GSA Public Buildings Service

ENERGY SAVINGS AND PERFORMANCE GAINS IN GSA BUILDINGS

SEVEN COST-EFFECTIVE STRATEGIES

SUSTAINABILITY

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

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"GSA is committed to incorporating principles of sustainable design and energy efficiency in the federal workplace. There are cost-effective ways to achieve this goal in existing facilities. Applying them across our national real estate portfolio will significantly reduce energy use and improve end user satisfaction."

ANTHONY COSTA,
Acting Commissioner, General Services Administration, Public Buildings Service

INTRODUCTION

STATE OF THE FEDERAL WORKPLACE

What is the state of the federal workplace? To answer that question, the GSA Workplace Performance Study surveyed over 6,000 federal workers and measured environmental conditions at 624 workstations in 43 workplaces in 22 separate buildings. The sample chosen is representative of the building ages, workplace types, and climate zones in GSA's national portfolio. The study evaluated everything from the technical attributes of building systems to acoustical, air quality, lighting, and thermal conditions; from workplace ergonomics to end user satisfaction. The resulting data set is compatible with one produced in a similar study by Canada Public Works and Government Services. This facilitates benchmarking and provides the largest, most comprehensive workstation data set in the world. GSA's study shows that **nearly all federal workstations surveyed met minimum requirements.** The study also identified seven key areas that offer the potential for significant performance gains.

SEVEN STRATEGIES FOR BETTER PERFORMANCE

Based on this research, the GSA Workplace Performance Study team recommends seven cost-effective strategies, applicable to every existing federal facility and workplace, that can save energy and increase end user satisfaction. We estimate that implementing these strategies across GSA's portfolio can yield more than **500 million kWh per year of energy savings.** Survey data indicate that each of these changes will also lead to improved occupant satisfaction. Together, the seven strategies provide a comprehensive approach that will enable GSA to meet its energy mandates—EPAct 2005, EO 13423, and EISA 2007—while reducing operating costs and achieving greater end user satisfaction.

REPORT OVERVIEW:

State of the Federal Workplace

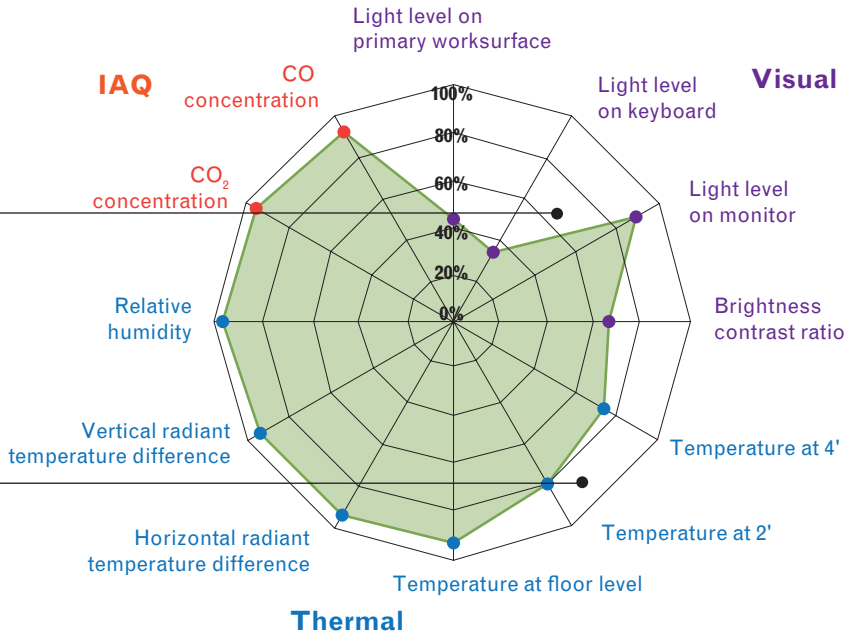
As part of its Workplace 20•20 research initiative, GSA partnered with a research team led by the Center for Building Performance & Diagnostics (CBPD) at Carnegie Mellon University, to conduct before and after field studies that linked technical attributes of building systems with end user satisfaction and measurements of physical conditions. Combining field research with end user surveys, the GSA Workplace Performance Study addressed a representative cross section of the federal workplace.

While most workstations in the sample met minimum requirements, with the exception of lighting and summertime temperatures, the research team found seven key areas with the potential for performance gains that both yield energy savings and improve end user satisfaction.

Figure 1: Percentage of Physical Conditions Meeting Standards

Ineffective lighting in federal facilities should be replaced with lower level ambient lighting and high quality task lights.

Average ambient indoor temperature conditions in the federal workplace should be adjusted to avoid overcooling.



This report documents seven pragmatic strategies for achieving these recommended performance gains in existing federal buildings and work settings. Aimed at building managers, facility managers, and others involved with ongoing facility management, operation, and maintenance, the report provides options that can be implemented quickly and cost-effectively to produce tangible results.

SEVEN STRATEGIES:

