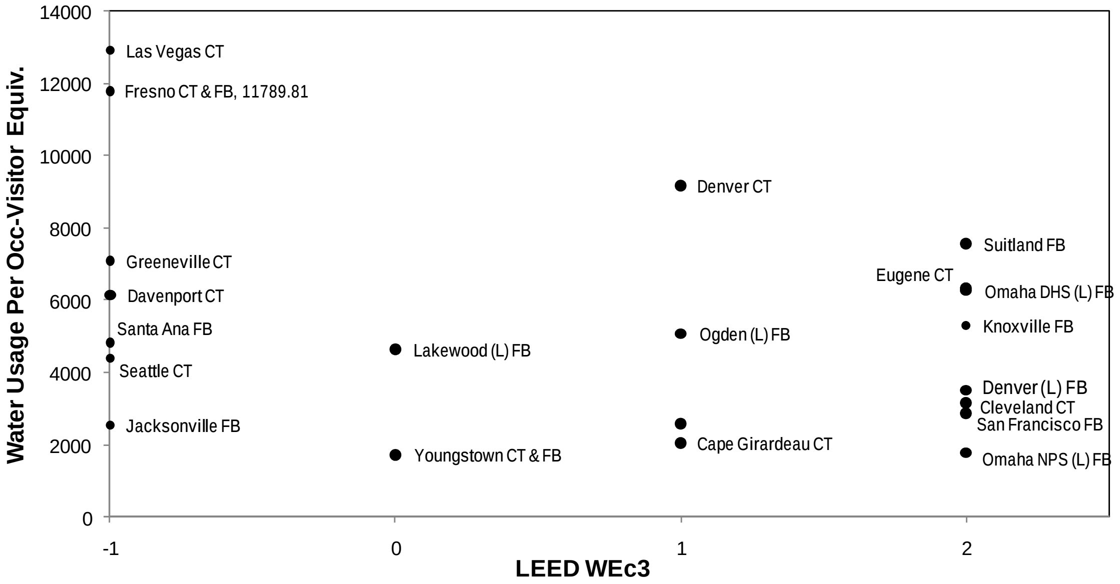


Figure 6. LEED WEc3 points and water usage

When considering all of the different ways to examine water use for a building, three buildings stand out as consistently using considerably more water and having higher water costs than the others: Fresno CT & FB, Las Vegas CT, and Suitland FB. It is recommended the cause for higher levels of water use at those buildings is investigated in the future.

Energy

Commercial buildings in the U.S. consume about 18% of the total energy.[17] Energy costs tend to be the largest utility cost for a building and with the current emphasis on global climate change there is an even greater interest to reduce energy use and modify energy sources in order to reduce the building's environmental impact.

The buildings in this study were selected because they were sustainably-designed or they were designed with energy efficiency as a goal. The research team chose Energy Star as the primary mechanism for comparison because it offers an easy to understand performance compared to similar building types and geographic locations. Energy Star scores are relative to the buildings' energy use in the database, and the weather for a given time period and location. Other mechanisms for comparison include a national and regional CBECS and national GSA averages, as well as average costs from BOMA and IFMA.

The unofficial Energy Star scores for each building were calculated using the following data from each site

- building type
- building location
- 12 to 24 months of energy use data
- number of occupants
- occupancy hours
- number of computers.

Energy Star® Portfolio Manager is a benchmarking tool that ranks the annual energy use of a building compared to average commercial buildings data. Each building receives a score between zero and 100. Buildings with scores above 50 can be considered better than average. Buildings with scores above 75 can receive an Energy Star Buildings Label that recognizes the building as performing in the top 25% of nationwide energy performance.

Some sites have received official Energy Star ratings for recent, but not for identical time periods as the data used in this study. The Energy Star related data provided by the site was used to correlate the unofficial scores calculated for this study with the official ratings the buildings received. Table 12 provides a summary of the energy use and cost values for each building.

Table 12. Energy use and cost by building

	Energy Use					
Building Name	**Electricity (MWH)**	**Nat Gas (1000 ft^3)**	**Steam (kBtu)**	**Chilled Water (Ton Hr)**	**Total Energy (mBtu)**	**Total Energy Cost**
Greeneville CT	1,640	2,530	0	0	8,198	$176,042
Jacksonville FB	4,578	396	0	0	16,020	$427,075
Knoxville FB	1,928	1,887	0	0	8,489	$198,759
Cleveland CT	1,954	0	14,052,186	440,719	26,009	$576,668
Youngstown CT & FB	724	0	1,683,240	0	4,152	$108,647
Cape Girardeau CT	2,512	4,914	0	0	13,547	$125,431
Davenport CT	858	2,236	0	0	5,194	$79,627
Omaha DHS (L) FB	1,443	0	0	0	4,923	$95,017
Omaha NPS (L) FB	821	1,784	0	0	4,586	$73,214
Denver CT	3,584	0	11,115,858	454,556	28,800	$631,891
Denver (L) FB	3,834	0	9,782,442	0	22,863	$367,301
Lakewood (L) FB	1,832	2,488	0	0	8,810	$213,099
Ogden (L) FB	2,053	2,342	0	0	9,348	$150,700
Fresno CT & FB	6,173	5,496	0	0	26,629	$854,680
Las Vegas CT	7,545	1,490	0	0	27,255	$720,041
San Francisco FB	6,001	442	4,973	0	31,501	$994,770
Santa Ana FB	2,367	0	1,703,838	543,812	16,308	$651,182
Auburn FB	2,017	2,580	0	0	9,495	$121,499
Eugene CT	2,581	4,161	0	0	13,020	$213,279
Seattle CT	8,064	18,062	0	0	45,810	$695,685
Rockville (L) FB	4,876	0	0	0	16,638	$733,918
Suitland FB	38,384	44,253	0	0	175,795	$4,708,207

Although energy use by fuel type and total energy use are useful information to have when considering the overall impact of a building, they do not offer a clear picture on the efficiency of a building's energy use. To assess energy efficiency, total energy use is typically normalized to building size (gross square footage or gsf) to provide an energy use intensity (EUI) value. In this study energy use was also normalized to hours of

EUI is a commonly used metric calculated when the annual energy use is divided by the total building square footage. EUI does not consider the impact of the occupants with respect to how occupant density, plug load, and operating hours may impact energy use.

regular occupancy and the number of full-time occupant equivalents and then compared to Energy Star Portfolio Manager scores as shown in Figure 7. The figure shows that although there is a relationship between EUI and Energy Star scores, it is not a direct relationship. Note in the top graph the buildings that have Energy Star scores greater than 75 and have EUIs above the line. Other than the Seattle CT (light red box), all of those buildings have greater energy utilization per hours of occupancy and number of building occupants, meaning longer operating hours and more occupants per square foot are impacting the EUI and that is reflected as efficiency in the Energy Star scores. These graphs also show the courthouse buildings tend to have a lower number of occupants than the federal buildings.

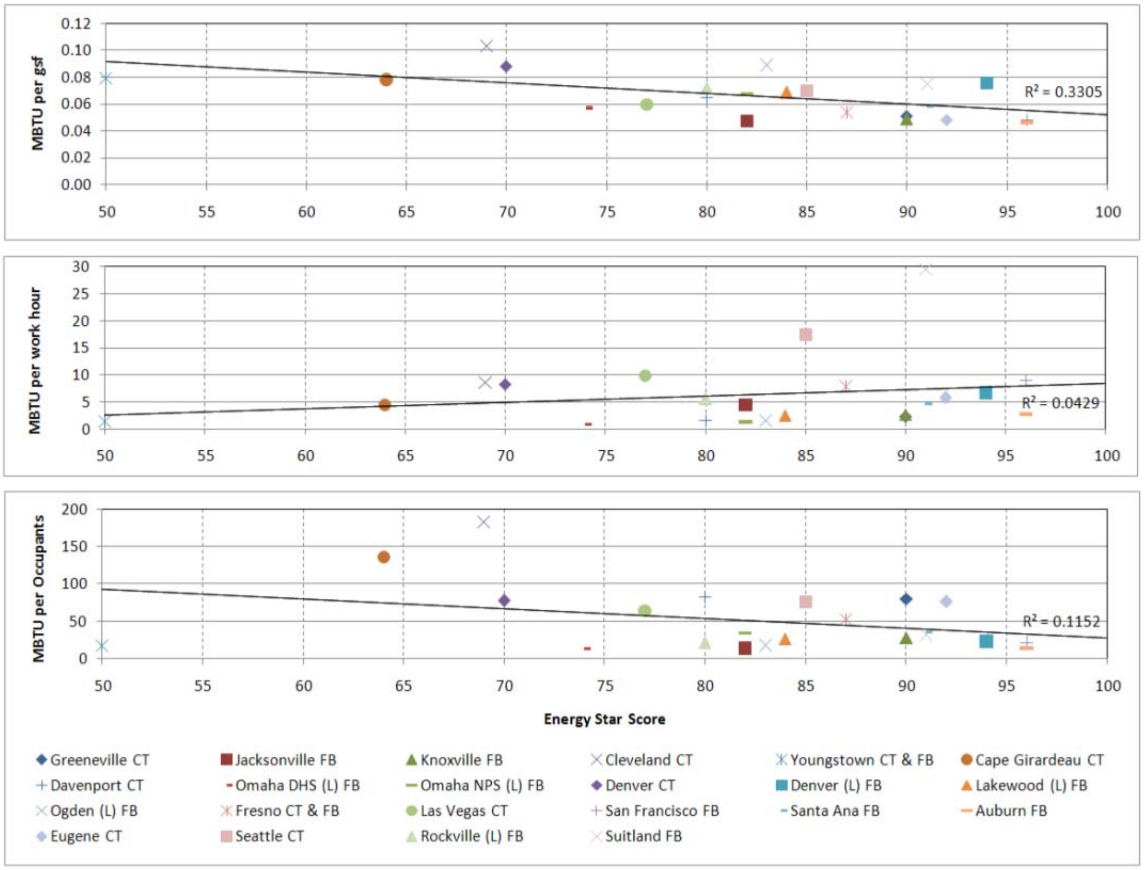


Figure 7. Energy Star rating compared to energy intensity

Table 13 summarizes the EUI data available for each building. Within the table, "Current EUI" is the EUI calculated in Energy Star from data provided by the sites and GSA's EUAS database. "FY09 GSA Regional EUI" values were provided by GSA energy professionals. "GSA FY09 Target" is the EUI goal documented in the Public Buildings Service (PBS). "Energy Star Baseline" is the

GSA has regional averages and national targets for EUI. These values are used to assess the GSA building stock's progress toward the energy and water reduction goals in Executive Order 13423 and 13514, the Energy Policy Act of 2005, and the Energy and Infrastructure Security Act of 2007.

50th percentile value calculated within Energy Star. "CBECS Regional Average" includes the average EUI for all building types within specific geographic regions, correlated to GSA regions. "CBECS Office" is the national average EUI for office buildings using 2003 data for office buildings built between 1990 and 2003.[18] For this analysis multiple baselines were considered in order to gain a broader comparison for how the buildings were performing.

Table 13. Various EUI values of interest

	EUI (kBTU/gsf)					
Building Name	**Current EUI**	**FY09 GSA Regional Averages**	**FY09 GSA Target**	**Energy Star Baseline (50%)**	**CBECS Regional Average**	**CBECS Office**
Greeneville CT	50	58	60	87	78	
Jacksonville FB	47	58	60	93	78	88
Knoxville FB	49	58	60	91	78	88
Cleveland CT	103	84	86	129	113	
Youngstown CT & FB	79	84	86	80	113	
Cape Girardeau CT	78	75	81	92	75	
Davenport CT	65	75	81	96	75	
Omaha DHS (L) FB	57	75	81	77	75	88
Omaha NPS (L) FB	67	75	81	103	75	88
Denver CT	98	89	92	123	81	
Denver (L) FB	76	89	92	144	81	88
Lakewood (L) FB	65	89	92	103	81	88
Ogden (L) FB	89	89	92	139	81	88
Fresno CT & FB	54	55	61	91	71	88
Las Vegas CT	60	55	61	84	71	
San Francisco FB	48	55	61	112	71	88
Santa Ana FB	58	55	61	109	71	88
Auburn FB	46	63	64	108	71	88
Eugene CT	48	63	64	90	71	
Seattle CT	70	63	64	111	71	
Rockville (L) FB	69	95	88	99	90	88
Suitland FB	75	95	88	140	90	88

CBECS is a publicly available database comprised of national survey data on U.S. commercial building energy consumption. CBECS data can be sorted by building type, age, region, size, fuel type, and various other parameters.

In Figure 8 the buildings' EUIs were compared to the different potential baselines including the CBECS national average for office buildings built from 1990-2003, CBECS regional averages for all building types, and GSA's regional averages and targets. All of GSA's buildings in this study perform better than or equivalent to the CBECS averages. Both of the buildings that are not performing better than the GSA's FY09 target are courthouses. Only one of the buildings in the Pacific Region, the San Francisco FB, is performing better than the GSA regional average. Outside of the Pacific Region, the only buildings that are not meeting the regional averages are three courthouses (note that in the Heartland Region the GSA regional average is the same as the CBECS regional average, so you cannot see the 'blue line' in the graph).

The energy performance average of the buildings in the study was 25% better than CBECS office building national average, 10% better than fiscal year 2009 GSA Regional Averages, 13% better than fiscal year 2009 GSA Target values, 18% better than CBECS regional averages, and 37% better than the Energy Star Portfolio Manager 50th percentile buildings.

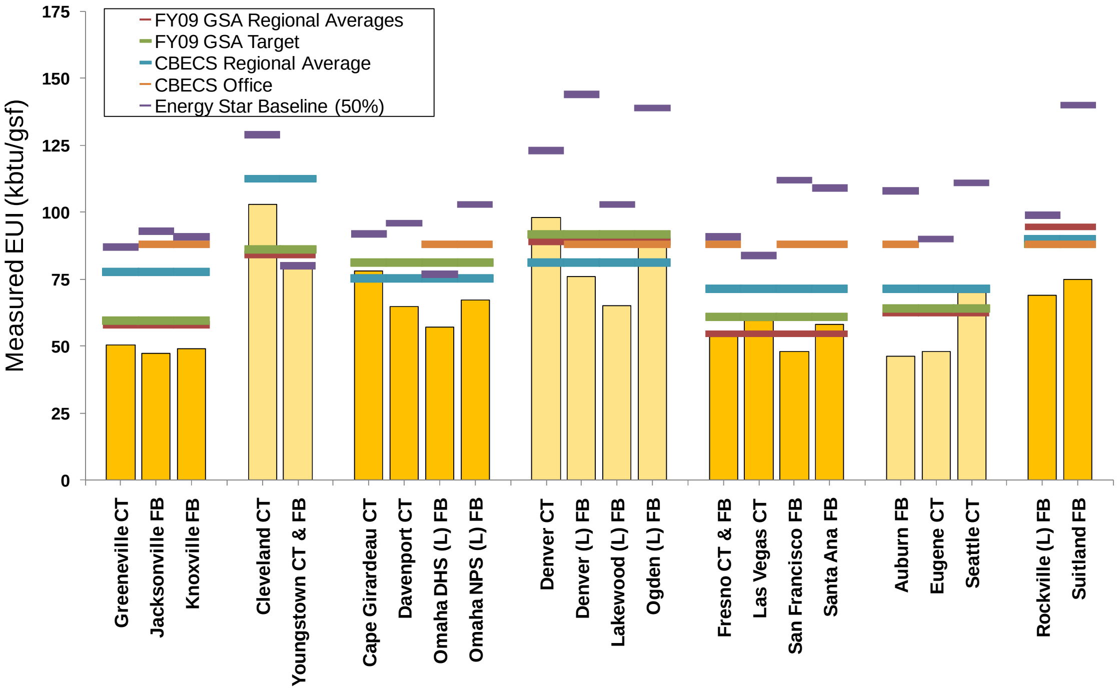


Figure 8. Study building EUIs compared to the GSA national average and CBECS national and regional EUIs

Table 14 provides the LEED total credits, EAc1 points, WEc3 points, and the calculated Energy Star scores. For the buildings that have earned an Energy Star rating, the official Energy Star value is provided in parentheses next to the certification level. The official values may be different from the values calculated for this study because of different timeframes for the assessment.

> LEED® Energy and Atmosphere credit 1 (EAc1), Optimize Energy Performance, allows for up to 10 points for reducing energy consumption by 42% or more.

Table 14. "Green" design certification by building

Building Name	**Certification Level**	**LEED® Total Credits**	**LEED® EAc1 Credits**	**LEED® WEc3 Credits**	**Energy Star® Score**
Greeneville CT	Energy Star 2007 (89)	N/A	N/A	N/A	90
Jacksonville FB	Energy Star 2007 (88)	N/A	N/A	N/A	82
Knoxville FB	LEED-EB Certified, Energy Star 2007 (88)	28	8	2	90
Cleveland CT	LEED-NC Certified	29	3	2	69
Youngstown CT & FB	LEED-NC Certified	27	0	0	50
Cape Girardeau CT	LEED-NC Silver	33	4	1	64
Davenport CT	LEED-NC Registered	N/A	N/A	N/A	80
Omaha DHS (L) FB	LEED-NC Gold	42	10	2	74
Omaha NPS (L) FB	LEED-NC Gold	40	3	2	82
Denver CT	Green Building Challenge, LEED-EB Silver	33	2	1	70
Denver (L) FB	LEED-NC Gold, Energy Star 2008 (96)	40	5	2	94
Lakewood (L) FB	LEED-NC Silver	35	4	0	84
Ogden (L) FB	LEED-NC Silver	34	5	1	83
Fresno CT & FB	California Energy Standard Title 24	N/A	N/A	N/A	87
Las Vegas CT	Energy Star 2007 (77)	N/A	N/A	N/A	77
San Francisco FB	LEED-NC Silver	34	2	2	96
Santa Ana FB	California Energy Standard Title 24	N/A	N/A	N/A	91
Auburn FB	LEED-NC Silver	36	5	2	96
Eugene CT	LEED-NC Gold, Energy Star 2009 (94)	39	4	2	92
Seattle CT	IFMA Sustainable Design and Energy Efficiency Award	N/A	N/A	N/A	85
Rockville (L) FB	LEED-NC Registered (Silver), Energy Star 2009 (76)	33	2	1	80
Suitland FB	LEED-NC Registered (Gold)	41	1	2	91

In addition to the LEED Optimize Energy Performance credits, key energy management credits are documented in Table 15. Note that the Youngstown FB & CT has zero optimize energy performance credits. Youngstown was designed to an early version of LEED that did not require points in this category.

Table 15. LEED Energy and Atmosphere Credits pursued

	LEED® Energy Credits				
Building Name	**Total EA Credits**	**Optimize Energy Performance EAc1**	**Additional Commissioning EAc3**	**Measurement & Verification EAc5**	**Green Power EAc6**
Greeneville CT	N/A	N/A	N/A	N/A	N/A
Jacksonville FB	N/A	N/A	N/A	N/A	N/A
Knoxville FB	11	8	N/A	N/A	N/A
Cleveland CT	3	3	0	0	0
Youngstown CT & FB	1	0	0	0	0
Cape Girardeau CT	6	4	0	1	0
Davenport CT	N/A	N/A	N/A	N/A	N/A
Omaha DHS (L) FB	13	10	0	1	1
Omaha NPS (L) FB	6	3	1	1	1
Denver CT	8	2	-	-	-
Denver (L) FB	9	5	1	1	1
Lakewood (L) FB	8	4	1	1	1
Ogden (L) FB	7	5	0	1	1
Fresno CT & FB	N/A	N/A	N/A	N/A	N/A
Las Vegas CT	N/A	N/A	N/A	N/A	N/A
San Francisco FB	4	2	1	1	0
Santa Ana FB	N/A	N/A	N/A	N/A	N/A
Auburn FB	9	5	1	1	1
Eugene CT	8	4	1	1	1
Seattle CT	N/A	N/A	N/A	N/A	N/A
Rockville (L) FB	4	2	0	1	0
Suitland FB	4	1	1	0	1

Comparing the Energy Star scores to the overall LEED score does not appear to offer a correlation between the measured energy use and the LEED scores.

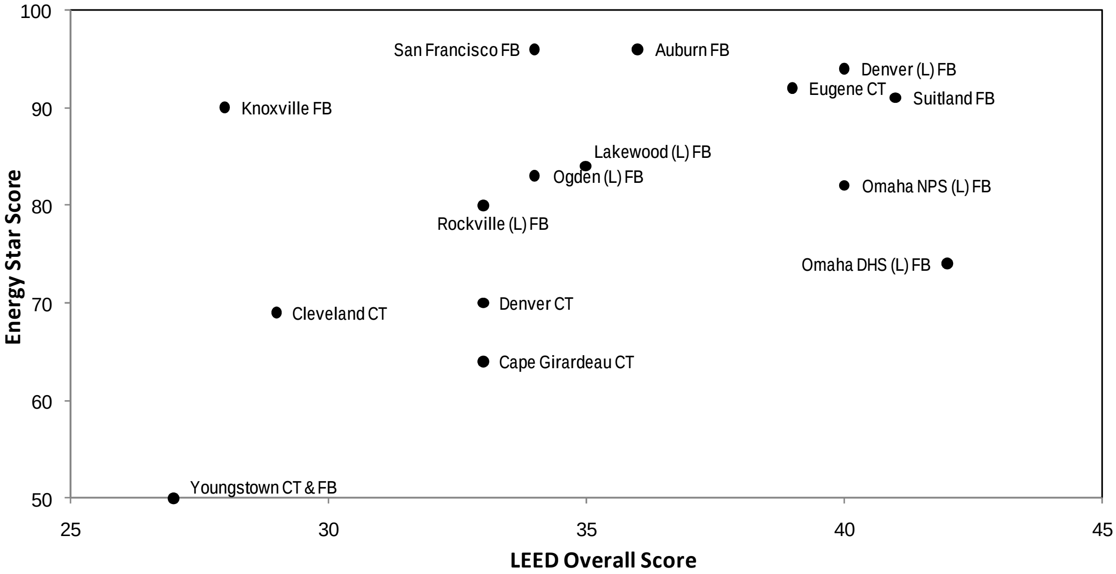


Figure 9. Energy Star rating and total LEED credits

Comparing Energy Star scores with the EAc1 points shows that 4 of the 5 buildings that had five or more EAc1 points had Energy Star scores above 80, with only 50% of the buildings with three points or less scoring 80 or above.

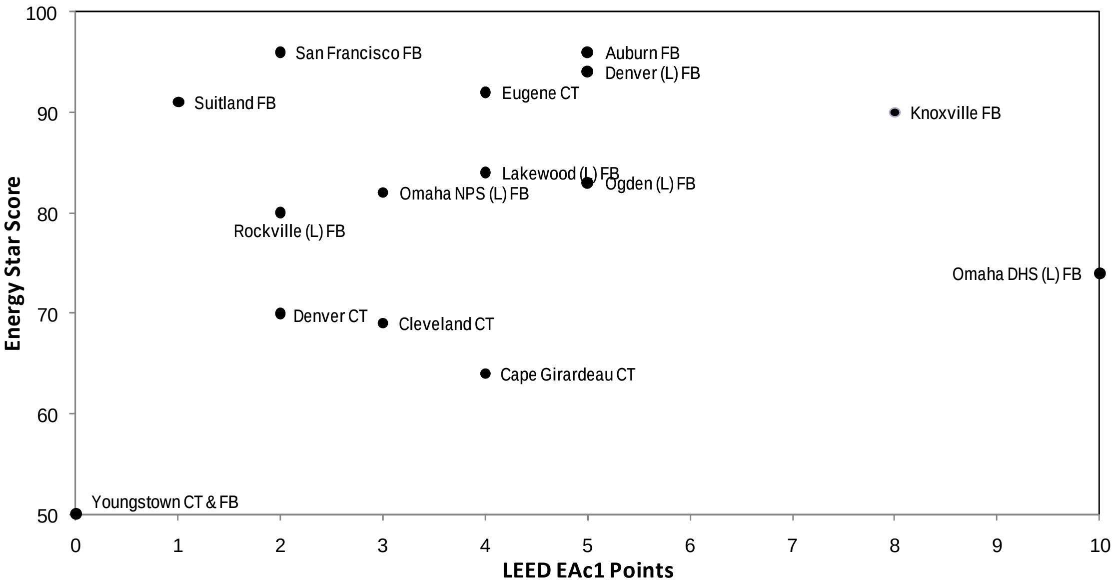


Figure 10. Energy Star rating and LEED energy credits

Eight of the twelve buildings included in the first round of performance measurement (Round 1, or R1) had lower Energy Star scores during timeframe of this assessment (Figure 11). Some of the changes were minor and could be because of an increase in building information in the Energy Star Portfolio Manager database. However three of those buildings had noticeable increases in energy consumption from the first assessment (Figure 12). It is recommended the changes in energy use are investigated at the Cleveland CT, Youngstown CT & FB, and the Omaha DHS FB.

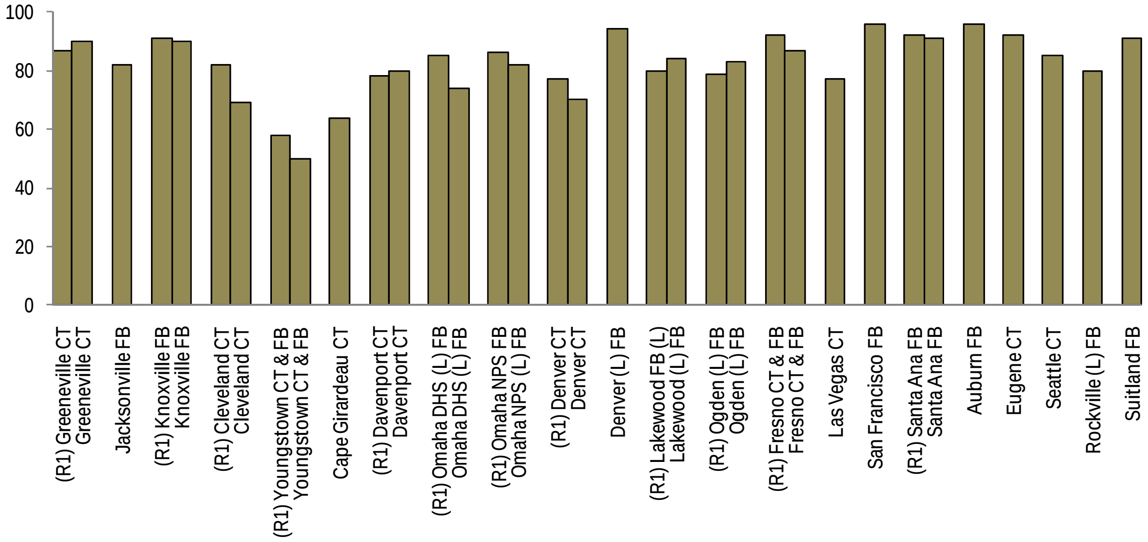


Figure 11. Energy Star Scores with Round 1 data included

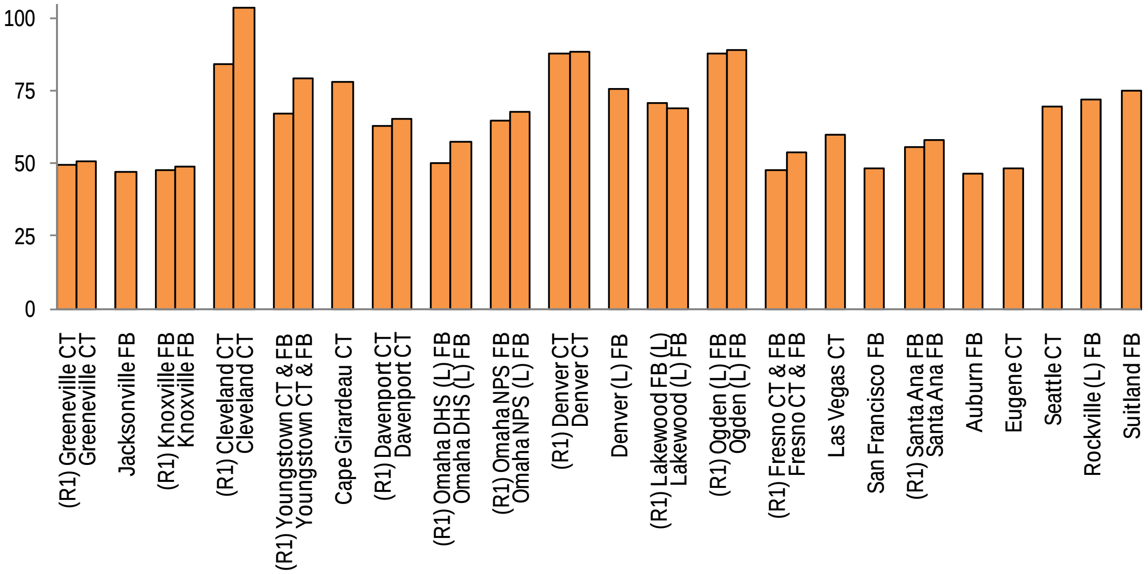


Figure 12. Annual Energy Use (kBtu/GSF)

Figure 13 shows the Energy Star Portfolio Manager scores in relationship to the water use per gross square foot. The energy performance for all of the buildings in this study is equal to or better than the industry average. Water use per gross square foot is better than the industry average for 15 of the 21 buildings with water data (buildings in the top right quadrant). Five of the buildings provided water use data for the indoor, domestic water use only (triangles), while the remaining buildings had a combination of process and irrigation water use included in the total building water use values. Thus, in sixteen of the buildings the water performance contributes to the energy efficiency of the buildings. Note that all but two of the buildings with an Energy Star Score of 80 and above use process water, while the building with the lowest Energy Star score is not using water to augment its energy performance.

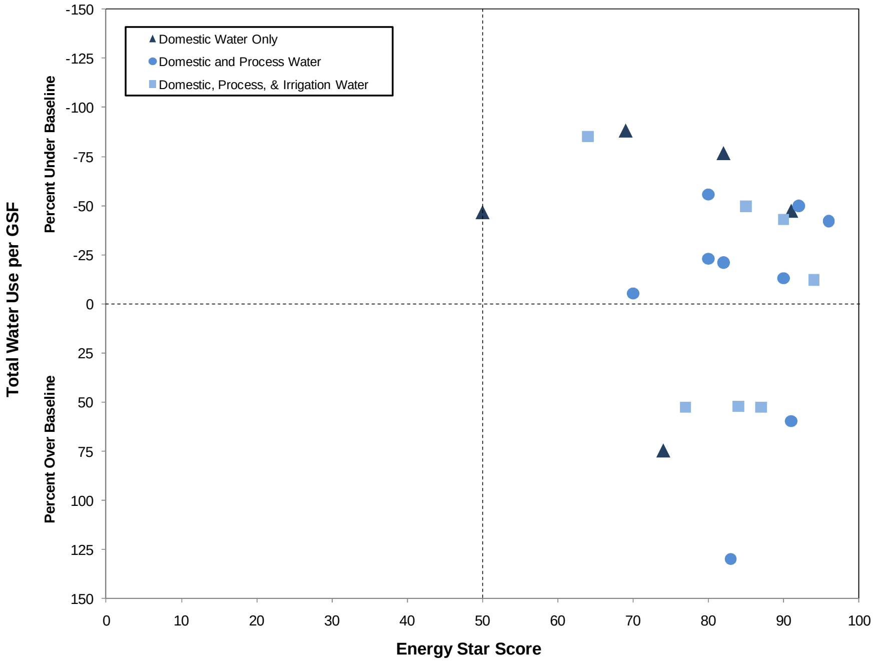


Figure 13. Energy Star score and water use per GSF performance

When examining energy use and thermal comfort, the subset of buildings that had under floor air distribution (UFAD) systems appeared to have better energy performance and lower thermal comfort scores. However, the buildings with UFAD systems have them only in part of the building. In contrast to the whole building data shown in Figure 14, the Center for the Built Environment survey results were examined by location within one building, and the space in the building that had the UFAD system had the highest thermal comfort scores in the building, with the other spaces scoring low, resulting in a low number for the whole building. Although it is interesting that this subset of buildings has better overall energy performance and lower thermal comfort scores, this is a very small sample and even a meta-analysis within this building set showed there is evidence that the whole building satisfaction levels are not representative of all UFAD spaces.

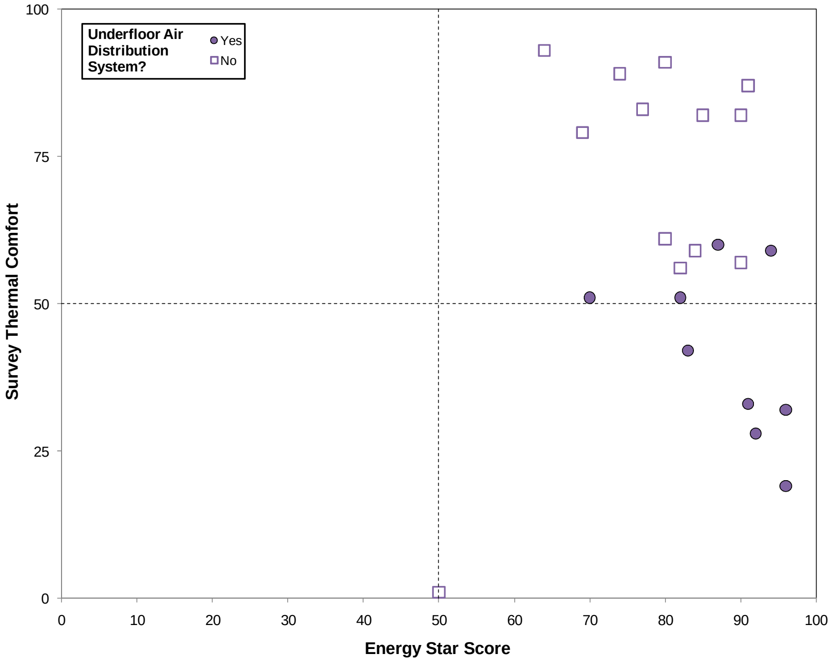


Figure 14. Energy Star score and thermal comfort with UFAD

Although there is value in high-level, whole building performance analysis, Figure 14 is an example of how summary data can be misleading if not carefully examined. The whole building performance data provided in this study is intended only for a summary analysis of the portfolio and to identify areas where further investigation may be needed.

The energy-related utility costs tend to be a significant portion of a building's operating costs. Energy costs are typically expressed as cost per rentable square foot (RSF). The baseline value for energy costs per gross square foot is based on office building values from IFMA and BOMA.[19,20,21,22] The baseline range shown in Figure 15 are national averages, thus location related differences in energy costs may explain some of the buildings outside of the range. For example, the states in the Heartland and Northwest/Arctic regions have lower than the U.S. average electricity costs, and states in National Capital region have higher than average electricity costs.[23] California is the only other state with buildings in the study that had electricity costs higher than the national average, which may explain the higher costs at the Santa Ana FB, especially given it has an Energy Star score of 91. Regardless of regional differences, the buildings with higher than average costs are worth investigating further in order to ensure everything possible is being done to reduce operating costs.

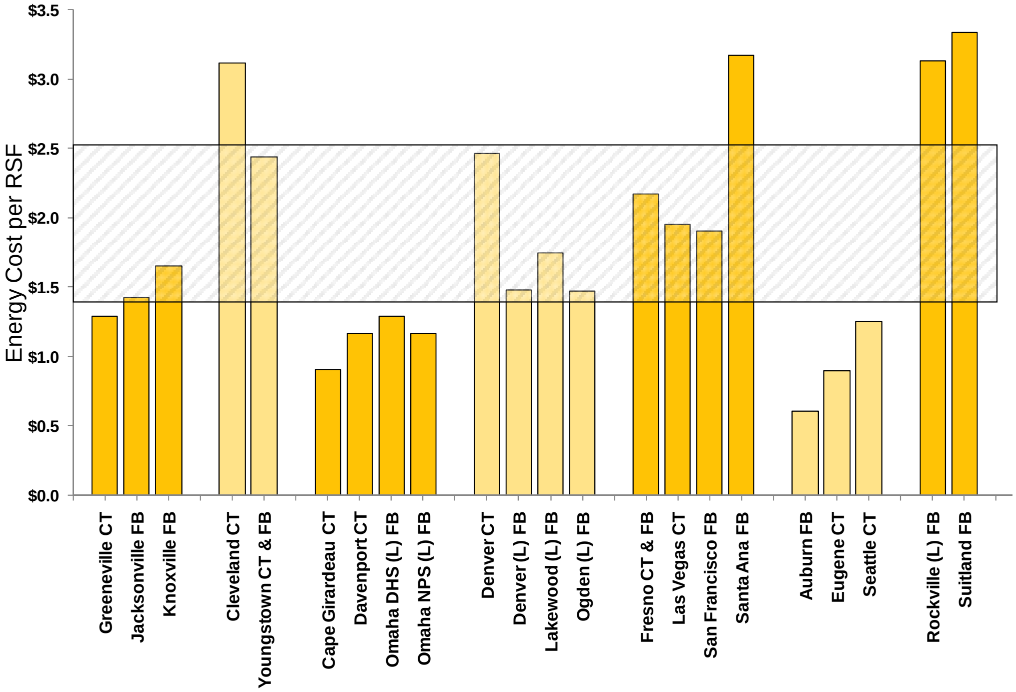


Figure 15. Energy cost per gross square foot

Note that the Cleveland CT and the Santa Ana FB buildings were evaluated in the previous round of GSA's whole building performance assessment. Both buildings' energy costs are noticeably higher than they were in the first round. The Cleveland CT energy use increased, but the Santa Ana FB energy remained relatively constant.

A key environmental impact of energy use is greenhouse gas emissions. Greenhouse gas emissions are represented as carbon dioxide (CO_2) equivalents. The CO_2 equivalents related to source energy use for the buildings in the study are calculated through the Energy Star Portfolio Manager and summarized in Table 16.

Table 16. Energy use, cost and CO_2 equivalent performance

	Energy Use Emissions		
Building Name	**Energy Use (kBTU) per GSF**	**Energy Cost per RSF**	**Building CO_2 Equivalent per GSF (Metric Tons)**
Greeneville CT	50	$1.29	0.0078
Jacksonville FB	47	$1.42	0.0082
Knoxville FB	49	$1.65	0.0083
Cleveland CT	103	$3.12	0.0109
Youngstown CT & FB	79	$2.44	0.0123
Cape Girardeau CT	78	$0.91	0.0136
Davenport CT	65	$1.16	0.0104
Omaha DHS (L) FB	57	$1.29	0.0139
Omaha NPS (L) FB	67	$1.17	0.0114
Denver CT	98	$2.46	0.0131
Denver (L) FB	76	$1.48	0.0135
Lakewood (L) FB	65	$1.74	0.0131
Ogden (L) FB	89	$1.47	0.0092
Fresno CT & FB	54	$2.17	0.0047
Las Vegas CT	60	$1.95	0.0101
San Francisco FB	48	$1.90	0.0043
Santa Ana FB	58	$3.17	0.0038
Auburn FB	46	$0.60	0.0047
Eugene CT	48	$0.90	0.0048
Seattle CT	70	$1.25	0.0065
Rockville (L) FB	69	$3.22	0.0109
Suitland FB	75	$3.34	0.0095

Figure 16 shows the relative baselines for each building given the energy use and utility. All of the buildings studied are below the industry average CO_2 equivalent emissions. Eight of the buildings also have contracts to purchase green power (Table 15, EAc6), which would result in lower emissions. Emissions reductions from green power purchases are not represented in this graphic.

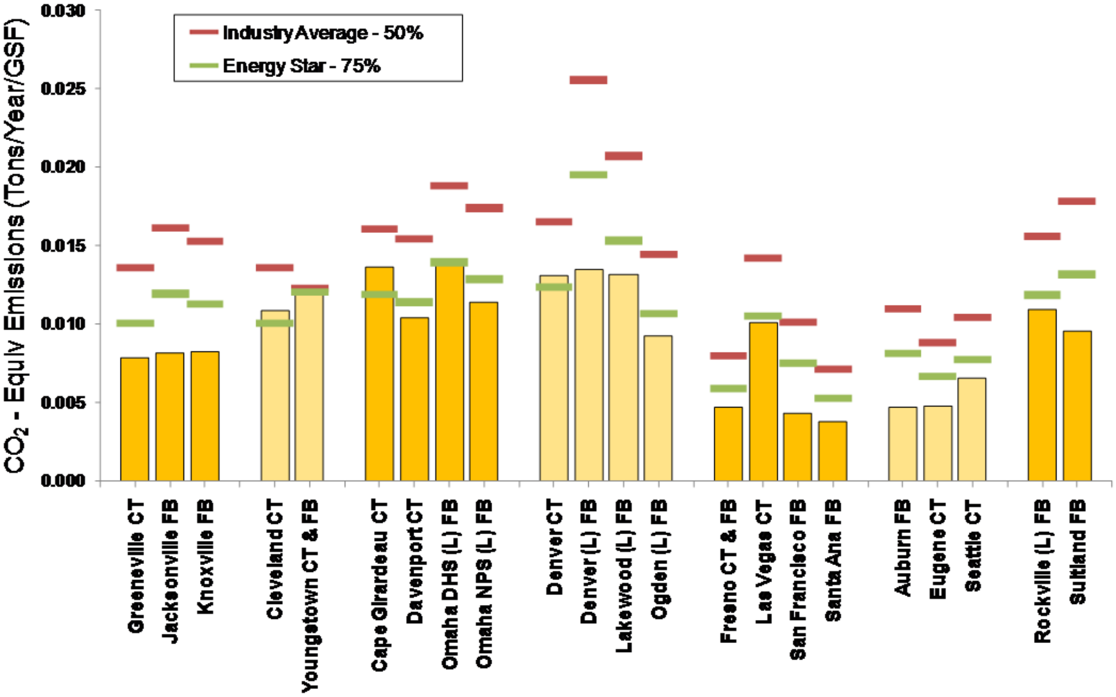


Figure 16. CO_2 equivalents compared to Energy Star baseline

On average, the buildings in the study use less energy, have lower energy costs, and have lower carbon emissions. Three of the buildings that were assessed in the first round of whole building performance measurement had increases in energy use. It is recommended those buildings be further investigated to better understand the change in energy use.

Maintenance and Operations

Interdependence in building systems means that a cost effective and high-performing operations and maintenance (O&M) program may cost more in training, monitoring, and preventative maintenance, but reduces the costs of occupant satisfaction and productivity, energy, water, materials, and repair costs. The details provided for each building's maintenance records varied and thus, when details were not available, it was assumed that the maintenance costs represented equivalent activities to other buildings. The O&M data available for each building are summarized in Table 17.

Table 17. O&M data and cost by building

Building Name	Green House-keeping	Maint Calls / Total Maint	Prev Maint / Total Maint	General Maint Cost	Janitorial Maint Cost	Grounds Maint Cost
Greeneville CT	Some	14%	86%	$163,419	$227,517	$4,000
Jacksonville FB	Yes	27%	73%	$523,958	$499,906	$2,148
Knoxville FB	Some	16%	84%	$237,836	$220,948	$5,300
Cleveland CT	Yes	46%	54%	$176,320	$297,728	$3,100
Youngstown CT & FB	Yes	29%	71%	$124,875	$99,267	$37,300
Cape Girardeau CT	Yes	N/A	N/A	$411,651	$172,282	$11,318
Davenport CT	Some	31%	69%	$179,011	$145,990	$6,421
Omaha DHS (L) FB	Some	35%	65%	$72,632	$70,800	$8,200
Omaha NPS (L) FB	Yes	62%	38%	$41,600	$56,400	$9,050
Denver CT	No	44%	56%	$643,227	$349,560	$29,791
Denver (L) FB	Yes	85%	15%	$184,607	$258,120	$16,833
Lakewood (L) FB	No	5%	95%	$103,644	$83,220	$7,394
Ogden (L) FB	Some	N/A	N/A	$39,068	$125,892	$3,584
Fresno CT & FB	No	20%	80%	$1,194,365	$821,414	$24,236
Las Vegas CT	Yes	40%	60%	$616,845	$174,441	$126,328
San Francisco FB	Yes	77%	23%	$1,152,725	$1,169,249	$25,000
Santa Ana FB	No	43%	57%	$478,557	$345,401	$15,018
Auburn FB	Yes	17%	83%	$233,367	$370,864	$22,497
Eugene CT	Yes	N/A	N/A	$381,904	$339,996	$51,808
Seattle CT	Yes	N/A	N/A	$597,755	$1,016,574	$29,635
Rockville (L) FB	Yes	84%	16%	$370,782	$301,832	$91,858
Suitland FB	Yes	54%	46%	$2,730,589	$3,213,210	$149,239

Figure 17 shows general maintenance costs per rentable square foot. The baseline values for the general, grounds, and janitorial maintenance costs were provided by GSA or collected from IFMA and BOMA resources.[24,25,26,27] For some of the buildings GSA provided maintenance values that included only the specific O&M data used in the GSA baseline and those that matched the BOMA baselines. These standardized values were different from the values provided by the building operators (Figure 18). Using the adapted general maintenance values, eleven of the buildings had general maintenance costs equal to or greater than the GSA baseline, with nine buildings costing more than the industry baseline.

The International Facilities Management Association (IFMA) and the Building Owners and Managers Association (BOMA) provide the main source of statistics on the state of commercial buildings.

Each organization publishes benchmarking reports on a variety of development, operations and maintenance topics. Their data are obtained primarily through surveys of their members, which exceed 15,000 in each organization.

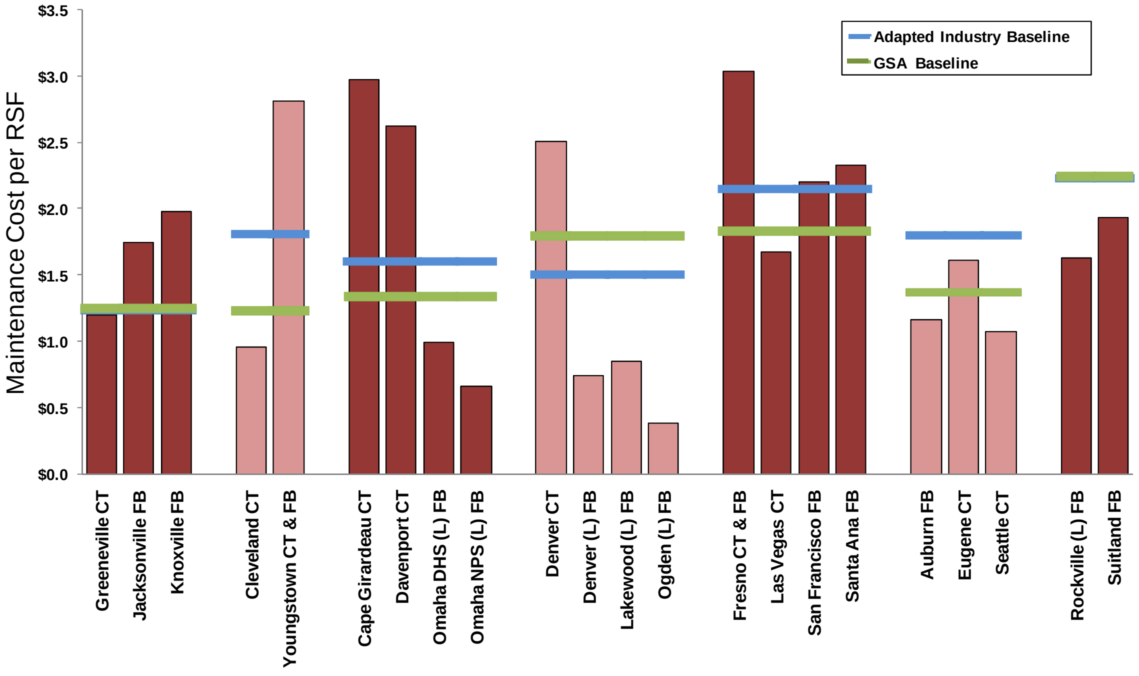
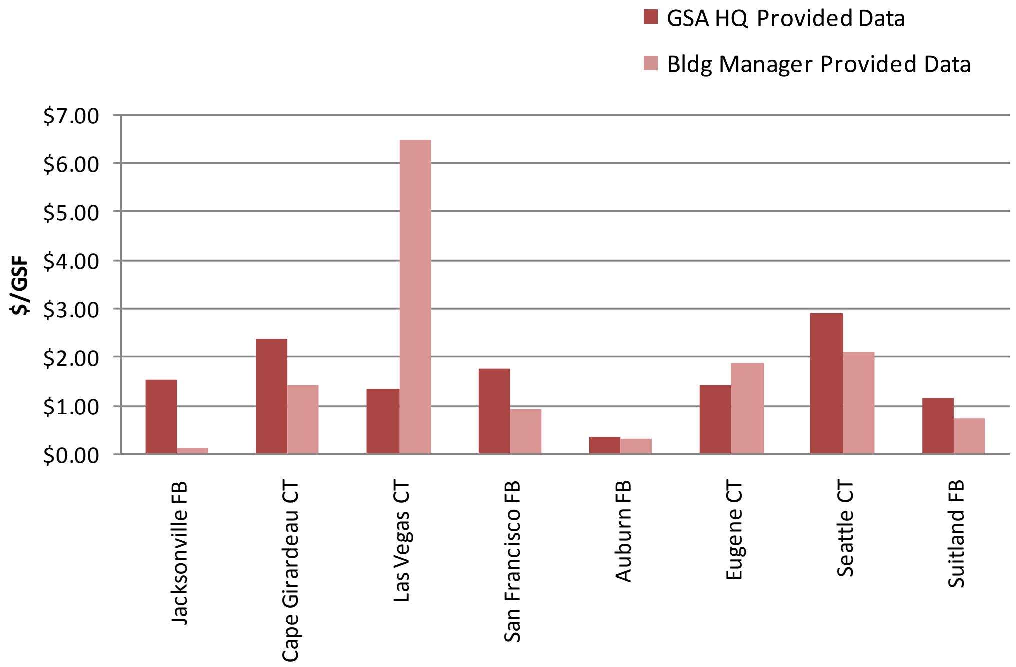


Figure 17. General maintenance cost per rentable square foot

Generally speaking the data provided by the building managers was lower than the adjusted data provided by GSA, except for Las Vegas CT and the Eugene CT.

Figure 18. General maintenance data source comparison



For some buildings we have multiple years of maintenance data (Figure 19). General maintenance costs are virtually the same for some buildings, higher, or lower for other buildings, with no obvious reason for the changes in costs. Thus, given that the data displayed in Figure 17 only represents one year of building O&M costs, the data should not be assumed to represent an average or expected cost for a building.

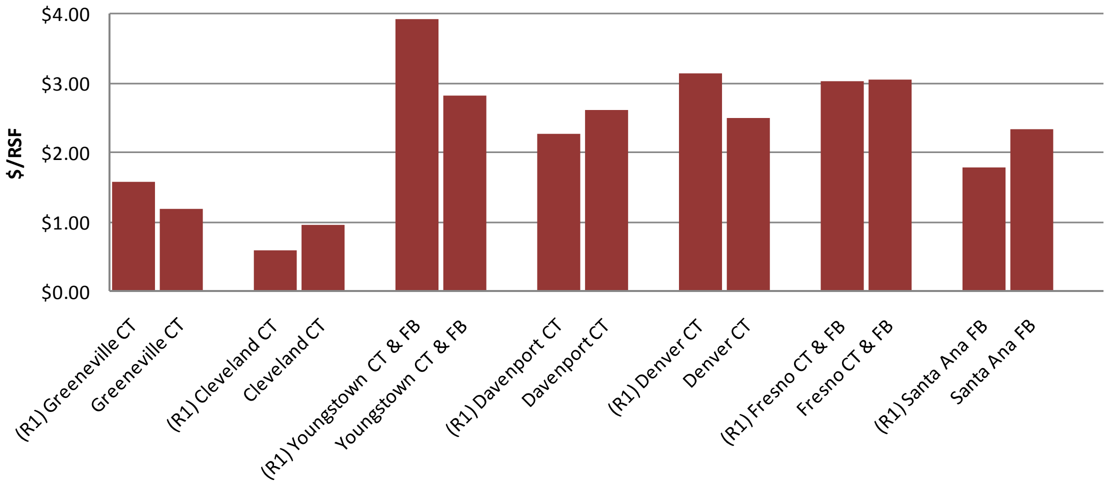


Figure 19. Multiple year general maintenance data

Figure 20 shows grounds maintenance costs per rentable square foot. All but one of the buildings fell within or below the baseline range. The building significantly above the baseline has manually weeded native prairie grass for landscaping, which may contribute to the higher grounds maintenance costs.

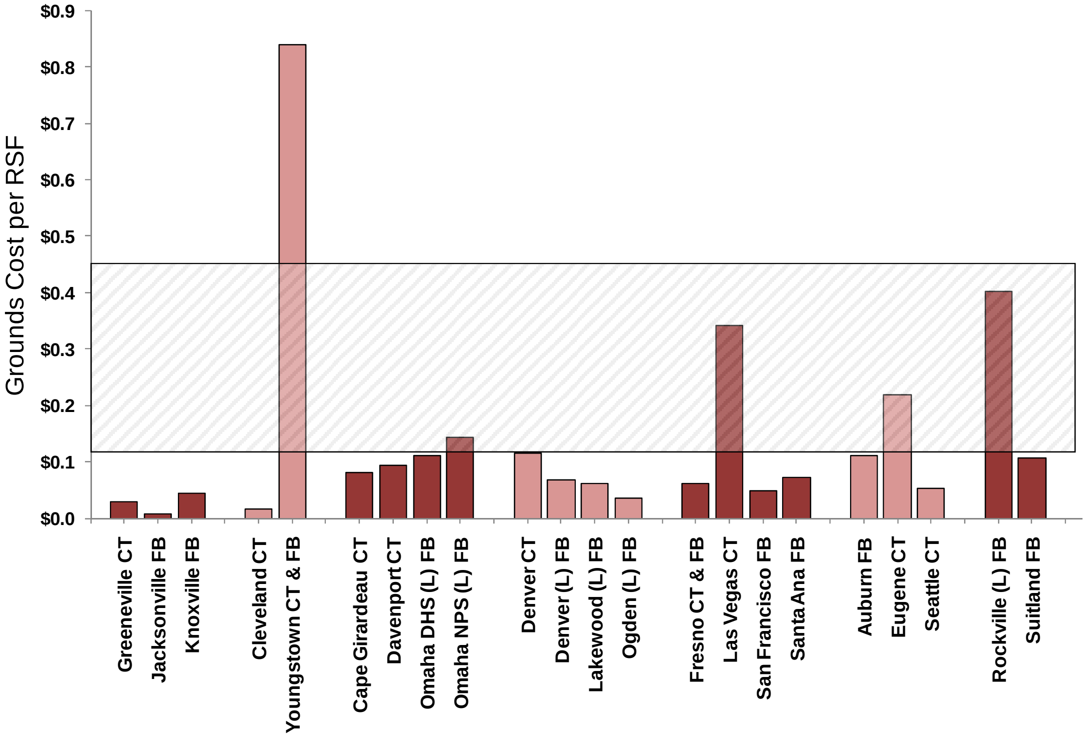


Figure 20. Grounds maintenance cost per rentable square foot

The janitorial maintenance costs for half of the buildings were above the baseline costs (Figure 21). As mentioned with general maintenance costs, the one year of costs provided in this study does not address the quality of work, potential regional cost differences, or the uniqueness of the year's janitorial needs.

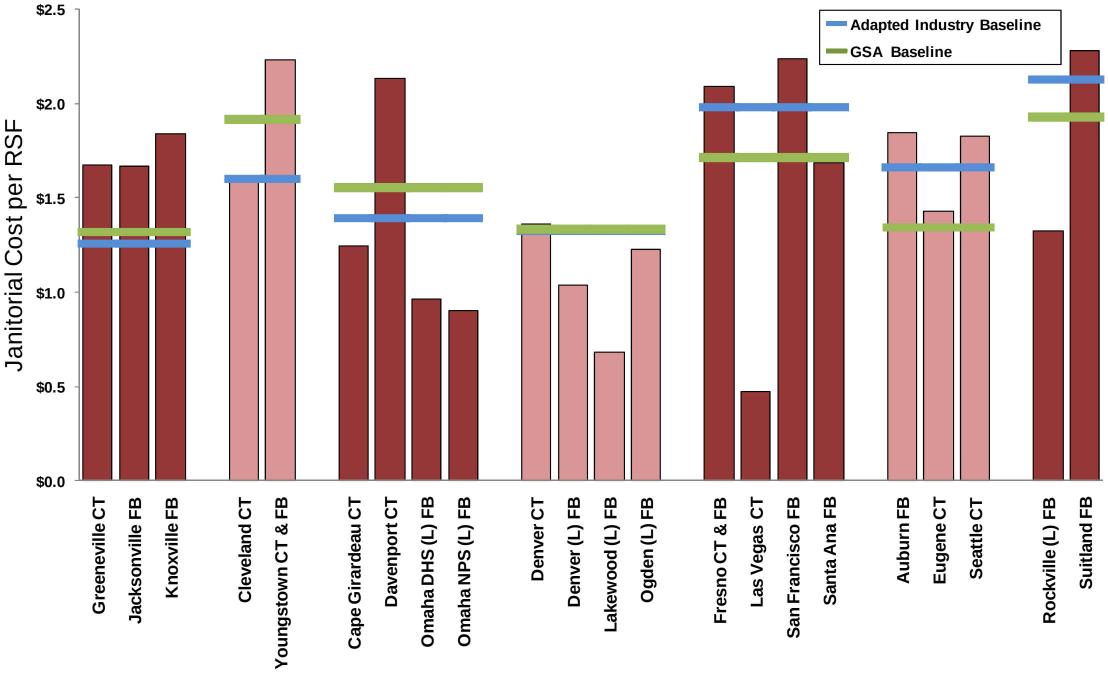


Figure 21. Janitorial cost per rentable square foot

The janitorial data provided by the building owners varied from what was in the GSA standard reporting system. The janitorial values were more similar to each other than the general maintenance values (Figure 22).

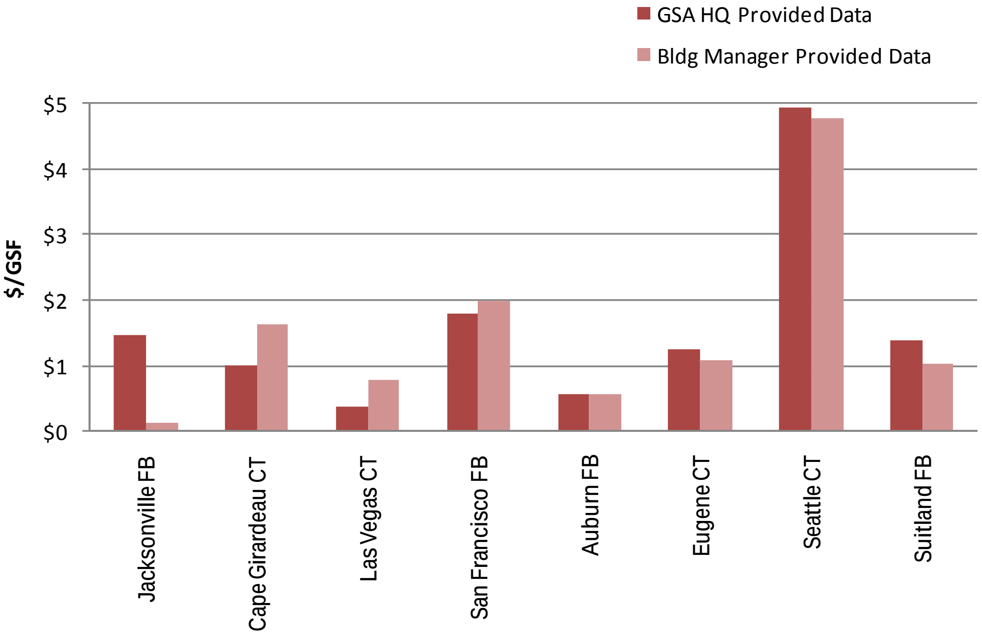


Figure 22. Janitorial data source comparison

Multiple years of janitorial maintenance cost data were available for some buildings (Figure 23). Similar to general maintenance, there is no consistency from one year to the next for these buildings. These data emphasize the importance of continuously monitoring a building's performance to fully understand whether it is performing well.

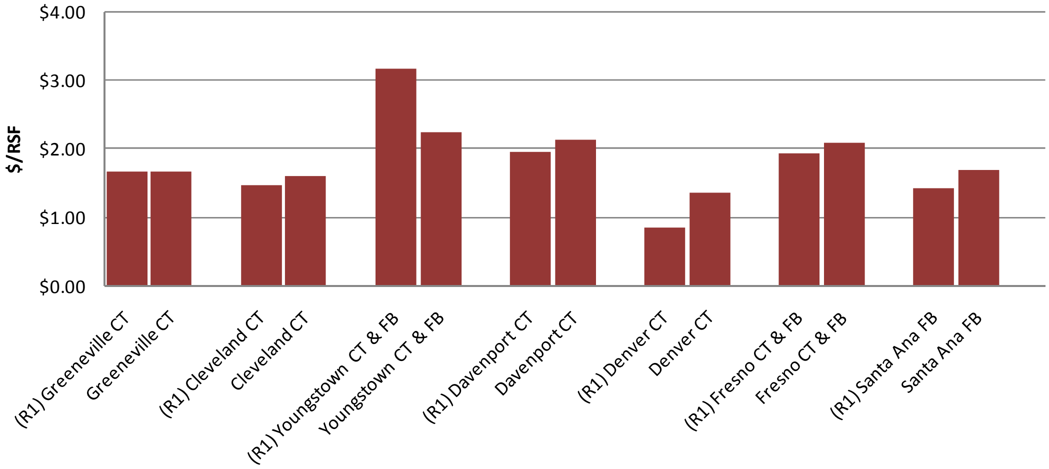


Figure 23. Multiple year janitorial maintenance cost data

Multiple baselines were used to compare the maintenance costs (Table 18). GSA has regional baselines addressing specific general and janitorial maintenance activities. A regional baseline value is available that was adapted from BOMA values to address the key areas identified by GSA. The grounds maintenance baseline was available through BOMA and represented as a range of 12-45 cents per rentable square foot. Depending on the location and type of landscape there will be varying grounds maintenance needs, which is the likely reason for the wide range in costs.

Table 18. Maintenance cost performance against baselines

	General Maint ($/rsf)			Janitorial Maint ($/rsf)			Grounds Maint ($/rsf)		
Building Name	Bldg Maint	GSA Baseline	Adapted Industry Baseline	Bldg Maint	GSA Baseline	Adapted Industry Baseline	Bldg Maint	BOMA Industry Baseline (Low)	BOMA Industry Baseline (High)
Greeneville CT	$1.20	$1.25	$1.23	$1.67	$1.32	$1.25	$0.03	$0.12	$0.45
Jacksonville FB	$1.75	$1.25	$1.23	$1.67	$1.32	$1.25	$0.01	$0.12	$0.45
Knoxville FB	$1.98	$1.25	$1.23	$1.84	$1.32	$1.25	$0.04	$0.12	$0.45
Cleveland CT	$0.95	$1.23	$1.81	$1.61	$1.91	$1.60	$0.02	$0.12	$0.45
Youngstown CT & FB	$2.81	$1.23	$1.81	$2.23	$1.91	$1.60	$0.84	$0.12	$0.45
Cape Girardeau CT	$2.97	$1.33	$1.60	$1.24	$1.55	$1.39	$0.08	$0.12	$0.45
Davenport CT	$2.62	$1.33	$1.60	$2.13	$1.55	$1.39	$0.09	$0.12	$0.45
Omaha DHS (L) FB	$0.99	$1.33	$1.60	$0.96	$1.55	$1.39	$0.11	$0.12	$0.45
Omaha NPS (L) FB	$0.66	$1.33	$1.60	$0.90	$1.55	$1.39	$0.14	$0.12	$0.45
Denver CT	$2.51	$1.79	$1.50	$1.36	$1.33	$1.32	$0.12	$0.12	$0.45
Denver (L) FB	$0.74	$1.79	$1.50	$1.04	$1.33	$1.32	$0.07	$0.12	$0.45
Lakewood (L) FB	$0.85	$1.79	$1.50	$0.68	$1.33	$1.32	$0.06	$0.12	$0.45
Ogden (L) FB	$0.38	$1.79	$1.50	$1.23	$1.33	$1.32	$0.03	$0.12	$0.45
Fresno CT & FB	$3.04	$1.83	$2.15	$2.09	$1.71	$1.98	$0.06	$0.12	$0.45
Las Vegas CT	$1.67	$1.83	$2.15	$0.47	$1.71	$1.98	$0.34	$0.12	$0.45
San Francisco FB	$2.20	$1.83	$2.15	$2.23	$1.71	$1.98	$0.05	$0.12	$0.45
Santa Ana FB	$2.33	$1.83	$2.15	$1.68	$1.71	$1.98	$0.07	$0.12	$0.45
Auburn FB	$1.16	$1.37	$1.80	$1.85	$1.34	$1.66	$0.11	$0.12	$0.45
Eugene CT	$1.61	$1.37	$1.80	$1.43	$1.34	$1.66	$0.22	$0.12	$0.45
Seattle CT	$1.07	$1.37	$1.80	$1.82	$1.34	$1.66	$0.05	$0.12	$0.45
Rockville (L) FB	$1.63	$2.24	$2.23	$1.32	$1.93	$2.12	$0.40	$0.12	$0.45
Suitland FB	$1.94	$2.24	$2.23	$2.28	$1.93	$2.12	$0.11	$0.12	$0.45

Fifteen of the 22 buildings had aggregate maintenance costs below baseline (Figure 24). Aggregate maintenance is the summation of the general, janitorial, and grounds maintenance values. Of the buildings with higher aggregate maintenance costs, all of their general maintenance costs were higher than baseline.

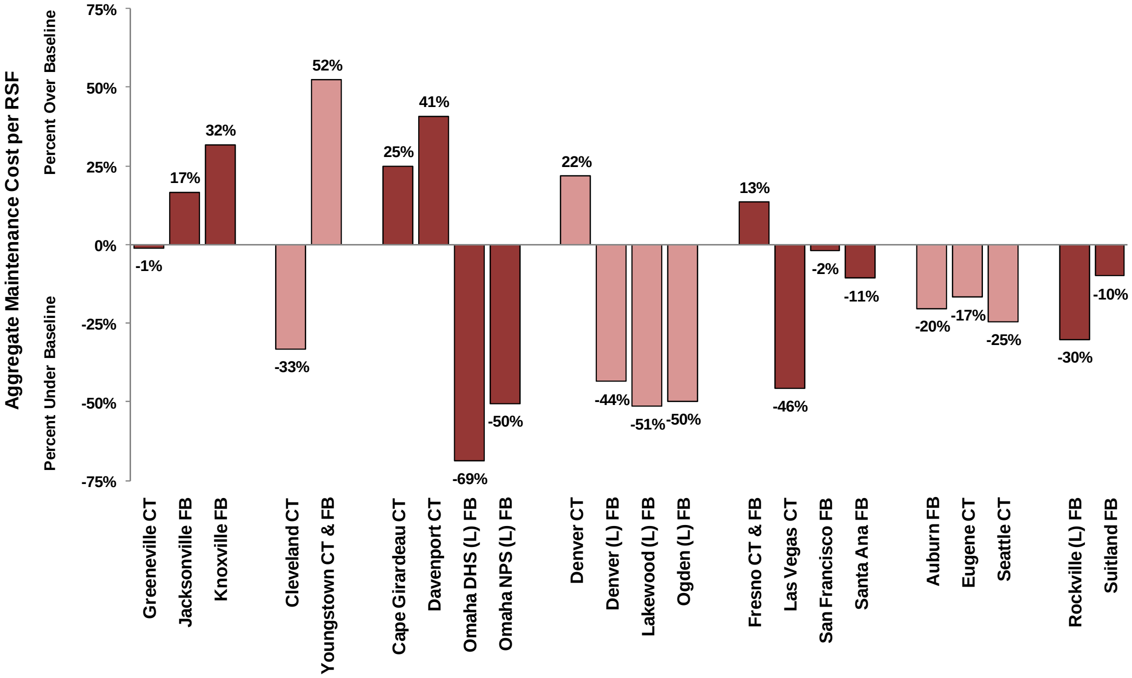


Figure 24. Aggregate maintenance cost comparison

Consistent with the first round of building assessments, the occupants appear satisfied with the cleanliness and maintenance of the buildings, with all of the satisfaction scores above zero. Note that although the buildings have positive satisfaction scores, five buildings have scores below the CBE survey 50th percentile.

Green housekeeping is a sustainable design and operations strategy used to provide a healthy, clean work environment. Figure 25 displays the relative occupant satisfaction with cleaning and maintenance compared to janitorial maintenance costs and aggregate maintenance costs. During site visits, the research team observed that some of the buildings with green cleaning policies had products that implied different operating practices. Buildings with green housekeeping policies that offered evidence of different operational practices are identified as "some" green housekeeping practices. There are buildings with green cleaning programs on both sides of the janitorial cost baseline.

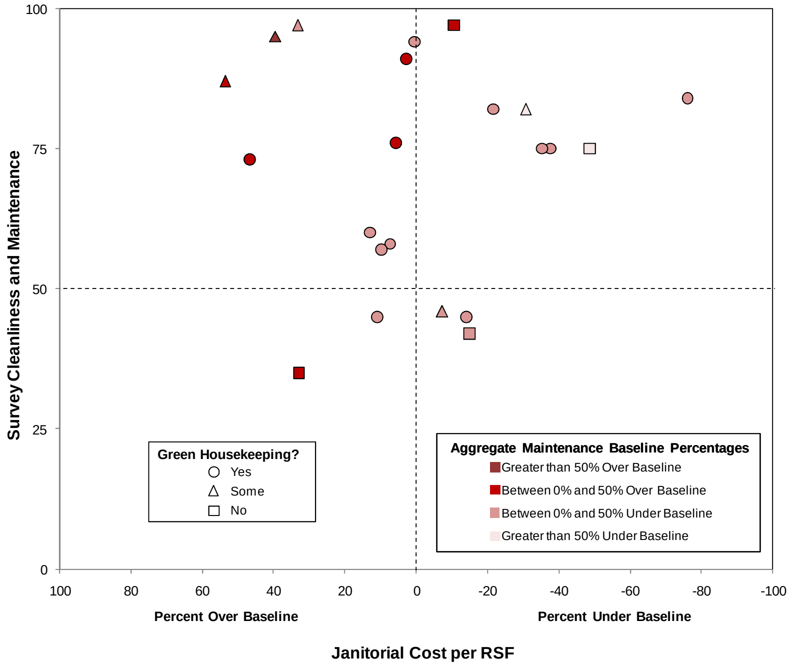


Figure 25. Janitorial cost per rentable square foot and cleaning satisfaction compared with green housekeeping

According to IFMA research, a building less than 5 years old would spend 75% of its maintenance funds on preventative maintenance and 27% on service call related maintenance. For buildings 5 to 10 years old the ratio changes to 63% and 37%.[28] The Denver FB, San Francisco FB, and Rockville FB had three to four times as many service calls as preventative maintenance tasks, which is significantly different from the IFMA baseline for buildings less than 5 years old. Two of those buildings had lower costs and one had higher costs than baseline. Excluding those buildings, the averaged ratio of preventative maintenance to service calls is 68% and 32% respectively, which is comparable to the IFMA baseline.

Waste Generation and Recycling

Waste disposal is a utility cost incurred by buildings that is an indicator of resource use by the building occupants. Although occupant waste generation is not typically seen as having a connection to a building, LEED requires recycle bins as part of the building design. This performance metric is being used to investigate whether the occupants of green buildings recycle at a greater rate than an industry baseline.

Although a building designer, manager and/or owner can offer space, services, and encouragement to recycle, recycling programs are more commonly successful when they are promoted by the building occupant's employer. In other words, recycling goals and/or incentives offered by the federal agencies that occupy these buildings, and coordinated with the building management would offer the greatest opportunity to reduce solid sanitary waste. Although some buildings had exemplary recycling programs, the research team did not observe a consistent emphasis to reduce solid sanitary waste or to increase recycling at the buildings in the study.

There are few useful baselines available for waste and recycling values. GSA's National Capitol Region (Region 11) has been collecting recycling data for over 40 buildings for the last 10 years, which offers a relevant point of reference for the buildings in this study. The average recycling value for the buildings in this study is just under half a pound per rentable square foot, which is higher than the average recycling quantity for every year Region 11 has been collecting the data (Figure 26).

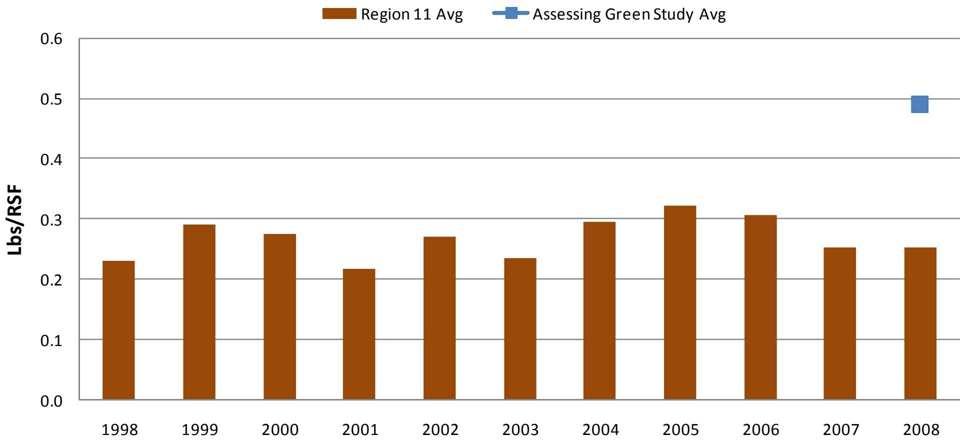


Figure 26. Region 11 recycling quantity

GSA's Recycling Guide has an average waste generation rate of 1.6 pounds of solid waste per building occupant per day. When considering the waste per occupant rate, Greeneville CT, Davenport CT, Omaha DHS FB, Omaha NPS FB, Denver FB, Lakewood FB, Ogden FB, and Santa Ana FB all generate quite a bit more waste per occupant (from 2.3 to 9.8 pounds per occupant per day).

Table 19 provides a summary of the waste and recycling quantity and cost data available for each building.

Table 19. Waste generation and recycling data and cost by building

Building Name	Waste per Year (Tons)	Waste Cost	Recycled Material	Recycle per year (Tons)	Recycle Cost	% Recycle of Total Waste Generation
Greeneville CT	39	$900	Paper	2	-$71	6%
Jacksonville FB	14	N/A	Paper (mixed & cardboard), wood pallets,	3	N/A	16%
Knoxville FB	41	$4,380	Paper & Metal	20	N/A	33%
Cleveland CT	24	$3,067	Paper & Metal	3	-$101	10%
Youngstown CT & FB	17	$1,530	Paper	29	$0	63%
Cape Girardeau CT	2	$325	Paper	0	$144	12%
Davenport CT	59	$907	Paper	2	$0	4%
Omaha DHS (L) FB	113	$2,400	Paper	24	$0	17%
Omaha NPS (L) FB	130	$1,500	Paper & Cardboard	11	$1,020	8%
Denver CT	38	N/A	Paper	N/A	N/A	N/A
Denver (L) FB	290	$15,862	Comingled recycling	177	$3,228	38%
Lakewood (L) FB	374	$3,600	Paper	204	$0	35%
Ogden (L) FB	220	$3,940	Paper & Cardboard	67	$16,081	23%
Fresno CT & FB	16	$24,236	Paper	18	$0	53%
Las Vegas CT	N/A	$25,266	Paper	24	$0	N/A
San Francisco FB	94	$31,970	Bottles, Cans, Paper, Compost and	45	-$880	32%
Santa Ana FB	562	$18,360	Paper	11	$1,600	2%
Auburn FB	75	$2,184	Plastic, aluminum, paper - mixed	7	N/A	9%
Eugene CT	5	Included	Comingled recycling	6	N/A	56%
Seattle CT	59	Included	Aluminum, pastic, glass, mixed paper,	38	-$533	39%
Rockville (L) FB	N/A	$22,056	Paper, tone, batteries, cell phones,	N/A	Included	N/A
Suitland FB	560	$107,871	Paper, cans (aluminum), bottles	129	-$2,480	19%

Analysis was performed comparing the recycling to waste ratio for each building. Eight of the buildings in the study recycled more than the national average. However, the waste and recycling data were not consistently available for each building. Some buildings shared services with other buildings and some estimated the quantity of waste or recycled material based on the frequency of service rather than measured quantities. Based on the site visits it was clear that recycling was not a strong expectation of the building occupants for at least some of the buildings. Although paper was recycled in all of the buildings, other commonly recycled items — glass, aluminum, and cardboard — were not consistently collected. In at least one building the PNNL research team was told how the building management gave up on recycling anything but paper because the occupants used the recycle bins as trash cans.

Figure 27 shows the waste cost per rentable square foot. Seven of the buildings are above the industry baseline.

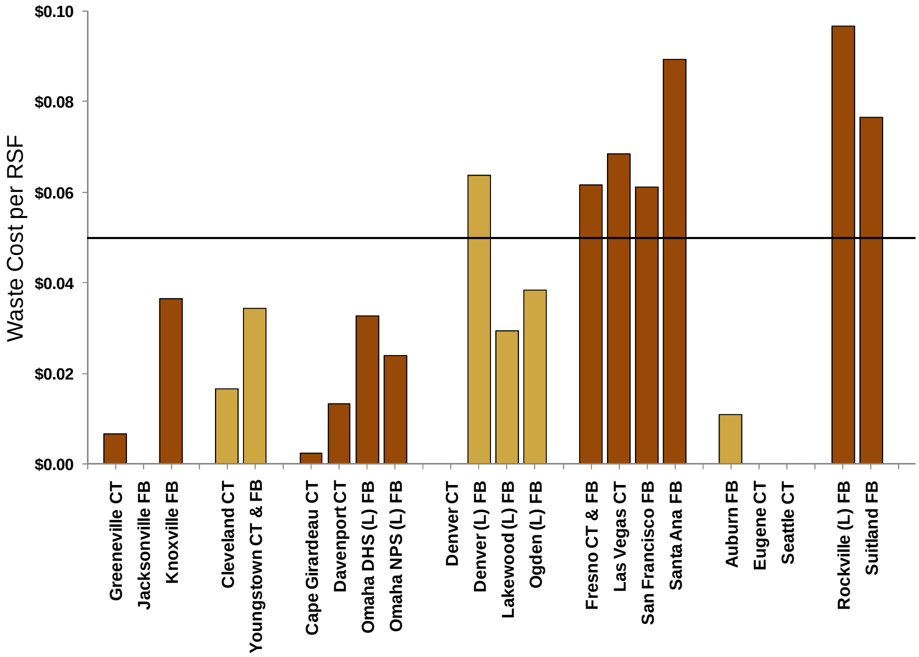


Figure 27. Waste cost per rentable square foot

Using the Region 11 average recycling cost, Figure 28 shows the average costs for the buildings in this study are higher for most years. Keep in mind the average quantity of waste was higher for the study buildings, which can impact the cost of recycling services.

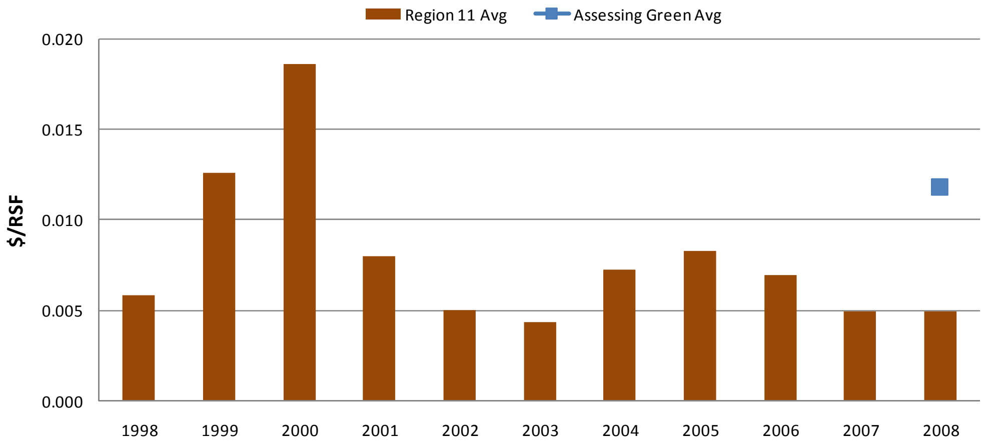


Figure 28. Region 11 recycling cost per rentable square foot

To better understand the impact the building design and operation have on the quantity of materials recycled, the building occupant employer programs would need to be equivalent. Additionally, the cost and availability of recycling programs in the community and the willingness of the building manager to manage a recycling program might impact the ability of building occupants to recycle.

Occupant Satisfaction

A primary aim of sustainable design is maximizing the occupant comfort and satisfaction, while minimizing the environmental impact and costs. Indoor environmental quality (IEQ) is the commonly used term to describe the building features that directly impact the occupants. The IEQ of a workplace reflects the interaction of air, lighting, and surroundings with occupants in a holistic sense. IEQ effects include occupant health, productivity, and satisfaction. Occupant satisfaction is crucial to staff retention. Studies have shown that employees planning to leave an organization were 25% less satisfied with their physical workplace than those that planned to stay.[29]

Occupant surveys are the typical mechanism used to gather occupant satisfaction data. This study used the Center for the Built Environment's (CBE) occupant satisfaction survey. The CBE core survey questions fit within the following categories

- Office Layout
- Office Furnishings
- Thermal Comfort
- Air Quality
- Lighting
- Acoustic Quality
- Cleanliness and Maintenance
- General Comments.

The University of California Berkeley's Center for the Built Environment (CBE) has developed an occupant satisfaction survey that has had over 48,000 survey responses. Occupants in 506 buildings have taken the CBE survey, with over 320 office buildings and 66 are LEED-certified. GSA has over 225 buildings in the database. The survey is distributed via the internet, takes approximately 10 minutes to complete, and protects the confidentiality of the respondents.

CBE allows for customization of the core survey. Previously, GSA has used a modified version of the CBE survey. This project started with the GSA modified survey and then added questions related to occupant commute. The additional questions increased the estimated time to complete the survey to 20 minutes. The survey tool used to measure building occupant satisfaction for this study is called SPOT (Sustainable Places and Organizational Trends). This survey is a GSA modified version of the CBE core survey that removes the office furnishings and office layout questions and adds occupant commute questions. The SPOT survey was distributed to building occupants electronically in 2008 through 2010. For a few buildings the electronic distribution, via an internet site, was unsuccessful because of limited access to the internet. In those cases, a paper version of the survey was distributed, collected, and the resulting data were entered into the electronic survey. A copy of the key questions provided in the survey can be found in Appendix E.

The industry baseline for the occupant satisfaction metrics is the CBE core survey responses. The survey questions offer a numerical response of between -3 and 3. CBE prepares building specific survey summary reports. These reports provide the average scores for each of the key elements addressed in the survey. The average response score and the average responses within the CBE database are compared. For example, if a building scored at the 50th percentile, 50% of the buildings in the database would have a lower score and 50% would have a higher score.

The percentiles for the surveys performed during the first round of this study were re-calculated against the current CBE database, which resulted in the percentiles for specific buildings changing.

The CBE preferred response rate for the survey is greater than 50%. More than half of the buildings in the study had response rates lower than desired. The Seattle CT was the only building that did not take the SPOT survey. Alternatively, the standard GSA survey administered in 2006 was used to compare occupant satisfaction. The scores were translated from a 5 point scale to the 7 point CBE scale using methods created by CBE.[30] Forty-three questions regarding the building features, its services, security, and management staff are included. The survey was completed either on-line or hard-copy and mailed. A copy of the survey can be found in Appendix F.

In addition to the CBE survey a rapid indoor air quality (IAQ) assessment was performed on one building, the Denver FB (Appendix G). The one day assessment involved five indoor and one outdoor location, and included measurements of temperature, relative humidity, atmospheric pressure, sound level, carbon dioxide, ozone, particulate matter, fungal spores, volatile organic compounds, and semivolatile organics. When the rapid IAQ assessment results were compared to available standards, there were no acute hazards identified and temperature and relative humidity measurements were within the American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE) Standard 55-2004 acceptable range.

Table 20 provides an individual building summary of the SPOT survey response rates and the percentile ranking in each IEQ category for each building as provided by CBE.

Table 20. SPOT Survey scores ranked against CBE database

	Percent Rank Within CBE Database						
Building Name	Response Rate	Acoustics	Air Quality	Cleanliness	Lighting	Thermal Comfort	General Building
Greeneville CT	64%	95%	93%	97%	91%	82%	98%
Jacksonville FB	45%	29%	42%	35%	50%	56%	38%
Knoxville FB	36%	43%	61%	73%	80%	57%	80%
Cleveland CT	57%	68%	85%	94%	74%	79%	82%
Youngstown CT & FB	62%	62%	58%	95%	42%	1%	58%
Cape Girardeau CT	58%	99%	97%	97%	96%	93%	97%
Davenport CT	61%	71%	81%	87%	46%	91%	77%
Omaha DHS (L) FB	89%	87%	86%	82%	65%	89%	95%
Omaha NPS (L) FB	68%	8%	75%	75%	32%	51%	70%
Denver CT	58%	63%	65%	91%	72%	51%	64%
Denver (L) FB	41%	59%	85%	82%	30%	59%	57%
Lakewood (L) FB	41%	40%	74%	75%	48%	59%	75%
Ogden (L) FB	29%	14%	53%	46%	36%	42%	52%
Fresno CT & FB	30%	88%	87%	76%	70%	60%	97%
Las Vegas CT	20%	76%	69%	84%	35%	83%	69%
San Francisco FB	40%	8%	46%	60%	10%	32%	13%
Santa Ana FB	35%	32%	56%	42%	47%	87%	58%
Auburn FB	74%	70%	58%	45%	20%	19%	49%
Eugene CT	38%	81%	58%	45%	43%	28%	47%
Seattle CT	21%	80%	33%	57%	11%	82%	57%
Rockville (L) FB	55%	74%	73%	75%	64%	61%	64%
Suitland FB	18%	11%	52%	58%	6%	33%	26%

The building results for key summary survey questions have been compared to the full CBE survey database. Figure 29 shows that the occupants of more than two-thirds of the buildings in the study were more satisfied with their acoustical quality than the 50th percentile of those surveyed by CBE.

In the next set of figures, the orange line represents the average survey responses by question category in the CBE database and the blue dots are the average scores for the 22 buildings in this study.

