Tracking Chart – Energy TAC

Mod #	Proponent	Chapter	Section	Summary	Approved as Submitted
8045	Joseph Belcher for FHBA	4	401.2	Eliminated mandatory automatic controlled receptacles.	

Commission Action

☐ AS ☐ AM ☐ I

☐ W ☐ NAR

Comment

☐ 1. Support comment. Comment sufficiently addresses the TAC's concern(s).		XX 2. Do Not Support comment. Comment does not address the TAC's concern(s).	G1
☐ 3. No comment is needed.		☐ 4. Straw Poll.	0 Yes – 8 No

EN8045

Date Submitted 12/12/2018
Chapter 4
Section 401.2
Affects HVHZ Yes
Proponent Joseph Belcher for FHBA
Attachments No
TAC Recommendation Approved as Submitted
Commission Action Pending Review

Comments

General Comments **Yes**

Alternate Language **No**

Related Modifications

Summary of Modification

Eliminated mandatory automatic controlled receptacles.

Rationale

ASHRAE 90.1 requires at least 50% of electric receptacles (125 volt, 15-and 20-amp) be on a control that cuts power off after some period of time or when areas are unoccupied. The provisions apply to receptacles in private offices, conference rooms, copy or printer rooms, break rooms, classrooms and individual workstations.

Numerous Florida electrical contractors report that there are significant associated costs to compliance. There is concern that in actual practice there is very little energy saved. The reasons for potentially diminished savings depend upon occupants choosing to use the controlled receptacles and upon the actual power saved when chosen devices are automatically switched off.

Persons working in the spaces tend to not use the controlled outlets. Reasons cited are they do not want to risk the receptacle turning off while they are using computers, telephone chargers, radios and other devices. Many workers intentionally leave personal computers on to allow access from outside the work location. Break rooms typically have microwaves, refrigerators, other appliances with clocks, coffee pots with warmer plates and controlled receptacles based on occupancy can create a myriad of problems. The controlling devices are considerably more expensive than a typical uncontrolled outlet with little chance of return through energy savings.

Electric contractors and others express concerns about the increased use of extension cords and power strips to avoid the controlled receptacles. There is also a serious potential for uncontrolled circuits to be overloaded with outlet multipliers and other devices meant for temporary use. The cumulative effect is believed to be increasing fire hazards. This proposal will eliminate the mandatory use of controlled receptacles. Building owners would still have the option to use such controls on their own volition

Fiscal Impact Statement

Impact to local entity relative to enforcement of code

No impact.

Impact to building and property owners relative to cost of compliance with code

Should result in reduced construction costs for property owners.

Impact to industry relative to the cost of compliance with code

Will result in reduced construction costs for industry.

Impact to small business relative to the cost of compliance with code

Will result in reduced construction costs for small business.

Requirements

Has a reasonable and substantial connection with the health, safety, and welfare of the general public

The change impacts public health and safety by eliminating a provision that indirectly may increase potential fire hazards.

Strengthens or improves the code, and provides equivalent or better products, methods, or systems of construction

The change improves the code by eliminating a provision that indirectly may increase potential fire hazards.

Does not discriminate against materials, products, methods, or systems of construction of demonstrated capabilities

The change does not discriminate against materials, products, methods, or systems of construction of demonstrated capabilities.

Does not degrade the effectiveness of the code

The proposed change upgrades the effectiveness of the code.

2nd Comment Period

EN8045-G1

Proponent Bryan Holland **Submitted** 5/21/2019 **Attachments** Yes

Comment:

Please reconsider this proposed modification and vote "quot;no affirmative recommendation". The section of the code being modified is not appropriate. C401.2.1 applies to those buildings elected by the owner or design professional to comply with ASHRAE 90.1 by choice. However, those who elect to comply with one of the other two compliance paths (C401.2.2 or C401.2.3) will still have to comply with C405.6 as this is a mandatory provision. Why would we want to exempt automatic receptacle requirements in ASHRAE 90.1 compliant buildings while still mandating this requirement in FBC, Energy Conservation compliant buildings? Besides, the substantiation provided by the proponent is unfounded and inaccurate. Please see the rationale and substantiation attached for the FACTS and TRUTH about automatic receptacle control.

C401.2 Application. Commercial buildings shall comply with one of the following:

1. The requirements of ANSI/ASHRAE/IESNA 90.1, excluding section 9.4.1.1(g) and section 8.4.2 of the standard.
2. The requirements of Sections C402 through C405. In addition, commercial buildings shall comply with Section C406 and tenant spaces shall comply with Section C406.1.1.
3. The requirements of Sections C402.5, C403.2, C404, C405.2, C405.3, C405.5, C405.6 and C407. The building energy cost shall be equal to or less than 85 percent of the standard reference design building.