For Energy Savings and Performance Gains

STRATEGY	COST	ENERGY SAVINGS
1. ADJUST WORKPLACE TEMPERATURE FOR THE SUMMER MONTHS **Study finding:** Federal workers report that overcool indoor air in summer is uncomfortable. **What to do:** In summer months, set the ambient indoor temperature to 74°F-78°F.	$	18.7 million kWh/year
2. REPLACE HVAC FILTERS ON SCHEDULE AND WITH HIGH-PERFORMANCE FILTERS **Study finding:** Expired filters reduce indoor air quality and increase building energy use. **What to do:** Implement a plan for HVAC filter replacement; use high-performance filters.	$	10.8 million kWh/year
3. CONSOLIDATE AND REDUCE THE NUMBER OF PRINTERS AND COPIERS **Study finding:** Consolidating printers and copiers saves energy and supports collaboration. **What to do:** Provide distributed printer-copier rooms with a 1:25 equipment/user ratio.	$$	55.0 million kWh/year
4. REPLACE CRT MONITORS WITH LCD MONITORS **Study finding:** CRT monitors create glare and are unacceptably bright and energy consuming. **What to do:** Replace CRT monitors (200,000 still on federal desks) with flat screen LCDs.	$$	39.0 million kWh/year
5. UPGRADE AMBIENT AND TASK LIGHTING IN THE WORKPLACE **Study finding:** Lighting needs differ depending on the kind of work; technology has changed. **What to do:** Upgrade both ambient and task lighting to support how people really work.	$$	199.1 million kWh/year
6. IMPROVE ACCESS TO DAYLIGHT IN THE WORKPLACE **Study finding:** Higher end user satisfaction is correlated with access to daylight and views. **What to do:** Use every opportunity to increase the amount of daylight and access to it.	$$$	118.1 million kWh/year
7. UPGRADE WINDOWS FOR BETTER ENERGY PERFORMANCE **Study finding:** Many federal buildings' windows are single-pane, with dark film, and drafty. **What to do:** Use every opportunity to upgrade buildings to high-performance R4 windows.	$$$	127.5 million kWh/year

Total Savings: 568.2 million kWh/year

STRATEGY 1:

Adjust Workplace Temperature for the Summer Months

The federal workplace is often uncomfortably cool in the summer. Raising the temperature just 2°F higher can reduce air-conditioning energy use by at least 4 percent in most federal facilities.

RESEARCH FINDINGS

Of the workstations measured during the summer months, 40 percent were colder than the ambient indoor temperature recommended in ***ASHRAE 55-2004, Thermal Environmental Conditions for Human Occupancy.*** Correlated satisfaction questionnaire responses showed that 61 percent of end users felt too cold. The age of buildings and building systems and their locations suggest that overcooling in the summer could be even more pervasive than the study found, affecting up to 50 percent of GSA's national real estate portfolio.

HOW TO IMPLEMENT

In hot summer months, raise the indoor temperature set points in the range of 74°F to 78°F. The comfort zone in cooling season is higher (see Figure 2) because end users are generally wearing light summer clothing. Note that the HVAC systems vary from building to building, so this step should be carried out by or with the building engineer or an appropriate consultant. For example, some building mechanical systems reheat supercooled outside air to squeeze out moisture and generate supply air at the desired temperature. Raising the indoor temperature may increase energy use with such systems that reheat cold air. Specialist advice may be needed to adjust such equipment and control indoor air temperature, humidity, and ventilation rates to achieve an optimal balance between energy efficiency and end user comfort.

EXPECTED BENEFITS

The California Energy Commission estimates a 1 to 3 percent energy savings for each degree the thermostat is set above 72°F[1]. Raising room temperatures by 2°F in facilities with ambient indoor air temperatures below 73°F in hot summer months will save an average of 4 percent of total annual cooling energy. Extrapolated over GSA's owned properties, this represents a total annual cooling energy savings of about 18.7 million kWh or $1.87 million per year.

End user productivity and satisfaction both stand to gain if people in the workplace feel comfortable. Other research suggests that people's productivity is affected by temperatures outside the bounds of comfort. When temperatures become too hot or cold for the seasonal clothes people wear to work, their task performance suffers. As surveys from GSA's study showed, their satisfaction levels also drop (see Figure 3).

Savings Calculation

2.7 kWh/sf/year (average office cooling load*)
x 4% (estimated percentage reduction in energy use)
0.106 kWh/sf/year (energy saved/sf/year)
0.106 kWh/sf/year
x 176.4 million sf (total area of GSA-owned facilities)
18.7 million kWh/year (total energy savings/year)
18.7 million kWh/year
x $0.10/kWh (GSA average electric energy cost**)
$1.87 million/year (total cost savings/year)

* U.S. Department of Energy: ***Buildings Energy Databook 2007***.

**GSA's average cost for electric energy in fiscal year 2008.

Figure 2: Measured Air Temperature Distribution in GSA Buildings

On average, the comfort zone is higher in the summer months (74°F to 82°F) than it is in the winter months (68°F to 78°F). For the GSA study, the facilities measured during the heating season had temperatures that mostly fell within the winter comfort zone. However, the facilities measured during the cooling season had temperatures that were below the summer comfort zone.