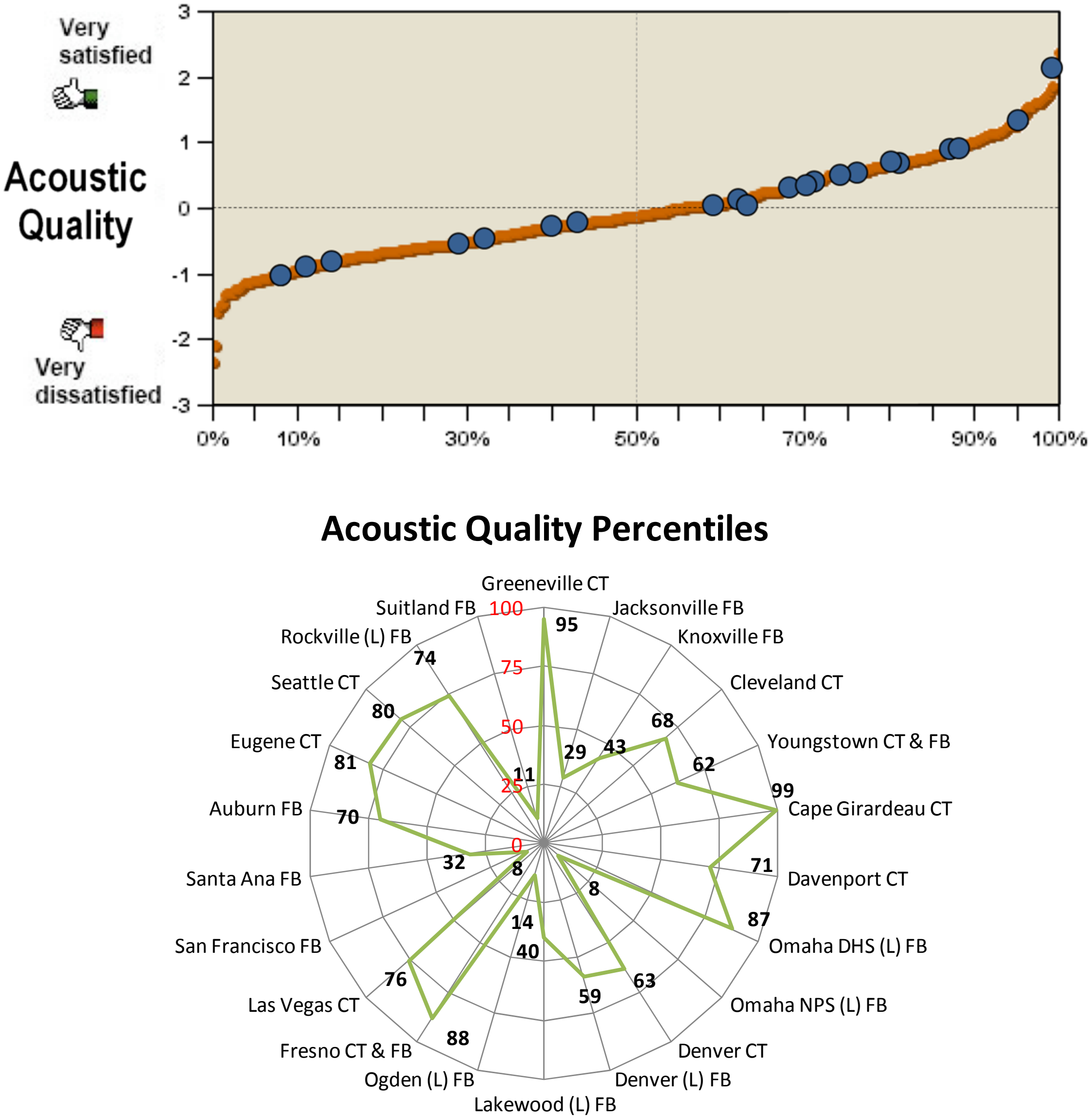


Figure 29. Acoustic quality rating from the occupant survey

Data presented by CBE have the average acoustics satisfaction score for LEED buildings at 0.45 with the average score of typical buildings in the CBE database at -0.16. The responses to sound privacy were lower than noise level. Thus it is CBE's conclusion that the information content of the noise causes distraction and dissatisfaction. CBE also compared the acoustic satisfaction levels to the type of office space. Not surprisingly, the highest levels of satisfaction are in private offices and the lowest are in open office spaces and cubicles.[31] For the buildings in this study where cubicle workspaces were predominant the acoustic satisfaction scores are shown in Figure 30. Two of the five buildings with cubicle style workspace, Denver FB and Auburn FB, have a positive acoustic satisfaction scores.

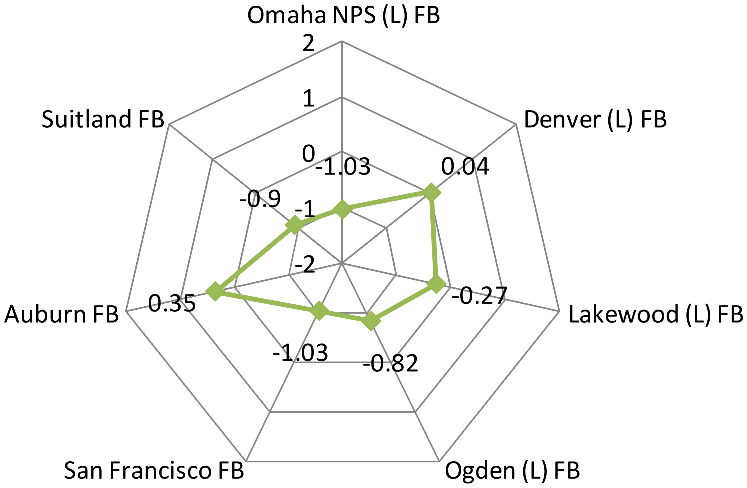


Figure 30. Acoustics quality satisfaction scores for cubicle workspaces

Photographs of the building workspaces show a variety of cubicle heights and types, which do not offer a consistent reason for the different acoustic satisfaction scores.

Auburn FB Denver FB Lakewood FB Ogden FB

Suitland FB Omaha NPB FB San Francisco FB

Figure 31. Photographs of cubicle workspaces

Figure 32 illustrates that occupants of all the buildings in the study were satisfied with building air quality. Occupants from all but three of the buildings were more satisfied with the air quality than the 50th percentile of those surveyed by CBE.

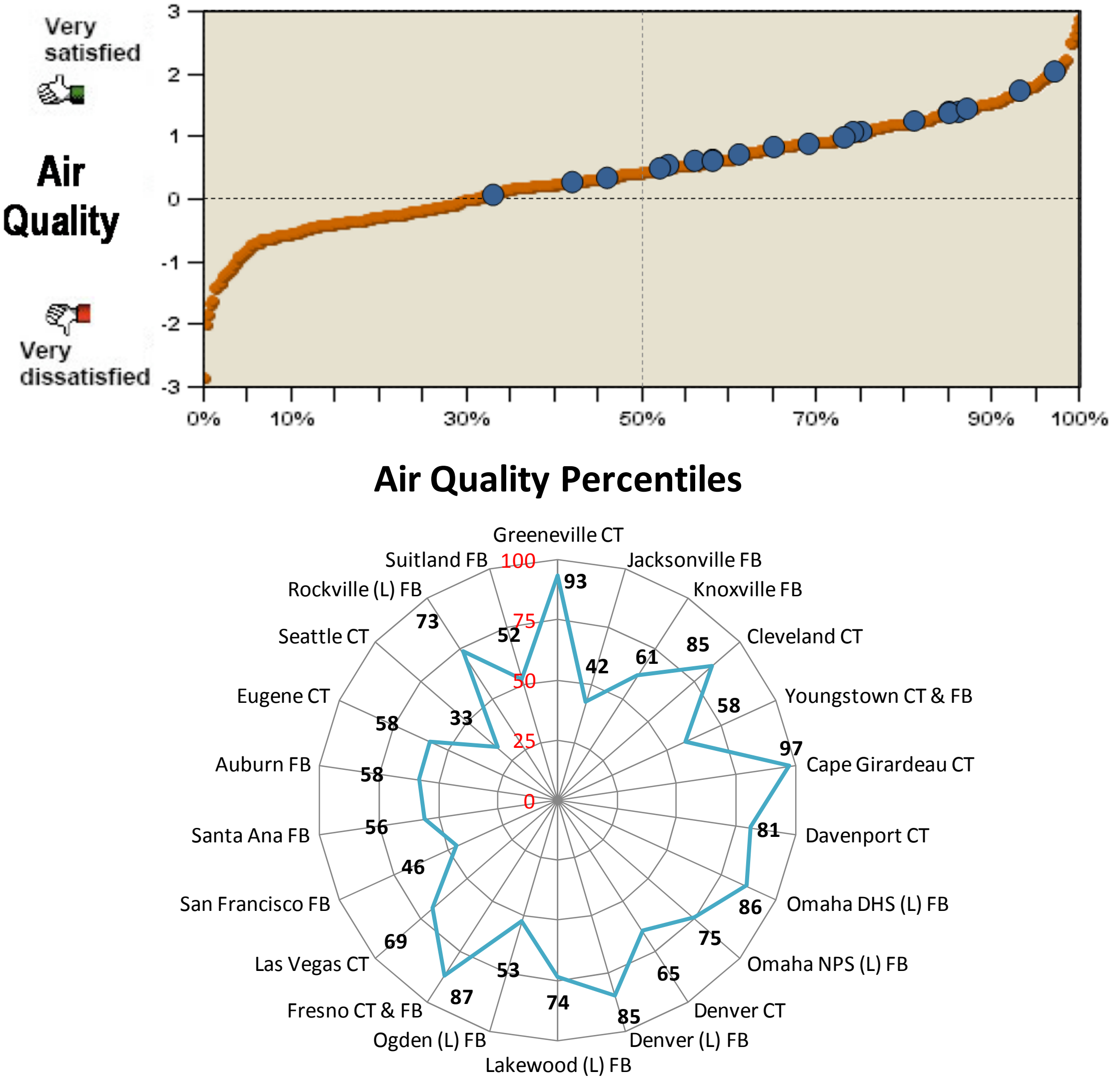


Figure 32. Air quality rating from the occupant survey

Figure 33 illustrates that occupants in all but four of the buildings in the study identified cleanliness and maintenance as being better than the 50th percentile of the CBE database. More than half of the buildings scored at the 75th percentile and above. When considering the cost data, the maintenance costs of some of the buildings in the study are high, yet the building occupants are pleased with the service they are receiving.

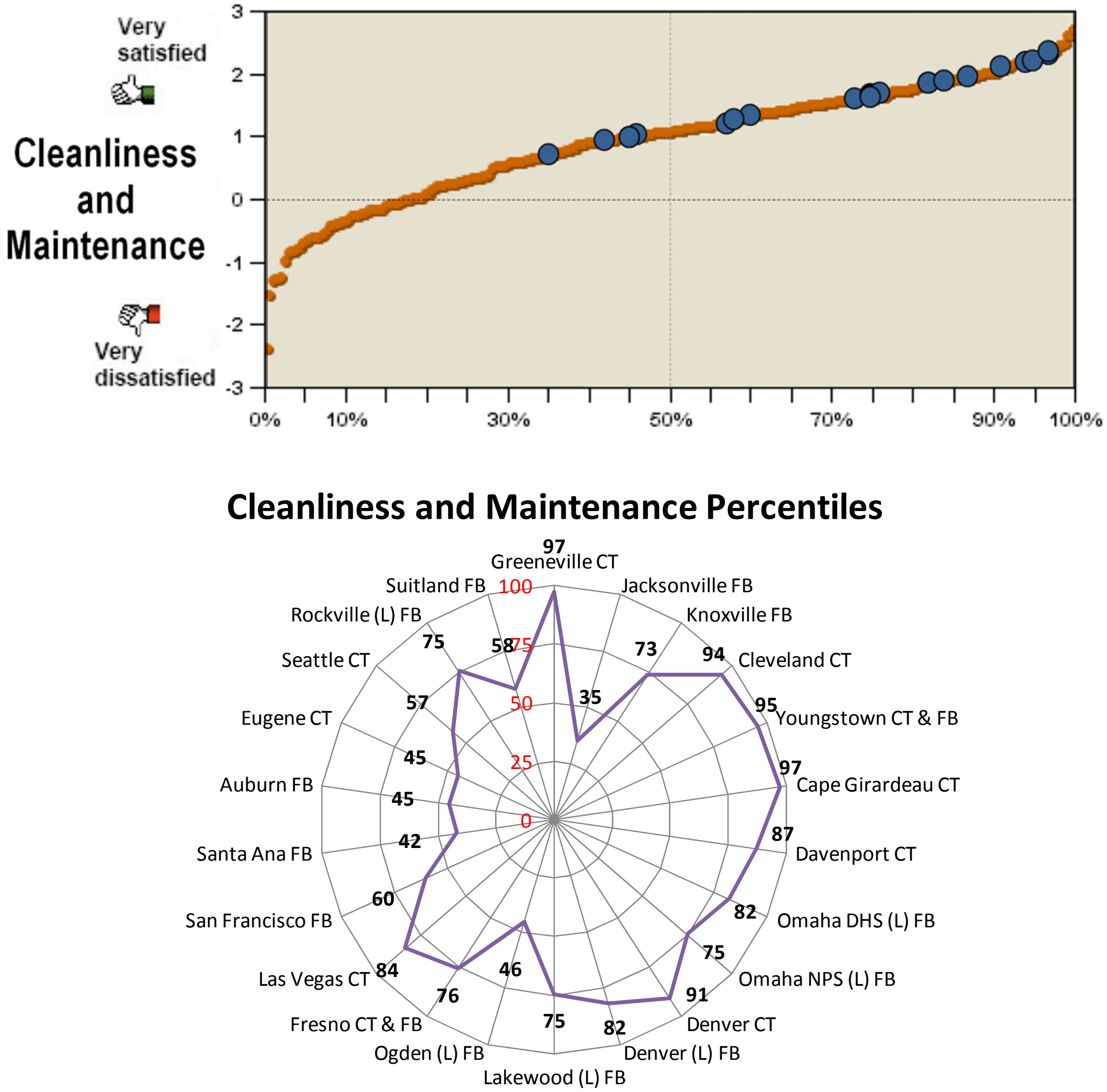


Figure 33. Cleanliness and maintenance rating from the occupant survey

Figure 34 illustrates that although all of the occupants scored the lighting as satisfactory (above zero), more than half of the buildings in the study identified lighting as being worse than the 50th percentile, with a quarter below the 30th percentile. The lighting occupant satisfaction rating needs to be considered in context with energy use. The primary questions that make up the lighting satisfaction level are

- How satisfied are you with the amount of light in your workspace?
- How satisfied are you with the visual comfort of the lighting?
- How satisfied are you with the degree of control you have over the lighting in your workspace?

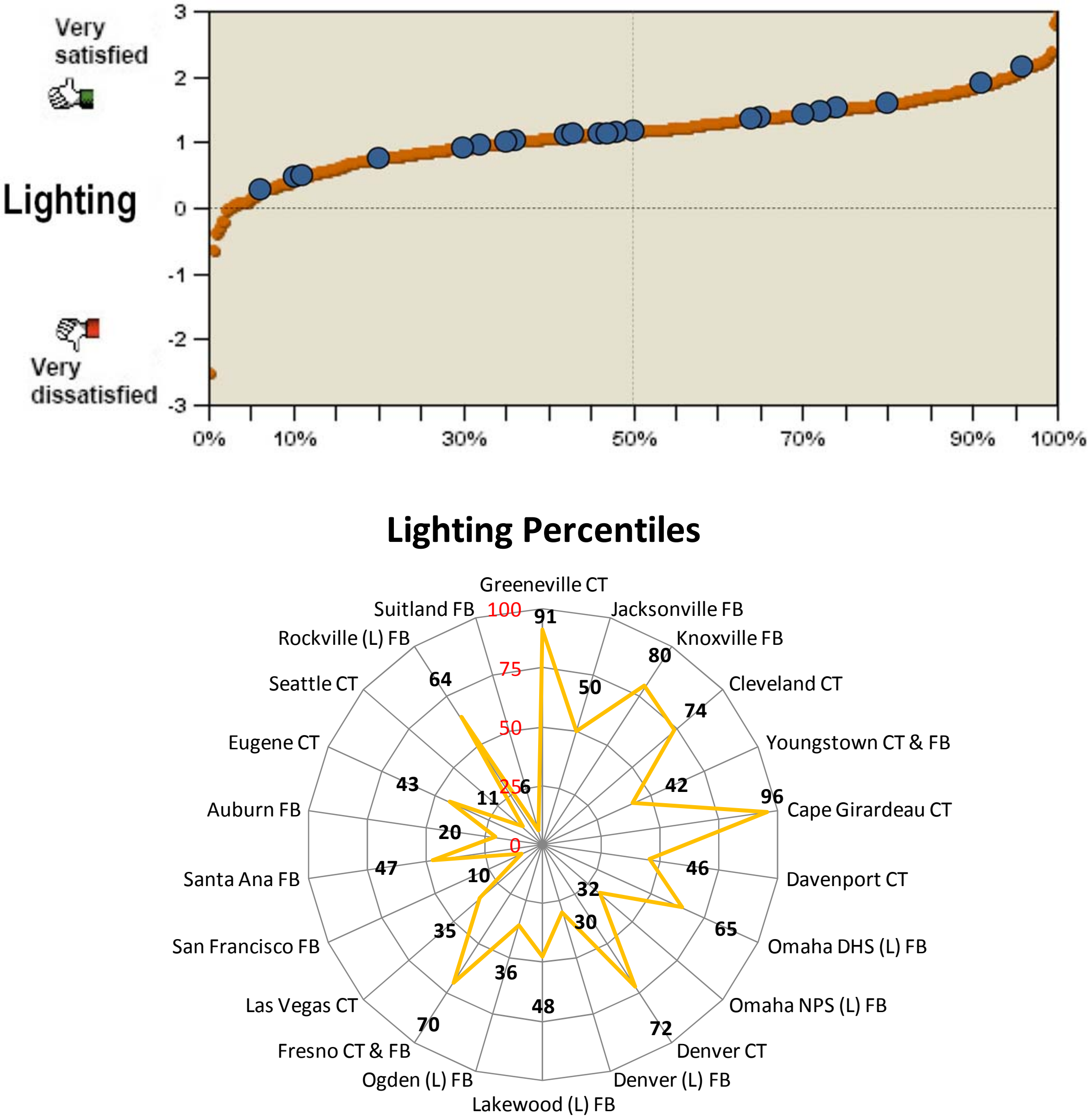
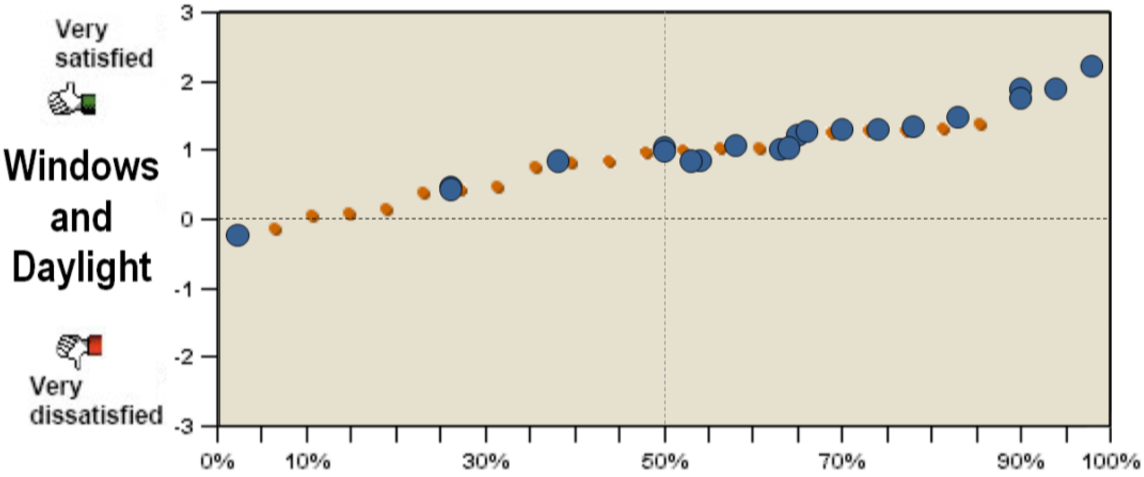


Figure 34. Lighting quality rating from the occupant survey

Figure 35 shows the satisfaction scores for the windows and daylight questions. The majority of the GSA buildings in the study scored above the 50th percentile, but note that the CBE database does not have many buildings in the database that have responded to these questions. The primary questions that make up the windows and daylight satisfaction level are

- How satisfied are you with the amount of daylight in your general office area?
- How satisfied are you with your access to a window view?



Windows and Daylight Percentiles

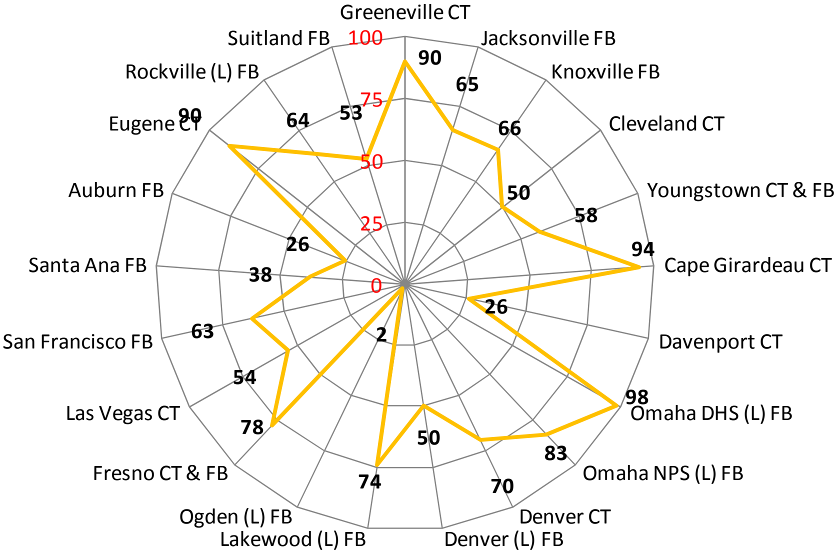


Figure 35. Windows and daylight satisfaction rating from the occupant survey

For thermal comfort, most of the buildings scored above the 50th percentile (Figure 36). One of the buildings whose occupants stated they were very dissatisfied with the thermal comfort has additional workspaces have been created from spaces that were not originally designed to be occupied. The building manager of this building commented that the additional occupant spaces negatively impacted ventilation.

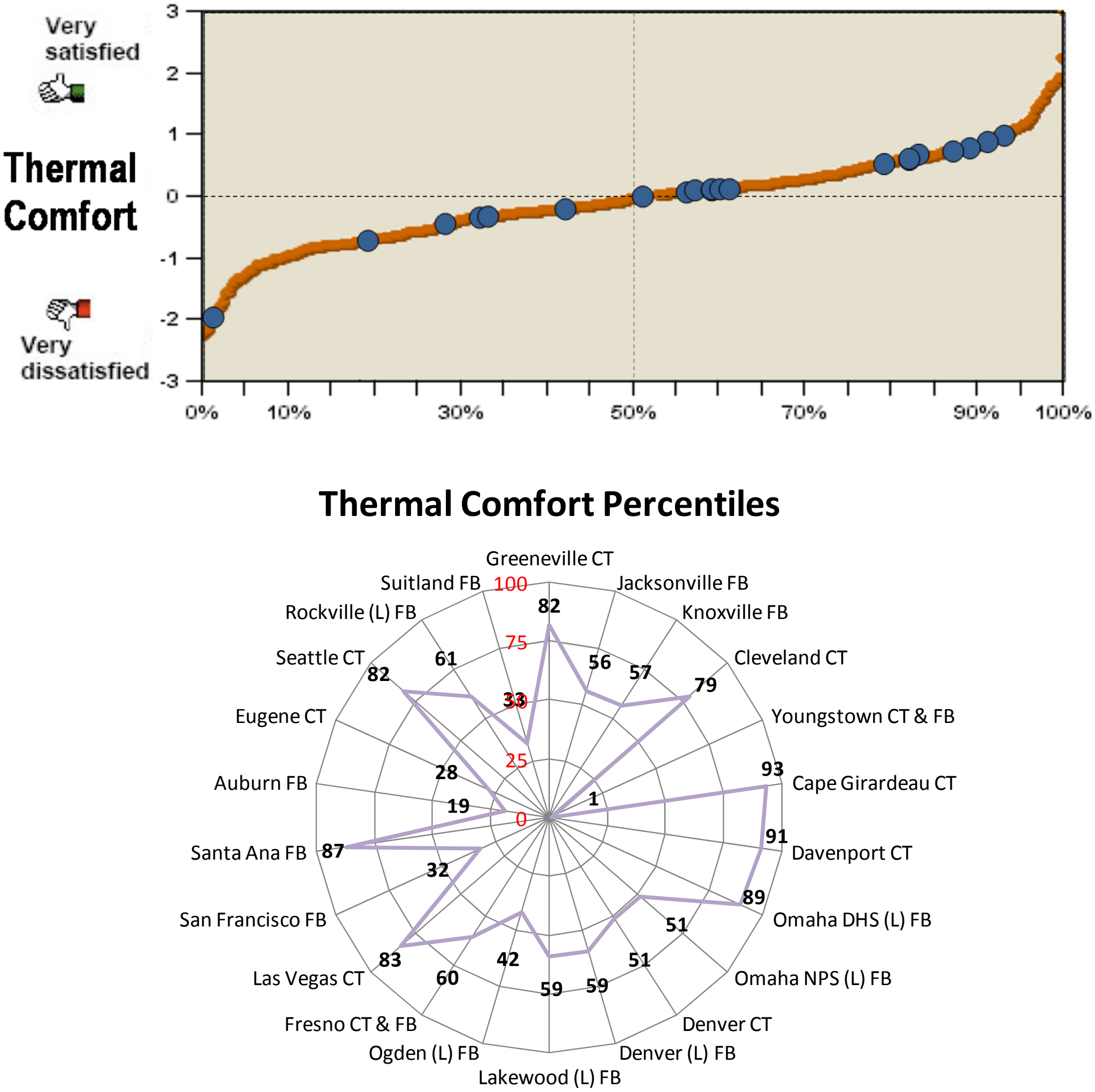


Figure 36. Thermal comfort rating from the occupant survey

Overall, the general satisfaction with the individual workspace was positive (above zero) and the majority of the buildings had average satisfaction scores above the 50th percentile (Figure 37).

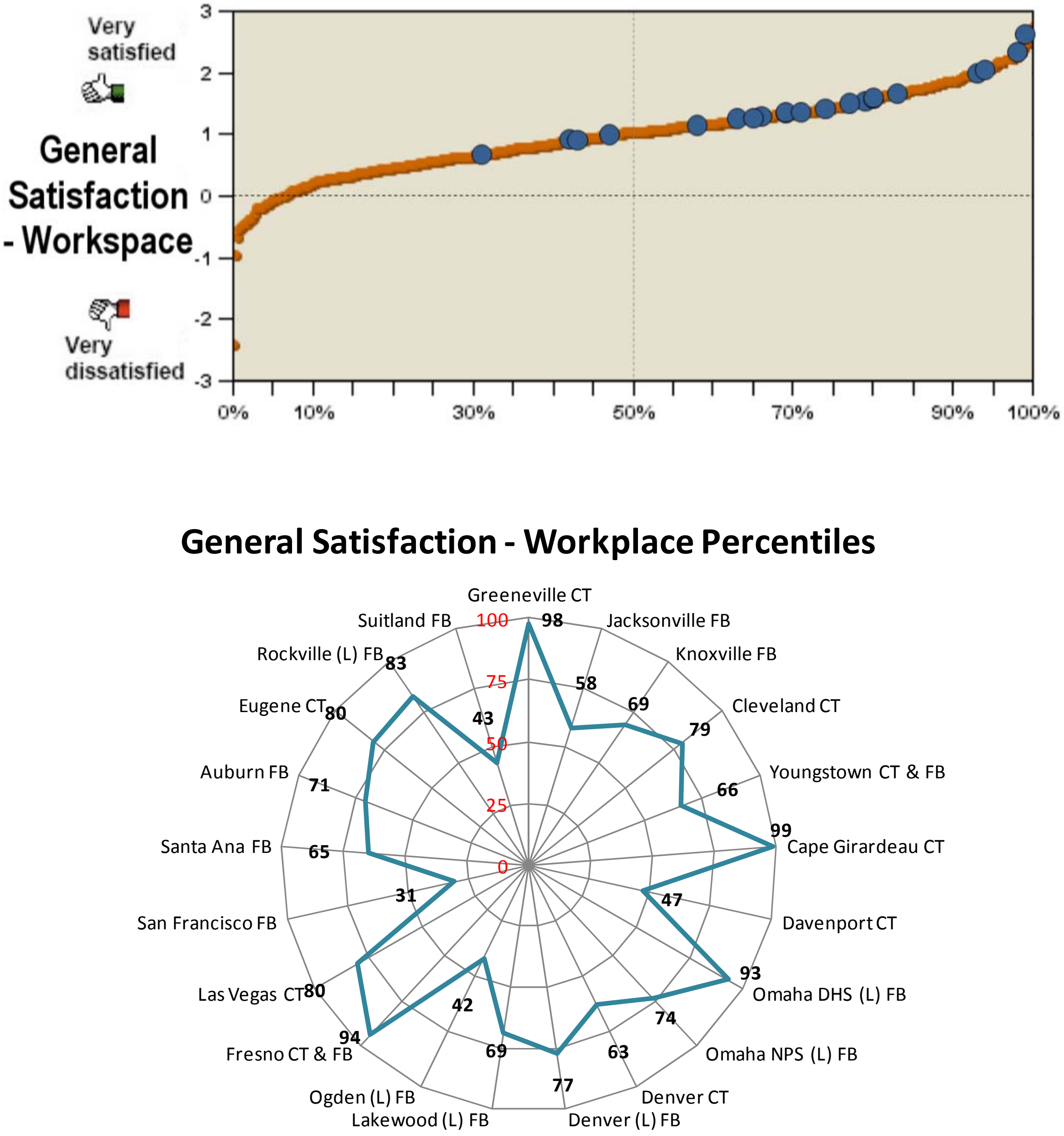


Figure 37. General workplace satisfaction rating from the occupant survey

Very few buildings have used the communication satisfaction survey question, thus the baseline comparison is limited. All of the buildings were satisfied with communication (above zero). Buildings with the lowest communication survey scores, Suitland FB and San Francisco FB, also have the lowest acoustic quality, thermal comfort, lighting, and general building satisfaction scores. The questions for the communication satisfaction level are

- How satisfied are you with your ability to communicate with co-workers in person?
- How satisfied are you with the ease of interaction with co-workers?
- How satisfied are you with your ability to communicate in privacy?
- How satisfied are you with the availability of space where you and your colleagues can talk into a speaker phone together.

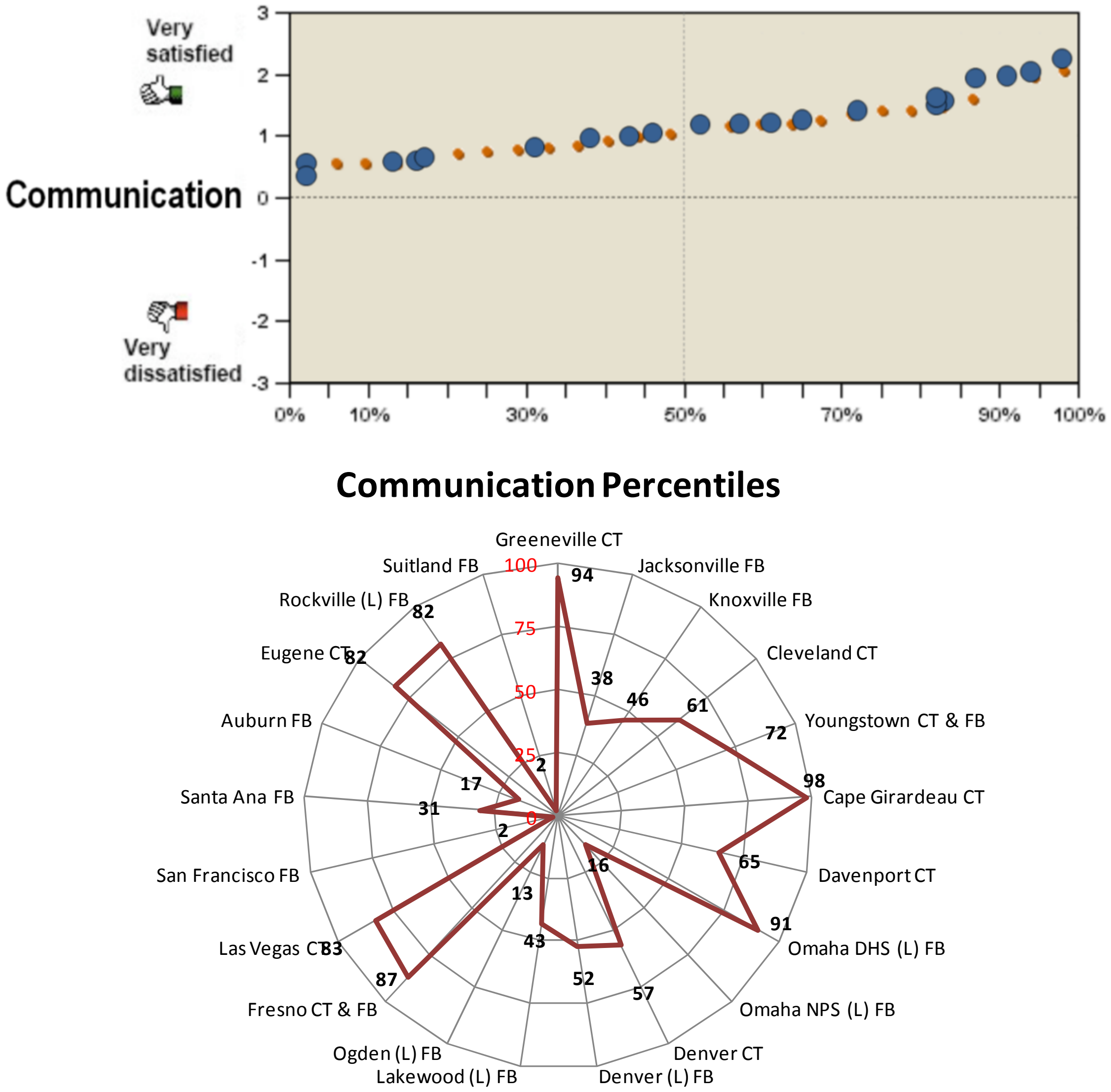


Figure 38. Communication satisfaction rating from the occupant survey

All of the GSA buildings in the study had positive general satisfaction scores (above zero) and two-thirds of the buildings scored above the 50th percentile (Figure 39).

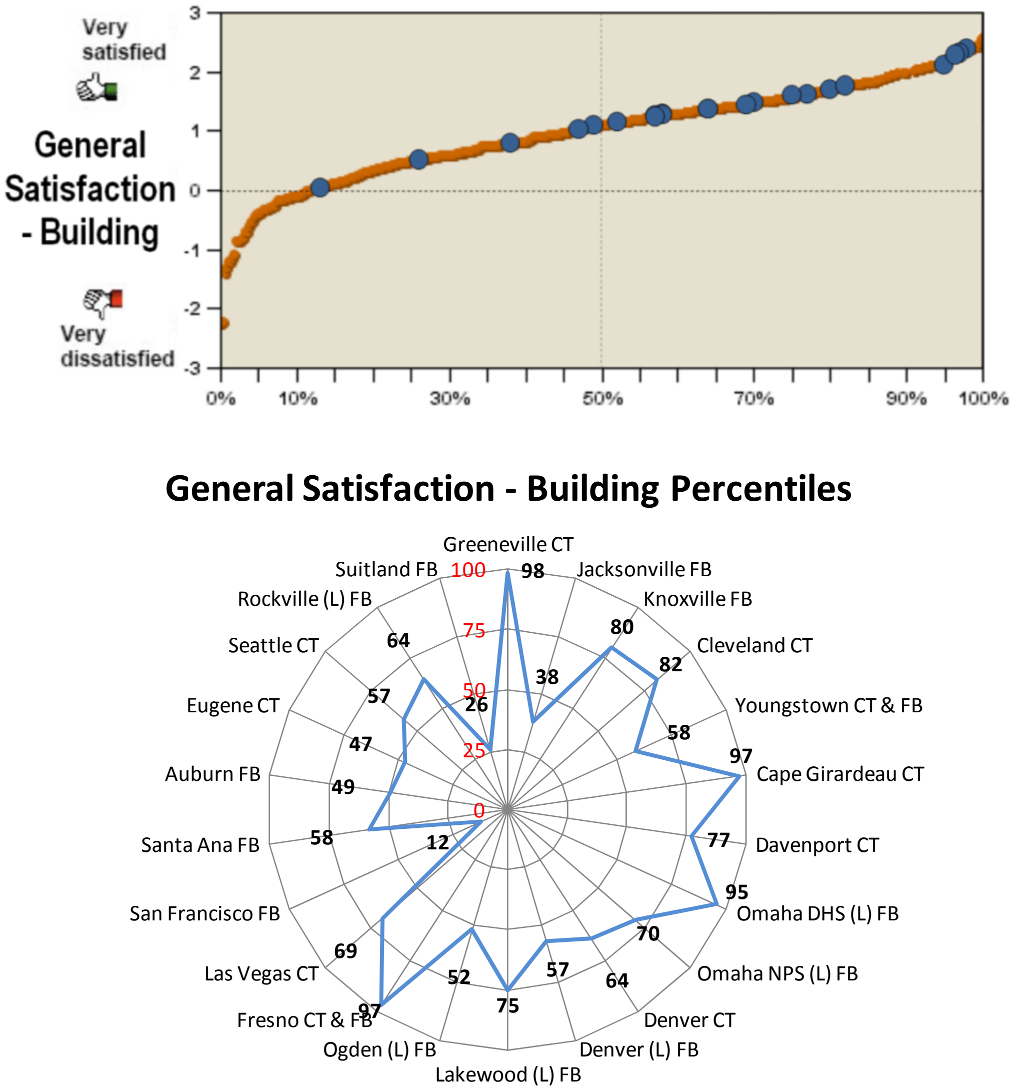


Figure 39. General building satisfaction rating from the occupant survey

Figure 40 shows that the average scores from the SPOT survey were higher than the average scores in the CBE database, except for lighting satisfaction questions, where the average survey responses were essentially the same. When compared to the LEED certified buildings in the CBE database, the SPOT survey responses were better for all questions except for air quality.

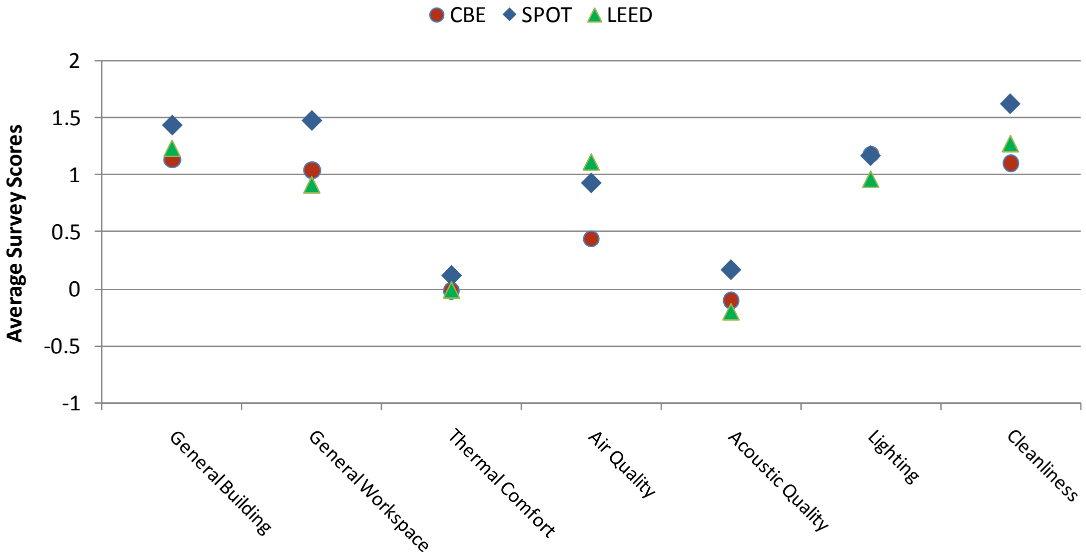


Figure 40. Study building occupants are more satisfied than the building occupants in the CBE database.

The occupant satisfaction information compared to the CBE baseline offers a snapshot of the relative satisfaction of these buildings' occupants at this point in time. More detailed building studies of why building occupants are responding as they are would offer additional insight. These data connect with the other building metrics, such as maintenance and janitorial costs compared to cleanliness and maintenance satisfaction scores and thermal comfort compared to EUI. Additional analysis across the metrics can be found in the conclusion section.

Transportation

The occupant commute to a building reflects the impact of siting, agency incentives, and the environmental ethic of the building occupants. The information for the transportation metric was collected using the SPOT survey. The impact of the occupant transportation choices is represented by the average distance traveled and the carbon dioxide (CO_2) equivalents. Table 21 shows the summary transportation data and CO_2 equivalents based on responses to the questions about occupant commute distance and vehicle type questions.

Table 21. Transportation data by building

Building Name	Survey N-Value	# Occ	% of Occupants who commute using mass transit, biking and/or walking	Avg Daily Roundtrip Miles Traveled/Occ	Transportation CO_2 Equiv/Occ (metric tons)	Baseline Transportation CO_2 Equiv/Occ (metric tons)	Bldg Transportation Performance
Greeneville CT	55	85	0%	22.4	2.6	2.3	11%
Jacksonville FB	393	1,000	25%	32.5	1.4	2.3	-39%
Knoxville FB	98	285	0%	28.9	2.2	2.3	-6%
Cleveland CT	55	105	56%	25.8	1.0	2.3	-55%
Youngstown CT & FB	28	45	0%	28.8	1.8	2.3	-23%
Cape Girardeau CT	26	45	8%	41.0	1.5	2.3	-36%
Davenport CT	22	45	0%	26.5	2.9	2.3	24%
Omaha DHS (L) FB	16	65	0%	29.7	2.1	2.3	-9%
Omaha NPS (L) FB	82	125	0%	21.4	1.7	2.3	-26%
Denver CT	58	170	53%	24.4	1.1	2.3	-51%
Denver (L) FB	339	922	87%	25.6	0.6	2.3	-75%
Lakewood (L) FB	103	318	9%	23.1	1.9	2.3	-18%
Ogden (L) FB	151	514	3%	19.6	1.9	2.3	-18%
Fresno CT & FB	64	235	0%	25.7	2.4	2.3	4%
Las Vegas CT	62	321	5%	24.9	1.1	2.3	-50%
San Francisco FB	485	1,314	94%	32.1	0.6	2.3	-72%
Santa Ana FB	118	409	12%	29.7	2.2	2.3	-3%
Auburn FB	427	675	7%	31.6	1.4	2.3	-39%
Eugene CT	48	120	19%	18.2	0.8	2.3	-66%
Seattle CT	N/A	500	N/A	N/A	N/A	2.3	N/A
Rockville (L) FB	230	720	18%	30.5	1.4	2.3	-41%
Suitland FB	945	5,360	22%	39.4	1.9	2.3	-18%

Although occupant commute is not typically seen as having a connection to a building, LEED encourages the consideration of the occupant commute during the building design. LEED points can be earned for siting the building near public transportation, providing preferred parking for carpools and alternative vehicles, and offering space and services for bicycle riders. This performance measure is being used to investigate whether the roundtrip commute of green building occupants has a lower environmental impact than the industry baseline.

In addition to the strategies used during building design, the building manager and/or owner can offer space, services and encouragement to alter commute practices. For example, the cost and availability of parking and/or public transportation may have a greater impact on occupant commute choices than preferential parking spaces for carpoolers. Other incentives provided by the occupant's employer, such as public transportation vouchers or the ability to telecommute, will also have an impact on occupant transportation decisions. Of course there is also the personal decision of vehicle type, and housing location that is not being addressed in this study. The rate of single occupant vehicle transportation changes by location, and the current economic and/or political situation. All but three of the buildings in the study have occupant commute emissions lower than industry baseline (Figure 41).

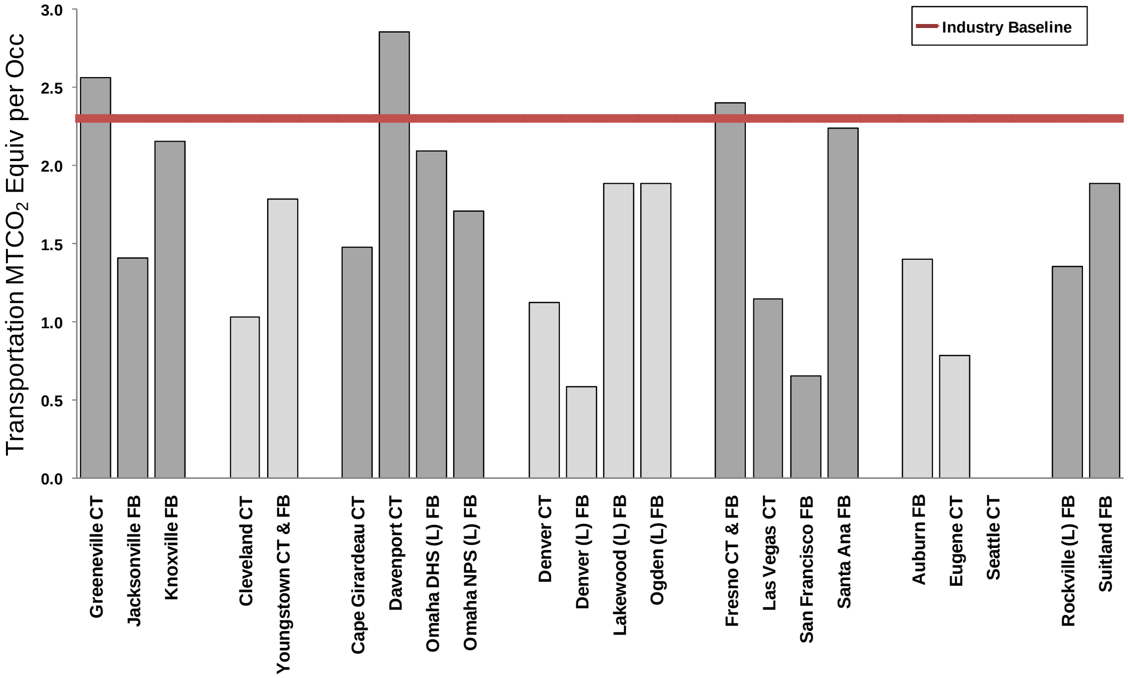


Figure 41. Occupant commute CO_2 equivalent emissions compared to the baseline

Per an Environmental Building News article, key factors associated with reducing occupant commute impact are the density of the building location, and distance to mass transit.[32] The industry average roundtrip is a little less than 24 miles per day. In this study, there is no correlation between the size of the community and the average length of commute. Most of the buildings in the study have longer commutes than baseline (Figure 42). Sustainable design siting considerations would ideally show a decrease in commute distance traveled, but there would also be a CO_2 emission shift because of preferential parking incentives to carpool and access to public transportation.

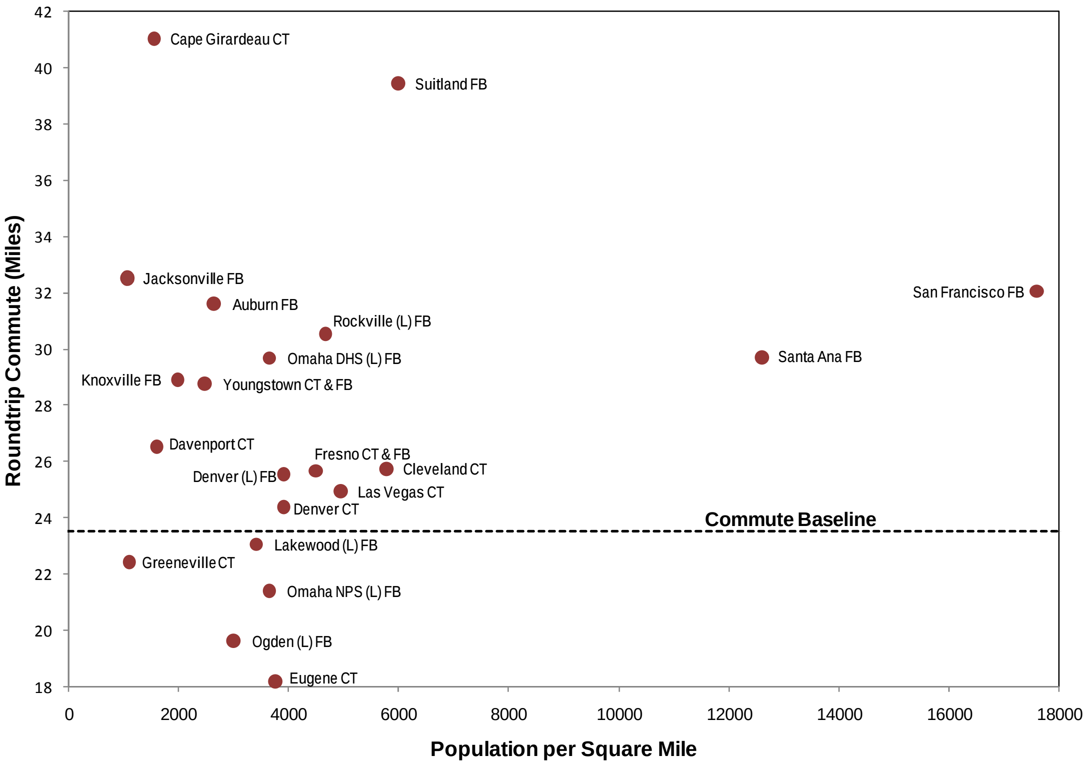


Figure 42. Average commute distance and community size

Given the average commute is longer than baseline, Figure 43 shows the occupants are choosing commute options with a lower emissions impact. One of the buildings that is higher than baseline is the only one located in a "town" as designated by the Census Bureau. The other two buildings are located in cities with limited access to mass transit.

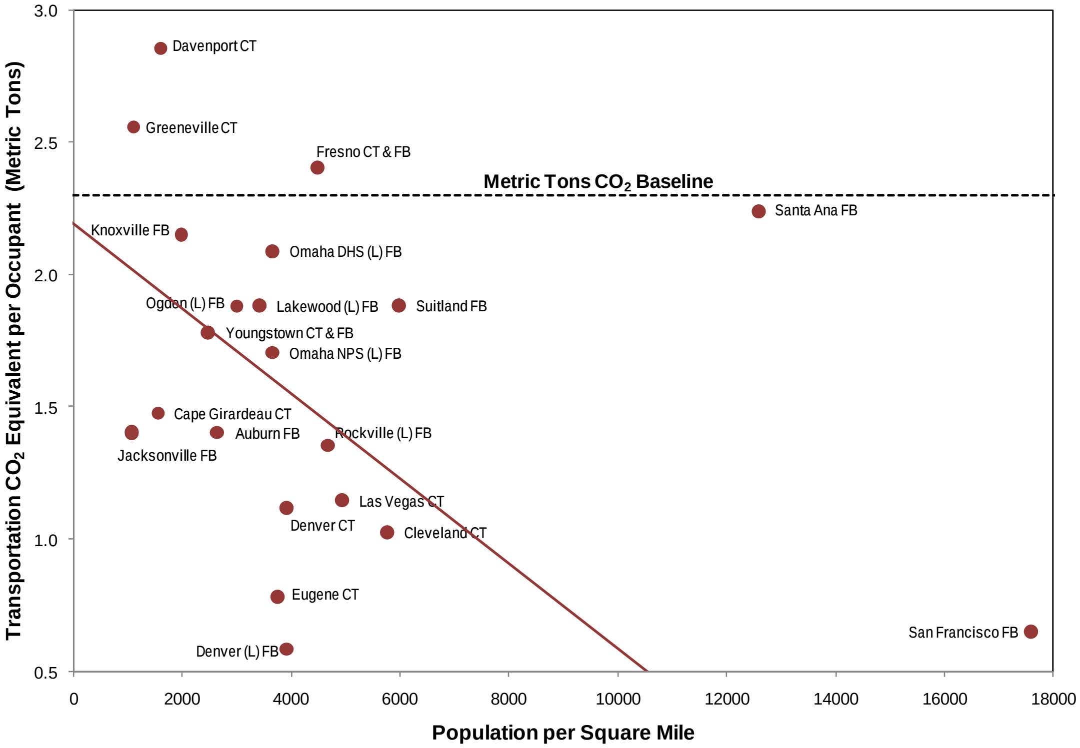


Figure 43. CO_2 equivalent emissions by community size

Table 22 shows the size of the cities with the calculated CO_2 equivalent emissions per occupant.

Table 22. Population density and commute distance by building

				Population Density		
Building Name	**Census Designation**	**Population**	**Square miles**	**people per sq mile**	**Roundtrip Commute distance**	**Transportation CO_2 Equiv/Occ (metric tons)**
Greeneville CT	Town	15,537	14	1,107	22.4	2.56
Jacksonville FB	City	807,815	757	1,067	32.5	1.40
Knoxville FB	City	182,337	92	1,982	28.9	2.15
Cleveland CT	City	444,313	77	5,770	25.8	1.03
Youngstown CT & FB	City	81,520	33	2,470	28.8	1.78
Cape Girardeau CT	City	37,370	24	1,557	41.0	1.47
Davenport CT	City	99,514	62	1,605	26.5	2.85
Omaha DHS (L) FB	City	419,545	115	3,648	29.7	2.09
Omaha NPS (L) FB	City	419,545	115	3,648	21.4	1.70
Denver CT	City	598,707	153	3,913	24.4	1.12
Denver (L) FB	City	598,707	153	3,913	25.6	0.58
Lakewood (L) FB	City	140,024	41	3,415	23.1	1.88
Ogden (L) FB	City	78,086	26	3,003	19.6	1.88
Fresno CT & FB	City	466,714	104	4,488	25.7	2.40
Las Vegas CT	City	558,383	113	4,941	24.9	1.15
San Francisco FB	City	808,976	46	17,586	32.1	0.65
Santa Ana FB	City	340,024	27	12,593	29.7	2.24
Auburn FB	City	55,426	21	2,639	31.6	1.40
Eugene CT	City	150,104	40	3,753	18.2	0.78
Seattle CT	City	598,541	83	7,211	N/A	N/A
Rockville (L) FB	City	60,734	13	4,672	30.5	1.35
Suitland FB	City	33,515	6	5,985	39.4	1.88

Table 23 and Figure 44 show the aggregate CO_2 equivalent emissions for occupant commute and building energy use. When the values are combined, all of the buildings perform better than baseline.

Table 23. Aggregate CO2 equivalent emissions for transportation and building

	Aggregate MTCO$_2$ Equivalent Emissions				
Building Name	**Transportation**	**Transportation Baseline**	**Building**	**Building Baseline**	**Aggregate CO$_2$ Emissions Performance**
Greeneville CT	263	237	1,263	2,183	-37%
Jacksonville FB	1,615	2,645	2,773	5,448	-46%
Knoxville FB	667	714	1,428	2,641	-38%
Cleveland CT	146	328	2,738	3,413	-23%
Youngstown CT & FB	432	558	640	642	-11%
Cape Girardeau CT	147	230	2,362	2,781	-17%
Davenport CT	180	145	833	1,230	-26%
Omaha DHS (L) FB	752	828	1,199	1,620	-20%
Omaha NPS (L) FB	228	308	777	1,182	-33%
Denver CT	414	851	4,281	5,395	-25%
Denver (L) FB	581	2,285	4,063	7,693	-53%
Lakewood (L) FB	631	772	1,684	2,656	-32%
Ogden (L) FB	980	1,198	969	1,514	-28%
Fresno CT & FB	1,225	1,173	2,334	3,967	-31%
Las Vegas CT	490	984	4,583	6,453	-32%
San Francisco FB	939	3,322	2,838	6,604	-62%
Santa Ana FB	1,028	1,056	1,066	2,002	-32%
Auburn FB	946	1,553	969	2,257	-50%
Eugene CT	133	391	1,287	2,390	-49%
Seattle CT	N/A	1,380	4,305	6,854	N/A
Rockville (L) FB	1,029	1,748	2,534	3,620	-34%
Suitland FB	10,218	12,478	22,332	41,670	-40%

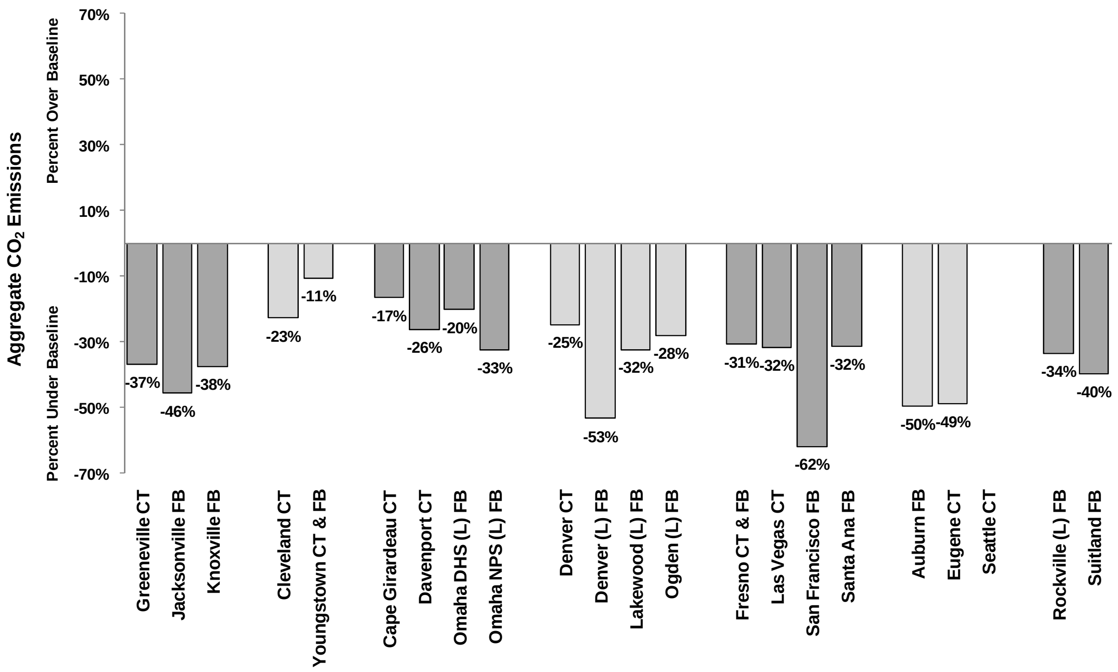


Figure 44. Aggregate CO_2 equivalent emissions compared to the baseline

When considering the CO_2 equivalent emissions impact of the buildings in this study, the occupant commute played a small part. Most of the buildings had a roundtrip commute longer than the industry average and the emissions were generally lower than industry average, it appears the occupants are choosing to walk, bike or use mass transit more than the general population. It is not clear whether this can be attributed to sustainable design siting practices or if it is just a coincidence. More detailed analysis on the mass transit options available in each location, cost of living, driving, and parking, and the incentives provided to occupants would be useful information to consider in building specific post occupancy evaluations.

Conclusions

The purpose of this study was to provide an overview of measured whole building performance as it compares to GSA and industry baselines. The PNNL research team found the data analysis illuminated strengths and weaknesses of individual buildings as well as the portfolio of buildings. This section includes summary data, observations that cross multiple performance metrics, discussion of lessons learned from this research, and opportunities for future research. Table 24 provides the cost data for each whole building performance metric.

Table 24. Annual costs and total project cost by building

	Annual Costs (US$)				
Building Name	Aggregate Maintenance	Waste & Recycle	Total Water	Total Energy	Aggregate Operating Cost per RSF
Greeneville CT	$394,936	$829	$6,352	$176,042	$4.25
Jacksonville FB	$1,026,012	-	$24,555	$427,075	$4.93
Knoxville FB	$464,084	$4,380	$16,061	$198,759	$5.69
Cleveland CT	$477,148	$2,966	$6,730	$576,668	$5.75
Youngstown CT & FB	$261,442	$1,530	$3,945	$108,647	$8.44
Cape Girardeau CT	$595,251	$469	$10,155	$125,431	$5.28
Davenport CT	$331,421	$907	$5,900	$79,627	$6.11
Omaha DHS (L) FB	$79,000	$2,400	$4,831	$95,017	$2.47
Omaha NPS (L) FB	$107,050	$2,520	$651	$73,214	$2.92
Denver CT	$1,022,579	-	$20,390	$631,891	$6.52
Denver (L) FB	$459,560	$19,090	$9,882	$367,301	$3.44
Lakewood (L) FB	$194,258	$3,600	$10,617	$213,099	$3.45
Ogden (L) FB	$168,544	$20,020	$10,088	$150,700	$3.41
Fresno CT & FB	$2,040,015	$24,236	$42,150	$854,680	$7.53
Las Vegas CT	$917,614	$25,266	$64,381	$720,041	$4.68
San Francisco FB	$2,346,974	$31,090	$88,562	$994,770	$6.62
Santa Ana FB	$838,976	$19,960	$12,724	$651,182	$7.41
Auburn FB	$626,728	$2,184	$8,448	$121,499	$3.78
Eugene CT	$773,708	Included	$13,208	$213,279	$4.21
Seattle CT	$1,643,964	Included	$74,016	$695,685	$4.33
Rockville (L) FB	$764,472	$22,056	$32,406	$733,918	$6.81
Suitland FB	$6,093,038	$105,390	$639,997	$4,708,207	$8.18

The summary of annual data for each of the performance metrics is provided in Table 25. The data represent 1 year of measurements and are not associated with any specific design features or strategies. Where available, multiple years of data were examined and there were minimal significant differences between the years. Individually focused post occupancy evaluation (POEs) would allow for more detailed analysis of the buildings. Examining building performance over multiple years could potentially offer a useful diagnostic tool for identifying building operations that are in need of operational changes. Investigating what the connection is between the building performance and the design intent would offer potential design guidance and possible insight into building operation strategies.

Table 25. Summary values for each performance metric

Building Name	GSF	Energy Star® Score	Total Water (1000 gal)	Aggregate Maintenance Cost	Waste Cost	General Bldg % Satisfaction	Metric Tons of CO_2 equiv/Occ
Greeneville CT	160,975	90	1,376	$394,936	$900	98%	14.8
Jacksonville FB	338,008	82	4,008	$1,026,012	N/A	59%	3.8
Knoxville FB	172,684	90	2,252	$464,084	$4,380	89%	6.8
Cleveland CT	251,314	69	450	$477,148	$3,067	89%	20.2
Youngstown CT & FB	52,240	50	419	$261,442	$1,530	70%	4.4
Cape Girardeau CT	173,392	64	385	$595,251	$325	92%	25.1
Davenport CT	79,872	80	530	$331,421	$907	89%	16.1
Omaha DHS (L) FB	86,000	74	2,252	$79,000	$2,400	100%	5.4
Omaha NPS (L) FB	68,000	82	239	$107,050	$1,500	81%	7.5
Denver CT	327,103	70	4,649	$1,022,579	N/A	74%	12.7
Denver (L) FB	301,292	94	3,970	$459,560	$15,862	72%	4.7
Lakewood (L) FB	128,342	84	2,928	$194,258	$3,600	82%	6.9
Ogden (L) FB	105,000	83	3,619	$168,544	$3,940	72%	3.7
Fresno CT & FB	495,914	87	11,345	$2,040,015	$24,236	92%	7.0
Las Vegas CT	454,877	77	10,413	$917,614	$25,266	74%	11.9
San Francisco FB	652,433	96	5,675	$2,346,974	$31,970	48%	2.6
Santa Ana FB	280,365	91	2,218	$838,976	$18,360	72%	4.6
Auburn FB	205,354	96	-	$626,728	$2,184	67%	2.8
Eugene CT	270,322	92	2,032	$773,708	Included	64%	8.3
Seattle CT	658,392	85	4,973	$1,643,964	Included	70%	N/A
Rockville (L) FB	232,000	80	2,680	$764,472	$22,056	75%	4.7
Suitland FB	2,340,988	91	56,110	$6,093,038	$107,871	52%	6.0

The "aggregate operating cost" metric used in this study represents the costs that were available for developing a comparative industry baseline for office buildings. The costs include water utilities, energy utilities, general maintenance, grounds maintenance, waste and recycling, and janitorial costs. Three of the buildings that cost more than the baseline in Figure 45 have higher maintenance costs than the baseline, and one has higher energy costs.

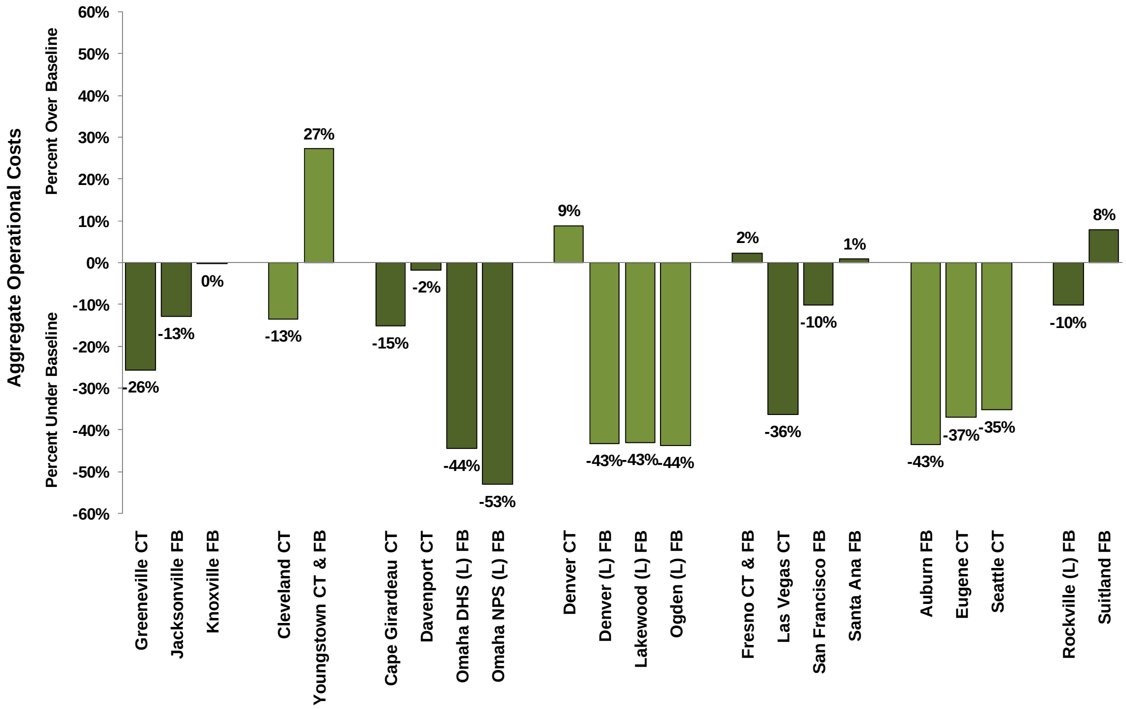


Figure 45. Aggregate operational costs compared to the baseline

Given the volume of data collected and analyzed for this study, the inevitable request is for a simple answer with respect to sustainably designed building performance. As previously stated, compiling the individual building values into single metrics is not statistically valid given the small number of buildings, but it has been done to provide a cursory view of this portfolio of sustainably designed buildings (Table 26). For all metrics except recycling cost per rentable square foot and CBE survey response rate, the averaged building performance was better than the baseline for the GSA buildings in this study.

Table 26. Summary performance for study buildings portfolio

Metric Description	Performance	Performance Description
Water Use	-11%	Average WUI (13.3 gallons/gsf) as compared to IFMA Industry average (15 gallons/gsf)
Energy Use	-25%	Average EUI (66 kBtu/gsf) as compared to CBECS office (88 kBtu/gsf)
Aggregate Operations Cost	-19%	Average percent better than baseline for Water, Energy, Maintenance, Janitoral, Grounds, Waste, and Recycling costs per RSF as compared to BOMA industry baselines
Aggregate Maintenance Cost	-12%	Average General, Janitorial and Grounds Maintenance Cost per RSF as compared to GSA adapted industry baselines for General and Janitorial, and BOMA for Grounds
CO2 Buildings + Transportation	-34%	Calculated CO_2 for each building as compared to Energy Star Baseline and emissions for the occupant commute as compared to EPA commute emissions baseline
Occupant Satisfaction	-27%	Average SPOT survey score (1.43) as compared to CBE Database average (1.13) for General Building Satisfaction
Average Survey Response Rate	47%	Average SPOT response rate
Water Cost	-46%	Average Water Cost per RSF ($0.10) as compared to BOMA baseline ($0.19)
Energy Cost	-28%	Average Energy Cost per RSF ($1.82) as compared to BOMA baseline ($2.53)
General Maintenance Cost	-2%	Average General Maintenance Cost per RSF as compared to GSA Adapted BOMA industry averages
Janitorial Maintenance Cost	-2%	Average Janitorial Maintenance Cost per RSF as compared to GSA Adapted BOMA industry averages
Grounds Maintenance Cost	-69%	Average Grounds Maintenance Cost per RSF ($0.14) as compared to BOMA high average ($0.45)
Waste Disposal Cost	-15%	Average Waste Disposal Cost per RSF as compared to BOMA industry average for Offices
Recycling Cost	17%	Average Recycling Cost per RSF as compared to BOMA industry average for Offices
CO2 Building	-36%	Average CO_2 difference from Energy Star building baseline
CO2 Transportation	-29%	Average CO_2 difference from EPA and Department of Transportation calucated baseline

Observations

Whole building performance measurement involves the analysis of the interaction between different metrics. Many comparisons can be made between energy, water, maintenance, and occupant satisfaction. Additional comparisons could include waste generation and commute data, but for those metrics no significant findings were evident.

Based on the LEED credits and Energy Star ratings, it was observed that when projects had incorporated sustainable design principles from the start and had included energy savings goals, the overall performance of the building was better than the industry standard. Additionally, the LEED Gold buildings performed consistently well in each metric (Figure 46).

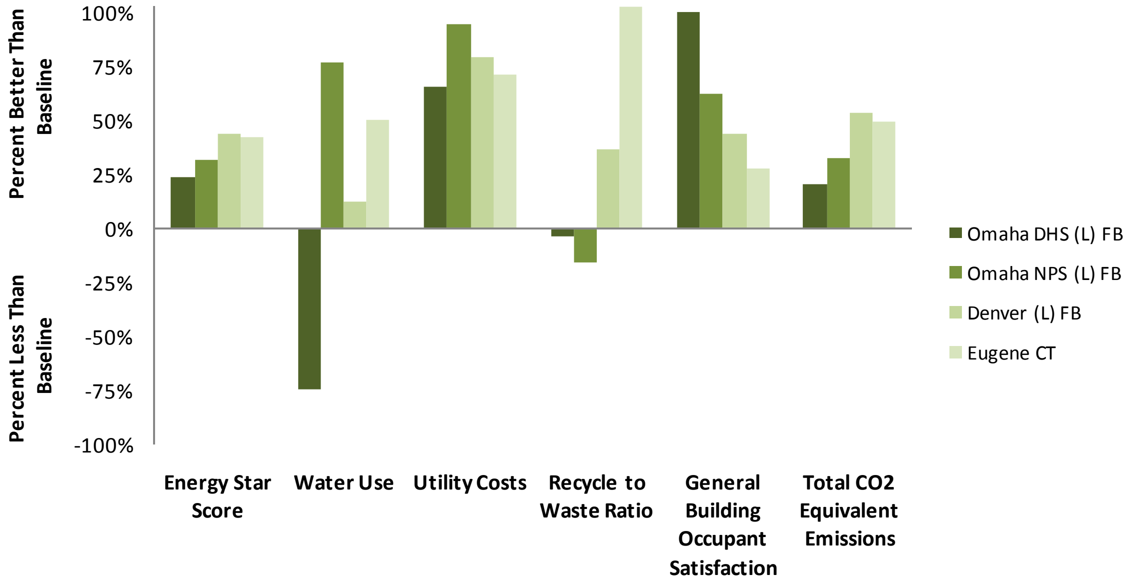


Figure 46. LEED Gold building baseline comparisons

Looking at the detailed SPOT survey results we have already discussed how almost all of the buildings have better than average thermal satisfaction and all of the buildings' energy performance were at or above the baseline. Figure 47 shows that the building with the lowest thermal comfort satisfaction is the one with the lowest EUI and with maintenance costs more than 50% greater than the baseline. This quad chart also shows the two least expensive buildings to maintain are in the top quadrant.

The next set of figures is referred to as "quad charts." Performance better than the baseline by the metrics on the x and y axis are placed to the right and above the baseline lines, that is, the top right quadrant. The color of the dot represents the aggregate maintenance cost.

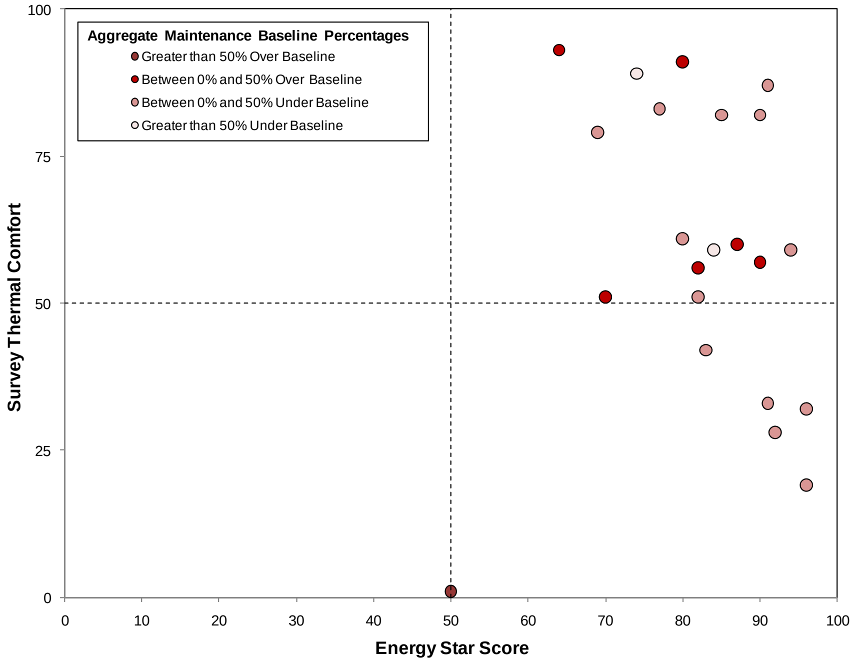


Figure 47. Thermal comfort compared to Energy Star Score and maintenance costs

All of the buildings had lighting satisfaction survey responses above zero, meaning the occupants were satisfied with the lighting. However, as mentioned previously, when the lighting satisfaction levels were compared to the CBE database baseline responses, more than half of the buildings are below the 50th percentile. There does not appear to be a correlation between the Energy Star Portfolio Manager scores and the lighting satisfaction levels, but it does appear that buildings that had lower maintenance costs were less satisfied with the lighting (Figure 48).

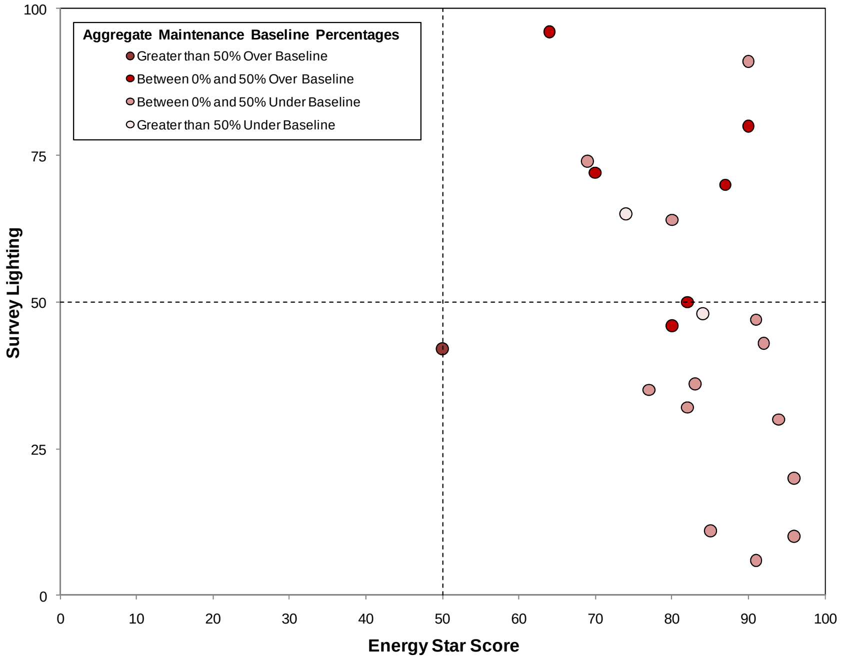


Figure 48. Lighting satisfaction percentile compared to Energy Star score and maintenance costs

Figure 49 offers a summary representation of the energy, water, occupant satisfaction, and aggregate maintenance costs for each of the buildings investigated. All of the Energy Star Portfolio Manager values were better than the baseline typical building, two-thirds of the water use intensity (WUI, gallons/occupant) values were better than or at the baseline, all of the occupant satisfaction scores were higher than the 50th percentile, and more than half of the buildings have aggregate maintenance costs that are below the baseline.

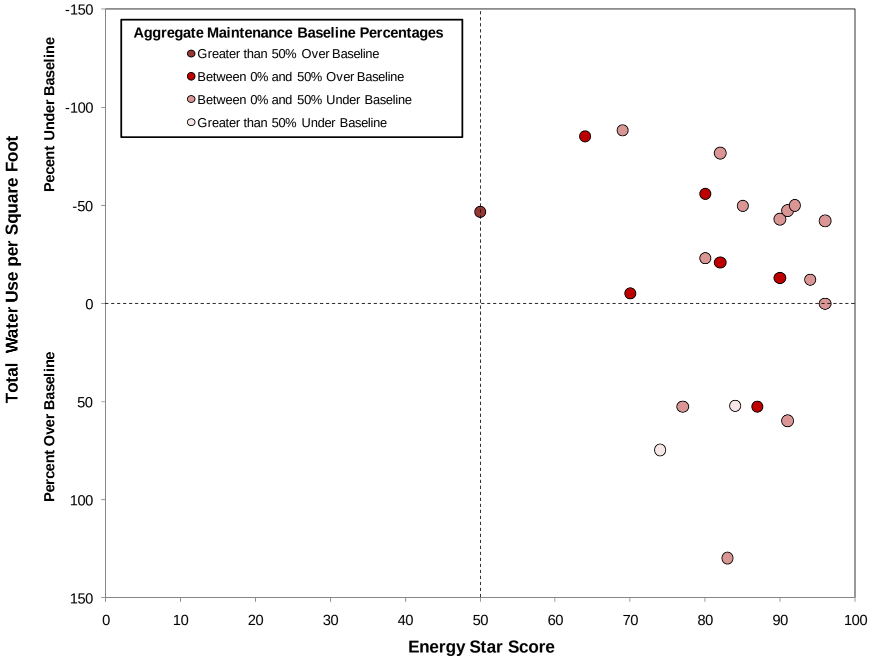


Figure 49. WUI compared to Energy Star Score and aggregate maintenance costs

Lessons Learned and Future Research Opportunities

This study includes almost half of GSA's LEED buildings. Although this is a respectable representation of the buildings that have been officially identified as being sustainably designed, the sample size is small, so it does not lend itself to broader inferences for the entire GSA building stock. Nevertheless, the lessons learned may be helpful for future design, construction, and operation of GSA buildings. Measuring the performance of more buildings will allow for a greater understanding of how sustainably designed buildings perform as a group. Based on the data collection and analysis experiences the following includes future research opportunities and observations of the current data set.

A detailed investigation into the water use for each building is needed to determine, with any confidence, an accurate understanding of water use within sustainably designed buildings. Design estimates focus on bathroom and kitchenette fixture specifications. How much water building occupants actually use is not well understood. Plus, many buildings use water for irrigation, process water, food service, and other activities without separately metering the water use. The impact of that "other" water use is also not well understood.

Energy use and cost are the metric that is most easily and commonly examined in a more detailed fashion. Sub-metered energy use data can provide insights into what aspects of the building operations are impacting energy use most significantly. In many buildings, the miscellaneous electric load is a significant portion of the energy use, but is not well understood since it is driven by the occupants. Large electric loads associated with computing equipment, in the form of small data centers, are a growing portion of building energy use. Additional data collection and research related to the miscellaneous electric load in buildings would identify potential opportunities for conservation and efficiency.

Operations and maintenance data are being tracked by more building managers, but the quality of the data varies by building. Additionally, there is no consistent level of detail collected at each building because of the flexibility of the tracking systems. This variability of data makes comparisons between buildings a challenge. Inferences from the regular maintenance and preventative maintenance ratio should be considered speculative unless the more consistent data and details are provided by all of the buildings for each metric. The ability to collect consistent data from each site is critical for building-to-building comparisons to industry baselines and for building to building comparisons.

Employer or community programs for recycling and occupant commute may impact the performance values of these metrics. Therefore, ideally, employer and community programs would be accounted for in the analysis. Additionally, the availability and cost of recycling programs and mass transit within a specific community have an impact on the occupants' willingness and ability to use those services. A consistent mechanism for comparing sanitary waste, recycling, and mass transit is needed.

When there are occupancy changes and/or unplanned uses of the buildings, the impact on building performance needs to be accounted when conducting a detailed performance measurement analysis. Additionally, a better understanding of response rate expectations is needed, especially given CBE's goal of a 50% response rate and the study's inability to meet that goal for many of its buildings. Many of the buildings in the study that had low response rates also had very high building occupancy. Survey response rate research data could not be found to define acceptable response rates or number of responses on a given survey.

Currently the transportation metric involves the calculation of CO_2 equivalent emissions based on building occupant responses to a survey regarding their daily commute. Although a survey is the method being used by national and internal greenhouse gas emission calculators, additional techniques might offer a better understanding as to why building occupants choose one mode of transportation over another. As mentioned above, different municipalities and employers have different resources and cultures related to occupant commute that could impact occupant choices.

One of the more important lessons learned with respect to whole building performance measurement and assessment is that the baselines selected for performance comparison are what define the study findings. When agency specific baselines are available they offer a comparison of how a building meets an agency's expectations, but they make the assessment results less comparable to the general building industry. Ideally performance measurement data should be compared to other measured building performance data. Comparing measured values to modeled or estimated values does not offer a valid comparison, and should be avoided whenever possible. For this study GSA baselines were used whenever they were made available, however, industry baselines are also provided in order to offer another basis for comparison.

In addition to the baselines needing consistency to make the performance measurement and assessment data useful, the buildings being studied need to be working properly to be representative of sustainably designed building performance. If a building is not operating well because it has not been properly commissioned, has had an equipment failure, or occupancy settings have not been optimized, it is not useful to include in a portfolio analysis of sustainably designed buildings. In the case of a building that is not working properly, it would be difficult to parse out what aspect of the performance data is related to the design rather than the insufficient operations, and it would be more effective to perform a detailed post occupancy evaluation to identify where changes could be made in the building to improve building performance.

A more detailed study of individual buildings could be used to determine which design features offer the best value. This type of investigation may be able to show the difference between early design expectations, as-built expectations, and operations. For example, with energy, compare design modeled data, number of LEED credits received, measured energy data, and Energy Star score. Additionally, multiple years of data would be useful in understanding whether the performance will be maintained or if it was a 'good' or 'bad' year for the building.

The snapshot view of these sustainably designed buildings provides a valuable picture of the overall performance. Continued work to assess more buildings and to include multiple years of whole building performance data could improve the accuracy and depth of this assessment. Of course, individual buildings had higher and lower performance in various metrics, as the performance of every building whether sustainably designed or typically designed depends on many factors, especially the building occupants. Nonetheless, as a portfolio of buildings, the average performance of the buildings in this study was better than the GSA and industry baselines for almost all of the performance metrics.

Appendix A: Site Summaries

Data were collected and site visits were performed for twenty-five buildings under the scope of this study. The site summaries in this appendix provide an overview for each building and offer site-specific observations. Each site summary includes the following

- building photo
- general building description
- table listing building and site characteristics data
- certification information
- operation costs compared to baseline costs
- occupant satisfaction survey summary results
- table summarizing building performance data.

The site summaries are presented in the following order

Building Type	Building Full Name	Abbreviation
Region 4		
Courthouse	James H. Quillen U.S. Courthouse	**Greeneville CT**
Federal Building	Chas. E. Bennett Federal Building	**Jacksonville FB**
Federal Building	John J. Duncan Federal Building	**Knoxville FB**
Region 5		
Courthouse	Howard M. Metzenbaum U.S. Courthouse	**Cleveland CT**
Courthouse & Federal Building	Nathaniel R. Jones Federal Building and U.S. Courthouse	**Youngstown CT & FB**
Region 6		
Courthouse	Rush H. Limbaugh U.S. Courthouse	**Cape Girardeau CT**
Courthouse	Davenport U.S. Courthouse	**Davenport CT**
Federal Building	DHS Citizenship & Immigration Services	**Omaha DHS (L) FB**
Federal Building	Carl T. Curtis NPS Midwest Regional Headquarters	**Omaha NPS (L) FB**
Region 8		
Courthouse	Alfred A. Arraj U.S. Courthouse	**Denver CT**
Federal Building	EPA Region 8 Headquarters	**Denver (L) FB**
Federal Building	DOT Colorado Field Office	**Lakewood (L) FB**
Federal Building	Scowcroft IRS Utah Field Office	**Ogden (L) FB**
Region 9		
Courthouse & Federal Building	Robert E. Coyle U.S. Courthouse and Federal Building	**Fresno CT & FB**
Courthouse	Lloyd D. George U.S. Courthouse	**Las Vegas CT**
Federal Building	San Francisco Federal Building	**San Francisco FB**
Federal Building	Santa Ana Federal Building	**Santa Ana FB**
Region 10		
Federal Building	Auburn SSA Teleservice Center	**Auburn FB**
Courthouse	Wayne L. Morse U.S. Courthouse	**Eugene CT**
Courthouse	New Seattle U.S. Courthouse	**Seattle CT**
Region 11		
Federal Building	SAMSHA Metropolitan Service Center	**Rockville (L) FB**
Federal Building	Census Bureau Office Complex	**Suitland FB**

The table above shows both the official building name and the name used within the body of this report, which includes building location and type. In this appendix, each site summary is titled using the same name as the body of the report and then the official building name is used throughout the text so that the site is recognizable to those who occupy each building.

The research team derived the majority of the information summarized in this appendix from site or other General Services Administration (GSA) contacts and databases. For each site, the general building characteristics are summarized in the first table, and the operational data are summarized in the final table.

The costs associated with whole building performance are represented as a percentage above or below the baseline for each metric. The baseline is the industry standard for each metric's cost per square foot. The aggregate operational cost compares the summation of the building's costs to the aggregate baseline costs. "Below the baseline" suggests it costs less to operate the building than the industry standard. The different colors for different buildings are the same colors used in the body of the report.

GSA representatives modified the University of California Berkeley's Center for the Built Environment's (CBE's) occupant satisfaction survey to address the occupant commute questions and GSA specific interests. The survey for this study was called the GSA Sustainable Places and Organizational Trends (SPOT) survey. GSA representatives distributed the survey to building occupants electronically, providing an internet link, and provided a hard copy of the SPOT survey at a few of the buildings where electronic distribution was not available to all occupants. GSA representatives manually entered the hard copy SPOT survey responses into the CBE database so that a summary report could be generated.

The SPOT survey questions offer a numerical response of between -3 and 3. CBE prepares building-specific survey summary reports. These reports provide the average scores for each of the key elements addressed in the survey. In this appendix, the average scores for each key element are provided.

Greeneville Courthouse

Description

The James H. Quillen U.S. Courthouse was completed in 2001 and received Energy Star recognition in 2007. The Quillen Courthouse replaced a smaller, historic courthouse, from which the occupants reclaimed the quality furniture. Some of the energy-efficiency features in the building include use a well-insulated white roof, and Energy Management Control System (EMCS) control of lighting and occupancy sensors. During the site visit, researchers noticed that occupants had their office lights turned off if they had sufficient daylight from a window.

Metrics	James H. Quillen U.S. Courthouse	
	Building Location	*220 W. Depot Street Greeneville Tennessee 37743-1100*
	Building Function	*Courthouse*
	Project Type	*New Construction*
	Design Certification	*Energy Star 2007 (89)*
	Year Built	*2001*
	# of Floors	*4*
	Gross Square Foot	*160,975*
	Rentable Square Foot	*136,104*
	Usable Square Foot	*99,957*
	Weekly Operating Hours	*70*
	Regular Occupants	*85*
	Average Daily Visitors (FTE)	*18*
	Electronic Equipment	*100*
	Site Cost	*N/A*
	Design Cost	*$1,947,600*
	Construction Cost	*$25,672,000*
	Management & Inspection	*N/A*
	Total Cost	*$31,068,600*

The landscape includes a large grassy area. Some green cleaning products are being used, but not all products would have been considered "green." The building has auto-flush toilets, but the building engineer wants them removed because of the maintenance challenges of this technology.

The building houses four courtrooms and sees a significant fluctuation in visitors depending on the need for those courtrooms.

Each building in the study had operational highlights and potential opportunities for improvement. Although it was not the focus of this study to investigate and/or document operational highlights and opportunities, the research team observed:

- Consider pursuing LEED for Existing Buildings Certification.