LBNL-53729-Revised

After-hours Power Status of Office Equipment and Energy Use of Miscellaneous Plug-Load Equipment

Judy A. Roberson, Carrie A. Webber, Marla C. McWhinney,
Richard E. Brown, Margaret J. Pinckard, and John F. Busch

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May 2004

To download this paper and related data go to:
http://enduse.lbl.gov/Projects/OffEqpt.html

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Abbreviations, Acronyms, and Glossary of Terms

As Used in This Report

CRT cathode ray tube (monitor)

CPU central processing unit

ICS integrated computer system, in which computer and monitor share a power cord, (e.g., an LCD monitor powered through a computer) and may also share a housing (e.g., an Apple iMac)

ILPS in-line power supply: a type of external power supply found on the cord between the plug and the device; aka "fat snake" because it looks like the power cord swallowed a box or cylinder

LBNL Lawrence Berkeley National Laboratory (aka LBL or Berkeley Lab)

LCD liquid crystal display (monitor)

ME miscellaneous (plug-load) equipment

MFD multi-function device: a unit of digital equipment that can perform at least two of the following functions: copy, fax, print, scan

OE office equipment

OEM original equipment manufacturer

OS operating system (e.g., Windows XP or Mac OS X)

PC personal computer: a generic term that includes laptop computers, desktop computers and integrated computer systems; it includes both Apple and Intel-architecture machines

PDA personal digital assistant; a cordless (i.e., rechargeable) hand-held computer device

PIPS plug-in power supply: a type of external power supply that is incorporated into the cord's plug; aka "wall wart"

PM power management: the ability of electronic equipment to automatically enter a low power mode or turn itself off after some period of inactivity; PM rate is the percent of units *not off* that are in low power.

PM rate: the extent to which a given sample or type of equipment is *actually found* to have automatically entered a low power mode or turned itself off.

PM Enabling rate: the extent to which *settings in the user interface* of a given sample or type of equipment indicate the equipment is set to automatically enter low power or turn itself off.

XPS external power supply: a power supply external to the device that it powers; a voltage regulating device incorporated into either the power cord or the wall plug of a device

Acknowledgements

This study would not have been possible without the support of the ENERGY STAR Office Equipment and Commercial Buildings programs, as well as the cooperation of the owners and facility managers of the businesses, institutions, and organizations that participated, and whose anonymity we promised to maintain.

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Judy A. Roberson, Carrie A. Webber, Marla C. McWhinney, Richard E. Brown, Margaret J. Pinckard, and John F. Busch

Abstract

This research was conducted in support of two branches of the EPA ENERGY STAR program, whose overall goal is to reduce, through voluntary market-based means, the amount of carbon dioxide emitted in the U.S. The primary objective was to collect data for the ENERGY STAR Office Equipment program on the after-hours power state of computers, monitors, printers, copiers, scanners, fax machines, and multi-function devices. We also collected data for the ENERGY STAR Commercial Buildings branch on the types and amounts of "miscellaneous" plug-load equipment, a significant and growing end use that is not usually accounted for by building energy managers. For most types of miscellaneous equipment, we also estimated typical unit energy consumption in order to estimate total energy consumption of the miscellaneous devices within our sample. This data set is the first of its kind that we know of, and is an important first step in characterizing miscellaneous plug loads in commercial buildings.

The main purpose of this study is to supplement and update previous data we collected on the extent to which electronic office equipment is turned off or automatically enters a low power state when not in active use. In addition, it provides data on numbers and types of office equipment, and helps identify trends in office equipment usage patterns. These data improve our estimates of typical unit energy consumption and savings for each equipment type, and enables the ENERGY STAR Office Equipment program to focus future effort on products with the highest energy savings potential.

This study expands our previous sample of office buildings in California and Washington DC to include education and health care facilities, and buildings in other states. We report data from sixteen commercial buildings in California, Georgia, and Pennsylvania: four education buildings, two medical buildings, two large offices (> 500 employees each), three medium offices (50-500 employees each), and five small business offices (< 50 employees each). Two buildings are in the San Francisco Bay area of California, nine (including the five small businesses) are in Pittsburgh, Pennsylvania, and five are in Atlanta, Georgia.

Introduction

Since the 1980s there has been continual growth in the market for electronic office equipment, particularly personal computers and monitors, but also printers and multi-function devices, which are replacing discrete copiers, fax machines and scanners in some office environments. According to 2003 projections by the Department of Energy, annual energy use by personal computers is expected to grow 3% per year, and energy use among other types of office equipment is expected to grow 4.2%; this growth is in spite of improvements in energy efficiency, which are expected to be offset by "continuing penetration of new technologies and greater use of office equipment" (EIA 2003).