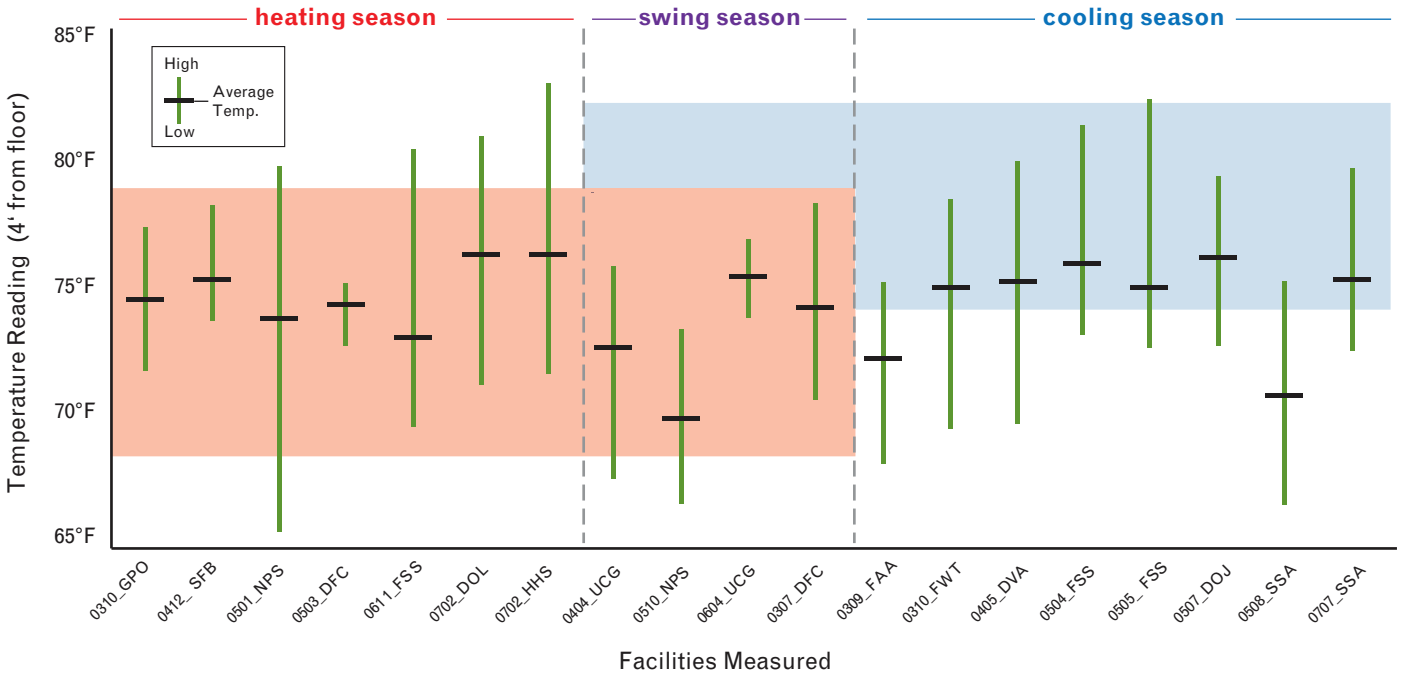


Figure 3: Occupant Satisfaction

Occupant satisfaction is low for temperature in the work area.

STRATEGY 2:

Replace HVAC Filter on Schedule and with High-Performance Filters

HVAC system filters reduce air contaminants and protect equipment from dust that impacts their performance. Any HVAC filter left in place past its expiration date can't do its job.

RESEARCH FINDINGS

The GSA Workplace Performance Study found that when HVAC filters are not replaced on schedule, the deterioration in HVAC system performance reduces energy efficiency and raises total HVAC costs by up to 10 percent. The U.S. Environmental Protection Agency's Building Assessment Survey and Evaluation Study (BASE) surveyed 100 public and commercial office buildings across the U.S., and found that at 30 percent of the buildings, HVAC filters were inspected at 6 month intervals or more[2]. This suggests that many HVAC filters in GSA buildings may not be replaced on schedule.

The GSA study also found that end users are significantly more satisfied with air quality and with air movement when small and large particulate levels are low.

HOW TO IMPLEMENT

Inspect the facility's HVAC filters and maintenance records to determine if filters are being replaced by their manufacturers' recommended expiration dates. Make note of the locations of air intakes relative to high-traffic areas and the cleanliness of the workspace. When possible, relocate air intakes away from high-traffic areas and institute better cleaning practices to help lower particulate levels.

Establish an HVAC filter inspection and maintenance schedule that ensures timely replacement. If conventional HVAC filters are in place, consider replacing them with high-performance filters. Filters with a Minimum Efficiency Reporting Value (MERV) rating of 13 or above will remove particles more efficiently, improving delivered air quality at the lowest energy cost[3].

EXPECTED BENEFITS

Based on the GSA study findings, low particulate levels will increase end user satisfaction. Low particulate levels will also keep HVAC operating costs down. Based on national averages for office energy use, energy savings for GSA's owned properties of a fully-implemented program of timely filter replacement is estimated to be 10.8 million kWh or $1.08 million per year.

Savings Calculation

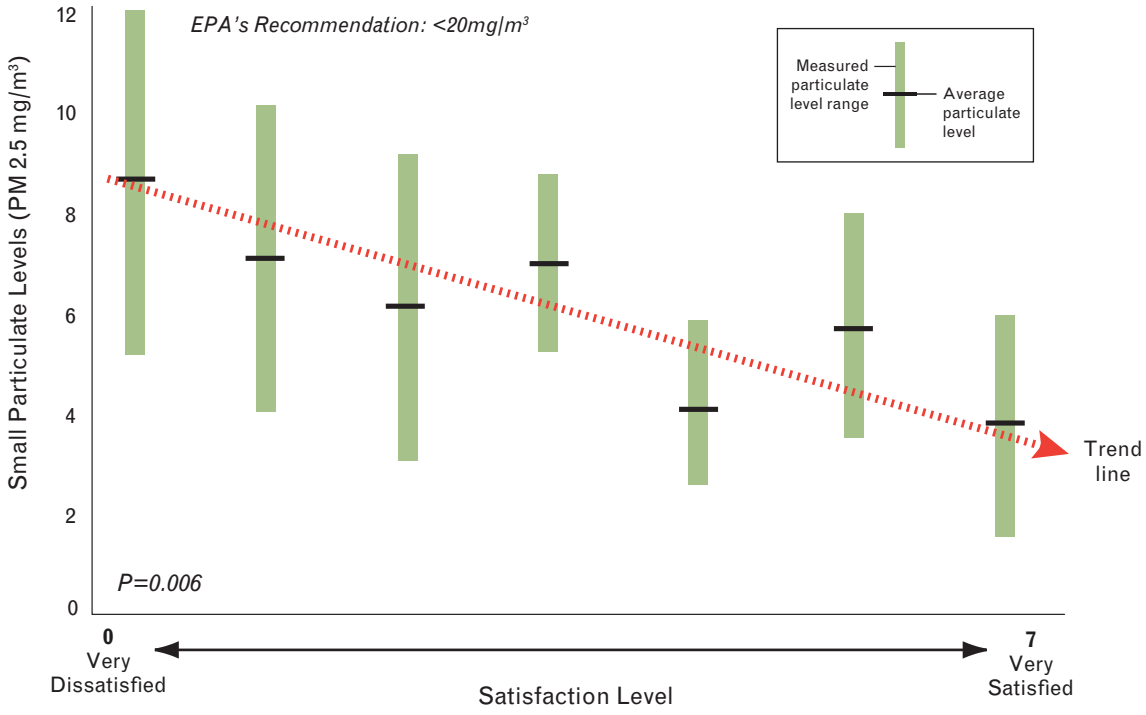
10.2 kWh/sf/year (office building energy load attributable to HVAC*)
x 2% (estimated percentage reduction in energy use)
0.204 kWh/sf/year (energy saved/sf/year)
0.204 kWh/sf/year
x 176.4 million sf (total area of GSA-owned facilities)
35.99 million kWh/year (gross energy saved)
35.99 million kWh/year
x 30% (estimated rate of federal facilities with infrequent HVAC filter inspection)
10.8 million kWh/year (total energy savings/year)
10.8 million kWh/year
x $0.10/kWh (GSA average electric energy cost**)
$1.08 million/year (total cost savings/year)