Certifications

ENERGY STAR

89

Bulding Name

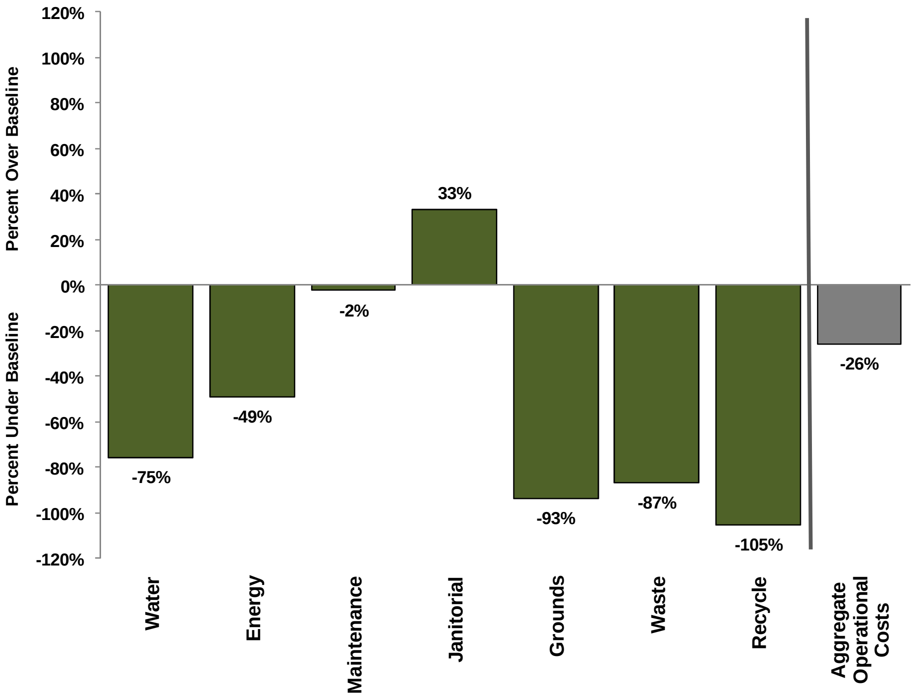
Greeneville CT

Year Certified

2007

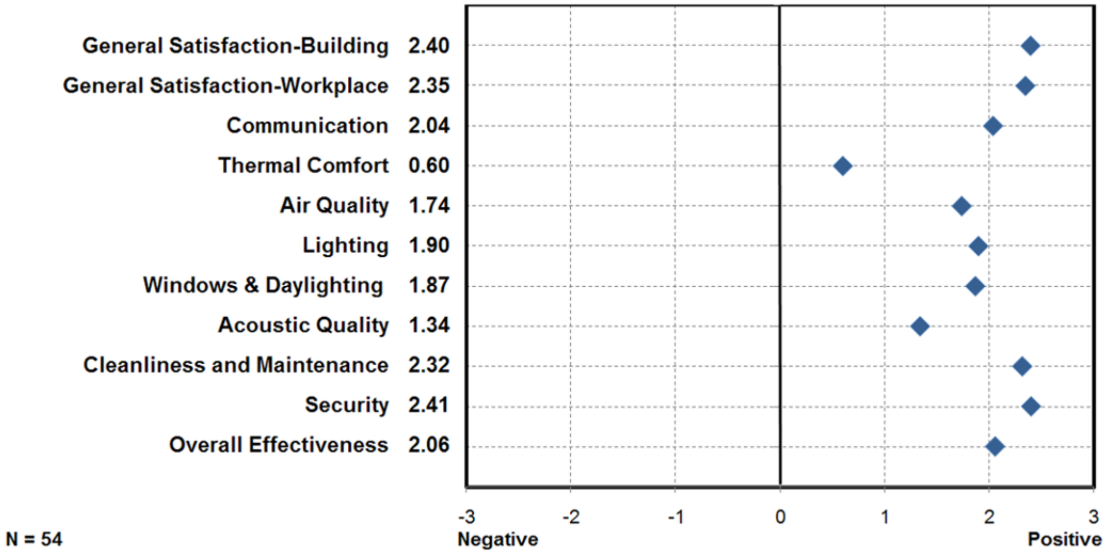
Whole Building Performance

The Quillen Courthouse operating costs are lower than the industry baseline for water, energy, general maintenance, grounds maintenance, waste, and recycling costs. The janitorial costs are higher than the industry baseline. Overall, the building costs less to operate than a baseline building.

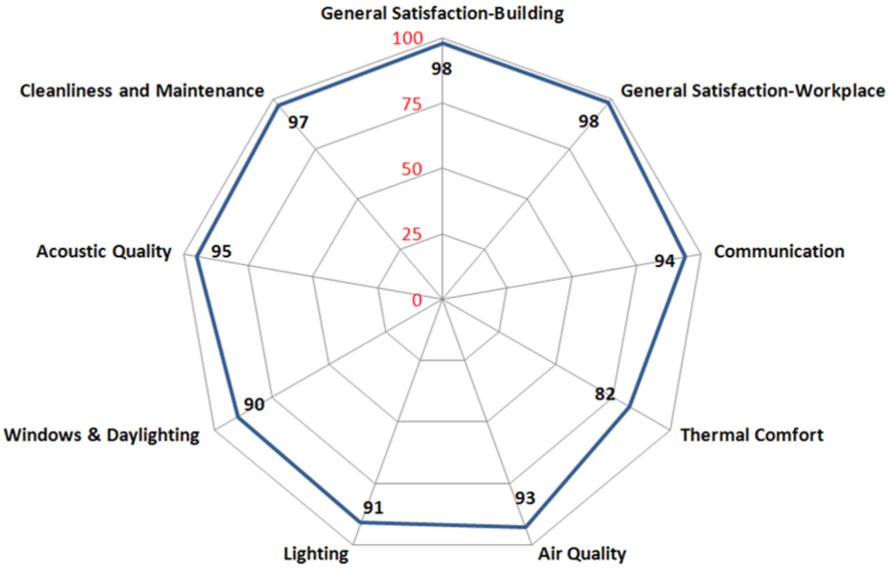


Occupant Satisfaction Survey

All 85 of the Quillen Courthouse occupants were surveyed and 54 responded. In addition to the electronic survey, GSA representatives issued the survey in hardcopy form as many staff did not have electronic access to the survey.

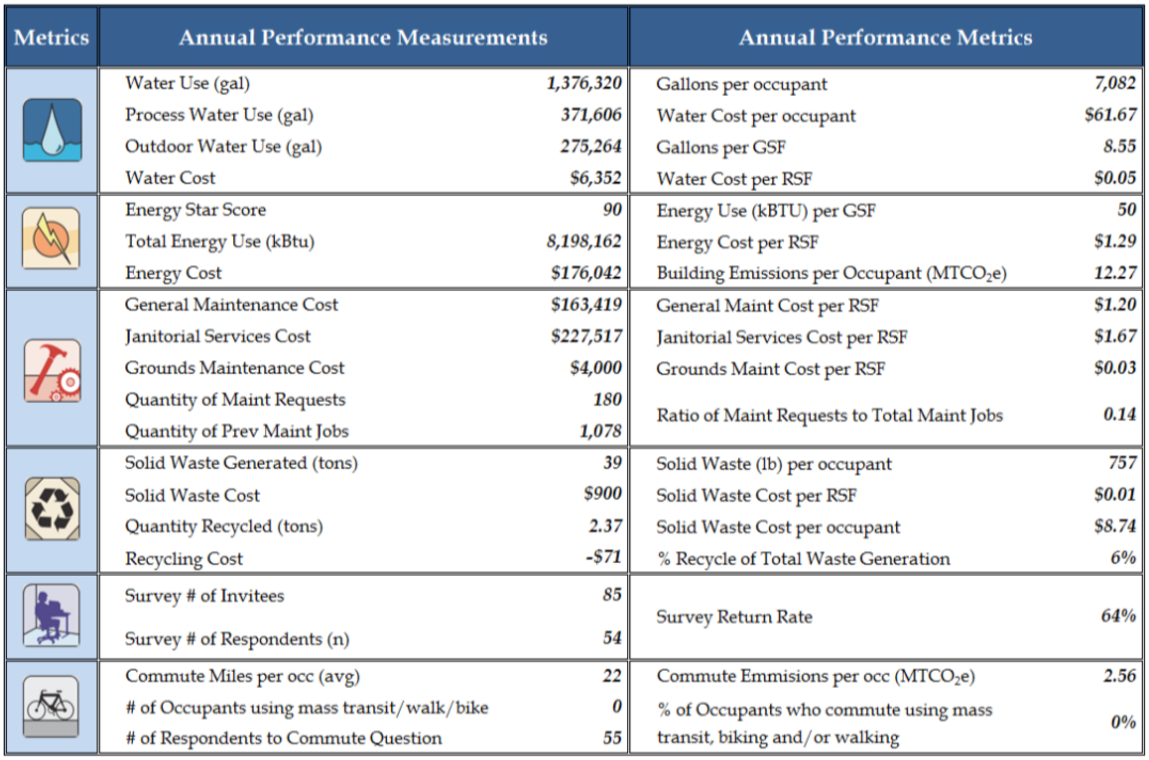


The results indicated that occupants of the Quillen Courthouse are significantly more satisfied with their building than occupants in the CBE baseline (98th percentile), with the highest occupant satisfaction score for all of the buildings in the study. The Quillen Courthouse also had some of the highest occupant satisfaction scores in the study for acoustic quality, air quality, cleanliness and maintenance, and lighting. Thermal comfort was the lowest scored occupancy metric, yet it scored in the 82th percentile when compared to the CBE building database.



Performance Data Summary

The research team collected, normalized, and compared whole building performance data for the Quillen Courthouse to industry baselines. The following table summarizes the annual performance data collected and normalized. The facility uses water-cooled chillers for its air-conditioning system; therefore, the cooling tower water use was estimated using the “rule-of-thumb” that 27% of total water use is process water. Outdoor water use was estimated using the “rule-of-thumb” that 20% of total water use for landscaping.



Metrics	Annual Performance Measurements		Annual Performance Metrics	
	Water Use (gal)	*1,376,320*	Gallons per occupant	*7,082*
	Process Water Use (gal)	*371,606*	Water Cost per occupant	*$61.67*
	Outdoor Water Use (gal)	*275,264*	Gallons per GSF	*8.55*
	Water Cost	*$6,352*	Water Cost per RSF	*$0.05*
	Energy Star Score	*90*	Energy Use (kBTU) per GSF	*50*
	Total Energy Use (kBtu)	*8,198,162*	Energy Cost per RSF	*$1.29*
	Energy Cost	*$176,042*	Building Emissions per Occupant ($MTCO_2e$)	*12.27*
	General Maintenance Cost	*$163,419*	General Maint Cost per RSF	*$1.20*
	Janitorial Services Cost	*$227,517*	Janitorial Services Cost per RSF	*$1.67*
	Grounds Maintenance Cost	*$4,000*	Grounds Maint Cost per RSF	*$0.03*
	Quantity of Maint Requests	*180*	Ratio of Maint Requests to Total Maint Jobs	*0.14*
	Quantity of Prev Maint Jobs	*1,078*		
	Solid Waste Generated (tons)	*39*	Solid Waste (lb) per occupant	*757*
	Solid Waste Cost	*$900*	Solid Waste Cost per RSF	*$0.01*
	Quantity Recycled (tons)	*2.37*	Solid Waste Cost per occupant	*$8.74*
	Recycling Cost	*-$71*	% Recycle of Total Waste Generation	*6%*
	Survey # of Invitees	*85*	Survey Return Rate	*64%*
	Survey # of Respondents (n)	*54*		
	Commute Miles per occ (avg)	*22*	Commute Emmisions per occ ($MTCO_2e$)	*2.56*
	# of Occupants using mass transit/walk/bike	*0*	% of Occupants who commute using mass transit, biking and/or walking	*0%*
	# of Respondents to Commute Question	*55*		

Jacksonville Federal Building

Description

The Chas E. Bennett Federal Building was renovated in 2004 and received Energy Star recognition in 2007. The building was completely gutted during renovation and all of the plumbing, electrical and mechanical systems were replaced. Some of the flooring and finishes used recycled materials.

The energy use intensity has reduced by 60% from a pre-renovation energy use intensity of 120 kBtu/SF. The renovation included envelope improvements including better insulation and low-E windows. A smaller "pony" chiller was added during the renovation to cool the spaces that require conditioning and humidity control during unoccupied hours. The EMCS system utilize computerized lighting controls that operate on time clocks that align with occupants schedules and housekeeping.

The landscaping was also included in the renovation and the amount of landscaping was decreased. Moisture sensors and rain sensors were installed with the irrigation system to minimize the water use and decrease the amount of grounds maintenance needed.

Metrics	Chas. E. Bennett Federal Building	
	Building Location	*400 West Bay St Jacksonville* *Florida 32202-4410*
	Building Function	*Federal Building*
	Project Type	*Renovation*
	Design Certification	*Energy Star 2007 (88)*
	Year Built	*1967*
	# of Floors	*11*
	Gross Square Foot	*338,008*
	Rentable Square Foot	*299,941*
	Usable Square Foot	*238,471*
	Weekly Operating Hours	*71*
	Regular Occupants	*1,000*
	Average Daily Visitors (FTE)	*150*
	Electronic Equipment	*1,080*
	Site Cost	*N/A*
	Design Cost	*$1,930,000*
	Construction Cost	*$25,762,323*
	Management & Inspection	*$1,851,000*
	Total Cost	*$29,543,323*

The building houses training space and sees a significant fluctuation in visitors depending on the training schedule.

Each building in the study had operational highlights and potential opportunities for improvement. Although it was not the focus of this study to investigate and/or document operational highlights and opportunities, the research team observed:

- Consider pursuing LEED for Existing Buildings Certification.

Certifications

88

Bulding Name

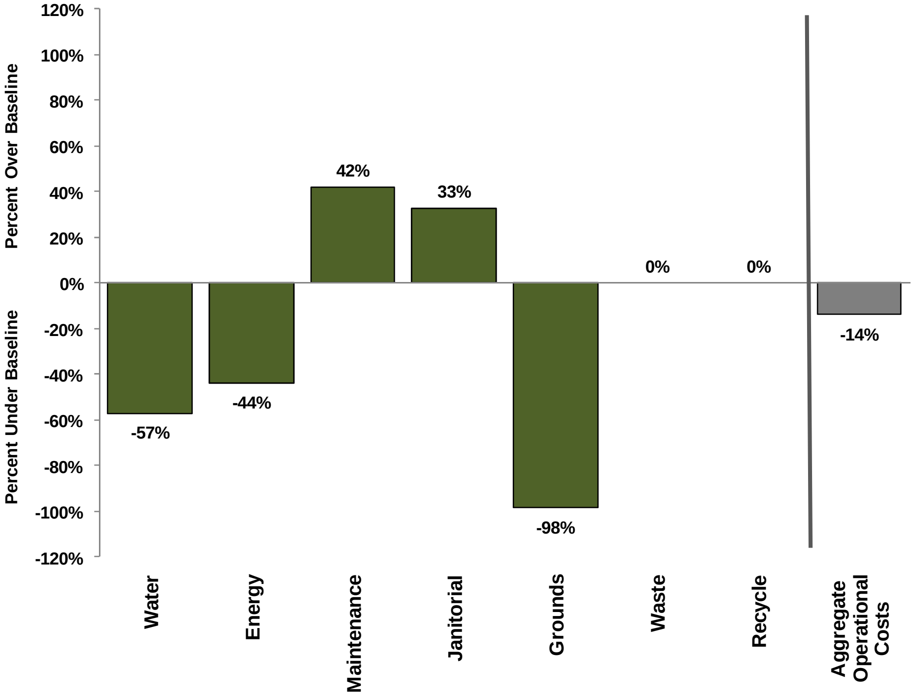
Jacksonville FB

Year Certified

2007

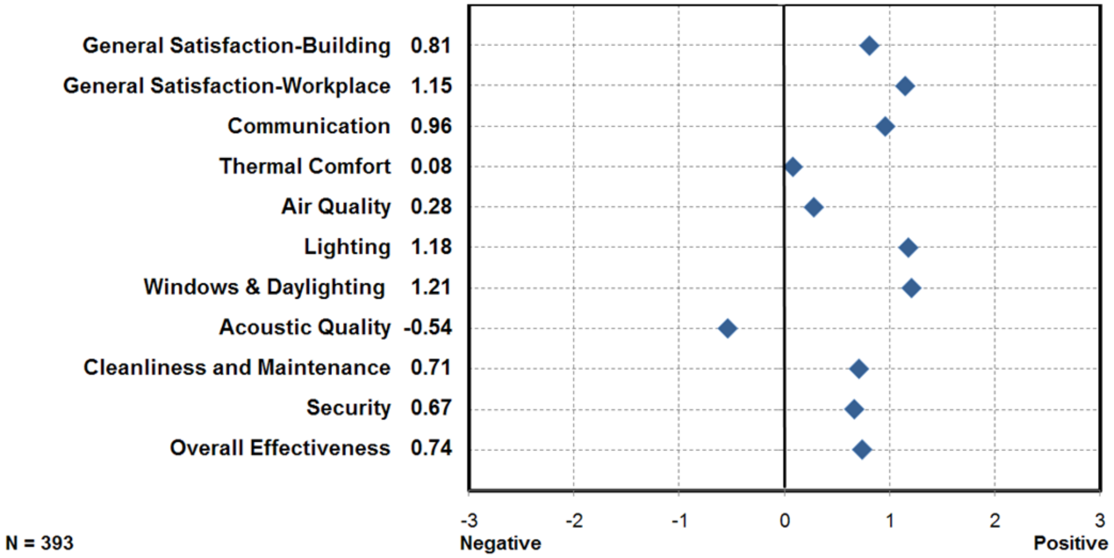
Whole Building Performance

The Bennett Federal Building operating costs are lower than the industry baseline for water, energy, and grounds maintenance. The janitorial costs are higher than the industry baseline; however the waste and recycling costs are included in the janitorial reporting and were not reported separately. The general maintenance costs are also above baseline. Overall, the building costs less to operate than a baseline building.

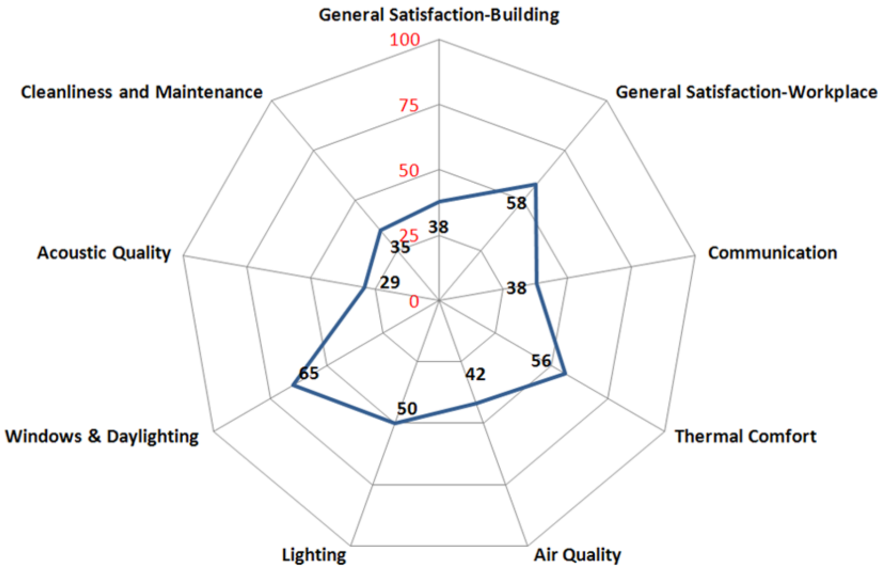


Occupant Satisfaction Survey

All 1,000 of the Bennett Federal Building occupants were surveyed and 393 responded. All of the main survey categories except acoustic quality had positive average scores.

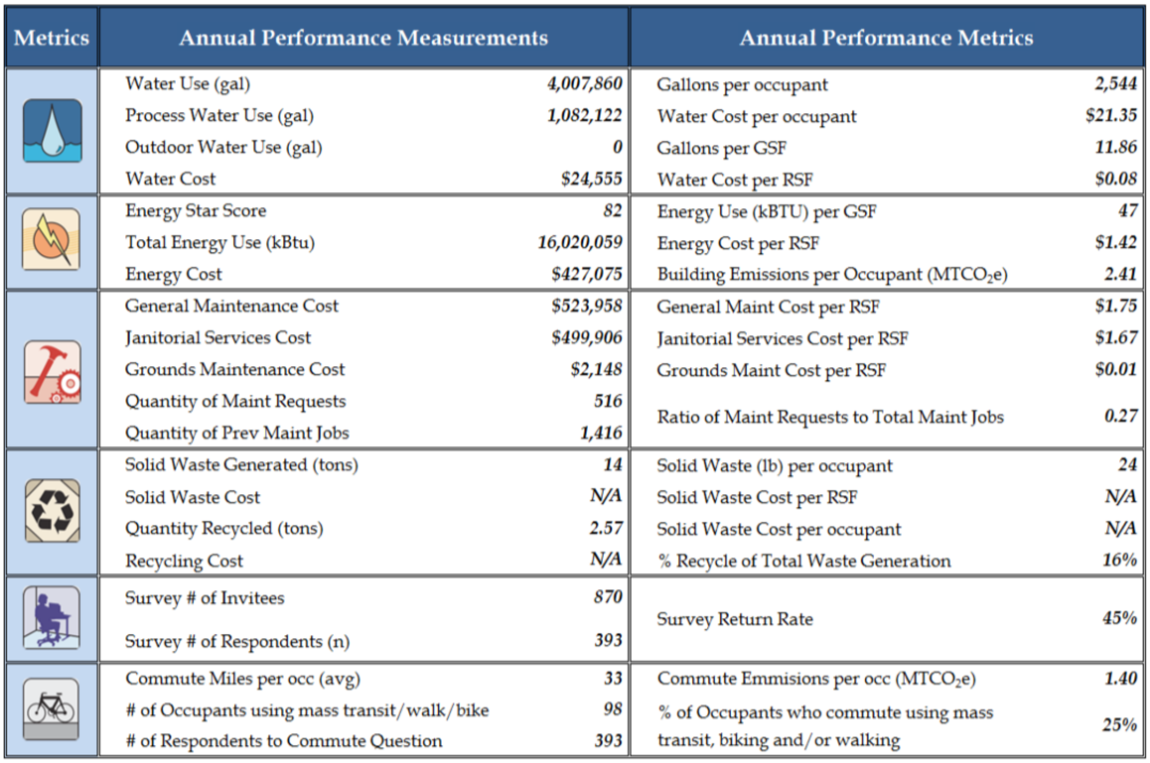


The results indicated that occupants of the Bennett Federal Building are less satisfied with their building than occupants in the CBE baseline (38th percentile). General workspace satisfaction, thermal comfort, lighting, windows and daylighting scored at or above the 50th percentile when compared to the CBE building database.



Performance Data Summary

The research team collected, normalized, and compared whole building performance data for the Bennett Federal Building to industry baselines. The following table summarizes the annual performance data collected and normalized. The facility uses water-cooled chillers for its air-conditioning system; therefore, the cooling tower water use was estimated using the "rule-of-thumb" that 27% of total water use is process water.



Metrics	Annual Performance Measurements		Annual Performance Metrics	
	Water Use (gal)	*4,007,860*	Gallons per occupant	*2,544*
	Process Water Use (gal)	*1,082,122*	Water Cost per occupant	*$21.35*
	Outdoor Water Use (gal)	*0*	Gallons per GSF	*11.86*
	Water Cost	*$24,555*	Water Cost per RSF	*$0.08*
	Energy Star Score	*82*	Energy Use (kBTU) per GSF	*47*
	Total Energy Use (kBtu)	*16,020,059*	Energy Cost per RSF	*$1.42*
	Energy Cost	*$427,075*	Building Emissions per Occupant (MTCO$_2$e)	*2.41*
	General Maintenance Cost	*$523,958*	General Maint Cost per RSF	*$1.75*
	Janitorial Services Cost	*$499,906*	Janitorial Services Cost per RSF	*$1.67*
	Grounds Maintenance Cost	*$2,148*	Grounds Maint Cost per RSF	*$0.01*
	Quantity of Maint Requests	*516*	Ratio of Maint Requests to Total Maint Jobs	*0.27*
	Quantity of Prev Maint Jobs	*1,416*		
	Solid Waste Generated (tons)	*14*	Solid Waste (lb) per occupant	*24*
	Solid Waste Cost	*N/A*	Solid Waste Cost per RSF	*N/A*
	Quantity Recycled (tons)	*2.57*	Solid Waste Cost per occupant	*N/A*
	Recycling Cost	*N/A*	% Recycle of Total Waste Generation	*16%*
	Survey # of Invitees	*870*	Survey Return Rate	*45%*
	Survey # of Respondents (n)	*393*		
	Commute Miles per occ (avg)	*33*	Commute Emmisions per occ (MTCO$_2$e)	*1.40*
	# of Occupants using mass transit/walk/bike	*98*	% of Occupants who commute using mass transit, biking and/or walking	*25%*
	# of Respondents to Commute Question	*393*		

Knoxville Federal Building

Description

The John J. Duncan Federal Building was remodeled in 2005, incorporating a new energy management system, high-efficiency lighting, motion sensors, variable frequency drives, enhanced metering, low-flow fixtures, and a 1400-gallon rainwater catchment system to increase both energy and water efficiency in the facility. The roof meets emissivity requirements to reduce heat the island effect, and houses solar lighting panels to power the roof lights. The steel-framed building has a curved front that includes a generous amount of glass in and above the entrance. The interior has an acoustic-tile ceiling and recessed fluorescent lighting, marble floors in the public areas and carpet in the private offices.

Metrics	John J. Duncan Federal Building	
	Building Location	*710 Locust Street Knoxville* *Tennessee 37902-2540*
	Building Function	*Federal Building*
	Project Type	*Renovation*
	Design Certification	*LEED-EB Certified, Energy Star 2007 (88)*
	Year Built	*1986*
	# of Floors	*8*
	Gross Square Foot	*172,684*
	Rentable Square Foot	*120,171*
	Usable Square Foot	*93,040*
	Weekly Operating Hours	*65*
	Regular Occupants	*285*
	Average Daily Visitors (FTE)	*25*
	Electronic Equipment	*285*
	Site Cost	*N/A*
	Design Cost	*N/A*
	Construction Cost	*N/A*
	Management & Inspection	*N/A*
	Total Cost	*$269,000*

The facility is located in downtown Knoxville and currently houses eight federal agencies. A small café is on the first floor and is used by many of the tenants..

Each building in the study had operational highlights and potential opportunities for improvement. Although it was not the focus of this study to investigate and/or document operational highlights and opportunities, the research team observed:

- The proximity of the bus stop to the building offers staff an opportunity not seen at many of the other buildings in this study: an easy commute via public transportation. Only 4% of those responding to the survey claimed they use the public transportation system. The availability of underground parking may have an impact on the incentive to use public transportation.

- The fact that many of the building occupants are not in the building every day may offer energy-management opportunities for the unoccupied spaces. Investigating whether occupant computers can be turned off when occupants are not present could reduce plug load and heat gain within the building.

Certifications

LEED® - EB v2.0

John J. Duncan Federal Building
710 Locust Street, Knoxville, Tennessee 37902-2540

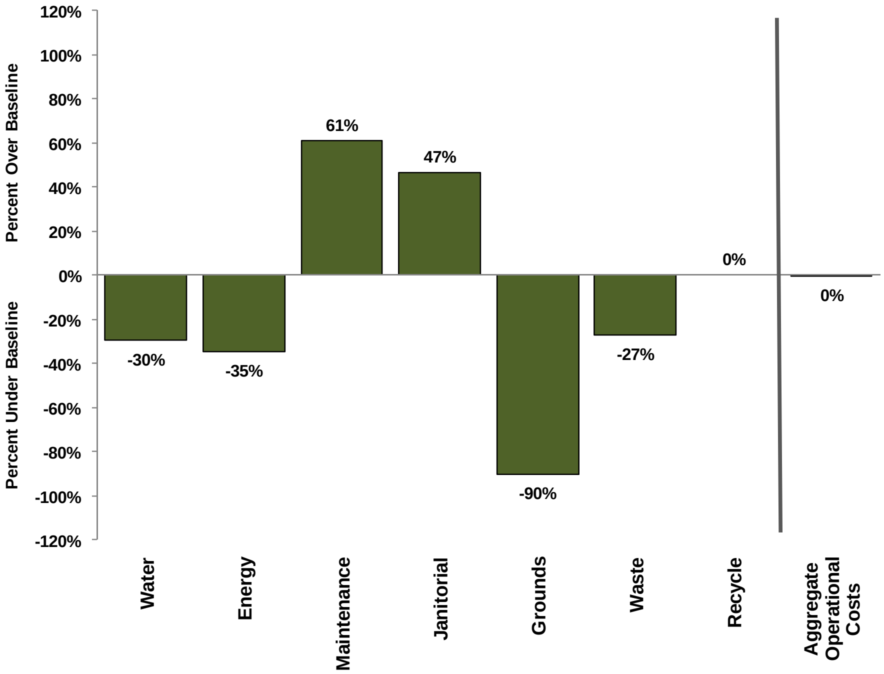
Certified **34 Points**

Sustainable Sites	6/14
Water Efficiency	2/5
Energy & Atmosphere	15/23
Materials & Resources	3/16
Indoor Environmental Quality	5/22
Innovation & Design	3/5

Certified: 31-39 points, Silver: 40-47 points, Gold: 48-63 points, Platinum: 64-85 points

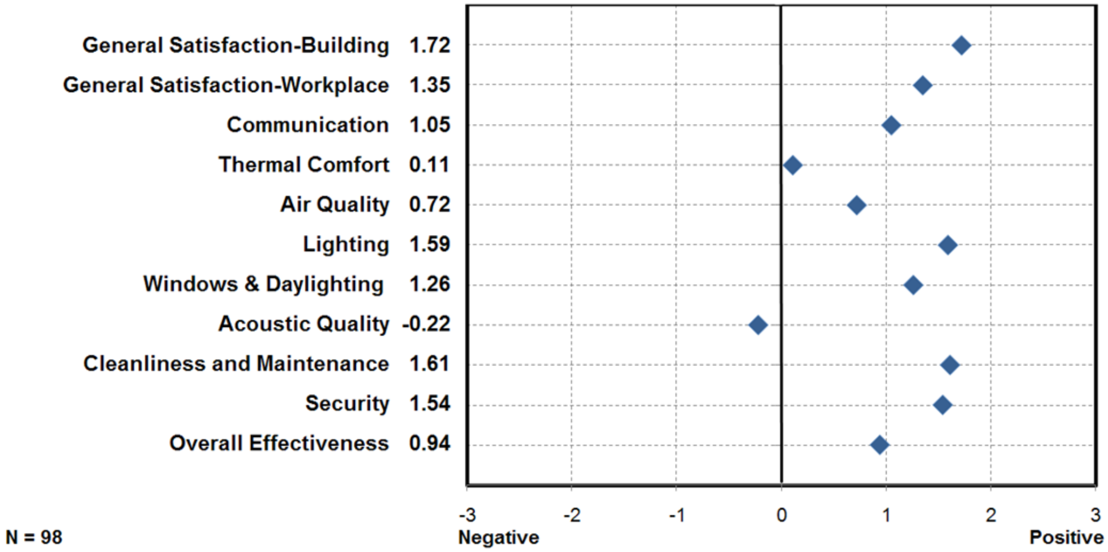
Whole Building Performance

The Duncan Federal Building operating costs are lower than the industry baseline for energy, water, and waste costs, and slightly higher for general maintenance and janitorial costs. When personnel from the Office of Surface Mines are working in the field and returning to the building, there are increased janitorial responsibilities because of dirty floors. There is no cost for operating the recycling program. Overall, the building costs less to operate than a baseline building.

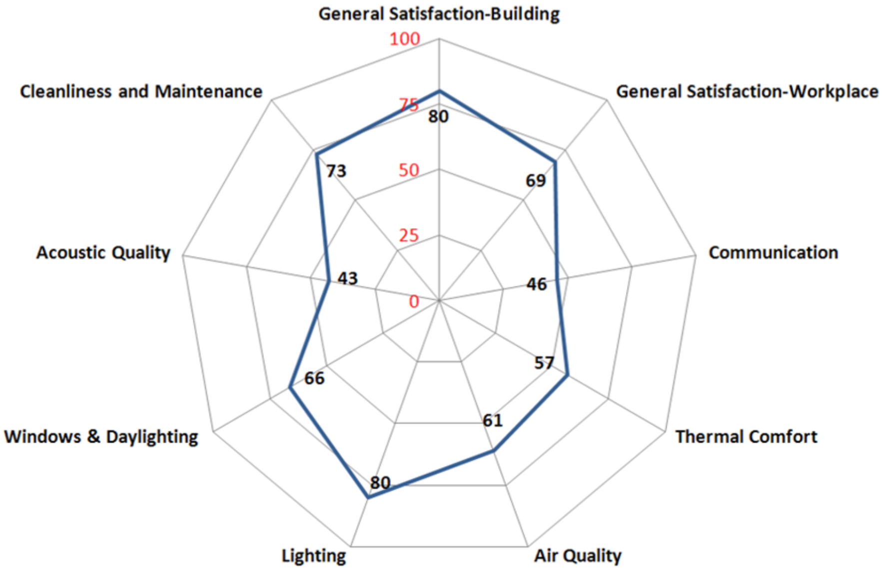


Occupant Satisfaction Survey

Of the 285 occupants in the Duncan Federal Building, 275 were surveyed and 98 responded. In addition to the electronic survey, GSA representatives issued the survey in hard-copy form to increase the response rate.

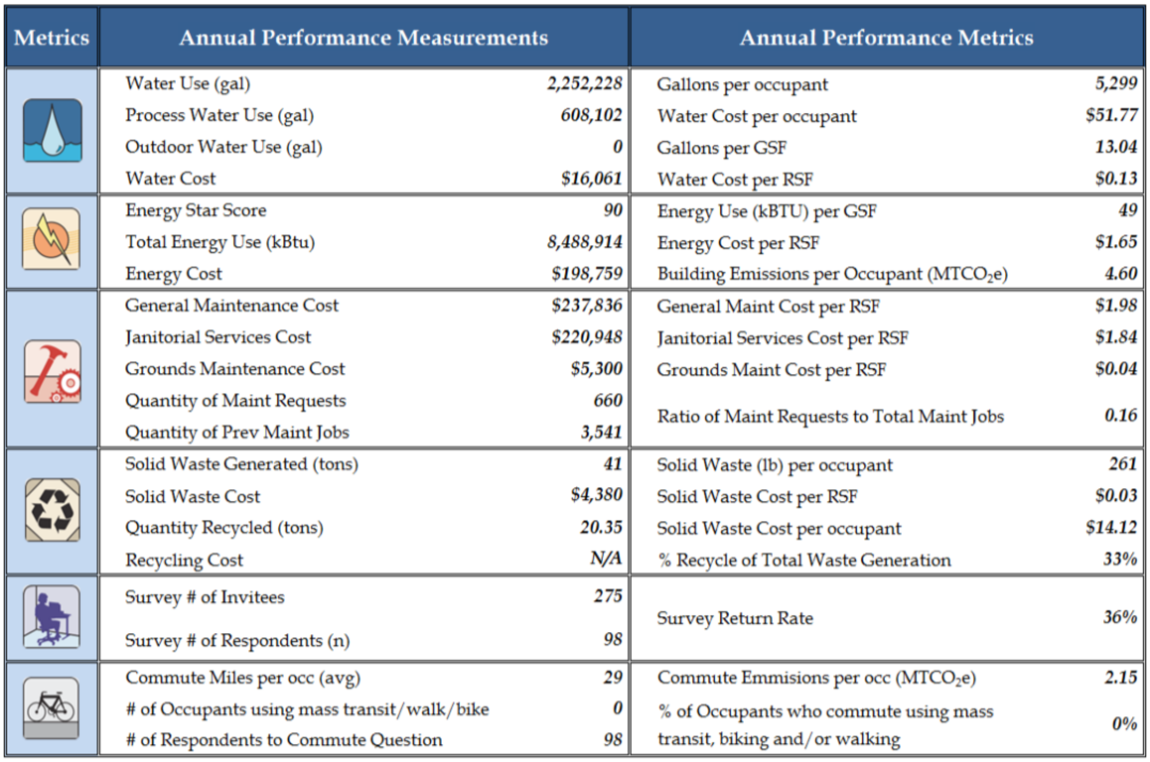


Survey results indicated that the occupants of the Duncan Federal Building are more satisfied with their building than occupants in the CBE baseline (84th percentile). The acoustic quality score is at the 50th percentile of all buildings surveyed by CBE. In the remainder of the categories, the Duncan Federal Building rated above the buildings in the CBE database.



Performance Data Summary

The research team collected, normalized, and compared whole building performance data for the Duncan Federal Building to industry baselines. The following table summarizes the annual performance data collected and normalized. The facility uses water-cooled chillers for its air-conditioning system; therefore, the cooling tower water use was estimated using the "rule-of-thumb" that 27% of total water use is process water.[33]



Metrics	Annual Performance Measurements		Annual Performance Metrics	
💧	Water Use (gal)	2,252,228	Gallons per occupant	5,299
	Process Water Use (gal)	608,102	Water Cost per occupant	$51.77
	Outdoor Water Use (gal)	0	Gallons per GSF	13.04
	Water Cost	$16,061	Water Cost per RSF	$0.13
⚡	Energy Star Score	90	Energy Use (kBTU) per GSF	49
	Total Energy Use (kBtu)	8,488,914	Energy Cost per RSF	$1.65
	Energy Cost	$198,759	Building Emissions per Occupant (MTCO$_2$e)	4.60
🔨	General Maintenance Cost	$237,836	General Maint Cost per RSF	$1.98
	Janitorial Services Cost	$220,948	Janitorial Services Cost per RSF	$1.84
	Grounds Maintenance Cost	$5,300	Grounds Maint Cost per RSF	$0.04
	Quantity of Maint Requests	660	Ratio of Maint Requests to Total Maint Jobs	0.16
	Quantity of Prev Maint Jobs	3,541		
♻	Solid Waste Generated (tons)	41	Solid Waste (lb) per occupant	261
	Solid Waste Cost	$4,380	Solid Waste Cost per RSF	$0.03
	Quantity Recycled (tons)	20.35	Solid Waste Cost per occupant	$14.12
	Recycling Cost	N/A	% Recycle of Total Waste Generation	33%
👤	Survey # of Invitees	275	Survey Return Rate	36%
	Survey # of Respondents (n)	98		
🚲	Commute Miles per occ (avg)	29	Commute Emmisions per occ (MTCO$_2$e)	2.15
	# of Occupants using mass transit/walk/bike	0	% of Occupants who commute using mass transit, biking and/or walking	0%
	# of Respondents to Commute Question	98		

Cleveland Courthouse

Description

The Howard M. Metzenbaum U.S. Courthouse is located in the hub of Cleveland's central business district. This LEED Certified facility maintained 96% of the existing shell and 59% of interior elements during its renovation.

Due to its urban location, alternative transportation is used widely and encouraged by management. No new landscaping was added during the building renovation. The existing trees do not require irrigation, and the building's low-flow fixtures increase its water efficiency.

Metrics	Howard M. Metzenbaum U.S. Courthouse	
	Building Location	*201 Superior Ave Cleveland Ohio 44114-1203*
	Building Function	*Courthouse*
	Project Type	*Renovation*
	Design Certification	*LEED-NC Certified*
	Year Built	*1910*
	# of Floors	*6*
	Gross Square Foot	*251,314*
	Rentable Square Foot	*185,105*
	Usable Square Foot	*93,790*
	Weekly Operating Hours	*60*
	Regular Occupants	*105*
	Average Daily Visitors (FTE)	*38*
	Electronic Equipment	*120*
$	Site Cost	*N/A*
	Design Cost	*$3,412,000*
	Construction Cost	*$37,925,000*
	Management & Inspection	*N/A*
	Total Cost	*$44,613,000*

The Metzenbaum Courthouse won GSA's Environmental Award for Recycling because of its seven-material collection system. The building has low-emitting carpets, CO_2 sensors, and practices green housekeeping to maintain high indoor environmental quality standards for its occupants.

Each building in the study had operational highlights and potential opportunities for improvement. Although it was not the focus of this study to investigate and/or document operational highlights and opportunities, the research team observed:

- During one of the site visits, researchers observed rust on new mechanical equipment caused by water leaking into the basement from the sidewalk. Addressing the leak will minimize maintenance costs in the future.

- The high level of occupant satisfaction on all categories implies that Metzenbaum's building systems are working well. Identifying and communicating the causes of these operational successes offers successful building operations strategies for other Federal buildings and courthouses.

Certifications

LEED® - NC v2.1

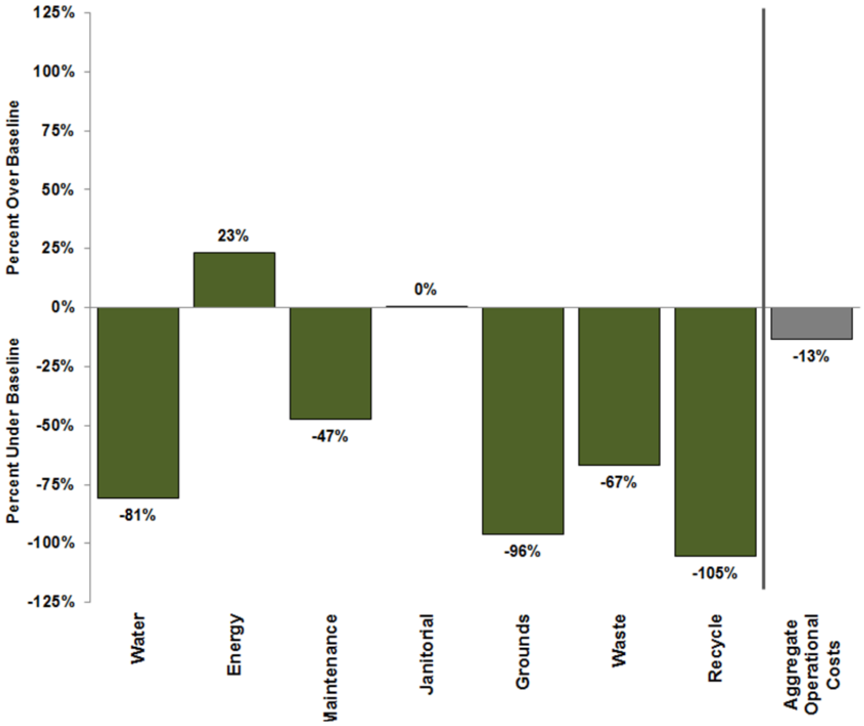
Howard M. Metzenbaum U.S. Courthouse
201 Superior Ave, Cleveland, Ohio 44114-1203

Certified	**29 Points**
Sustainable Sites	**6/14**
Water Efficiency	**4/5**
Energy & Atmosphere	**3/17**
Materials & Resources	**6/13**
Indoor Environmental Quality	**7/15**
Innovation & Design	**3/5**

Certified: 26-32 points, **Silver:** 33-38 points, **Gold:** 39-51 points, **Platinum:** 52-69 points

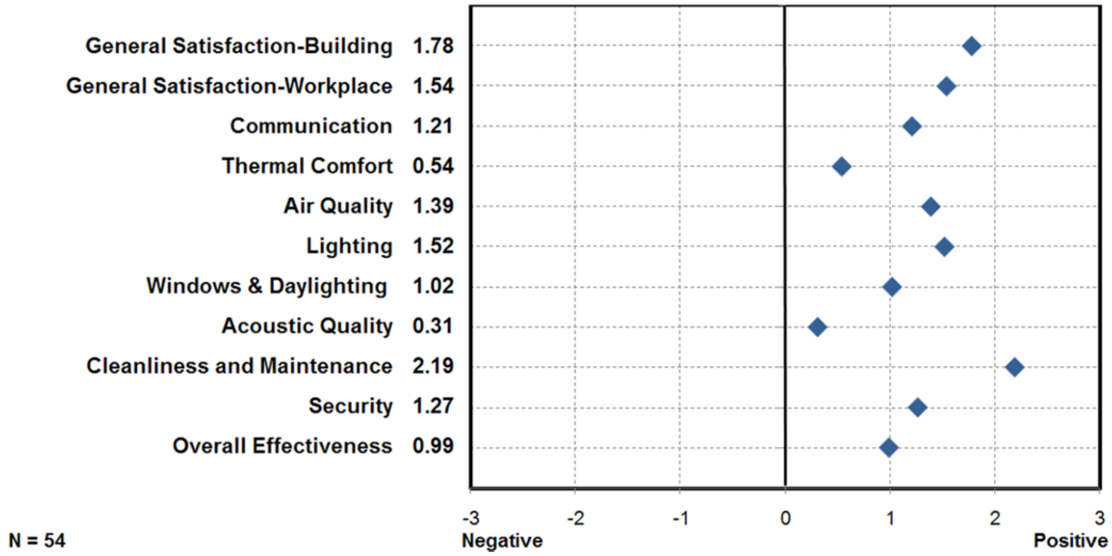
Whole Building Performance

The Metzenbaum Courthouse operating costs are lower than the industry baseline for all metrics other than energy. Overall, the building costs less to operate than a baseline building.

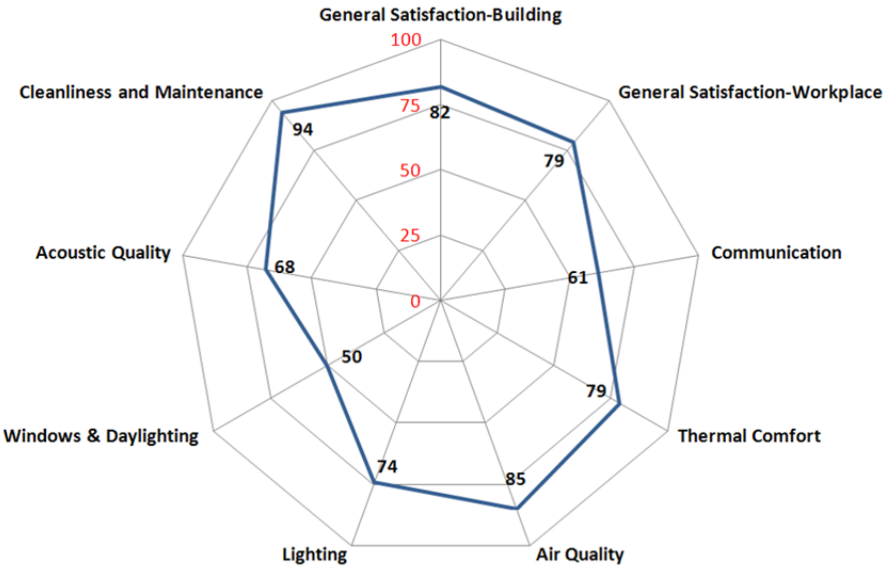


Occupant Satisfaction Survey

Of the 105 occupants in the building, 95 were surveyed and 54 responded. All of the main survey categories had positive average scores.



The results indicated that occupants of the Metzenbaum Courthouse are more satisfied with their building than occupants in the CBE baseline (82nd percentile). In all of the key measurements—acoustic quality, air quality, cleanliness and maintenance, thermal comfort and lighting—Metzenbaum occupants scored above the 50th percentile of the CBE buildings surveyed.



Performance Data Summary

The research team collected, normalized, and compared whole building performance data for the Metzenbaum Courthouse to industry baselines. The following table summarizes the annual performance data collected and normalized.

Metrics	Annual Performance Measurements		Annual Performance Metrics	
💧	Water Use (gal)	450,295	Gallons per occupant	3,160
	Process Water Use (gal)	0	Water Cost per occupant	$47.23
	Outdoor Water Use (gal)	0	Gallons per GSF	1.79
	Water Cost	$6,730	Water Cost per RSF	$0.04
⚡	Energy Star Score	69	Energy Use (kBTU) per GSF	103
	Total Energy Use (kBtu)	26,009,475	Energy Cost per RSF	$3.12
	Energy Cost	$576,668	Building Emissions per Occupant (MTCO$_2$e)	19.21
🔨	General Maintenance Cost	$176,320	General Maint Cost per RSF	$0.95
	Janitorial Services Cost	$297,728	Janitorial Services Cost per RSF	$1.61
	Grounds Maintenance Cost	$3,100	Grounds Maint Cost per RSF	$0.02
	Quantity of Maint Requests	684	Ratio of Maint Requests to Total Maint Jobs	0.46
	Quantity of Prev Maint Jobs	805		
♻	Solid Waste Generated (tons)	24	Solid Waste (lb) per occupant	337
	Solid Waste Cost	$3,067	Solid Waste Cost per RSF	$0.01
	Quantity Recycled (tons)	2.80	Solid Waste Cost per occupant	$21.52
	Recycling Cost	-$101	% Recycle of Total Waste Generation	10%
🪑	Survey # of Invitees	95	Survey Return Rate	57%
	Survey # of Respondents (n)	54		
🚲	Commute Miles per occ (avg)	26	Commute Emmisions per occ (MTCO$_2$e)	1.03
	# of Occupants using mass transit/walk/bike	31	% of Occupants who commute using mass transit, biking and/or walking	56%
	# of Respondents to Commute Question	55		

Sault Ste. Marie Port

Description

The Sault Ste. Marie Port-of-Entry is located on the U.S. side of the northern international border and operates 24 hours a day, 365 days a year. The building has primary and secondary vehicle inspection bays and two commercial truck lanes and three car lanes for in-bound inspections.

The facility's steel-frame construction with glass curtainwall offers daylighting to the interior space, and the facility sits on top of an at-grade parking garage.

Metrics	Sault Sainte Marie Border Station	
	Building Location	*989 W. Portage Ave Sault Sainte Michigan 49783-0000*
	Building Function	*Border Station*
	Project Type	*New Construction*
	Design Certification	*LEED-NC Registered*
	Year Built	*2005*
	# of Floors	*2*
	Gross Square Foot	*63,874*
	Rentable Square Foot	*39,709*
	Usable Square Foot	*29,263*
	Weekly Operating Hours	*168*
	Regular Occupants	*74*
	Average Daily Visitors (FTE)	*10*
	Electronic Equipment	*80*
	Site Cost	*N/A*
	Design Cost	*$700,000*
	Construction Cost	*$10,653,500*
	Management & Inspection	*N/A*
	Total Cost	*$13,711,500*

The facility houses an indoor firing range, a fitness room and locker facilities, holding cells and customs related laboratories. The multi-pitched roof features vegetative cover. The facility operates three boilers, a chiller, and three air-handling units. Lighting is controlled by both occupancy and daylight sensors.

Because of the facility's security function, the space houses various types of monitors, screening machines, and cameras. The screening booths and inspection bays are mostly open to the outside and pose a challenge for temperature control during the winter months.

Each building in the study had operational highlights and potential opportunities for improvement. Although it was not the focus of this study to investigate and/or document operational highlights and opportunities, the research team observed:

- For both the Sault Ste. Marie and Sweetgrass Port facilities, this study used an office building baseline, because there is nothing equivalent to a Port in the publically available industry baseline data. To fairly assess the performance of these buildings, an alternative baseline is needed.

- The vegetative roof has been a challenge to keep up due to potential installation flaws and the less-than-average annual rainfall over the past two years. Maintenance personnel training on upkeep of this feature may improve the health of the roof.

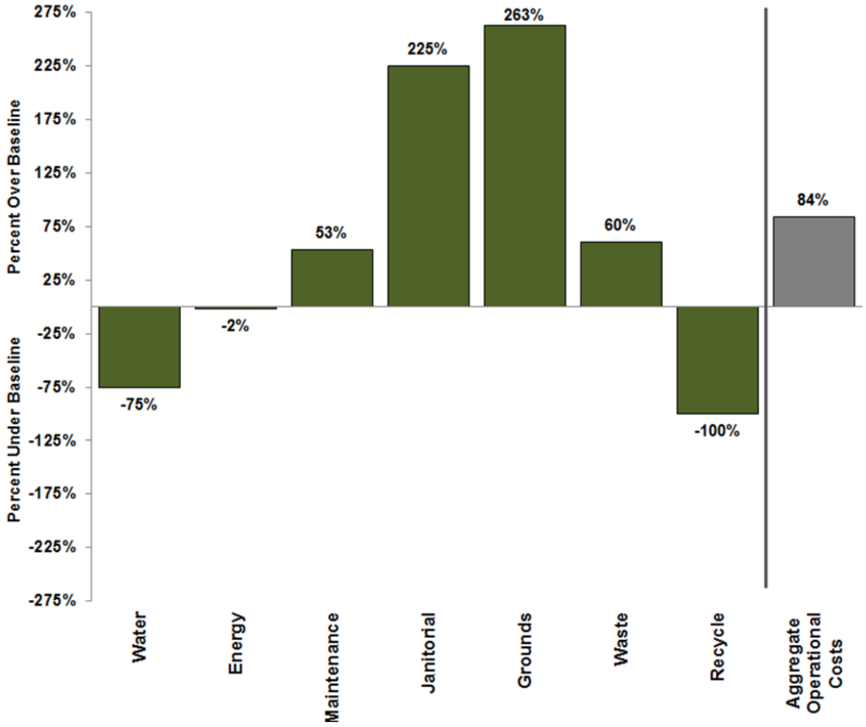
- Based on the CBE survey results, issues appear to exist with thermal comfort, daylighting, lighting, and acoustics. Interviews of occupants regarding these issues may result in a more detailed understanding of how operations might be adjusted to improve occupant satisfaction.

Certifications

LEED-NC Registered

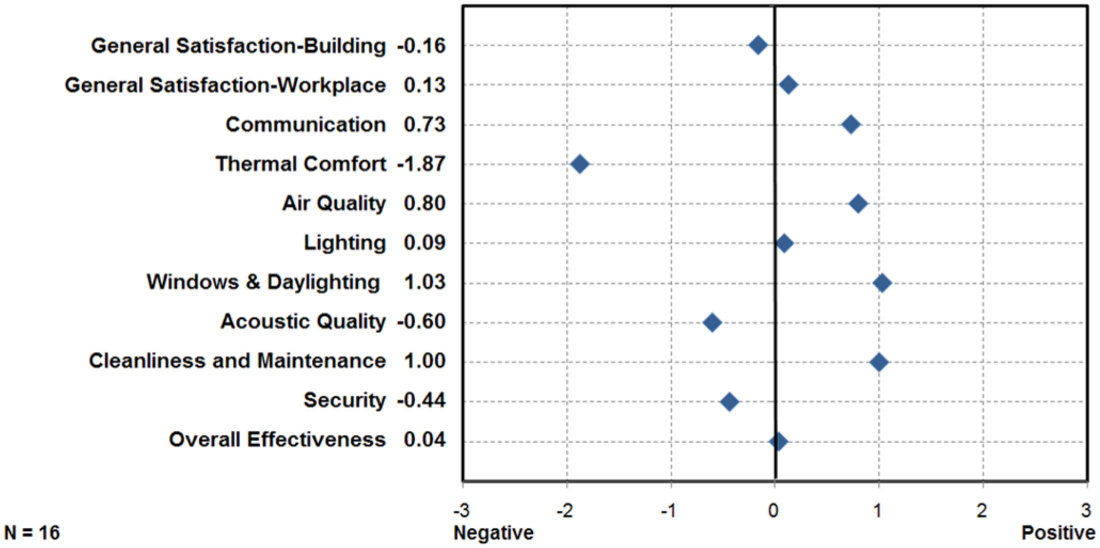
Whole Building Performance

The Sault Ste. Marie Port's operating costs are higher than the industry baseline for general maintenance, janitorial, and grounds costs. The water, energy and waste costs are lower than the industry baseline. Overall, the building costs more to operate than a baseline building. The baseline used for this analysis was an office building, because there is no equivalent to Ports available for comparison. Significant consideration must be given to the building's operational function when reviewing these costs.

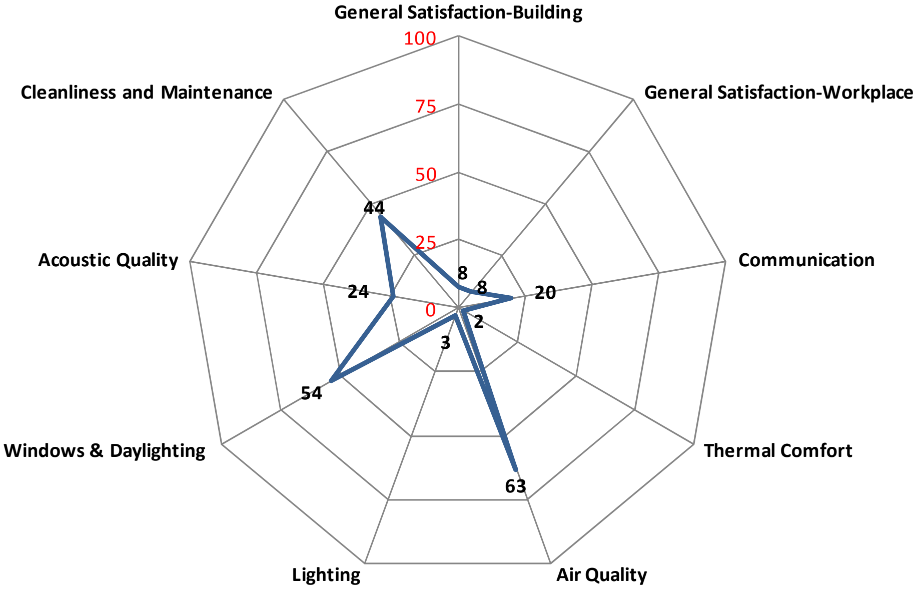


Occupant Satisfaction Survey

All 74 of the Sault Ste. Marie Port occupants were surveyed and 16 responded.

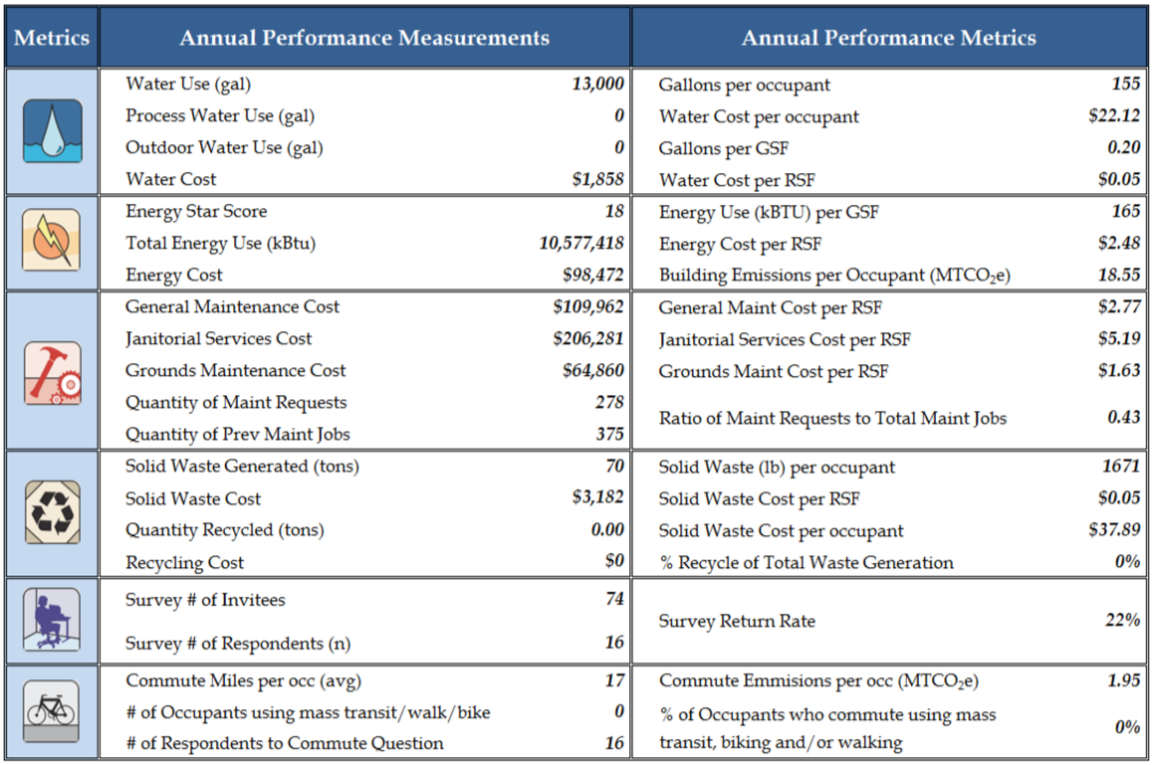


The results indicated that occupants of the Sault Ste. Marie Port are generally less satisfied with their building than occupants in the CBE baseline (2nd percentile), and the building scored the lowest of all of the GSA buildings surveyed in this study. The acoustic quality, thermal comfort, cleanliness and maintenance, and lighting all scored below the 50th percentile of the CBE buildings surveyed. Satisfaction with windows and daylighting and air quality scored above the 50th percentile. Problems with glare and temperature due to the daylighting were identified as a persistent lighting and thermal comfort issue.



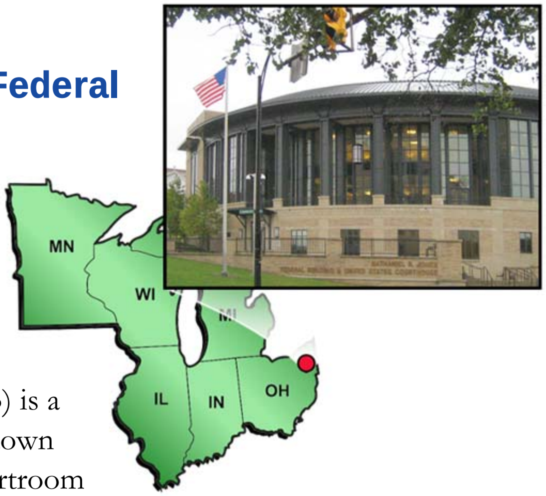
Performance Data Summary

The research team collected, normalized, and compared whole building performance data for the Sault Sainte Marie Port to industry baselines. The following table summarizes the annual performance data collected and normalized.



Metrics	Annual Performance Measurements		Annual Performance Metrics	
	Water Use (gal)	13,000	Gallons per occupant	155
	Process Water Use (gal)	0	Water Cost per occupant	$22.12
	Outdoor Water Use (gal)	0	Gallons per GSF	0.20
	Water Cost	$1,858	Water Cost per RSF	$0.05
	Energy Star Score	18	Energy Use (kBTU) per GSF	165
	Total Energy Use (kBtu)	10,577,418	Energy Cost per RSF	$2.48
	Energy Cost	$98,472	Building Emissions per Occupant ($MTCO_2e$)	18.55
	General Maintenance Cost	$109,962	General Maint Cost per RSF	$2.77
	Janitorial Services Cost	$206,281	Janitorial Services Cost per RSF	$5.19
	Grounds Maintenance Cost	$64,860	Grounds Maint Cost per RSF	$1.63
	Quantity of Maint Requests	278	Ratio of Maint Requests to Total Maint Jobs	0.43
	Quantity of Prev Maint Jobs	375		
	Solid Waste Generated (tons)	70	Solid Waste (lb) per occupant	1671
	Solid Waste Cost	$3,182	Solid Waste Cost per RSF	$0.05
	Quantity Recycled (tons)	0.00	Solid Waste Cost per occupant	$37.89
	Recycling Cost	$0	% Recycle of Total Waste Generation	0%
	Survey # of Invitees	74	Survey Return Rate	22%
	Survey # of Respondents (n)	16		
	Commute Miles per occ (avg)	17	Commute Emmisions per occ ($MTCO_2e$)	1.95
	# of Occupants using mass transit/walk/bike	0	% of Occupants who commute using mass transit, biking and/or walking	0%
	# of Respondents to Commute Question	16		

Youngstown Courthouse and Federal Building



Description

The Nathaniel R. Jones Federal Building and United States Courthouse (Youngstown CT & FB) is a part of the urban revitalization of the city's downtown district. The building houses one bankruptcy courtroom and various types of office space to accommodate a variety of tenants.

Metrics	Nathaniel R. Jones Federal Building and U.S. Courthouse	
	Building Location	***10 East Commerce Youngstown Ohio 44503-1677***
	Building Function	***Courthouse & Federal Building***
	Project Type	***New Construction***
	Design Certification	***LEED-NC Certified***
	Year Built	***2002***
	# of Floors	***4***
	Gross Square Foot	***52,240***
	Rentable Square Foot	***44,476***
	Usable Square Foot	***31,421***
	Weekly Operating Hours	***60***
	Regular Occupants	***45***
	Average Daily Visitors (FTE)	***198***
	Electronic Equipment	***60***
	Site Cost	***N/A***
	Design Cost	***$1,264,000***
	Construction Cost	***$10,594,831***
	Management & Inspection	***N/A***
	Total Cost	***$16,465,331***

The facility is GSA's first courthouse to achieve LEED certification. The facility was built on a brownfield and incorporates building controls, combined with air-cooled chillers and municipal utility steam, and daylighting to over 75% of occupied spaces into building operations.

Unique features of the Youngstown CT & FB include a native landscape and stormwater management demonstration adjacent to the building, and use of a white membrane roof and light-colored pavement to reduce the heat island effect.

Each building in the study had operational highlights and potential opportunities for improvement. Although it was not the focus of this study to investigate and/or document operational highlights and opportunities, the research team observed:

- The Youngstown CT & FB was the lowest scoring in the thermal comfort category of the CBE survey (1st percentile). Building management is aware of problems with its cooling system and plans exist to upgrade the system.

- Native prairie grass landscaping is manually weeded, which may contribute to the higher grounds maintenance costs.

Certifications

LEED® - NC v2.1

Frank J. Battisti and Nathaniel R. Jones Federal Building and U.S. Courthouse

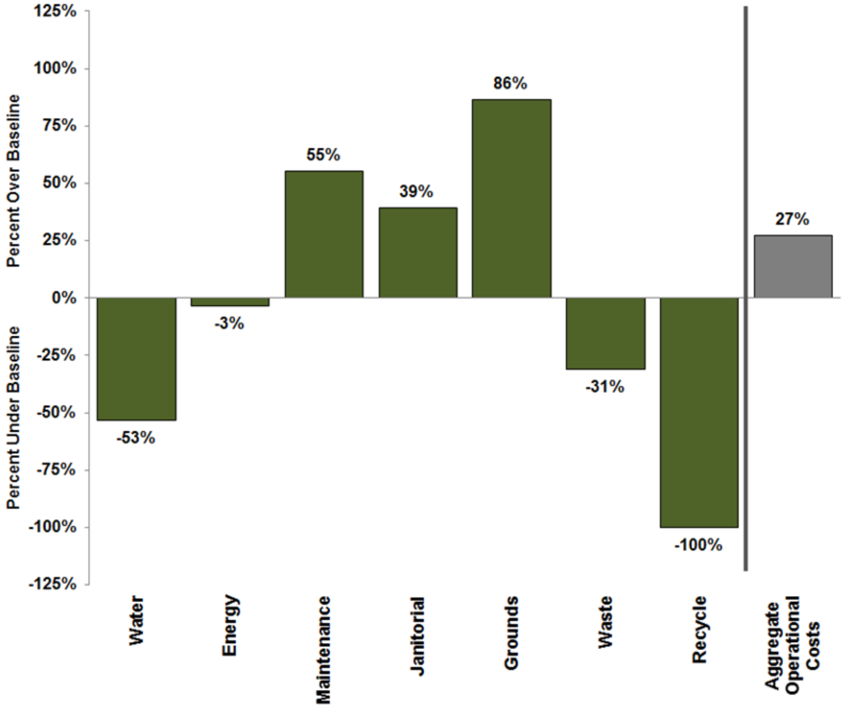
10 East Commerce Street, Youngstown, Ohio 44503-1677

Certified	**27 Points**
Sustainable Sites	**10/14**
Water Efficiency	**2/5**
Energy & Atmosphere	**1/17**
Materials & Resources	**4/13**
Indoor Environmental Quality	**8/15**
Innovation & Design	**2/5**

Certified: 26-32 points, **Silver:** 33-38 points, **Gold:** 39-51 points, **Platinum:** 52-69 points

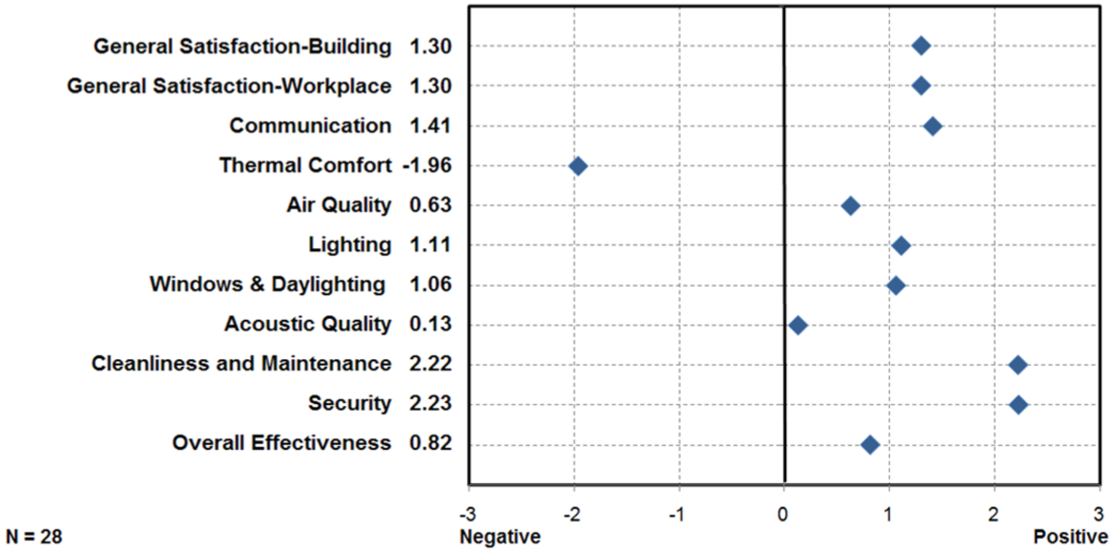
Whole Building Performance

The costs of operating the Youngstown CT & FB are lower than the industry baseline for water, energy and waste costs. The general maintenance, janitorial, and grounds maintenance costs were higher than the industry baseline, and overall the building costs more to operate than the baseline. Note that the building's mechanical systems have been malfunctioning, and the basement has flooded five times since its commissioning, potentially affecting the maintenance and janitorial costs.

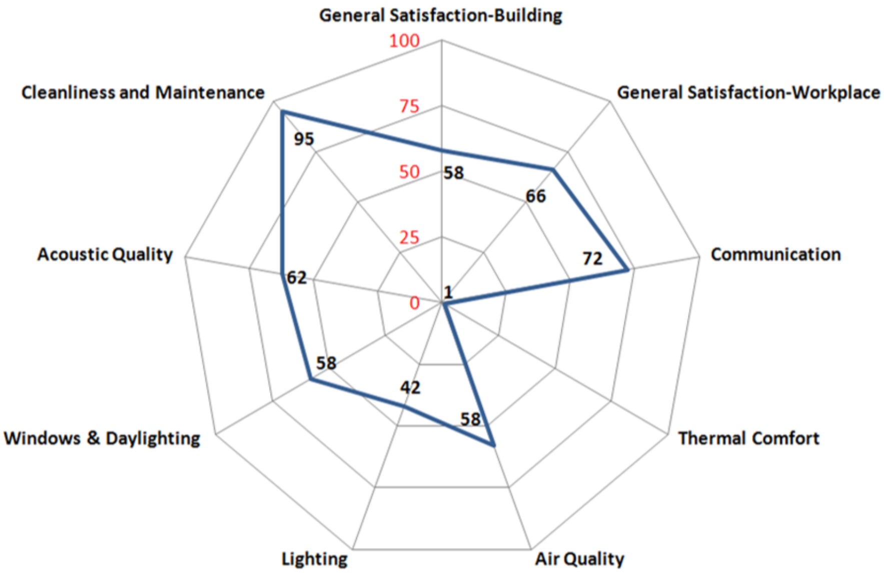


Occupant Satisfaction Survey

All 45 of the Youngstown CT & FB occupants were surveyed and 28 responded. All of the main survey categories except thermal comfort had positive average scores.

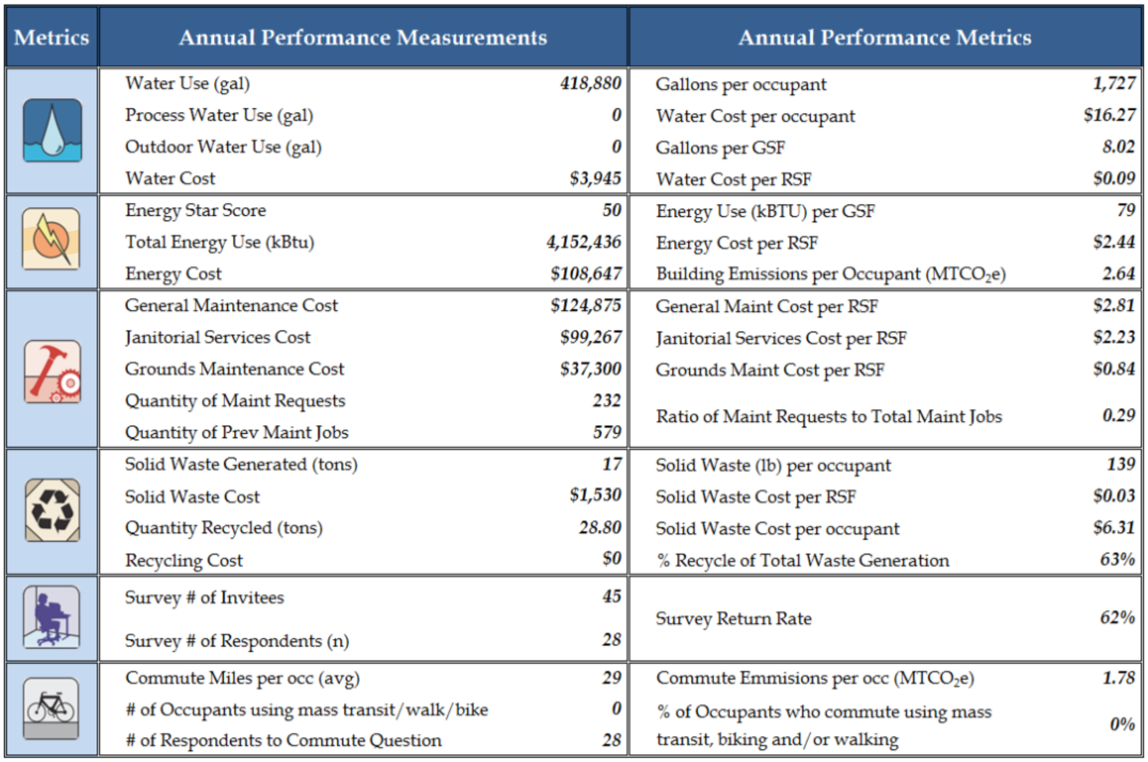


The results indicated that occupants of the Youngstown CT & FB are generally more satisfied with their building than occupants in the CBE baseline (58th percentile). Thermal comfort and lighting quality scored below the 50th percentile of the CBE buildings surveyed. Acoustics, air quality, and cleanliness and maintenance all scored above the 50th percentile.



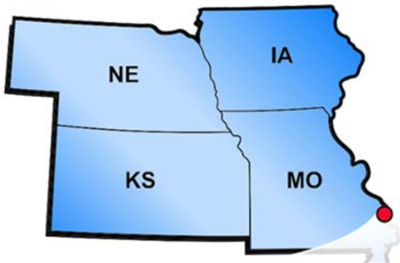
Performance Data Summary

The research team collected, normalized, and compared whole building performance data for the Youngstown CT & FB to industry baselines. The following table summarizes the annual performance data collected and normalized.



Metrics	Annual Performance Measurements		Annual Performance Metrics	
💧	Water Use (gal)	*418,880*	Gallons per occupant	*1,727*
	Process Water Use (gal)	*0*	Water Cost per occupant	*$16.27*
	Outdoor Water Use (gal)	*0*	Gallons per GSF	*8.02*
	Water Cost	*$3,945*	Water Cost per RSF	*$0.09*
⚡	Energy Star Score	*50*	Energy Use (kBTU) per GSF	*79*
	Total Energy Use (kBtu)	*4,152,436*	Energy Cost per RSF	*$2.44*
	Energy Cost	*$108,647*	Building Emissions per Occupant (MTCO$_2$e)	*2.64*
🔨	General Maintenance Cost	*$124,875*	General Maint Cost per RSF	*$2.81*
	Janitorial Services Cost	*$99,267*	Janitorial Services Cost per RSF	*$2.23*
	Grounds Maintenance Cost	*$37,300*	Grounds Maint Cost per RSF	*$0.84*
	Quantity of Maint Requests	*232*	Ratio of Maint Requests to Total Maint Jobs	*0.29*
	Quantity of Prev Maint Jobs	*579*		
♻	Solid Waste Generated (tons)	*17*	Solid Waste (lb) per occupant	*139*
	Solid Waste Cost	*$1,530*	Solid Waste Cost per RSF	*$0.03*
	Quantity Recycled (tons)	*28.80*	Solid Waste Cost per occupant	*$6.31*
	Recycling Cost	*$0*	% Recycle of Total Waste Generation	*63%*
🪑	Survey # of Invitees	*45*	Survey Return Rate	*62%*
	Survey # of Respondents (n)	*28*		
🚲	Commute Miles per occ (avg)	*29*	Commute Emmisions per occ (MTCO$_2$e)	*1.78*
	# of Occupants using mass transit/walk/bike	*0*	% of Occupants who commute using mass transit, biking and/or walking	*0%*
	# of Respondents to Commute Question	*28*		

Cape Girardeau Courthouse

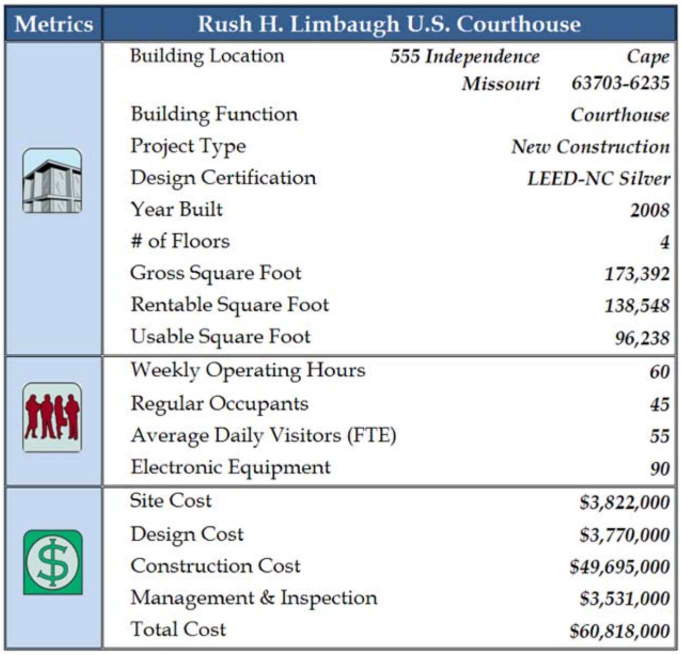


Description

The Rush H. Limbaugh U.S. Courthouse is located in Cape Girardeau, Missouri, about 115 miles southeast of St. Louis. Completed in 2008, this LEED Silver facility replaced a 1950s era building and one of the first sustainably designed buildings in the area.

To increase the energy efficiency a 30 % energy reduction from the ASHRAE 90.1-1999 standard was built into the design. Energy-efficient features of the building include occupancy sensors, daylight sensors, a white roof, Lighting Control System control of lighting, and Building Automation System (BAS) control of HVAC systems.

The building houses three courtrooms and sees a significant fluctuation in visitors depending on the need for those courtrooms.



Metrics	Rush H. Limbaugh U.S. Courthouse	
	Building Location	*555 Independence Cape* *Missouri 63703-6235*
	Building Function	*Courthouse*
	Project Type	*New Construction*
	Design Certification	*LEED-NC Silver*
	Year Built	*2008*
	# of Floors	*4*
	Gross Square Foot	*173,392*
	Rentable Square Foot	*138,548*
	Usable Square Foot	*96,238*
	Weekly Operating Hours	*60*
	Regular Occupants	*45*
	Average Daily Visitors (FTE)	*55*
	Electronic Equipment	*90*
$	Site Cost	*$3,822,000*
	Design Cost	*$3,770,000*
	Construction Cost	*$49,695,000*
	Management & Inspection	*$3,531,000*
	Total Cost	*$60,818,000*

Cape Girardeau is a small town with a population of about 36,600, and public transportation is not widely used.

The landscape includes a grassy area and small trees. An automatic irrigation system is in place that includes rain sensors and drip zones. Low flow fixtures add to the water efficiency of the building.

Each building in the study had operational highlights and potential opportunities for improvement. Although it was not the focus of this study to investigate and/or document operational highlights and opportunities, the research team observed:

- The automatic controls of the building are still being commissioned to ensure proper functionality. Once operating correctly, the lighting and HVAC controls in the courthouse offer opportunities for future energy reductions.

Certifications

LEED® - NC v2.1

Rush H. Limbaugh U.S. Courthouse
555 Independence St., Cape Girardeau, Missouri 63703-623

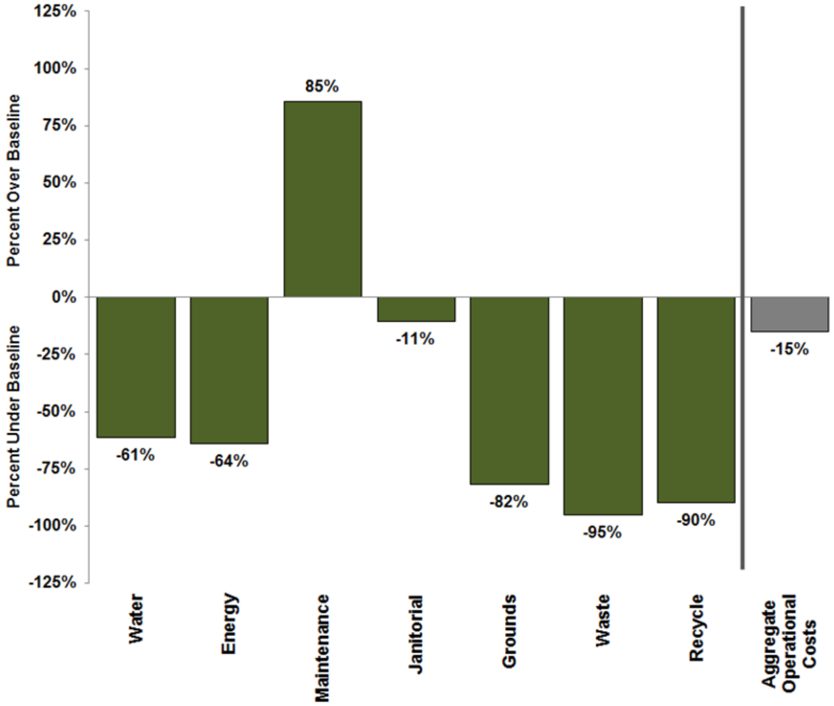
Silver **33 Points**

Sustainable Sites	7/14
Water Efficiency	2/5
Energy & Atmosphere	6/17
Materials & Resources	5/13
Indoor Environmental Quality	8/15
Innovation & Design	5/5

Certified: 26-32 points, **Silver:** 33-38 points, **Gold:** 39-51 points, **Platinum:** 52-69 points

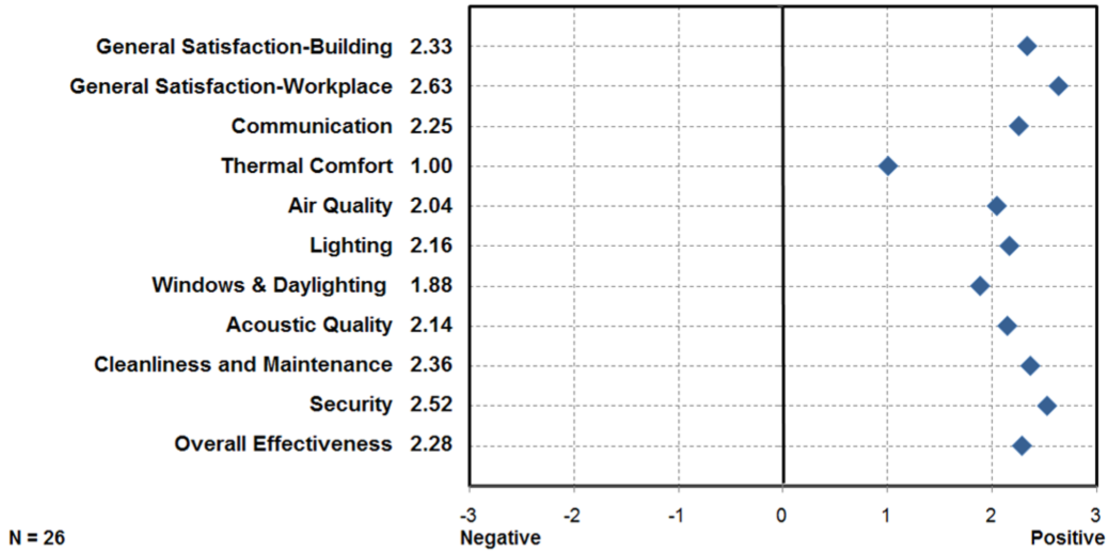
Whole Building Performance

The Limbaugh Courthouse operating costs are lower than the industry baseline for all metrics other than maintenance. The higher than average maintenance costs are attributed in part to flooding in the main atrium that occurred in the winter of 2008. Overall, the building costs less to operate than a baseline building.

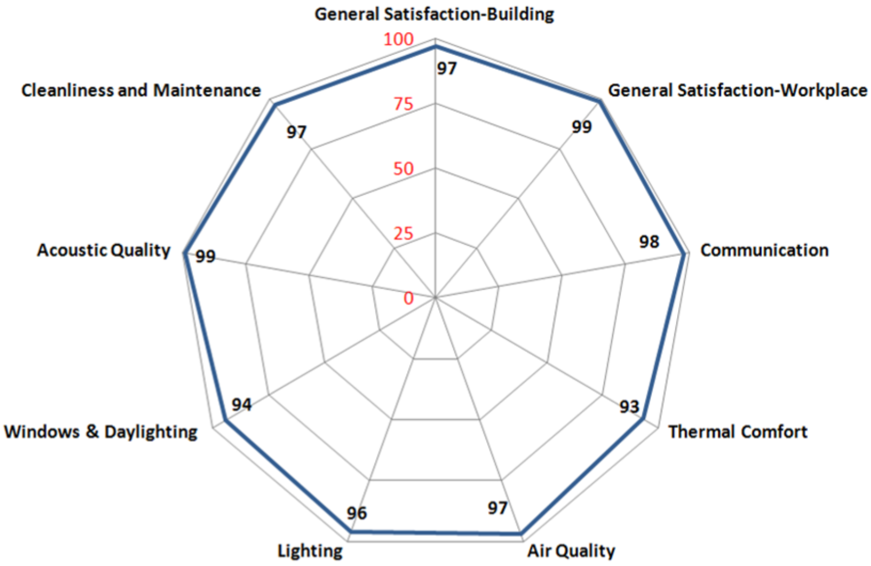


Occupant Satisfaction Survey

All of the 45 occupants in the Limbaugh Courthouse were surveyed and 26 responded. All of the main survey categories had positive average scores.