In 1992 the US Environmental Protection Agency (EPA) launched the voluntary ENERGY STAR program, designed to curb the growth of CO_2 emissions by labeling the most energy-efficient electronic products for the mutual benefit of manufacturers, consumers, and the environment.[1] The first products to be labeled were computers and monitors; printers were added in 1993, fax machines in 1994, copiers in 1995, and scanners and multi-function devices in 1997 (EPA/DOE 2003). Continued improvement in energy savings among office equipment remains a focus of the ENERGY STAR program, which updates its product specifications as necessary to respond to changes in technology, energy consumption, and usage patterns.

ENERGY STAR labeled office equipment reduces energy use primarily through power management (PM), in which equipment is factory-enabled to automatically turn off or enter low power (any power level between off and on) after some period of inactivity, usually 15 or 30 minutes. Most office equipment is idle more often than it is active; among equipment that users tend to leave on when not in use, such as shared and networked devices, PM can save significant energy. ENERGY STAR devices have a large market share, but the percentage that actually power manage is lower for several reasons. Power management is sometimes delayed or disabled by users, administrators, or even software updates that change the factory settings in the interface; in addition, some network and computing environments (e.g., the Windows NT operating system) effectively prevent PM from functioning.

To accurately estimate energy savings attributable to the ENERGY STAR program, and target future efforts, current data are needed on the extent to which each type of office equipment is turned off or successfully enters low power mode when idle. Combined with measurements of the energy used in each power state, we can estimate typical unit energy consumption (UEC), which, combined with number of units currently in use, provides an estimate of total energy use, and program savings (Webber, Brown et al. 2002).

In our ongoing technical support of the ENERGY STAR program, the Energy Analysis Department at Lawrence Berkeley National Lab (LBNL) has conducted after-hours surveys (aka night-time audits) of office equipment in commercial buildings. Our previous series of surveys was conducted during the summer of 2000; it included nine buildings in the San Francisco Bay area and two in the Washington DC area. We recruited and surveyed a diversity of office types and documented just over 100 computers per site, on average. We collected data on the types, power states and PM delay settings of ENERGY STAR labeled office equipment (computers, monitors, copiers, fax machines, printers, scanners and multi-function devices). The methods and results of that study were reported previously (Webber, Roberson et al. 2001).

[1] The ENERGY STAR® program has expanded to include residential appliances and heating and cooling equipment, consumer electronics, building materials and components, refrigeration equipment, commercial buildings and new homes. Since 1996 it has been jointly administered by the U.S. EPA and DOE (http://energystar.gov/).

In that study we also recorded (but did not report) numbers of some 'miscellaneous office equipment,' such as computer speakers, external disk drives, portable fans and heaters, boomboxes, and battery chargers.

In this report, we present the results of our most recent (2003) after-hours survey of commercial buildings, which expanded on the previous study to include:

- buildings in Pittsburgh, Pennsylvania and Atlanta, Georgia,
- education buildings, health care buildings, and small offices, and
- an inventory of miscellaneous plug-load equipment.

As part of our ongoing effort to improve the accuracy of data used to evaluate the ENERGY STAR program, we wanted to capture data from a wider range of commercial building types and geographic regions. While our sample is not large enough to distinguish regional differences in equipment night-time or after-hours power status, we hope to improve the robustness of our data by increasing its geographic diversity. Also, because office equipment is not confined to offices or office buildings, we wanted to capture data from other types of commercial buildings, such as schools, which also have significant numbers of computers.

Collecting data on after-hours power status involves visiting buildings when most employees are gone. Given the difficulty of arranging after-hours access to most commercial buildings, we used this opportunity to simultaneously collect data for the ENERGY STAR Commercial Buildings program on the types and numbers of miscellaneous plug-load equipment, and to develop a taxonomy by which to categorize them. These data allow us to begin to better characterize the large 'plug-load' building energy end use category.

Methodology

The protocol used in this series of surveys changed from that of 2000 because of the need to develop a data collection protocol for miscellaneous equipment, and then integrate it with our office equipment protocol.

Building Sample

Table 1 below outlines the buildings in our sample, which are identified by a letter; for this purpose the small businesses are aggregated into one 'small office.' Appendix A describes them in more detail, but only in generic terms, to preserve the anonymity of occupants. As in 2000, our initial target was to collect data on at least 1,000 computers. In selecting types and numbers of commercial buildings to comprise that sample, we referred to data on computer densities provided by the Commercial Building Energy Consumption Survey (CBECS) (EIA/CBECS 2002). According to CBECS, in 1999, 74% of the U.S. population of computers were found among office, education, and health care buildings; therefore, our building recruitment effort focused on these three types of buildings. CBECS further characterizes offices by number of employees: 0-19 (small), 20-499 (medium), and 500+ (large).