* U.S. Department of Energy: ***Buildings Energy Databook 2007***.

**GSA's average cost for electric energy in fiscal year 2008.

Figure 4: Relationship of Air Quality Satisfaction to Small Particulate Levels (PM 2.5)

Overall air quality satisfaction increases as the small particulate level in workstations decreases.



STRATEGY 3:

Consolidate and Reduce the Number of Printers and Copiers

Despite digital communications, paper use is on the rise. Fewer printers mean less paper, and that means less resource use and landfill waste, and less energy use in the federal workplace.

Source: Environmental Defense Fund, *Tips for Selecting, Buying and Reducing Paper*, 30 October 2007.

RESEARCH FINDINGS

The Environmental Defense Fund reports that paper production is the third most energy-intensive of the US manufacturing industries, using 11.5 percent of all energy in the industrial sector. One-third of the wood harvested in the US goes into paper products[4]. So, reducing paper use has both energy use and environmental benefits. The GSA Workplace Performance Study found that in the federal workplace, the average printer or copier use ratio is 1:5 (one printer or copier serving five users). Instead of being consolidated in separate rooms—a strategy that supports collaboration and reduces distraction—this equipment is predominantly located in individual workstations or in circulation space. The optimal approach, the study found, is to distribute printers and copiers in several rooms across a full office floor.

HOW TO IMPLEMENT

To save energy and reduce paper use, do the following:

- Reduce the number of printers and copiers to achieve a 1:25 ratio of equipment to users. They should be located to serve clusters of end users, not individuals or small groups.
- While reducing and consolidating printers and copiers, upgrade them to achieve the best possible performance in terms of speed, reliability, and energy efficiency.
- Set all printers and copiers to default to double-sided printing mode to save paper.
- If possible, provide dedicated rooms for printers and copiers, distributed across the workspace (see Figure 5). The rooms should be acoustically separate from the main workspace, with adequate counter, layout, and storage space, dedicated ventilation, effective lighting, and amenities that encourage gathering and interaction.

EXPECTED BENEFITS

The U.S. Department of Energy's Federal Energy Management Program estimates that setting equipment to double-sided printing mode will cut annual paper use by 25 percent[5]. A lower equipment-to-user ratio can also reduce paper use by making people think twice about printing if they have to walk some distance to retrieve a document. If the above recommendations are implemented for the entire federal workforce—1.1 million people—the estimated energy savings would be up to 50 kWh per person. That translates to 55 million kWh or $5.5 million per year.

There are also human performance reasons to make the shift. The GSA study found that dedicated printer and copier rooms serving at least 25 end users will support higher levels of collaboration and lower levels of distraction compared to the same equipment deployed at workstations or in circulation spaces (see Figure 5).

Savings Calculation

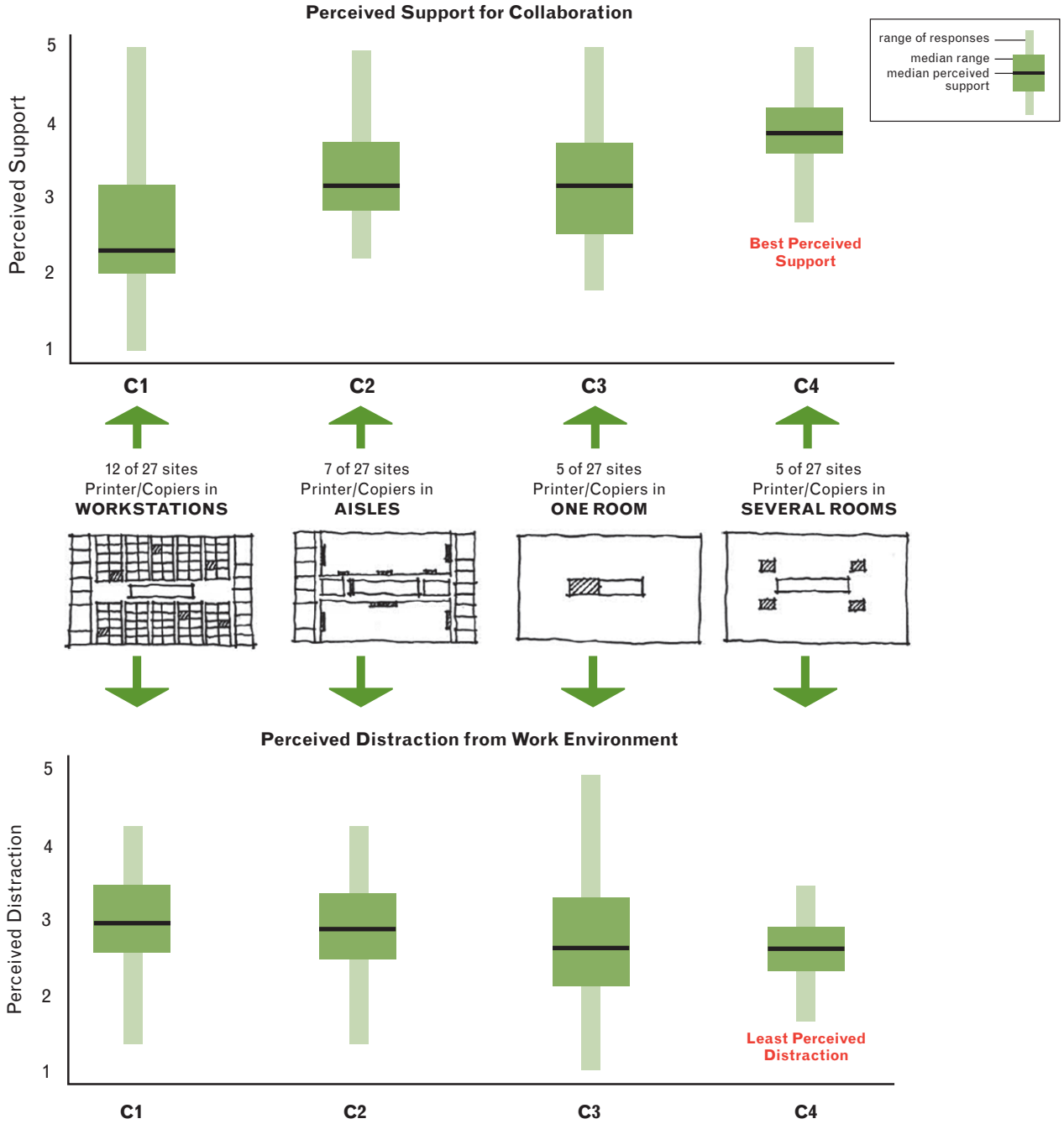
50 kWh/person/year (energy savings/person/year attributable to printer consolidation and reduction to 1:25 equipment/user ratio*)
x 1.1 million workers (total federal workforce)
55 million kWh/year (total energy savings/year)
55 million kWh/year
x $0.10/kWh (GSA average electric energy cost**)
$5.5 million/year (total cost savings/year)