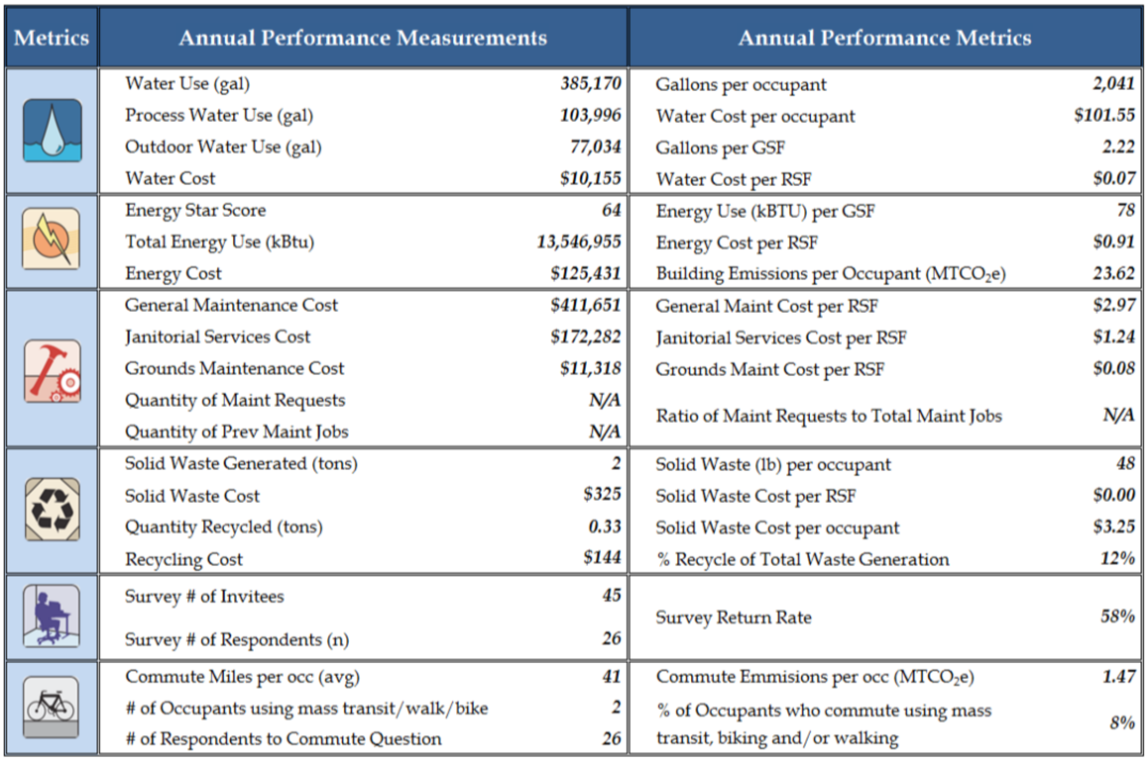


The results indicated that occupants of the Limbaugh Courthouse are more satisfied with their building than occupants in the CBE baseline (97th percentile). In all of the key measurements—acoustic quality, air quality, cleanliness and maintenance, thermal comfort and lighting—Limbaugh occupants scored above the 90th percentile of the CBE buildings surveyed.



Performance Data Summary

The research team collected, normalized, and compared whole building performance data for the Rush H. Limbaugh Courthouse to industry baselines. The following table summarizes the annual performance data collected and normalized. The facility uses water-cooled chillers for its air-conditioning system; therefore, the cooling tower water use was estimated using the "rule-of-thumb" that 27% of total water use is process water. Outdoor water use was estimated using the "rule-of-thumb" that 20% of total water used is for landscaping.



Metrics	Annual Performance Measurements		Annual Performance Metrics	
	Water Use (gal)	*385,170*	Gallons per occupant	*2,041*
	Process Water Use (gal)	*103,996*	Water Cost per occupant	*$101.55*
	Outdoor Water Use (gal)	*77,034*	Gallons per GSF	*2.22*
	Water Cost	*$10,155*	Water Cost per RSF	*$0.07*
	Energy Star Score	*64*	Energy Use (kBTU) per GSF	*78*
	Total Energy Use (kBtu)	*13,546,955*	Energy Cost per RSF	*$0.91*
	Energy Cost	*$125,431*	Building Emissions per Occupant ($MTCO_2e$)	*23.62*
	General Maintenance Cost	*$411,651*	General Maint Cost per RSF	*$2.97*
	Janitorial Services Cost	*$172,282*	Janitorial Services Cost per RSF	*$1.24*
	Grounds Maintenance Cost	*$11,318*	Grounds Maint Cost per RSF	*$0.08*
	Quantity of Maint Requests	*N/A*	Ratio of Maint Requests to Total Maint Jobs	*N/A*
	Quantity of Prev Maint Jobs	*N/A*		
	Solid Waste Generated (tons)	*2*	Solid Waste (lb) per occupant	*48*
	Solid Waste Cost	*$325*	Solid Waste Cost per RSF	*$0.00*
	Quantity Recycled (tons)	*0.33*	Solid Waste Cost per occupant	*$3.25*
	Recycling Cost	*$144*	% Recycle of Total Waste Generation	*12%*
	Survey # of Invitees	*45*	Survey Return Rate	*58%*
	Survey # of Respondents (n)	*26*		
	Commute Miles per occ (avg)	*41*	Commute Emmisions per occ ($MTCO_2e$)	*1.47*
	# of Occupants using mass transit/walk/bike	*2*	% of Occupants who commute using mass transit, biking and/or walking	*8%*
	# of Respondents to Commute Question	*26*		

Davenport Courthouse

Description

The Davenport Courthouse is on the National Register of Historic Places. The renovation was completed in 2005 and increased the number of courtrooms, improved security by building new holding cells and a vehicle sally port, and updated the mechanical systems and controls in the building.

The remodel retained the historic integrity of the original the courtroom, the main lobby, staircases, windows, and hallways throughout the building.

Metrics	Davenport U.S. Courthouse	
	Building Location	*131 E. 4th Street Davenport* *Iowa 52801-1516*
	Building Function	*Courthouse*
	Project Type	*Renovation*
	Design Certification	*LEED-NC Registered*
	Year Built	*1933*
	# of Floors	*4*
	Gross Square Foot	*79,872*
	Rentable Square Foot	*68,391*
	Usable Square Foot	*48,836*
	Weekly Operating Hours	*70*
	Regular Occupants	*45*
	Average Daily Visitors (FTE)	*18*
	Electronic Equipment	*60*
$	Site Cost	*N/A*
	Design Cost	*N/A*
	Construction Cost	*N/A*
	Management & Inspection	*N/A*
	Total Cost	*$20,000,000*

The new courtrooms incorporate daylighting and the mechanical systems use variable frequency drives. The HVAC system consists of water-cooled chillers, boilers, and air handling units. The mailroom was specifically remodeled with high-efficiency particulate air filters for HAZMAT purposes.

Each building in the study had operational highlights and potential opportunities for improvement. Although it was not the focus of this study to investigate and/or document operational highlights and opportunities, the research team observed the following:

- Two third-party commissioning studies have been performed at the Davenport Courthouse to investigate operational challenges related to the mechanical equipment. Reevaluating the energy performance, maintenance costs, and occupant satisfaction following the implementation of the studies' recommendations would offer tangible evidence of the impact.

- Mechanical equipment is difficult to access. Future Federal design projects should carefully evaluate mechanical room space to enable easy access for maintenance.

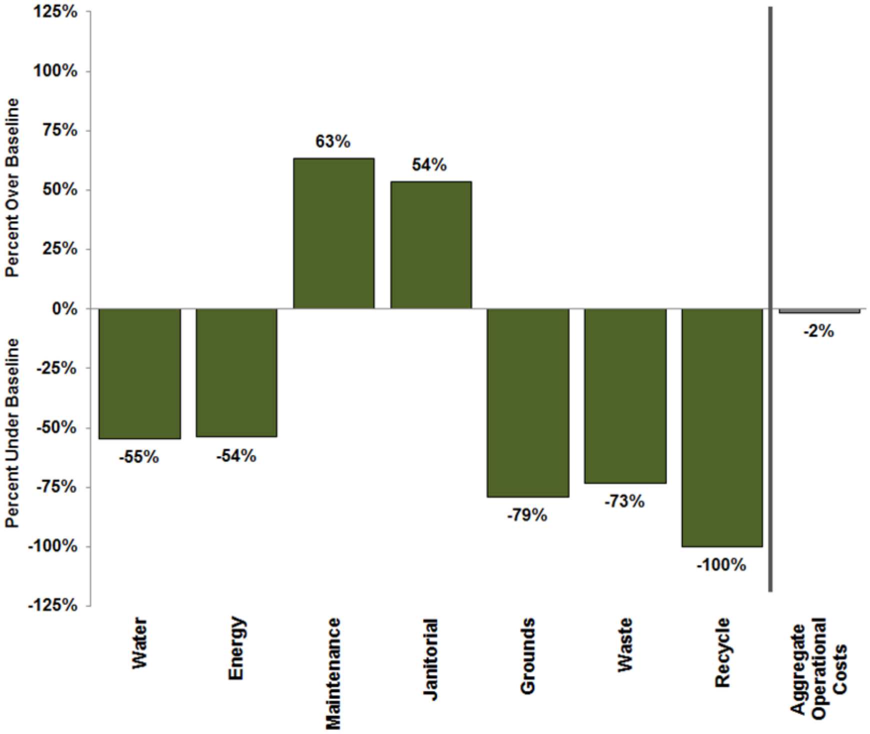
- Based on the CBE survey results and site visit, it appears that issues exist with lighting, acoustics, and some security features. Interviews of the occupants and design team regarding these issues may result in a more detailed understanding of how future designs might be adjusted to improve occupant satisfaction.

Certifications

LEED-NC Registered

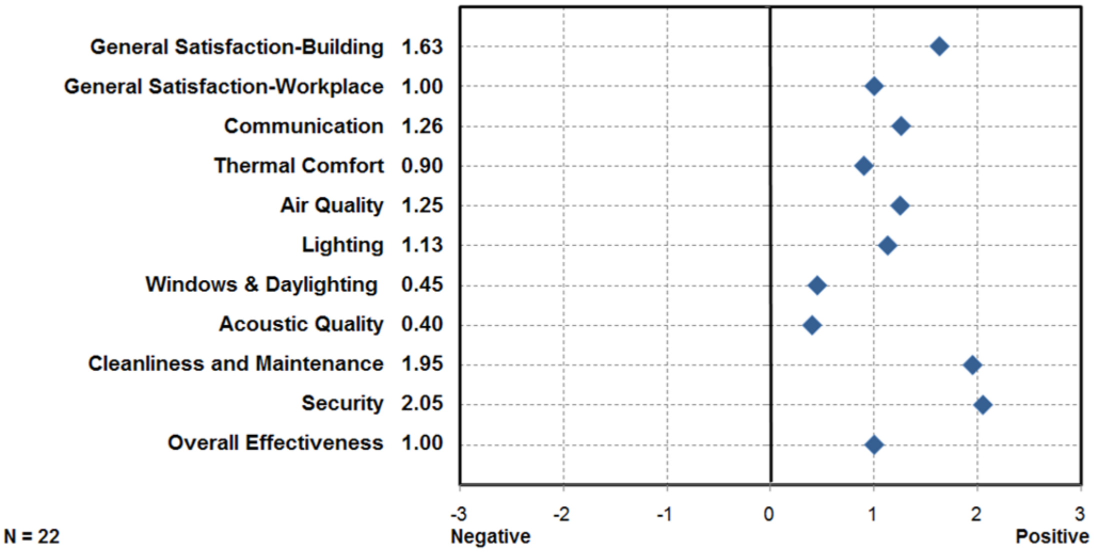
Whole Building Performance

The Davenport Courthouse operating costs are lower than the industry baseline for water, energy, grounds, and waste costs. The general maintenance, and janitorial costs are higher the industry baseline. Overall, the building costs less to operate than a baseline building. Because parts of the facility are still original (dating back to 1933) and the building flooded in April 2006, maintenance and janitorial cost could be expected to be more than industry baseline.

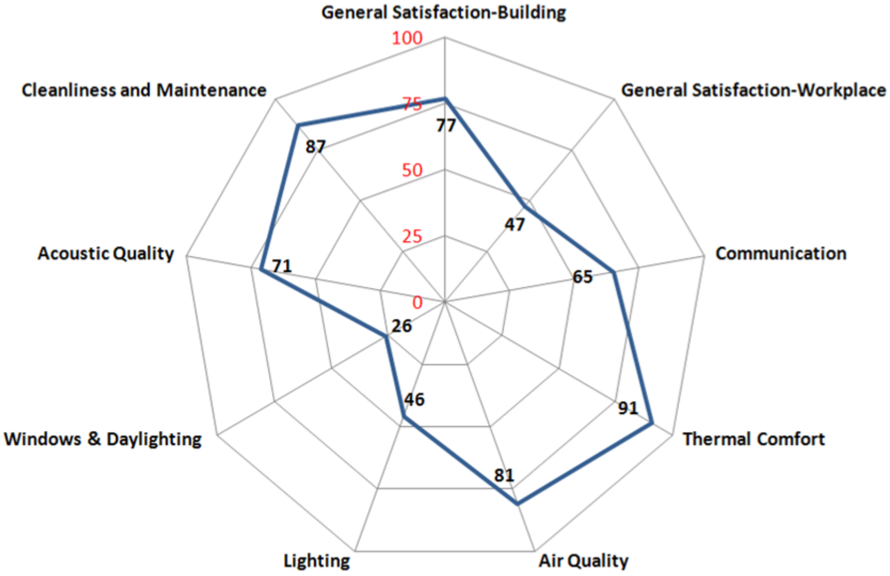


Occupant Satisfaction Survey

All 45 of the Davenport Federal Building occupants were surveyed and 22 responded. All of the main survey categories had positive average scores.

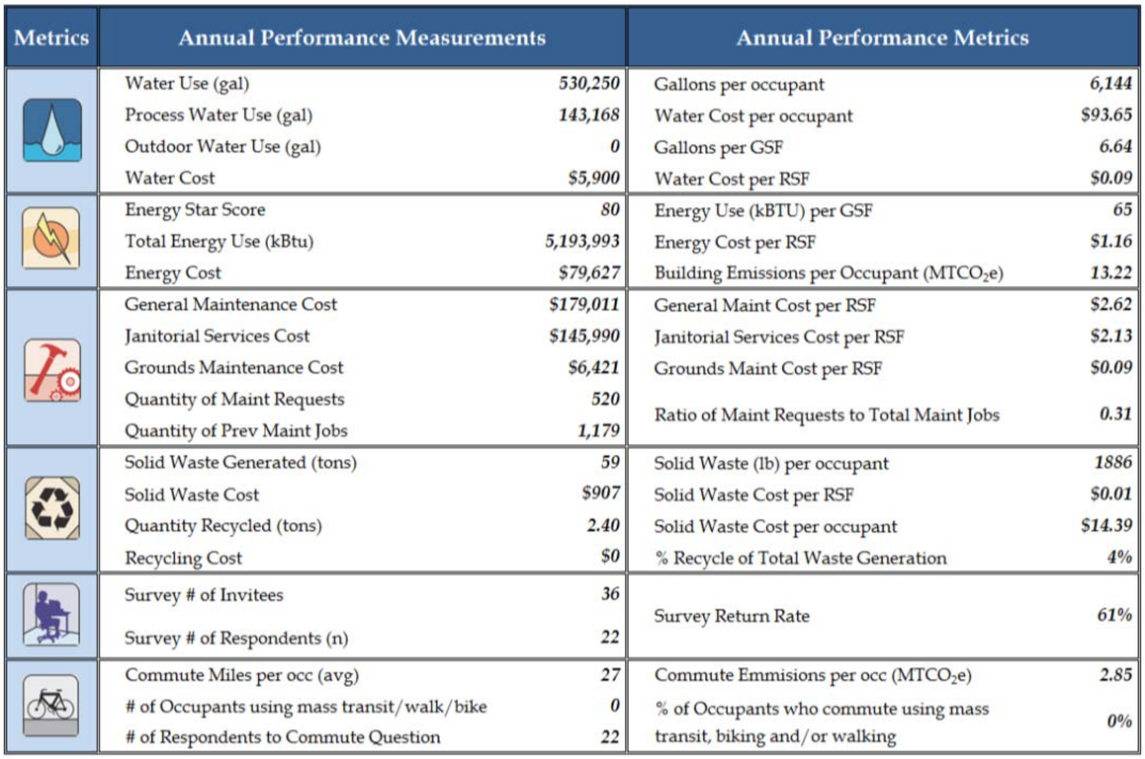


The results indicated that the occupants of the Davenport Courthouse are generally more satisfied with their building than occupants in the CBE baseline (77th percentile). Lighting quality, general satisfaction with the workplace, and windows and daylighting scored below the 50th percentile of the CBE buildings surveyed. Acoustic quality, thermal comfort, cleanliness and maintenance, and air quality all scored above the 50th percentile.



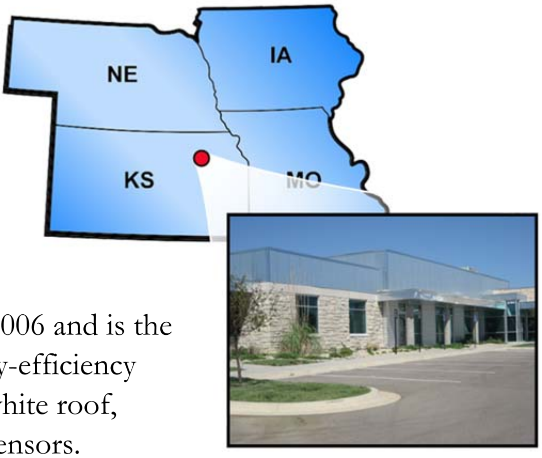
Performance Data Summary

The research team collected, normalized, and compared whole building performance data for the Davenport Courthouse to industry baselines. The following table summarizes the annual performance data collected and normalized. The facility uses water-cooled chillers for its air-conditioning system; therefore, the cooling tower water use was estimated using the "rule-of-thumb" that 27% of total water use is process water.



Metrics	Annual Performance Measurements		Annual Performance Metrics	
	Water Use (gal)	*530,250*	Gallons per occupant	*6,144*
	Process Water Use (gal)	*143,168*	Water Cost per occupant	*$93.65*
	Outdoor Water Use (gal)	*0*	Gallons per GSF	*6.64*
	Water Cost	*$5,900*	Water Cost per RSF	*$0.09*
	Energy Star Score	*80*	Energy Use (kBTU) per GSF	*65*
	Total Energy Use (kBtu)	*5,193,993*	Energy Cost per RSF	*$1.16*
	Energy Cost	*$79,627*	Building Emissions per Occupant ($MTCO_2e$)	*13.22*
	General Maintenance Cost	*$179,011*	General Maint Cost per RSF	*$2.62*
	Janitorial Services Cost	*$145,990*	Janitorial Services Cost per RSF	*$2.13*
	Grounds Maintenance Cost	*$6,421*	Grounds Maint Cost per RSF	*$0.09*
	Quantity of Maint Requests	*520*	Ratio of Maint Requests to Total Maint Jobs	*0.31*
	Quantity of Prev Maint Jobs	*1,179*		
	Solid Waste Generated (tons)	*59*	Solid Waste (lb) per occupant	*1886*
	Solid Waste Cost	*$907*	Solid Waste Cost per RSF	*$0.01*
	Quantity Recycled (tons)	*2.40*	Solid Waste Cost per occupant	*$14.39*
	Recycling Cost	*$0*	% Recycle of Total Waste Generation	*4%*
	Survey # of Invitees	*36*	Survey Return Rate	*61%*
	Survey # of Respondents (n)	*22*		
	Commute Miles per occ (avg)	*27*	Commute Emmisions per occ ($MTCO_2e$)	*2.85*
	# of Occupants using mass transit/walk/bike	*0*	% of Occupants who commute using mass transit, biking and/or walking	*0%*
	# of Respondents to Commute Question	*22*		

Manhattan Federal Building



Description

The USDA Service Center in was completed in 2006 and is the smallest building in the study. Some of the energy-efficiency features in the building include a well-insulated white roof, efficient lighting, heat recovery, and occupancy sensors.

The landscape includes low water buffalo grass with native prairie grasses around the perimeter of the parking lot. There have been challenges with erosion of the buffalo grass and invasive weeds in the prairie. The buffalo grass has been re-seeded several times. Some green cleaning products are being used, but not all products would have been considered "green." The building has a waterless urinal and low flow fixtures.

Metrics	USDA Service Center	
	Building Location	*3705 Miller Manhattan Kansas 66503-7600*
	Building Function	*Federal Building*
	Project Type	*New Construction*
	Design Certification	*LEED-NC Silver*
	Year Built	*2006*
	# of Floors	*1*
	Gross Square Foot	*13,500*
	Rentable Square Foot	*12,262*
	Usable Square Foot	*10,800*
	Weekly Operating Hours	*60*
	Regular Occupants	*28*
	Average Daily Visitors (FTE)	*2*
	Electronic Equipment	*35*
	Site Cost	*$361,333*
	Design Cost	*N/A*
	Construction Cost	*$1,989,400*
	Management & Inspection	*-*
	Total Cost	*$2,350,733*

Each building in the study had operational highlights and potential opportunities for improvement. Although it was not the focus of this study to investigate and/or document operational highlights and opportunities, the research team observed the following:

- High levels of humidity were cited as a frequent complaint of the occupants. The set-back on the system had been overridden to condition the space during unoccupied hours. Building management has a contract in place to modify the HVAC system to address these problems. Recommissiong of the HVAC equipment and controls is recommended after modifications are complete.

- During the site visit, researchers noticed that the occupants had their shades closed to control for glare from the windows. Most of the lights were on in these spaces, not taking full advantage of the daylighting. Building management may want to consider installing shading devices that allow some of the light through the material.

Certifications

LEED® - NC v2.2

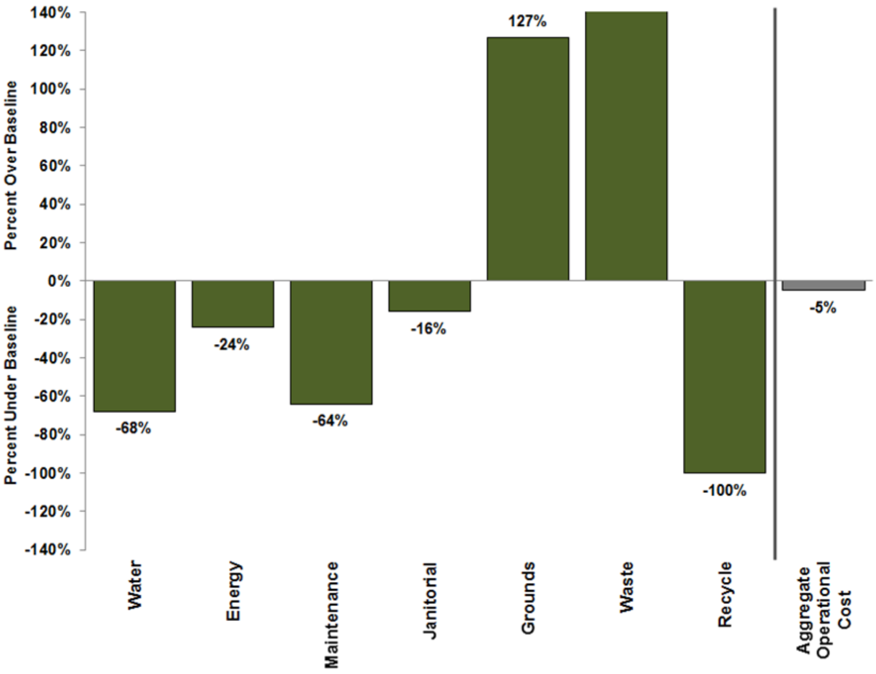
USDA Nebraska Service Center
3705 Miller Parkway, Manhattan, Kansas 66503-7600

Silver	**33 Points**
Sustainable Sites	**5/14**
Water Efficiency	**4/5**
Energy & Atmosphere	**2/17**
Materials & Resources	**4/13**
Indoor Environmental Quality	**13/15**
Innovation & Design	**5/5**

Certified: 26-32 points, **Silver:** 33-38 points, **Gold:** 39-51 points, **Platinum:** 52-69 points

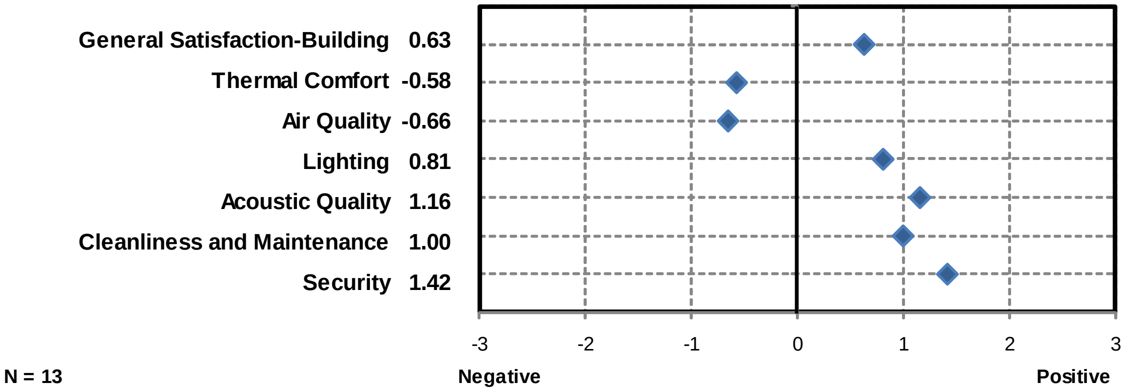
Whole Building Performance

The USDA Service Center operating costs are lower than the industry baseline for water, energy, general maintenance, and janitorial costs. The grounds maintenance, waste, and recycling costs are higher than the industry baseline. Overall, the building costs less to operate than a baseline building.

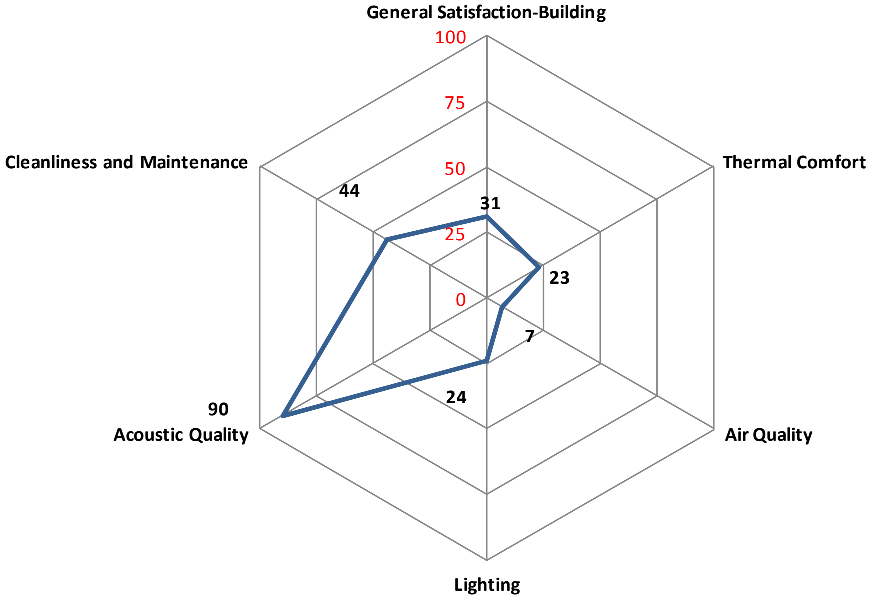


Occupant Satisfaction Survey

Occupants in the USDA Service Center occupants were surveyed by GSA in 2006 and 13 responded. A comparison of questions between the GSA survey and the CBE survey was made, and for available categories the values were translate to the CBE scale and are shown below.

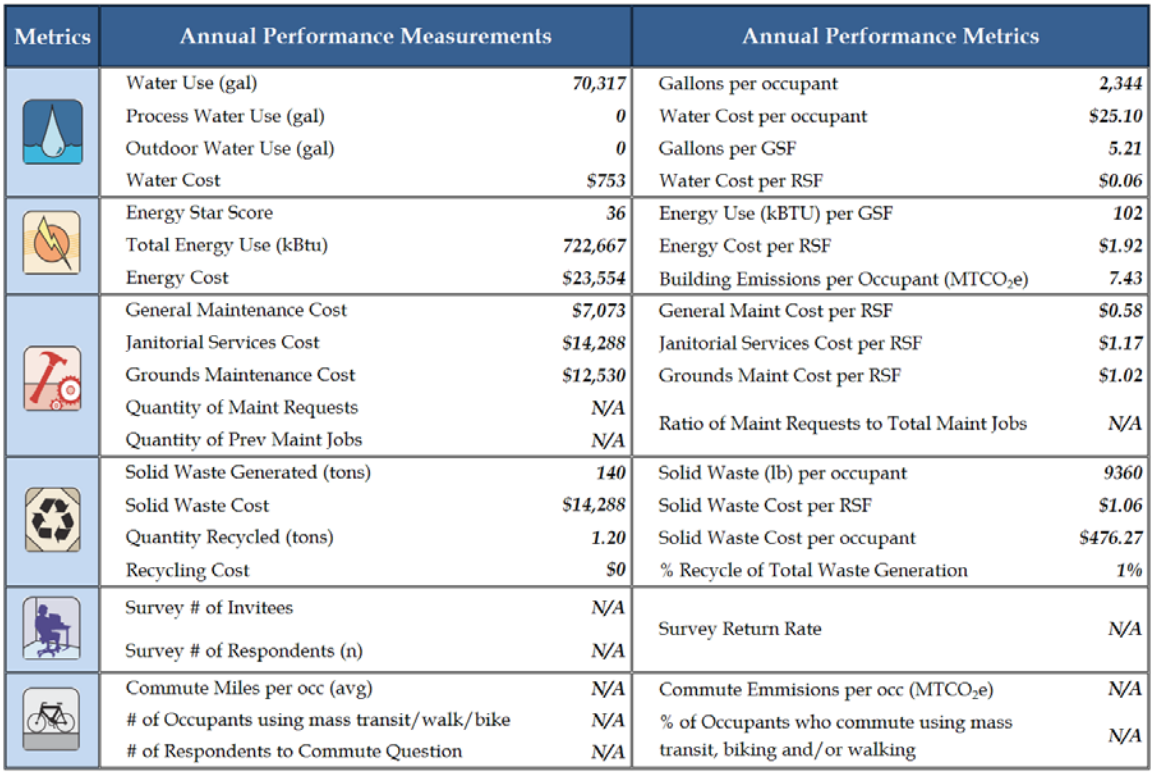


The results indicated that the occupants of the USDA Service Center occupants are generally less satisfied with their building than occupants in the CBE baseline (31st percentile). Thermal comfort, cleanliness and maintenance, air quality, lighting quality, and general satisfaction scored below the 50th percentile of the CBE buildings surveyed. Acoustic quality scored in the 90th percentile, one of the highest scoring buildings in the study.



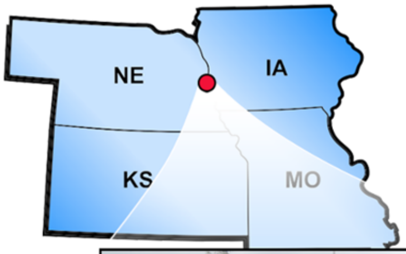
Performance Data Summary

The research team collected, normalized, and compared whole building performance data for the USDA Service Center to industry baselines. The following table summarizes the annual performance data collected and normalized.



Metrics	Annual Performance Measurements		Annual Performance Metrics	
💧	Water Use (gal)	70,317	Gallons per occupant	2,344
	Process Water Use (gal)	0	Water Cost per occupant	$25.10
	Outdoor Water Use (gal)	0	Gallons per GSF	5.21
	Water Cost	$753	Water Cost per RSF	$0.06
⚡	Energy Star Score	36	Energy Use (kBTU) per GSF	102
	Total Energy Use (kBtu)	722,667	Energy Cost per RSF	$1.92
	Energy Cost	$23,554	Building Emissions per Occupant (MTCO$_2$e)	7.43
🔨	General Maintenance Cost	$7,073	General Maint Cost per RSF	$0.58
	Janitorial Services Cost	$14,288	Janitorial Services Cost per RSF	$1.17
	Grounds Maintenance Cost	$12,530	Grounds Maint Cost per RSF	$1.02
	Quantity of Maint Requests	N/A	Ratio of Maint Requests to Total Maint Jobs	N/A
	Quantity of Prev Maint Jobs	N/A		
♻	Solid Waste Generated (tons)	140	Solid Waste (lb) per occupant	9360
	Solid Waste Cost	$14,288	Solid Waste Cost per RSF	$1.06
	Quantity Recycled (tons)	1.20	Solid Waste Cost per occupant	$476.27
	Recycling Cost	$0	% Recycle of Total Waste Generation	1%
	Survey # of Invitees	N/A	Survey Return Rate	N/A
	Survey # of Respondents (n)	N/A		
🚲	Commute Miles per occ (avg)	N/A	Commute Emmisions per occ (MTCO$_2$e)	N/A
	# of Occupants using mass transit/walk/bike	N/A	% of Occupants who commute using mass transit, biking and/or walking	N/A
	# of Respondents to Commute Question	N/A		

Omaha DHS Federal Building



Description

The Omaha Department of Homeland Security (DHS) Federal Building was designed to accommodate the varying needs of multiple DHS agencies and is the central facility for all immigration services.

The LEED Gold certified building uses a ground source heat pump system, and in combination with the building envelope and daylight-harvesting system, the building energy model predicted a 66% energy reduction over ASHRAE 90.1-1999. Water efficiency features include a rainwater-harvesting system, and low-flow and auto-flow lavatory fixtures. The building recently won the 2007 American Council of Engineering Award for its design.

Metrics	DHS Citizenship & Immigration Services	
	Building Location	*1717 Avenue H Omaha* *Nebraska 68110-2752*
	Building Function	*Federal Building*
	Project Type	*New Construction*
	Design Certification	*LEED-NC Gold*
	Year Built	*2005*
	# of Floors	*1*
	Gross Square Foot	*86,000*
	Rentable Square Foot	*73,459*
	Usable Square Foot	*64,549*
	Weekly Operating Hours	*112*
	Regular Occupants	*65*
	Average Daily Visitors (FTE)	*295*
	Electronic Equipment	*80*
$	Site Cost	*N/A*
	Design Cost	*N/A*
	Construction Cost	*N/A*
	Management & Inspection	*N/A*
	Total Cost	*N/A*

The majority of the building square footage is devoted to detention, courthouse, public, or unoccupied space. The occupied office portion of the building consumes approximately 40% of the gross square footage.

Each building in the study had operational highlights and potential opportunities for improvement. Although it was not the focus of this study to investigate and/or document operational highlights and opportunities, the research team observed:

- Erosion from the construction fill and clogged filters from the roof runoff have resulted in maintenance challenges with the rainwater-harvesting system. Investigating strategies to address the current issues and communicating the lessons learned from this operations challenge will improve future implementations.

- The ground source heat pump system (GSHP) is innovative as well, resulting in a low energy use intensity for the building. Connecting the high level of satisfaction with the building's thermal comfort (89th percentile on the CBE Survey) enhances that success. Communicating this operational success improves the chances of the GSHP technology being implemented effectively on future building projects.

Certifications

LEED® - NC v2.1

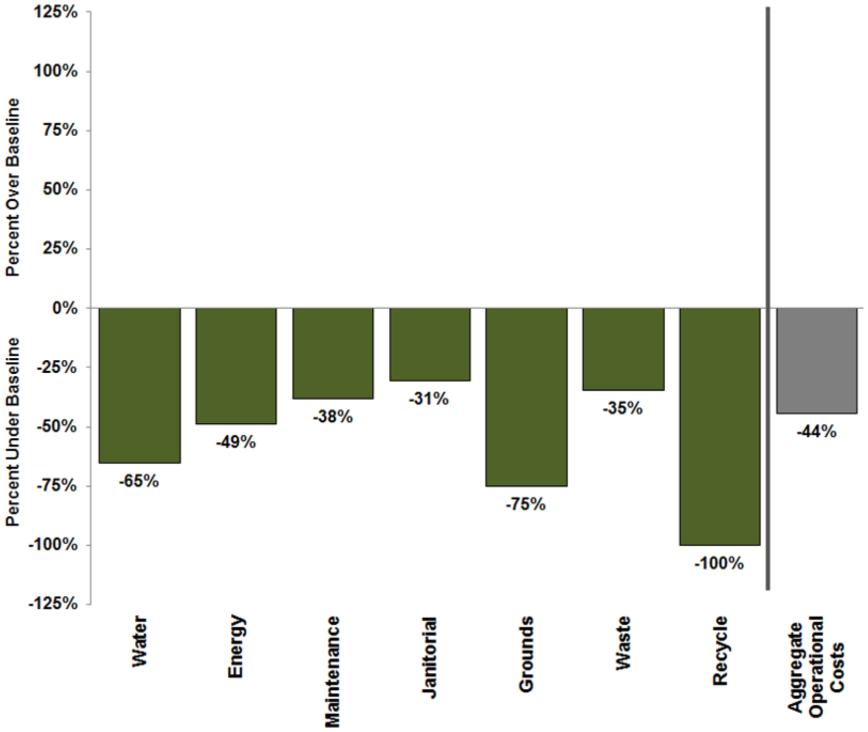
DHS Citizenship & Immigration Services
1717 Avenue H, Omaha, Nebraska 68110-2752

Gold	**42 Points**
Sustainable Sites	**6/14**
Water Efficiency	**3/5**
Energy & Atmosphere	**13/17**
Materials & Resources	**6/13**
Indoor Environmental Quality	**9/15**
Innovation & Design	**5/5**

Certified: 26-32 points, **Silver:** 33-38 points, **Gold:** 39-51 points, **Platinum:** 52-69 points

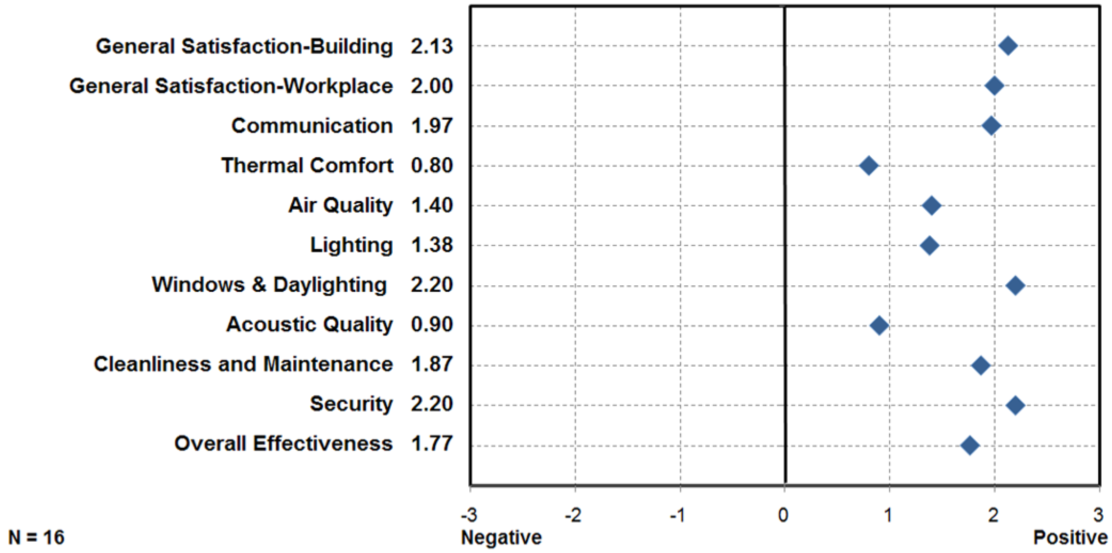
Whole Building Performance

The Omaha DHS Federal Building operating costs are lower than the industry baseline for all key metrics.

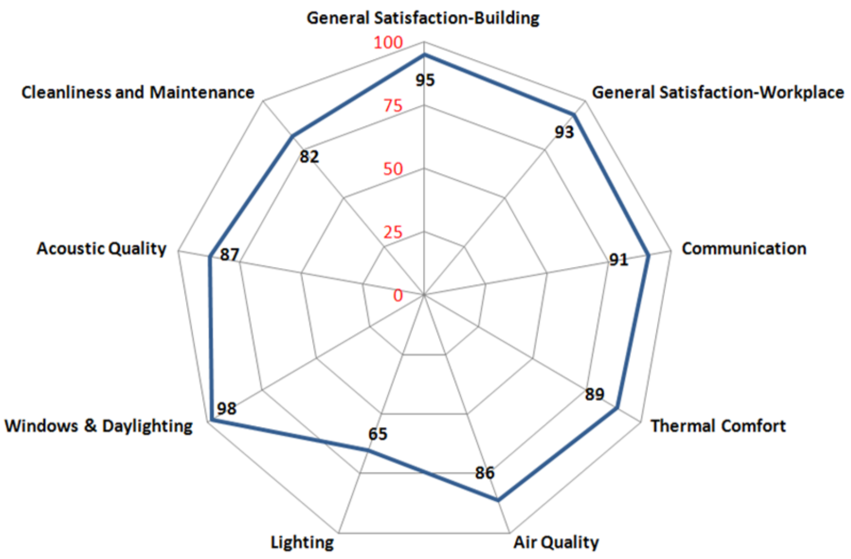


Occupant Satisfaction Survey

Of the 65 regular occupants in the Omaha DHS Federal Building, 18 were surveyed and 16 responded. It is unknown why such a small percentage of the occupants were invited to take the survey.

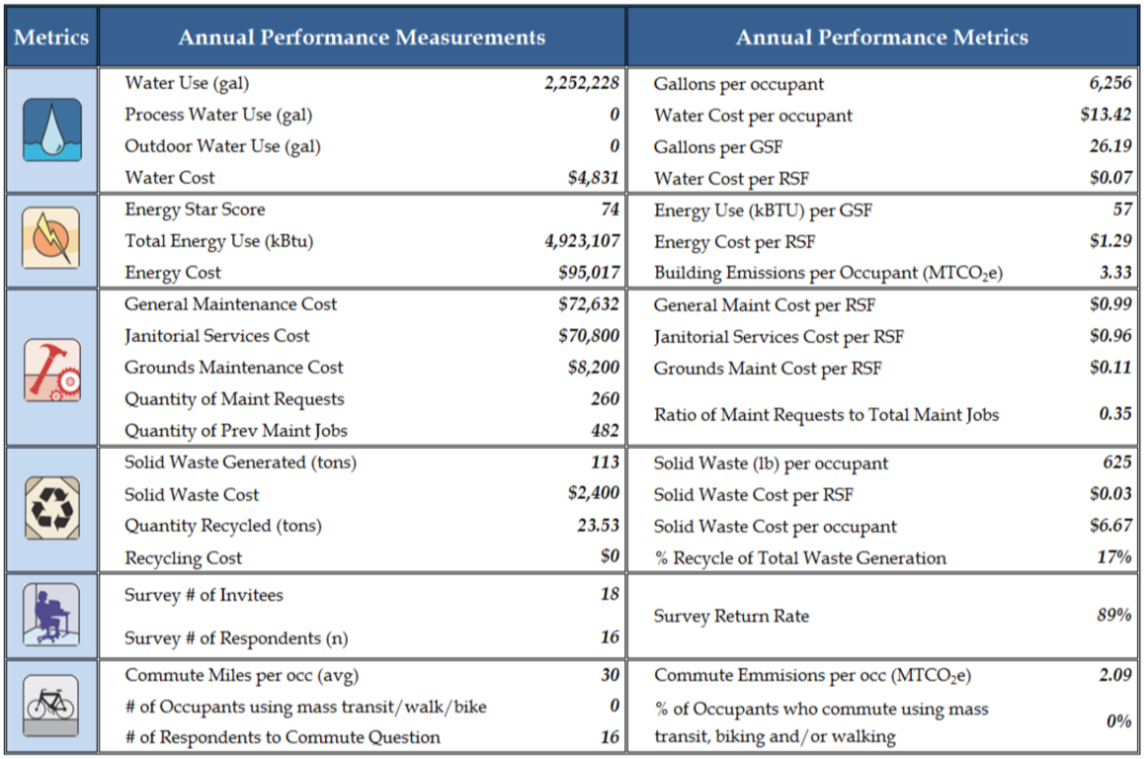


The survey results indicated that building occupants are significantly more satisfied with their building than occupants in the CBE baseline (95th percentile). Acoustic quality, air quality, cleanliness and maintenance, and thermal comfort scored in the 80th percentile or above. Occupant satisfaction with lighting scored in the 65th percentile, which is in the top half of the buildings in this study.



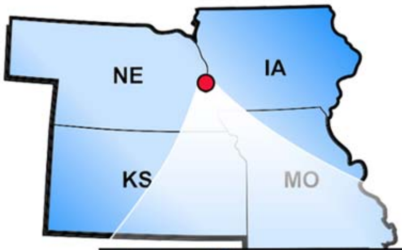
Performance Data Summary

The research team collected, normalized, and compared the whole building performance data for the Omaha DHS Federal Building to industry baselines. The following table summarizes the annual performance data that were collected and normalized. The rainwater-harvesting system that was intended for landscaping and nonpotable water use, was not functioning properly at the time of the site visit. No outdoor potable water use was estimated because researchers assumed that the system was functioning during the period of time that water use data were collected and that the system would be repaired.



Metrics	Annual Performance Measurements		Annual Performance Metrics	
	Water Use (gal)	2,252,228	Gallons per occupant	6,256
	Process Water Use (gal)	0	Water Cost per occupant	$13.42
	Outdoor Water Use (gal)	0	Gallons per GSF	26.19
	Water Cost	$4,831	Water Cost per RSF	$0.07
	Energy Star Score	74	Energy Use (kBTU) per GSF	57
	Total Energy Use (kBtu)	4,923,107	Energy Cost per RSF	$1.29
	Energy Cost	$95,017	Building Emissions per Occupant (MTCO$_2$e)	3.33
	General Maintenance Cost	$72,632	General Maint Cost per RSF	$0.99
	Janitorial Services Cost	$70,800	Janitorial Services Cost per RSF	$0.96
	Grounds Maintenance Cost	$8,200	Grounds Maint Cost per RSF	$0.11
	Quantity of Maint Requests	260	Ratio of Maint Requests to Total Maint Jobs	0.35
	Quantity of Prev Maint Jobs	482		
	Solid Waste Generated (tons)	113	Solid Waste (lb) per occupant	625
	Solid Waste Cost	$2,400	Solid Waste Cost per RSF	$0.03
	Quantity Recycled (tons)	23.53	Solid Waste Cost per occupant	$6.67
	Recycling Cost	$0	% Recycle of Total Waste Generation	17%
	Survey # of Invitees	18	Survey Return Rate	89%
	Survey # of Respondents (n)	16		
	Commute Miles per occ (avg)	30	Commute Emmisions per occ (MTCO$_2$e)	2.09
	# of Occupants using mass transit/walk/bike	0	% of Occupants who commute using mass transit, biking and/or walking	0%
	# of Respondents to Commute Question	16		

Omaha NPS Federal Building



Description

The Carl T. Curtis Midwest Regional National Park Service (NPS) Headquarters Federal Building in Omaha was built on a brownfield as part of an urban redevelopment effort. This LEED Gold-certified building uses passive solar design; daylighting for 75% of building occupants; daylight harvesting; lightshelves; high-efficiency windows; heating, ventilation, and air-conditioning (HVAC) occupancy sensors; and underfloor air distribution. Use of native and adaptive vegetation eliminated the need for irrigation water, and use of a composting toilet, waterless urinals, low-flow fixtures, and water-efficient appliances resulted in a projected reduction of 39% of potable water use.

Metrics	Carl T. Curtis NPS Midwest Regional Headquarters	
	Building Location	*601 Riverfront Omaha* *Nebraska 68102-4226*
	Building Function	*Federal Building*
	Project Type	*New Construction*
	Design Certification	*LEED-NC Gold*
	Year Built	*2004*
	# of Floors	*3*
	Gross Square Foot	*68,000*
	Rentable Square Foot	*62,772*
	Usable Square Foot	*0*
	Weekly Operating Hours	*70*
	Regular Occupants	*125*
	Average Daily Visitors (FTE)	*9*
	Electronic Equipment	*140*
$	Site Cost	*N/A*
	Design Cost	*N/A*
	Construction Cost	*$8,500,000*
	Management & Inspection	*N/A*
	Total Cost	*$27,864,000*

The building occupants are aware of the "green" building features and were involved in selecting the office furniture. To minimize materials during construction, the building has exposed concrete interior walls and beams. Operation of the facility incorporates green janitorial practices.

Each building in the study had operational highlights and potential opportunities for improvement. Although it was not the focus of this study to investigate and/or document operational highlights and opportunities, the research team observed the following:

- The acoustic quality CBE score for the Omaha NPS was the lowest of all the buildings in the study and well below the average building at the 8th percentile. In an open office layout, it is important to offer small meeting spaces for staff to schedule and conduct impromptu meetings. Identifying opportunities to increase alternative locations for staff to convene and investigating sound-masking technologies may improve the occupants' perception of the building's acoustic quality.

- Although considerable thought went into the daylighting design features, the CBE survey lighting score was below the 50th percentile. Interviews of the occupants regarding these issues may result in a more detailed understanding of how operations might be adjusted to improve occupant satisfaction.

Certifications

LEED® - NC v2.1

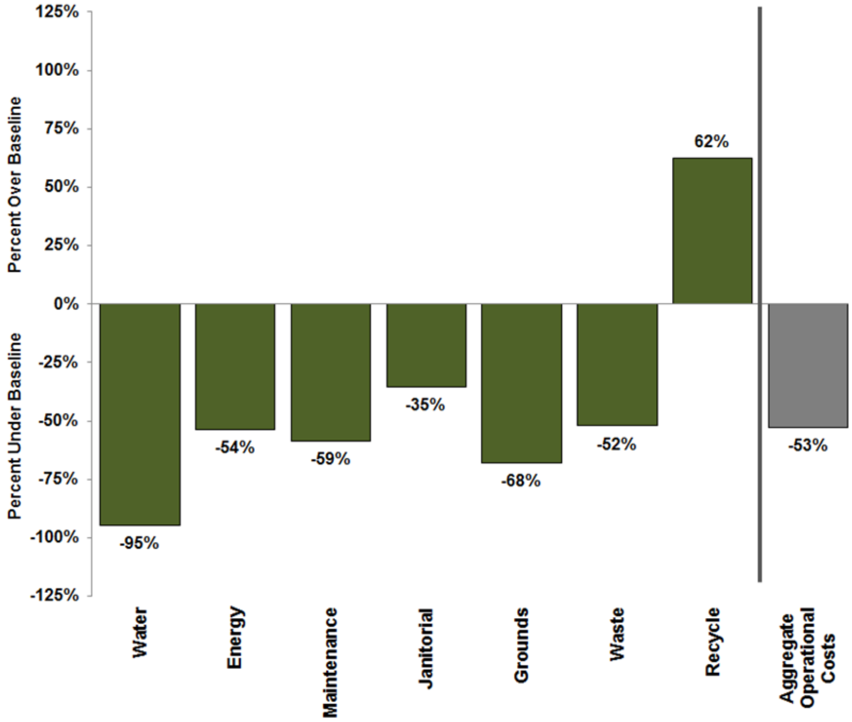
Carl T. Curtis NPS Midwest Regional Headquarters
601 Riverfront Drive, Omaha, Nebraska 68102-4226

Gold	**40 Points**
Sustainable Sites	**8/14**
Water Efficiency	**4/5**
Energy & Atmosphere	**6/17**
Materials & Resources	**6/13**
Indoor Environmental Quality	**11/15**
Innovation & Design	**5/5**

Certified: 26-32 points, **Silver:** 33-38 points, **Gold:** 39-51 points, **Platinum:** 52-69 points

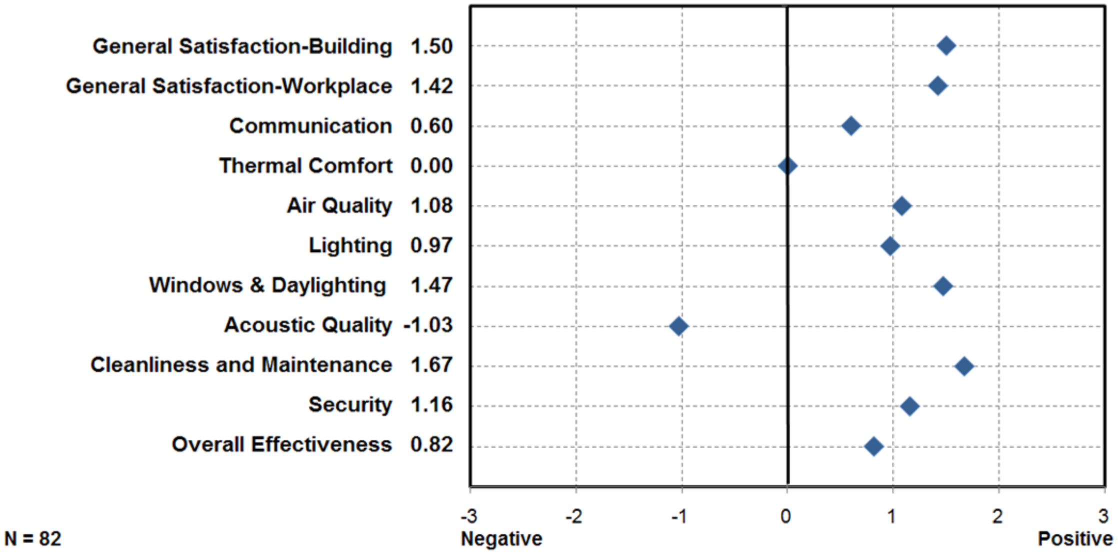
Whole Building Performance

The Omaha NPS operating costs are lower than the industry baseline for all of the metrics except recycling.

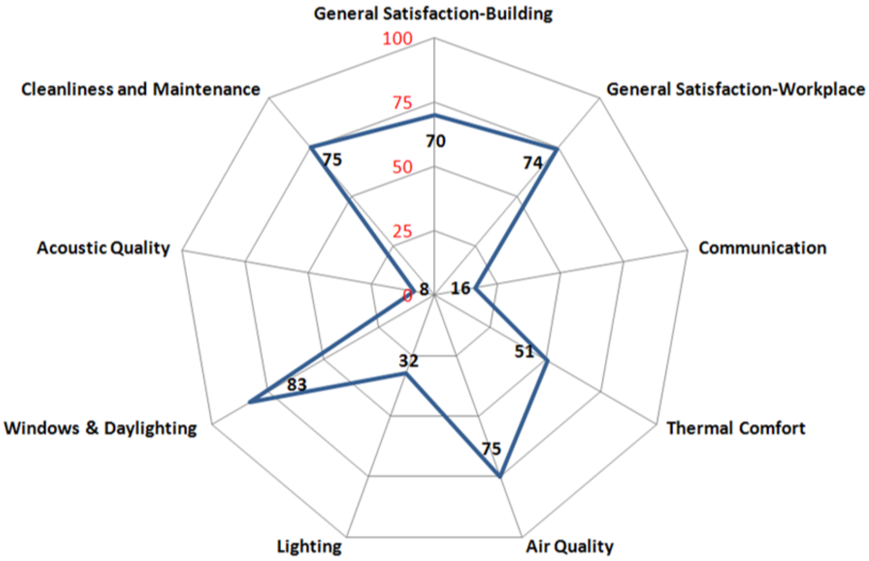


Occupant Satisfaction Survey

Of the 125 regular occupants in the Omaha NPS Federal Building, 120 were surveyed and 82 responded.



The results indicated that building occupants are more satisfied with their building than occupants in the CBE baseline (70th percentile). Acoustic quality scored at the 8th percentile of the CBE buildings database, which was the lowest score of all the buildings in the study. Lighting scored at the 32th percentile, which was one of the lower scores of the buildings in the study. Thermal comfort, air quality, and cleanliness and maintenance scored above the 50th percentile.

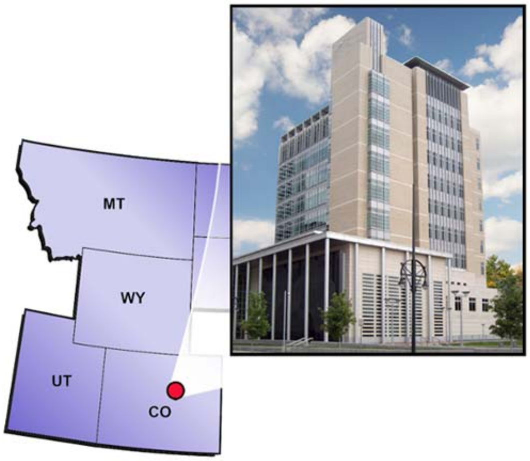


Performance Data Summary

The research team collected, normalized, and compared the whole building performance data for the Omaha NPS Federal Building to industry baselines. The following table summarizes the annual performance data collected and normalized.

Metrics	Annual Performance Measurements		Annual Performance Metrics	
	Water Use (gal)	238,629	Gallons per occupant	1,783
	Process Water Use (gal)	0	Water Cost per occupant	$4.87
	Outdoor Water Use (gal)	0	Gallons per GSF	3.51
	Water Cost	$651	Water Cost per RSF	$0.01
	Energy Star Score	82	Energy Use (kBTU) per GSF	67
	Total Energy Use (kBtu)	4,585,846	Energy Cost per RSF	$1.17
	Energy Cost	$73,214	Building Emissions per Occupant (MTCO$_2$e)	5.81
	General Maintenance Cost	$41,600	General Maint Cost per RSF	$0.66
	Janitorial Services Cost	$56,400	Janitorial Services Cost per RSF	$0.90
	Grounds Maintenance Cost	$9,050	Grounds Maint Cost per RSF	$0.14
	Quantity of Maint Requests	180	Ratio of Maint Requests to Total Maint Jobs	0.62
	Quantity of Prev Maint Jobs	109		
	Solid Waste Generated (tons)	130	Solid Waste (lb) per occupant	1937
	Solid Waste Cost	$1,500	Solid Waste Cost per RSF	$0.02
	Quantity Recycled (tons)	10.96	Solid Waste Cost per occupant	$11.21
	Recycling Cost	$1,020	% Recycle of Total Waste Generation	8%
	Survey # of Invitees	120	Survey Return Rate	68%
	Survey # of Respondents (n)	82		
	Commute Miles per occ (avg)	21	Commute Emmisions per occ (MTCO$_2$e)	1.70
	# of Occupants using mass transit/walk/bike	0	% of Occupants who commute using mass transit, biking and/or walking	0%
	# of Respondents to Commute Question	82		

Denver Courthouse



Description

The Alfred A. Arraj Courthouse is the U.S. District Courthouse of Colorado, and it houses 15 courtrooms. The Arraj Courthouse was designed using the Green Building Challenge, and recently earned LEED-EB Silver certification. The building has an underfloor air distribution system on the first floor and in the courtrooms on the second floor, occupancy sensors for HVAC and lighting in the courtrooms, indirect T-5 fluorescent lamps, photocell controls, and electronic dimming ballasts. Photovoltaic solar power panels are on the building roof, but they generate a low amount of energy.

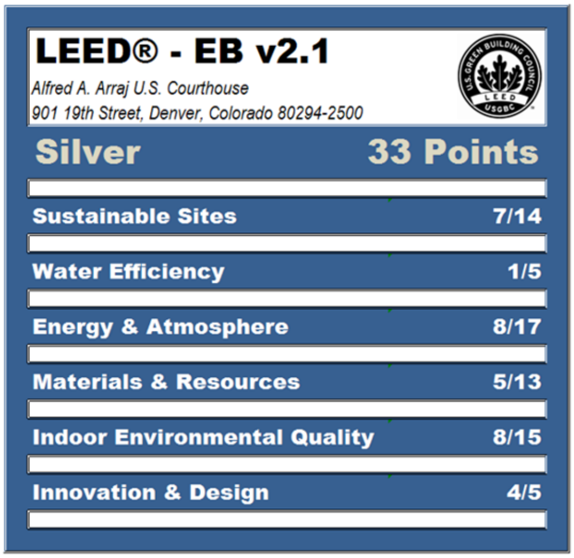
Metrics	Alfred A. Arraj U.S. Courthouse	
	Building Location	*901 19th Street Denver* *Colorado 80294-2500*
	Building Function	*Courthouse*
	Project Type	*New Construction*
	Design Certification	*Green Building Challenge, LEED-EB Silver*
	Year Built	*2002*
	# of Floors	*13*
	Gross Square Foot	*327,103*
	Rentable Square Foot	*256,718*
	Usable Square Foot	*188,142*
	Weekly Operating Hours	*70*
	Regular Occupants	*170*
	Average Daily Visitors (FTE)	*200*
	Electronic Equipment	*185*
	Site Cost	*N/A*
	Design Cost	*$4,912,000*
	Construction Cost	*$83,086,000*
	Management & Inspection	*N/A*
	Total Cost	*$99,088,000*

The Court gives its occupants passes for mass transit and despite the availability of inexpensive parking within two blocks, the occupants have a smaller CO_2-equivalent than the baseline and a smaller than would be expected based on the size of the community. The sanitary waste and recycling programs are combined with other federal buildings in the neighborhood. Currently, 900 tons of central chilled water per month must be purchased regardless of the quantity used. The values provided and used for this study were for only the quantity used, not the total purchased.

Each building in the study had operational highlights and potential opportunities for improvement. Although it was not the focus of this study to investigate and/or document operational highlights and opportunities, the research team observed:

- Energy use intensity (EUI) for the Arraj Courthouse is better than the Energy Star baseline; however, the courthouse has the second highest EUI of the courthouses in the study, and its EUI is higher than expected when considered against GSA's National Baseline. Sub-metering end uses and/or performing a re-commissioning study could be used to investigate and optimize building operations.

Certifications



LEED® - EB v2.1

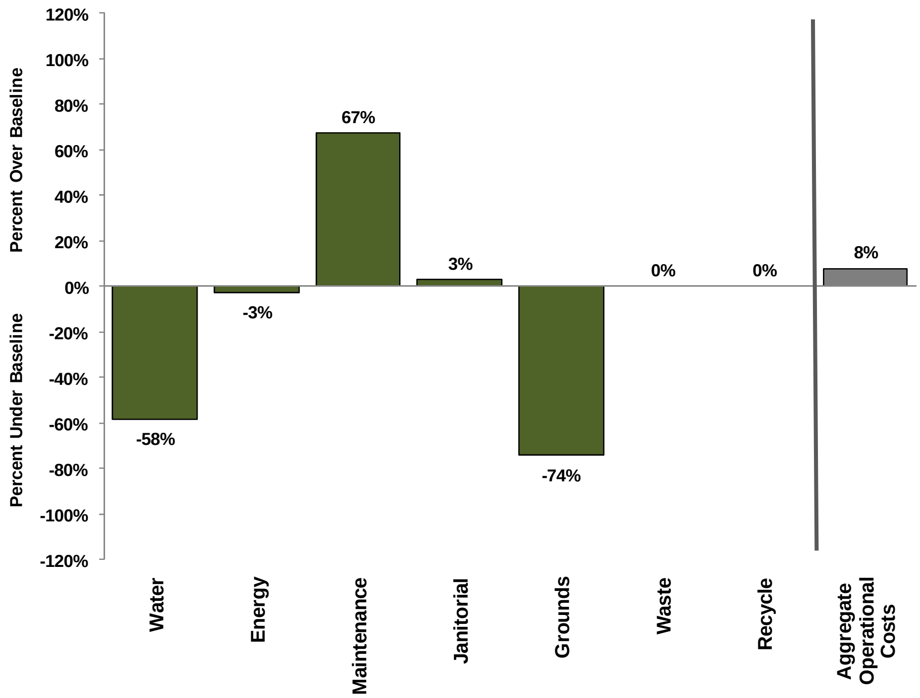
Alfred A. Arraj U.S. Courthouse
901 19th Street, Denver, Colorado 80294-2500

Silver	**33 Points**
Sustainable Sites	**7/14**
Water Efficiency	**1/5**
Energy & Atmosphere	**8/17**
Materials & Resources	**5/13**
Indoor Environmental Quality	**8/15**
Innovation & Design	**4/5**

Certified: 26-32 points, **Silver:** 33-38 points, **Gold:** 39-51 points, **Platinum:** 52-69 points

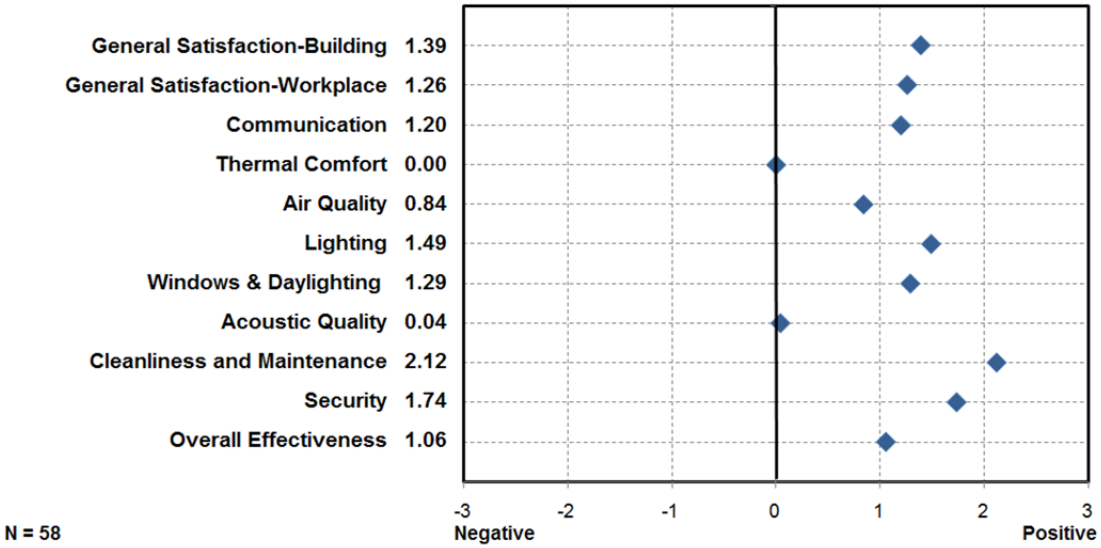
Whole Building Performance

The Arraj Courthouse operating costs are higher than the industry baseline for energy and general maintenance costs. No building-specific recycling and waste costs were available for this courthouse, because waste and recycling services are combined with other nearby buildings. Overall, the building costs more to operate than a baseline building.

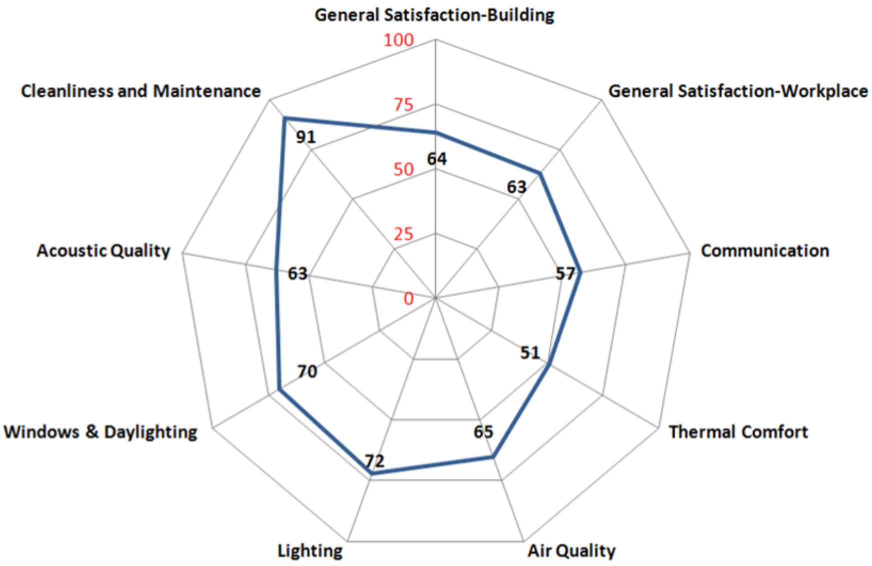


Occupant Satisfaction Survey

Of the 170 building occupants, 100 were surveyed and 58 responded. All of the main survey categories had neutral or positive average scores.



The results indicated that occupants of the Arraj Courthouse are more satisfied with their building than occupants in the CBE baseline (64th percentile). For all of the survey categories that were the primary focus of this study—acoustic quality, air quality, lighting, cleanliness and maintenance, and thermal comfort—the Arraj Courthouse scored at the 50th percentile or better.

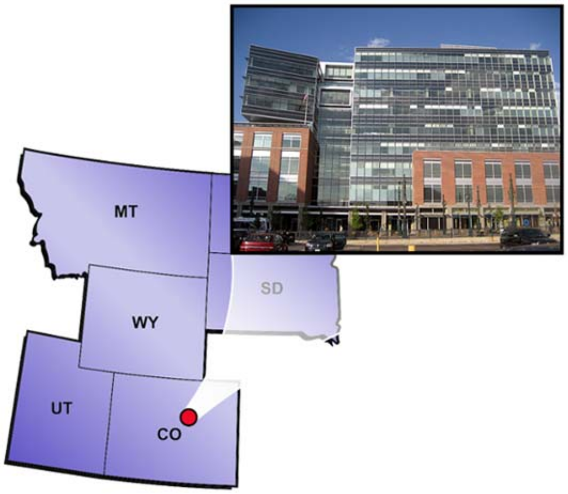


Performance Data Summary

The research team collected, normalized, and compared whole building performance data for the Arraj Courthouse to industry baselines. The following table summarizes the annual performance data collected and normalized. The facility uses evaporative cooling for its primary air-conditioning system; therefore, the evaporative cooling water use was estimated using the "rule-of-thumb" that 27% of total water use is process water.

Metrics	Annual Performance Measurements		Annual Performance Metrics	
💧	Water Use (gal)	*4,649,000*	Gallons per occupant	*9,172*
	Process Water Use (gal)	*1,255,230*	Water Cost per occupant	*$55.11*
	Outdoor Water Use (gal)	*0*	Gallons per GSF	*14.21*
	Water Cost	*$20,390*	Water Cost per RSF	*$0.08*
⚡	Energy Star Score	*70*	Energy Use (kBTU) per GSF	*98*
	Total Energy Use (kBtu)	*28,800,226*	Energy Cost per RSF	*$2.46*
	Energy Cost	*$631,891*	Building Emissions per Occupant ($MTCO_2e$)	*11.57*
🔨	General Maintenance Cost	*$643,227*	General Maint Cost per RSF	*$2.51*
	Janitorial Services Cost	*$349,560*	Janitorial Services Cost per RSF	*$1.36*
	Grounds Maintenance Cost	*$29,791*	Grounds Maint Cost per RSF	*$0.12*
	Quantity of Maint Requests	*684*	Ratio of Maint Requests to Total Maint Jobs	*0.44*
	Quantity of Prev Maint Jobs	*881*		
♻	Solid Waste Generated (tons)	*38*	Solid Waste (lb) per occupant	*208*
	Solid Waste Cost	*N/A*	Solid Waste Cost per RSF	*N/A*
	Quantity Recycled (tons)	*N/A*	Solid Waste Cost per occupant	*N/A*
	Recycling Cost	*N/A*	% Recycle of Total Waste Generation	*N/A*
	Survey # of Invitees	*100*	Survey Return Rate	*58%*
	Survey # of Respondents (n)	*58*		
🚲	Commute Miles per occ (avg)	*24*	Commute Emmisions per occ ($MTCO_2e$)	*1.12*
	# of Occupants using mass transit/walk/bike	*31*	% of Occupants who commute using mass transit, biking and/or walking	*53%*
	# of Respondents to Commute Question	*58*		

Denver Federal Building



Description

The EPA Region 8 Headquarters was built on a brownfield in the Denver Lower Downtown Historic District as part of an urban redevelopment effort. The proximity to public transport has enabled nearly 90% of the occupants surveyed to take some type of alternative transportation to their workplace.

This LEED-NC Gold-certified and Energy Star rated building uses a number of strategies contributing to a predicted 35% energy savings from an ASHRAE 90.1 1999 energy model; daylighting for 85% of occupied spaces, daylighting dimmers, occupancy sensors, and underfloor air distribution HVAC system.

Metrics	EPA Region 8 Headquarters	
	Building Location	*1595 Wynkoop Street Denver Colorado 80202-9999*
	Building Function	*Federal Building*
	Project Type	*New Construction*
	Design Certification	*LEED-NC Gold, Energy Star 2008 (96)*
	Year Built	*2006*
	# of Floors	*9*
	Gross Square Foot	*301,292*
	Rentable Square Foot	*248,849*
	Usable Square Foot	*0*
	Weekly Operating Hours	*68*
	Regular Occupants	*922*
	Average Daily Visitors (FTE)	*71*
	Electronic Equipment	*1,289*
$	Site Cost	*N/A*
	Design Cost	*N/A*
	Construction Cost	*$90,400,000*
	Management & Inspection	*N/A*
	Total Cost	*$90,400,000*

With respect to water, use of native and adaptive vegetation eliminated the need for irrigation water for landscaping. 51% of the roof is covered with a modular green roof system planted with sedum, and a portion of remainder is covered by 48 solar panels that generates 10kW at peak output.

Each building in the study had operational highlights and potential opportunities for improvement. Although it was not the focus of this study to investigate and/or document operational highlights and opportunities, the research team observed:

- Although considerable thought went into the daylighting design features, the CBE survey lighting score was below the 50th percentile. Interviews of the occupants regarding these issues may result in a more detailed understanding of how operations might be adjusted to improve occupant satisfaction.

Certifications

LEED® - NC v2.1

EPA Region 8 Headquarters
1595 Wynkoop Street, Denver, Colorado 80202-9999

Gold	**40 Points**
Sustainable Sites	**9/14**
Water Efficiency	**4/5**
Energy & Atmosphere	**9/17**
Materials & Resources	**7/13**
Indoor Environmental Quality	**6/15**
Innovation & Design	**5/5**

Certified: 26-32 points, **Silver:** 33-38 points, **Gold:** 39-51 points, **Platinum:** 52-69 points

ENERGY STAR

96

Bulding Name

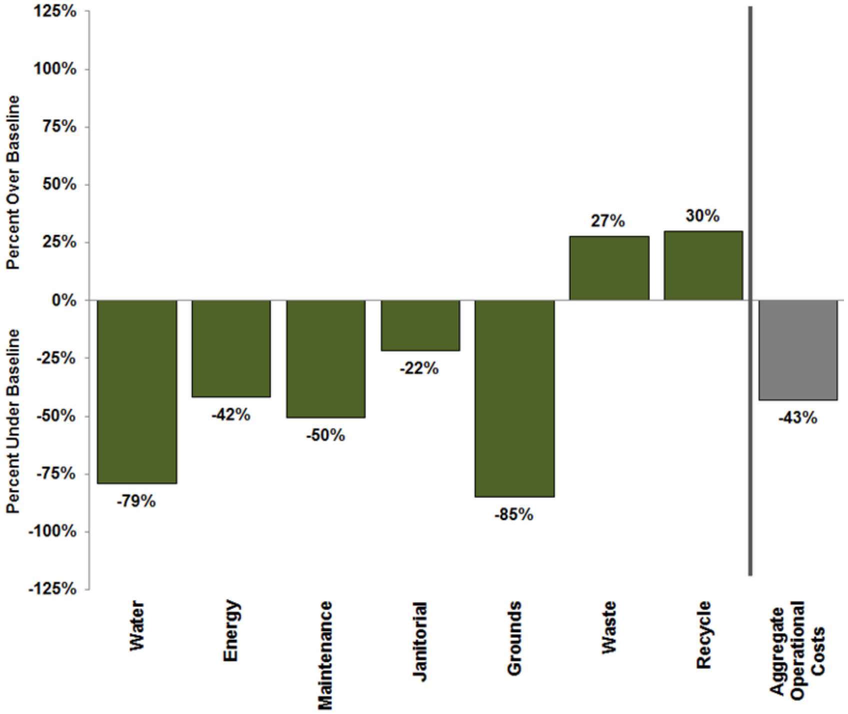
Denver (L) FB

Year Certified

2008

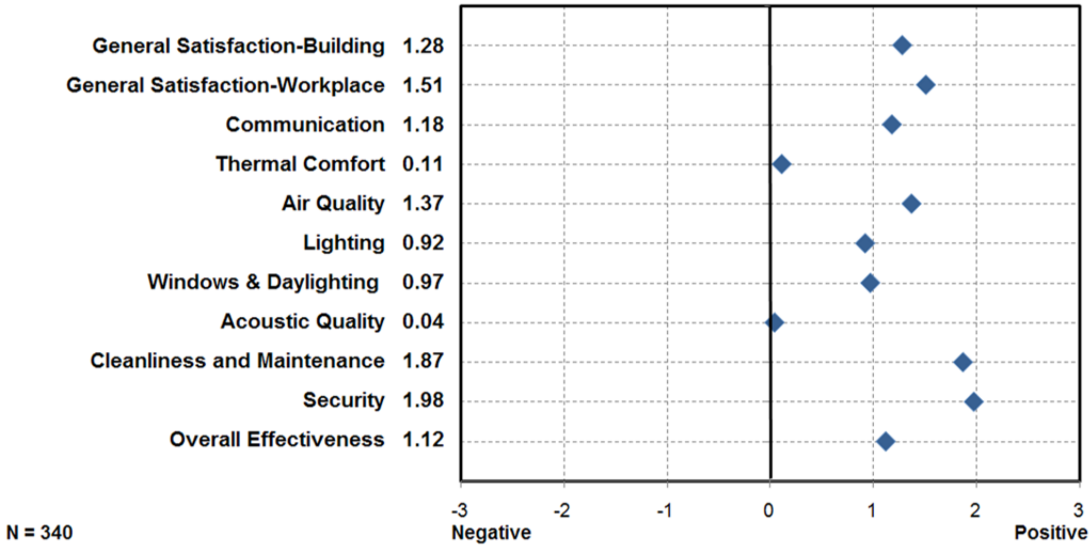
Whole Building Performance

The EPA Region 8 Headquarters operating costs are lower than the industry baseline for all metrics except waste and recycling.

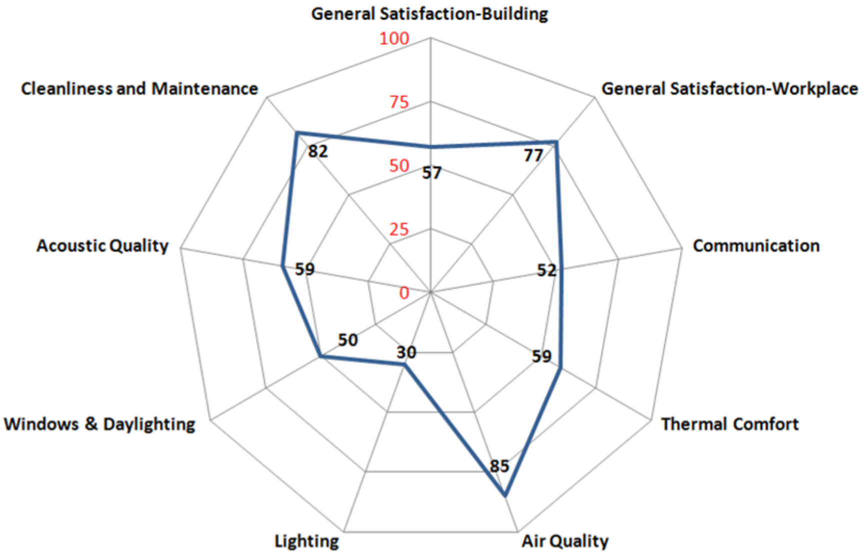


Occupant Satisfaction Survey

All 922 of the EPA Region 8 Headquarters occupants were surveyed and 340 responded. All of the main survey categories had positive average scores.

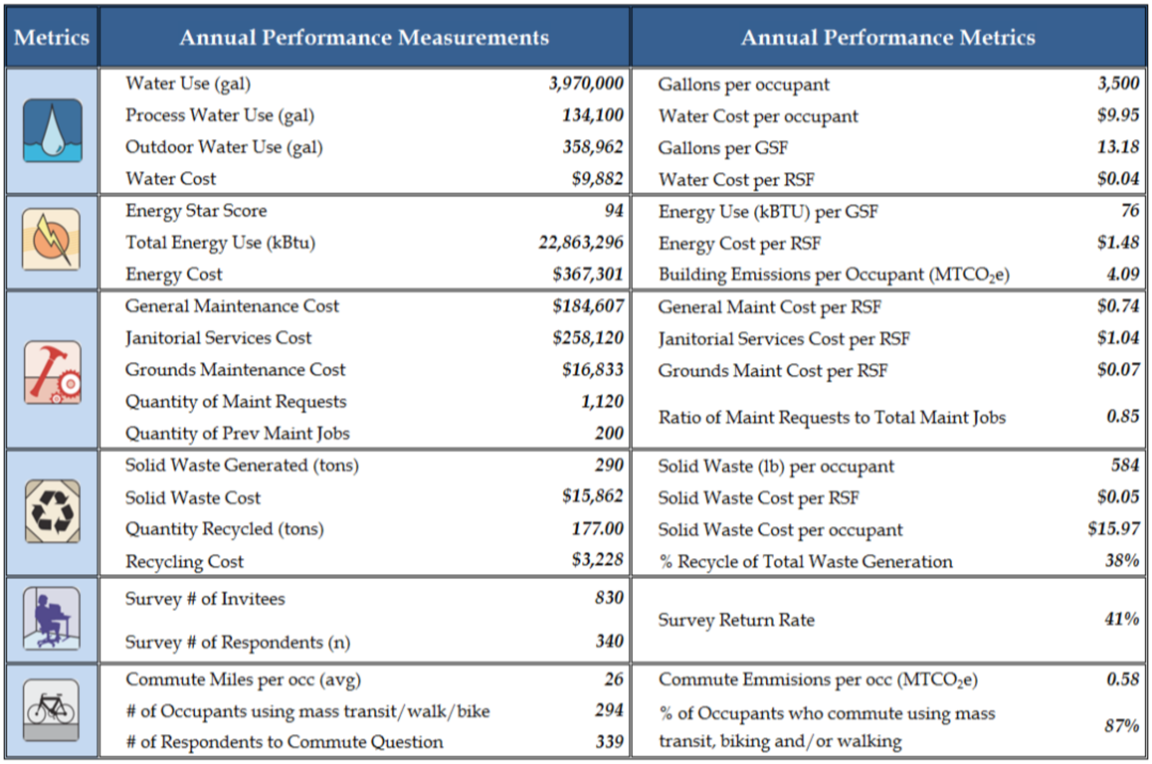


When the Denver EPA Federal Building survey responses are compared with the CBE database we see the occupants are more satisfied with their building (57th percentile). Lighting was the only metric below the median (30th percentile). For the other survey categories that were the primary focus of this study—acoustic quality, air quality, cleanliness and maintenance, and thermal comfort—the EPA Region 8 Headquarters scored above, or at, the 50th percentile. Meaning the occupants were more satisfied with the building than those in the CBE baseline.



Performance Data Summary

The research team collected, normalized, and compared whole building performance data for the EPA Region 8 Headquarters to industry baselines. The following table summarizes the annual performance data collected and normalized. This is the only facility in the study that consistently records the potable water used for the water-cooled chillers and to irrigate the green roof.



Metrics	Annual Performance Measurements		Annual Performance Metrics	
💧	Water Use (gal)	3,970,000	Gallons per occupant	3,500
	Process Water Use (gal)	134,100	Water Cost per occupant	$9.95
	Outdoor Water Use (gal)	358,962	Gallons per GSF	13.18
	Water Cost	$9,882	Water Cost per RSF	$0.04
⚡	Energy Star Score	94	Energy Use (kBTU) per GSF	76
	Total Energy Use (kBtu)	22,863,296	Energy Cost per RSF	$1.48
	Energy Cost	$367,301	Building Emissions per Occupant ($MTCO_2e$)	4.09
🔨	General Maintenance Cost	$184,607	General Maint Cost per RSF	$0.74
	Janitorial Services Cost	$258,120	Janitorial Services Cost per RSF	$1.04
	Grounds Maintenance Cost	$16,833	Grounds Maint Cost per RSF	$0.07
	Quantity of Maint Requests	1,120	Ratio of Maint Requests to Total Maint Jobs	0.85
	Quantity of Prev Maint Jobs	200		
♻	Solid Waste Generated (tons)	290	Solid Waste (lb) per occupant	584
	Solid Waste Cost	$15,862	Solid Waste Cost per RSF	$0.05
	Quantity Recycled (tons)	177.00	Solid Waste Cost per occupant	$15.97
	Recycling Cost	$3,228	% Recycle of Total Waste Generation	38%
👤	Survey # of Invitees	830	Survey Return Rate	41%
	Survey # of Respondents (n)	340		
🚲	Commute Miles per occ (avg)	26	Commute Emmisions per occ ($MTCO_2e$)	0.58
	# of Occupants using mass transit/walk/bike	294	% of Occupants who commute using mass transit, biking and/or walking	87%
	# of Respondents to Commute Question	339		

Lakewood Federal Building

Description

The Lakewood Department of Transportation (DOT) Federal Building is a leased facility designed by Opus Architects and Engineers, Incorporated. This LEED Silver-certified building incorporated low-emitting materials, adhesives, and sealants; daylight and views in 91% of regularly occupied spaces; and recycled content materials. Seventy-two percent of the building materials were manufactured locally, and 41% of the materials were harvested locally. Additional features include light and motion sensors, air-side economizers, and carbon dioxide (CO_2) monitors. Although the building is located on a large plot of land in a suburban community outside of Denver, a portion of the landscape is xeriscape.

Metrics	DOT Colorado Field Office	
	Building Location	*12300 W. Dakota Lakewood Colorado 80228-2583*
	Building Function	*Federal Building*
	Project Type	*New Construction*
	Design Certification	*LEED-NC Silver*
	Year Built	*2004*
	# of Floors	*3*
	Gross Square Foot	*128,342*
	Rentable Square Foot	*122,225*
	Usable Square Foot	*88,901*
	Weekly Operating Hours	*70*
	Regular Occupants	*318*
	Average Daily Visitors (FTE)	*18*
	Electronic Equipment	*383*
$	Site Cost	*N/A*
	Design Cost	*N/A*
	Construction Cost	*N/A*
	Management & Inspection	*N/A*
	Total Cost	*$25,108,301*

All building occupants received a booklet about the design and operations of the building. The building was designed to house 400 occupants and currently has 318 occupants.

Each building in the study had operational highlights and potential opportunities for improvement. Although it was not the focus of this study to investigate and/or document operational highlights and opportunities, the research team observed:

- The formal system for tracking service calls is not being regularly utilized. Using the service call tracking system is recommended to identify maintenance trends, and to anticipate future maintenance needs.

- Based on the CBE survey results, issues appear to exist with acoustics, air quality, and lighting. Interviews of occupants regarding these issues may result in a more detailed understanding of how operations might be adjusted to improve occupant satisfaction.