To familiarize ourselves with what to expect (in recruitment effort and equipment found) in schools and health care buildings, we began by surveying a high school and a medical clinic in the San Francisco area. We then recruited and surveyed a variety of buildings in Pittsburgh in April, and Atlanta in June 2003.

Site recruitment is one of the most difficult and time consuming aspects of commercial building surveys. Usually it involves cold-calling from a list of prospective business or building types (e.g., high schools), briefly describing our research activity, and trying to connect with the person who is able and willing to grant after-hours access, which involves providing a key and/or escort. Most facilities have real concerns about safety, security, and privacy (e.g., of client or patient records), which of course must be addressed.

In each building, we surveyed as much area as possible in four hours or until we covered the area accessible to us, whichever came first. At two sites we surveyed a single floor, at four sites we surveyed the entire space available to us, and at the remaining six sites we surveyed portions of two or three floors. In general, the greater the density and variety of equipment found, the less area we covered in four hours. Floor areas are approximate gross square feet, based on floor plans or information from facility managers.

Table 1. Building Sample and Computer Density

site	state	building type	occupancy	in area surveyed (approximate no.)			computer density per	
				computers	ft^2	employees	1000 ft^2	employee
A	GA	education	university classroom bldg	171	28,000	n/a	6.1	n/a
B	PA	medium office	non-profit headquarters	182	55,000	128	3.3	1.42
C	GA	large office	corporate headquarters	262	28,000	120	9.4	2.18
D	CA	education	high school	112	40,000	n/a	2.8	n/a
E	GA	medium office	business consulting firm	37	22,000	70	1.7	0.53
F	PA	education	high school	248	100,000	n/a	2.5	n/a
G	CA	health care	outpatient clinic	177	45,000	n/a	3.9	n/a
H	GA	medium office	information services dept	153	24,000	76	6.4	2.01
J	PA	health care	private physicians' offices	56	26,000	n/a	2.2	n/a
K	PA	small office	5 small businesses combined	117	20,000	77	5.9	1.52
M	PA	large office	corporate headquarters	73	40,000	125	1.8	0.58
N	GA	education	university classroom bldg	95	20,000	n/a	4.8	n/a
			total	**1,683**	**448,000**	n/a = not available		

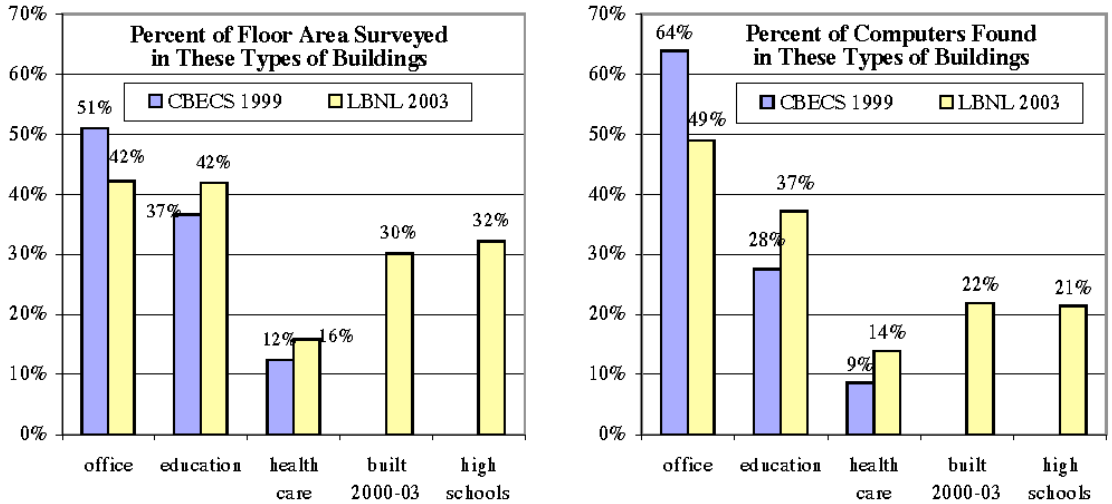
Our characterization of offices differs slightly from that of CBECS. By our definition a small office has <50 employees, a medium office has 50-500 employees, and a large office has >500 employees on site. Also, CBECS appears to classify offices by the number of employees per building, while we classify them by the number of employees per location. For example, our site E is a 'medium office' (50-500 employees) that occupies one floor of a high-rise office tower; however, CBECS might consider the same office to be part of a 'large office' (over 500 employees) that includes all offices within the entire building.