* Federal Energy Management Program, U.S. Department of Energy: ***How to Buy an Energy Efficient Printer***, July 2001.

** GSA's average cost for electric energy in fiscal year 2008.

Figure 5: Perceived Support versus Perceived Distraction

The GSA study found that copy|print areas in dedicated spaces distributed within neighborhoods of workstations (C4) ensure higher levels of perceived collaboration and lower levels of perceived distraction from the work environment, as compared to the layouts with copiers|printers in circulation aisles or at desks (C1, C2).



STRATEGY 4:

Replace CRT Monitors with LCD Monitors

Converting old-style CRT monitors to high-performance LCD flat screen monitors has a potentially huge payoff in energy savings—close to 40 million kWh per year—in the federal office workplace.

RESEARCH FINDINGS

The GSA Workplace Performance Study found that 22 percent of surveyed workstations have cathode ray tube (CRT) monitors, an obsolete technology in terms of energy consumption and human performance. A CRT monitor draws at least 3 times the energy of a liquid crystal display (LCD) monitor—75 watts versus 20–25 watts of peak energy[6]. Field measurements showed that the average brightness contrast (average luminance) ratio experienced with CRT monitors greatly exceed accepted limits[7]. LCD flat screens have average ratios below the limit—a level that current research suggests may improve human performance of visual tasks.

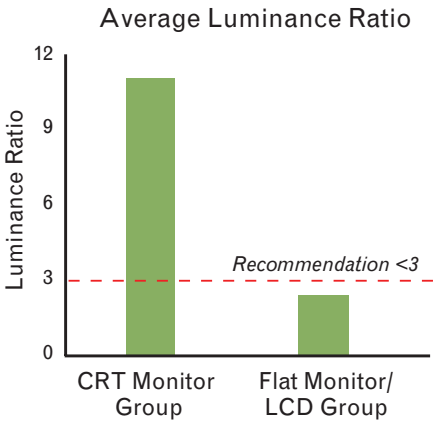
HOW TO IMPLEMENT

Replace CRT monitors with flat screen LCD monitors with Power Management (PM). Monitors should be sized appropriately for the type of work done by the end users. To save additional energy, activate the power management feature of the computer or laptop driving the monitor and install updates to this feature as they become available. Attach privacy screens to monitors when visual privacy is an issue.

EXPECTED BENEFITS

If the 200,000 CRT monitors still on federal desks are replaced with flat screen LCD monitors and power management features are implemented, electric energy consumption across the federal workplace would be reduced by 39 million kWh or $3.9 million per year.

Other research suggests that the brightness contrast (average luminance) performance of LCD monitors is better for visual tasks and may also enhance end user performance[8]. Research also suggests that the wider horizontal "landscape" format possible with LCD monitors speeds up organizational tasks[9].



Savings Calculation

195 kWh/year (energy savings per CRT monitor replaced with LCD monitor with PM*)	
x 0.2 million (CRT monitors still on federal desks)	
39 million kWh/year (total energy savings/year)	
39 million kWh/year	
x $0.10/kWh (GSA average electric energy cost**)	
$3.9 million/year (total cost savings/year)	

* Lawrence Berkeley National Laboratory: ***Energy Use and Power Levels in New Monitors and Personal Computers***, 2002.

**GSA's average cost for electric energy in fiscal year 2008.

GSA Mid-Atlantic Regional Offices
Philadelphia, PA
Renovation of the Wanamaker Building

STRATEGY 5:

Upgrade Ambient and Task Lighting in the Workplace

Most knowledge workers today make simultaneous use of computers and paper documents. To support them effectively, the workplace should provide ambient and task lighting as an integrated system.