Certifications

LEED® - NC v2.1

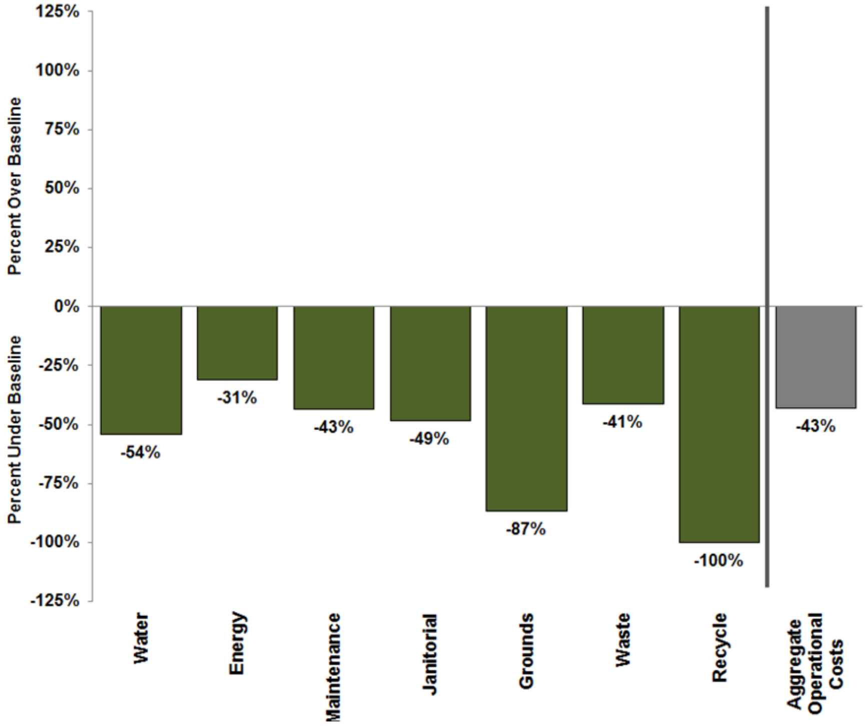
DOT Colorado Field Office
12300 W. Dakota Ave., Lakewood, Colorado 80228-2583

Silver	**35 Points**
Sustainable Sites	**8/14**
Water Efficiency	**1/5**
Energy & Atmosphere	**8/17**
Materials & Resources	**6/13**
Indoor Environmental Quality	**7/15**
Innovation & Design	**5/5**

Certified: 26-32 points, **Silver:** 33-38 points, **Gold:** 39-51 points, **Platinum:** 52-69 points

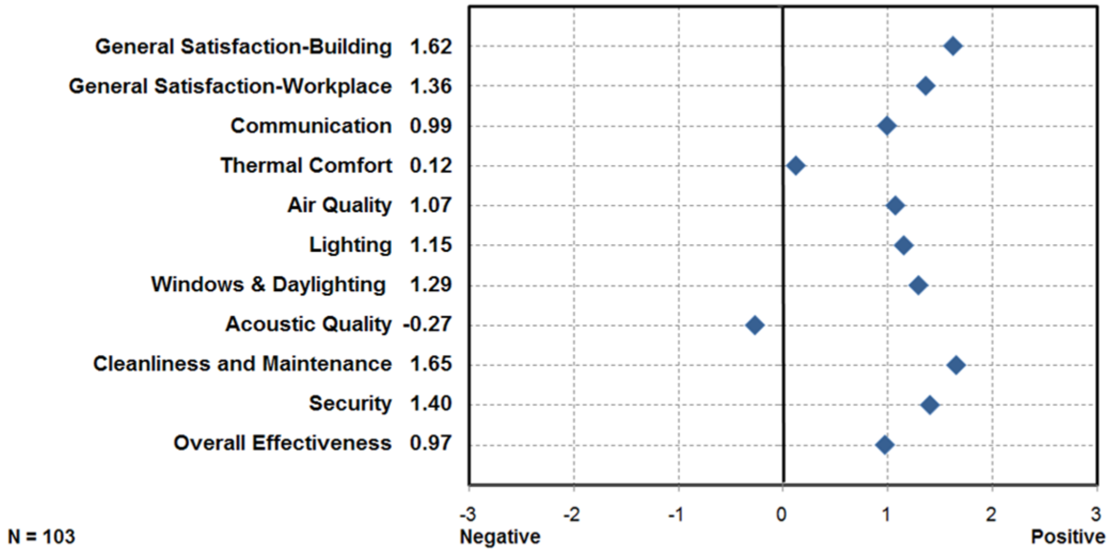
Whole Building Performance

The Lakewood Federal Building operating costs are lower than the industry baseline for all metrics.

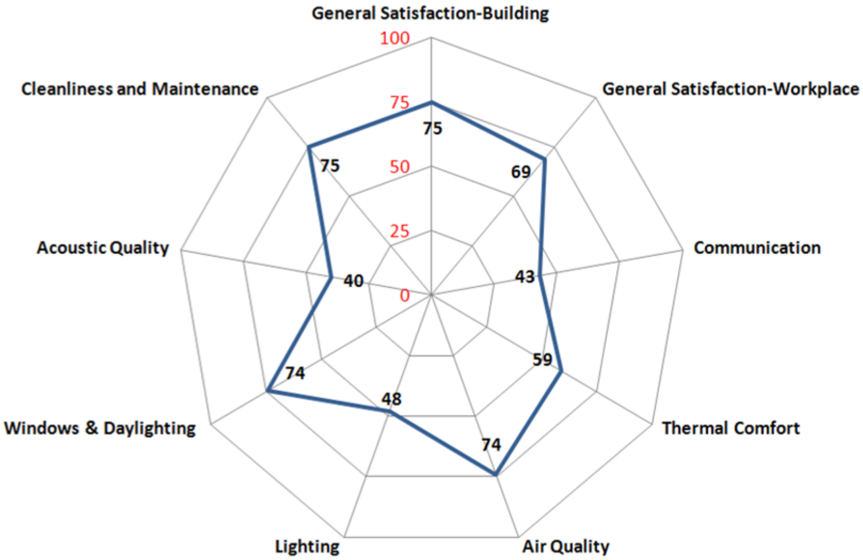


Occupant Satisfaction Survey

Of the 318 occupants in the building, 250 were surveyed and 103 responded.

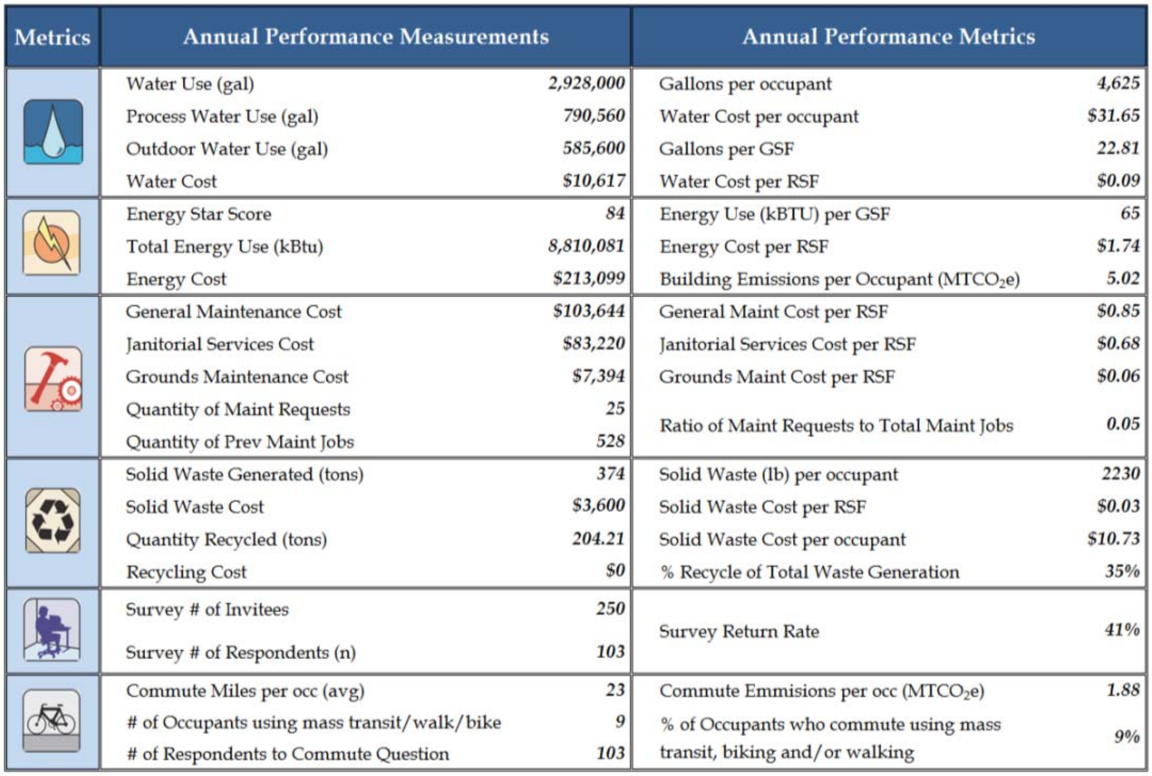


The result indicated that occupants of the Lakewood Federal Building are more satisfied with their building than occupants in the CBE baseline (75th percentile). Acoustic quality, and lighting scored below the 50th percentile of the CBE buildings surveyed. Cleanliness and maintenance, air quality, and thermal comfort scored above the 50th percentile.



Performance Data Summary

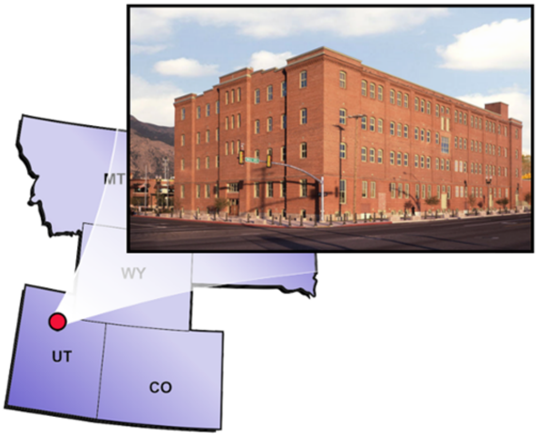
The research team collected, normalized, and compared the whole building performance data for the Lakewood DOT Federal Building to industry baselines. The following table summarizes the annual performance data collected and normalized. The facility uses water-cooled chillers for its air-conditioning system; therefore, the cooling tower water use was estimated using the "rule-of-thumb" that 27% of total water use is process water. Outdoor water use was estimated using the "rule-of-thumb" that 20% of total water use is for landscaping.



Metrics	Annual Performance Measurements		Annual Performance Metrics	
	Water Use (gal)	*2,928,000*	Gallons per occupant	*4,625*
	Process Water Use (gal)	*790,560*	Water Cost per occupant	*$31.65*
	Outdoor Water Use (gal)	*585,600*	Gallons per GSF	*22.81*
	Water Cost	*$10,617*	Water Cost per RSF	*$0.09*
	Energy Star Score	*84*	Energy Use (kBTU) per GSF	*65*
	Total Energy Use (kBtu)	*8,810,081*	Energy Cost per RSF	*$1.74*
	Energy Cost	*$213,099*	Building Emissions per Occupant ($MTCO_2e$)	*5.02*
	General Maintenance Cost	*$103,644*	General Maint Cost per RSF	*$0.85*
	Janitorial Services Cost	*$83,220*	Janitorial Services Cost per RSF	*$0.68*
	Grounds Maintenance Cost	*$7,394*	Grounds Maint Cost per RSF	*$0.06*
	Quantity of Maint Requests	*25*	Ratio of Maint Requests to Total Maint Jobs	*0.05*
	Quantity of Prev Maint Jobs	*528*		
	Solid Waste Generated (tons)	*374*	Solid Waste (lb) per occupant	*2230*
	Solid Waste Cost	*$3,600*	Solid Waste Cost per RSF	*$0.03*
	Quantity Recycled (tons)	*204.21*	Solid Waste Cost per occupant	*$10.73*
	Recycling Cost	*$0*	% Recycle of Total Waste Generation	*35%*
	Survey # of Invitees	*250*	Survey Return Rate	*41%*
	Survey # of Respondents (n)	*103*		
	Commute Miles per occ (avg)	*23*	Commute Emmisions per occ ($MTCO_2e$)	*1.88*
	# of Occupants using mass transit/walk/bike	*9*	% of Occupants who commute using mass transit, biking and/or walking	*9%*
	# of Respondents to Commute Question	*103*		

Ogden Federal Building

Description



Prior to its transformation to a four-story office building, the Scowcroft Internal Revenue Service (IRS) Federal Building was a warehouse. The original main staircase and middle stairs have been preserved, and an office suite has been restored. The renovation cost included costly earthquake prevention upgrades and tenant specific requests.

The Scowcroft Federal Building remodel incorporated improved roof insulation, radiant baseboard heating, variable speed condensers, and improved lighting power density. The underfloor air distribution system was coupled with indirect/direct evaporative cooling. These systems allowed for increased ventilation effectiveness and temperature controllability for nonperimeter spaces. Presently, the building and operates 22 hours a day, 350 days a year. Office space includes a high number of cubicles with varying heights (6 to 10 feet).

Metrics	Scowcroft IRS Utah Field Office	
	Building Location	*105 23rd Street Ogden* *Utah 84401-1306*
	Building Function	*Federal Building*
	Project Type	*Renovation*
	Design Certification	*LEED-NC Silver*
	Year Built	*1900*
	# of Floors	*5*
	Gross Square Foot	*105,000*
	Rentable Square Foot	*102,579*
	Usable Square Foot	*94,562*
	Weekly Operating Hours	*120*
	Regular Occupants	*514*
	Average Daily Visitors (FTE)	*7*
	Electronic Equipment	*745*
	Site Cost	*N/A*
	Design Cost	*N/A*
	Construction Cost	*$11,442,705*
	Management & Inspection	*N/A*
	Total Cost	*$11,442,705*

Each building in the study had operational highlights and potential opportunities for improvement. Although it was not the focus of this study to investigate and/or document operational highlights and opportunities, the research team observed:

- Based on the CBE survey results, it appears that issues exist with thermal comfort, daylighting, lighting, cleanliness and maintenance, and acoustics. Interviews of occupants regarding these issues may result in a more detailed understanding of how operations might be adjusted to improve occupant satisfaction.

- Separately metering the process water would allow for the comparison of Scowcroft Federal Building domestic water use to a comparable baseline. Once measured domestic water use data are available, potential water conservation opportunities could be identified.

Certifications

LEED® - NC v2.1

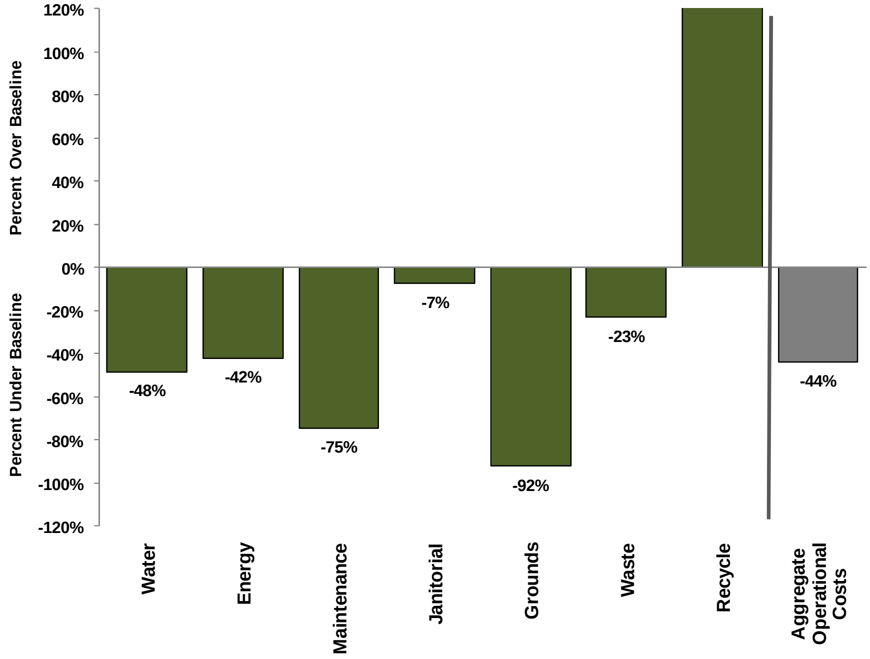
Scowcroft IRS Utah Field Office
105 23rd Street, Ogden, Utah 84401-1306

Silver	**34 Points**
Sustainable Sites	**7/14**
Water Efficiency	**2/5**
Energy & Atmosphere	**7/17**
Materials & Resources	**6/13**
Indoor Environmental Quality	**9/15**
Innovation & Design	**3/5**

Certified: 26-32 points, **Silver:** 33-38 points, **Gold:** 39-51 points, **Platinum:** 52-69 points

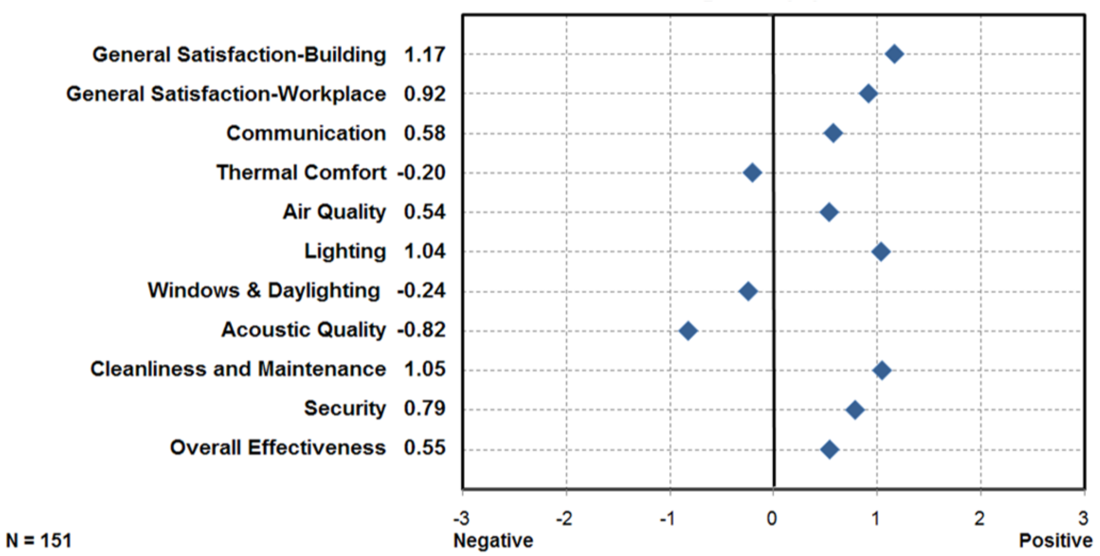
Whole Building Performance

The costs of operating the Scowcroft Federal Building are lower than the industry baseline for energy, water, waste, general maintenance, and janitorial costs. The recycling costs are higher than the industry baseline. Overall, the building costs less to operate than a baseline building.

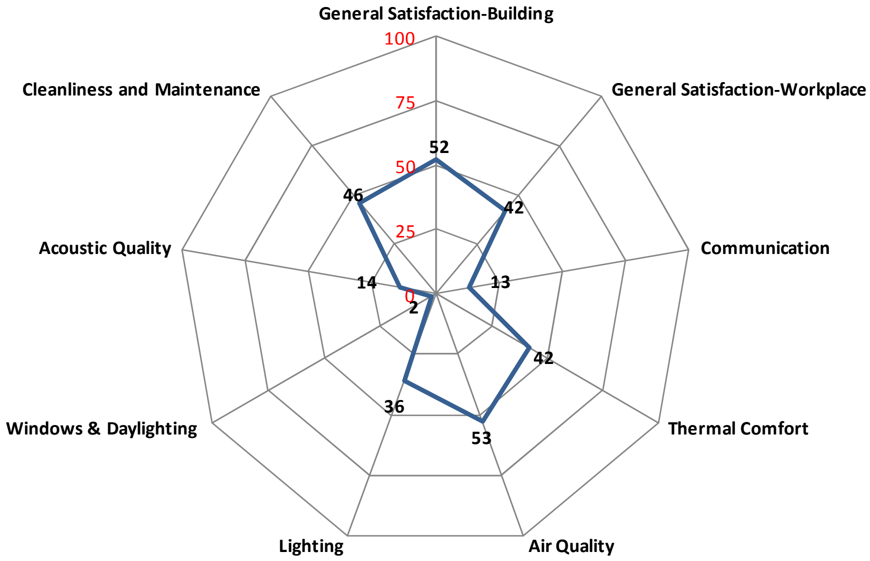


Occupant Satisfaction Survey

All 514 of the Scowcroft Federal Building occupants were surveyed and 151 responded. In addition to the electronic survey, GSA representatives issued the survey in hardcopy form because many staff did not have electronic access to the survey.

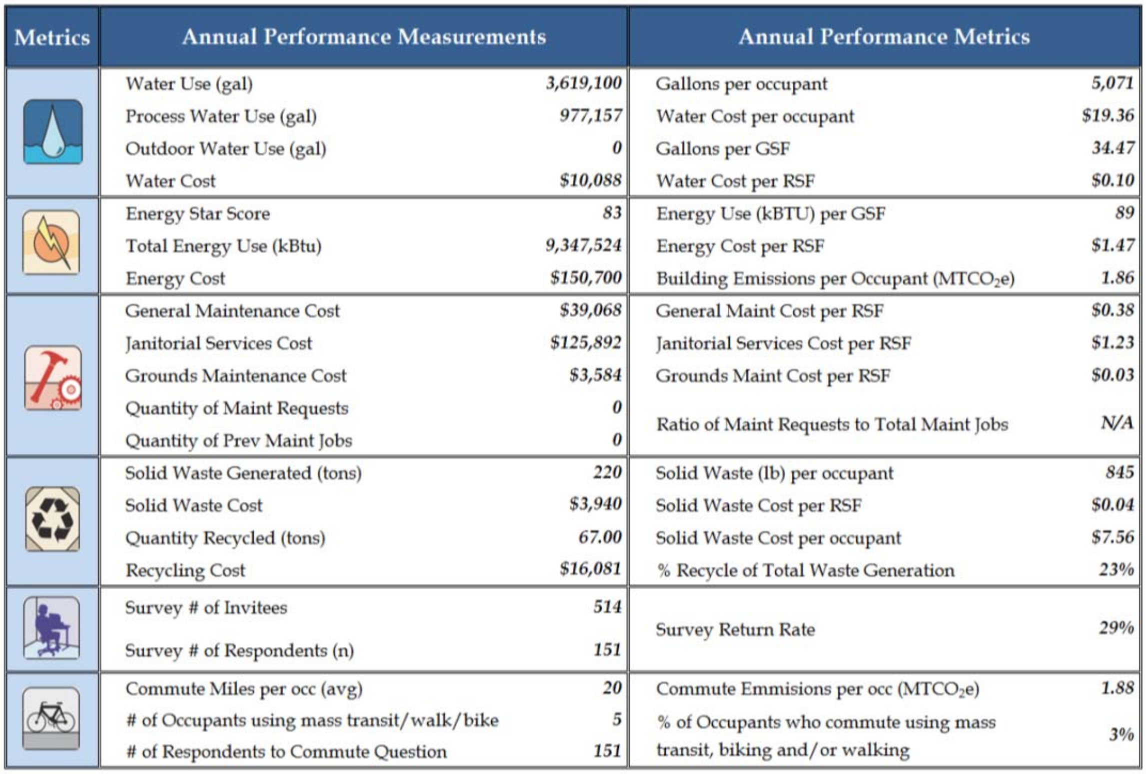


The results indicated that occupants are generally more satisfied with their building than occupants in the CBE baseline (52nd percentile). The acoustic quality, thermal comfort, lighting, and cleanliness and maintenance all scored below the 50th percentile of the CBE buildings surveyed. Frequently clogged toilets were identified as a persistent maintenance issue, and a large number of snack tables located throughout the building may be impacting the occupant satisfaction ratings.



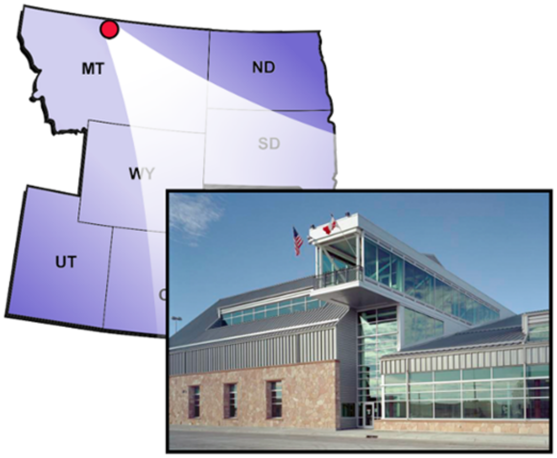
Performance Data Summary

The research team collected, normalized, and compared the whole building performance data for the Scowcroft Federal Building to industry baselines. The following table summarizes the annual performance data that were collected and normalized. The facility uses evaporative cooling for its air conditioning system; therefore, the amount of water used for evaporative cooling was estimated using the "rule-of-thumb" that 27% of total water use is process water.



Metrics	Annual Performance Measurements		Annual Performance Metrics	
💧	Water Use (gal)	*3,619,100*	Gallons per occupant	*5,071*
	Process Water Use (gal)	*977,157*	Water Cost per occupant	*$19.36*
	Outdoor Water Use (gal)	*0*	Gallons per GSF	*34.47*
	Water Cost	*$10,088*	Water Cost per RSF	*$0.10*
⚡	Energy Star Score	*83*	Energy Use (kBTU) per GSF	*89*
	Total Energy Use (kBtu)	*9,347,524*	Energy Cost per RSF	*$1.47*
	Energy Cost	*$150,700*	Building Emissions per Occupant (MTCO$_2$e)	*1.86*
🔨	General Maintenance Cost	*$39,068*	General Maint Cost per RSF	*$0.38*
	Janitorial Services Cost	*$125,892*	Janitorial Services Cost per RSF	*$1.23*
	Grounds Maintenance Cost	*$3,584*	Grounds Maint Cost per RSF	*$0.03*
	Quantity of Maint Requests	*0*	Ratio of Maint Requests to Total Maint Jobs	*N/A*
	Quantity of Prev Maint Jobs	*0*		
♻	Solid Waste Generated (tons)	*220*	Solid Waste (lb) per occupant	*845*
	Solid Waste Cost	*$3,940*	Solid Waste Cost per RSF	*$0.04*
	Quantity Recycled (tons)	*67.00*	Solid Waste Cost per occupant	*$7.56*
	Recycling Cost	*$16,081*	% Recycle of Total Waste Generation	*23%*
🪑	Survey # of Invitees	*514*	Survey Return Rate	*29%*
	Survey # of Respondents (n)	*151*		
🚲	Commute Miles per occ (avg)	*20*	Commute Emmisions per occ (MTCO$_2$e)	*1.88*
	# of Occupants using mass transit/walk/bike	*5*	% of Occupants who commute using mass transit, biking and/or walking	*3%*
	# of Respondents to Commute Question	*151*		

Sweetgrass Port



Description

The Shared Port-of-Entry, bordering the towns of Sweetgrass, Montana and Coutts, Alberta, Canada was constructed as a facility jointly shared between GSA, the Canada Border Services Agency, and the regional U.S. and Canadian highway departments. This is the nation's first LEED Certified Port, and it has won GSA's Environmental Award because of its water-efficiency features, indoor air quality, sustainable siting, and green housekeeping features.

Metrics	Shared Port-of-Entry, Sweet Grass, MT; Coutts, AB	
	Building Location	*Main Port Building Sweetgrass* *Montana 59485-9707*
	Building Function	*Port of Entry*
	Project Type	*New Construction*
	Design Certification	*LEED-NC Certified*
	Year Built	*2003*
	# of Floors	*3*
	Gross Square Foot	*98,196*
	Rentable Square Foot	*84,928*
	Usable Square Foot	*61,826*
	Weekly Operating Hours	*168*
	Regular Occupants	*190*
	Average Daily Visitors (FTE)	*63*
	Electronic Equipment	*320*
	Site Cost	*N/A*
	Design Cost	*N/A*
	Construction Cost	*N/A*
	Management & Inspection	*N/A*
	Total Cost	*$31,200,000*

This study included the main port building as well as two commercial inspection bays, two vehicle inspection bays, and two hazardous materials inspection bays. Half of these facilities are located in the United States and half are in Canada, resulting in contracting challenges for the maintenance and operations of the facilities.

The design incorporated the security function of the building with the goal of 96% of all occupants having a direct line of sight to the outdoors. Because of Sweetgrass' northern location and function, snow removal is critical to building operations. Glycol loops are used to heat the traffic areas and inspection facilities during the winter.

Each building in the study had operational highlights and potential opportunities for improvement. Although it was not the focus of this study to investigate and/or document operational highlights and opportunities, the research team observed:

- The primary challenge facing the Sweetgrass Port is available labor for operations and maintenance tasks. Joint ownership by Canada and the United States requires two contracts for each task. An agreement between the two governments to resolve the citizenship related contracting requirements would decrease operating costs and improve operations.

Certifications

LEED® - NC v2.1

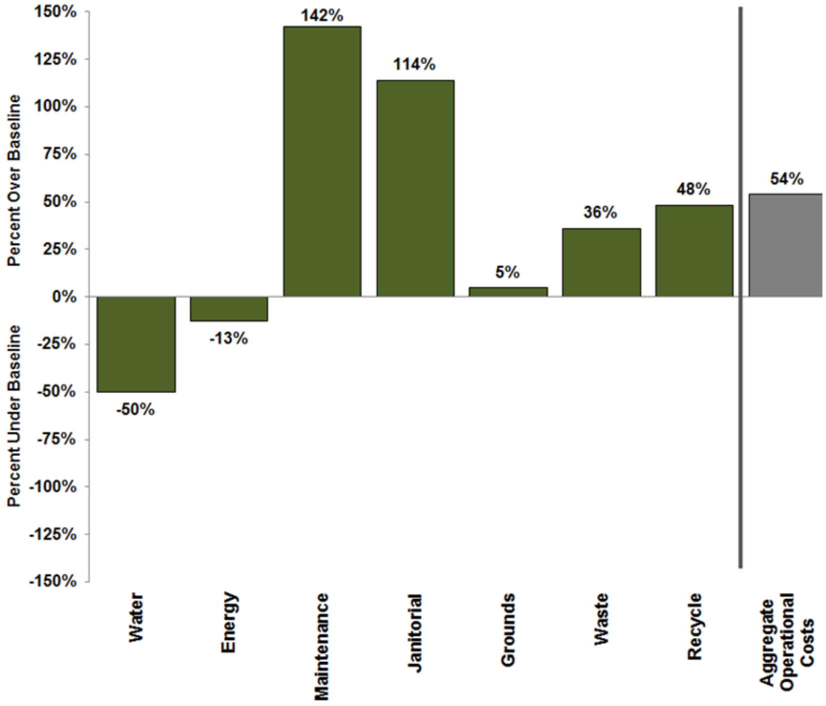
Shared Port-of-Entry, Sweet Grass, MT; Coutts, AB
Main Port Building, Sweetgrass, Montana 59485-9707

Certified	**27 Points**
Sustainable Sites	**6/14**
Water Efficiency	**3/5**
Energy & Atmosphere	**1/17**
Materials & Resources	**4/13**
Indoor Environmental Quality	**8/15**
Innovation & Design	**4/5**

Certified: 26-32 points, **Silver:** 33-38 points, **Gold:** 39-51 points, **Platinum:** 52-69 points

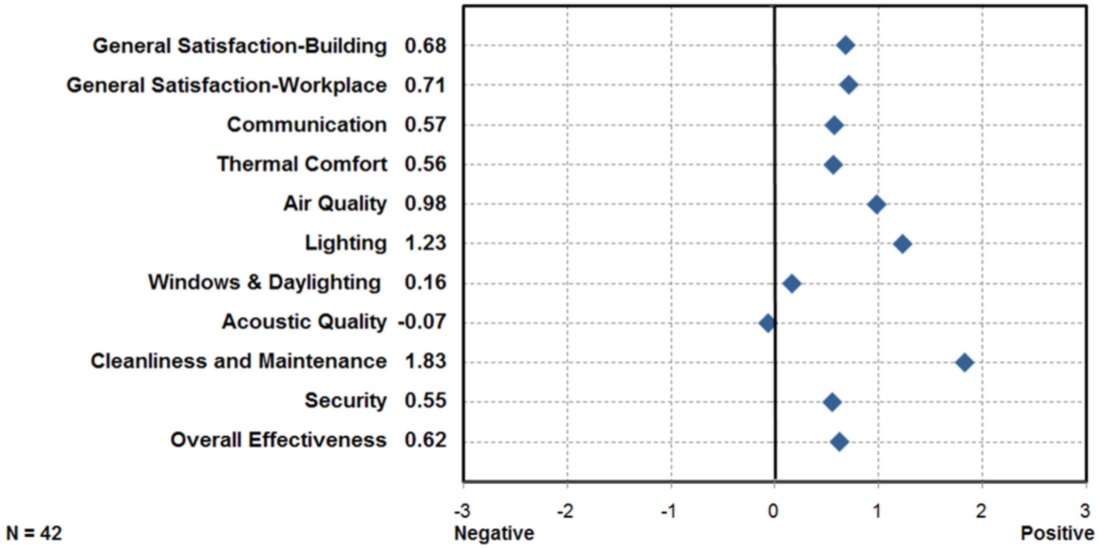
Whole Building Performance

The Sweetgrass Port operating costs are generally higher than the industry baseline for general maintenance, janitorial, and grounds. The energy, water, waste, and recycling costs were lower than the industry baseline. Overall, the building costs more to operate than a baseline building. The baseline used for this analysis was an office building, because no equivalent to Ports is available for comparison. Significant consideration must be given to the building's operational function and remote location when reviewing these costs.

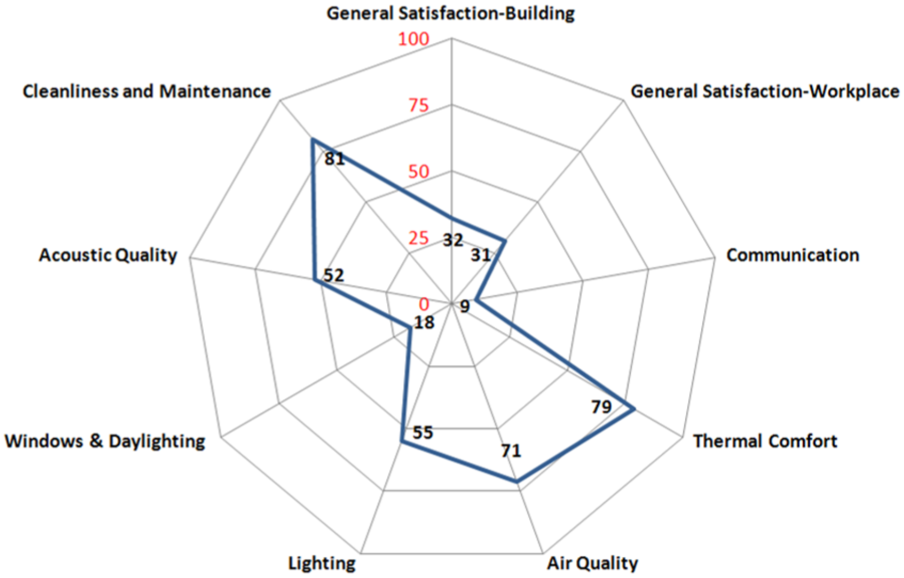


Occupant Satisfaction Survey

Of the 190 building occupants, 70 were surveyed and 42 responded.

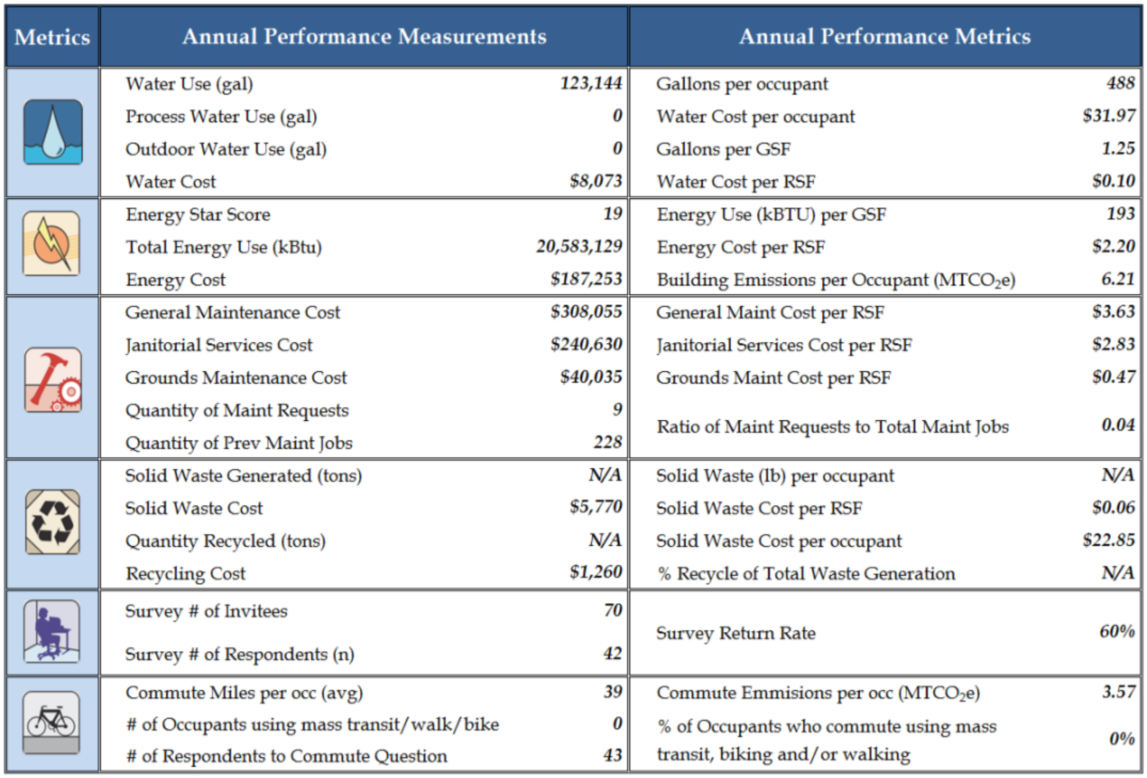


The results indicated that occupants of the Sweetgrass Port are less satisfied with their building than occupants in the CBE baseline (32nd percentile), yet all of the major satisfaction metrics scored above the CBE baseline buildings. Acoustic quality and lighting scored in the 52th and 55th percentile respectively, while air quality, cleanliness and maintenance, and thermal comfort all scored in or above the 70th percentile.



Performance Data Summary

The research team collected, normalized, and compared whole building performance data for the Sweetgrass Port to industry baselines. The following table summarizes the annual performance data collected and normalized.



Metrics	Annual Performance Measurements		Annual Performance Metrics	
	Water Use (gal)	*123,144*	Gallons per occupant	*488*
	Process Water Use (gal)	*0*	Water Cost per occupant	*$31.97*
	Outdoor Water Use (gal)	*0*	Gallons per GSF	*1.25*
	Water Cost	*$8,073*	Water Cost per RSF	*$0.10*
	Energy Star Score	*19*	Energy Use (kBTU) per GSF	*193*
	Total Energy Use (kBtu)	*20,583,129*	Energy Cost per RSF	*$2.20*
	Energy Cost	*$187,253*	Building Emissions per Occupant (MTCO$_2$e)	*6.21*
	General Maintenance Cost	*$308,055*	General Maint Cost per RSF	*$3.63*
	Janitorial Services Cost	*$240,630*	Janitorial Services Cost per RSF	*$2.83*
	Grounds Maintenance Cost	*$40,035*	Grounds Maint Cost per RSF	*$0.47*
	Quantity of Maint Requests	*9*	Ratio of Maint Requests to Total Maint Jobs	*0.04*
	Quantity of Prev Maint Jobs	*228*		
	Solid Waste Generated (tons)	*N/A*	Solid Waste (lb) per occupant	*N/A*
	Solid Waste Cost	*$5,770*	Solid Waste Cost per RSF	*$0.06*
	Quantity Recycled (tons)	*N/A*	Solid Waste Cost per occupant	*$22.85*
	Recycling Cost	*$1,260*	% Recycle of Total Waste Generation	*N/A*
	Survey # of Invitees	*70*	Survey Return Rate	*60%*
	Survey # of Respondents (n)	*42*		
	Commute Miles per occ (avg)	*39*	Commute Emmisions per occ (MTCO$_2$e)	*3.57*
	# of Occupants using mass transit/walk/bike	*0*	% of Occupants who commute using mass transit, biking and/or walking	*0%*
	# of Respondents to Commute Question	*43*		

Fresno Courthouse and Federal Building

Description

The Fresno Courthouse and Federal Building is a part of the urban revitalization of the city's downtown district. There are 14 courtrooms that house district, magistrate and bankruptcy courts, and eight elevators in the tallest building in Fresno.

The facility was designed under California's Title 24 energy standards and incorporates high-efficiency lighting (T5s, T8s and CFLs), underfloor air distribution systems for floors 1 through 4, water-cooled chillers, natural gas boilers, and variable speed drives. The lighting controls operate both on occupancy and time-of-day routines.

Metrics	Robert E. Coyle U.S. Courthouse and Federal Building	
	Building Location	*2500 Tulare Street Fresno* *California 93721-0000*
	Building Function	*Courthouse & Federal Building*
	Project Type	*New Construction*
	Design Certification	*California Energy Standard Title 24*
	Year Built	*2005*
	# of Floors	*11*
	Gross Square Foot	*495,914*
	Rentable Square Foot	*393,243*
	Usable Square Foot	*279,618*
	Weekly Operating Hours	*68*
	Regular Occupants	*235*
	Average Daily Visitors (FTE)	*275*
	Electronic Equipment	*250*
	Site Cost	*N/A*
$	Design Cost	*$6,385,000*
	Construction Cost	*$119,589,000*
	Management & Inspection	*N/A*
	Total Cost	*$132,718,000*

There are five primary federal agency tenants in the building. Unique features include a nurse's station that is supported by the tenants, a fitness room, underground parking, a public garden, and a library with original Ansel Adams photographs of the Yosemite Valley.

Each building in the study had operational highlights and potential opportunities for improvement. Although it was not the focus of this study to investigate and/or document operational highlights and opportunities, the research team observed the following:

- The building landscaping is attractive, but water intensive. There is a large public garden (1.5 acres of the total 3.9-acre property size). The outdoor pond and waterfall, native plants, and conifers along with the indoor water feature offer a gathering space and a key attribute to the urban revitalization.

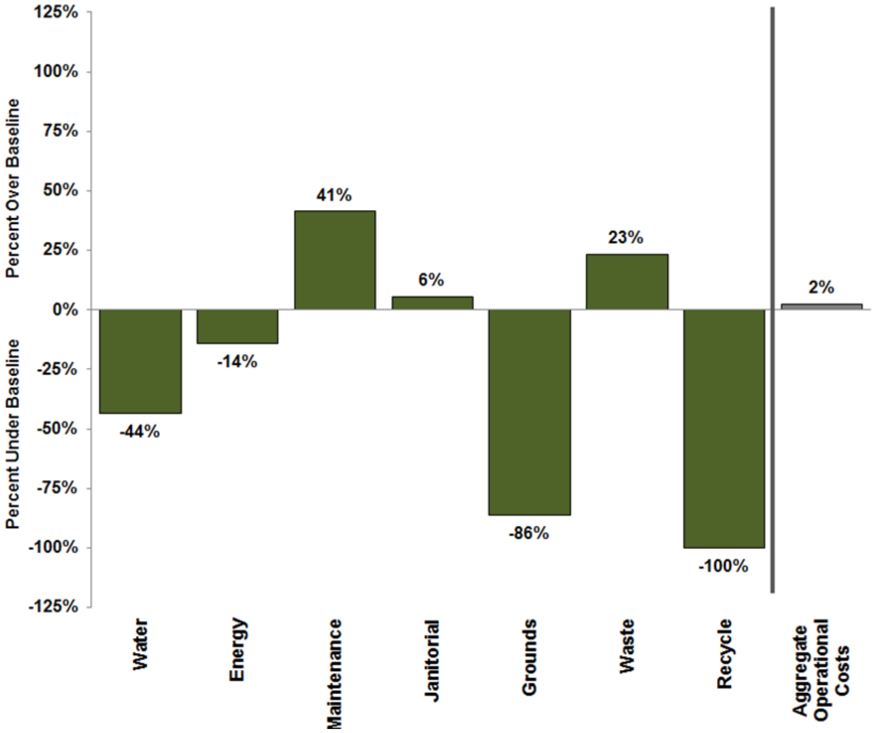
- A project is underway to purchase new window blinds with reflective backing to block heat and glare.

Design Certification

California Energy Standard Title 24

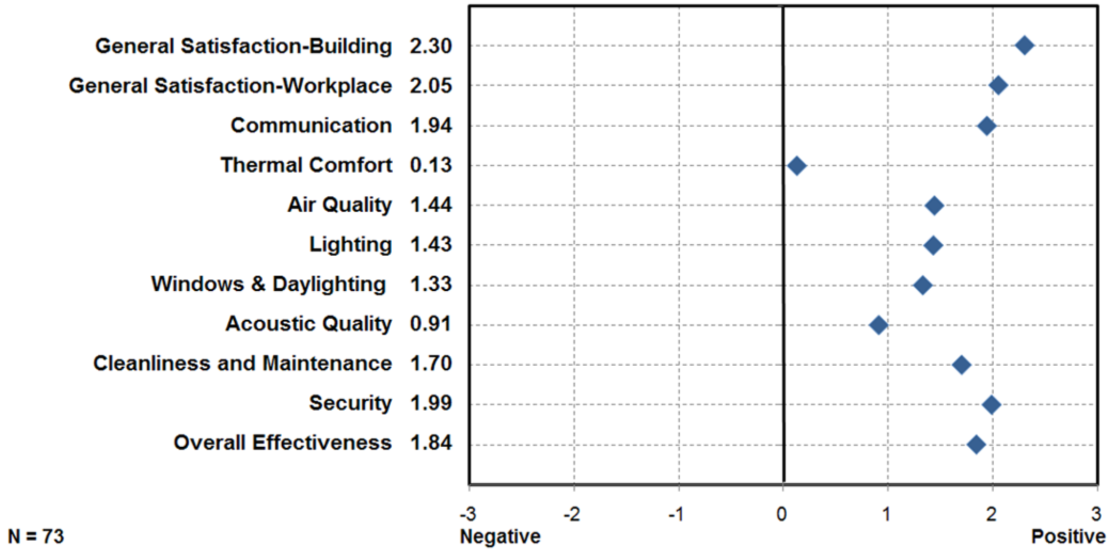
Whole Building Performance

The costs of operating the Fresno CT & FB are lower than the industry baseline for water, energy, grounds, and waste costs. The general maintenance and janitorial costs were higher than the industry baseline. Overall, the building costs slightly more to operate than a baseline building.

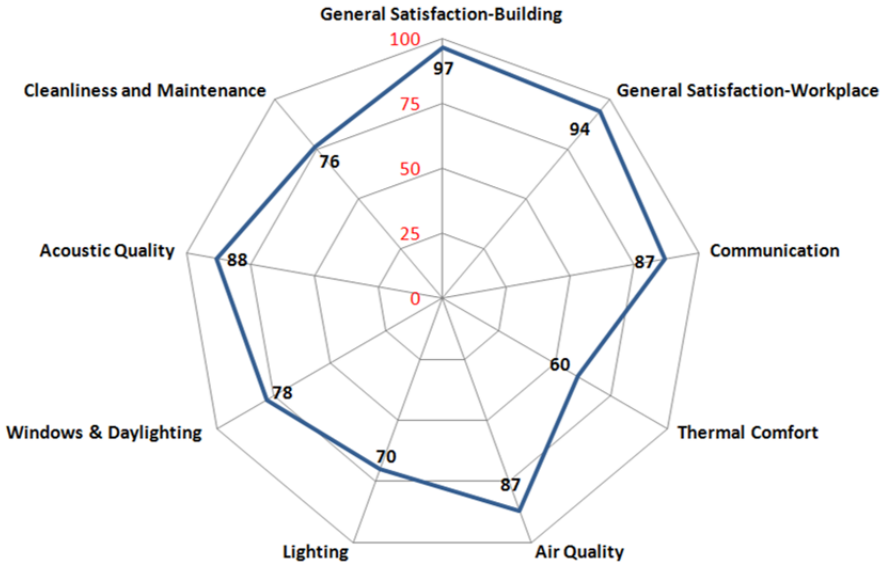


Occupant Satisfaction Survey

All 235 of the Fresno CT & FB occupants were surveyed and 73 responded.

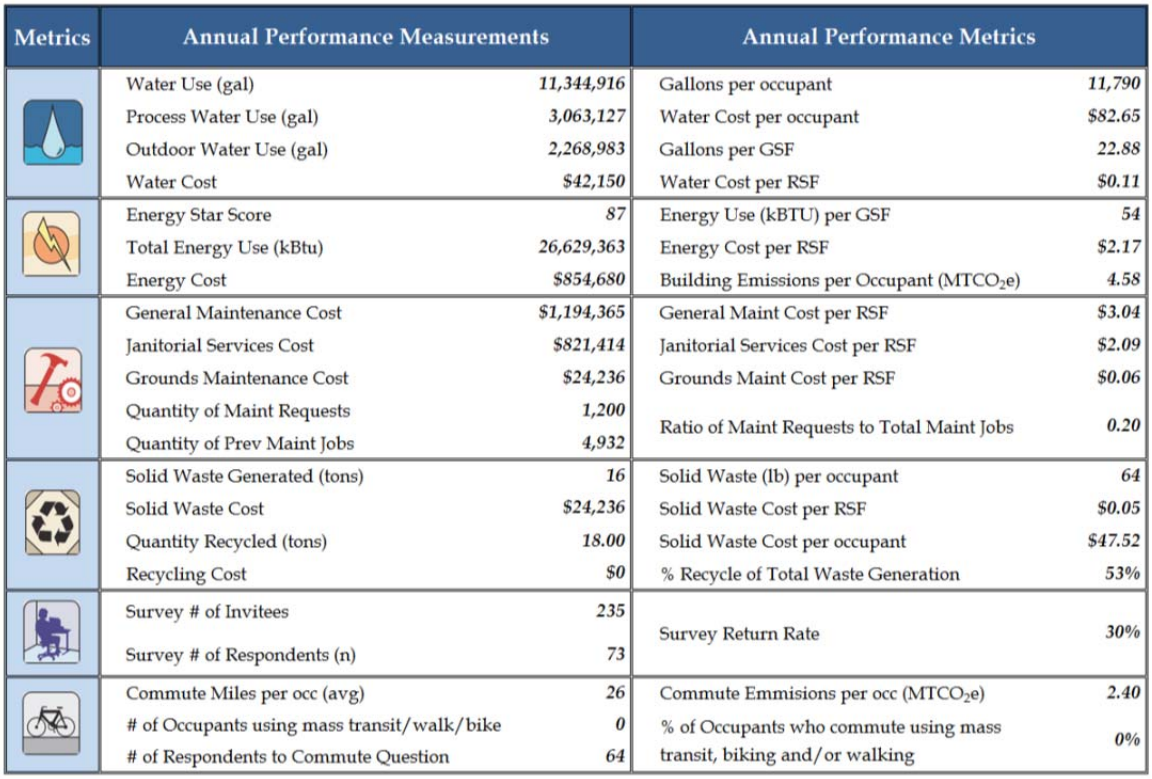


The result indicated that occupants of the Fresno CT & FB are significantly more satisfied with their building than occupants in the CBE baseline (97th percentile). Acoustic quality, air quality, and cleanliness and maintenance scored in the 75th percentile or above. Occupant satisfaction with lighting and thermal comfort scored above the 50th percentile.



Performance Data Summary

The research team collected, normalized, and compared whole building performance data for the Fresno CT & FB to industry baselines. The following table summarizes the annual performance data collected and normalized. The facility uses water-cooled chillers for its air-conditioning system; therefore, the cooling tower water use was estimated using the "rule-of-thumb" that 27% of total water use is process water. Outdoor water use was estimated using the "rule-of-thumb" that 20% of total water use is for landscaping.



Metrics	Annual Performance Measurements		Annual Performance Metrics	
	Water Use (gal)	*11,344,916*	Gallons per occupant	*11,790*
	Process Water Use (gal)	*3,063,127*	Water Cost per occupant	*$82.65*
	Outdoor Water Use (gal)	*2,268,983*	Gallons per GSF	*22.88*
	Water Cost	*$42,150*	Water Cost per RSF	*$0.11*
	Energy Star Score	*87*	Energy Use (kBTU) per GSF	*54*
	Total Energy Use (kBtu)	*26,629,363*	Energy Cost per RSF	*$2.17*
	Energy Cost	*$854,680*	Building Emissions per Occupant ($MTCO_2e$)	*4.58*
	General Maintenance Cost	*$1,194,365*	General Maint Cost per RSF	*$3.04*
	Janitorial Services Cost	*$821,414*	Janitorial Services Cost per RSF	*$2.09*
	Grounds Maintenance Cost	*$24,236*	Grounds Maint Cost per RSF	*$0.06*
	Quantity of Maint Requests	*1,200*	Ratio of Maint Requests to Total Maint Jobs	*0.20*
	Quantity of Prev Maint Jobs	*4,932*		
	Solid Waste Generated (tons)	*16*	Solid Waste (lb) per occupant	*64*
	Solid Waste Cost	*$24,236*	Solid Waste Cost per RSF	*$0.05*
	Quantity Recycled (tons)	*18.00*	Solid Waste Cost per occupant	*$47.52*
	Recycling Cost	*$0*	% Recycle of Total Waste Generation	*53%*
	Survey # of Invitees	*235*	Survey Return Rate	*30%*
	Survey # of Respondents (n)	*73*		
	Commute Miles per occ (avg)	*26*	Commute Emmisions per occ ($MTCO_2e$)	*2.40*
	# of Occupants using mass transit/walk/bike	*0*	% of Occupants who commute using mass transit, biking and/or walking	*0%*
	# of Respondents to Commute Question	*64*		

Las Vegas Courthouse

Description

The Lloyd George U.S. Courthouse creates a federal presence in downtown Las Vegas as part of an urban redevelopment effort. The courthouse was competed in 2000 and received Energy Star recognition in 2007. The Lloyd George Courthouse was the first Federal Building built to the post-Oklahoma City blast resistant standards. In 2000 the Lloyd George Courthouse won GSA's honor award for design excellence.

There are 12 courtrooms that house district courts, and office spaces house various other agencies. The building sees a significant fluctuation in visitors depending on the need for those courtrooms. The design features high efficient lighting, a well-utilized EMCS system, water-cooled chillers, natural gas boiler with variable speed drives. The occupancy sensors on the lighting were removed because of complaints that they were malfunctioning. The landscaping is xeriscape, but still requires some level of daily irrigation depending on weather conditions.

Metrics	Lloyd D. George U.S. Courthouse	
	Building Location	*333 Las Vegas Las Vegas* *Nevada 89101-7065*
	Building Function	*Courthouse*
	Project Type	*New Construction*
	Design Certification	*Energy Star 2007 (77)*
	Year Built	*2000*
	# of Floors	*8*
	Gross Square Foot	*454,877*
	Rentable Square Foot	*368,969*
	Usable Square Foot	*281,049*
	Weekly Operating Hours	*55*
	Regular Occupants	*321*
	Average Daily Visitors (FTE)	*107*
	Electronic Equipment	*242*
$	Site Cost	*$3,030,000*
	Design Cost	*$1,200,000*
	Construction Cost	*$92,598,000*
	Management & Inspection	*$3,500,000*
	Total Cost	*$100,328,000*

Each building in the study had operational highlights and potential opportunities for improvement. Although it was not the focus of this study to investigate and/or document operational highlights and opportunities, the research team observed:

- Building management has identified several projects to improve the operations in the HVAC area. Challenges have been cited with maintain temperatures in the entryway, and revolving doors may be one solution. Additionally, there is no smaller "pony" chiller to condition the spaces that require 24-7 cooling.

Certifications

ENERGY STAR

77

Bulding Name

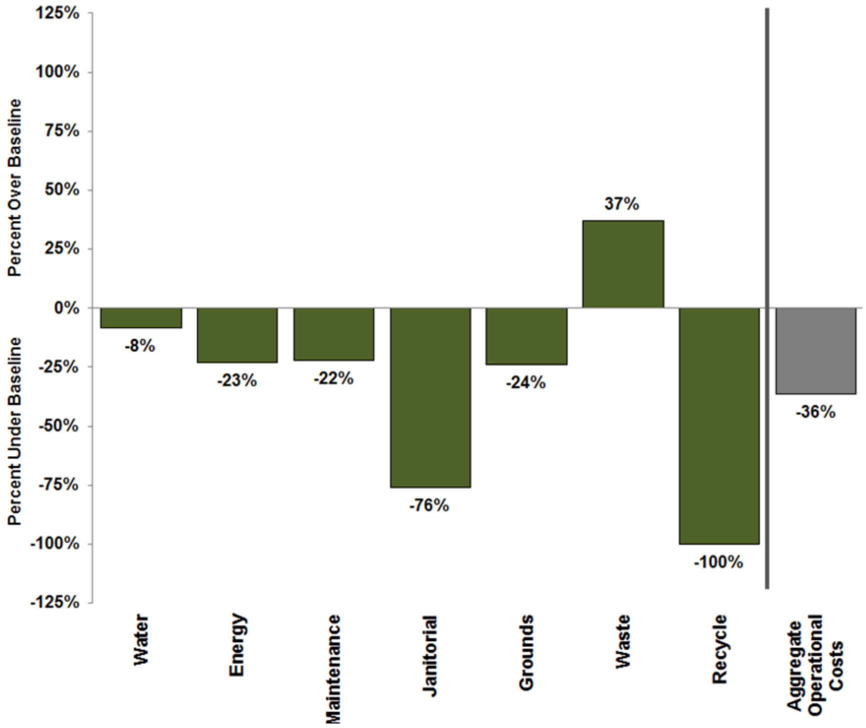
Las Vegas CT

Year Certified

2007

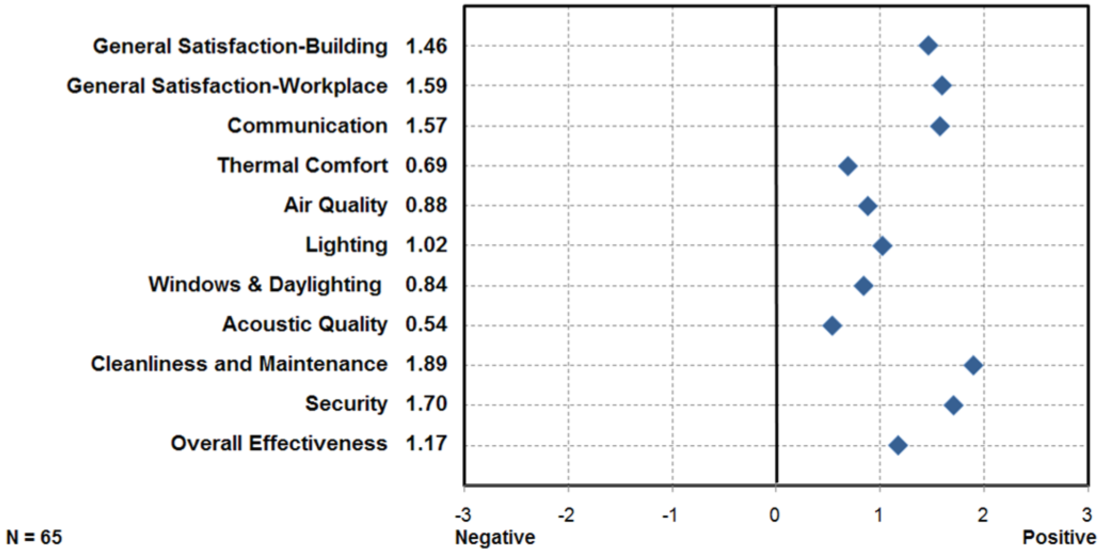
Whole Building Performance

The Lloyd George Courthouse operating costs are lower than the industry baseline in all categories.

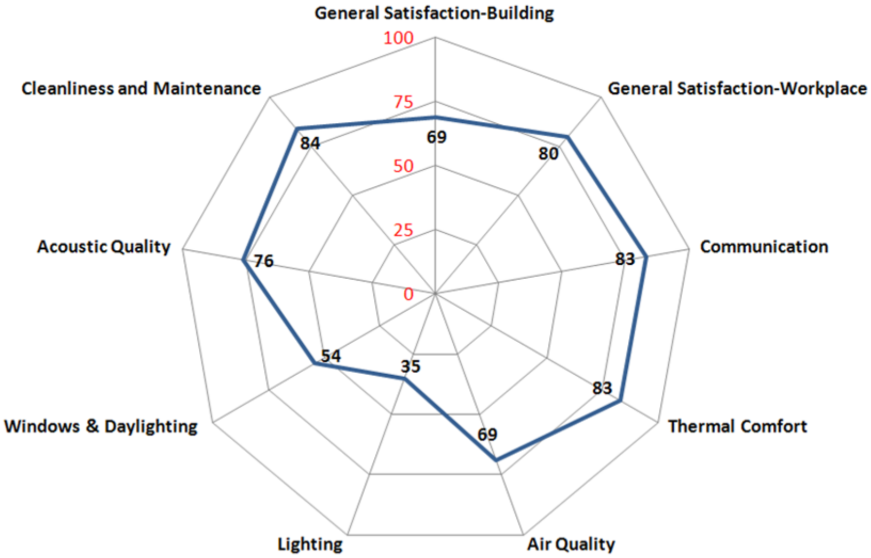


Occupant Satisfaction Survey

All 321 of the Lloyd George Courthouse occupants were surveyed and 65 responded. In addition to the electronic survey, GSA representatives issued the survey in hardcopy form as many staff did not have electronic access to the survey.

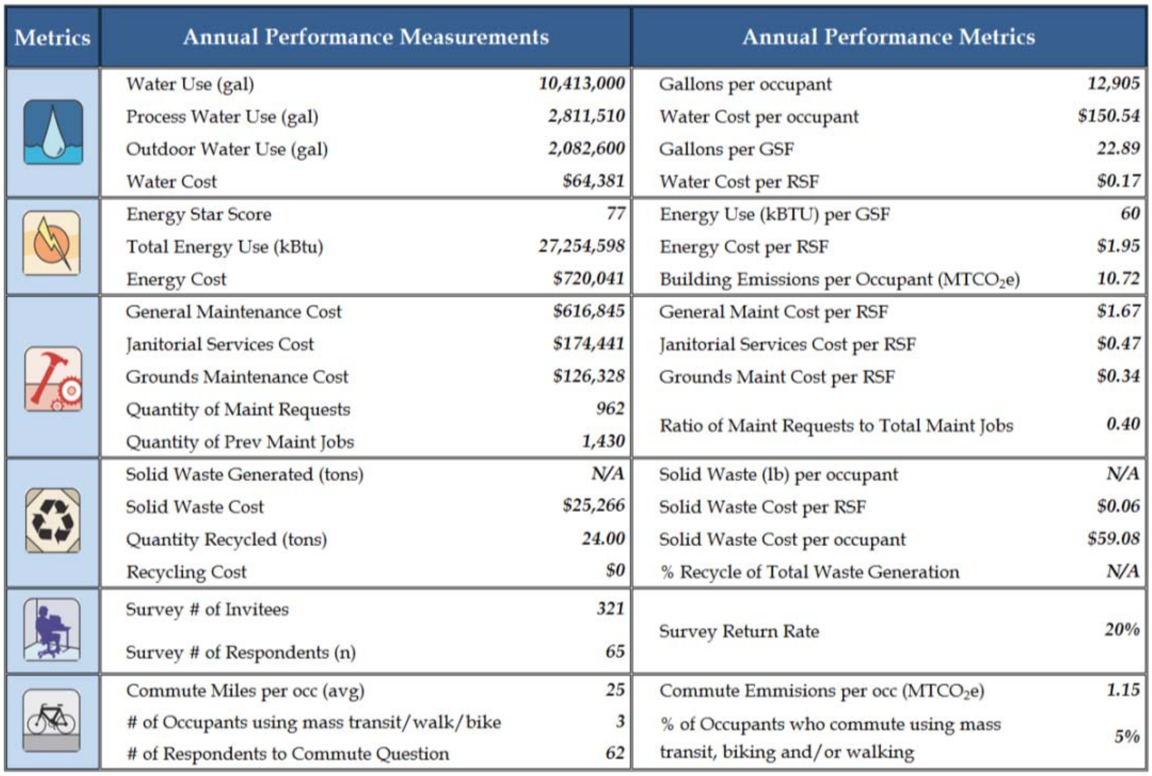


The results indicated that occupants of the Lloyd George Courthouse are more satisfied with their building than occupants in the CBE baseline (69th percentile). For the other survey categories that were the primary focus of this study—acoustic quality, air quality, cleanliness and maintenance, and thermal comfort—the Lloyd George Courthouse scored above the 65th percentile. Lighting satisfaction was the only metric scoring below the 50th percentile.



Performance Data Summary

The research team collected, normalized, and compared whole building performance data for the Lloyd George Courthouse to industry baselines. The following table summarizes the annual performance data collected and normalized. The facility uses water-cooled chillers for its air-conditioning system; therefore, the cooling tower water use was estimated using the "rule-of-thumb" that 27% of total water use is process water. Outdoor water use was estimated using the "rule-of-thumb" that 20% of total water use for landscaping.



Metrics	Annual Performance Measurements		Annual Performance Metrics	
💧	Water Use (gal)	*10,413,000*	Gallons per occupant	*12,905*
	Process Water Use (gal)	*2,811,510*	Water Cost per occupant	*$150.54*
	Outdoor Water Use (gal)	*2,082,600*	Gallons per GSF	*22.89*
	Water Cost	*$64,381*	Water Cost per RSF	*$0.17*
⚡	Energy Star Score	*77*	Energy Use (kBTU) per GSF	*60*
	Total Energy Use (kBtu)	*27,254,598*	Energy Cost per RSF	*$1.95*
	Energy Cost	*$720,041*	Building Emissions per Occupant ($MTCO_2e$)	*10.72*
🔨	General Maintenance Cost	*$616,845*	General Maint Cost per RSF	*$1.67*
	Janitorial Services Cost	*$174,441*	Janitorial Services Cost per RSF	*$0.47*
	Grounds Maintenance Cost	*$126,328*	Grounds Maint Cost per RSF	*$0.34*
	Quantity of Maint Requests	*962*	Ratio of Maint Requests to Total Maint Jobs	*0.40*
	Quantity of Prev Maint Jobs	*1,430*		
♻	Solid Waste Generated (tons)	*N/A*	Solid Waste (lb) per occupant	*N/A*
	Solid Waste Cost	*$25,266*	Solid Waste Cost per RSF	*$0.06*
	Quantity Recycled (tons)	*24.00*	Solid Waste Cost per occupant	*$59.08*
	Recycling Cost	*$0*	% Recycle of Total Waste Generation	*N/A*
	Survey # of Invitees	*321*	Survey Return Rate	*20%*
	Survey # of Respondents (n)	*65*		
🚲	Commute Miles per occ (avg)	*25*	Commute Emmisions per occ ($MTCO_2e$)	*1.15*
	# of Occupants using mass transit/walk/bike	*3*	% of Occupants who commute using mass transit, biking and/or walking	*5%*
	# of Respondents to Commute Question	*62*		

San Francisco Federal Building

Description

The San Francisco Federal Building (SFFB) was completed in 2007 and consists of an 18 story tower, four story annex, day care center, and cafeteria. The tower has a thin footprint at 65 feet wide, with floors six through 18 using natural ventilation strategies to minimize mechanical heating and cooling. A three story open air sky garden is located on the 11th floor to offer an outdoor venue for the building occupants and visitors without having to leave the building.

Features highlighted through the LEED Silver certification include: all on-site parking is underground reducing the urban heat-island effect, drip irrigation and dual-flush valves were used to reduce potable-water consumption. Low- or zero-toxicity building materials were used during construction, and green cleaning custodial products are used during building operation. During construction, over 90% of construction waste was diverted from landfill through separation and recycling.

Metrics	San Francisco Federal Building	
	Building Location	*90 7th Street San Francisco California 94103-1516*
	Building Function	*Federal Building*
	Project Type	*New Construction*
	Design Certification	*LEED-NC Silver*
	Year Built	*2007*
	# of Floors	*18*
	Gross Square Foot	*652,433*
	Rentable Square Foot	*523,208*
	Usable Square Foot	*406,475*
	Weekly Operating Hours	*70*
	Regular Occupants	*1,314*
	Average Daily Visitors (FTE)	*130*
	Electronic Equipment	*1,400*
$	Site Cost	*$2,000,000*
	Design Cost	*$9,200,000*
	Construction Cost	*$143,180,204*
	Management & Inspection	*$6,100,000*
	Total Cost	*$160,480,204*

The proximity to mass transit enables 94% of the building occupants to use some form of transit to get to the workplace. Most occupants use the BART, buses, or walk to SFFB

Each building in the study had operational highlights and potential opportunities for improvement. Although it was not the focus of this study to investigate and/or document operational highlights and opportunities, the research team observed:

- Commissioning of the building is still underway, specifically for the building automation system and HVAC balancing. The operations team has a plan in place for fine tuning of the building systems to optimize the functionality and reduce operations cost.

Certifications

LEED® - NC v2.1

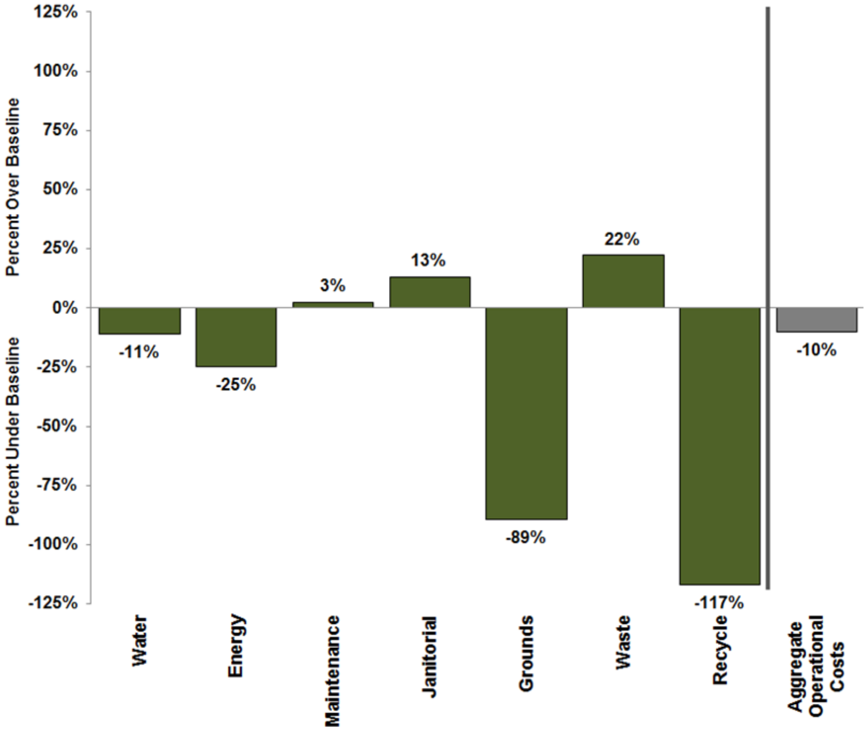
San Francisco Federal Building
90 7th Street, San Francisco, California 94103-1516

Silver	**34 Points**
Sustainable Sites	**8/14**
Water Efficiency	**3/5**
Energy & Atmosphere	**4/17**
Materials & Resources	**4/13**
Indoor Environmental Quality	**10/15**
Innovation & Design	**5/5**

Certified: 26-32 points, **Silver:** 33-38 points, **Gold:** 39-51 points, **Platinum:** 52-69 points

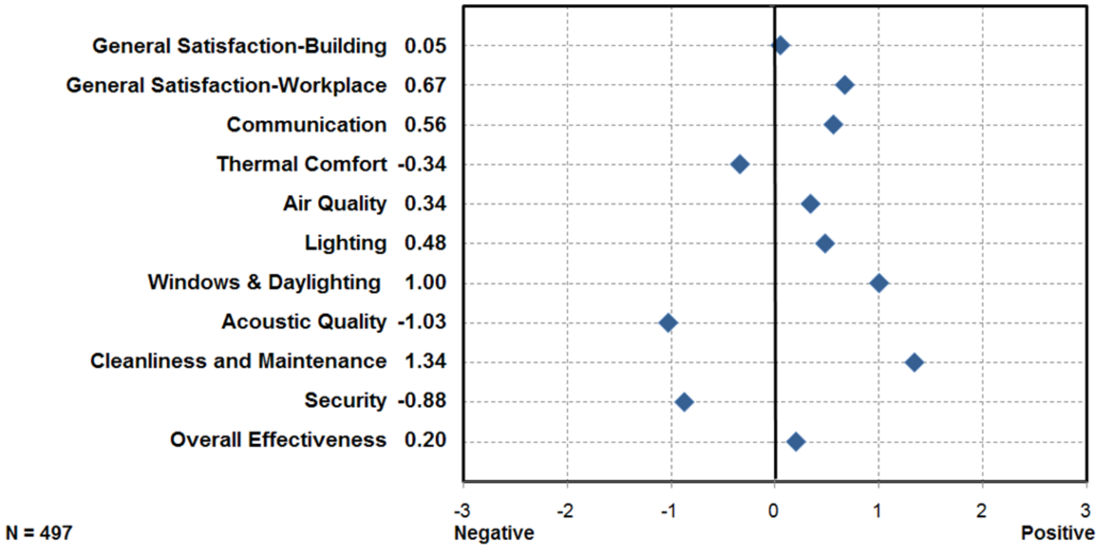
Whole Building Performance

The San Francisco Federal Building operating costs are lower than the industry baseline for water, energy, grounds maintenance, waste, and recycling costs. The general maintenance and janitorial costs are higher than the industry baseline. Overall, the building costs less to operate than a baseline building.

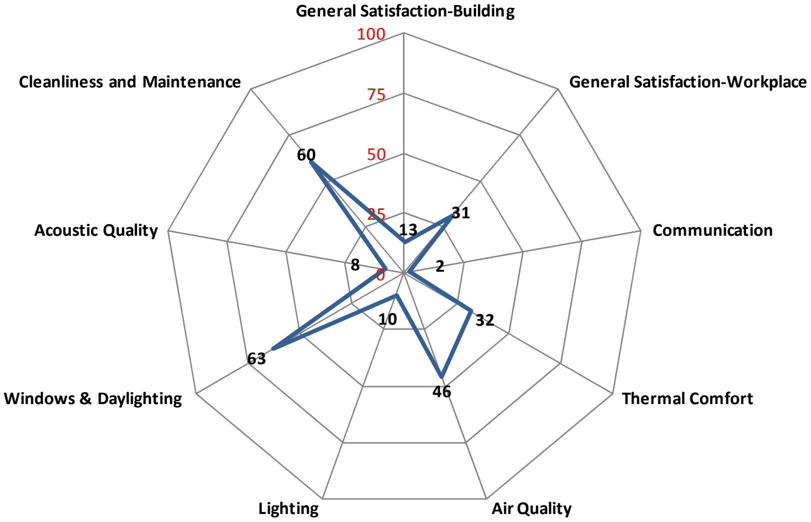


Occupant Satisfaction Survey

Of the 1314 occupants at the San Francisco Federal Building, 1244 were surveyed and 497 responded. In addition to the electronic survey, GSA representatives issued the survey in hardcopy in the lobby of the building.

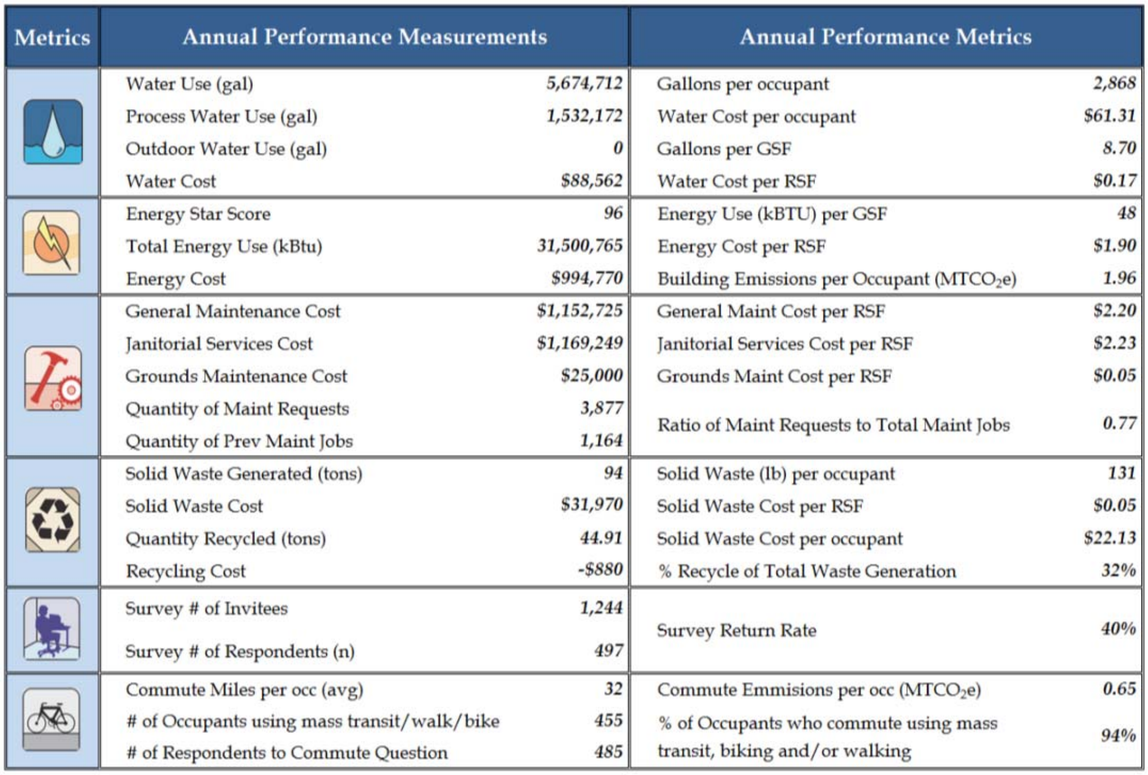


The results indicated that occupants of the San Francisco Federal Building are less satisfied with their building than occupants in the CBE baseline (12th percentile). The acoustic quality, thermal comfort, and lighting all scored below the 50th percentile of the CBE buildings surveyed. The San Francisco Federal Building had cleanliness and maintenance and windows and daylighting scores above the 60th percentile.



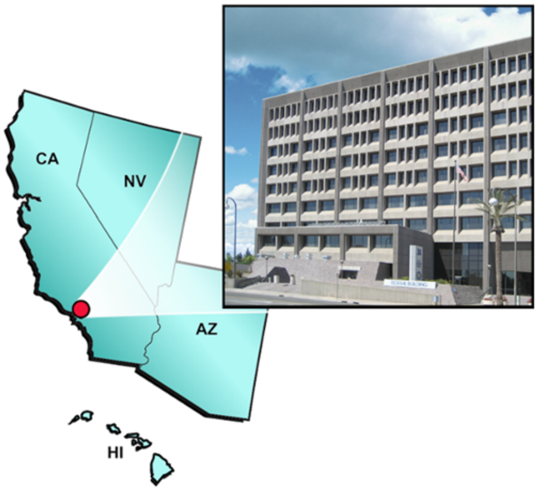
Performance Data Summary

The research team collected, normalized, and compared whole building performance data for the San Francisco Federal Building to industry baselines. The following table summarizes the annual performance data collected and normalized. The facility uses water-cooled chillers for a portion of its air-conditioning system; therefore, the cooling tower water use was estimated using the "rule-of-thumb" that 27% of total water use is process water.



Metrics	Annual Performance Measurements		Annual Performance Metrics	
	Water Use (gal)	*5,674,712*	Gallons per occupant	*2,868*
	Process Water Use (gal)	*1,532,172*	Water Cost per occupant	*$61.31*
	Outdoor Water Use (gal)	*0*	Gallons per GSF	*8.70*
	Water Cost	*$88,562*	Water Cost per RSF	*$0.17*
	Energy Star Score	*96*	Energy Use (kBTU) per GSF	*48*
	Total Energy Use (kBtu)	*31,500,765*	Energy Cost per RSF	*$1.90*
	Energy Cost	*$994,770*	Building Emissions per Occupant ($MTCO_2e$)	*1.96*
	General Maintenance Cost	*$1,152,725*	General Maint Cost per RSF	*$2.20*
	Janitorial Services Cost	*$1,169,249*	Janitorial Services Cost per RSF	*$2.23*
	Grounds Maintenance Cost	*$25,000*	Grounds Maint Cost per RSF	*$0.05*
	Quantity of Maint Requests	*3,877*	Ratio of Maint Requests to Total Maint Jobs	*0.77*
	Quantity of Prev Maint Jobs	*1,164*		
	Solid Waste Generated (tons)	*94*	Solid Waste (lb) per occupant	*131*
	Solid Waste Cost	*$31,970*	Solid Waste Cost per RSF	*$0.05*
	Quantity Recycled (tons)	*44.91*	Solid Waste Cost per occupant	*$22.13*
	Recycling Cost	*-$880*	% Recycle of Total Waste Generation	*32%*
	Survey # of Invitees	*1,244*	Survey Return Rate	*40%*
	Survey # of Respondents (n)	*497*		
	Commute Miles per occ (avg)	*32*	Commute Emmisions per occ ($MTCO_2e$)	*0.65*
	# of Occupants using mass transit/walk/bike	*455*	% of Occupants who commute using mass transit, biking and/or walking	*94%*
	# of Respondents to Commute Question	*485*		

Santa Ana Federal Building



Description

The Santa Ana Federal Building was remodeled in 2005, incorporating new lighting and HVAC systems, a new roof, variable frequency drives, energy-efficient elevators, occupancy temperature control, and light-level sensors. All major commodities used in the building are recycled, including plastic, glass, cans, batteries, paper, and cardboard. A concrete and steel high-rise building originally built in 1975, the Santa Ana Federal Building is located in the heart of the civic center district. The landscaping requires minimal maintenance and attractive.

Metrics	Santa Ana Federal Building	
	Building Location	*34 Civic Center Santa Ana* *California 92701-4025*
	Building Function	*Federal Building*
	Project Type	*Renovation*
	Design Certification	*California Energy Standard Title 24*
	Year Built	*1975*
	# of Floors	*10*
	Gross Square Foot	*280,365*
	Rentable Square Foot	*205,378*
	Usable Square Foot	*164,946*
	Weekly Operating Hours	*70*
	Regular Occupants	*409*
	Average Daily Visitors (FTE)	*50*
	Electronic Equipment	*424*
	Site Cost	*N/A*
	Design Cost	*$236,000*
	Construction Cost	*$26,875,000*
	Management & Inspection	*N/A*
	Total Cost	*$27,864,000*

The building currently houses five federal agencies. One of those offices serves approximately 300 customers daily and another office processes 75 to 100 detainees daily. The family-owned, full-service restaurant has an estimated 250 to 300 customers per day.

Each building in the study had operational highlights and potential opportunities for improvement. Although it was not the focus of this study to investigate and/or document operational highlights and opportunities, the research team observed the following:

- The Santa Ana Federal Building has a low energy use intensity and thus is performing well from an energy performance perspective. Applying for an Energy Star rating and/or LEED Existing Building certification would formally document the impact of this building.

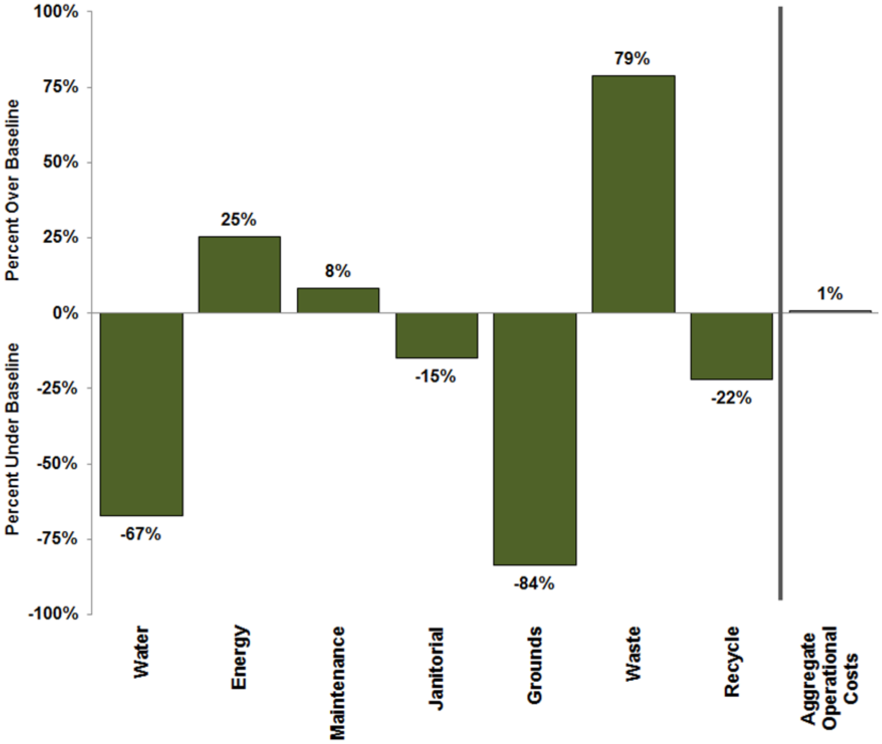
- Thermal comfort scored high (87th percentile) and acoustic quality, cleanliness and maintenance, and lighting scored below the 50th percentile on the CBE buildings survey. Interviews of occupants regarding these issues may result in a more detailed understanding of how operations might be adjusted to improve occupant satisfaction and what to communicate regarding the thermal comfort success.

Certifications

California Energy Standard Title 24

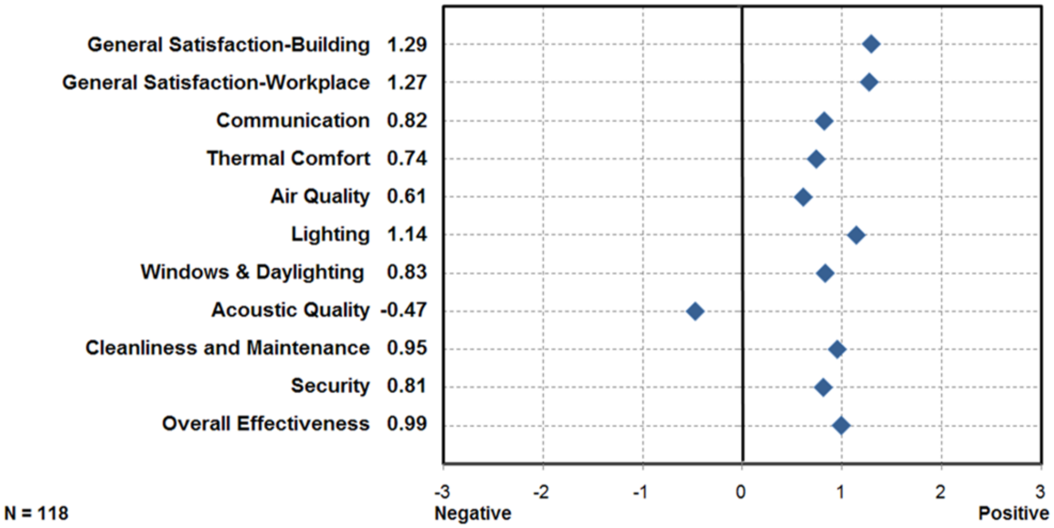
Whole Building Performance

The Santa Ana Federal Building operating costs are lower than the industry baseline for water, grounds maintenance, janitorial, waste, and recycling costs. Overall, the building costs slightly more to operate than a baseline building.

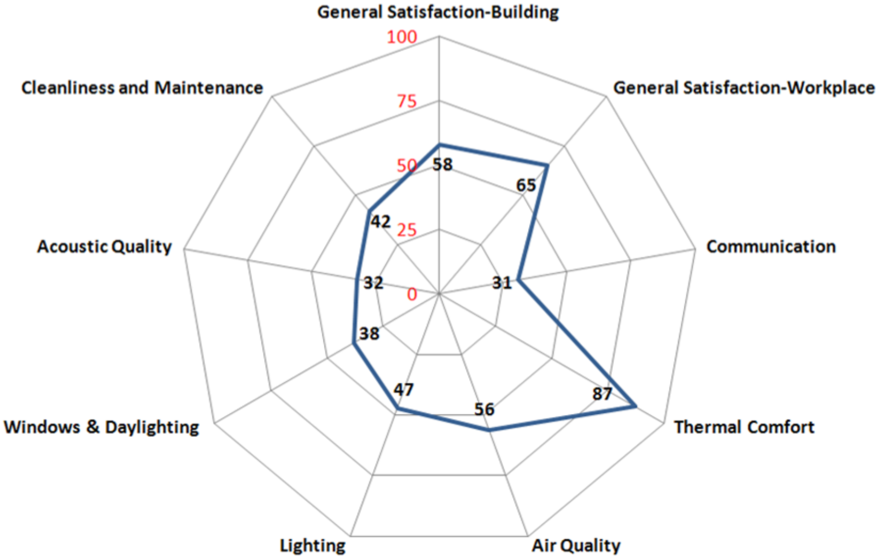


Occupant Satisfaction Survey

Of the 409 occupants in the Santa Ana Federal Building, 336 were surveyed and 118 responded.