Our 'small office' is actually aggregated results for five small businesses in three different buildings: (1) a graphics and printing business, (2) an environmental consulting firm, (3) a commodity brokerage firm, (4) a software development firm, and (5) an engineering firm. Their number of employees ranged from 4 to 25, with a collective total of 77 employees.

For the six offices in our sample, Table 1 also shows the approximate density of computers by gross square feet as well as per employee. We do not have number of employees (or computer density per employee) for education and medical facilities. For high schools, where the number of students is known, equipment density per student could be a useful metric if we had surveyed the entire building, which we did not. The number of students regularly using a university classroom building, as well as the number of employees in both education and medical buildings is much more variable and difficult to determine.

Although we used the CBECS data as a starting point in our building selection and recruitment efforts, our resulting building sample does not necessarily correspond to the much larger CBECS building sample. Figure 1 below compares our building sample to CBECS, based on the sum of floor area surveyed and number of computers found among all office, education, and health care buildings in each sample. Compared to CBECS, offices are somewhat under-represented in our current sample, while education and health care buildings are somewhat over-represented. In addition, new buildings and high schools may be over-represented in our building sample, though we don't have corresponding CBECS data for comparison.

Figure 1. Comparison of LBNL and CBECS Commercial Building Samples



Survey Protocol

Each survey takes four people up to four hours to complete, and occurs on a weekday evening or weekend. We usually work in two teams of two people, with one calling out information and the other recording it. Using a floor plan, clipboard, flashlight and tape measure, we systematically record each plug-load device. The flashlight helps in tracing cords to plugs, and the tape is used to measure TV and monitor screen sizes. Our data collection is as unobtrusive as possible; we don't turn computers on or off or access any programs, settings, or files. If a workspace is occupied or obviously in use, we skip it and return later, if possible.

Office Equipment Data Collection

For our purposes in this study, office equipment includes the following equipment categories and types:

computers: desktop, laptop (notebook or mobile), server, and integrated computer system (ICS);
monitors: cathode ray tube (CRT), and liquid crystal display (LCD);
printers: impact, inkjet, laser, thermal, solid ink, and wide format;
fax machines: inkjet, laser, and thermal;
copiers;
scanners: document, flatbed, slide, and wide format; and
multi-function devices: inkjet and laser.

For each unit of office equipment, we recorded the make (brand) and model as it appears on the front or top of the unit (we did not record information from the nameplate on the bottom or back of the unit). We recorded the diagonal measurement, to the nearest inch, of monitor screens, except those of laptops (note: for CRT monitors this measurement is smaller than the nominal screen (or tube) size). For laser printers and MFDs we scrolled through the menu options available in the user interface to find the "power save delay setting," which usually ranges from 15 minutes to "never."

We tried to record each unit of office equipment that had an external power supply (XPS). These devices offer significant potential for energy efficiency improvement because they draw power even when the unit of which they are part is turned off or disconnected (e.g., when a laptop computer or cell phone is removed from its charger, which remains plugged in). We distinguish two types of external power supply: a plug-in power supply (PIPS), in which an AC/DC voltage transformer is incorporated into the plug, and an in-line power supply (ILPS), which is incorporated into and appears as an enlarged part of the power cord. We also tried to record whether or not each printer, copier, and MFD was connected to a network via cable (to the extent that networks become wireless, network connection will become more difficult to determine).

The power state of each unit was recorded as on, low, off, or unplugged (exception: we did not record units that were unplugged if it appeared they were never used). Although some office equipment, particularly copiers, may have features that enable them to turn off automatically or enter low power manually (by user action), we assume that the vast majority of units found off were turned off manually (i.e., by a user) and that units found in low power entered that state automatically (i.e., without user action).

If a monitor/computer pair were both on, we recorded the screen content; the most common occurrences are a screensaver, application, log-in or other dialog box (e.g., "It is now safe to turn off your computer"). When a monitor is off and the computer to which it is connected is not, it can be difficult to tell whether the computer is on or in low power. The method we used to determine a PC's power state is outlined in Appendix B; in short, a clampmeter is used to measure relative current in the computer power cord before and after initiating a computer wake function, such as touching the mouse or keyboard (McCarthy, 2002).

The power state of a laptop computer is usually difficult to determine, unless it is in use and obviously on. A closed laptop has few external indicators, and those that are present are often ambiguous and inconsistent (e.g., between brands or models). In terms of improving our estimates of laptop unit energy consumption, the most relevant data are the amount of time each laptop spends plugged in, and how often its battery is (re)charged. Therefore, we recorded, at a minimum, whether or not each laptop was plugged in.