Savings Calculation

1.24 watts/sf (average energy savings, replacing conventional with high-performance lighting*)
x 2,600 hours/year (end user occupancy hours per year in federal facilities)
3.2 kWh/sf/year (energy savings/sf/year)
3.2 kWh/sf/year
x 176.4 million sf (total area of GSA-owned facilities)
568.7 million kWh/year (gross energy savings/year)
568.7 million kWh/year
x 35% (percentage of GSA facilities retrofitted for lighting)
199.1 million kWh/year (total energy savings/year)
199.1 million kWh/year
x $0.10/kWh (GSA average electric energy cost**)
$19.9 million/year (total cost savings/year)

* California Department of Energy: ***PIER Technical Brief: Integrated Office Lighting Systems: Making It Personal***, November 2007.

**GSA's average cost for electric energy in fiscal year 2008.

RESEARCH FINDINGS

In terms of energy efficiency, the GSA Workplace Performance Study found that for ambient lighting, 30 percent of the fixtures in the workspaces studied use inefficient T-12 lamps with magnetic ballasts.

Light levels at 43 percent of surveyed workstations were too high for computer work, yet 57 percent of surveyed workstations lacked adequate light levels for paper work on primary work surfaces. In the offices studied, 60 percent of the light fixtures had flush lens covers and no parabolic reflectors, a condition that creates direct and reflected glare detrimental to computer work.

HOW TO IMPLEMENT

Ambient and task lighting should be addressed together.

- **Ambient lighting:** For 9-foot ceilings, upgrade to high-efficiency fixtures that deliver a lighting level of 200 lux at a lighting power density as low as 0.3 watts/square foot; for ceilings higher than 9 feet, upgrade to indirect-direct lighting. Ambient electric light levels should be 200–300 lux. To save additional energy, install occupancy sensors that turn lights off when the space is unoccupied.
- **Task lighting:** Provide flexible task lighting delivering at least 500 lux for end users doing paper-based work. Two LED task lights per workstation have a power density of less than 0.23 watts/square foot.

Ambient lighting levels below 300 lux are acceptable when task lighting is provided at each workstation to support paper work. To integrate ambient and task lighting with available daylight in the workplace effectively, engage a lighting consultant.

EXPECTED BENEFITS

Replacing T-12 lamps with magnetic ballasts with T-8 lamps with electronic ballasts will cut energy use by 17 to 48 percent, according to the Oregon Department of Energy[10]. Assuming that 35 percent of ambient lighting in GSA's owned properties is upgraded to high-efficiency fixtures, the energy savings would be 199.1 million kWh of electric energy or $19.9 million/year.

Research also shows that lighting that is too bright or dim can cause headaches and negatively affect end user performance and productivity[11]. Providing ambient and task lighting at appropriate lux levels should therefore result in significant gains in organizational performance and end user satisfaction[12].

Ceiling lights with flush lens covers create direct and reflected glare for computer work.

Ceiling lights with parabolic louvers reduce glare but often light the wrong surfaces.

Effective integration of ambient lighting, task lighting, and daylight can reduce energy use and increase end user satisfaction.

STRATEGY 6:

Improve Access to Daylight in the Workplace

Providing daylight effectively in the workplace can cut total lighting energy loads in half. Better access to daylight and outside views is also correlated with improved end user performance.

Savings Calculation

7.65 kWh/sf/year (office building energy load attributable to lighting*)
x 25% (estimated percentage reduction in energy use)
1.91 kWh/sf/year (energy savings/sf)
1.91 kWh/sf/year
x 176.4 million sf (total area of GSA-owned facilities)
337.37 million kWh/year (gross energy savings)
337.37 million kWh/year
x 35% (estimated percentage of GSA facilities with unrealized daylight potential)
118.1 million kWh/year (total energy savings/year)
118.1 million kWh/year
x $0.10/kWh (GSA average electric energy cost**)
$11.8 million/year (total cost savings/year)

* U.S. Department of Energy: ***Buildings Energy Databook 2007.***

**GSA's average cost for electric energy in fiscal year 2008.

RESEARCH FINDINGS

The GSA Workplace Performance Study found various obstacles to daylight access in the federal workplace. For example, 95 percent of surveyed buildings have horizontal venetian blinds rather than light redirecting blinds that provide glare-free daylight. The GSA study's end user surveys found that those with seated views of a window were more productive and 21 percent more satisfied with the workplace than those without a seated view of a window. However, these surveys also found that 55 percent of the end users surveyed sit more than 15 feet from a window; 20 feet is the maximum distance from the window wall that still provides effective daylight access.

HOW TO IMPLEMENT

Wherever the opportunity for daylight access exists, replace horizontal venetian blinds with light redirecting blinds that provide daylight while shading the summer sun. In case of early morning or late afternoon direct sunlight, use adjustable mesh roller-shades or shades that are automatically adjusted for daylight.

Older buildings sometimes have dark-tinted window film that can reduce visible transmission of daylight to the interior. **Where sun exposure conditions warrant, remove and replace this film with new solar film designed to mitigate solar heat gain and glare without diminishing daylight access.**

To have good access to daylight and views, **seat people within 15 feet of the window wall.** Moving circulation aisles out of this zone and concentrating seating within it will ensure this. Seating assignments within this zone should favor people who spend the most time at their desks.

When renovating or remodeling, **lower partitions and relocate private perimeter offices to the interior.** If perimeter offices cannot be removed, redesign them if possible with glazed interior walls for maximum transparency. If necessary, provide blinds in these offices for use only when visual privacy is required.