The results indicated that occupants of the Santa Ana Federal Building are generally more satisfied with their building than occupants in the CBE baseline (58th percentile). The acoustic quality, cleanliness and maintenance, and lighting scored below the 50th percentile of the CBE buildings surveyed. Thermal comfort and air quality scored above the 50th percentile, with thermal comfort at the 87th percentile (one of the highest scoring buildings in the study).



Performance Data Summary

The research team collected, normalized, and compared the whole building performance data for the Santa Ana Federal Building to industry baselines. The following table summarizes of the annual performance data collected and normalized.

Metrics	Annual Performance Measurements		Annual Performance Metrics	
💧	Water Use (gal)	*2,217,820*	Gallons per occupant	*4,832*
	Process Water Use (gal)	*0*	Water Cost per occupant	*$27.72*
	Outdoor Water Use (gal)	*0*	Gallons per GSF	*7.91*
	Water Cost	*$12,724*	Water Cost per RSF	*$0.06*
⚡	Energy Star Score	*91*	Energy Use (kBTU) per GSF	*58*
	Total Energy Use (kBtu)	*16,307,863*	Energy Cost per RSF	*$3.17*
	Energy Cost	*$651,182*	Building Emissions per Occupant (MTCO$_2$e)	*2.32*
🔨	General Maintenance Cost	*$478,557*	General Maint Cost per RSF	*$2.33*
	Janitorial Services Cost	*$345,401*	Janitorial Services Cost per RSF	*$1.68*
	Grounds Maintenance Cost	*$15,018*	Grounds Maint Cost per RSF	*$0.07*
	Quantity of Maint Requests	*327*	Ratio of Maint Requests to Total Maint Jobs	*0.43*
	Quantity of Prev Maint Jobs	*438*		
♻	Solid Waste Generated (tons)	*562*	Solid Waste (lb) per occupant	*2447*
	Solid Waste Cost	*$18,360*	Solid Waste Cost per RSF	*$0.07*
	Quantity Recycled (tons)	*10.67*	Solid Waste Cost per occupant	*$40.00*
	Recycling Cost	*$1,600*	% Recycle of Total Waste Generation	*2%*
	Survey # of Invitees	*336*	Survey Return Rate	*35%*
	Survey # of Respondents (n)	*118*		
🚲	Commute Miles per occ (avg)	*30*	Commute Emmisions per occ (MTCO$_2$e)	*2.24*
	# of Occupants using mass transit/walk/bike	*14*	% of Occupants who commute using mass transit, biking and/or walking	*12%*
	# of Respondents to Commute Question	*118*		

Auburn Federal Building

Description

Prior to its transformation to a office building, the Social Services Administration (SSA) Teleservice Center was a warehouse. The LEED Silver-certified remodel incorporated improved thermal envelope, high efficiency windows, reduced lighting power density, occupancy sensors, daylighting controls, and variable speed drives. The underfloor air distribution system was coupled with high efficiency chillers and boilers with night flush and demand control ventilation. The building management is actively involved with the electric utility in their demand response program.

Metrics	Auburn SSA Teleservice Center	
	Building Location	*1901 C St Sw Auburn Washington 98001-7426*
	Building Function	*Federal Building*
	Project Type	*Renovation*
	Design Certification	*LEED-NC Silver*
	Year Built	*1944*
	# of Floors	*1 + Mezz*
	Gross Square Foot	*205,354*
	Rentable Square Foot	*201,003*
	Usable Square Foot	*189,249*
	Weekly Operating Hours	*70*
	Regular Occupants	*675*
	Average Daily Visitors (FTE)	*0*
	Electronic Equipment	*675*
	Site Cost	*N/A*
	Design Cost	*$1,134,000*
	Construction Cost	*$16,943,000*
	Management & Inspection	*$1,372,000*
	Total Cost	*$19,449,000*

The open floor plan with cubicles offers relatively high acoustic quality ratings by the occupants (70th percentile).

Use of native and adaptive vegetation reduced the need for irrigation water by 50%. The use of dual flush toilets, and low-flow fixtures, resulted in a projected reduction of 39% of potable water use.

Each building in the study had operational highlights and potential opportunities for improvement. Although it was not the focus of this study to investigate and/or document operational highlights and opportunities, the research team observed the following:

- The building management staff reported challenges in keeping temperatures within acceptable ranges. The CBE survey thermal comfort score was below the 50th percentile. Recommisioning of the systems may alleviate some of these problems.

- The CBE survey lighting score was below the 50th percentile. Interviews of the occupants regarding these issues may result in a more detailed understanding of how operations might be adjusted to improve occupant satisfaction.

Certifications

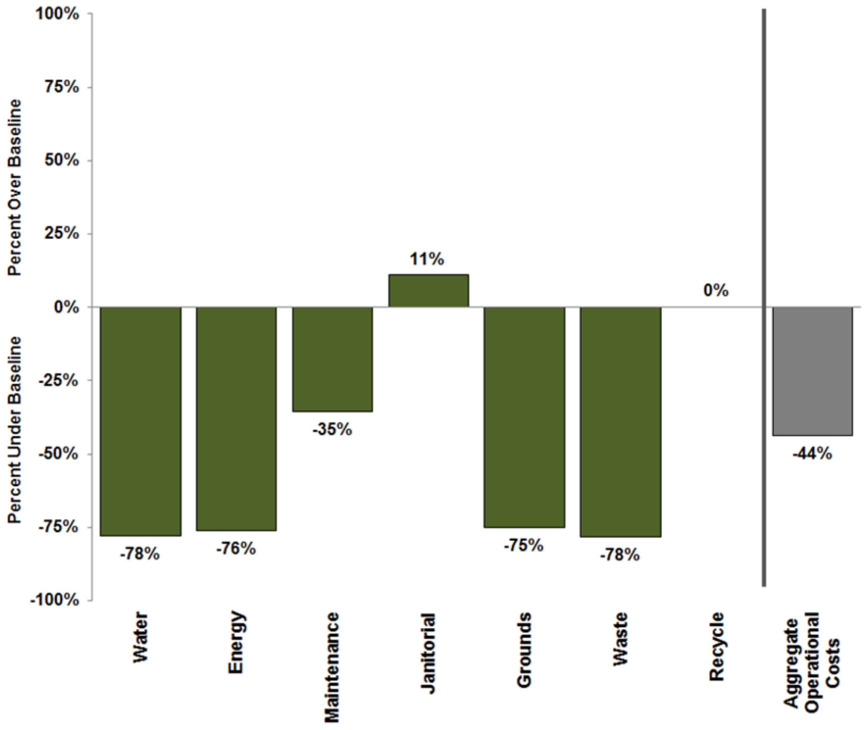
LEED® - NC v2.1
Auburn SSA Teleservice Center
1901 C St Sw, Auburn, Washington 98001-7426

Silver	**36 Points**
Sustainable Sites	**4/14**
Water Efficiency	**3/5**
Energy & Atmosphere	**9/17**
Materials & Resources	**6/13**
Indoor Environmental Quality	**10/15**
Innovation & Design	**4/5**

Certified: 26-32 points, **Silver:** 33-38 points, **Gold:** 39-51 points, **Platinum:** 52-69 points

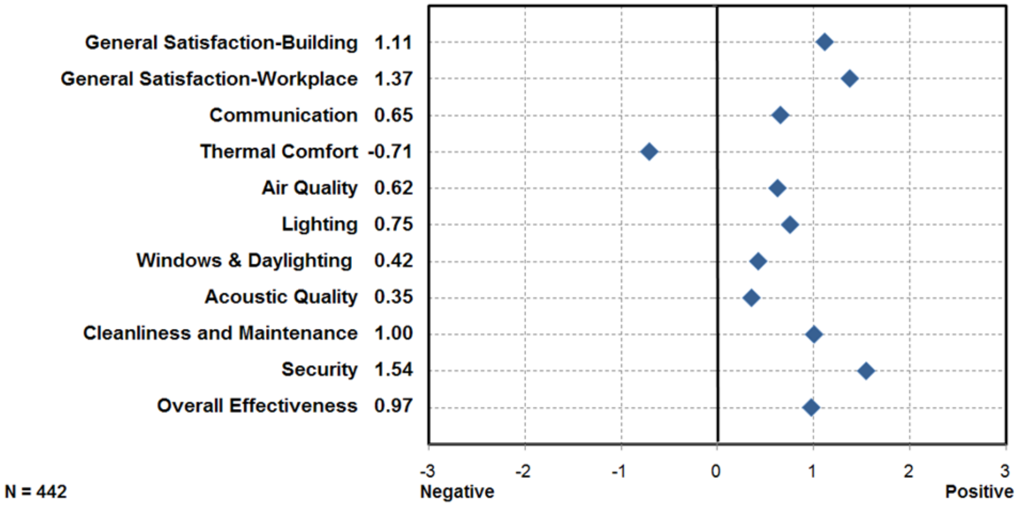
Whole Building Performance

The Auburn SSA Teleservice Center operating costs are lower than the industry baseline for water, energy, general maintenance, grounds maintenance, and waste. The janitorial costs are higher than the industry baseline, and recycling costs are not tracked for the building. Overall, the building costs less to operate than a baseline building.

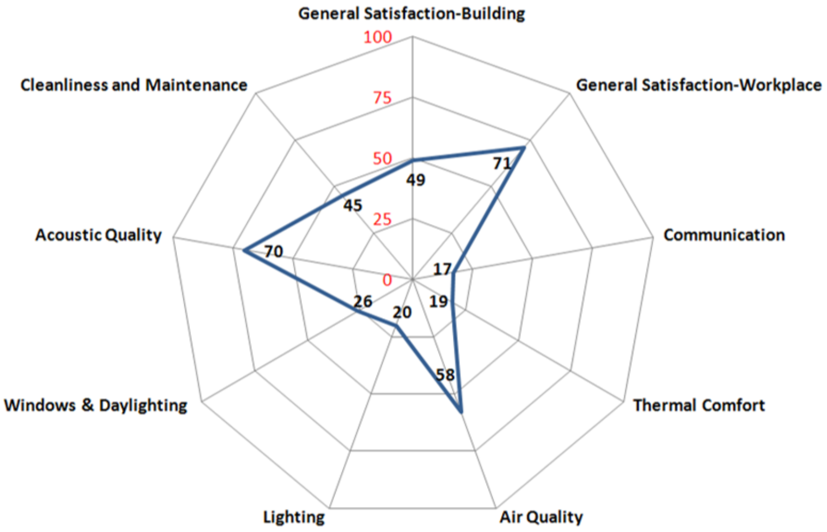


Occupant Satisfaction Survey

Of the 675 occupants at the Auburn SSA Teleservice Center , 600 were surveyed and 442 responded All of the main survey categories except thermal comfort had positive average scores.

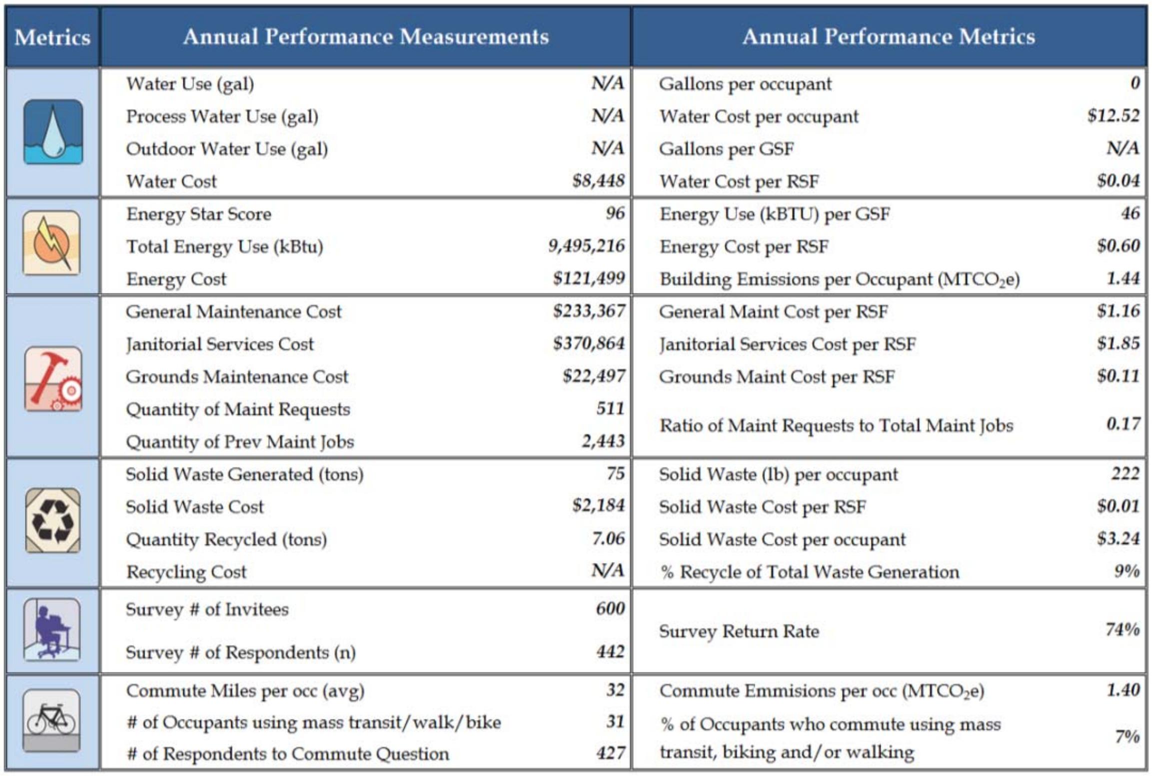


The results indicated that occupants of the Auburn SSA Teleservice Center are slightly less satisfied with their building than occupants in the CBE baseline (49th percentile). The cleanliness and maintenance, lighting, and thermal comfort scored below the 50th percentile of the CBE buildings surveyed. Acoustic quality and air quality scored above the 50th percentile, with acoustic quality at the 70th percentile (one of the highest scoring buildings in the study with an open plan design).



Performance Data Summary

The research team collected, normalized, and compared whole building performance data for the Auburn SSA Teleservice Center to industry baselines. The following table summarizes the annual performance data collected and normalized. The building is part of a campus and is not metered for water use. The water cost is estimated.



Metrics	Annual Performance Measurements		Annual Performance Metrics	
💧	Water Use (gal)	N/A	Gallons per occupant	0
	Process Water Use (gal)	N/A	Water Cost per occupant	$12.52
	Outdoor Water Use (gal)	N/A	Gallons per GSF	N/A
	Water Cost	$8,448	Water Cost per RSF	$0.04
⚡	Energy Star Score	96	Energy Use (kBTU) per GSF	46
	Total Energy Use (kBtu)	9,495,216	Energy Cost per RSF	$0.60
	Energy Cost	$121,499	Building Emissions per Occupant ($MTCO_2e$)	1.44
🔨	General Maintenance Cost	$233,367	General Maint Cost per RSF	$1.16
	Janitorial Services Cost	$370,864	Janitorial Services Cost per RSF	$1.85
	Grounds Maintenance Cost	$22,497	Grounds Maint Cost per RSF	$0.11
	Quantity of Maint Requests	511	Ratio of Maint Requests to Total Maint Jobs	0.17
	Quantity of Prev Maint Jobs	2,443		
♻	Solid Waste Generated (tons)	75	Solid Waste (lb) per occupant	222
	Solid Waste Cost	$2,184	Solid Waste Cost per RSF	$0.01
	Quantity Recycled (tons)	7.06	Solid Waste Cost per occupant	$3.24
	Recycling Cost	N/A	% Recycle of Total Waste Generation	9%
👤	Survey # of Invitees	600	Survey Return Rate	74%
	Survey # of Respondents (n)	442		
🚲	Commute Miles per occ (avg)	32	Commute Emmisions per occ ($MTCO_2e$)	1.40
	# of Occupants using mass transit/walk/bike	31	% of Occupants who commute using mass transit, biking and/or walking	7%
	# of Respondents to Commute Question	427		

Eugene Courthouse

Description

The Wayne L. Morse U.S. Courthouse is located in Eugene, Oregon. Completed in 2006, this facility was the first LEED Gold courthouse in the U.S. The building houses six courtrooms and sees a significant fluctuation in visitors depending on the need for those courtrooms.

Primary energy-efficient features include under floor air distribution (UFAD), fan wall technology, heat reclaim chillers, radiant heating and cooling, condensing boilers, and daylight sensors.

Nearby access to the local bus line, secured bicycle storage, and preferred carpool parking encourage occupants to utilize alternative modes of transportation, although the courthouse's location near a main thoroughfare poses a hindrance for pedestrian traffic.

The Morse Courthouse was received multiple awards for the design, environmental elements, and sustainability features implemented throughout the facility.

Metrics	Wayne L. Morse U.S. Courthouse	
	Building Location	*405 East Eighth Eugene Oregon 97401-2705*
	Building Function	*Courthouse*
	Project Type	*New Construction*
	Design Certification	*LEED-NC Gold, Energy Star 2009 (94)*
	Year Built	*2006*
	# of Floors	*6*
	Gross Square Foot	*270,322*
	Rentable Square Foot	*237,852*
	Usable Square Foot	*181,137*
	Weekly Operating Hours	*45*
	Regular Occupants	*120*
	Average Daily Visitors (FTE)	*50*
	Electronic Equipment	*176*
	Site Cost	*$7,500,000*
	Design Cost	*$4,160,000*
	Construction Cost	*$75,687,500*
	Management & Inspection	*$4,319,000*
	Total Cost	*$91,666,500*

Each building in the study had operational highlights and potential opportunities for improvement. Although it was not the focus of this study to investigate and/or document operational highlights and opportunities, the research team observed:

- A smaller "pony chiller" was installed in 2009 which allowed building management to adjust the chiller operations to respond efficiently to the building loads. The building has received substantial rebates from state utilities and agencies.
- De-lamping during night-time hours while maintaining required lumen levels for security purposes could result in future energy savings.

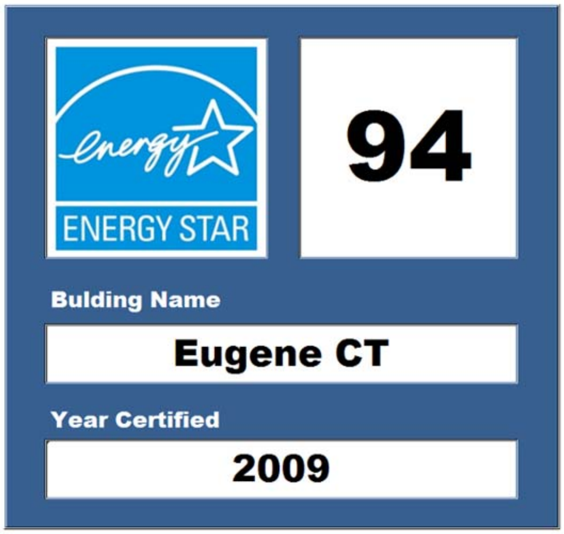
Certifications

LEED® - NC v2.1

Wayne L. Morse U.S. Courthouse
405 East Eighth Avenue, Eugene, Oregon 97401-2705

Gold	**39 Points**
Sustainable Sites	**8/14**
Water Efficiency	**3/5**
Energy & Atmosphere	**8/17**
Materials & Resources	**6/13**
Indoor Environmental Quality	**9/15**
Innovation & Design	**5/5**

Certified: 26-32 points, **Silver:** 33-38 points, **Gold:** 39-51 points, **Platinum:** 52-69 points



ENERGY STAR

94

Bulding Name

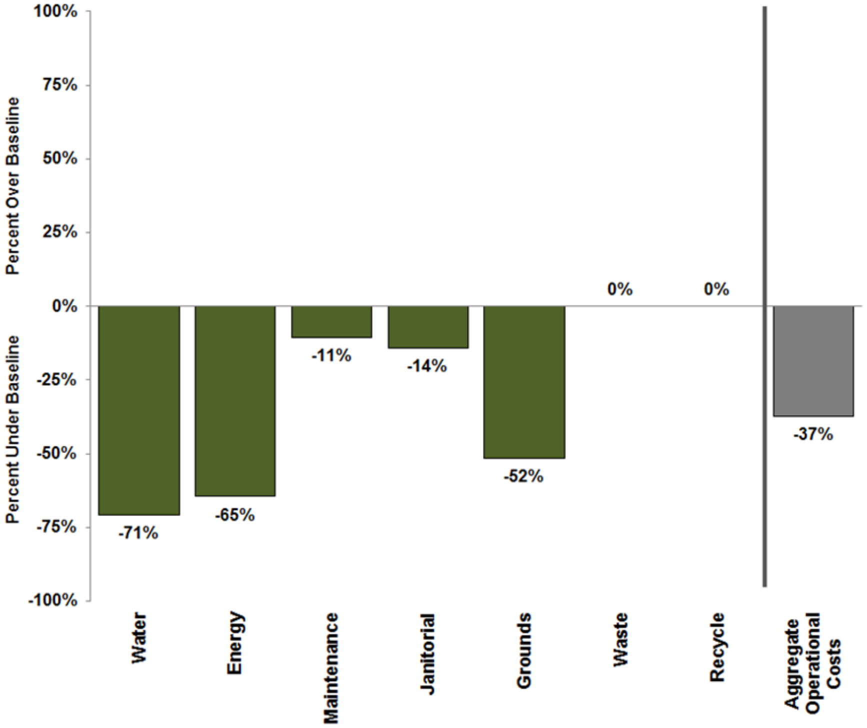
Eugene CT

Year Certified

2009

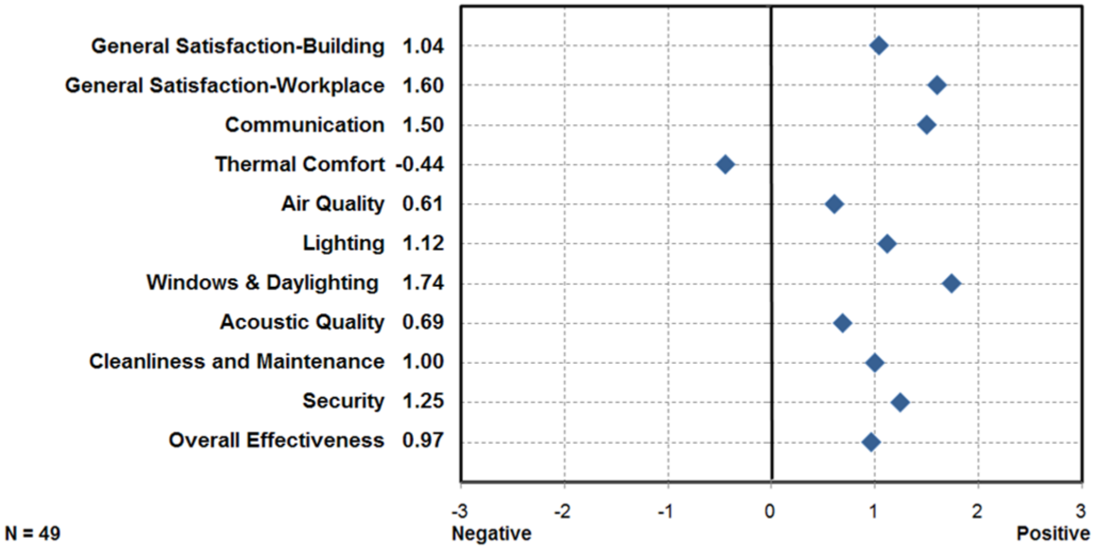
Whole Building Performance

The Morse Courthouse operating costs are lower than the industry baseline for all metrics. The waste and recycling costs are included in the janitorial cost reporting. Overall, the building costs less to operate than a baseline building.

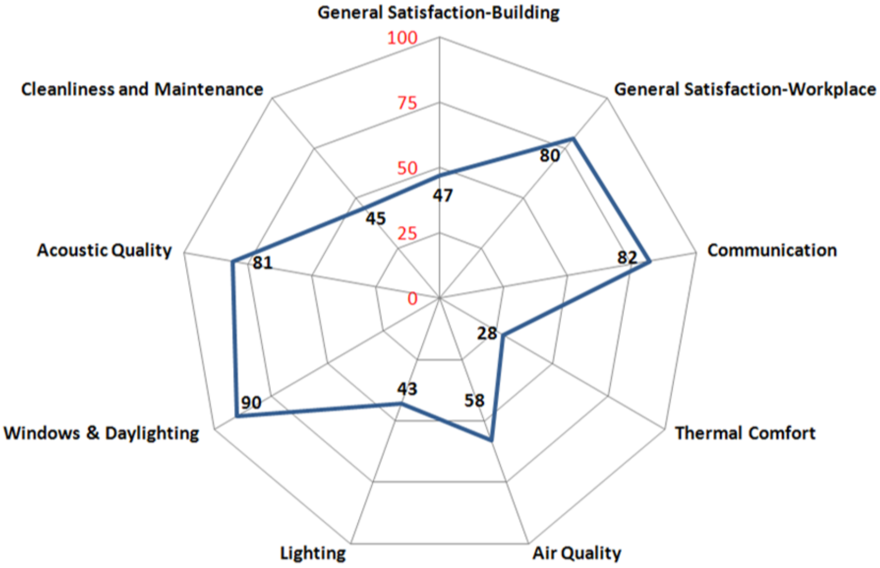


Occupant Satisfaction Survey

All 120 of the Morse Courthouse occupants were surveyed and 49 responded. All of the main survey categories except thermal comfort had positive average scores.

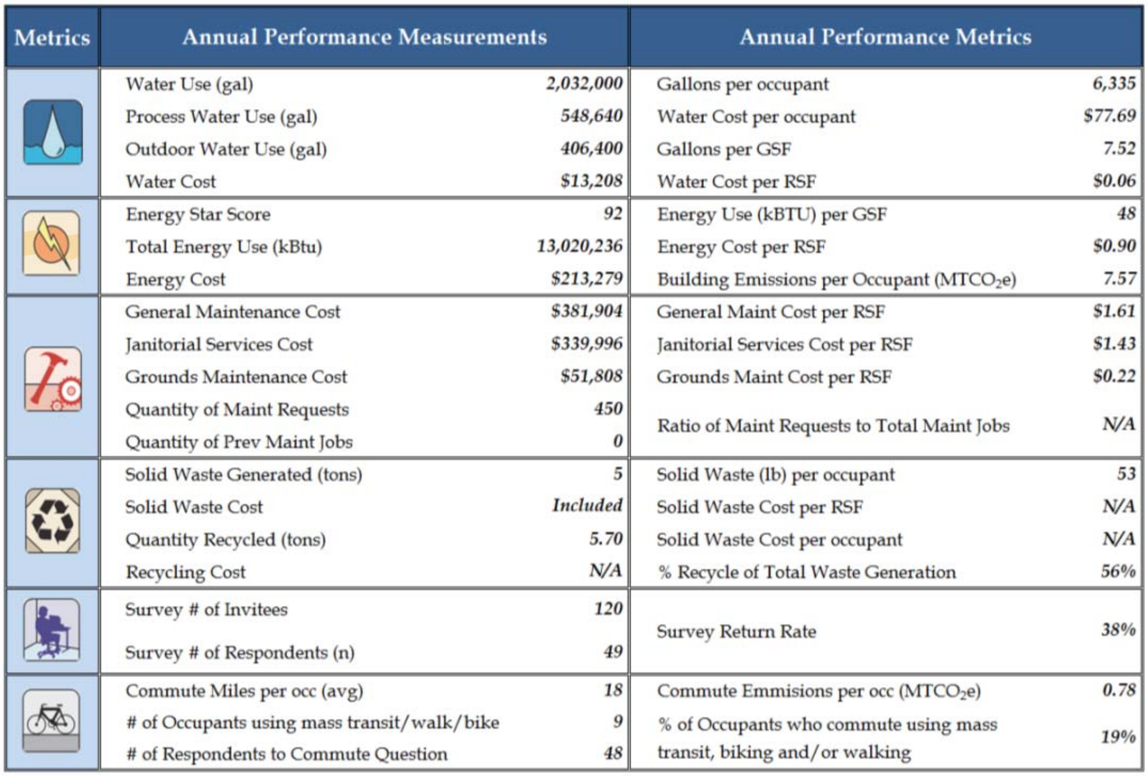


The results indicated that occupants of the Morse Courthouse are slightly less satisfied with their building than occupants in the CBE baseline (47th percentile). The cleanliness and maintenance, lighting, and thermal comfort scored below the 50th percentile of the CBE buildings surveyed. Acoustic quality and air quality in the Morse Courthouse scored above the 50th percentile, with acoustic quality at the 81st percentile (one of the highest scoring buildings in the study).



Performance Data Summary

The research team collected, normalized, and compared whole building performance data for the Morse Courthouse to industry baselines. The following table summarizes the annual performance data collected and normalized. The facility uses water-cooled chillers for its air-conditioning system; therefore, the cooling tower water use was estimated using the "rule-of-thumb" that 27% of total water use is process water. Outdoor water use was estimated using the "rule-of-thumb" that 20% of total water used is for landscaping.

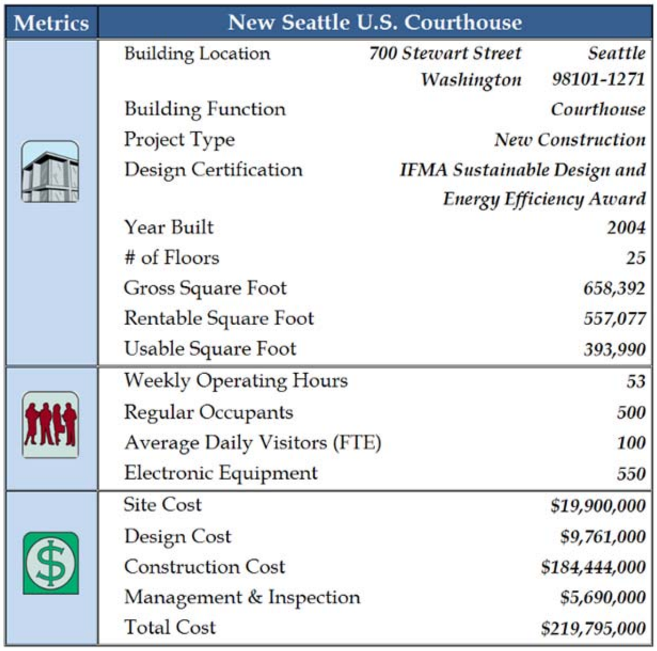


Metrics	Annual Performance Measurements		Annual Performance Metrics	
	Water Use (gal)	*2,032,000*	Gallons per occupant	*6,335*
	Process Water Use (gal)	*548,640*	Water Cost per occupant	*$77.69*
	Outdoor Water Use (gal)	*406,400*	Gallons per GSF	*7.52*
	Water Cost	*$13,208*	Water Cost per RSF	*$0.06*
	Energy Star Score	*92*	Energy Use (kBTU) per GSF	*48*
	Total Energy Use (kBtu)	*13,020,236*	Energy Cost per RSF	*$0.90*
	Energy Cost	*$213,279*	Building Emissions per Occupant (MTCO$_2$e)	*7.57*
	General Maintenance Cost	*$381,904*	General Maint Cost per RSF	*$1.61*
	Janitorial Services Cost	*$339,996*	Janitorial Services Cost per RSF	*$1.43*
	Grounds Maintenance Cost	*$51,808*	Grounds Maint Cost per RSF	*$0.22*
	Quantity of Maint Requests	*450*	Ratio of Maint Requests to Total Maint Jobs	*N/A*
	Quantity of Prev Maint Jobs	*0*		
	Solid Waste Generated (tons)	*5*	Solid Waste (lb) per occupant	*53*
	Solid Waste Cost	*Included*	Solid Waste Cost per RSF	*N/A*
	Quantity Recycled (tons)	*5.70*	Solid Waste Cost per occupant	*N/A*
	Recycling Cost	*N/A*	% Recycle of Total Waste Generation	*56%*
	Survey # of Invitees	*120*	Survey Return Rate	*38%*
	Survey # of Respondents (n)	*49*		
	Commute Miles per occ (avg)	*18*	Commute Emmisions per occ (MTCO$_2$e)	*0.78*
	# of Occupants using mass transit/walk/bike	*9*	% of Occupants who commute using mass transit, biking and/or walking	*19%*
	# of Respondents to Commute Question	*48*		

Seattle Courthouse

Description

Located in downtown Seattle, the courthouse has been deemed one of the safest structures ever built. There are 18 courtrooms that house district courts. It features radiant floor heating, high efficient lighting, a well-utilized EMCS system, water-cooled chillers, natural gas boiler with variable speed drives, waterless urinals, and photovoltaic panels. The lighting controls operate both on occupancy and time-of-day routines. A small "pony" chiller was recently added to the HVAC system to condition the spaces that require 24-7 cooling.



Metrics	New Seattle U.S. Courthouse	
	Building Location	*700 Stewart Street Seattle* *Washington 98101-1271*
	Building Function	*Courthouse*
	Project Type	*New Construction*
	Design Certification	*IFMA Sustainable Design and Energy Efficiency Award*
	Year Built	*2004*
	# of Floors	*25*
	Gross Square Foot	*658,392*
	Rentable Square Foot	*557,077*
	Usable Square Foot	*393,990*
	Weekly Operating Hours	*53*
	Regular Occupants	*500*
	Average Daily Visitors (FTE)	*100*
	Electronic Equipment	*550*
$	Site Cost	*$19,900,000*
	Design Cost	*$9,761,000*
	Construction Cost	*$184,444,000*
	Management & Inspection	*$5,690,000*
	Total Cost	*$219,795,000*

Unique features include a fitness room, underground parking, a public garden, and a library.

In 2004 the Seattle Courthouse won GSA's award for construction excellence, and in 2006 was named the most impressive engineering achievement at the 40th Annual Engineering Excellence Awards, sponsored by the American Council for Engineering Companies.

Each building in the study had operational highlights and potential opportunities for improvement. Although it was not the focus of this study to investigate and/or document operational highlights and opportunities, the research team observed the following:

- Building management has identified several projects to improve the operations in the HVAC area. Challenges have been cited with boiler fouling, simultaneous heating and cooling, and pressurization imbalances. Recommisioning of the entire system is recommended after specific projects are completed.

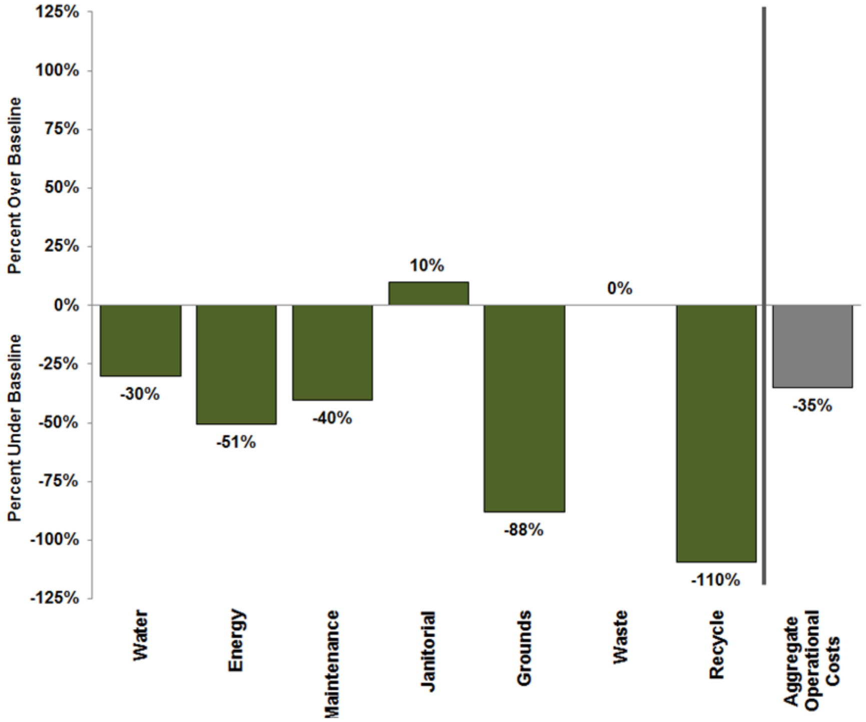
- A study in underway to evaluate the building for daylighting controls to take advantage of the high amount of glazing.

Certifications

IFMA Sustainable Design and Energy Efficiency Award

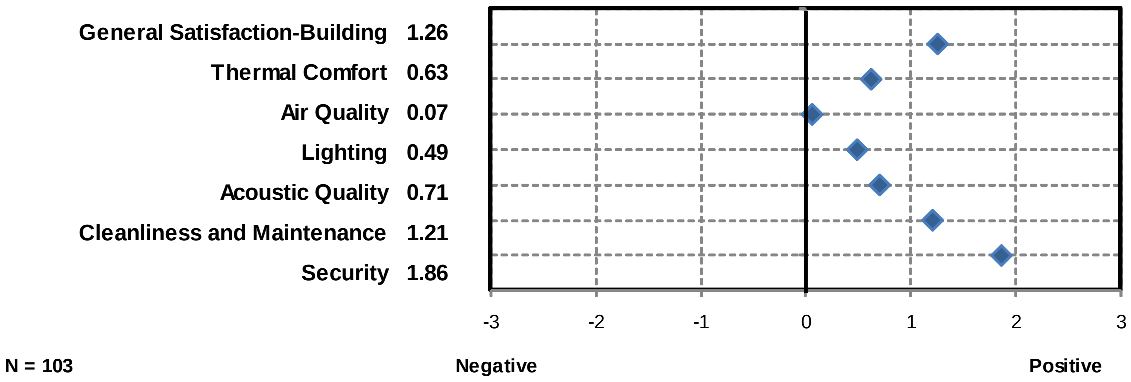
Whole Building Performance

The Seattle Courthouse operating costs are lower than the industry baseline for water, energy, general maintenance, grounds maintenance, and recycling costs. The janitorial costs are higher than the industry baseline and waste is included in this cost. Overall, the building costs less to operate than a baseline building.

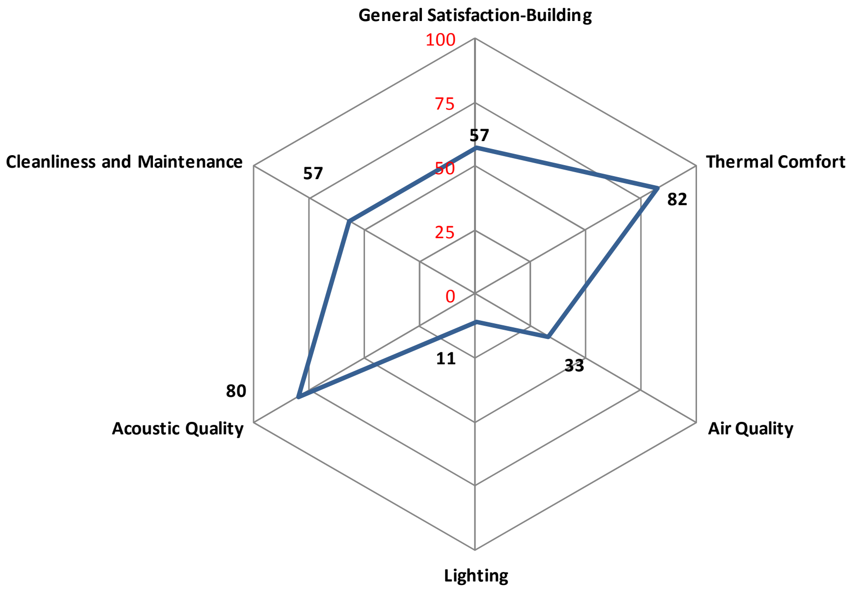


Occupant Satisfaction Survey

Occupants in the Seattle Courthouse occupants were surveyed by GSA in 2006 and 103 responded. A comparison of questions between the GSA survey and the CBE survey was made, and for available categories the values were translate to the CBE scale and are shown below.

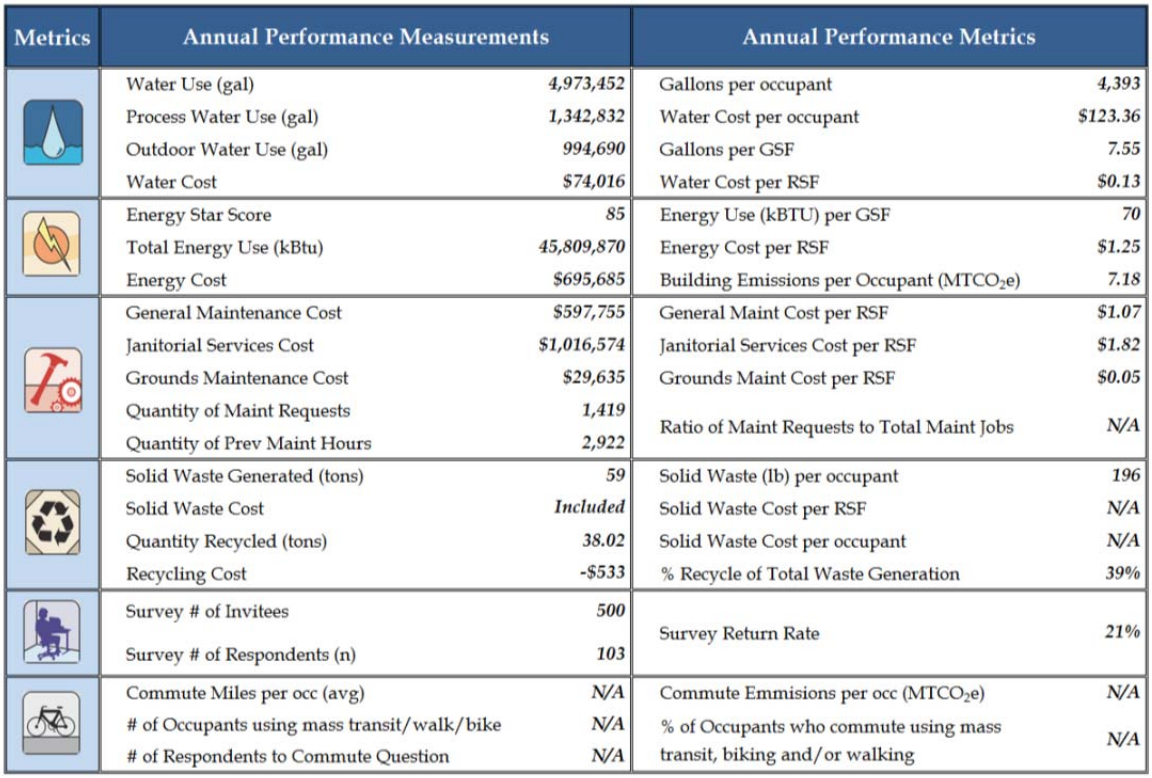


The results indicated that occupants of the Seattle Courthouse are satisfied with their building than occupants in the CBE baseline (57th percentile). For the other survey categories that were the primary focus of this study—acoustic quality, cleanliness and maintenance, and thermal comfort—the Seattle Courthouse scored above the 60th percentile. The courthouse scored below the 50th percentile in the lighting and air quality categories.



Performance Data Summary

The research team collected, normalized, and compared whole building performance data for the Seattle Courthouse to industry baselines. The following table summarizes the annual performance data collected and normalized. The facility uses water-cooled chillers for its air-conditioning system; therefore, the cooling tower water use was estimated using the "rule-of-thumb" that 27% of total water use is process water. Outdoor water use was estimated using the "rule-of-thumb" that 20% of total water use if for landscaping.



Metrics	Annual Performance Measurements		Annual Performance Metrics	
	Water Use (gal)	4,973,452	Gallons per occupant	4,393
	Process Water Use (gal)	1,342,832	Water Cost per occupant	$123.36
	Outdoor Water Use (gal)	994,690	Gallons per GSF	7.55
	Water Cost	$74,016	Water Cost per RSF	$0.13
	Energy Star Score	85	Energy Use (kBTU) per GSF	70
	Total Energy Use (kBtu)	45,809,870	Energy Cost per RSF	$1.25
	Energy Cost	$695,685	Building Emissions per Occupant (MTCO$_2$e)	7.18
	General Maintenance Cost	$597,755	General Maint Cost per RSF	$1.07
	Janitorial Services Cost	$1,016,574	Janitorial Services Cost per RSF	$1.82
	Grounds Maintenance Cost	$29,635	Grounds Maint Cost per RSF	$0.05
	Quantity of Maint Requests	1,419	Ratio of Maint Requests to Total Maint Jobs	N/A
	Quantity of Prev Maint Hours	2,922		
	Solid Waste Generated (tons)	59	Solid Waste (lb) per occupant	196
	Solid Waste Cost	Included	Solid Waste Cost per RSF	N/A
	Quantity Recycled (tons)	38.02	Solid Waste Cost per occupant	N/A
	Recycling Cost	-$533	% Recycle of Total Waste Generation	39%
	Survey # of Invitees	500	Survey Return Rate	21%
	Survey # of Respondents (n)	103		
	Commute Miles per occ (avg)	N/A	Commute Emmisions per occ (MTCO$_2$e)	N/A
	# of Occupants using mass transit/walk/bike	N/A	% of Occupants who commute using mass transit, biking and/or walking	N/A
	# of Respondents to Commute Question	N/A		

Rockville Federal Building

Description

The Substance Abuse and Mental Health Services Administration (SAMSHA) Federal Building was designed to accommodate the needs of the Metropolitan Service Center.

The LEED Silver-registered building features include a reflective white roof, 90% daylighting factor in occupied spaces, occupancy sensors, and use of renewable, local, and recovered materials in both interior finishes and furniture. The building also earned an Energy Star certification in 2009.

Metrics	SAMSHA Metropolitan Service Center	
	Building Location	*1 Choke Cherry Rockville* *Maryland 20850-4030*
	Building Function	*Federal Building*
	Project Type	*New Construction*
	Design Certification	*LEED-NC Registered (Silver),* *Energy Star 2009 (76)*
	Year Built	*2004*
	# of Floors	*9*
	Gross Square Foot	*232,000*
	Rentable Square Foot	*228,020*
	Usable Square Foot	*0*
	Weekly Operating Hours	*60*
	Regular Occupants	*720*
	Average Daily Visitors (FTE)	*40*
	Electronic Equipment	*800*
	Site Cost	*N/A*
	Design Cost	*N/A*
	Construction Cost	*N/A*
	Management & Inspection	*N/A*
	Total Cost	*N/A*

The landscaping incorporates the native and drought tolerant species of plants and trees. While originally designed without an irrigation system, recently hose bibs have been installed for watering during dry periods.

The building houses conference and training rooms that see a fluctuation in visitors. Unique features include a fitness center, locker room, library, and tenant supported nurse's office. The SAMSHA Service Center is within close proximity to the train, and the building management provides a bus shuttle from the station to the building for the occupants.

Each building in the study had operational highlights and potential opportunities for improvement. Although it was not the focus of this study to investigate and/or document operational highlights and opportunities, the research team observed the following:

- Building management has plans to perform a LEED feasibility study mid-2010 and register with the U.S. Green Building Council for LEED-EB certification.

Certifications

LEED® - NC v2.1

SAMSHA Metropolitan Service Center
1 Choke Cherry Road, Rockville, Maryland 20850-4030

Registered	33 Points
Sustainable Sites	9/14
Water Efficiency	3/5
Energy & Atmosphere	#N/A
Materials & Resources	5/13
Indoor Environmental Quality	12/15
Innovation & Design	0/5

Certified: 26-32 points, **Silver:** 33-38 points, **Gold:** 39-51 points, **Platinum:** 52-69 points

ENERGY STAR

76

Bulding Name

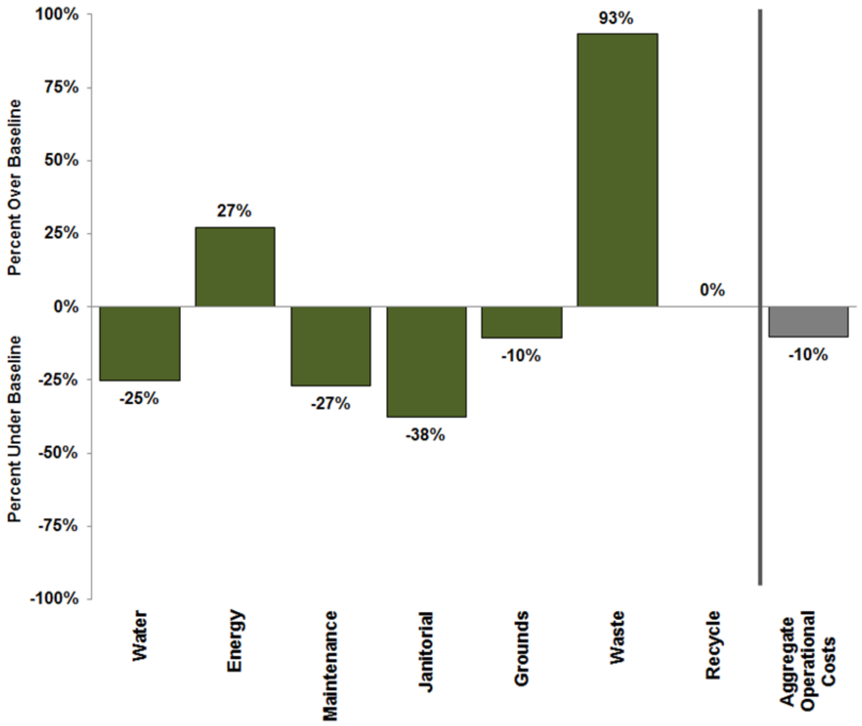
Rockville (L) FB

Year Certified

2009

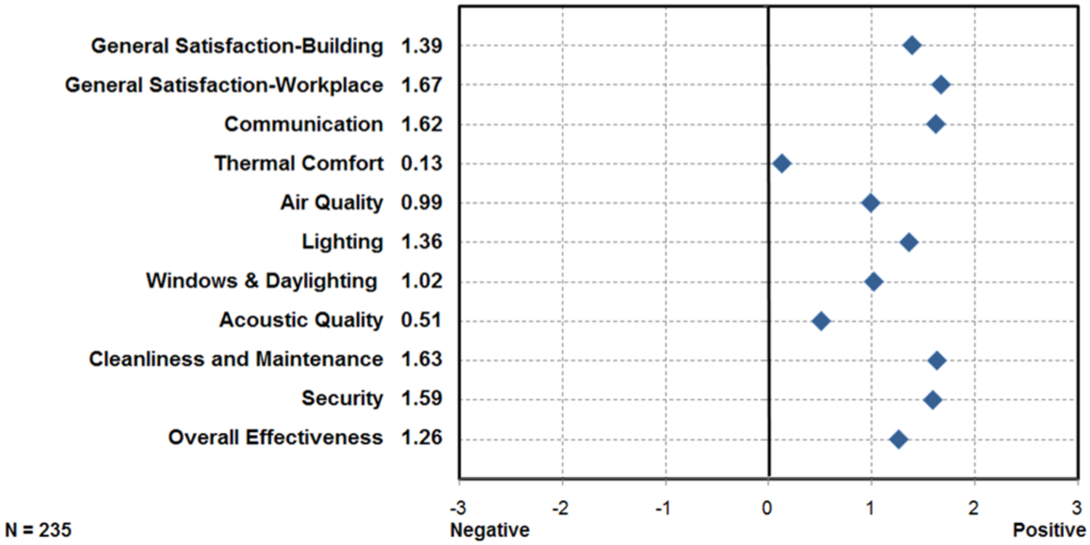
Whole Building Performance

The SAMSHA Service Center operating costs are lower than the industry baseline for water, general maintenance, grounds maintenance, janitorial and waste costs. The energy costs are higher than the industry baseline. Overall, the building costs less to operate than a baseline building.

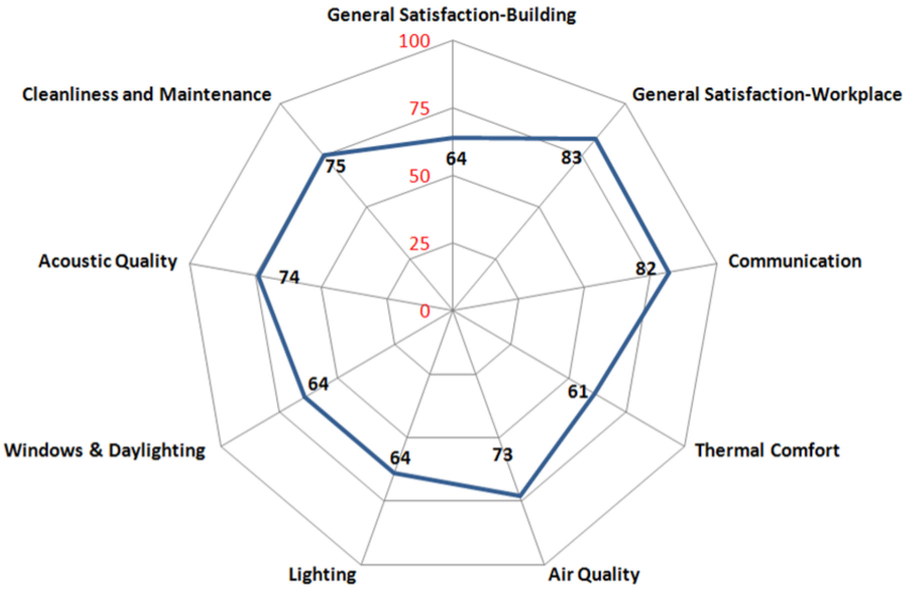


Occupant Satisfaction Survey

All 430 of the SAMSHA Service Center occupants were surveyed and 235 responded. All of the main survey categories had positive average scores.

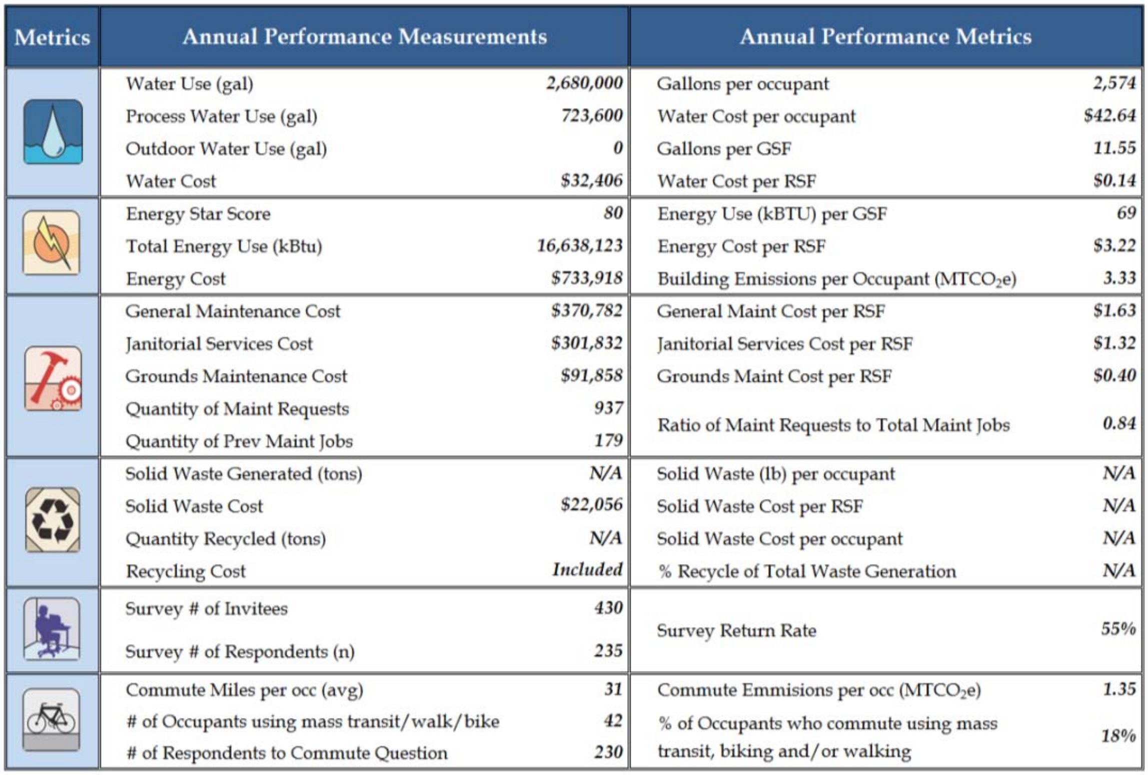


The results indicated that occupants of the SAMSHA Service Center are more satisfied with their building than occupants in the CBE baseline (64th percentile). For the other survey categories that were the primary focus of this study—acoustic quality, air quality, cleanliness and maintenance, and thermal comfort—the SAMSHA Service Center scored above the 60th percentile.



Performance Data Summary

The research team collected, normalized, and compared whole building performance data for the SAMSHA Service Center to industry baselines. The following table summarizes the annual performance data collected and normalized. The facility uses water-cooled chillers for its air-conditioning system; therefore, the cooling tower water use was estimated using the "rule-of-thumb" that 27% of total water use is process water.



Metrics	Annual Performance Measurements		Annual Performance Metrics	
💧	Water Use (gal)	2,680,000	Gallons per occupant	2,574
	Process Water Use (gal)	723,600	Water Cost per occupant	$42.64
	Outdoor Water Use (gal)	0	Gallons per GSF	11.55
	Water Cost	$32,406	Water Cost per RSF	$0.14
⚡	Energy Star Score	80	Energy Use (kBTU) per GSF	69
	Total Energy Use (kBtu)	16,638,123	Energy Cost per RSF	$3.22
	Energy Cost	$733,918	Building Emissions per Occupant (MTCO_2e)	3.33
🔨	General Maintenance Cost	$370,782	General Maint Cost per RSF	$1.63
	Janitorial Services Cost	$301,832	Janitorial Services Cost per RSF	$1.32
	Grounds Maintenance Cost	$91,858	Grounds Maint Cost per RSF	$0.40
	Quantity of Maint Requests	937	Ratio of Maint Requests to Total Maint Jobs	0.84
	Quantity of Prev Maint Jobs	179		
♻	Solid Waste Generated (tons)	N/A	Solid Waste (lb) per occupant	N/A
	Solid Waste Cost	$22,056	Solid Waste Cost per RSF	N/A
	Quantity Recycled (tons)	N/A	Solid Waste Cost per occupant	N/A
	Recycling Cost	Included	% Recycle of Total Waste Generation	N/A
👤	Survey # of Invitees	430	Survey Return Rate	55%
	Survey # of Respondents (n)	235		
🚲	Commute Miles per occ (avg)	31	Commute Emmisions per occ (MTCO_2e)	1.35
	# of Occupants using mass transit/walk/bike	42	% of Occupants who commute using mass transit, biking and/or walking	18%
	# of Respondents to Commute Question	230		

Suitland Federal Building

Description

The Census Bureau Office Complex in Suitland is the largest building in the study at 2.3 million square feet. This LEED Registered building has a curved design with shallow floor plate that takes advantage of the natural daylighting. Unique design features include underfloor air distribution, vertically mounted wood fins shades the curtain wall to reduce the solar glare, vegetative roofs, and a retention pond with bioswales.

Waterless urinals, low-flow fixtures, and water-efficient appliances resulted in a projected reduction of more than 30% of potable water use. Operation of the facility incorporates green janitorial practices.

Metrics	Census Bureau Office Complex	
	Building Location	*4600a Silver Hill Suitland Maryland 20746-2402*
	Building Function	*Federal Building*
	Project Type	*New Construction*
	Design Certification	*LEED-NC Registered (Gold)*
	Year Built	*2006*
	# of Floors	*8*
	Gross Square Foot	*2,340,988*
	Rentable Square Foot	*1,410,988*
	Usable Square Foot	*1,195,551*
	Weekly Operating Hours	*119*
	Regular Occupants	*5,360*
	Average Daily Visitors (FTE)	*65*
	Electronic Equipment	*5,500*
	Site Cost	*N/A*
	Design Cost	*$8,013,000*
	Construction Cost	*$306,372,000*
	Management & Inspection	*$16,998,000*
	Total Cost	*$331,383,000*

The complex is located next to commuter train station enabling alternative commuting. Unique features include amenities such as cafeteria, banks, fitness center, health clinic, and retail stores.

Each building in the study had operational highlights and potential opportunities for improvement. Although it was not the focus of this study to investigate and/or document operational highlights and opportunities, the research team observed the following:

- In an open office layout, it is important to offer small meeting spaces for staff to schedule and conduct impromptu meetings. The acoustic quality CBE score for the Suitland Census was well below the average building at the 11th percentile. Identifying opportunities to increase alternative locations for staff to convene and investigating sound-masking technologies may improve the occupants' perception of the building's acoustic quality.

Certifications

LEED® - NC v2.1

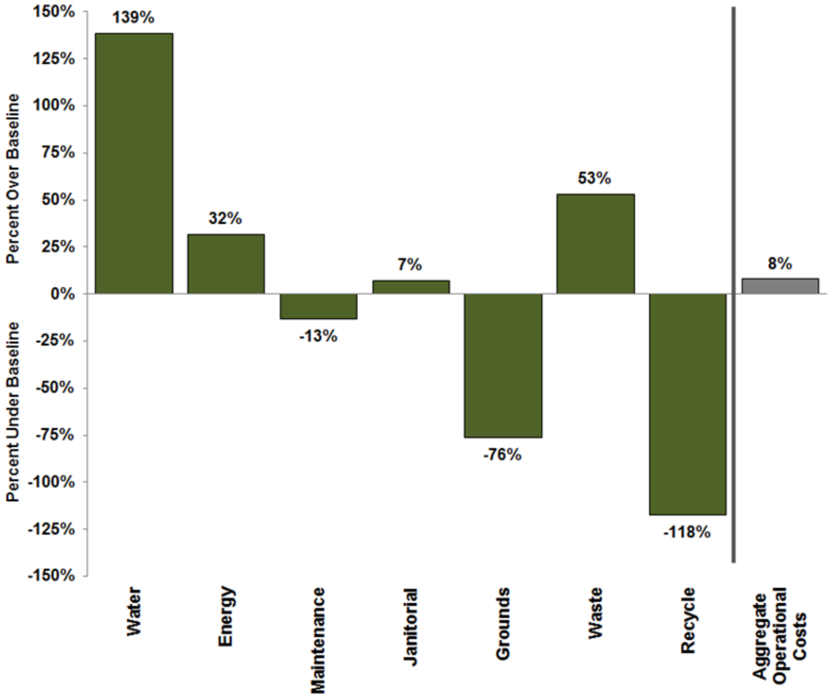
Census Bureau Office Complex
4600a Silver Hill Road, Suitland, Maryland 20746-2402

Registered	41 Points
Sustainable Sites	10/14
Water Efficiency	4/5
Energy & Atmosphere	4/17
Materials & Resources	6/13
Indoor Environmental Quality	12/15
Innovation & Design	5/5

Certified: 26-32 points, **Silver**: 33-38 points, **Gold**: 39-51 points, **Platinum**: 52-69 points

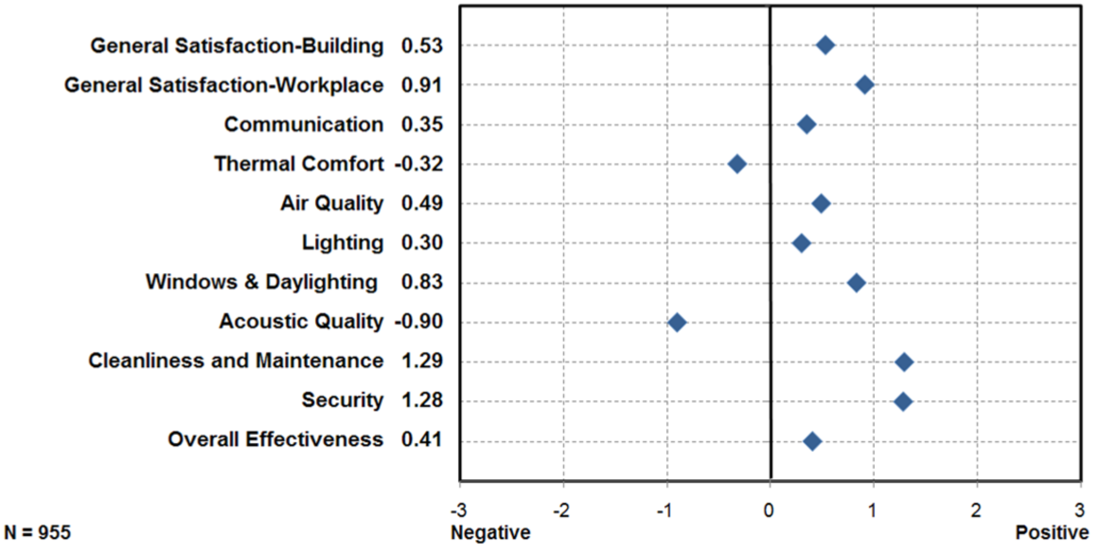
Whole Building Performance

The Census Bureau Complex operating costs are lower than the industry baseline for general maintenance, grounds maintenance, waste, and recycling costs. The water, energy, and janitorial costs are higher than the industry baseline. Overall, the building costs slightly more to operate than a baseline building.

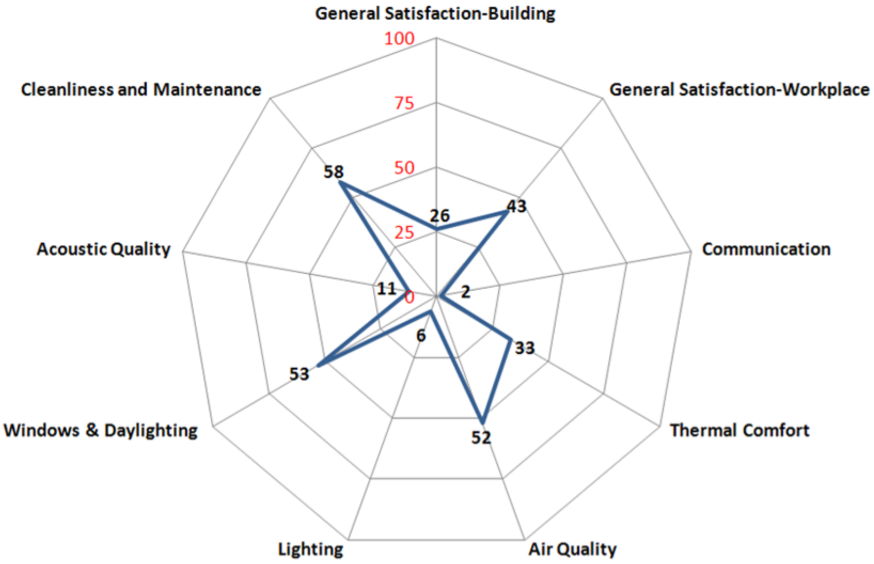


Occupant Satisfaction Survey

All 5,360 of the Census Bureau Complex occupants were surveyed and 955 responded. All of the main survey categories except thermal comfort and acoustic quality had positive average scores.

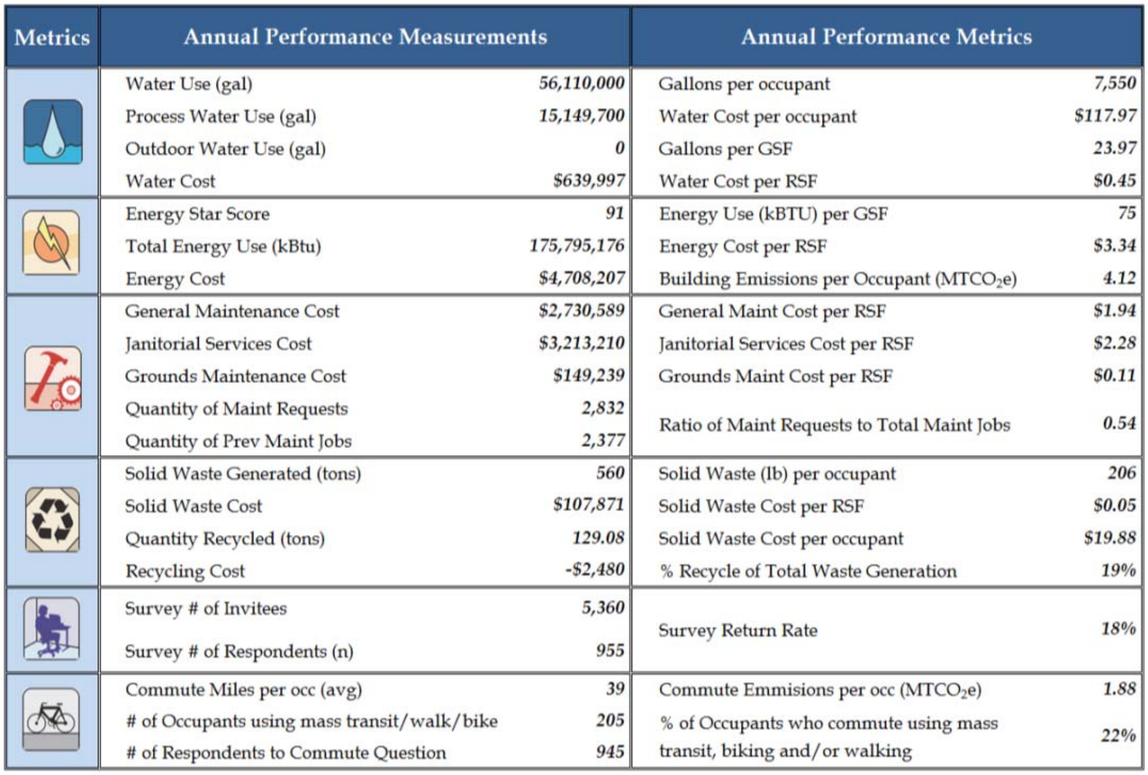


The results indicated that occupants of the Census Bureau Complex are less satisfied with their building than occupants in the CBE baseline (26th percentile). The acoustic quality, lighting, and thermal comfort scored below the 50th percentile of the CBE buildings surveyed. Cleanliness and maintenance and air quality in the Census Bureau Complex scored above the 50th percentile.



Performance Data Summary

The research team collected, normalized, and compared whole building performance data for the Census Bureau Complex to industry baselines. The following table summarizes the annual performance data collected and normalized. The facility uses water-cooled chillers for its air-conditioning system; therefore, the cooling tower water use was estimated using the "rule-of-thumb" that 27% of total water use is process water.



Metrics	Annual Performance Measurements		Annual Performance Metrics	
💧	Water Use (gal)	*56,110,000*	Gallons per occupant	*7,550*
	Process Water Use (gal)	*15,149,700*	Water Cost per occupant	*$117.97*
	Outdoor Water Use (gal)	*0*	Gallons per GSF	*23.97*
	Water Cost	*$639,997*	Water Cost per RSF	*$0.45*
⚡	Energy Star Score	*91*	Energy Use (kBTU) per GSF	*75*
	Total Energy Use (kBtu)	*175,795,176*	Energy Cost per RSF	*$3.34*
	Energy Cost	*$4,708,207*	Building Emissions per Occupant ($MTCO_2e$)	*4.12*
🔨	General Maintenance Cost	*$2,730,589*	General Maint Cost per RSF	*$1.94*
	Janitorial Services Cost	*$3,213,210*	Janitorial Services Cost per RSF	*$2.28*
	Grounds Maintenance Cost	*$149,239*	Grounds Maint Cost per RSF	*$0.11*
	Quantity of Maint Requests	*2,832*	Ratio of Maint Requests to Total Maint Jobs	*0.54*
	Quantity of Prev Maint Jobs	*2,377*		
♻	Solid Waste Generated (tons)	*560*	Solid Waste (lb) per occupant	*206*
	Solid Waste Cost	*$107,871*	Solid Waste Cost per RSF	*$0.05*
	Quantity Recycled (tons)	*129.08*	Solid Waste Cost per occupant	*$19.88*
	Recycling Cost	*-$2,480*	% Recycle of Total Waste Generation	*19%*
🪑	Survey # of Invitees	*5,360*	Survey Return Rate	*18%*
	Survey # of Respondents (n)	*955*		
🚲	Commute Miles per occ (avg)	*39*	Commute Emmisions per occ ($MTCO_2e$)	*1.88*
	# of Occupants using mass transit/walk/bike	*205*	% of Occupants who commute using mass transit, biking and/or walking	*22%*
	# of Respondents to Commute Question	*945*		

Appendix B: Excluded Buildings

This appendix includes data from two Port of Entry buildings and the Manhattan FB. Initial analysis of the Port of Entry data demonstrated that none of the commonly used baselines for office buildings would apply to Ports of Entry. During the site visit of the Manhattan FB, researchers observed a number of significant operational problems assumed to be related to the building's HVAC system. Building management worked with a number of entities to engineer a solution and shortly after the site visit had signed a contract to implement solutions to improve building performance. For this study, the Manhattan FB was not included in the main body of the report as it was considered to be not fully commissioned. Some of the reasons for removing the Port of Entry buildings from the body of the report include

- Port of Entry buildings operate 24 hours a day for 365 days a year.
- Ports of Entry contain a considerable amount of electronic equipment (e.g., monitoring equipment, computers, etc.).
- A considerable number of public visitors impact the water use, energy use, and janitorial costs.
- The remote location of Ports of Entry tends to increase their associated labor costs.
- A portion of the space includes large heated garages for vehicle inspections.

For these reasons, a summary of the data for Manhattan FB, Sault Sainte Marie Port and Sweetgrass Port and are provided in this appendix.

General Building Information

The Manhattan FB is a leased facility in a medium-sized community in central Kansas. The Sault Sainte (Ste.) Marie Port of Entry is on the US-side of the US-Canadian border surrounded by a small community. The Sweetgrass, Montana/Coutts, Alberta (Sweetgrass) Port of Entry straddles the US-Canadian border in a remote location. Appendix A offers a detailed site summary for these facilities.

For each of the key metrics in this study, the following table offers the summary results. The remaining tables in this appendix provide detail for each individual metric.

Building Name	GSF	Energy Star® Score	Total Water (1000 gal)	Aggregate Maintenance Cost	Waste Cost	General Bldg % Satisfaction	Metric Tons of CO_2 equiv/Occ
Manhattan (L) FB	13,500	36	70	$33,891	$14,288	75%	n/a
Sault Ste. Marie Port	63,874	18	13	$381,104	$3,182	47%	20.5
Sweetgrass Port	98,196	19	123	$588,720	$5,770	61%	9.8

The Manhattan FB is the smallest building in the study. The Sweetgrass Port of Entry is larger than the Sault Sainte Marie Port of Entry and has more daily visitors that stopped to use the facilities.

Building Name	Building ID #	Region	Year Built/ Renovated	GSF	RSF	# Occ	Occ-Vis Equiv	Hours/ week	# Comps
Manhattan (L) FB	KS1597ZZ	6	2006	13,500	12,262	28	30	60	35
Sault Ste. Marie Port	MI0724SB	5	2005	63,874	39,709	74	84	168	80
Sweetgrass Port	MT0767AI	8	2003	98,196	84,928	190	253	168	320

Manhattan is LEED-Silver certified with two Energy & Atmosphere (EA) Optimize Energy Performance (EAc1) points and two Water Efficiency (WE) Water Use Reduction (WEc3) points. Sweetgrass is LEED-NC certified with no Energy EAc1 points and only one WEc3 point. Manhattan has an Energy Star score below 40, and both Port of Entry buildings have scores below 20. Manhattan and Sweetgrass also each have two points for Water-Efficient Landscaping (WEc1), and Sweetgrass has one EA point for Green Power (EAc6).

Building Name	Certification Level	LEED® Total Credits	LEED® EAc1 Credits	LEED® WEc3 Credits	Energy Star® Score
Manhattan (L) FB	LEED-NC Silver	33	2	2	36
Sault Ste. Marie Port	LEED-NC Registered	N/A	N/A	N/A	18
Sweetgrass Port	LEED-NC Certified	27	0	1	19

Water

None of the sites use process water for cooling or potable water for landscaping. Manhattan has buffalo grass landscaping that has been a challenge to get established. Sault Ste. Marie has a vegetated roof, but no significant landscaping. Sweetgrass has minimal trees and native plants that require no additional water once they are established.

Water Use (gallons)						
Building Name	**Water Consuming Equipment**	**Total Water**	**Estimated Landscape**	**Estimated Process**	**Domestic Portion**	**Total Water Cost**
Manhattan (L) FB	-	70,317	0	0	70,317	$753
Sault Ste. Marie Port	-	13,000	0	0	13,000	$1,858
Sweetgrass Port	-	123,144	0	0	123,144	$8,073

Energy

None of the buildings have access to central steam or chilled water. All buildings use natural gas and electricity.

Energy Use						
Building Name	**Electricity (MWH)**	**Nat Gas (1000 ft^3)**	**Steam (kBtu)**	**Chilled Water (Ton Hr)**	**Total Energy (mbtu)**	**Total Energy Cost**
Manhattan (L) FB	210	661	0	0	723	$23,554
Sault Ste. Marie Port	1,918	3,982	0	0	10,577	$98,472
Sweetgrass Port	2,432	12,127	0	0	20,583	$187,253

The most comparable information for the energy use intensity (EUI) is information specific to the GSA information. Manhattan is above all of the comparable values, which is not surprising given that the HVAC equipment has been operated 24-7 in an attempt to address humidity problems. When all GSA Port of Entry energy use is averaged the EUI is 109 kBTU/gsf. When only the northern Port of Entry energy use is averaged, the EUI is 132 kBTU/gsf, which is closer to the measured use than the Commercial Buildings Energy Consumption Survey (CBECS) values by region.

	EUI (kBTU/gsf)						
Building Name	**Current EUI**	**FY09 GSA Regional Averages**	**FY09 GSA Target**	**Energy Star Baseline (50%)**	**CBECS Regional Average**	**CBECS Office**	**GSA Northern Port Average**
Manhattan (L) FB	102	75	81	88	75	88	n/a
Sault Ste. Marie Port	165	84	86	114	108	n/a	132
Sweetgrass Port	193	89	92	133	104	n/a	132

Maintenance and Operations

The Manhattan building manager indicated that the HVAC maintenance cost was significantly higher than expected due to the number of problems with the system. The site personnel at the Sweetgrass Port of Entry indicated that they had considerable difficulty getting reasonably priced contractors on site because of their remote location of the site. The site does not routinely track maintenance calls, thus the estimated ratio of maintenance calls to preventative maintenance provided by site personnel.

Building Name	Green House-keeping	Maint Calls / Total Maint	Prev Maint / Total Maint	General Maint Cost	Janitorial Maint Cost	Grounds Maint Cost
Manhattan (L) FB	No	N/A	N/A	$7,073	$14,288	$12,530
Sault Ste. Marie Port	Some	43%	57%	$109,962	$206,281	$64,860
Sweetgrass Port	Yes	4%	96%	$308,055	$240,630	$40,035

Waste Disposal and Recycling

Manhattan does have a recycling program that tracks quantity, and there is no cost to the site. Sault Ste. Marie did not have a recycling program, and although a recycling program exists at Sweetgrass, the PNNL research team was not able to obtain the numbers related to quantities of waste and recycled materials to enable a performance comparison.

Building Name	Waste per Year (Tons)	Waste Cost	Recycled Material	Recycle per year (Tons)	Recycle Cost	% Recycle of Total Waste Generation
Manhattan (L) FB	140	$14,288	Paper	1	$0	1%
Sault Ste. Marie Port	70	$3,182	None	-	$0	0%
Sweetgrass Port	N/A	$5,770	Paper	N/A	$1,260	N/A

Transportation

The occupants of the Sault Ste. Marie Port of Entry building have the shortest average commute distances of all the buildings in the study, while Sweetgrass building occupants have the longest average commute distance. For both buildings, the majority of the building occupants drive trucks or sport utility vehicles. The occupants at Manhattan were not given the study specific survey that requested information on commute distance or type of vehicle driven. Alternatively the standard GSA survey had been administered earlier in the year and the occupants could not be re-surveyed.

Building Name	Survey N-Value	# Occ	% of Occupants who commute using mass transit, biking and/or walking	Avg Daily Roundtrip Miles Traveled/Occ	Transportation CO_2 Equiv/Occ (metric tons)	Baseline Transportation CO_2 Equiv/Occ (metric tons)	Bldg Transportation Performance
Manhattan (L) FB	13	28	N/A	N/A	N/A	2.3	N/A
Sault Ste. Marie Port	16	74	0%	16.7	2.0	2.3	-15%
Sweetgrass Port	43	190	0%	38.6	3.6	2.3	55%

	Aggregate $MTCO_2$ Equivalent Emissions				
Building Name	Transportation	Transportation Baseline	Building	Building Baseline	Aggregate CO_2 Emissions Performance
Manhattan (L) FB	N/A	69	223	193	N/A
Sault Ste. Marie Port	164	193	1,558	1,071	36%
Sweetgrass Port	902	581	1,568	1,079	49%

Recommissioning of the Manhattan Federal Building is recommended after modifications to the HVAC systems are incorporated. As more Port of Entry buildings are designed and built, the need to understand how to optimize the design and operation of this building type will become greater. A detailed analysis of a Port of Entry building's performance would offer additional insight into factors impacting the water and energy use, maintenance and waste costs, occupant commute, and occupant satisfaction considerations. This level of analysis would require sub-metered energy and water use and more detailed investigation into costs and occupant-related factors.

Appendix C: Building Selection Process

The purpose of the study was to assess as many of GSA's sustainably designed buildings as possible. The GSA and PNNL research team identified buildings that had the potential for being included in the whole building performance measurement study. To identify the list of potential buildings a variety of resources were considered (see list of resources provided prior to the table of buildings). Once the list of buildings was identified, each was considered using the building selection criteria. The table in this appendix includes the list of buildings considered for this study, and the reason why a building was or was not included in the study.

(†) NREL. March 2008. Federal Building Projects Registered for LEED® Certification Partial Listing. http://www1.eere.energy.gov/femp/pdfs/fed_leed_bldgs_reg.pdf Accessed October 2008.

(‡) NREL. March 2007. Federal Buidings Awarded LEED® Certification. www1.eere.energy.gov/femp/pdfs/fed_leed_bldgs_sum.pdf Accessed October 2008.

(#) GSA. LEED Certified Projects. http://www.gsa.gov/Portal/gsa/ep/channelView.do?pageTypeId=17109&channelPage=%2Fep%2Fchannel%2FgsaOverview.jsp&channelId=-24332. Accessed October 2008.

(*) Energy Star. 2008. ENERGY STAR Labeled Buildings & Plants. http://www.energystar.gov/index.cfm?fuseaction=labeled_buildings.locator Accessed October 2008.

OCA = Office of the Chief Architect

PBS = Public Buildings Service

R1 = Round 1 Assessing Green Building Performance Study

R2 = Round 2 Re-Assessing Green Building Performance Study

Project Name	Building Type	Region	Source	Status
Quillen U.S. CT	Courthouse	Southeast Region 4	PBS	Included R1
John J. Duncan Federal Building	Office	Southeast Region 4	PBS	Included R1
Metzenbaum U.S. CT	Courthouse	Great Lakes Region 5	PBS	Included R1
Scowcroft IRS Building	Office	Rocky Mountain Region 8	PBS	Included R1
Lakewood DOT Office	Office	Rocky Mountain Region 8	PBS	Included R1
DHS Omaha Office	Office	Heartland Region 6	PBS	Included R1
Curtis NPS Headquarters Omaha	Office	Heartland Region 6	PBS	Included R1
Santa Ana Federal Building	Office	Pacific Rim Region 9	PBS	Included R1

Project Name	Building Type	Region	Source	Status
Alfred Arraj U.S. CT	Courthouse	Rocky Mountain Region 8	PBS	Included R1
Davenport CT	Courthouse	Heartland Region 6	PBS	Included R1
Jones Federal Building and CT	Office & Courthouse	Great Lakes Region 5	PBS	Included R1
Coyle CT and Office	Office & Courthouse	Pacific Rim Region 9	PBS	Included R1
Sault Ste Marie Port	Port of Entry	Great Lakes Region 5	PBS	Included R1
Sweetgrass Port	Port of Entry	Rocky Mountain Region 8	PBS	Included R1
U.S. Census Bureau Headquarters	Office	National Capital Region 11	‡	Included R2
U.S. Department of Agriculture Service Center	Office	Heartland Region 6	#	Included R2
Social Services Administration Telework Center	Office	NW/Arctic Region 10	#	Included R2
San Francisco FB	Office	Pacific Rim Region 9	OCA	Included R2
Montgomery SAMHSA Lse	Office	National Capital Region 11	OCA	Included R2
Las Vegas George CT	Courthouse	Pacific Rim Region 9	OCA	Included R2
Seattle New CT	Courthouse	NW/Arctic Region 10	OCA	Included R2
Jacksonville Bennett FB R	Office	Southeast Region 4	OCA/*	Included R2
Denver EPA Region 8 Headq	Office	Rocky Mountain Region 8	OCA/#	Included R2
Eugene CT	Courthouse	NW/Arctic Region 10	OCA/#	Included R2
Cape Girardeau CT	Courthouse	Heartland Region 6	PBS	Included R2
Veterans Affairs Regional Office	Office	Pacific Rim Region 9	†	Commissioning Underway
New Richmond U.S. Courthouse	Courthouse	Mid-Atlantic Region 3	‡	Commissioning Underway
US CIS Detroit District Office	Cargo Inspection	Great Lakes Region 5	‡	No Building Type Comparison
NNSA Campus	Production Facility	Heartland Region 6	‡	No Building Type Comparison
Center for Devices and Radiological Health	Laboratory	Mid-Atlantic Region 3	‡	No Building Type Comparison
David Skaggs Research Center	Laboratory	Rocky Mountain Region 8	‡	No Building Type Comparison
NOAA Building 1 Extension	Research	Rocky Mountain Region 8	‡	No Building Type Comparison
U.S. EPA Science and Technology Center	Laboratory /Office	Heartland Region 6	#	No Building Type Comparison
Child Care Building for Social Security	Child Care	Mid-Atlantic Region 3	#	No Building Type

Project Name	Building Type	Region	Source	Status
Administration				Comparison
U.S. EPA New England Regional Laboratory	Laboratory	New England Region 1	#	No Building Type Comparison
OSHA Salt Lake Technical Center	Laboratory /Office	Rocky Mountain Region 8	#	No Building Type Comparison
OKC Federal Campus	Campus	Greater Southwest Region 7	OCA	No Building Type Comparison
Suitland NOAA Satellite O	Research/ Satellite Operations	Mid-Atlantic Region 3	OCA/#	No Building Type Comparison
536 S. Clark FB	Office/Laboratory	Great Lakes Region 5		No Building Type Comparison
Concord Cleveland FB-PO-C	Office/Post Office/ Courthouse	New England Region 1	OCA	No Building Type Comparison, Not LEED
Courthouse Square	Courthouse	Rocky Mountain Region 8	‡	Not Cooperative
Potomac Yard 1 and 2/EPA	Office	Mid-Atlantic Region 3	†	Not Cooperative
Newport News Federal Courthouse	Courthouse	Mid-Atlantic Region 3	‡	Not Cooperative
IRS Service Center	Office	Heartland Region 6	#	Not Cooperative
CIS Nebraska Service Center	Office	Heartland Region 6	#	Not Cooperative
Wash DC ATF HQ	Office	National Capital Region 11	OCA	Not Cooperative
Liberty IV at Park Place	Office	Great Lakes Region 5	†	Not GSA
DEA Pittsburgh District Office	Office	Mid-Atlantic Region 3	†	Not GSA
The Bureau of the Public Debt	Office	Mid-Atlantic Region 3	‡	Not GSA
USDA Headquarters Modernization: South	Office	National Capital Region 11	‡	Not GSA
NIH Building 3	Office	National Capital Region 11	‡	Not GSA
U.S. District Court, District of Montana	Courthouse	Rocky Mountain Region 8	‡	Not GSA
CIS Denver District Office	Office	Rocky Mountain Region 8	‡	Not GSA
US CIS West Palm Beach	Office	Southeast Region 4	‡	Not GSA
GSA Building Manager	Office	National Capital Region 11	‡	Not GSA Building
Hoover Building Modernization	Office	National Capital Region 11	‡	Not LEED, no Sustainable Design Features

Project Name	Building Type	Region	Source	Status
U.S. District Courthouse, SLC	Courthouse	Rocky Mountain Region 8	‡	Not LEED, no Sustainable Design Features
White Federal Bldg	Office/Courthouse	Greater Southwest Region 7	Region	Not LEED, no Sustainable Design Features
Cleveland Stokes CT	Courthouse	Great Lakes Region 5	OCA	Not LEED, no Sustainable Design Features
San Antonio FB LEASE	Office	Greater Southwest Region 7	OCA	Not LEED, no Sustainable Design Features
Laredo New FB-CT	Courthouse /Office	Greater Southwest Region 7	OCA	Not LEED, no Sustainable Design Features
Rockville AHRQ Lease	Office	National Capital Region 11	OCA	Not LEED, no Sustainable Design Features
Wash DC 20 Mass Ave LEASE	Office	National Capital Region 11	OCA	Not LEED, no Sustainable Design Features
Wash DC FTC Lease	Office	National Capital Region 11	OCA	Not LEED, no Sustainable Design Features
CB King CT	Courthouse	Southeast Region 4	OCA	Not LEED, no Sustainable Design Features
Orlando FB-CT	Courthouse	Southeast Region 4	OCA	Not LEED, no Sustainable Design Features
Hammond CT	Courthouse	Great Lakes Region 5	OCA/*	Not LEED, no Sustainable Design Features
Corpus Christi FB-CT	Courthouse	Greater Southwest Region 7	OCA/*	Not LEED, no Sustainable Design Features
Jacksonville CT	Courthouse	Southeast Region 4	OCA/*	Not LEED, no Sustainable Design Features

Project Name	Building Type	Region	Source	Status
Annex Building for Social Security Administration	Office	Mid-Atlantic Region 3	#	Not Separately Metered
Byron G. Rogers U.S. Courthouse	Courthouse /Office	Rocky Mountain Region 8	#	Not Separately Metered
Arlington One Liberty Cen	Office	National Capital Region 11	OCA	Not Separately Metered
Wash DC NPS Lease	Office?	National Capital Region 11	OCA	Not Separately Metered
Gulfport FB-CT	Courthouse	Southeast Region 4	OCA/*	Not Separately Metered
Federal Office Building No.8	Office	National Capital Region 11	‡	Project on Hold
GSA 1800 F	Office	National Capital Region 11	‡	Project on Hold
Lafayette Building Modernization	Office	National Capital Region 11	‡	Project on Hold
Minton-Capehart Federal Building	Office	Great Lakes Region 5	‡	Under Construction
New United States Courthouse	Courthouse	Great Lakes Region 5	‡	Under Construction
U.S. District Court, Toledo, OH	Courthouse	Great Lakes Region 5	‡	Under Construction
Anthony J. Celebrezze Federal Building	Office	Great Lakes Region 5	‡	Under Construction
Birch Bayh Federal Building and U.S. Courthouse	Office/Courthouse	Great Lakes Region 5	‡	Under Construction
GT Mickey Leland R&A	Office	Greater Southwest Region 7	‡	Under Construction
San Antonio Federal Building	Office	Greater Southwest Region 7	‡	Under Construction
New Jefferson City Courthouse	Courthouse	Heartland Region 6	‡	Under Construction
John F. Kennedy Federal Building	Office	New England Region 1	‡	Under Construction
J.W. McCormack Repair and Alterations	Office	New England Region 1	‡	Under Construction
M.C. Smith Federal Bldg. & Courthouse	Office/Courthouse	New England Region 1	‡	Under Construction
Thurgood Marshall U.S. Courthouse	Courthouse	Northeast and Caribbean Region 2	‡	Under Construction
GSA Coeur D'Alene Federal Courthouse	Courthouse	NW/Arctic Region 10	‡	Under Construction
Sam Nunn Atlanta Federal Center	Office	Southeast Region 4	‡	Under Construction
United States Courthouse	Courthouse	Southeast Region 4	‡	Under Construction
Modernization of the U.S. Courthouse	Courthouse	Southeast Region 4	‡	Under Construction
Nashville Federal Courthouse	Courthouse	Southeast Region 4	‡	Under Construction

Project Name	Building Type	Region	Source	Status
Martin Luther King Jr. Federal Building	Office	Southeast Region 4	‡	Under Construction
Dr. A. H. McCoy Federal Building	Office	Southeast Region 4	‡	Under Construction
U.S. Citizen and Immigration Services	Office	Southeast Region 4	‡	Under Construction
Chicago FBI Office LEASE	Office	Great Lakes Region 5	OCA	Under Construction

Appendix D: Baseline Development Documentation

For each of the major whole building performance metrics, an industry baseline was determined for comparison purposes. The baselines were developed specifically for this study and should therefore be evaluated for applicability if they are considered for use in other performance measurement efforts.