In this report the term 'computer workstation' refers to any combination of computer(s) and monitor(s) physically used by one person at a time; generally, there is a workstation associated with each office chair. Workstation configurations vary widely; most common is one desktop computer connected to one monitor, but we have noticed growing numbers of other configurations, including multiple computers with one monitor, multiple (usually LCD) monitors with one computer, and laptops used with a docking station and monitor. In this series of surveys, we identified each computer workstation by a unique number; i.e., all components of each workstation were identified by the same number. We did this for two reasons: first, to facilitate subsequent analysis of the relationship between computer and monitor power states; and second, to be able to characterize the variety of workstations found. These analyses are discussed in the Results.

Miscellaneous Equipment Data Collection

'Miscellaneous equipment' (ME) refers to plug-load devices whose energy use is not usually accounted for by building energy managers because they are portable, often occupant-provided units whose number, power consumption and usage patterns are largely unknown. All ME in this report, including lighting, is plug-load, as opposed to hard-wired, although for some equipment (e.g., commercial refrigerators) we did *assume* a plug. The sheer variety of ME necessitates development of a taxonomy by which it can be categorized and summarized. Appendix C presents our current miscellaneous equipment taxonomy.

For each unit of miscellaneous equipment we recorded any information (e.g., power state or rated power) that could be used to estimate unit energy consumption. For lighting we recorded lamp type (e.g., halogen), wattage, and fixture type (desk, floor, track, etc.). For battery chargers, we noted the portable component (drill, oto-opthalmoscope, walkie-talkie. etc.) and whether the charger was empty or full. For vending machines, we recorded temperature and product (e.g., cold beverage) and any lighting. For unknown equipment we noted make and model for later determination of identity and power specifications.

As with office equipment, we noted if there was a PIPS or ILPS. We also recorded PIPSs and ILPSs that were plugged in but unattached to equipment (such as a PIPS used to charge an absent cell phone) and those whose equipment could not be identified, such as among a maze of cords in a server room. Nevertheless, we undoubtedly missed some, so our reported number of PIPSs and ILPSs is actually a conservative estimate.

Limitations of This Methodology

One advantage of conducting after-hours building walk-throughs to collect data on office equipment power status is that a good variety and number of buildings can be recruited and surveyed. On the other hand, the data collected represent a snapshot in time, and do not capture variations in user behavior over time, which would require automated long-term time series metering of equipment power state and power levels.

This is our most robust sample of buildings to date for collecting data on the after hours power status of office equipment. It includes data on 1,683 computers (including desktops, ICSs, laptops and servers) and about 448,000 ft^2 in 12 commercial buildings, including schools and health care facilities in California, Georgia, and Pennsylvania. (In comparison, our previous (2000) survey included 1,280 computers in 11 office buildings in California and Washington DC.) However, we do not suggest that this sample is representative of commercial buildings as a whole or in part (e.g., by type, size, age, or location), or that the results presented here are statistically significant. It is a record of what we found that we hope will be of use to policy makers, researchers, and building managers.

Results and Discussion

Equipment Density

Table 2 shows the number and density, per 1000 approximate gross square feet, of office equipment, miscellaneous equipment, and the sum of OE and ME in each building, and for all buildings. Our survey captured data on over 10,000 units of equipment, including almost 4,000 units of office equipment.

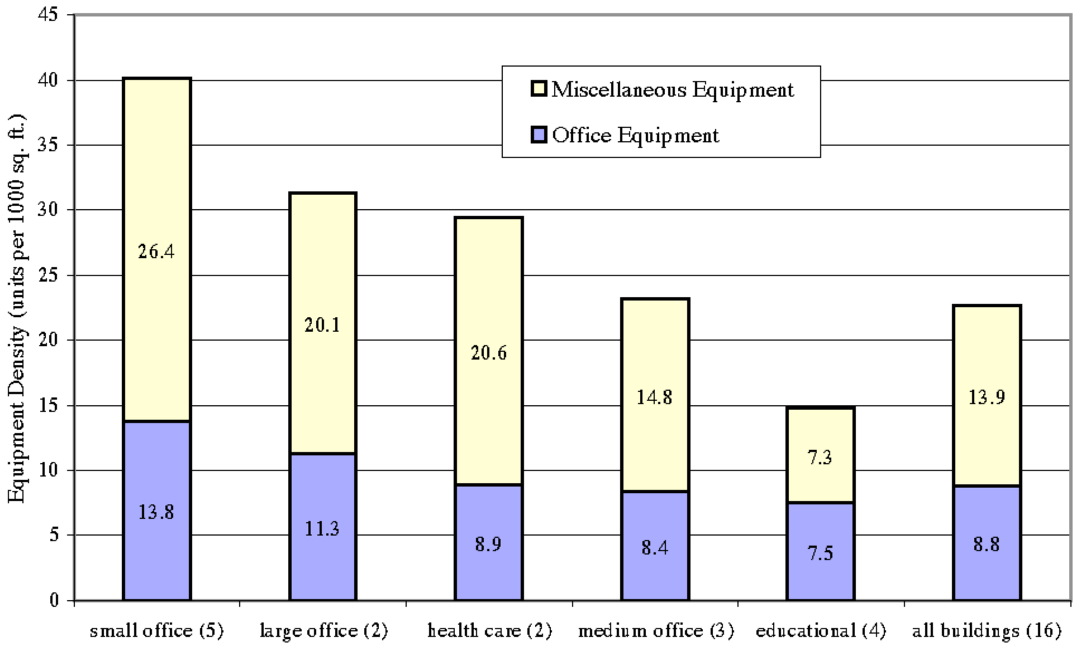
Table 2. Office and Miscellaneous Equipment: Number of Units and Density
sorted by Density of Office Equipment (units/1000 ft^2)