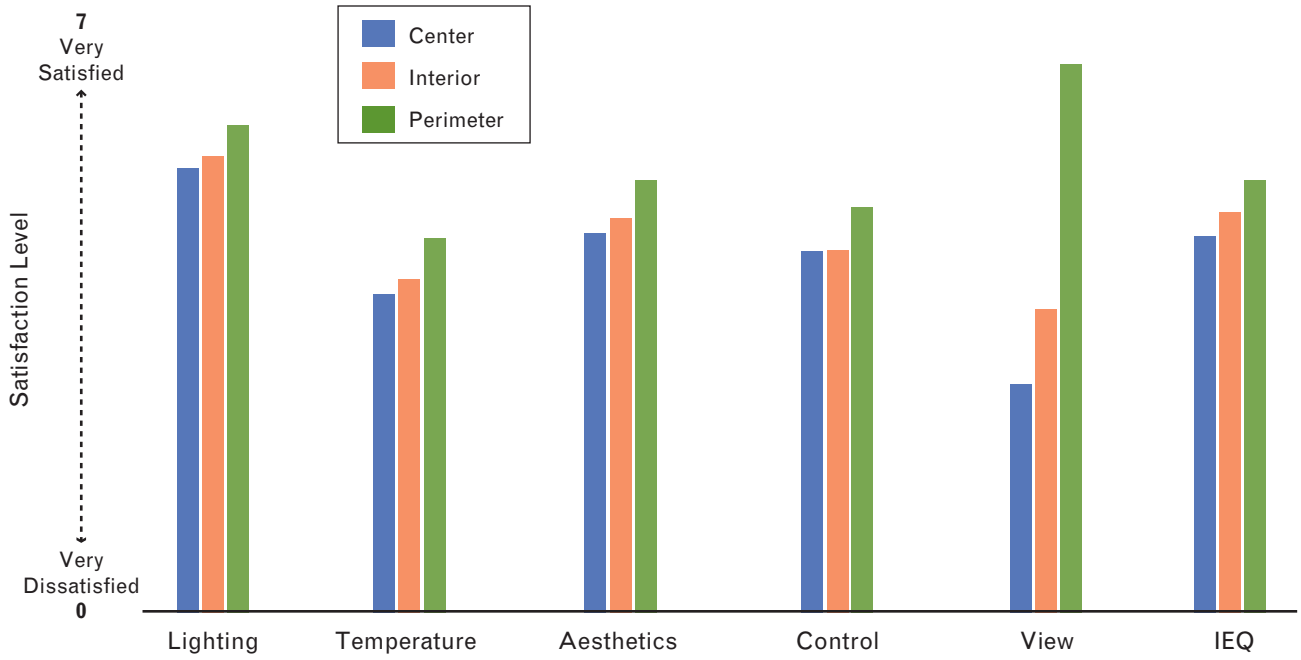
EXPECTED BENEFITS

Depending on the depth of the building, captured daylight can reduce total lighting energy loads by up to 50 percent[13]. Electric lighting represents nearly 30 percent of the total power load in office buildings[14]. If 35 percent of GSA's owned properties have the potential for greater daylight access, and that the lighting load in each is reduced by 25 percent, the resulting savings would be 118.1 million kWh or $11.8 million.

Health and productivity in the workspace are also likely to be enhanced if more people in a given workspace have unobstructed seated views that give them access to usable daylight and outdoor views. Studies by the U.S. Department of Energy[15] and the California Department of Energy[16] found fewer negative health symptoms and greater productivity among workers with seated outdoor views.

Figure 6: Average User Satisfaction with Environmental Conditions

User satisfaction is highest at the perimeter.



Seated views of windows and effective daylight (correct contrast) are centerpieces of the National Park Service's workplace design in Omaha, Nebraska.

STRATEGY 7:

Upgrade Windows for Better Energy Performance

Many older federal buildings have perimeter heating and cooling units and single-glazed windows. Both are ready to be replaced—with potentially major gains in energy and daylight performance.

Savings Calculation

2.41 kWh/sf/year (average office building cooling and heating load attributable to windows*)
x 75% (percentage energy savings due to installing high-performance windows)
1.81 kWh/sf/year (energy saved/sf/year due to installing new windows)
1.81 kWh/sf/year
x 176.4 million sf (total area of GSA-owned facilities)
318.84 million kWh/year (gross energy saved)
318.84 million kWh/year
x 40% (percentage of GSA-owned buildings with single glazing, feasible to upgrade)
127.54 million kWh/year (total energy savings/year)
127.54 million kWh/year
x $0.10/kWh (GSA average electric energy cost**)
$12.8 million/year (total cost savings /year)

* U.S. Department of Energy, Energy Information Agency: ***2003 Commercial Building Energy Consumption Survey***.

** GSA's average cost for electric energy in fiscal year 2008.

RESEARCH FINDINGS

The GSA Workplace Performance Study found that many federal buildings have perimeter fan-coils, induction units, and radiators that are nearing the end of their useful lives. GSA has a great opportunity to replace such equipment and to upgrade the exterior windows of these buildings at the same time. The GSA study found that nearly three-quarters of the buildings surveyed (73 percent) have discrete windows set in solid facades, as opposed to curtain walls, a condition that allows window-only replacement.

The GSA study also found that 64 percent of the buildings surveyed have single-glazed windows and window walls that insulate poorly and are often improperly sealed. Single glazing loses heat in the winter and gains heat in the summer. Tinted window film, found in some of the buildings surveyed, was often used in the past to mitigate summer heat gain. However, tinted window film significantly limits daylight access, and high-performance windows and solar films have made these films obsolete.

HOW TO IMPLEMENT

Remove or replace perimeter heating-cooling systems and upgrade windows and window walls at the same time. In many US climate zones, high-performance glazing can eliminate or reduce the need for perimeter conditioning, making it possible to replace existing units with smaller units that use much less energy. Single-glazed windows should be replaced with modern, high-performance R4 windows. Use high visible transmission glass (60 percent or greater) to maximize daylight.

EXPECTED BENEFITS

Properly sealed, R4 windows with a U factor of 0.25 will reduce heat loss by 75 percent[17]. If 40 percent of GSA-owned buildings that are single-glazed are retrofitted with properly sealed high-performance R4 windows with high visible transmission, the estimated annual energy savings would be 127.5 kWh or $12.8 million. Assuming a 5 percent/year replacement rate, the annual savings would be 15.9 kWh or $1.6 million. Upgrading single-glazed windows will also contribute to human comfort and performance by reducing drafts and noise, and improving end user access to daylight and views.