In addition to baseline calculations, some of the metrics needed additional values calculated and/or analyzed in order for the values to be useful in the analysis. The supporting values and baseline calculations included in this appendix are

- Occupant-Visitor equivalent
- Water baselines
    - Indoor water use baseline
    - Outdoor water use
- Monthly energy and water use
- Multiple year data analysis for energy, water, and maintenance
- Operations and maintenance baselines
- Operational cost baselines

Occupant-Visitor Equivalent Calculations

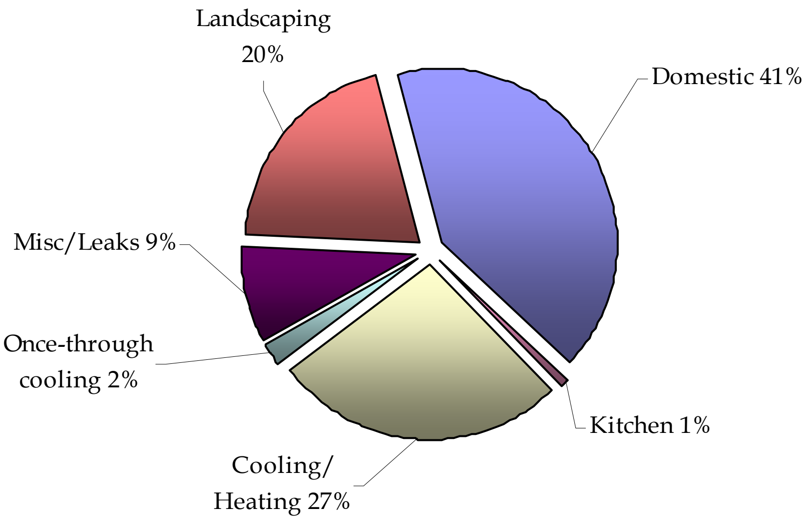
For each building, the number and type of visitors were requested in order to estimate visitor impact on water and energy use. The building contacts typically provided the number of visitors per day, the typical length of stay for each visitor, and the reason for the visit. Depending on the type and length of visit, the number of visitors was assigned from 25-100% of a regular building occupant. The sum of the regular building occupants and the visitor value is the occupant-visitor equivalent, which is intended to represent the number of people using contributing to the building's performance during a typical workday.

				Occupant Visitor Equivalent Calculation				
Building Name	**Regular Occupants per Day**	**Detainees per year**	**Detainees per day**	**Visitors per year**	**Visitors per day**	**Hours per Visitor Estimate**	**Visitor FTE**	**Occupant & Visitor Equivalent**
Greeneville CT	85	-	-	9,000	36	half	18	103
Jacksonville FB	1000	-	-	75,000	300	half	150	1,150
Knoxville FB	285	-	-	25,250	101	1 use	25	310
Cleveland CT	105	-	-	18,750	75	half	38	143
Youngstown CT & FB	45	-	-	61,750	247	half & 1 use	198	243
Cape Girardeau CT	45	-	-	27,500	110	half	55	100
Davenport CT	45	-	-	9,000	36	half	18	63
Omaha DHS (L) FB	65	2,750	7.86	65,250	250	NA	295	360
Omaha NPS (L) FB	125	-	-	8,800	35	1use	9	134
Denver CT	170	-	-	100,000	400	half	200	370
Denver (L) FB	922	-	-	35,700	143	half	71	993
Lakewood (L) FB	318	-	-	9,900	40	1 use for 7500 + meetings for 2400	18	336
Ogden (L) FB	514	-	-	1,800	7	equiv to occ	7	521
Fresno CT & FB	235	-	-	275,000	1,100	1 use	275	510
Las Vegas CT	321	-	-	53,333	213	half	107	428
San Francisco FB	1314	-	-	See Note	See Note	Confr. Cetner 1500/month at 8, Tours 345/month at 1.5, Visitors 75/day at 1.5, SSA 200/day at 1.5, DOL 12/month at 8	130	1,444
Santa Ana FB	409	250	0.71	50,000	200	1use	50	459
Auburn FB	675	-	-	-	-	-	-	675
Eugene CT	120	-	-	25,000	100	half	50	170
Seattle CT	500	-	-	50,000	200	half	100	600
Rockville (L) FB	720	-	-	20,000	80	half	40	760
Suitland FB	5360	-	-	32,500	130	half	65	5,425

Water Baseline Calculations

Water consumption in a commercial office building typically consists primarily of domestic use (i.e., faucet, toilet, and urinal use), landscape irrigation, and process water (i.e., cooling and/or heating processes).[34]

Water Distribution in a Typical Office Building



These three primary uses of water were separated for each building. Domestic water consumption depends on human operation and fixed equipment efficiency. Therefore, typical indoor water consumption is best expressed as per occupant. For water use comparisons to the baseline, gallons per occupant per year is used. Occupancy gender data allow for a more accurate comparison of indoor water use, because the quantity and type of water-using fixtures vary by gender. Many of these buildings also have a large number of visitors, who are likely to contribute to the total domestic water consumption. To address this, an estimate of visitor water use was added to the total based on expected quantities of visitors and an appropriate gallon also compared to a visitor-adjusted baseline in gallons used per occupant and visitor per year value.

For water use analysis, the indoor potable water use data had to be estimated from the water utility bills. The baselines for comparison include indoor potable water use per occupant per day, total water use per gross square footage, and water cost per rentable square foot. Process and landscape water analysis were not performed as detailed water use information was not available.

Indoor Water Use Per Occupant

The reference data used for calculating the water use baseline was the federal Water Use Indices (Indices).[35] The Indices provide basic guidance on typical water usage for different building types. Indoor water use for office buildings is estimated at an average of 15 gallons per occupant per day (gpd/occupant), with a range of 8 to 20 gpd.

When landscape irrigation water and process water have been removed from the total water consumption, the majority of the building water consumption is from "domestic uses." Due to the difference in fixture type (i.e., urinals and toilets), occupant gender plays a role in the quantity of water used in a typical federal building, courthouse, or port of entry building. However, the federal Indices do not provide detail on use for male and female building occupants. The following assumptions were made to support the adjustment of the Indices and develop a gender-specific water use baseline:

- The federal Indices were developed with a 50-50 ratio of male-to-female building occupants.
- In an office building, 61% of the domestic water use is for toilets, 17% for urinals, and 22% for faucets.
- On average, females use toilets three times per day with males only once per day plus urinals two times per day.[36]
- Faucet use is equal for males and females.
- 15 gpd/occupant is the average between male and female water use.

Based on these assumptions, the following calculations were made:

Domestic Water Use = Female Toilet Use + Male Toilet Use + Female Faucet Use + Male Faucet Use + Male Urinal Use

Toilet Use = Female Use (75%) + Male Use (25%)

Faucet Use = Female Use (50%) + Male Use (50%)

*Female Use = [(75% Toilet) * (61% Water Use for Toilets)] + [(50% Faucets) * (22% Water use for Faucets)]*

Female Use = 57% Total Water Use or 17.1 gpd/occupant

*Male Use = [(25% Toilet) * (61% Water Use for Toilets)] + [17% Urinal] + [(50% Faucets) * (22% Water use for Faucets)]*

Male Use = 43% Total Water Use or 12.9 gpd/occupant

Thus, the quantity of male and female occupants was used to adjust the Indices for the Indoor Water Use baseline as follows:

*Water Use Baseline (gpd/occupant) = (Total Occupants * % Female * 17.1 gpd/occupant) + (Total Occupants * % Male * 12.9 gpd/occupant)*

The Port of Entry buildings, the Department of Homeland Security federal building, and the Santa Ana courthouse and federal building also included inmates. Inmate water use was assumed to be 120 gpd/occupant. Although several buildings had showers and a few buildings had a small restaurant, those water usages were not included in the baseline calculations. And finally, in all but the Port of Entry buildings, it was assumed the water use would occur 250 days per year (i.e., five workdays a week and fifty workweeks per year). The following table provides the baseline values for each of the buildings.

		# of Occupants by Type			Gallons Per Occupant Type			Baseline Comparison		
Building Name	**Occupant & Visitor Equivalent**	**Male**	**Female**	**Detainees**	**Male (12.9 gal/day)**	**Female (17.1gal/day)**	**Detainee (120 gal/day)**	**Baseline gal per Occ-Vis Equiv**	**Building gal per Occupant Equiv**	**Building Water Performance**
Greeneville CT	103	52	52	-	166,088	220,163	-	3,750	7,082	89%
Jacksonville FB	1150	575	575	-	1,854,375	2,458,125	-	3,750	2,544	-32%
Knoxville FB	310	155	155	-	500,278	663,159	-	3,750	5,299	41%
Cleveland CT	143	71	71	-	229,781	304,594	-	3,750	3,160	-16%
Youngstown CT & FB	243	121	121	-	391,031	518,344	-	3,750	1,727	-54%
Cape Girardeau CT	100	60	40	-	193,500	171,000	-	3,645	2,041	-44%
Davenport CT	63	32	32	-	101,588	134,663	-	3,750	6,144	64%
Omaha DHS (L) FB	360	176	176	7.86	567,830	752,705	235,714	4,323	6,256	45%
Omaha NPS (L) FB	134	74	60	-	237,328	257,398	-	3,698	1,783	-52%
Denver CT	370	185	185	-	596,625	790,875	-	3,750	9,172	145%
Denver (L) FB	993	497	497	-	1,601,858	2,123,393	-	3,750	3,500	-7%
Lakewood (L) FB	336	201	134	-	649,193	573,705	-	3,645	4,625	27%
Ogden (L) FB	521	52	469	-	168,023	2,004,548	-	4,170	5,071	22%
Fresno CT & FB	510	255	255	-	822,375	1,090,125	-	3,750	11,790	214%
Las Vegas CT	428	214	214	-	689,613	914,138	-	3,750	12,905	244%
San Francisco FB	1444	578	867	-	1,863,272	3,704,878	-	3,855	2,868	-26%
Santa Ana FB	459	229	229	0.71	738,986	979,586	21,429	3,791	4,832	27%
Auburn FB	675	236	439	-	761,906	1,875,656	-	3,908	N/A	N/A
Eugene CT	170	68	102	-	219,300	436,050	-	3,855	6,335	64%
Seattle CT	600	300	300	-	967,500	1,282,500	-	3,750	4,393	17%
Rockville (L) FB	760	266	494	-	857,850	2,111,850	-	3,908	2,574	-34%
Suitland FB	5425	1,628	3,798	-	5,248,688	16,234,313	-	3,960	7,550	91%

Indoor Water Use Baseline Observations

The Indices have not been updated since 1996. The last federal ruling on flow rates of water-consuming technologies was in the Energy Policy Act (EPAct) of 1992. As buildings update their faucets, toilets, urinals, and showerheads, it is conceivable that a savings of 50% could be achieved. When the Indices are updated, it is likely that the average use per occupant will decrease. Rather than updating the water baseline to an assumed use under the EPAct standard, the documented FEMP Water Use Indices baseline were used, which may represent a greater savings than current practice would offer.

Outdoor Water Use

Irrigation water use depends on the size of the irrigated area, as well as the climate and type of plants or turf being watered. A water-thirsty landscape (appropriate for climates with 40+ inches of annual precipitation) in a dry climate typically uses about 25 gallons of water per square foot per season. However, use of native and drought-tolerant plants can reduce irrigation needs to about 5 to 10 gallons per square foot per season.[37]

Only one of the buildings in the study had separately metered landscape irrigation (Denver FB). Many of the buildings had minimal landscaping. For those it was easy to dismiss landscape water use as minimal (see Jacksonville, FB, Ogden FB, Cleveland CT, Davenport CT, San Francisco FB, and Santa Ana FB). Other buildings have rainwater capture systems or bioswales that are used to store irrigation water (Knoxville FB, Omaha Department of Homeland Security FB, and Suitland FB), and Omaha National Park Service's FB, Youngstown CT & FB, Rockville FB properties only has native trees, plants, and grasses that do not require any irrigation. However, several buildings had enough water-intensive landscaping that it was necessary to examine seasonal water use in order to estimate landscape irrigation use. A FEMP estimate of 20 percent of a building's water use being attributed to landscaping was applied to buildings with water-intensive landscaping.

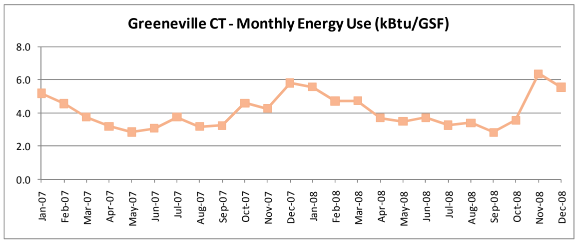
		Water Use (gallons)		
Building Name	**Landscaping Type**	**Total Water**	**20% Estimated Landscape**	**Metered Landscape**
Greeneville CT	Trees, Shrubs & Grass	1,376,320	275,264	-
Jacksonville FB	Urban setting, Trees, palm trees, shrubs, grass, ribbon grass	4,007,860	0	-
Knoxville FB	Trees & Groundcover w/rainwater capture	2,252,228	0	-
Cleveland CT	Minimal Established Trees	450,295	0	-
Youngstown CT & FB	Trees, Groundcover & Grass, Bioswale	418,880	0	-
Cape Girardeau CT	Grass & small trees	385,170	77,034	-
Davenport CT	Minimal Groundcover	530,250	0	-
Omaha DHS (L) FB	Trees, Shrubs & Grass w/rainwater capture	2,252,228	0	-
Omaha NPS (L) FB	Trees, plants & native grasses	238,629	0	-
Denver CT	Fountain, trees,arid plants, grass	4,649,000	0	-
Denver (L) FB	Urban setting, no landscaping (Green Roof)	3,970,000	-	358,962
Lakewood (L) FB	Trees, arid plants & grass	2,928,000	585,600	-
Ogden (L) FB	Minimal trees, shrubs & arid plants	3,619,100	0	-
Fresno CT & FB	Fountain, trees, Plants, Shrubs & Fountain	11,344,916	2,268,983	-
Las Vegas CT	Fountain, xeriscape, cactus, small trees, bunch grasses	10,413,000	2,082,600	-
San Francisco FB	Drip irrigation, small trees, shrubs,	5,674,712	0	-
Santa Ana FB	Minimal Trees & Plants	2,217,820	0	-
Auburn FB	Small trees, shrubs, bunch grass	N/A	N/A	-
Eugene CT	Small trees, shrubs, grasses	2,032,000	406,400	-
Seattle CT	Fountain, small & medium trees, shrubs, grasses	4,973,452	994,690	-
Rockville (L) FB	Native grass, small trees, drought-resistant shrubs	2,680,000	0	-
Suitland FB	Small & medium trees, shrubs, grasses (Green roof)	56,110,000	0	-

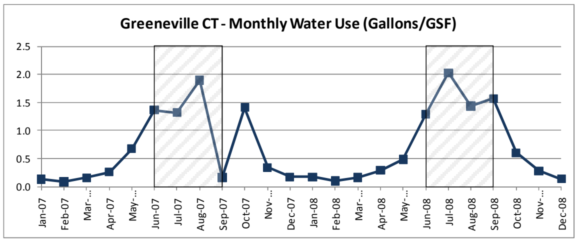
The summary of indoor and outdoor water uses is offered below.

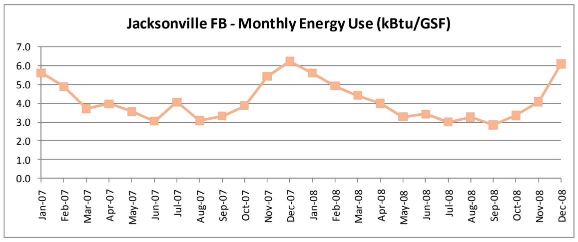
		Water Use (gallons)			
Building Name	**Water Consuming Equipment**	**Total Water**	**Estimated Landscape**	**Estimated Process**	**Estimated Domestic**
Greeneville CT	Cooling Towers	1,376,320	275,264	371,606	729,450
Jacksonville FB	Cooling Towers	4,007,860	0	1,082,122	2,925,738
Knoxville FB	Cooling Towers	2,252,228	0	608,102	1,644,126
Cleveland CT	-	450,295	0	0	450,295
Youngstown CT & FB	-	418,880	0	0	418,880
Cape Girardeau CT	Cooling Towers	385,170	77,034	103,996	204,140
Davenport CT	Cooling Towers	530,250	0	143,168	387,083
Omaha DHS (L) FB	-	2,252,228	0	0	2,252,228
Omaha NPS (L) FB	-	238,629	0	0	238,629
Denver CT	Evap Cooling	4,649,000	0	1,255,230	3,393,770
Denver (L) FB	Cooling Towers	3,970,000	358,962	134,100	3,476,938
Lakewood (L) FB	Cooling Towers	2,928,000	585,600	790,560	1,551,840
Ogden (L) FB	Evap Cooling	3,619,100	0	977,157	2,641,943
Fresno CT & FB	Cooling Towers	11,344,916	2,268,983	3,063,127	6,012,805
Las Vegas CT	Cooling Towers	10,413,000	2,082,600	2,811,510	5,518,890
San Francisco FB	Cooling Towers, Small Snack Bar	5,674,712	0	1,532,172	4,142,540
Santa Ana FB	-	2,217,820	0	0	2,217,820
Auburn FB	-	N/A	N/A	N/A	N/A
Eugene CT	Cooling Towers	2,032,000	406,400	548,640	1,076,960
Seattle CT	Cooling Towers	4,973,452	994,690	1,342,832	2,635,930
Rockville (L) FB	Cooling Tower	2,680,000	0	723,600	1,956,400
Suitland FB	Cooling Towers	56,110,000	0	15,149,700	40,960,300

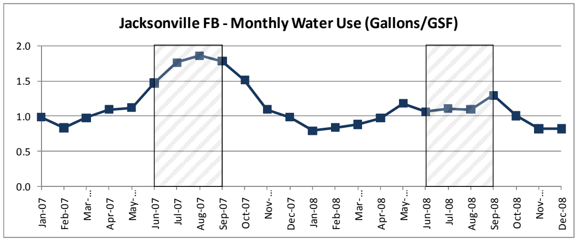
Water & Energy Use Profiles

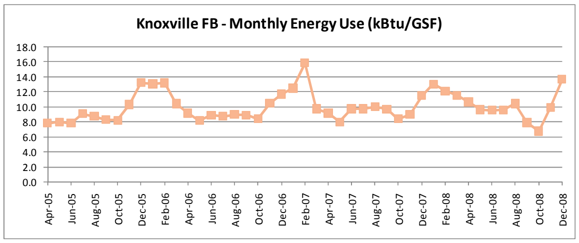
Monthly water and energy use were evaluated for seasonal trends. Seasonal energy use variations are observed at most of the buildings. The Energy Star Portfolio Manager accounts for annual weather patterns in the calculations of Energy Star scores. Seasonal water use can be observed for the Greenville CT, Jacksonville FB, Knoxville FB, Cape Girardeau CT, Davenport CT, Denver CT, Lakewood FB, Odgen FB, Fresno CT & FB, Las Vegas CT, San Francisco, Eugene CT, Seattle CT, Rockville FB, and the Suitland FB. These buildings have evaporative cooling and/or cooling towers and/or landscaping that cause spikes in water use. The figures below show the water use by month for each building, with the summer months shaded gray.

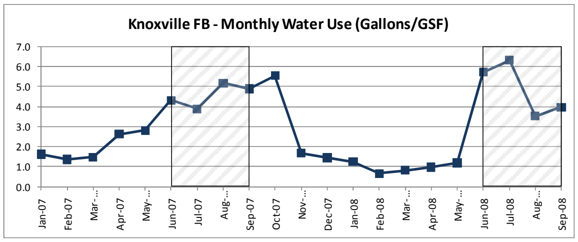


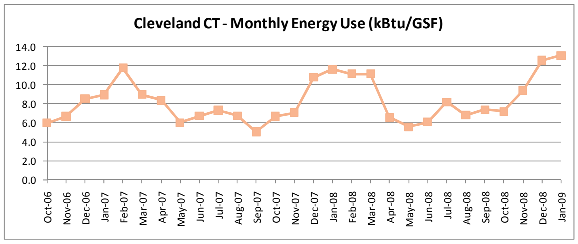


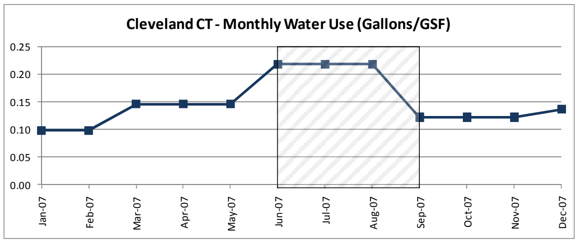


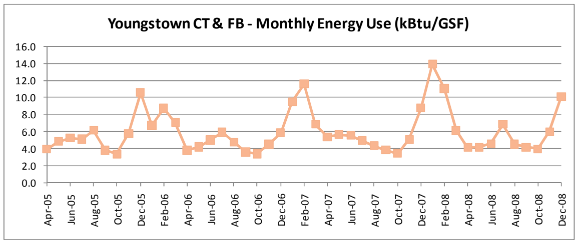


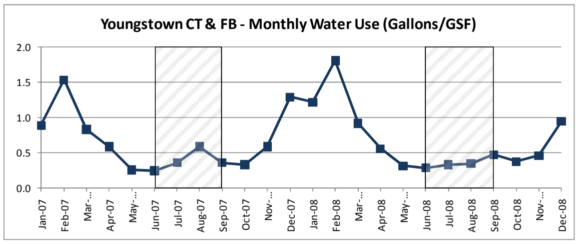


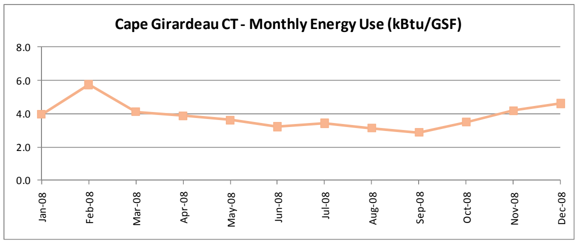


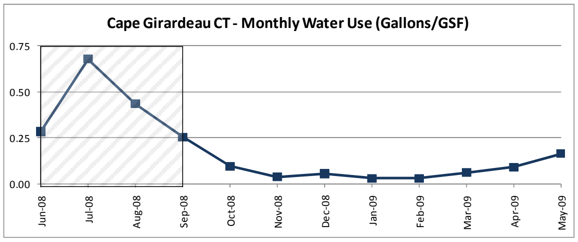


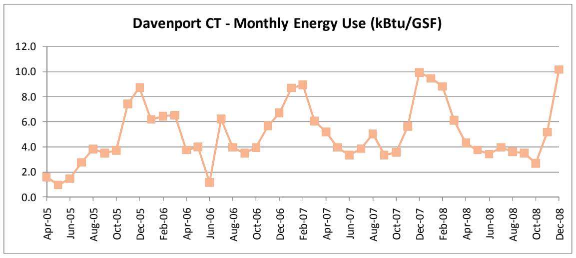


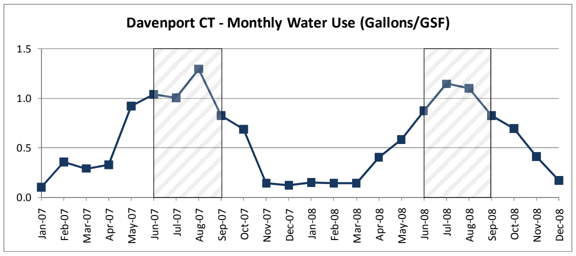


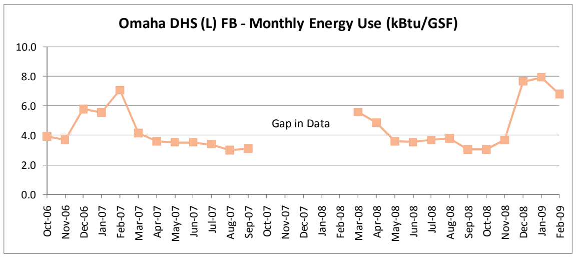


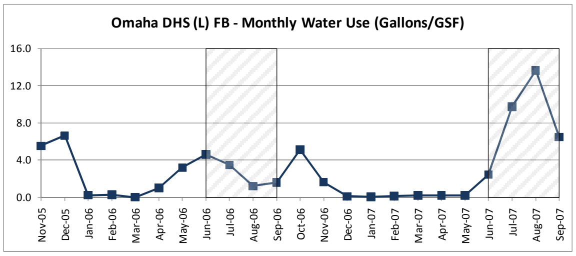


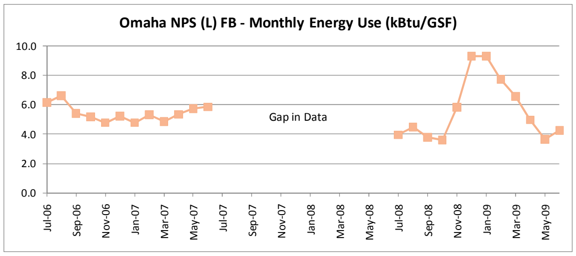


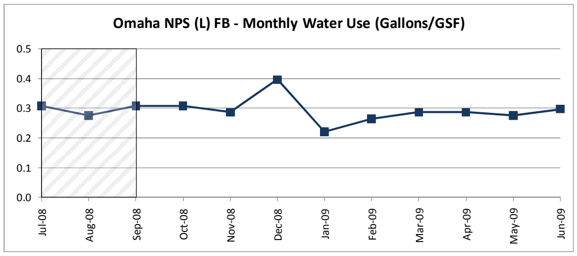

Davenport CT - Monthly Energy Use (kBtu/GSF)

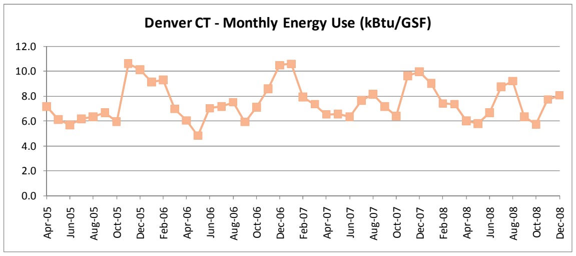

Davenport CT - Monthly Water Use (Gallons/GSF)

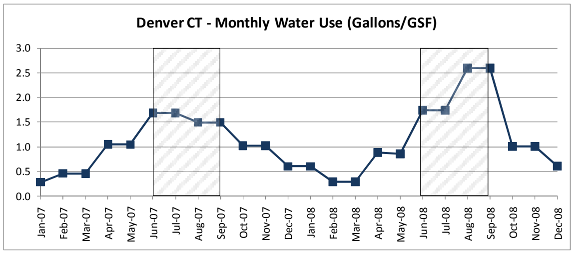

Omaha DHS (L) FB - Monthly Energy Use (kBtu/GSF)

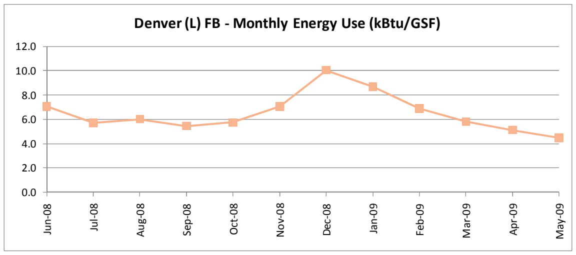

Omaha DHS (L) FB - Monthly Water Use (Gallons/GSF)

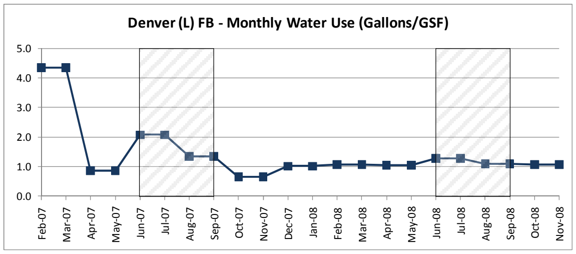

Omaha NPS (L) FB - Monthly Energy Use (kBtu/GSF)

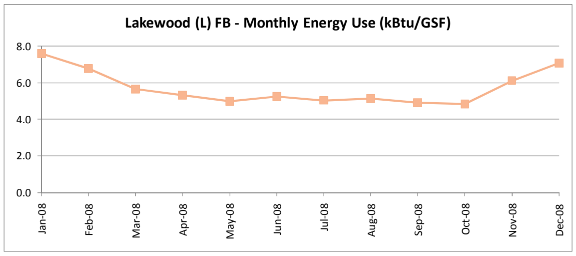

Omaha NPS (L) FB - Monthly Water Use (Gallons/GSF)

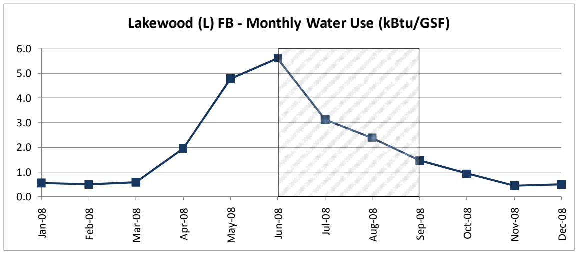

Denver CT - Monthly Energy Use (kBtu/GSF)

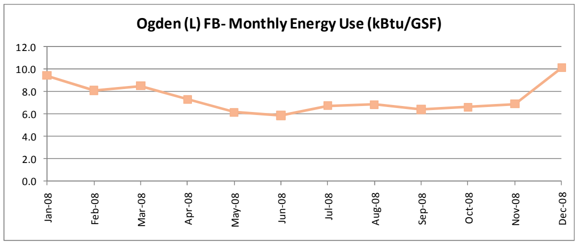

Denver CT - Monthly Water Use (Gallons/GSF)

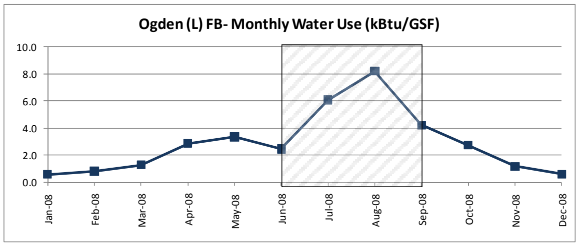

Denver (L) FB - Monthly Energy Use (kBtu/GSF)

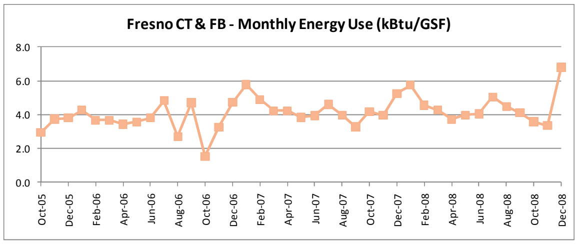

Denver (L) FB - Monthly Water Use (Gallons/GSF)

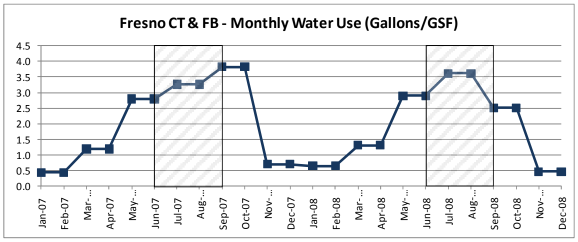

Lakewood (L) FB - Monthly Energy Use (kBtu/GSF)

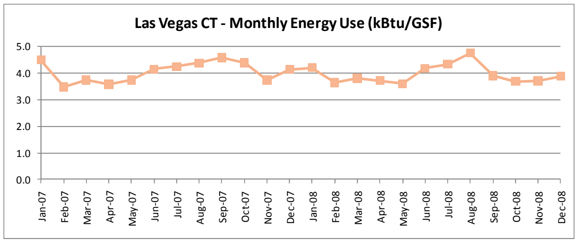

Lakewood (L) FB - Monthly Water Use (kBtu/GSF)

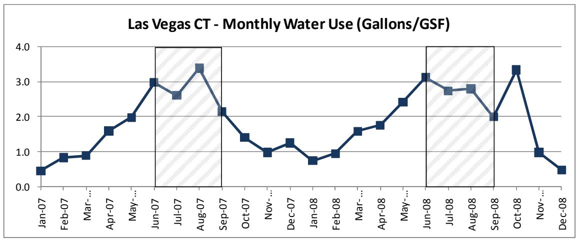

Ogden (L) FB- Monthly Energy Use (kBtu/GSF)

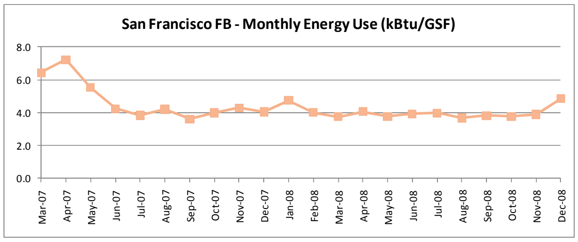

Ogden (L) FB- Monthly Water Use (kBtu/GSF)

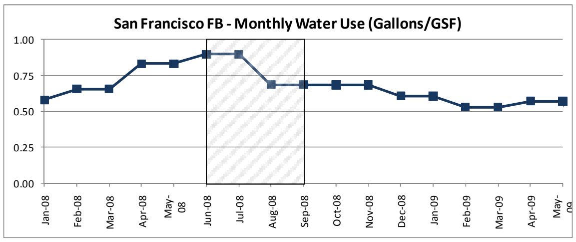

Fresno CT & FB - Monthly Energy Use (kBtu/GSF)

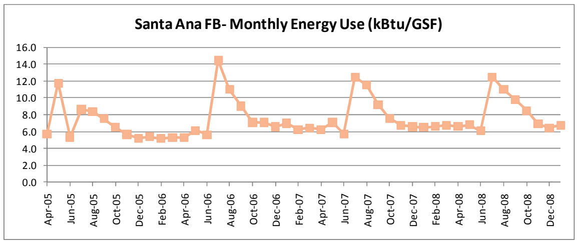

Fresno CT & FB - Monthly Water Use (Gallons/GSF)

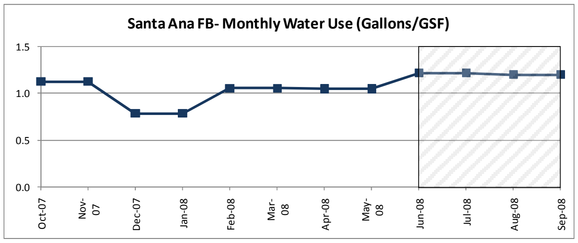

Las Vegas CT - Monthly Energy Use (kBtu/GSF)

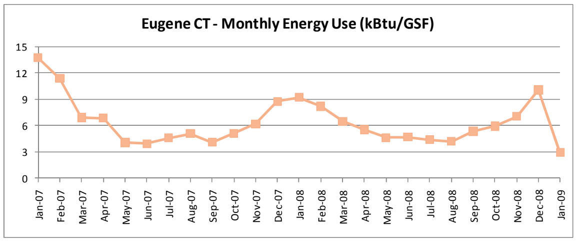

Las Vegas CT - Monthly Water Use (Gallons/GSF)

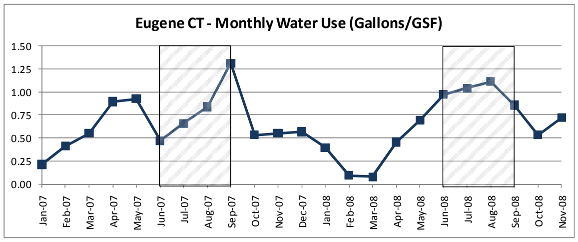

San Francisco FB - Monthly Energy Use (kBtu/GSF)

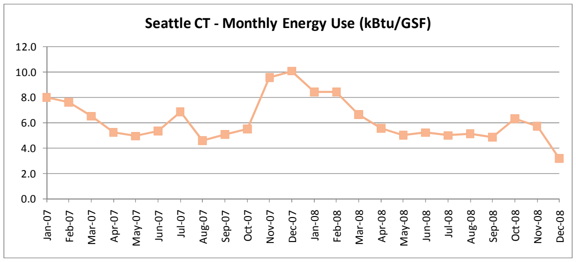

San Francisco FB - Monthly Water Use (Gallons/GSF)

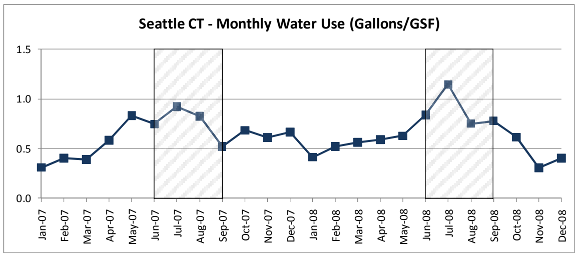

Santa Ana FB- Monthly Energy Use (kBtu/GSF)

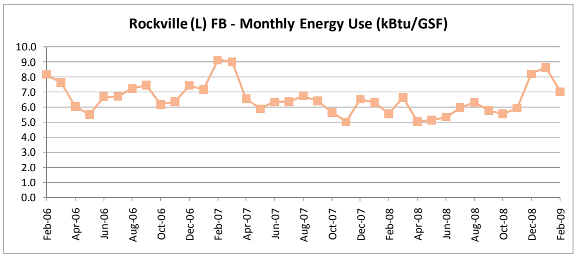

Santa Ana FB- Monthly Water Use (Gallons/GSF)

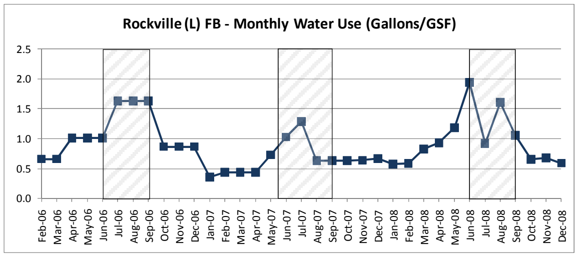

Eugene CT - Monthly Energy Use (kBtu/GSF)

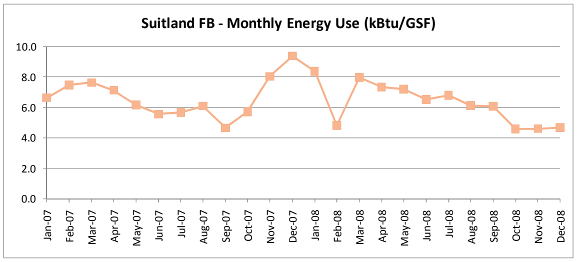

Eugene CT - Monthly Water Use (Gallons/GSF)

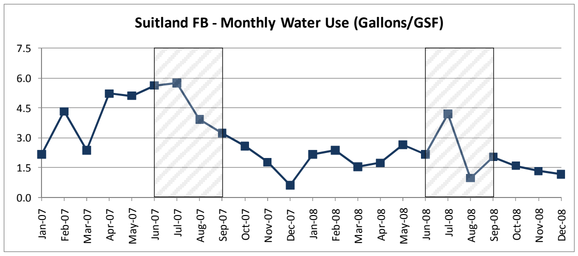

Seattle CT - Monthly Energy Use (kBtu/GSF)


Seattle CT - Monthly Water Use (Gallons/GSF)


Rockville (L) FB - Monthly Energy Use (kBtu/GSF)

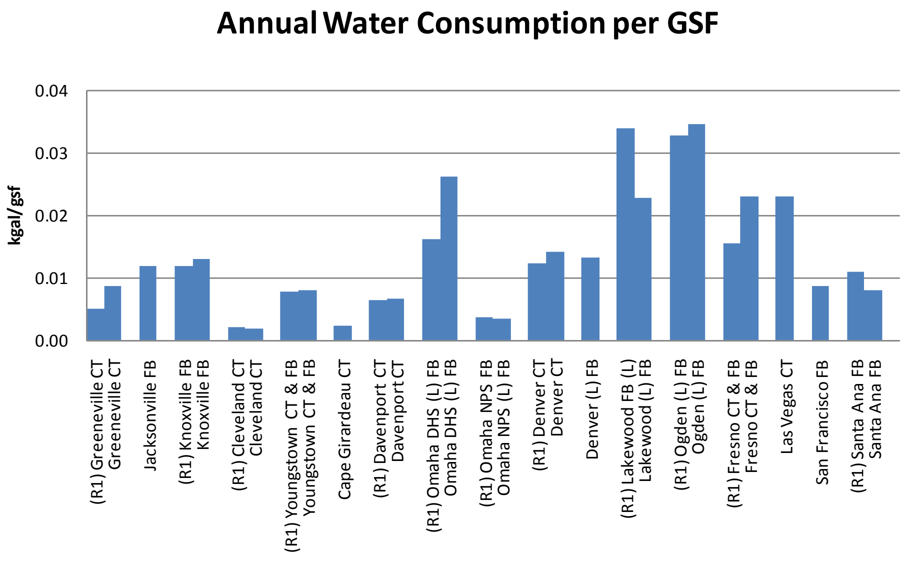

Rockville (L) FB - Monthly Water Use (Gallons/GSF)


Suitland FB - Monthly Energy Use (kBtu/GSF)

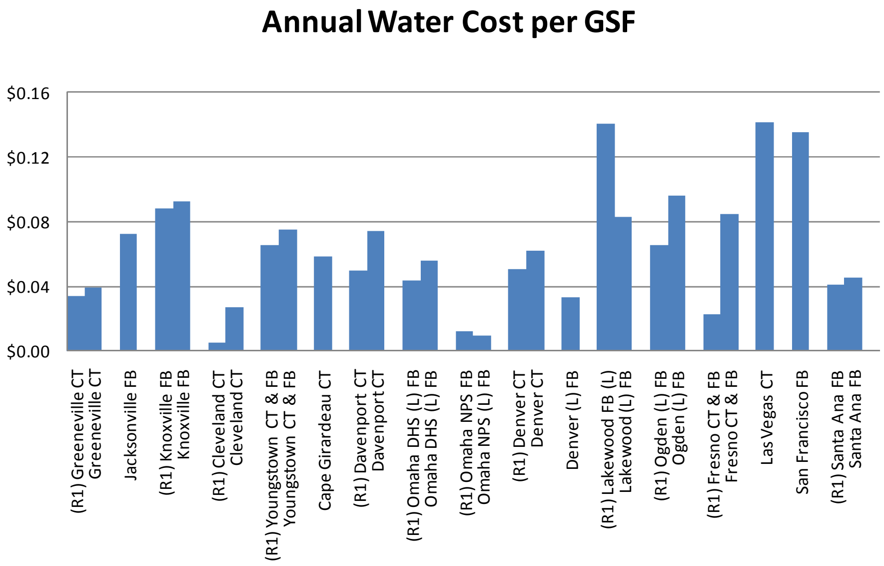

Suitland FB - Monthly Water Use (Gallons/GSF)

Multiple Year Performance Analysis

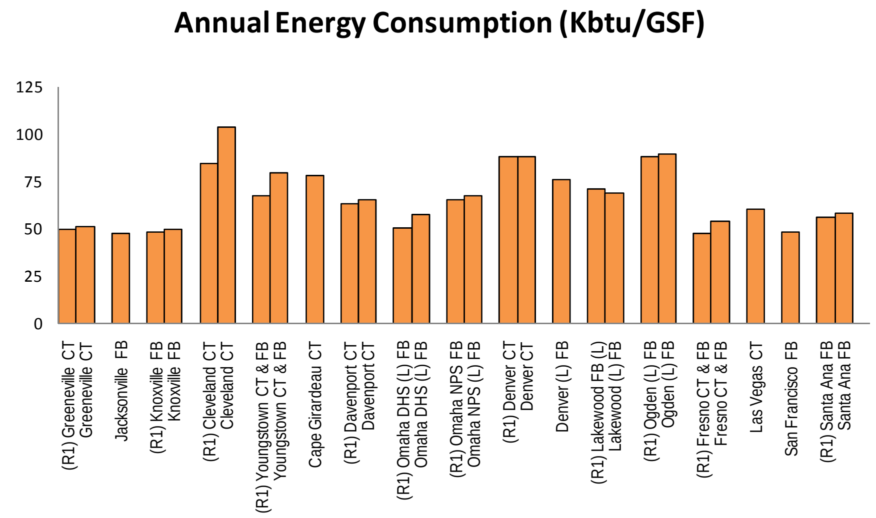
The graphs below compare energy and water consumption for consecutive years. Maintenance costs can also change from year to year. For the buildings that provided two years of data, these variations are also shown below.

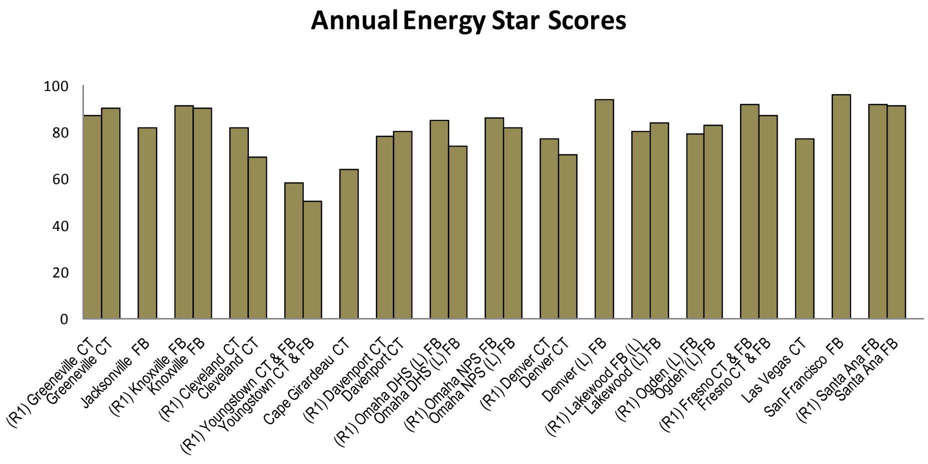


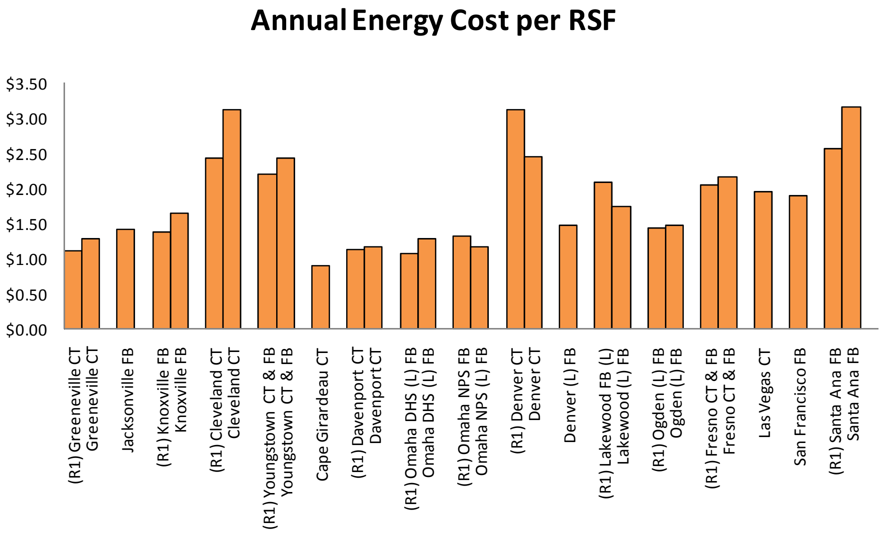
Annual Water Consumption per GSF



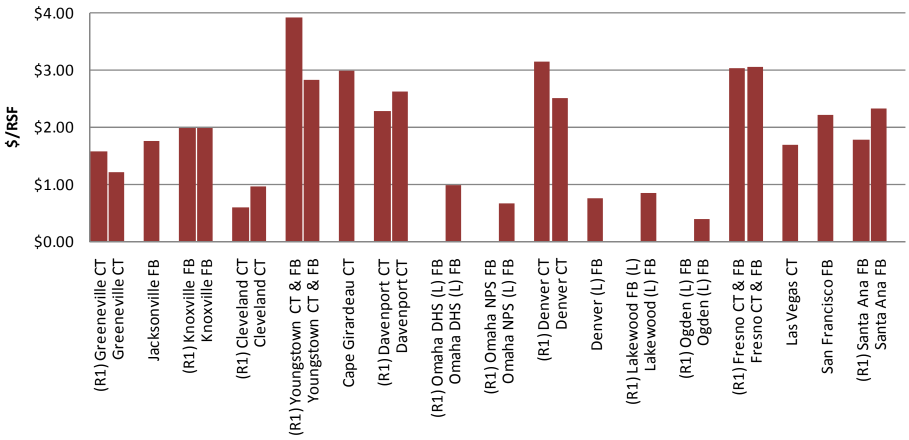
Annual Water Cost per GSF


Annual Energy Consumption (Kbtu/GSF)
125
100
75
50
25
0
(R1) Greeneville CT
Greeneville CT
Jacksonville FB
(R1) Knoxville FB
Knoxville FB
(R1) Cleveland CT
Cleveland CT
(R1) Youngstown CT & FB
Youngstown CT & FB
Cape Girardeau CT
(R1) Davenport CT
Davenport CT
(R1) Omaha DHS (L) FB
Omaha DHS (L) FB
(R1) Omaha NPS FB
Omaha NPS (L) FB
(R1) Denver CT
Denver CT
Denver (L) FB
(R1) Lakewood FB (L)
Lakewood (L) FB
(R1) Ogden (L) FB
Ogden (L) FB
(R1) Fresno CT & FB
Fresno CT & FB
Las Vegas CT
San Francisco FB
(R1) Santa Ana FB
Santa Ana FB

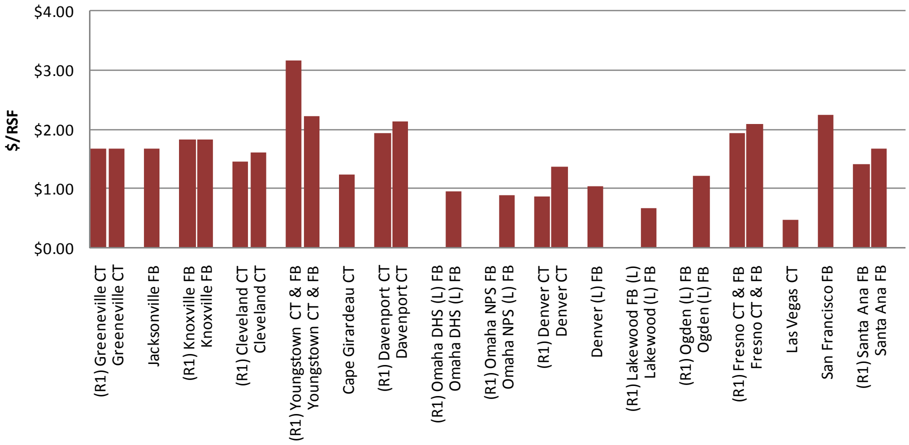

Annual Energy Star Scores
100
80
60
40
20
0
(R1) Greeneville CT
Greeneville CT
Jacksonville FB
(R1) Knoxville FB
Knoxville FB
(R1) Cleveland CT
Cleveland CT
(R1) Youngstown CT & FB
Youngstown CT & FB
Cape Girardeau CT
(R1) Davenport CT
Davenport CT
(R1) Omaha DHS (L) FB
Omaha DHS (L) FB
(R1) Omaha NPS FB
Omaha NPS (L) FB
(R1) Denver CT
Denver CT
Denver (L) FB
(R1) Lakewood FB (L)
Lakewood (L) FB
(R1) Ogden (L) FB
Ogden (L) FB
(R1) Fresno CT & FB
Fresno CT & FB
Las Vegas CT
San Francisco FB
(R1) Santa Ana FB
Santa Ana FB


Annual Energy Cost per RSF
$3.50
$3.00
$2.50
$2.00
$1.50
$1.00
$0.50
$0.00
(R1) Greeneville CT
Greeneville CT
Jacksonville FB
(R1) Knoxville FB
Knoxville FB
(R1) Cleveland CT
Cleveland CT
(R1) Youngstown CT & FB
Youngstown CT & FB
Cape Girardeau CT
(R1) Davenport CT
Davenport CT
(R1) Omaha DHS (L) FB
Omaha DHS (L) FB
(R1) Omaha NPS FB
Omaha NPS (L) FB
(R1) Denver CT
Denver CT
Denver (L) FB
(R1) Lakewood FB (L)
Lakewood (L) FB
(R1) Ogden (L) FB
Ogden (L) FB
(R1) Fresno CT & FB
Fresno CT & FB
Las Vegas CT
San Francisco FB
(R1) Santa Ana FB
Santa Ana FB

General Maintenance - 2 Year Comparison



Janitorial Maintenance - 2 Year Comparison



Operations and Maintenance Baselines

Comparable baselines were identified for each of the metrics. Where available, GSA, regional, and industry baselines are shown together. The following tables are summaries of the baselines used in the study. The first table includes the baselines that apply to all of the buildings, regardless of location, size, or number of occupants. The next includes baseline values that applied to specific GSA regions. The last shows building specific baselines that were calculated specifically for the building because of occupancy and/or location.

Metric	Value	Units	Source
Water	15	gal/gsf	IFMA # 32 50th Percentile (2009 pg 59)
	13	gal/gsf	GSA FY2015 Target
	0.19	$/rsf	BOMA 2008 All Sector Total Building Rentable Area - Utility Water/Sewer
Energy	2.53	$/rsf	BOMA 2008 All Sector Total Building Rentable Area - Utility (less water)
	88	kBTU/gsf	EIA CBECS Table C12 Office 1990-2003
Maintenance - Grounds	0.45	$/rsf	BOMA 2008 All Sector Total Building Rentable Area - Roads/Grounds
Maintenance - Preventative	0.75	Ratio	IFMA #32 Facilities less than 5 years old (2009 pg. 47)
Maintenance - Service	0.25	Ratio	IFMA #32 Facilities less than 5 years old (2009 pg. 47)
Waste	0.05	$/rsf	IFMA #25 (2004 pg. 27)
Recycling	0.01	$/rsf	IFMA #25 (2004 pg. 27)
Occupant	1.13		CBE 2009 Survey Average Score - General Building Satisfaction
Satisfaction	1.23		CBE 2009 Survey Average Score - LEED General Building Satisfaction
Transportation	2.3	MTCO2e/ occ/year	EPA Climate Leaders Guidance (2008) and DOT Travel Survey (2001)

	Regional Baselines						
	Energy kBTU/gsf			**Maintenance $/rsf**			
GSA Region	GSA FY09 Regional EUI	GSA FY09 Regional Target	CBECS Regional EUI	GSA General Maint	Adapted BOMA General Maint	GSA Janitorial Maint	Adapted BOMA Janitorial Maint
4	58	60	78	$1.25	$1.23	$1.32	$1.25
5	84	86	113	$1.23	$1.81	$1.91	$1.60
6	75	81	75	$1.33	$1.60	$1.55	$1.39
8	89	92	81	$1.79	$1.50	$1.33	$1.32
9	55	61	71	$1.83	$2.15	$1.71	$1.98
10	63	64	71	$1.37	$1.80	$1.34	$1.66
11	95	88	90	$2.24	$2.23	$1.93	$2.12

Building Name	Energy kBTU/gsf Energy Star Baseline-50%	CO$_2$ MTCO$_2$e/gsf Industry Average - 50%	Energy Star - 75%	Water gal per Occ-Vis Equiv FEMP Water Use Intensity
Greeneville CT	87	0.014	0.010	3750
Jacksonville FB	93	0.016	0.012	3750
Knoxville FB	91	0.015	0.011	3750
Cleveland CT	129	0.014	0.010	3160
Youngstown CT & FB	80	0.012	0.012	3750
Cape Girardeau CT	92	0.016	0.012	3645
Davenport CT	96	0.015	0.011	3750
Omaha DHS (L) FB	77	0.019	0.014	4323
Omaha NPS (L) FB	103	0.017	0.013	3698
Denver CT	123	0.016	0.012	3750
Denver (L) FB	144	0.026	0.019	3750
Lakewood (L) FB	103	0.021	0.015	3645
Ogden (L) FB	139	0.014	0.011	4170
Fresno CT & FB	91	0.008	0.006	3750
Las Vegas CT	84	0.014	0.010	3750
San Francisco FB	112	0.010	0.007	3855
Santa Ana FB	109	0.007	0.005	3791
Auburn FB	108	0.011	0.008	3908
Eugene CT	90	0.009	0.007	3855
Seattle CT	111	0.010	0.008	3750
Rockville (L) FB	99	0.016	0.012	3908
Suitland FB	140	0.018	0.013	3960

Operational Costs Baselines

Each of the baselines discussed above were applied to the buildings where a baseline cost was developed for every metric. The actual operational costs were compared and a building performance value was calculated. The following tables document these values.

	Water Performance		
Building Name	Baseline Cost	Bldg Cost	Bldg Performance
Greeneville CT	$25,860	$6,352	-75%
Jacksonville FB	$56,989	$24,555	-57%
Knoxville FB	$22,832	$16,061	-30%
Cleveland CT	$35,170	$6,730	-81%
Youngstown CT & FB	$8,450	$3,945	-53%
Cape Girardeau CT	$26,324	$10,155	-61%
Davenport CT	$12,994	$5,900	-55%
Omaha DHS (L) FB	$13,957	$4,831	-65%
Omaha NPS (L) FB	$11,927	$651	-95%
Denver CT	$48,776	$20,390	-58%
Denver (L) FB	$47,281	$9,882	-79%
Lakewood (L) FB	$23,223	$10,617	-54%
Ogden (L) FB	$19,490	$10,088	-48%
Fresno CT & FB	$74,716	$42,150	-44%
Las Vegas CT	$70,104	$64,381	-8%
San Francisco FB	$99,410	$88,562	-11%
Santa Ana FB	$39,022	$12,724	-67%
Auburn FB	$38,191	$8,448	-78%
Eugene CT	$45,192	$13,208	-71%
Seattle CT	$105,845	$74,016	-30%
Rockville (L) FB	$43,324	$32,406	-25%
Suitland FB	$268,088	$639,997	139%

	Energy Performance		
Building Name	Baseline Cost	Bldg Cost	Bldg Performance
Greeneville CT	$344,343	$176,042	-49%
Jacksonville FB	$758,851	$427,075	-44%
Knoxville FB	$304,033	$198,759	-35%
Cleveland CT	$468,316	$576,668	23%
Youngstown CT & FB	$112,524	$108,647	-3%
Cape Girardeau CT	$350,526	$125,431	-64%
Davenport CT	$173,029	$79,627	-54%
Omaha DHS (L) FB	$185,851	$95,017	-49%
Omaha NPS (L) FB	$158,813	$73,214	-54%
Denver CT	$649,497	$631,891	-3%
Denver (L) FB	$629,588	$367,301	-42%
Lakewood (L) FB	$309,229	$213,099	-31%
Ogden (L) FB	$259,525	$150,700	-42%
Fresno CT & FB	$994,905	$854,680	-14%
Las Vegas CT	$933,492	$720,041	-23%
San Francisco FB	$1,323,716	$994,770	-25%
Santa Ana FB	$519,606	$651,182	25%
Auburn FB	$508,538	$121,499	-76%
Eugene CT	$601,766	$213,279	-65%
Seattle CT	$1,409,405	$695,685	-51%
Rockville (L) FB	$576,891	$733,918	27%
Suitland FB	$3,569,800	$4,708,207	32%

Building Name	Maintenance Performance Baseline Cost	 Bldg Cost	 Bldg Performance
Greeneville CT	$167,371	$163,419	-2%
Jacksonville FB	$368,845	$523,958	42%
Knoxville FB	$147,777	$237,836	61%
Cleveland CT	$334,683	$176,320	-47%
Youngstown CT & FB	$80,416	$124,875	55%
Cape Girardeau CT	$222,089	$411,651	85%
Davenport CT	$109,629	$179,011	63%
Omaha DHS (L) FB	$117,753	$72,632	-38%
Omaha NPS (L) FB	$100,622	$41,600	-59%
Denver CT	$384,620	$643,227	67%
Denver (L) FB	$372,831	$184,607	-50%
Lakewood (L) FB	$183,120	$103,644	-43%
Ogden (L) FB	$153,686	$39,068	-75%
Fresno CT & FB	$845,169	$1,194,365	41%
Las Vegas CT	$792,999	$616,845	-22%
San Francisco FB	$1,124,494	$1,152,725	3%
Santa Ana FB	$441,404	$478,557	8%
Auburn FB	$361,591	$233,367	-35%
Eugene CT	$427,880	$381,904	-11%
Seattle CT	$1,002,144	$597,755	-40%
Rockville (L) FB	$507,815	$370,782	-27%
Suitland FB	$3,142,358	$2,730,589	-13%

Building Name	Janitorial Performance Baseline Cost	 Bldg Cost	 Bldg Performance
Greeneville CT	$170,704	$227,517	33%
Jacksonville FB	$376,192	$499,906	33%
Knoxville FB	$150,721	$220,948	47%
Cleveland CT	$296,271	$297,728	0%
Youngstown CT & FB	$71,186	$99,267	39%
Cape Girardeau CT	$192,595	$172,282	-11%
Davenport CT	$95,070	$145,990	54%
Omaha DHS (L) FB	$102,115	$70,800	-31%
Omaha NPS (L) FB	$87,259	$56,400	-35%
Denver CT	$339,981	$349,560	3%
Denver (L) FB	$329,560	$258,120	-22%
Lakewood (L) FB	$161,867	$83,220	-49%
Ogden (L) FB	$135,849	$125,892	-7%
Fresno CT & FB	$777,618	$821,414	6%
Las Vegas CT	$729,617	$174,441	-76%
San Francisco FB	$1,034,617	$1,169,249	13%
Santa Ana FB	$406,124	$345,401	-15%
Auburn FB	$334,139	$370,864	11%
Eugene CT	$395,396	$339,996	-14%
Seattle CT	$926,063	$1,016,574	10%
Rockville (L) FB	$484,222	$301,832	-38%
Suitland FB	$2,996,366	$3,213,210	7%

	Grounds Performance		
Building Name	Baseline Cost	Bldg Cost	Bldg Performance
Greeneville CT	$61,247	$4,000	-93%
Jacksonville FB	$134,973	$2,148	-98%
Knoxville FB	$54,077	$5,300	-90%
Cleveland CT	$83,297	$3,100	-96%
Youngstown CT & FB	$20,014	$37,300	86%
Cape Girardeau CT	$62,347	$11,318	-82%
Davenport CT	$30,776	$6,421	-79%
Omaha DHS (L) FB	$33,057	$8,200	-75%
Omaha NPS (L) FB	$28,247	$9,050	-68%
Denver CT	$115,523	$29,791	-74%
Denver (L) FB	$111,982	$16,833	-85%
Lakewood (L) FB	$55,001	$7,394	-87%
Ogden (L) FB	$46,161	$3,584	-92%
Fresno CT & FB	$176,959	$24,236	-86%
Las Vegas CT	$166,036	$126,328	-24%
San Francisco FB	$235,444	$25,000	-89%
Santa Ana FB	$92,420	$15,018	-84%
Auburn FB	$90,451	$22,497	-75%
Eugene CT	$107,033	$51,808	-52%
Seattle CT	$250,685	$29,635	-88%
Rockville (L) FB	$102,609	$91,858	-10%
Suitland FB	$634,945	$149,239	-76%

	Waste Performance		
Building Name	Baseline Cost	Bldg Cost	Bldg Performance
Greeneville CT	$10,815	$900	-92%
Jacksonville FB	$0	N/A	0%
Knoxville FB	$32,576	$4,380	-87%
Cleveland CT	$14,963	$3,067	-80%
Youngstown CT & FB	$25,463	$1,530	-94%
Cape Girardeau CT	$10,500	$325	-97%
Davenport CT	$6,615	$907	-86%
Omaha DHS (L) FB	$37,800	$2,400	-94%
Omaha NPS (L) FB	$14,049	$1,500	-89%
Denver CT	$0	N/A	0%
Denver (L) FB	$104,307	$15,862	-85%
Lakewood (L) FB	$35,228	$3,600	-90%
Ogden (L) FB	$54,705	$3,940	-93%
Fresno CT & FB	$53,550	$24,236	-55%
Las Vegas CT	$44,905	$25,266	-44%
San Francisco FB	$151,662	$31,970	-79%
Santa Ana FB	$48,195	$18,360	-62%
Auburn FB	$70,875	$2,184	-97%
Eugene CT	$17,850	Included	0%
Seattle CT	$63,000	Included	0%
Rockville (L) FB	$79,800	$22,056	-72%
Suitland FB	$569,625	$107,871	-81%

Building Name	Baseline Cost	Bldg Cost	Bldg Performance
		Recycle Performance	
Greeneville CT	$2,884	-$71	-102%
Jacksonville FB	$0	N/A	0%
Knoxville FB	$0	N/A	0%
Cleveland CT	$3,990	-$101	-103%
Youngstown CT & FB	$6,790	$0	-100%
Cape Girardeau CT	$2,800	$144	-95%
Davenport CT	$1,764	$0	-100%
Omaha DHS (L) FB	$10,080	$0	-100%
Omaha NPS (L) FB	$3,746	$1,020	-73%
Denver CT	$0	N/A	0%
Denver (L) FB	$27,815	$3,228	-88%
Lakewood (L) FB	$9,394	$0	-100%
Ogden (L) FB	$14,588	$16,081	10%
Fresno CT & FB	$14,280	$0	-100%
Las Vegas CT	$11,975	$0	-100%
San Francisco FB	$40,443	-$880	-102%
Santa Ana FB	$12,852	$1,600	-88%
Auburn FB	$0	N/A	0%
Eugene CT	$0	N/A	0%
Seattle CT	$16,800	-$533	-103%
Rockville (L) FB	$21,280	Included	0%
Suitland FB	$151,900	-$2,480	-102%

Building Name	Baseline Cost	Bldg Cost	Bldg Performance
		Aggregate Operational Performance	
Greeneville CT	$783,224	$578,159	-26%
Jacksonville FB	$1,695,850	$1,477,642	-13%
Knoxville FB	$712,017	$683,284	-4%
Cleveland CT	$1,236,689	$1,063,512	-14%
Youngstown CT & FB	$324,844	$375,564	16%
Cape Girardeau CT	$867,182	$731,306	-16%
Davenport CT	$429,878	$417,855	-3%
Omaha DHS (L) FB	$500,613	$253,880	-49%
Omaha NPS (L) FB	$404,664	$183,435	-55%
Denver CT	$1,538,397	$1,674,860	9%
Denver (L) FB	$1,623,364	$855,833	-47%
Lakewood (L) FB	$777,062	$421,574	-46%
Ogden (L) FB	$684,003	$349,351	-49%
Fresno CT & FB	$2,937,198	$2,961,081	1%
Las Vegas CT	$2,749,128	$1,727,301	-37%
San Francisco FB	$4,009,785	$3,461,396	-14%
Santa Ana FB	$1,559,624	$1,522,842	-2%
Auburn FB	$1,403,785	$758,859	-46%
Eugene CT	$1,595,116	$1,000,195	-37%
Seattle CT	$3,773,941	$2,413,133	-36%
Rockville (L) FB	$1,815,940	$1,552,852	-14%
Suitland FB	$11,333,081	$11,546,632	2%

Appendix E: Occupant Satisfaction Key Survey Questions

This appendix includes the key questions included in the GSA adaptation of the CBE survey, which was named the Sustainable Places and Organizational Trends "SPOT" survey and the GSA Customer Satisfaction survey questions.

SPOT Survey

Part 1 - Background Information

1. How would you describe the work you do?
2. Which organization do you work for?
3. How many years have you worked in this building?
4. How long have you been working at your present workspace?

Part 2 – Commute

1. On average, how many days per week do you travel to the office (i.e., commute)?
2. How far is your typical daily commute to and from this building? _______ Miles Roundtrip

3. Please indicate the *number of days* per week you commute to and from this building for each mode of transportation that applies.

☐	Walk	☐	Bicycle
☐	Car, truck or van - single occupant	☐	Car, truck or van - multiple occupants (e.g. carpool, vanpool or rideshare)
☐	Bus	☐	Train (including light rail)
☐	Combination of multiple modes (e.g., driving to ride share locations then taking mass transit)		
☐	Other		

4. Please describe any other issues related to your commute to and from this building that are important to you; and/or provide additional detail on your modes of transportation as you see fit.

Part 3 – Personal Workspace Location

1. On which floor is your workspace located?
2. In which area of the building is your workspace located?
3. Are you near an exterior wall (within 15 feet)?
4. Are you near a window (within 15 feet)?
5. Describe your personal workspace.

Part 4 – Your Workstation

In this section, please note your level of satisfaction with features and attributes of your workstation.

If any of these aspects are not important to you, please indicate so instead of answering with a level of satisfaction.

1. How satisfied are you with the comfort of your office furnishings (chair, desk, computer, equipment, etc.)? This is not important to me ____

VERY SATISFIED **VERY DISSATISFIED**

☐	☐	☐	☐	☐	☐	☐
7	6	5	4	3	2	1

2. How satisfied are you with your ability to adjust your furniture to meet your needs?

This is not important to me ____

VERY SATISFIED **VERY DISSATISFIED**

☐	☐	☐	☐	☐	☐	☐
7	6	5	4	3	2	1

3. How satisfied are you with the colors and textures of flooring, furniture, and surface finishes?

This is not important to me ____

VERY SATISFIED **VERY DISSATISFIED**

☐	☐	☐	☐	☐	☐	☐
7	6	5	4	3	2	1

4. How satisfied are you with the amount of space available for individual work?

This is not important to me ____

VERY SATISFIED **VERY DISSATISFIED**

☐	☐	☐	☐	☐	☐	☐
7	6	5	4	3	2	1

5. How satisfied are you with the level of visual privacy in your workspace?

This is not important to me ____

VERY SATISFIED **VERY DISSATISFIED**

☐	☐	☐	☐	☐	☐	☐
7	6	5	4	3	2	1

6. Please describe any other issues related to your personal workspace that are of importance to you.

Part 5 – Communication

1. How satisfied are you with your ability to communicate with co-workers in person (face to face)?

This is not important to me ____

VERY SATISFIED **VERY DISSATISFIED**

☐	☐	☐	☐	☐	☐	☐
7	6	5	4	3	2	1

2. How satisfied are you with the ease of interaction with co-workers?

This is not important to me ____

VERY SATISFIED **VERY DISSATISFIED**

☐	☐	☐	☐	☐	☐	☐
7	6	5	4	3	2	1

3. How satisfied are you with your ability to communicate in privacy?

This is not important to me ____

VERY SATISFIED **VERY DISSATISFIED**

☐	☐	☐	☐	☐	☐	☐
7	6	5	4	3	2	1

4. How satisfied are you with the availability of space where you and your colleagues can talk into a speaker phone together?

This is not important to me ____

VERY SATISFIED VERY DISSATISFIED

☐	☐	☐	☐	☐	☐	☐
7	6	5	4	3	2	1

5. Please describe any other issues related to communication with others that are important to you.

Part 6 – Meeting Facilities

1. How satisfied are you with the availability of meeting rooms on short notice?

This is not important to me ____

VERY SATISFIED VERY DISSATISFIED

☐	☐	☐	☐	☐	☐	☐
7	6	5	4	3	2	1

2. How satisfied are you with the availability of equipment in meeting rooms? (white boards, speaker phone, computer access, LCD projectors, etc.)

This is not important to me ____

VERY SATISFIED VERY DISSATISFIED

☐	☐	☐	☐	☐	☐	☐
7	6	5	4	3	2	1

3. How satisfied are you with the temperature of meeting rooms?

This is not important to me ____

VERY SATISFIED VERY DISSATISFIED

☐	☐	☐	☐	☐	☐	☐
7	6	5	4	3	2	1

4. How satisfied are you with the acoustic quality of meeting rooms?

This is not important to me ____

VERY SATISFIED **VERY DISSATISFIED**

☐ ☐ ☐ ☐ ☐ ☐ ☐

7 6 5 4 3 2 1

5. How satisfied are you with the variety of meeting rooms available to you?

This is not important to me ____

VERY SATISFIED **VERY DISSATISFIED**

☐ ☐ ☐ ☐ ☐ ☐ ☐

7 6 5 4 3 2 1

6. Please describe any other issues related to meeting facilities that are important to you.

Part 7 – Work Experiences

In this section, please rate your level of agreement with the following statements about experiences at work.

1. I look forward to working in the building.

STRONGLY AGREE **STRONGLY DISAGREE**

☐ ☐ ☐ ☐ ☐ ☐ ☐

7 6 5 4 3 2 1

2. I am proud to show the office to visitors.

STRONGLY AGREE **STRONGLY DISAGREE**

☐ ☐ ☐ ☐ ☐ ☐ ☐

7 6 5 4 3 2 1

3. The overall appearance of the workplace is consistent with the mission of the agency.

STRONGLY AGREE **STRONGLY DISAGREE**

☐ ☐ ☐ ☐ ☐ ☐ ☐

7 6 5 4 3 2 1

4. There is a good sense of connection to the outdoors from inside the building.

STRONGLY AGREE **STRONGLY DISAGREE**

☐ ☐ ☐ ☐ ☐ ☐ ☐
7 6 5 4 3 2 1

5. There is a definite space that is the 'heart' of the workplace.

STRONGLY AGREE **STRONGLY DISAGREE**

☐ ☐ ☐ ☐ ☐ ☐ ☐
7 6 5 4 3 2 1

6. It is easy to locate other people and spaces (offices, meeting rooms, etc.) even when I have not been there before.

STRONGLY AGREE **STRONGLY DISAGREE**

☐ ☐ ☐ ☐ ☐ ☐ ☐
7 6 5 4 3 2 1

7. Communication within my group is good.

STRONGLY AGREE **STRONGLY DISAGREE**

☐ ☐ ☐ ☐ ☐ ☐ ☐
7 6 5 4 3 2 1

8. I learn a lot about what is going on by seeing and hearing others.

STRONGLY AGREE **STRONGLY DISAGREE**

☐ ☐ ☐ ☐ ☐ ☐ ☐
7 6 5 4 3 2 1

9. I often stop and talk to others in corridors or break areas.

STRONGLY AGREE **STRONGLY DISAGREE**

☐ ☐ ☐ ☐ ☐ ☐ ☐
7 6 5 4 3 2 1

10. The security features of our building are adequate.

STRONGLY AGREE STRONGLY DISAGREE

☐	☐	☐	☐	☐	☐	☐
7	6	5	4	3	2	1

11. I feel safe walking to and from the building.

STRONGLY AGREE STRONGLY DISAGREE

☐	☐	☐	☐	☐	☐	☐
7	6	5	4	3	2	1

12. We have comfortable spaces to have lunch or takes breaks inside the building.

STRONGLY AGREE STRONGLY DISAGREE

☐	☐	☐	☐	☐	☐	☐
7	6	5	4	3	2	1

13. We have adequate restroom facilities in our offices.

STRONGLY AGREE STRONGLY DISAGREE

☐	☐	☐	☐	☐	☐	☐
7	6	5	4	3	2	1

14. I use the building stairs rather than the elevator at least once a day.

STRONGLY AGREE STRONGLY DISAGREE

☐	☐	☐	☐	☐	☐	☐
7	6	5	4	3	2	1

Part 8 – Indoor Environmental Quality

The following section of the survey focuses on your satisfaction with indoor environmental quality in your workplace. How important is each of the following items to doing your job well?

Thermal Comfort

1. Which of the following do you personally adjust or control in your workspace? (check all that apply)

☐ Window blinds or shades
☐ Thermostat
☐ Permanent heater
☐ Portable fan
☐ Adjustable air vent in wall or ceiling
☐ Door to interior space
☐ None of the above

☐ Operable window
☐ Portable heater
☐ Room air-conditioning unit
☐ Ceiling fan
☐ Ajustable air vent in floor (diffuser)
☐ Door to exterior space
☐ Other

2. How satisfied are you with the temperature in your workspace?

VERY SATISFIED **VERY DISSATISFIED**

☐	☐	☐	☐	☐	☐	☐
7	6	5	4	3	2	1

Air Quality

1. How satisfied are you with the air quality in your workspace (i.e. stuffy/stale air, cleanliness, odors)?

VERY SATISFIED **VERY DISSATISFIED**

☐	☐	☐	☐	☐	☐	☐
7	6	5	4	3	2	1

Lighting

1. Which of the following controls do you have over the lighting in your workspace? (check all that apply)

- ☐ Light switch for ceiling lights
- ☐ Window blinds or shades
- ☐ None of the above
- ☐ Dimmer switch for ceiling lights
- ☐ Desk (task) light
- ☐ Other

2. How satisfied are you with the amount of light in your workspace?

VERY SATISFIED VERY DISSATISFIED

☐	☐	☐	☐	☐	☐	☐
7	6	5	4	3	2	1

3. How satisfied are you with the visual comfort of the lighting (e.g., glare, reflections, contrast)?

VERY SATISFIED VERY DISSATISFIED

☐	☐	☐	☐	☐	☐	☐
7	6	5	4	3	2	1

4. How satisfied are you with the degree of control you have over the lighting in your workspace?

VERY SATISFIED VERY DISSATISFIED

☐	☐	☐	☐	☐	☐	☐
7	6	5	4	3	2	1

Windows and Daylight

1. How satisfied are you with the amount of daylight in your general office area?

VERY SATISFIED VERY DISSATISFIED

☐	☐	☐	☐	☐	☐	☐
7	6	5	4	3	2	1

2. How satisfied are you with your access to a window view?

VERY SATISFIED **VERY DISSATISFIED**

☐	☐	☐	☐	☐	☐	☐
7	6	5	4	3	2	1

Acoustic Quality

1. How satisfied are you with the noise level in your workspace?

VERY SATISFIED **VERY DISSATISFIED**

☐	☐	☐	☐	☐	☐	☐
7	6	5	4	3	2	1

2. How satisfied are you with the speech privacy in your workspace (ability to have conversations without your neighbors overhearing and vice versa)?

VERY SATISFIED **VERY DISSATISFIED**

☐	☐	☐	☐	☐	☐	☐
7	6	5	4	3	2	1

Cleanliness and Maintenance

1. How satisfied are you with the cleanliness and maintenance of the building?

VERY SATISFIED **VERY DISSATISFIED**

☐	☐	☐	☐	☐	☐	☐
7	6	5	4	3	2	1

Please describe any other issues related to Indoor Environmental Quality that are important to you.

Part 9 – General Comments

1. All things considered, how satisfied are you with your personal workspace?

VERY SATISFIED **VERY DISSATISFIED**

☐	☐	☐	☐	☐	☐	☐
7	6	5	4	3	2	1

2. How satisfied are you with the building overall?

VERY SATISFIED **VERY DISSATISFIED**

☐	☐	☐	☐	☐	☐	☐
7	6	5	4	3	2	1

3. To what extent does your workplace enhance or interfere with your individual work effectiveness?

ENHANCES **INTERFERES**

☐	☐	☐	☐	☐	☐	☐
7	6	5	4	3	2	1

4. To what extent does your workplace enhance or interfere with your ability to work effectively with others?

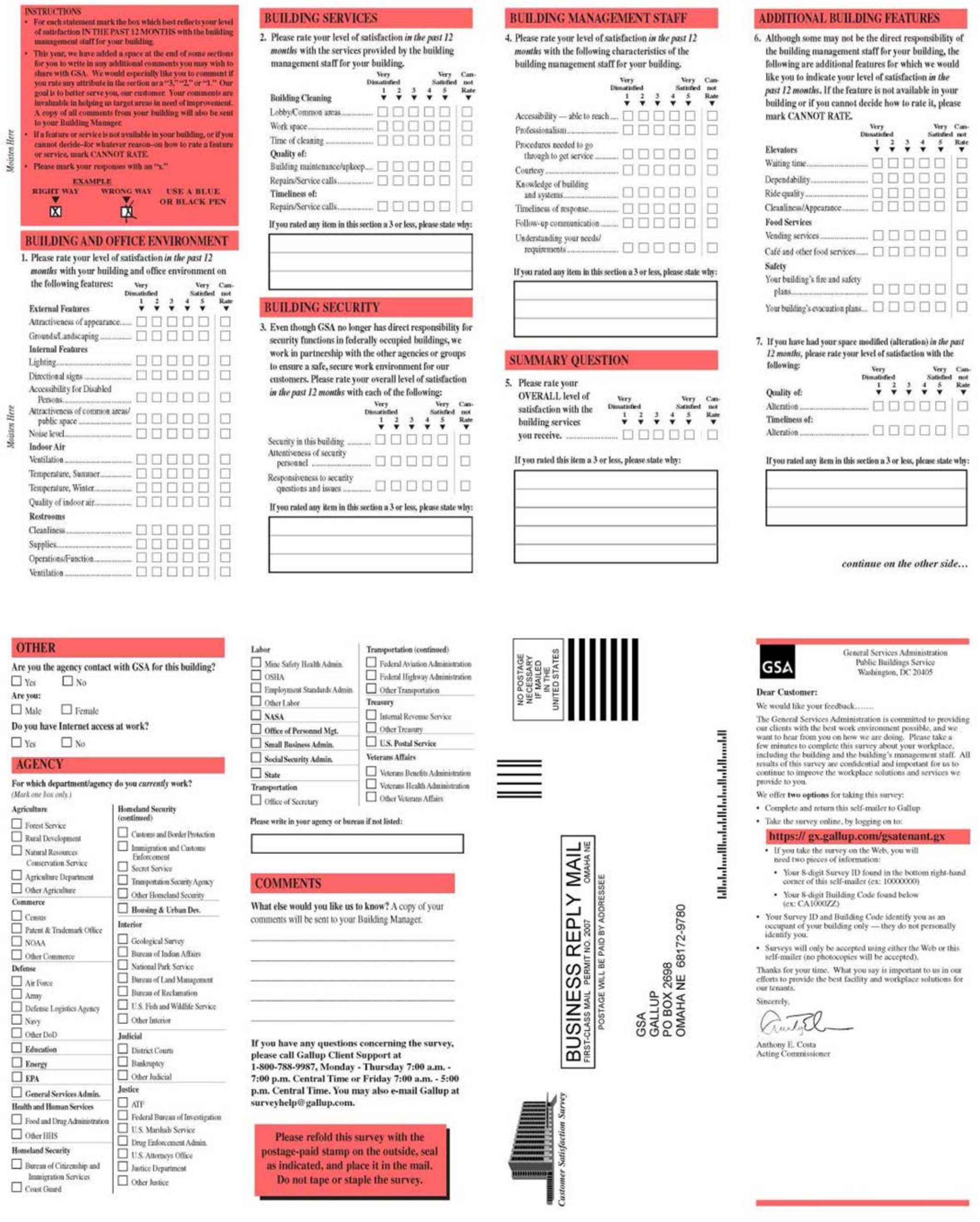
ENHANCES **INTERFERES**

☐	☐	☐	☐	☐	☐	☐
7	6	5	4	3	2	1

5. If you wanted to show a visitor around the building, but could only show one space, which space would you show?

6. Any additional comments or recommendations about your personal workspace or building overall?

Appendix F: GSA Customer Satisfaction Survey



Moisten Here

INSTRUCTIONS

- For each statement mark the box which best reflects your level of satisfaction IN THE PAST 12 MONTHS with the building management staff for your building.
- This year, we have added a space at the end of some sections for you to write in any additional comments you may wish to share with GSA. We would especially like you to comment if you rate any attribute in the section as a "3," "2," or "1." Our goal is to better serve you, our customer. Your comments are invaluable in helping us target areas in need of improvement. A copy of all comments from your building will also be sent to your Building Manager.
- If a feature or service is not available in your building, or if you cannot decide–for whatever reason–on how to rate a feature or service, mark CANNOT RATE.
- Please mark your responses with an "x."