		Number of Units			Density (units/1000 ft^2)			Density (units/employee)		
bldg type	**site**	OE	ME	OE+ME	OE	ME	OE+ME	OE	ME	OE+ME
medium office	E	98	441	**539**	4.5	20.0	**24.5**	1.4	6.3	7.7
education	F	574	596	**1,170**	5.7	6.0	**11.7**			
large office	M	227	753	**980**	5.7	18.8	**24.5**	1.8	6.0	**7.8**
education	D	258	291	**549**	6.5	7.3	**13.7**			
health care	J	171	458	**629**	6.6	17.6	**24.2**			
medium office	B	410	422	**832**	7.5	7.7	**15.1**	3.2	3.3	**6.5**
education	N	204	234	**438**	10.2	11.7	**21.9**			
health care	G	460	1,002	**1,462**	10.2	22.3	**32.5**			
education	A	377	259	**636**	13.5	9.3	**22.7**			
small office	K	275	528	**803**	13.8	26.4	**40.2**	3.6	6.9	**10.4**
medium office	H	340	630	**970**	14.2	26.3	**40.4**	4.5	8.3	**12.8**
large office	C	540	612	**1,152**	19.3	21.9	**41.1**	4.5	5.1	**9.6**
all buildings		**3,934**	**6,226**	**10,160**	**8.8**	**13.9**	**22.7**	**3.2**	**5.7**	**8.9**

Note that the numbers of miscellaneous equipment units in Table 2 are lower than those in Appendix D because Table 2 does not include plug-in and in-line power supplies, while Appendix D does.

Figure 2 illustrates office and miscellaneous equipment density (per 1000 square feet), by building type.

Figure 2. Office and Miscellaneous Equipment Density, by Building Type (and number)



From Table 2 we see that the two buildings with the lowest combined equipment density are high schools, and Figure 2 shows that education buildings in our sample had the lowest equipment densities overall. Among our sample of 12 buildings, building types with the highest densities are small and large offices. We suggest that small offices may have high equipment density because every office needs certain devices (e.g., copier, fax machine, microwave oven, refrigerator), regardless of how many (or few) people share it. Medium offices exhibited a range of density (see Table 2, sites B, H), but on average their office equipment density is similar to and their miscellaneous equipment density is lower than that of health care facilities.

Closer examination of the results for each building reveals some underlying trends. For example, the only two buildings with a computer density less than 2 per 1000 ft^2 (from Table 1) were offices (one medium, one large) whose employees tend to rely on laptop computers, most of which were absent during our visit; one of these companies *requires* employees to take their laptops home or lock them up when not at work.

Office Equipment

Our sample includes data on the power state of 1,453 desktop computers (well above our target of 1,000), 1,598 monitors, 353 printers, 89 servers, 79 MFDs, 47 fax machines, 45 ICSs, 34 scanners, and 33 copiers. Among printers, our discussion of results will focus on the 158 laser and 123 inkjet printers found.

Among all buildings, computer density ranges from 1.7 to 9.4 per 1000 ft^2 gross floor area, (see Table 1). Among office buildings only, computer density ranges from 0.53 to 2.18 per employee. Office equipment density ranges from 4.5 to 19.3 units per 1000 ft^2 gross floor area, with an average of 8.8 (see Table 2). Among offices, office equipment density ranges from 1.4 to 4.5 units per employee, with an average of 3.2.

When analyzing the numbers of equipment in each power state, we are primarily interested in two values: turn-off rates and power management rates. 'Turn-off rate' is the percent of each equipment type that is turned off, while 'PM rate' is the percent of those *not off* that are in low power.

Table 3 shows the numbers of each type of office equipment, and their after-hours power state. Table 3 does not include laptop computers, units that were unplugged, or units whose power state was unknown.