While R4 windows cost more than code-minimum windows with lower insulation values, their greater efficiency will pay for the cost difference in 3 to 5 years[18]. Upgrading windows to R4 should reduce, and in some cases will eliminate, the need for perimeter heating and cooling. This will provide additional savings in energy use and operating costs.

Figure 7: Cost Trade-offs of Replacement Windows versus Perimeter HVAC Equipment

HIGH PERFORMANCE DESIGN OPTIONS INTEGRATED DESIGN*	
Elimination of Perimeter Heating System	
High Performance Windows	+ $15,000
Perimeter Heating System	- $25,000
Down-sized HVAC System	- $10,000
Net First Cost Impact	**- $20,000**

* Deru, M., et al: ***Analysis of the Design and Energy Performance of the Pennsylvania Department of Environment Protection Cambria Office Building***, National Renewable Energy Laboratory, March 2005.

Discrete windows (Federal Center, Denver) are good candidates for cost effective replacements.

GSA WORKPLACE PERFORMANCE STUDY:

A Comprehensive Study of the Federal Workplace

These seven strategies for improving energy and human performance in the federal workplace reflect a comprehensive study that captures its current state and how end users perceive it.

ABOUT THE STUDY

The seven strategies presented in this report reflect a study commissioned and led by GSA and carried out in collaboration with the Center for Building Performance & Diagnostics (CBPD) at Carnegie Mellon University (CMU) and others. This study accomplished three things. First, it documented the state of the federal workplace, using GSA-managed buildings and work settings as its sample. Second, it documented how the end users of these facilities perceive them—their sense of their immediate work environment and the larger workspace, from the standpoints of comfort, performance, satisfaction, and other measures. Third, it combined these findings to identify modernization strategies with the most potential to improve energy and end user performance. These strategies offer the highest return on investment for dollars spent.

STUDY METHODOLOGY

For environmental assessment, the GSA Workplace Performance Study used a sample comprising 22 federal office buildings nationwide—43 office floors in total. A statistically valid sample of 624 workstations—approximately 10 percent of the study population—was measured for temperature, relative humidity, air flow, lighting, air quality and acoustics. Cost-effective Open–plan Environment (COPE) User Satisfaction Questionnaires were distributed on-site at the time of the measurements. University of California at Berkeley's Center for the Built Environment (CBE) user satisfaction questionnaires were distributed online to all employees on those floors, either before or after the field measurements. Technical Attributes of Building Systems (TABS) were recorded on each of the office floors studied, using a consistent walk-through protocol.

NEAT COMPONENTS

The GSA study used the five components of the National Environmental Assessment Toolkit (NEAT):

NEAT Spot Measurements and COPE Questionnaire: The NEAT measurement cart was developed by the CBPD with GSA support. The cart makes the following measurements: temperature at three heights; relative humidity; CO_2 and CO; total particulates; and Volatile Organic Compounds (VOC) levels. While the cart is being used to record physical measurements in a workstation, the occupant is asked to complete the 2-page, 25-question COPE User Satisfaction Questionnaire to assess satisfaction on the day of the physical measurements. The COPE questionnaire was developed by the National Research Council Canada.

Workgroup Measurements: In addition to spot measurements, 24-hour continuous measures were taken in several locations within the workgroup to enhance the environmental profile. An Airquity Optima system was used to measure temperature; relative humidity, CO_2 and CO; large and small particulates, total VOC; radon; and ozone. To add depth to these findings, additional measurements were taken at 3 different workstations, continuously measuring temperature, relative humidity, CO_2 and CO, total particulates, and VOC over the same 24-hour period.

On-line User Satisfaction Questionnaire: A 68-question survey developed by CBE with GSA support was used to evaluate occupant long-term satisfaction with personal workstation spatial characteristics: thermal comfort, air quality, lighting and views, acoustic quality, and maintenance. Additional questions assessed occupant perceptions of workspace functionality, community, and well-being. Distributed over the Internet to all employees in the workgroup being studied, the survey typically preceded the field evaluation.

TABS Walk-through Protocol: To achieve its goals, the GSA Workplace Performance Study had to consistently link objective physical measurements and subjective occupant responses with the technical attributes of the building systems in which the occupants were working. To identify how these different attributes relate to the outcomes measured or reported, CMU developed an expert walk-through protocol, TABS. Its use ensures that the data captured across the federal workplace sampled are truly comparable.

User Collaboration Satisfaction Questionnaires: A two-page questionnaire developed by CBPD was given to on-site end users to address the tension between individual and collaborative work.

Measurements Taken at Each Workstation*	Standards/Thresholds
Temperature at 4 feet *(spot & 24 hr. continuous)* Temperature at 2 feet Temperature at floor level Horizontal and vertical radiant temperature difference	ASHRAE 55-2004 cooling and heating season
Relative humidity *(spot & 24 hr. continuous)*	ASHRAE 62-2004
Air flow rate at floor and 4 foot level	ASHRAE 55-2004
CO_2 concentration *(spot & 24 hr. continuous)*	ASHRAE 62-2004, EPA IAQ specs
CO concentration *(spot & 24 hr. continuous)*	EPA IAQ specifications
Small and large particulates *(24 hr. continuous)*	HPSH based on EPA IAQ specs
TVOC index, Ozone, Radon *(24 hr. continuous)*	EPA IAQ specifications
Light level*:* on primary work surface *(w/task light off)* on keyboard *(w/task light off)* on monitor *(w/task light off)* on primary work surface *(w/task light on)* on keyboard *(w/task light on)* on monitor *(w/task light on)* Calculated luminance/brightness contrast ratio	IESNA RP-1-04
Background noise level (RC) and noise quality (QAI)	ASHRAE Applications Handbook 2003
Partition noise reduction (dBA) Privacy Index (PI) Calculated: Predicted Occupancy Dissatisfaction	ASTM E1130-02

* spot measurements unless noted

FOR MORE INFORMATION

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