EXAMPLE

RIGHT WAY ☒ WRONG WAY ☒

USE A BLUE OR BLACK PEN

BUILDING AND OFFICE ENVIRONMENT

1. Please rate your level of satisfaction *in the past 12 months* with your building and office environment on the following features:

	Very Dissatisfied 1	2	3	4	Very Satisfied 5	Cannot Rate
External Features						
Attractiveness of appearance	☐	☐	☐	☐	☐	☐
Grounds/Landscaping	☐	☐	☐	☐	☐	☐
Internal Features						
Lighting	☐	☐	☐	☐	☐	☐
Directional signs	☐	☐	☐	☐	☐	☐
Accessibility for Disabled Persons	☐	☐	☐	☐	☐	☐
Attractiveness of common areas/ public space	☐	☐	☐	☐	☐	☐
Noise level	☐	☐	☐	☐	☐	☐
Indoor Air						
Ventilation	☐	☐	☐	☐	☐	☐
Temperature, Summer	☐	☐	☐	☐	☐	☐
Temperature, Winter	☐	☐	☐	☐	☐	☐
Quality of indoor air	☐	☐	☐	☐	☐	☐
Restrooms						
Cleanliness	☐	☐	☐	☐	☐	☐
Supplies	☐	☐	☐	☐	☐	☐
Operations/Function	☐	☐	☐	☐	☐	☐
Ventilation	☐	☐	☐	☐	☐	☐

Moisten Here

BUILDING SERVICES

2. Please rate your level of satisfaction *in the past 12 months* with the services provided by the building management staff for your building.

	Very Dissatisfied 1	2	3	4	Very Satisfied 5	Cannot Rate
Building Cleaning						
Lobby/Common areas	☐	☐	☐	☐	☐	☐
Work space	☐	☐	☐	☐	☐	☐
Time of cleaning	☐	☐	☐	☐	☐	☐
Quality of:						
Building maintenance/upkeep	☐	☐	☐	☐	☐	☐
Repairs/Service calls	☐	☐	☐	☐	☐	☐
Timeliness of:						
Repairs/Service calls	☐	☐	☐	☐	☐	☐

If you rated any item in this section a 3 or less, please state why:

BUILDING SECURITY

3. Even though GSA no longer has direct responsibility for security functions in federally occupied buildings, we work in partnership with the other agencies or groups to ensure a safe, secure work environment for our customers. Please rate your overall level of satisfaction *in the past 12 months* with each of the following:

	Very Dissatisfied 1	2	3	4	Very Satisfied 5	Cannot Rate
Security in this building	☐	☐	☐	☐	☐	☐
Attentiveness of security personnel	☐	☐	☐	☐	☐	☐
Responsiveness to security questions and issues	☐	☐	☐	☐	☐	☐

If you rated any item in this section a 3 or less, please state why:

BUILDING MANAGEMENT STAFF

4. Please rate your level of satisfaction *in the past 12 months* with the following characteristics of the building management staff for your building.

	Very Dissatisfied 1	2	3	4	Very Satisfied 5	Cannot Rate
Accessibility — able to reach	☐	☐	☐	☐	☐	☐
Professionalism	☐	☐	☐	☐	☐	☐
Procedures needed to go through to get service	☐	☐	☐	☐	☐	☐
Courtesy	☐	☐	☐	☐	☐	☐
Knowledge of building and systems	☐	☐	☐	☐	☐	☐
Timeliness of response	☐	☐	☐	☐	☐	☐
Follow-up communication	☐	☐	☐	☐	☐	☐
Understanding your needs/ requirements	☐	☐	☐	☐	☐	☐

If you rated any item in this section a 3 or less, please state why:

SUMMARY QUESTION

5. Please rate your OVERALL level of satisfaction with the building services you receive.

	Very Dissatisfied 1	2	3	4	Very Satisfied 5	Cannot Rate
you receive.	☐	☐	☐	☐	☐	☐

If you rated this item a 3 or less, please state why:

ADDITIONAL BUILDING FEATURES

6. Although some may not be the direct responsibility of the building management staff for your building, the following are additional features for which we would like you to indicate your level of satisfaction *in the past 12 months*. If the feature is not available in your building or if you cannot decide how to rate it, please mark CANNOT RATE.

	Very Dissatisfied 1	2	3	4	Very Satisfied 5	Cannot Rate
Elevators						
Waiting time	☐	☐	☐	☐	☐	☐
Dependability	☐	☐	☐	☐	☐	☐
Ride quality	☐	☐	☐	☐	☐	☐
Cleanliness/Appearance	☐	☐	☐	☐	☐	☐
Food Services						
Vending services	☐	☐	☐	☐	☐	☐
Café and other food services	☐	☐	☐	☐	☐	☐
Safety						
Your building's fire and safety plans	☐	☐	☐	☐	☐	☐
Your building's evacuation plans	☐	☐	☐	☐	☐	☐

7. If you have had your space modified (alteration) *in the past 12 months*, please rate your level of satisfaction with the following:

	Very Dissatisfied 1	2	3	4	Very Satisfied 5	Cannot Rate
Quality of:						
Alteration	☐	☐	☐	☐	☐	☐
Timeliness of:						
Alteration	☐	☐	☐	☐	☐	☐

If you rated any item in this section a 3 or less, please state why:

continue on the other side…

OTHER

Are you the agency contact with GSA for this building?

☐ Yes ☐ No

Are you:

☐ Male ☐ Female

Do you have Internet access at work?

☐ Yes ☐ No

AGENCY

For which department/agency do you *currently* work? *(Mark one box only.)*

Agriculture
- ☐ Forest Service
- ☐ Rural Development
- ☐ Natural Resources Conservation Service
- ☐ Agriculture Department
- ☐ Other Agriculture

Commerce
- ☐ Census
- ☐ Patent & Trademark Office
- ☐ NOAA
- ☐ Other Commerce

Defense
- ☐ Air Force
- ☐ Army
- ☐ Defense Logistics Agency
- ☐ Navy
- ☐ Other DoD

☐ **Education**

☐ **Energy**

☐ **EPA**

☐ **General Services Admin.**

Health and Human Services
- ☐ Food and Drug Administration
- ☐ Other HHS

Homeland Security
- ☐ Bureau of Citizenship and Immigration Services
- ☐ Coast Guard

Homeland Security (continued)
- ☐ Customs and Border Protection
- ☐ Immigration and Customs Enforcement
- ☐ Secret Service
- ☐ Transportation Security Agency
- ☐ Other Homeland Security

☐ **Housing & Urban Dev.**

Interior
- ☐ Geological Survey
- ☐ Bureau of Indian Affairs
- ☐ National Park Service
- ☐ Bureau of Land Management
- ☐ Bureau of Reclamation
- ☐ U.S. Fish and Wildlife Service
- ☐ Other Interior

Judicial
- ☐ District Courts
- ☐ Bankruptcy
- ☐ Other Judicial

Justice
- ☐ ATF
- ☐ Federal Bureau of Investigation
- ☐ U.S. Marshals Service
- ☐ Drug Enforcement Admin.
- ☐ U.S. Attorneys Office
- ☐ Justice Department
- ☐ Other Justice

Labor
- ☐ Mine Safety Health Admin.
- ☐ OSHA
- ☐ Employment Standards Admin.
- ☐ Other Labor

☐ **NASA**

☐ **Office of Personnel Mgt.**

☐ **Small Business Admin.**

☐ **Social Security Admin.**

☐ **State**

Transportation
- ☐ Office of Secretary

Transportation (continued)
- ☐ Federal Aviation Administration
- ☐ Federal Highway Administration
- ☐ Other Transportation

Treasury
- ☐ Internal Revenue Service
- ☐ Other Treasury

☐ **U.S. Postal Service**

Veterans Affairs
- ☐ Veterans Benefits Administration
- ☐ Veterans Health Administration
- ☐ Other Veterans Affairs

Please write in your agency or bureau if not listed:

COMMENTS

What else would you like us to know? A copy of your comments will be sent to your Building Manager.

If you have any questions concerning the survey, please call Gallup Client Support at 1-800-788-9987, Monday - Thursday 7:00 a.m. - 7:00 p.m. Central Time or Friday 7:00 a.m. - 5:00 p.m. Central Time. You may also e-mail Gallup at surveyhelp@gallup.com.

Please refold this survey with the postage-paid stamp on the outside, seal as indicated, and place it in the mail. Do not tape or staple the survey.

NO POSTAGE
NECESSARY
IF MAILED
IN THE
UNITED STATES

BUSINESS REPLY MAIL
FIRST-CLASS MAIL PERMIT NO. 2007 OMAHA NE
POSTAGE WILL BE PAID BY ADDRESSEE

GSA
GALLUP
PO BOX 2698
OMAHA NE 68172-9780

Customer Satisfaction Survey

GSA

General Services Administration
Public Buildings Service
Washington, DC 20405

Dear Customer:

We would like your feedback…….

The General Services Administration is committed to providing our clients with the best work environment possible, and we want to hear from you on how we are doing. Please take a few minutes to complete this survey about your workplace, including the building and the building's management staff. All results of this survey are confidential and important for us to continue to improve the workplace solutions and services we provide to you.

We offer **two options** for taking this survey:

- Complete and return this self-mailer to Gallup
- Take the survey online, by logging on to:

https:// gx.gallup.com/gsatenant.gx

  - If you take the survey on the Web, you will need two pieces of information:
    - Your 8-digit Survey ID found in the bottom right-hand corner of this self-mailer (ex: 10000000)
    - Your 8-digit Building Code found below (ex: CA1000ZZ)
- Your Survey ID and Building Code identify you as an occupant of your building only — they do not personally identify you.
- Surveys will only be accepted using either the Web or this self-mailer (no photocopies will be accepted).

Thanks for your time. What you say is important to us in our efforts to provide the best facility and workplace solutions for our tenants.

Sincerely,

Anthony E. Costa
Acting Commissioner

Appendix G: Indoor Environmental Quality Assessment for Denver Federal Building

Indoor Environmental Quality Measurements at the EPA Region VIII LEED Gold Certified Office Building

Bradley P. Goodwin, Ian C. MacGregor, and Marcia G. Nishioka
Assessment Date: July 22, 2009
Battelle, Columbus, OH

Abstract

Indoor environmental quality (IEQ) measurements of temperature, relative humidity, atmospheric pressure, sound level, carbon dioxide, ozone, particulate matter, fungal spores, volatile organic compounds (VOCs), and semivolatile organic compounds (SVOCs) were performed at five indoor locations and one outdoor location at a Leadership in Energy and Environmental Design (LEED) Gold certified EPA Region VIII office building in Denver, Colorado. The goal of this assessment was to provide a rapid assessment of the indoor environmental quality of the building so that it could be compared to industry standards and the occupant satisfaction scores of the building's indoor environmental quality.

Compared to available standards, no acute hazards were identified given this was a one-day sampling of only five locations. All of the temperature and relative humidity combinations were within the acceptable range (23-28°C) according to ASHRAE Standard 55-2004. However, temperatures measured in four of the indoor spaces exceeded the optimal temperature range (20-23°C) for workplace productivity reported by Seppänen and Fisk (2006). The University of California – Berkeley's Center for the Built Environment (CBE) IEQ occupant satisfaction survey had occupant thermal comfort at 46% satisfied, which is the 59th percentile in the CBE database of over 500 buildings.

To assess indoor air quality carbon dioxide, ozone, particulate matter, volatile organic compounds, semi-volatile organic compounds were measured. Carbon dioxide concentrations measured indoors (585-697 ppm) were acceptable based on the recommendation that indoor carbon dioxide levels not exceed outdoor levels by more than 650 ppm. Indoor ozone concentrations were all less than 27 ppb and the indoor/outdoor ozone ratios were in the range of 0.09 to 0.17 which is comparable to the ratios observed in other indoor spaces with central air conditioning. Particulate matter concentrations were measured to be less than 25 $\mu g/m^3$ in the indoor spaces and were less than half of the LEED new construction standard of 50 $\mu g/m^3$. The occupant responses to the CBE survey had air quality at 76% satisfied, which is the 85th percentile within the CBE database.

Indoor fungal spore concentrations were measured to be less than 100 spores/m^3 in all locations and were well below the 1000 spore/m^3 level of concern. Indoor formaldehyde concentrations (20-26 μg/m^3) were greater than the outdoor concentration (5.3 μg/m^3) but still less than indoor air quality guidelines (the LEED new construction standard is 64.1 μg/m^3) and are below levels of concern. Ethanol (133-217 μg/m^3) and acetone (46-79 μg/m^3) were detected at levels higher than outdoor concentrations because of typical human activity in the building; HAPs 2-butanone (6.8-11 μg/m^3), toluene (7.3-13 μg/m^3), and hexane (2.5-3.7 μg/m^3) were also detected at concentrations higher than the outdoor air.

Synthetic musks AHTN (3.7-23 ng/m^3) and HHCB (40-467 ng/m^3) were found in the indoor air with concentrations in one office approximately an order of magnitude higher than the other indoor locations. BDEs and phthalates were, in general, found at levels similar to those reported for other indoor environments. Limonene and its oxidation products were detected in the indoor samples, at relatively low concentrations. Samples collected from the copy room were found to have elevated concentrations of several poly-aromatic hydrocarbons (PAHs) (predominantly the lower volatility PAHs). The concentration of total PAHs found in the copy room was higher than the other spaces measured in the building.

Sound levels measured indoors (61-65 dBa) did not exceed the range of normal conversation (60-70 dBa). The occupant responses to the CBE survey had acoustic quality at 46% satisfied, which is the 59th percentile within the CBE database.

In general, the various IEQ parameters measured during this limited study at the EPA Region VIII LEED Gold office building were within the ranges of applicable standards and were similar to the results of measurements in other indoor spaces, with the exception of PAH concentrations in the copy room.

Introduction and Background

Humans in modern society spend the bulk of their time indoors, and indoor environmental quality (IEQ) not only affects the health, comfort, and well-being of building occupants, but also their productivity and efficiency on the job in workplace environments. To assess the IEQ at the U.S. Environmental Protection Agency (EPA) Region VIII Headquarters, a U.S. Green Building Council Leadership in Energy and Environmental Design – New Construction (LEED-NC) Gold certified building, in Denver, Colorado, measurements were performed, on July 22, 2009, in six different locations throughout the building. Data collected during the field sampling event include continuous measurements of carbon dioxide, ozone, PM_{10} (particulate matter with an aerodynamic diameter of less than 10 microns), temperature, relative humidity, atmospheric pressure, and sound level. In addition, integrated samples were collected to quantify concentrations of fungal spores, volatile organic compounds (VOCs) and semi-volatile organic compounds (SVOCs).

Measurements of these various IEQ parameters are reported and compared to similar measurements conducted at other indoor locations. The goal of this assessment was to provide a rapid assessment of the indoor environmental quality of the building so that it could be compared to industry standards and the occupant satisfaction scores of the building's indoor environmental quality. The major source of indoor air quality reference measurements is the Building Assessment Survey and Evaluation Study (BASE). This study, conducted between 1994 and 1998, looked at indoor air quality in addition to other building parameters (HVAC, occupant satisfaction, etc.) at one hundred office buildings throughout the United States. Other sources of data used for comparison include standards for indoor environments published by the American Society of Heating, Refrigerating, and Air Conditioning Engineers (ASHRAE), LEED new construction standards, as well as data published in the peer-reviewed literature. Potential sources of VOCs and SVOCs are also discussed, as are implications of the findings, as are recommendations for improving the IEQ in this building.

Methods

Sampling locations

Indoor sampling locations were selected throughout the building to characterize the IEQ in the different areas of the building where staff spend the bulk of their time. One location was outdoors on the roof of the building near the air intake for the HVAC system. This location was on a tiled path near the outer edge of the building. The sampling location was on the "green" portion of the roof (vegetation was present in close proximity to the sampling location). Of the five interior locations, four were located in office spaces while one was located in a dedicated copy room. Of the office spaces, two locations were closed offices and two were open offices. One each of the open and closed offices had underfloor ventilation, while the others had overhead ventilation. Table 1 lists the six sampling locations and specifies the location and ventilation conditions present in each. Figure 1 through Figure 6 show each of the sampling locations at various stages in the sampling process.

Table 1. Sampling Locations and Characteristics

Location	Floor	Room Number	Office Type	Ventilation
Roof	9 (Outside)	NA	NA	Natural
Copy Room (CR)	8	Copy Center	NA	Overhead
Office 1 (O1)	8	8271	Closed	Underfloor
Office 2 (O2)	3	3153	Closed	Overhead
Office 3 (O3)	3	3151	Open	Overhead
Office 4 (O4)	7	7173	Open	Underfloor

Figure 1. Roof sampling location.

Figure 2. Copy Room (CR) sampling location and SVOC cartridge.

Figure 3. Office 1 (O1) sampling location and SVOC sampling setup.

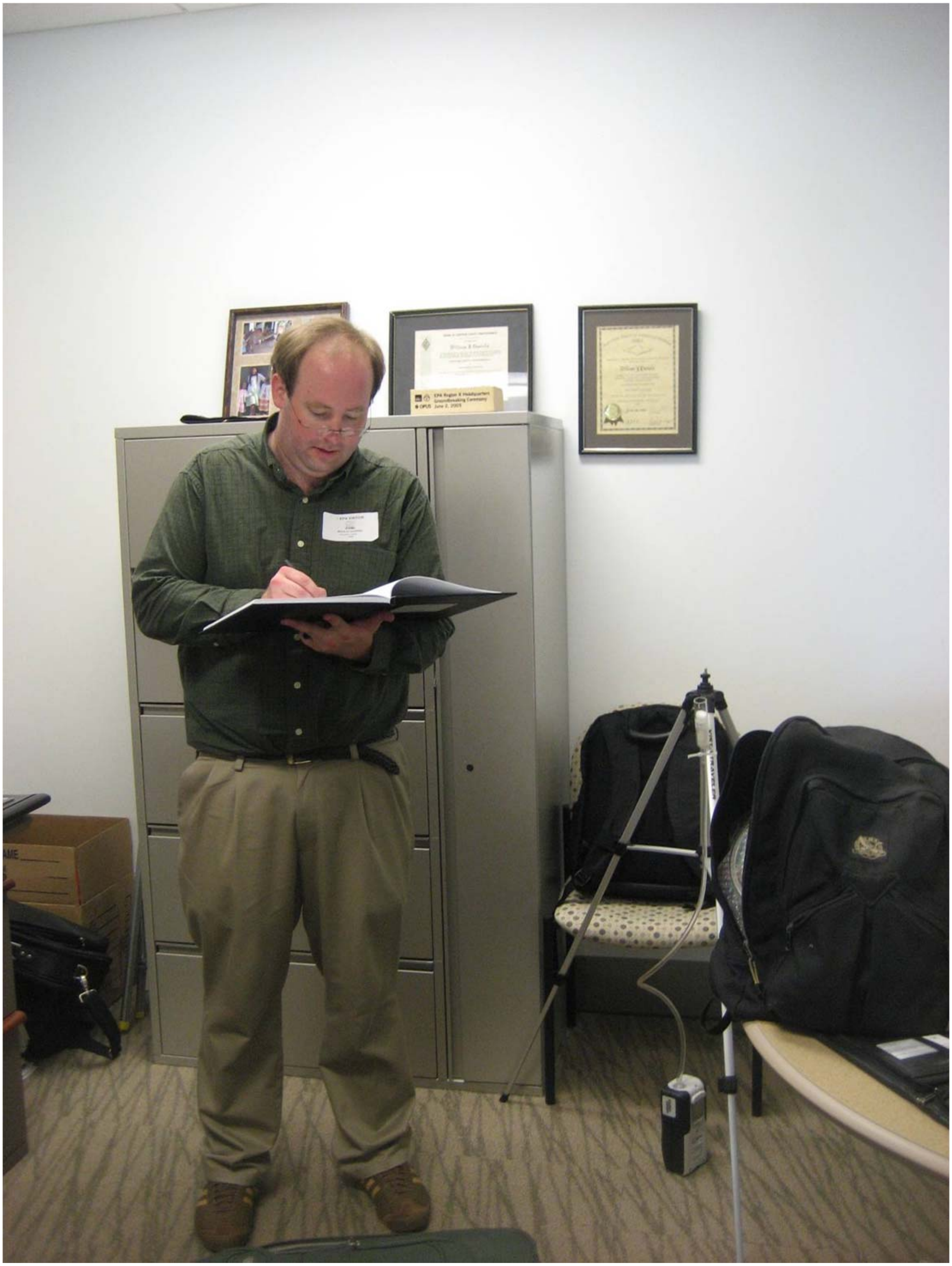


Figure 4. Office 2 (O2) sampling location.

Figure 5. Office 3 (O3) sampling location.

Figure 6. Office 4 (O4) sampling location with SVOC sampler and continuous instruments.

Field sampling

Integrated VOC (canisters and cartridges), SVOC, and fungi samples were collected at each location in addition to continuous measurements of carbon dioxide, ozone, particulate matter, temperature, relative humidity, atmospheric pressure, and sound level. Selected VOCs were collected by sampling whole air into evacuated 400 mL passivated, stainless steel canisters. Grab samples were collected by simply opening the valve on each canister and allowing the canister to fill to atmospheric pressure over the course of approximately 30 seconds. Other VOCs (selected carbonyls) were collected using adsorbent cartridges containing silica gel coated with the derivitization agent 2,4-dinitrophenyl hydrazine (DNPH) at a flow rate of 2 liters per minute for 10 minutes. The DNPH cartridges were purchased commercially from Supelco, and were shipped to the office building on ice, in individual sealed bags. Each SVOC cartridge consisted of 5 g of pre-cleaned styrene-divinyl benzene copolymer XAD-2 (Supelco) sandwiched between two plugs of polyurethane foam (PUF; Supelco), each plug being 22 mm in diameter and 19 mm in length. SVOC samples were collected at a flow rate of 8 liters per minute for a minimum of two hours. Fungi samples were collected on Air-O-Cell cassettes at a flow rate of 15 liters per minute for 10 minutes. Temperature, relative humidity, and sound level were measured by probes protruding from the side of the continuous instrument package (Figure 7). Atmospheric pressure was measured by a sensor housed inside the package. Concentrations of particulate matter, carbon dioxide, and ozone were determined by pulling air into instruments in the continuous instrument package. Air samples were collected at a height above the floor to approximate the height of the breathing zone of a seated individual (~1 m).

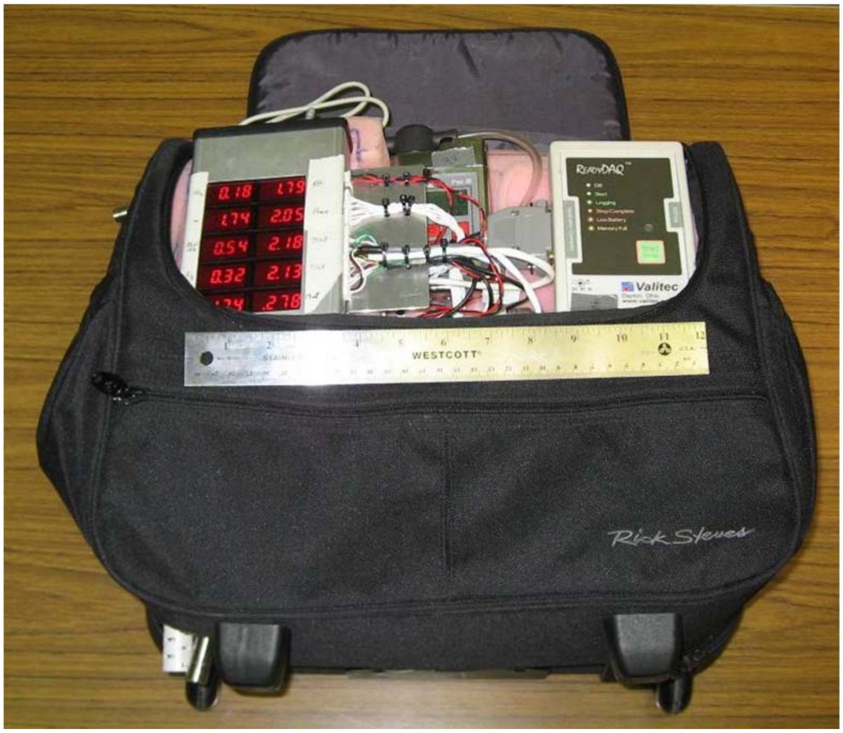


Figure 7. Continuous instrument package.

The SVOC samples were deployed at each sampling location early in the day, beginning on the roof, to maximize the sampling duration at each location. Following deployment of these samples, the continuous package was moved to each location for 30 minute sampling events. During these events, the VOC, carbonyl, and fungi samples were collected and field blanks were generated. The SVOC sampling was concluded only after a minimum of 2 hours had elapsed. Continuous sampling was conducted a second time at the rooftop location at the end of the day.

Calibration and Analysis

Continuous monitoring instrumentation

Table 2 lists the instrumentation contained in the continuous monitoring package. The table contains the parameter measured, manufacturer, and model number for each piece of equipment.

Table 2. Continuous Monitoring Instrumentation

Parameter	Manufacturer	Model Number
Carbon Dioxide	Li-Cor	LI-820
Ozone	2B Technologies	Model 202
Particulate Matter	TSI	AM510 SidePak
Temperature/RH	Vaisala	HMWY71 Humicap
Atmospheric Pressure	Vaisala	PTB 100
Sound Level	Quest Technologies	2100

Prior to the field sampling event, calibrations were performed on the equipment in the continuous sampling package as well as the pumps used to collect the integrated samples. Flows for all pumps were verified with blank media to be within ten percent of the true value using a calibrated flow meter. The carbon dioxide instrument was calibrated using certified gas standards. The calibrations of the temperature, relative humidity, sound level, and pressure instruments were checked by comparison to calibrated instruments. The ozone and PM_{10} measurements were made using the factory supplied calibration for each instrument. The ozone instrument was compared to two other calibrated ozone measurements at concentrations below 50 ppb and found to be acceptable. At concentrations above 50 ppb the calibration is based on extrapolation. All data from the continuous instrumentation package were collected at 1 Hz as voltage outputs using a data logger and converted using the calibration information to the appropriate parameter values.

Data are reported for each sampling location as average values over the measurement interval in each location. Measurement intervals were approximately 30 minutes for all indoor office locations and approximately 15 minutes on the roof. At each location, the sampling interval started when the package was deployed and stopped when the package was moved. The start and stop times were recorded in the field and verified using data from a motion sensor incorporated into the sampling package.

Fungal spore analysis

Fungal samples collected using Air-O-Cell cassettes were sent to EMSL Analytical Laboratory for analysis. Fungal analysis consisted of enumeration and identification of fungal spores present on the Air-O-Cell cassette using optical microscopy. Data were reported for both total fungal spores and for spores identified by type. A blank sample was included in the analysis batch for quality assurance purposes. No fungal spores were detected on the blank cartridge, so no blank correction was applied to the fungal data.

VOC analysis

1. Stainless steel canisters

Air sampling canisters were cleaned and evacuated in the laboratory prior to field use. The cleaning/evacuation process involved a series of pressurization/evacuation steps incorporating heat treatment (~ 75°C) and humidification. The final evacuation step evacuated each canister to ~20 millitorr. After sample collection the canisters were packaged and delivered to Battelle's laboratories in Columbus, OH. Upon receipt at the laboratory, the canister pressures were measured and recorded and the canisters were then filled to 30 psi absolute pressure (psia) with hydrocarbon-free, humidified air to facilitate analysis. Reported concentrations have been corrected by the dilution factor determined from the initial and final canister pressures. One field blank was generated by filling an evacuated canister with hydrocarbon-free, humidified air.

An Agilent 6890 gas chromatographic system equipped with a 5973 mass spectrometer (GC/MS) was used for the analysis of the VOCs present in the canister samples. The GC was connected to an Entech 7100A cryogenic preconcentration system with 7016C canister autosampler. Analysis generally followed the procedures as outlined in US EPA Compendium Method TO-15: http://www.epa.gov/ttnamti1/files/ambient/airtox/to-15r.pdf. Briefly, the volatile compounds in a sample volume of 200 mL were concentrated and injected onto an 100% polydimethylsiloxane fused silica capillary column, 60 m by 0.32 mm inner diameter (i.d.) (1 μm film thickness). Analytes were chromatographically resolved using helium carrier gas that was maintained at a constant flow rate of 1.2 mL/min. Optimal analytical results were achieved by temperature programming the GC oven from 35°C to 150°C at 6°C/min (5 minute initial hold) followed by temperature ramping to 220°C at 15°C/minute. The mass spectrometer was operated in the full scan mode so that all masses between 35 and 300 atomic mass units (amu) were scanned at a rate of 1 scan per 0.4 seconds. The VOCs were identified by comparison of their retention times and their ion abundance ratios to those of known standards. Quantification of the analytes was based upon instrument response to known concentrations from a dilute calibration gas containing the target VOCs (traceable to a certified gas standard). Individual VOC detection limits were approximately 0.2 parts per billion (ppb). Blank concentration levels were typically below the 0.2 ppb detection limit. No blank correction was applied to the data.

2. DNPH cartridges

Upon completion of the day's sampling activities, the DNPH cartridges were shipped to Battelle's laboratories in Columbus, OH. Upon receipt in the laboratory, the cartridges were refrigerated until they were extracted with 2 mL of acetonitrile into a 2 mL volumetric flask. An aliquot of the sample solution was then transferred to a 1 mL vial and analyzed as described below. The remaining solution was refrigerated and archived.

The acetonitrile extracts were analyzed by an Agilent Series 1100 high performance liquid chromatograph equipped with an ultraviolet detector (HPLC-UV). Analytical procedures generally followed those outlined in US EPA Compendium Method TO-11A: http://www.epa.gov/ttn/amtic/files/ambient/airtox/to-11ar.pdf. Briefly, the instrument was equipped with an autosampler and was operated at a fixed wavelength of 360 nm. Chromatographic separation of the carbonyl compounds was accomplished using two C-18 reversed phase columns (Supelcosil LC-18, 4.6 mm i.d. by 25 cm long) which were connected in series and maintained at room temperature. The solvent flow was 1.5 mL/minute, and the mobile phase was a 70/30 (volume/volume) mixture of acetonitrile/water. The analysis was carried out isocratically, with an injection volume of 20 µL and run time of 15 minutes. Cartridge blank levels ranged from less than 0.02 ug (not detected) for propionaldehyde to no more than 0.04 ug for formaldehyde and acetaldehyde. The results reported here have been blank-corrected. Estimated carbonyl limits of detection are approximately 1 µg/m^3, 0.5 to 1 ppb depending on the compound.

SVOC analysis

After assembly, the XAD-2 was spiked with the field recovery standards shown in Table 3.

Table 3. XAD-2 Field Recovery spikes

Field spike amount	Compound	Function
100 ng	d8-naphthalene	Retention efficiency of 1-2 ring compounds
100 ng	d10-anthracene	Retention efficiency of 3 ring compounds
100 ng	d10-fluoranthene	Retention efficiency of 4 ring compounds
100 ng	d12-benzo(a)pyrene	Retention efficiency of 5 ring compounds
100 ng	d12-indeno-(1,2,3-cd)pyrene	Retention efficiency of 6 ring compounds

The ends of each sampler cartridge were sealed with foil lined caps. The cartridge was placed in a polyethylene zip-seal bag, wrapped in bubble wrap and shipped to the field on ice. After use, each cartridge was recapped and wrapped as before and returned to the analysis lab. Cartridges were stored at -20°C until analysis.

For analysis, the two sections of PUF and the 5 g of XAD-2 of each sample were transferred to a 22 mL accelerated solvent extractor (ASE; Dionex) cell and spiked with the following surrogate recovery standards (SRSs). SRSs are added just prior to extraction; their recovery is an indication of method performance on a sample-by-sample basis and indicates general compound class recovery through extraction and concentration steps. Spike amounts are similar to the levels anticipated for analytes of that compound class in field samples. Table 4 presents the surrogate recovery spikes.

Table 4. Surrogage Recovery Standards

Lab SRS spike amount	Compound	Function
750 ng	d4- Butyl benzyl phthalate	SRS: method performance for phthalate esters
100 ng	13C6-phenanthrene	SRS: method performance for diverse neutral compounds
20 ng	BDE 126	SRS: method performance for BDEs 47, 99, 100
40 ng	13C12-BDE 209	SRS: method performance for BDE 209

The laboratory matrix spike sample was spiked with all analytes, in addition to the SRSs. The spike amounts of the analytes, by compound class, are indicated below. Laboratory matrix spikes are shown in Table 5.

Table 5. Laboratory Matrix Spikes

Lab matrix spike amount	Compounds
10 ug	All phthalate esters
150 ng	All PAHs
200 ng	All other neutral compounds (fragrances, pesticides, PCBs, etc)
50 ng	BDEs 47, 99, 100
100 ng	BDE 209

The ASE cells were extracted twice using dichloromethane (DCM) at 2000 psi and 100° C, using 5 minute extraction cycles. The extract was transferred with two 5 mL DCM rinses to a Kuderna-Danish evaporator tube and concentrated at 45° C to 1 mL. Then, 5 mL of methyl-t-butyl ether was added, and the extract was reconcentrated to 1 mL. A 100 uL aliquot of the extract was removed to a GC vial, and spiked with 100 ng of the internal standard (IS) bromobiphenyl. This fraction was analyzed for the phthalate esters using GC/MS in the multiple ion detection (MID) mode with electron impact ionization. The analyses were carried out using an Agilent 6890 GC interfaced to a 5973 MSD and an RTx-5ms capillary column (30 m, 0.25 mm if, 0.25 µm film thickness; Restek), with the GC oven temperature programmed from 50-100 C @ 8° C/min, and then from 100-300°C @ 10° C/min.

The remaining 900 uL extract was concentrated using a gentle stream of dry nitrogen to 0.1 mL, spiked with 5 ng of both bromobiphenyl and dibromobiphenyl and transferred to a GC vial. This fraction was analyzed first for the PAHs, PCBs, fragrances and other neutral compounds using conventional electron impact GC/MS/MID; the fraction was then reanalyzed using negative chemical ionization (NCI) GC/MS/MID for the selected brominated flame retardants (brominated diphenyl ethers, BDEs). The same instrument, GC column and temperature program as listed above was used for the EI GC/MS/MID analyses of the diverse neutral compounds. The BDEs were analyzed with the same instrument, albeit with a chemical ionization source, using a DB-5 GC column (15 m, 0.25 mm id, 0.10 µm film thickness; Agilent), with the GC oven temperature programmed from 100-200°C @ 10°C/min and then 200-300°C @ 30° C/min.

The same approach to quantification was used for all 3 GC/MS analyses. For each analysis, a series of calibration solutions was prepared that spanned the linear range of the detector and the expected analyte concentrations in the extracts. The field recovery standards and the compound class SRSs were also included in these calibration solutions at levels which would bracket concentrations expected for these compounds; the IS for each method was held at a constant level in each solution. The phthalate ester calibration curve consisted of a 0 level standard and 5 other solutions spanning the range of 0.1-50 µg/mL. The diverse neutrals calibration curve consisted of a 0 level standard and 7 solutions spanning the range of 1-900 ng/mL. The BDE calibration curve consisted of a 0 level standard and 5 solutions spanning the range of 2-1000 ng/mL. The samples were run in an interspersed order with the calibration solutions. At the conclusion of data acquisition, linear regression analysis was used to generate the calibration curve for each analyte. The curve was applied to detected quantities using the internal standard method of quantification for the phthalate ester and diverse neutral analyses; the external standard method of quantification was used for the BDE analyses because of an interference to the IS from an unknown brominated compound. Solution concentration values were determined using the GC/MS software; concentration values were transferred to an Excel spreadsheet for further data processing.

Detection limits for SVOC compounds in air were estimated using the minimum amount (mass) of a compound detectable in a sample. These minimum detectable masses were treated as sample analysis results and corrected for surrogate recovery in the same way sample results were adjusted. The minimum air volume sampled from the six SVOC samples was used to determine a detection limit in mass per volume of air sampled. Only one detection limit (the most conservative, based on the lowest volume of air collected) is reported for each compound.

Results and Discussion

Table 6 presents the sampling start and stop times for continuous measurements, SVOCs, carbonyls, and fungal sampling in each of the sampling locations. The collection time for each of the VOC samples is also shown. All times are in Mountain Daylight Time.

Table 6. Sampling Times

	Location					
Parameter	**Roof**	**CR**	**O1**	**O2**	**O3**	**O4**
Continuous Start Time	14:57	13:16	13:55	10:37	11:09	10:03
Continuous Stop Time	15:10	13:45	14:22	11:07	13:10	10:33
SVOC Start Time	08:39	09:30	09:22	09:39	09:48	10:00
SVOC Stop Time	14:57	13:46	14:22	14:41	14:37	14:29
Carbonyl Start Time	08:45	13:30	14:02	10:52	11:25	10:19
Carbonyl Stop Time	08:55	13:40	14:12	11:02	11:35	10:29
Fungi Start Time	09:00	13:18	13:56	10:40	11:13	10:07
Fungi Stop Time	09:10	13:28	14:06	10:50	11:23	10:17
VOC Collection Time	09:15	13:21	13:58	10:43	11:15	10:09

Continuous data

Data for the continuously monitored chemical and physical parameters (carbon dioxide, ozone, PM_{10}, temperature, humidity, sound level, and atmospheric pressure) were averaged over each measurement interval. Table 7 presents the average values for each of these parameters at each sampling location.

Table 7. Continuous Monitoring Results

	Location						**Acceptable Indoor Range**
Parameter	**Roof**	**CR**	**O1**	**O2**	**O3**	**O4**	
CO_2 (ppm)	402	619	697	645	585	694	<1052[a]
Ozone (ppb)	157	14.2	17.7	19.5	17.1	26.8	75[b]
PM_{10} ($\mu g/m^3$)	33.9	20.6	22.3	18.6	18.6	13.8	<50[c]
Temperature (°C)	31.2	26.1	26.8	23.5	25.6	22.9	20-23[d] 24-27°C[e]
Relative Humidity (%)	19	32	32	43	38	35	30-60%
Sound Level (dBa)	61	65	62	61	62	62	60-70[f]
Atm. Pressure (mbar)	850	851	851	854	854	852	NA

[a] ASHRAE 62.1-2007 standard of outdoor CO_2 plus 650 ppm.

[b] 8-hour National Ambient Air Quality Standard (NAAQS) for ambient ozone.

[c] LEED new construction standard.

[d] Seppänen and Fisk (2006) optimal work performance range.

[e] ASHRAE Standard 55-2004 acceptable temperature range for 0.5 Clo at measured humidity.
[f] range of normal conversation.

Temperature and relative humidity

The day of the field measurement campaign was relatively warm with outdoor temperatures near 90° F (32°C). Temperatures at the five indoor measurement locations varied from 22.9°C to 26.8°C (73.3 to 80.2°F). Relative humidity was 19% outdoors and ranged from 35 to 43% inside. As expected, the temperature steadily rose over the course of the day. The highest recorded indoor air temperature was found in Office 1 in the early afternoon. Each recorded indoor temperature/relative humidity combination falls within the acceptable ranges given in ASHRAE Standard 55-2004 (Thermal Environmental Conditions for Human Occupancy) (ASHRAE, 2004). The lower temperature environments (Office 2 and Office 4) fall within the occupant satisfaction range for a clothing insulation level of 1.0 (equivalent to trousers, long sleeve shirt, and sweater). The other environments fall within the occupant satisfaction range for a clothing insulation level of 0.5 (equivalent to trousers and a short sleeve shirt).

Even though the temperature/relative humidity combinations are acceptable under ASHRAE 55, the temperatures in the Copy Room, Office 1, and Office 3 exceed the 95th percentile (24.9°C) of the temperature measurements collected during the BASE study between 8:00 am and 5:00 pm (EPA, 2006) indicating that such temperatures are on the upper end of those typically encountered in office environments. In addition, Seppänen and Fisk (2006) found that optimal work performance occurs at temperatures between 20°C and 23°C, with statistically significant decreases in work performance at temperatures greater than 23°C. Only one of the five indoor locations had a temperature between 20°C and 23°C, the remainder were higher.

Carbon dioxide

The carbon dioxide measurements show that indoor levels of carbon dioxide were higher than outdoor levels, which is to be expected, given that sampling occurred on a weekday when the building was occupied. The levels measured in Office 1 and Office 4 were the highest, and those areas had the greatest density of people in the area while the measurements were being conducted. Measurements in Office 3 were conducted over lunch when the occupant density was low. This is reflected in the lower carbon dioxide measurements from Office 3 compared to the other indoor locations. Carbon dioxide levels in the Copy Room, Office 2 and Office 3 were between the 50th (564 ppm) and 75th (684 ppm) percentile of the measurements conducted during the BASE study between 8:00 am and 5:00 pm. Measurements from Office 1 and Office 4 were between the 75th and 95th (920 ppm) percentiles of the same subset of the BASE data (EPA, 2006).

All indoor carbon dioxide measurements were well below the OSHA and ACGIH indoor standards of 5000 ppm. The indoor carbon dioxide readings were also less than the ASHRAE 62.1-2007 standard which specifies that indoor carbon dioxide concentrations should be no more than 650 ppm greater than outdoor carbon dioxide levels.

Ozone

Ozone is one of six criteria air pollutants whose outdoor concentrations are regulated by the US EPA (by way of National Ambient Air Quality Standards, NAAQS) because of its potential harm to human health and to the environment (http://www.epa.gov/air/urbanair/). In general, ozone encountered indoors is present because of transport from outdoors and indoor ozone concentrations are generally lower than outdoor levels (Weschler, 2000; Weschler, 2006). Nonetheless, minimizing indoor ozone concentrations is important given that ozone chemistry (reactions with VOCs and SVOCs, for instance) can generate sensory (eye and airway) irritants (Wolkoff et al., 2006).

On the day of the sampling event, outdoor ozone concentrations in Denver were very high. The outdoor concentration measured on the roof was 157 ppb. Indoor ozone concentrations were significantly lower, falling between 14 and 27 ppb. Indoor ozone concentrations are expected to be lower than outdoor concentrations due to losses during transport indoors. The indoor-to-outdoor (I:O) ratio was in the range of 0.09 to 0.17 for the sampling locations. These I:O ozone ratios are lower than the range of 0.22-0.9 for offices reported by Weschler (2000). I:O ratios of ozone have been found to be <0.10 for residences with central air conditioning (Weschler, 2006). The lower I:O ratios measured in this study may be due to more efficient removal of ozone in this building's HVAC system than in other buildings' HVAC systems. Ozone is very reactive and is often removed to a large degree by a HVAC system and other indoor surfaces. Ozone measurements were not among those performed during the BASE study so no comparison to BASE data can be performed.

Particulate matter

Similar to ozone, outdoor particulate matter (PM) is a criteria pollutant and ambient PM concentrations governed by the NAAQS (http://www.epa.gov/air/particlepollution/). Exposure to particle pollution also occurs indoors. In this study, PM concentrations measured in the indoor spaces were generally low. Concentrations increased slightly over the course of the day, but this increase may be due to instrument drift observed in the measurements when particulate concentrations are low. Indoor particulate concentrations were lower than those measured in outdoor air (13.8-22.3 $\mu g/m^3$ inside compared to 33.1 $\mu g/m^3$ outside). All of the measured concentrations were well below the LEED new construction standard of 50 $\mu g/m^3$ (LEED, 2005) but were elevated (between the 75th and 95th percentiles) compared to office buildings monitored in the BASE study. Outdoor particulate may be transported indoors through the HVAC system, although losses are expected. Resuspension may also cause elevated particulate matter levels (Ferro et al., 2004). In general, particulate matter concentrations are low and are not above levels of concern.

Sound levels

The sound levels measured at the various sampling locations showed little variability with all locations at either 61 or 62 dBa except for the Copy Room which had a sound level of 65 dBa. These sound levels are likely to be slightly higher than actual ambient sound levels due to the operation of the monitoring equipment during the sound level measurements. This slight positive bias may account for the fact that all of the sound level measurements in the EPA Region VIII Headquarters building were between the 75th (59 dBa) and 95th (68 dBa) percentiles of the BASE data collected between 8:00 am and 5:00 pm (EPA, 2006). For comparison, a whisper quiet library is typically 30 dBa, while normal conversation at three to five feet is in the range of 60 to 70 dBa. Nonetheless, excessive indoor noise is not a problem at this office building.

Fungal spores

Microbiological contamination in occupied buildings has been reported to cause respiratory symptoms and other negative health outcomes associated with Sick Building Syndrome (SBS) (see Wu et al., 2004 and references therein). Thus sampling for airborne fungi was undertaken as part of this IEQ survey. Data for the fungal spore traps are presented in Table 8. The table includes the total fungi count in number per cubic meter, as well as the raw counts of individual types of spores found on each spore trap. In addition to the types listed, 12 types of spores (Bipolaris++, Chaetomium, Curvularia, Epicoccum, Fusarium, Ganoderma, Rust, Scopulariopsis, Stachybotrys, Torula, Ulocladium, and Zygomycetes) were not detected in any of the samples. Levels of non-fungal material (skin fragments, fibrous particulate and background) were reported on a scale of 1 (low loading) to 5 (high loading). Background levels of 5 may interfere with spore identification and enumeration. All samples collected had background levels of 3 or lower.

Table 8. Concentrations of Fungal Spores

Parameter	Location						Acceptable Indoor Range
	Roof	CR	O1	O2	O3	O4	
Total Spores (#/m^3)	3510	84	84	63	42	42	<1000[a]
Total Fungi (raw count)	167	4	4	3	2	2	
Alternaria (raw count)	3	2	0	0	0	0	
Ascospores (raw count)	65	0	0	0	0	0	
Aspergillus/Penicillium (raw count)	10	0	1	2	0	0	
Basidiospores	37	0	1	0	0	0	
Cladosporium	34	1	1	0	1	1	
Myxomycete	16	1	1	1	1	1	

Pithomyces	1	0	0	0	0	0	
Peronospora	1	0	0	0	0	0	

[a] Typical level of concern for fungi in indoor air (Wu et al., 2004)

Fungi measurements in the indoor spaces were very low. All of the sampling locations had fungi loading below the 50th percentile of the BASE data (121 spores/m^3). The indoor fungi concentrations were significantly lower than the outdoor concentration indicating that fungi in the outdoor air may be removed by the HVAC system or by deposition to surfaces. A typical threshold level of concern for fungi in indoor air is 1000 spores/m^3 (Wu et al., 2004). Daisey et al. (2003) performed fungi measurements in schools and found (1) at concentrations less than 700 spores/m^3, occupants did not voice complaints related to fungi; and (2) outdoor fungi concentrations were typically higher than those measured indoors. The concentrations of fungi measured in this office building are lower than in most other office buildings and are below typical levels of concern.

VOC data

VOCs are organic compounds (compounds containing carbon and hydrogen) that have vapor pressures between 0.1 to 380 mm Hg at 25° C (Spicer et al., 2002). A total of 67 VOCs and very volatile organic compounds (VVOCs, those with VPs > 380 mm Hg at 25°C; Spicer et al., 2002) were measured during this study – 64 using stainless steel canisters and 3 by way of air sampling onto DNPH cartridges. (For the purpose of this study, the VVOCs and VOCs will be referred to together simply as VOCs.) Forty five of these 68 VOCs are classified by the US EPA under the US Clean Air Act Amendments of 1990 to be among the 187 hazardous air pollutants (HAPs), defined as "those pollutants that are known or suspected to cause cancer or other serious health effects, such as reproductive effects or birth defects, or adverse environmental effects" (http://www.epa.gov/ttn/atw/allabout.html). Given the prevalence and variety of indoor sources of VOCs, for instance, from adhesives, paints, consumer products, and furnishings, indoor concentrations of these compounds can in many cases be higher than outdoor concentrations.

Although most VOC levels found indoors are well below levels shown to demonstrate measureable (immediate or acute) health impacts (Jones, 1999), minimizing exposure to these compounds – given their toxicity and potential to cause cancer – is of great importance to promoting the health of building occupants.

Of the 67 VOCs for which analysis was performed in the present work, 40 were monitored as part of the BASE study. A total of 25 of the 67 compounds measured in this study were detected in at least one sample, and concentrations of these 25 compounds for these VOCs are shown in Tables 9 and 10. Shown as well in these tables are corresponding BASE data and other typical indoor concentrations measured in other studies and applicable standards. In these and future tables, "benchmark" indoor air concentrations against which concentrations measured in this study are compared may be data from indoor air in residences, retail commercial buildings, office environments, or miscellaneous workplace environments.

Table 9. VOC Concentrations Compared to BASE Data and Other Benchmarks ($\mu g/m^3$)

Compound	Location							BASE Data[a]			Other Benchmark (reference)
	DL	Roof	CR	O1	O2	O3	O4	5th	50th	95th	
Acetone	0.47	30	61	62	46	46	79	9.9	30	110	
Acrolein	0.46	< DL	2.3	1.9	2.0	< DL	< DL	[b]			< DL[c], 0.59[d], 5.54[e] (1)
Benzene	0.64	1.5	1.7	1.6	2.3	2.4	2.1	1.1	3.6	9.1	
2-Butanone	0.59	6.1	8.1	6.8	6.9	8.0	11	0.81	2.6	7.8	
Carbon disulfide	0.62	< DL	0.65	0.68	0.72	0.68	0.65	≤ LOQ[f]	≤ LOQ	6.4	
Chloromethane	0.41	1.3	1.3	1.4	1.2	1.3	1.4	1.8	2.5	4.3	
Cyclohexane	0.69	< DL	0.93	0.86	1.1	1.2	0.96	[b]			< 0.054[d], 26.8[g] (2)
Dichlorodifluoromethane	0.99	2.6	2.7	2.6	2.6	2.7	2.6	≤ LOQ	6.8	36	
Ethanol	0.38	34	204	217	133	168	158	≤ LOQ	79	260	
Ethylbenzene	0.87	< DL	< DL	< DL	1.0	1.0	1.0	0.43	1.5	6.2	
Heptane	0.82	< DL	1.0	0.94	1.4	1.5	1.4	[b]			0.9[d], 3.8[h] (3)
Hexane	0.70	2.2	3.1	2.5	3.4	3.7	2.9	≤ LOQ	2.5	12	
Isoprene	0.56	< DL	2.3	4.0	0.75	1.6	3.1	[b]			[i]
Isopropyl alcohol	0.49	< DL	15	22	21	21	31	[b]			6.2[d], 676[h] (3)
Methylene chloride	0.69	< DL	0.90	< DL	0.83	0.73	0.83	≤ LOQ	2.9	16	
Propene	0.34	7.1	8.3	6.6	9.5	10	8.6	[b]			[i]
Toluene	0.75	4.1	13	7.3	9.4	9.8	11	2.7	8.7	39	
Trichlorofluoromethane	1.1	1.3	1.4	1.4	1.5	1.4	1.5	≤ LOQ	3.9	51	
1,2,4-Trimethylbenzene	0.98	< DL	< DL	< DL	< DL	< DL	1.03	0.61	1.9	12	
Vinyl acetate	0.70	< DL	< DL	1.2	< DL	< DL	< DL	[b]			[i]
m- & p-Xylenes	0.87	1.5	1.9	1.8	2.6	2.8	2.6	1.3	5.1	24	
o-Xylene	0.87	< DL	< DL	< DL	1.0	1.0	1.0	0.59	2.1	8.2	

[a] BASE data (percentiles) are available at http://www.epa.gov/iaq/base/voc_master_list.html (EPA, 2006).

[b] No BASE data for these compounds.

[c] 5th, [d] 50th, and [e] 95th percentiles.

[f] Limit of quantification for BASE data.

[g] Maximum.

[h] 90th percentile.

[i] Typical concentrations encountered indoors not available.

(1) Liu et al., 2006; data from Relationships of Indoor, Outdoor, and Personal air (RIOPA) study of residential air.
(2) Jia et al., 2008; data from residences.
(3) Eklund et al., 2008; data from commercial retail buildings.

Of the compounds listed in Table 9, only 2-butanone (methyl ethyl ketone) was measured at a concentration greater than the 95th percentile of the BASE data, or similar upper limit from another benchmark study. 2-butanone is used as a solvent in resins, adhesives, and vinyl films. It is also present in some cleaning fluids and can be used as a printing catalyst. Levels of 2-butanone were measured above the 95th percentile concentration in three locations (Copy Room, Office 3, and Office 4). The outdoor concentration of 2-butanone was elevated, but was lower than all of the 2-butanone concentrations measured at the indoor locations. Higher indoor levels of 2-butanone may be the result of emissions from resins or adhesives in consumer products or may come from cleaning agents used in the indoor spaces. Longer term measurement, including observation of building occupant activity would be needed to determine if this was a one-time or sustained concentration.

Of the remaining compounds in Table 6 for which benchmarks are available, acetone, acrolein, cyclohexane, ethanol, heptane, hexane, isopropyl alcohol, toluene, and m/p-xylenes were detected at levels greater than the 50th percentile concentrations reported from the BASE study. Ethanol and acetone are human bioeffluents (Fenske & Paulson, 1999) so the presence of these compounds is expected in areas which are populated. Isopropyl alcohol is found in many surface and packaged hand cleaners, thus its presence at higher indoor concentrations than outdoor concentrations in office environments is not surprising. Acrolein is a toxic HAP and a severe lung irritant which may be formed indoors by reaction of VOCs offgassing from building materials, adhesives, and carpets (Seaman et al., 2007, and references therein). Hexane, toluene, and m&p-xylenes are also HAPs and are indicative of the penetration of automobile exhaust into the building envelope, and may also be due to emissions from indoor sources such as solvents, cleaners, and office equipment (Destaillats et al., 2008). This is especially the case with the higher level of toluene in the Copy Room; toluene is emitted from photocopiers (Destaillats et al., 2008 and references therein).

Table 10 presents data for the three VOCs measured using the DNPH cartridges. Data have been blank corrected; blank corrections did not exceed the equivalent concentration of 1.85 $\mu g/m^3$. Detection limits for all three carbonyls are conservatively estimated to be ~0.5 $\mu g/m^3$.

Table 10. Concentrations of Selected Carbonyls Compared to BASE Data and Other Benchmarks ($\mu g/m^3$)

Compound	Location						BASE Data[a]			LEED NC[b]	RIOPA[c]		
	Roof	CR	O1	O2	O3	O4	5th	50th	95th		5th	50th	95th
Acetaldehyde	4.3	11.3	10.8	8.9	9.2	8.6	2.6	7.2	15	[d]	7.53	18.6	50.2
Formaldehyde	5.3	20.4	20.9	21.3	20.6	26.1	4.4	15	32	61.4	12.5	20.1	32.5
Propionaldehyde	1.5	2.3	2.2	1.9	2.0	1.8	[e]			[d]	0.23	1.74	3.65

[a] BASE data (given as percentiles) are available at http://www.epa.gov/iaq/base/voc_master_list.html (EPA, 2006).

[b] LEED New Construction standard.

[c] Percentiles from Relationships of Indoor, Outdoor, and Personal Air (RIOPA) study of residential air; see Liu et al., 2006.

[d] No LEED standards for these compounds.

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[e] No BASE data for this compound.

The concentrations of formaldehyde and acetaldehyde measured in the outdoor sample are typical of those found in urban atmospheres (Finlayson-Pitts & Pitts, 2000). It is typical to see elevated indoor concentrations of the aldehydes in Table 10 due to the presence of indoor sources. Indoor concentrations for these compounds are between the 50th and 95th percentiles of the BASE or RIOPA (Relationships of Indoor, Outdoor, and Personal Air; Liu et al., 2006) data.
Formaldehyde is the most ubiquitous carbonyl found in the gas phase, and is a carcinogenic HAP (Liu et al., 2006). Indoor concentrations of formaldehyde throughout the EPA Region VIII office building were below the LEED new construction formaldehyde standard of 50 ppb (61.4 $\mu g/m^3$) (LEED, 2005). Concentrations of indoor formaldehyde are also well below the American Conference of Governmental & Industrial Hygienists (ACGIH) Threshold Limit Value (TLV) for occupational exposures of 300 ppb (368 $\mu g/m^3$), a ceiling value which should not be exceeded at any time. The formaldehyde concentrations are somewhat elevated compared to measurements performed in other office buildings. This may be due to elevated outdoor ozone levels on the sampling day, as outdoor ozone penetrating indoors causes chemical reactions in which formaldehyde is formed, or may be due to the presence of indoor sources of formaldehyde, such as adhesives, insulation, and composite wood materials in the building. While the levels are somewhat elevated compared to concentrations measured in other office buildings and compared to outdoor concentrations, they do not reach levels of concern with respect to the health of the building occupants.

Forty-two of the 67 VOCs measured in this study were not detected in any of the six samples. Table 11 lists these compounds, estimated detection limits in $\mu g/m^3$ (based on ~0.2 ppb DL for each compound), and benchmark data for these compounds. Of note is that ethyl acetate was detected in 100% of the BASE samples but was not detected in any of the samples collected during this study. Ethyl acetate is a solvent found in consumer products.

For the 67 VOCs measured in this study, concentrations are low and similar to those found in other studies of indoor air in residences and office environments. Such indicates that, for the 67 VOCs measured, acute health hazards caused by high VOC concentrations are not a concern in this building. However, the presence of hazardous air pollutants at any concentration in indoor air represents a non-negligible long-term health concern for building occupants. At minimum, reducing indoor levels of HAPs to ambient outdoor levels either by source control or by filtration through activated carbon is a goal to be considered.

Table 11. VOCs Not Detected in Any Samples, Compared to BASE and Other Benchmark Data ($\mu g/m^3$)

Compound	DL	BASE Data[a]			Benchmark (reference)
		5th	50th	95th	
Benzyl chloride	1.0	[b]			< 1[c] (1)
Bromodichloromethane	1.3	[b]			< 0.6[d] – 5[e]; < 5[f] (1)
Bromoform (Tribromomethane)	2.1	[b]			< 1[c] (1)
1,3-Butadiene	0.44	≤ LOQ[g]	≤ LOQ	≤ LOQ	
Carbon tetrachloride	1.3	≤ LOQ	≤ LOQ	0.74	
Chlorobenzene	0.92	≤ LOQ	≤ LOQ	0.26	
Chloroform (Trichloromethane)	0.98	≤ LOQ	≤ LOQ	1.3	
Dibromochloromethane	1.7	[b]			< 0.6[c] (1)
1,2-Dibromoethane	1.5	≤ LOQ	≤ LOQ	≤ LOQ	
1,2-Dichlorobenzene	1.2	≤ LOQ	≤ LOQ	≤ LOQ	
1,3-Dichlorobenzene	1.2	[b]			< 1.6[d] – 5[e]; < 2[f] (1)
1,4-Dichlorobenzene	1.2	≤ LOQ	0.54	13	
1,1-Dichloroethane	0.81	LOQ	≤ LOQ	≤ LOQ	
1,2-Dichloroethane	0.81	≤ LOQ	≤ LOQ	≤ LOQ	
1,1-Dichloroethene	0.79	≤ LOQ	≤ LOQ	≤ LOQ	
cis-1,2-Dichloroethene	0.79	[b]			< 1[c] (1)
trans-1,2-Dichloroethene	0.79	[b]			< 4[c] (1)
1,2-Dichloropropane	0.92	[b]			< 1[c] (1)
cis-1,3-Dichloropropene	0.91	≤ LOQ	≤ LOQ	≤ LOQ	
trans-1,3-Dichloropropene	0.91	≤ LOQ	≤ LOQ	≤ LOQ	
1,2-dichlorotetrafluoroethane	1.4	[b]			< 1.6[c] (1)
1,4-Dioxane	0.72	[b]			[h]
Ethyl acetate	0.72	0.34	2.0	7.5	
Ethyl chloride (Chloroethane)	0.53	≤ LOQ	≤ LOQ	≤ LOQ	
Hexachloro-1,3-butadiene	2.1	[b]			< 2[c] (1)
4-Ethyl toluene	0.98	[b]			2.26[f], 61.6[e] (2)
2-Hexanone	0.82	[b]			[h]
Methyl bromide (Bromomethane)	0.78	≤ LOQ	≤ LOQ	0.12	
Methyl isobutyl ketone	0.82	≤ LOQ	1.0	7.2	
Methyl methacrylate	0.82	[b]			< 0.17[f], 26.8[e] (2)
Methyl tert-butyl ether	0.72	≤ LOQ	≤ LOQ	14	
Styrene	0.85	0.091	0.91	3	
1,1,2,2-Tetrachloroethane	1.4	[b]			< 5[c] (1)
Tetrachloroethene	1.4	0.3	1.5	18	
Tetrahydrofuran	0.59	[b]			< 0.17[f], 244[e] (2)
1,2,4-Trichlorobenzene	1.5	≤ LOQ	≤ LOQ	≤ LOQ	
1,1,1-Trichloroethane	1.1	0.97	3.1	21	
1,1,2-Trichloroethane	1.1	[b]			< 1[c] (1)
Trichloroethene	1.1	[b]			< 0.6[d] – 13[e]; < 2.8[f] (1)
1,1,2-Trichloro-1,2,2-Trifluoroethane	1.5	[b]			0.5[f], 7[e] (3)
1,3,5-Trimethylbenzene	0.98	≤ LOQ	0.54	3.9	
Vinyl chloride (Chloroethene)	0.51	≤ LOQ	≤ LOQ	≤ LOQ	

[a] BASE data (percentiles) are available at http://www.epa.gov/iaq/base/voc_master_list.html (EPA, 2006).

[b] No BASE data for these compounds. [c] No detects above DL. [d] Minimum, [e] maximum, [f] median.

[g] Limit of quantification for BASE data. [h] Typical concentrations encountered indoors not available.
(1) New York State Department of Health 1997 survey of residential indoor air. Available at: http://www.health.state.ny.us/environmental/investigations/soil_gas/svi_guidance/
(2) Jia et al., 2008; data from residences.
(3) Dawson and McAlary, 2009; data from residences.

SVOC data

SVOCs are organic compounds that have vapor pressures generally between 10^{-7} and 0.1 mm Hg at 25° C (Spicer et al., 2002). Few measurements of the large suite of SVOCs measured in this study have been made in office environments. For instance, of the 43 SVOCs measured in this study, only limonene and naphthalene were measured in the BASE study. Also, few single studies (with the exception of Rudel et al., 2003) have measured as many different classes of SVOCs during a single study. Many of the SVOCs measured here are considered to be among those known as endocrine disrupting compounds (EDCs) whose potential health effects have recently become the subject of intense scientific investigation (see Rudel et al., 2003, and references therein). In general, minimizing concentrations of such SVOCs in the workplace is becoming acknowledged as important for maintaining the long-term health of building occupants.

Tables 12, 13, and 14 present SVOC concentrations measured in this study, in the BASE study, as well as benchmark data from other studies. Table 12 presents data for the phthalate esters and BDEs; PAH concentrations are given in Table 13; and indoor air concentrations for a variety of different SVOCs such as pesticides, those found in fragranced consumer products, and phosphate flame retardants are shown in Table 14.

Table 12. Phthalate and BDE Concentrations Compared to Benchmark Data (ng/m^3)

Compound	DL	Location						Benchmark (reference)
		Roof	CR	O1	O2	O3	O4	
Diethyl phthalate (DEP)	10	50	270	540	240	140	270	130[a] - 4300[b]; 590[c] (1) 353[c] - 5481[b] (2)
Dibutyl phthalate (DBP)	10	2240	170	150	180	190	90	52[a]-1100[b]; 220[c] (1) 1083[c] - 13305[b] (2)
Butyl benzyl phthalate (BBP)	10	< DL	70	< DL	20	10	10	< 31[a] - 480[b]; < 31[c] (1) 18[c] - 575[b] (2)
Di-2-ethyl hexyl phthalate (DEHP)	10	10	170	50	50	50	30	< 59[a] - 1000[b]; 77[c] (1) 156[c] - 2253[b] (2)
BDE 47	0.01	< DL	0.01	< DL	0.22	0.08	0.01	0.058[a] - 7.14[b]; 0.690[c] (3) <0.062[a] - 2.37[b]; 0.145[d] (4)
BDE 100	0.01	< DL	< DL	< DL	0.03	< DL	0.07	0.004[a] - 1.45[b]; 0.063[c] (3) <0.010[a] - 0.156[b]; 0.012[d] (4)
BDE 99	0.03	< DL	< DL	< DL	0.07	< DL	0.28	0.009[a] - 6.51[b]; 0.173[c] (3) <0.049[a] - 0.553[b]; 0.060[d] (4)
BDE 209	0.78	< DL	< DL	< DL	< DL	< DL	< DL	<0.048[a] - 0.651[b]; 0.094[d] (4) 0.058[a] - 7.14[b]; 0.690[c] (3)

[a]Minimum; [b]Maximum; [c]Median; [d]Geometric mean
(1) Rudel et al., 2003; data from residences

(2) Fromme et al., 2004; data from kindergartens and residences
(3) Harrad et al., 2004; data from workplace environments
(4) Allen et al., 2007; data from the main living area in residences

Phthalate esters are plasticizers used in the production of soft plastics such as softened polyvinyl chloride (PVC); other uses for phthalates are for dielectrics in electronics components, emulsifiers in personal care products, and as additives in glues, paints, and coatings (Fromme et al., 2004). Furthermore, as plasticizers, phthalates are only loosely bound in the polymer matrix; thus they slowly offgas into the environment over the lifetime of a plasticizer-containing product (evidence of which is the plastic becoming brittle over time). Phthalate esters are among compounds considered to be EDCs.

Airborne phthalate concentrations in residential environments have been reported previously; those in the present work may represent the first reported for office environments (see Table 12). Indoor air concentrations are available from Rudel et al. (2003) and Fromme et al. (2004), and are summarized in Weschler and Nazaroff (2008). Comparison to previous results indicates that phthalate concentrations in the various office locations in the EPA Region VIII building are in general on the lower end of the ranges reported for other indoor environments. This may indicate that the selection of building materials to meet LEED standards has resulted in smaller amounts of plasticizers being introduced into the built environment. In only three instances were phthalates found at concentrations above a benchmark study's medians, and in two such instances, the exceedances were in the copy room: butyl benzyl phthalate (BBP) at 70 ng/m^3, and di(2-ethylhexyl)phthalate (DEHP) at 170 ng/m^3. Offgassing of phthalates from copy equipment is a potential source for these elevated concentrations (see, for instance, Destaillats et al., 2008). Minimizing DEHP in the built environment – for instance, in PVC flooring materials – is also important given that it may hydrolyze under basic conditions to form 2-ethyl-1-hexanol, which is an odor nuisance and potentially one of the many causes of SBS (Sakai et al., 2009). It is unknown at the present time what caused the elevated level of dibutyl phthalate in the outdoor air.

The BDEs are typically used as flame retardants in office furniture such as polyurethane foam cushions and polymer enclosures for personal computers. The Penta BDE mixture, one of the most popular commercially available formulations for treatment of polyurethane foam, is composed primarily of tetra- to hexa-brominated congeners such as BDE 47 (2,2',4,4'-tetrabromodiphenyl ether), BDE 99 (2,2',4,4',5-pentabromodiphenyl ether), and BDE 100 (2,2',4,4',6-pentabromodiphenyl ether), and is primarily BDE 47 (~40%) and BDE 99 (~46%) (Allen et al., 2007). OctaBDE and DecaBDE products are mainly used in electronics; DecaBDE is composed wholly of the fully brominated congener, BDE 209. Studies in animals have shown that BDEs are endocrine disrupters, and very recently studies have shown that exposure to BDEs leads to adverse health effects in humans such as hormone problems and low birth weights (Stapleton et al., 2009, and references therein).

These compounds were detected only at low levels in the indoor air samples, and in many instances concentrations were not above the relatively modest detection limits that can be achieved by only sampling several cubic meters of air (See Table 12). In general, the

BDEs are found at low concentrations in air primarily because they preferentially partition to surfaces and dust, rather than remain airborne. Weschler and Nazaroff (2008) have reviewed and presented summaries of BDE indoor air measurements, which have only been performed in the past decade. In two instances, the concentrations of BDE 47 (in Office 2) and BDE 99 (in Office 4) at the EPA Region VIII building exceeded the median concentration of BDEs in benchmark studies (Harrad et al., 2004 and Allen et al., 2007). Such concentrations could be indicative of the presence of office equipment treated with a BDE-containing flame retardant. BDE 209 was not detected in this study.

Table 13. PAH Concentrations Compared to BASE and Other Benchmark Data (ng/m^3)

Compound	DL	Location						Benchmark Data (reference)
		Roof	CR	O1	O2	O3	O4	
Naphthalene	0.03	147	301	252	338	271	348	≤ LOQ[a], 730[b], 2600[c] (1)
Biphenyl	0.07	14	29	25	25	23	24	[d]
Acenaphthylene	0.07	1.5	1.9	0.34	1.3	1.7	1.0	[d]
Acenaphthene	0.07	23	21	17	20	22	18	[d]
Fluorene	0.07	30	27	27	24	23	22	[d]
Phenanthrene	0.04	81	36	27	26	34	25	13[e] – 330[f]; 33[g] (2)
Anthracene	0.04	0.60	0.32	0.28	0.78	1.2	< DL	< 1[e] - 3.7[e]; < 1[h] (3)
Fluoranthene	0.04	19	8.3	0.91	2.4	5.0	0.73	[d]
Pyrene	0.04	7.9	7.3	0.71	2.1	3.8	0.38	< 1[e] - 3.4[f]; < 1[h] (3)
Benzo(a)anthracene	0.05	< DL	4.8	< DL	0.32	1.5	< DL	[d]
Chrysene	0.05	0.35	4.1	< DL	0.21	1.4	< DL	[d]
Benzo(b)fluoranthene	0.09	< DL	4.5	< DL	< DL	2.1	< DL	[d]
Benzo(k)fluoranthene	0.09	< DL	2.5	< DL	0.10	1.6	< DL	[d]
Benzo(e)pyrene	0.09	< DL	3.8	< DL	< DL	2.1	< DL	[d]
Benzo(a)pyrene	0.09	0.85	3.8	< DL	0.35	1.6	< DL	0.0055[e] – 0.23[f]; 0.055[g] (2)
Dibenzo (a,h)anthracene	0.08	< DL	0.54	< DL	< DL	0.21	< DL	[d]
Indeno(1,2,3-cd)pyrene	0.08	< DL	3.1	< DL	0.14	1.3	< DL	[d]
Benzo(ghi)pyrelene	0.08	< DL	3.7	< DL	0.11	2.3	< DL	[d]
ΣPAH[i] (incl napthalene)	NA	325	463	351	441	399	439	22[e] – 350[f] (2)
ΣPAH[i] (w/o napthalene)	NA	178	162	99	103	128	91	2[e] – 147[f]; 30[h] (4)

[a,b,c] BASE 5th, 50th (median), and 95th percentile data, respectively.

[d] Data for all individual PAHs not provided here; they are available elsewhere, i.e. references (2) and (4) below.

[e] Minimum, [f] maximum, [g] geometric mean, [h] median.

[i] 1/2 DL substituted for non-detects to calculate ΣPAH; thus this sum is an upper bound.

(1) BASE data are available at http://www.epa.gov/iaq/base/voc_master_list.html (EPA, 2006).
(2) Naumova et al., 2002; data from residences in Elizabeth, NJ.
(3) Rudel et al., 2003; data from residences.
(4) Li et al., 2005; data from Chicago residences.

Concentrations of polycylic aromatic hydrocarbons (PAHs) are given in Table 13. PAHs are byproducts of incomplete combustion of all variety of organic matter, including gasoline, diesel fuel, coal, and wood. Indoor sources relevant to modern office environments include transport from outdoors through open windows or the building ventilation system, boiler/heating operations, and potentially from the resuspension of particles generated from office equipment (Naumova et al., 2002; Ren et al., 2006). Many of the PAHs are known, probable, or possible human carcinogens (Li et al., 2005).

PAHs in Table 12 are given in order of decreasing volatility. As volatility decreases, airborne concentrations should decrease, and the indoor PAH concentrations measured follow this generate trend. Naphthalene concentrations are the highest of all the PAHs, consistent with its high volatility. In addition, naphthalene concentrations are higher indoors than outdoors, indicating an indoor source for this compound. Considering the identity of a potential indoor source for naphthalene leads to discussion of perhaps the most striking feature of the PAH data in Table 12: the elevated concentration of PAHs found in the Copy Room. For instance, in the Copy Room, total PAH concentrations (ΣPAH), with and without naphthalene, and of pyrene and benzo[a]pyrene, are higher than the maxima measured in benchmark studies. Furthermore, the concentration of benzo[a]pyrene in the Copy Room is an order of magnitude higher than the maximum concentration observed in Elizabeth, NJ, residences by Naumova et al. (2002), and is similar to the maximum concentration found in Chicago homes by Li et al. (2005). Emissions from copy room equipment may be responsible for the elevated PAHs concentrations (Ren et al., 2006); however, no study has been performed to quantify PAH emissions from office equipment (Destaillats et al., 2008).

Table 14. SVOC Concentrations Compared to BASE and Other Benchmark Data (ng/m^3)

Compound	DL	Location						Benchmark Data (reference)
		Roof	CR	O1	O2	O3	O4	
Pesticides								
cis-permethrin	0.08	0.43	< DL	< DL	< DL	< DL	< DL	< 1[a] - 3.7[b]; < 1[c] (1)
trans-permethrin	0.08	0.55	0.08	< DL	0.08	< DL	0.08	< 1[a] - 5.4[b]; < 1[c] (1)
Sumithrin	0.08	< DL	< DL	< DL	< DL	< DL	< DL	NA[d]
Fragrance Compounds								
Limonene	0.13	42	2323	2086	2774	2598	2155	1100[e], 7100[f], 44000[g] (2)
Carvone	1.3	5.0	78	69	74	76	81	[h]
cis-limonene oxide	0.65	41	230	222	241	244	217	[h]
trans-limonene oxide	0.65	24	127	115	139	141	113	[h]
Benzyl acetate	6.5	< DL	70	103	60	90	61	NA[d]
Hexyl cinnemal	0.04	< DL	53	90	74	61	63	NA[d]
Phenethyl alcohol	13	< DL	< DL	< DL	82	109	< DL	NA[d]
AHTN	0.04	0.20	3.7	23	5.1	5.0	4.4	44[c] - 107[b] (3) 0.6[a] - 13.4[b] (4)
HHCB	0.04	0.21	45	467	43	62	40	15[a] - 299[b]; 101[c] (3) 2.5[a] - 44.3[b] (4)
Other Semivolatile Compounds								
PCB 11	0.03	< DL	0.33	0.55	0.37	0.75	0.30	NA[d]
PCB 52	0.04	0.07	0.31	0.25	0.16	0.14	< DL	< 1[a] - 25[b]; < 1[c] (1) 0.154[a] - 14.8[b] (5)
4,4'methylene bis (o-chloroaniline)	0.38	< DL	< DL	< DL	< DL	< DL	< DL	80,000 (6)

Tris(2-chloroethyl) Phosphate (TCEP)	0.26	0.77	5.6	2.1	4.6	12	0.91	6.1[a] – 56[b] (7) < 5[a] – 6000[b]; 10[c] (8)
Tris(1,3-dichloro-2-propyl) phosphate (TDCPP)	0.08	0.21	0.23	2.0	1.1	0.48	0.34	NA[i]

[a] Minimum, [b]maximum, [c]median.

[d]Typical indoor air concentration has not been measured or is not available in the published literature.

[e,f,g]BASE 5th, 50th (median), and 95th percentile data, respectively.

[h]Indoor air concentrations of these limonene oxidation products measured as part of recently completed study conducted by Battelle. We are currently awaiting client permission to share these results.

[i]Concentrations have not been measured in air, but are available for house dust; see Stapleton et al. (2009).

(1) Rudel et al., 2003; data from residences.
(2) BASE data are available at http://www.epa.gov/iaq/base/voc_master_list.html (EPA, 2006).
(3) Fromme et al., 2004; data from kindergartens.
(4) Kallenborn and Gatermann, 2004; data from various indoor locations.
(5) Currado and Harrad, 1998; data for office environments.
(6) OSHA 8-h workday Permissible Exposure Limit (PEL)
(7) Hartmann et al., 2004; data from office environments.
(8) Ingerowski et al., 2001; various indoor locations sampled.

Concentrations of numerous different additional SVOCs are given in Table 14. Permethrin and sumithrin are synthetic pyrethroid pesticides used for indoor insect control. These pesticides were only found indoors right at or below the detection limit of ~0.08 ng/m^3; these low concentrations are consistent with those measured by Rudel et al. (2003). Airborne pesticide contamination does not appear to be a problem in this building, although given the low volatility of these pyrethroid pesticides, it is more likely for them to be adhered to surfaces and dust. Concentrations of SVOCs adhered to interior surfaces and associated with settled dust were not measured in the present work.

Concentrations of limonene fall between the 5th and 50th percentiles of concentrations measured in indoor spaces in the BASE study. Limonene is found in a wide variety of fragranced consumer products and reacts with ozone indoors to form various irritant species (e.g., Wolkoff et al., 2006) that can cause degradation in perceived indoor air quality (Tamas et al., 2006). Such reaction products include cis- and trans-limonene oxide and carvone (Uhde and Salthammer, 2007). Benzyl acetate, hexyl cinnemal, and phenethyl alcohol are also found in fragranced consumer products and essential oils; hexyl cinnemal may undergo similar indoor chemistry as limonene. Concentrations for these various fragrance compounds and reaction products are low (sub parts per billion by volume), but indoor concentrations are higher than outdoor concentrations. As such, indoor sources such as volatilization from consumer products and indoor air chemistry are the most likely sources for these compounds.

To the best of our knowledge, this study is the first to measure the three limonene oxidation products and three other fragrance compounds in indoor air in occupied buildings. We have also measured concentrations of the three limonene reaction products in another indoor environment as part of a Battelle-funded independent research program; the results are roughly comparable. These results will be made known if permission of the owner of the indoor space is granted.

The compounds AHTN (7-acetyl-1,1,3,4,4,6-hexamethyl-1,2,3,4-tetrahydronapthalene; Tonalide®) and HHCB (1,3,4,6,7,8-hexahydro-4,6,6,7,8,8-hexamethylcyclopenta[g]-2-benzopyran; Galaxolide®) are synthetic musk fragrances found in numerous household and personal care products and cleaning agents. Their toxicological properties are not fully known, although these compounds may affect human health (Fromme et al., 2004). Outdoor concentrations reported here are similar to those measured in other urban areas (Peck and Hornbuckle, 2006). Indoor concentrations are one to three orders of magnitude greater, indicating strong indoor sources for these compounds. Such sources may include laundry detergents, deodorants, and perfumes. AHTN concentrations were below the median found by Fromme et al. (2004). HHCB concentrations are in general greater than AHTN; both were highest in Office 1, and the concentration of HHCB in Office 1 was higher than the maximum concentration reported by Fromme et al. (2004). This office remained occupied during sampling, and offgassing of AHTN and HHCB from personal care products worn by the office occupant may be responsible for the elevated concentrations of these synthetic musk fragrances.

In general, minimizing the concentrations of fragrance compounds will lead to fewer potential indoor air quality problems. Preventing occupants from using fragranced personal care products is not feasible, but intelligent choices of cleaning products and enhanced ventilation and ozone removal during cleaning are possible methods for reducing concentrations of reactive and potentially irritant reaction byproduct species indoors.

The most important remaining SVOCs to discuss, based on concentrations measured, are the organophosphate flame retardants tris(2-chloroethyl)phosphate (TCEP) and tris(1,3-dichloro-2-propyl)phosphate (TDCPP). As the Penta- and Octa-BDE flame retardants are phased out (they were banned or removed voluntarily from use in many countries worldwide beginning in 2002), alternative flame retardants for polyurethane foams such as TCEP and TDCPP have become more prevalent (Stapleton et al., 2009). These compounds also function as plasticizers and additives in textiles, paints, and certain wallpapers (Ingerowski et al., 2001). Some research suggests that organophosphates such as TCEP may be neurotoxic and carcinogenic (Hartmann et al., 2004, and references therein). Furthermore, hydrolysis of TDCPP forms the VOC 1,3-dichloro-2-propanol, a carcinogen (Uhde and Salthammer, 2007).

Indoor air concentrations of TCEP measured in the EPA Region VIII office building were in general similar to those found in other studies: concentrations were on the low end of those measured by Hartmann et al. (2004) and Ingerowski et al. (2001). Only the concentration in Office 3 exceeded the median found by Ingerowski et al. (2001). This study appears to be the first to report TDCPP concentrations in air; others such as Stapleton et al. (2009) have reported TDCPP concentrations in dust. As with many other species measured here, minimizing indoor concentrations of these organophosphate flame retardants may be important for maintaining the long-term health of building occupants.

Summary

In general, the various IEQ parameters measured during this limited study at the EPA Region VIII LEED Gold office building were within the ranges of applicable standards and were similar to the results of measurements in other indoor spaces, with the exception of PAH concentrations in the copy room. Furthermore, no immediate and acute indoor environmental quality problems were identified in this short-term IEQ investigation, although it is not feasible nor was it attempted to measure every possible irritant compound or perform measurements in every possible indoor space.

This study did not formally assess the human exposure or health risks associated to the occupants of this building, nor did it intend to. However, steps can still be taken from a precautionary standpoint to ensure the overall long-term health of building occupants, given that concentrations of various compounds of known or potential concern were present indoors at elevated concentrations compared to outdoors. A broad recommendation for IEQ improvement is to minimize, through source control and filtration, the indoor concentrations of PM, O_3, and harmful and potentially harmful VOCs and SVOCs.

Results of the various measurements are summarized below.

- **Temperature and Relative Humidity** – All measurements were within ASHRAE occupant comfort range for the combination of temperature and relative humidity; several temperature measurements were above the optimal levels for worker performance (20-23°C) reported by Seppänen and Fisk.
- **Carbon Dioxide** – All measurements were within ASHRAE, ACGIH, and OSHA limits for indoor concentrations. Indoor concentrations were elevated between 180 and 300 ppm above outdoor concentrations, but fall within the recommendation that indoor concentrations of CO_2 not exceed outdoor concentrations by more than 650 ppm.
- **Ozone** – indoor/outdoor ozone ratios were on the low end of ratios measured in indoor environments. All indoor concentrations were less than 30 ppb, which is less than half of the 8 hour NAAQS for outdoor ambient ozone.
- **PM_{10}** – Indoor particulate matter concentrations were all less than 25 $\mu g/m^3$, which is below the LEED new construction standard as well as lower than ambient outdoor levels.
- **Sound Level** – Sound level measurements in the indoor spaces did not exceed normal conversation levels of 60-70 dBa.
- **Fungi** – Concentrations of fungal spores were very low indoors (all indoor measurements were below 100 spores/m^3) and below levels of concern for indoor air (1000 spores/m^3).
- **VOCs** – Indoor formaldehyde (20-26 $\mu g/m^3$) concentrations were greater than the outdoor concentration (5.3 $\mu g/m^3$) but still less than indoor air quality guidelines (the LEED new construction standard is 64.1 $\mu g/m^3$); ethanol (133-217 $\mu g/m^3$) and acetone (46-79 $\mu g/m^3$) were detected at elevated concentrations due to human

activity in the occupied building; HAPs 2-butanone (6.8-11 μg/m^3), toluene (7.3-13 μg/m^3), and hexane (2.5-3.7 μg/m^3) were detected in the indoor air.

- **SVOCs** – Synthetic musks AHTN (3.7-23 ng/m^3) and HHCB (40-467 ng/m^3) were found in the indoor air with concentrations in one office approximately an order of magnitude higher than the other indoor locations. BDEs and phthalates were in general found at levels similar to those reported for other indoor environments. Limonene and its oxidation products, potential sensory irritants, were detected in the indoor samples, albeit at low concentrations. Samples collected from the copy room were found to have elevated concentrations of several PAHs (predominantly the lower volatility PAHs). Concentrations of PAHs found in the copy room were higher than have been measured in other indoor environments. It is recommended the source of these compounds be investigated.

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Appendix H: Conversion Factors

Volume Conversions[38]

Water: 1 cubic feet = 7.48052 gallons

1 cubic meter = 264.172 gallons

Dry: 1 cubic yard = 27 cubic feet

Energy Utility Conversions

Electricity: 1 kwh = 3,413 Btu

Natural Gas: 1 cubic feet average = 1000 Btu

1 ccf = 100 cubic feet

1mcf = 1000 cubic feet

1 gigajoule = 948 cubic feet

1 therm = 100,000 Btu

1 decatherm = 10 therms

Steam: 1 lb. steam = 1,000 Btu

Chilled Water: 1 ton hour of chilled water = 12,000 Btu

Material Conversions[39]

Municipal Solid Waste: 1 cubic yard = 450 pounds

Recycled Computer Paper: 1 cubic yard = 655 pounds

Monetary Conversions

For purposes of this study, Canadian and American dollars were estimated to be at par.

Currency Exchange: 1 U.S. $ = 1 CDN $

Appendix I: Building Contacts

Many GSA and leased building site personnel assisted the PNNL research team with this study. The following is a list, in alphabetical order, of those that contributed time and data.

Laura Anderson	Assistant Property Manager - JBG Companies Rockville FB
Paul Anderson	Senior Property Manager, Iowa Office Davenport CT
Danielle Bogni	Environmental Protection Specialist - Region 9 Las Vegas CT
Alex Bonaparte	Lead Engineer - JBG Companies Rockville FB
Jonathan Bringewatt	Public Buildings Service Lakewood DOT FB
Jim Brown	Building Engineer - Cottonwood Management Services Ogden FB
Gina Carter	Assistant Property Manager - Cottonwood Management Services Ogden FB
Stephen Casey	Operations Manager - Enovity Inc. San Francisco FB
Diana Ciryak	Property Manager Cleveland CT
Chris Cockrill	Energy Coordinator - Region 6 Cape Girardeau CT, Manhattan FB
Pamela Coleman	IRS Real Estate and Facilities Management Ogden FB
Scott Crews	Cottonwood Management Services Ogden FB
Mike Daniels	Facilities Representative Rockville FB
Tim Essebaggers	Property Manager

	Seattle CT
Dan Fenner	Building Manager - Michigan Service Center Sault Ste. Marie Port
John Garner	Lease Management Representative Omaha NPS FB and Omaha DHS FB
Christopher Grigsby	Asset Management Services Denver CT
Angel Gonzalez	Building Management Specialist San Francisco FB
Richard Gordon	Building Management Specialist Auburn FB
Scott Hawkins	Building Engineer -Urban/Meridian Joint Venture Greeneville CT and Knoxville FB
Sue Heeren	Public Buildings Service Davenport CT
Tina Hingorani	Property Manager Santa Ana FB
Richard Hosey	Property Manager Jacksonville FB
Jason Hunt	Property Manager Fresno CT & FB
Nicholas Infantino	Property Manager Youngstown CT & FB
Mary Ann Kosmicki	Deputy Director - Nebraska Office Omaha NPS FB and Omaha DHS FB
Kristina Lee	Senior Property Manager - Grubb & Ellis Omaha NPS FB
Chris Litsey	Building Management Specialist - Region 9 Auburn FB, Eugene CT, Seattle CT
Jill McCormick	Asset Services - CBRE Omaha DHS FB
Donald Murphy	Property Manager Eugene CT
William Murphy	Assistant Property Manager

	Auburn FB
Lorento Neequaye	Assistant Building Manager Suitland FB
J. Michael Ortega	Public Buildings Service Denver CT
Peter Pocius	Property Manager, Montana Field Office Sweetgrass Port
Cheri Sayer	Energy Manager - Region 9 Auburn FB, Eugene CT, Seattle CT
Sharon Schuler	Building Manager - St. Louis Field Office Cape Girardeau CT
Wendy Schuman	Property Manager - NorthMarq Lakewood FB
Warren Sitterley	Deputy Property Manager San Francisco FB
Sandy Sitton	Program Analyst Fresno CT & FB
C. Johnathan Sitzlar	Property Manager Greeneville CT and Knoxville FB
Amy Smith	Property Manger - NorthMarq Denver FB
Don Smyth	NPS Property Management & Office Services Omaha NPS FB
Mark Stanford	Site Engineer – Public Works and Government Services Canada Sweetgrass Port
Joni Teter	Green Build Education & EMS Coordinator - EPA Region 8 Denver FB
Tim Trubey	Property Manager - McCullough Development Manhattan FB
Steven Underhill	Assistant Property Manager Las Vegas CT
Christopher Wentzell	Property Manager - Public Works and

	Government Services Canada Sweetgrass Port
Stephen West	Property Manager – Cottonwood Management Services Ogden FB
Ryan Wilcoxen	Senior Building Engineer - NorthMarq Denver FB
Bruce Williams	Building Management Specialist Las Vegas CT

Appendix J: References

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