Table 3. Office Equipment: After-hours Power States

Equipment		Number				Percent			
Category	**Type**	**on**	**low**	**off**	**sum**	**on**	**low**	**off**	**PM rate**
computers	desktop	869	60	524	1453	60%	4%	36%	6%
	server	87		2	89	98%	0%	2%	n/a
	ICS	7	11	27	45	16%	24%	60%	61%
monitors	CRT	259	648	422	1329	19%	49%	32%	71%
	LCD	56	164	49	269	21%	61%	18%	75%
printers	laser	53	81	24	158	34%	51%	15%	60%
	inkjet	86		37	123	70%	n/a	30%	n/a
	impact	16		6	22	73%	n/a	27%	n/a
	thermal	31		7	38	82%	n/a	18%	n/a
	wide format	2		6	8	25%	0%	75%	0%
	solid ink	1	3		4	25%	75%	0%	75%
MFDs	inkjet	9	4	3	16	56%	25%	19%	31%
	laser	36	14	13	63	57%	22%	21%	28%
copiers	all	12	5	16	33	36%	15%	48%	29%
fax machines	all	44	3		47	94%	6%	0%	6%
scanners	all	8	12	14	34	24%	35%	41%	60%

Note: "PM rate" is the percent of units *not off* that were in low power.

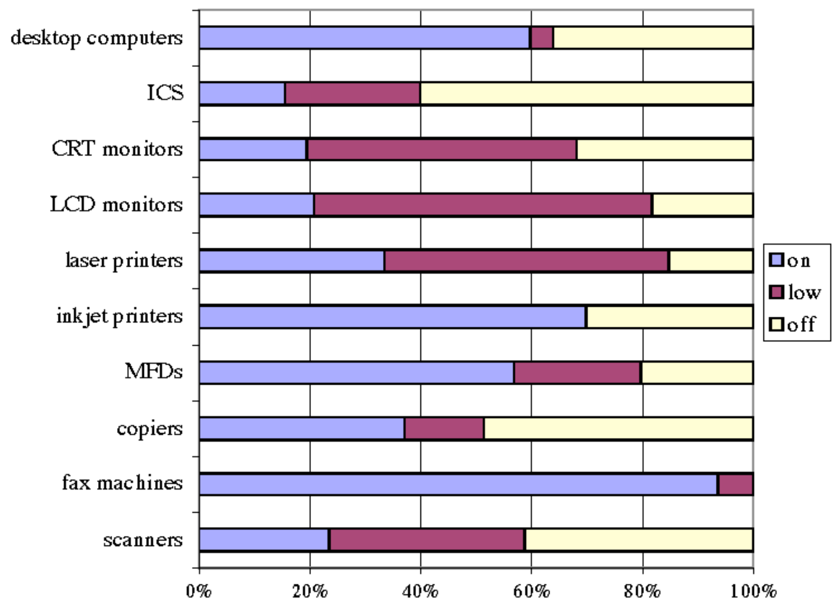
Not surprisingly, turn-off rates were lowest among fax machines and server computers. Turn-off rates were highest for integrated computer systems (60%), copiers (48%), and scanners (41%). PM rates were highest among LCD monitors (75%), CRT monitors (71%), ICSs (61%), scanners (60%), and laser printers (60%).

The lowest power management rates were among desktop computers and fax machines (6% of each). Because copiers and MFDs often have long (2-4 hour) PM delay settings that may not have elapsed at the time of our visit, PM rates in Table 3 for this equipment should be considered a minimum or lower bound. Figure 3 (below) graphically shows the breakdown by power state of each major type of office equipment.

Computers

We categorized computers as either desktop, integrated computer systems, servers, or laptops. Among 1,453 desktop computers the turn-off rate was 36%; it ranged from 5% (at Site E, medium office) to 67% (at Site B, medium office). Only 6% of all desktop computers that were not off were in low power. This PM rate is similar to the 5% rate found in a previous study (Webber, Roberson et al. 2001). Among the 45 ICSs in Table 3 the turn-off rate was 60%, and the PM rate was 61%. However, it is possible that of the 11 ICSs found in low power, only the display (but not the CPU) was in low power.

Figure 3. Office Equipment Power States



Among education buildings in our sample, the majority of the desktop computers, monitors and ICSs were found in classrooms clearly dedicated to computer-based learning. These "computer labs" typically have a 1:1 ratio between computers and chairs. Among the two high schools, 65% of desktop computers and ICSs were found in computer labs with at least 15 (and up to 77) computers each; among the two university classroom buildings, 68% of desktop computers and ICSs were found in computer labs with at least 15 (and up to 57) computers each. Because a single instructor likely controls the after-hours power status of all equipment in these rooms, and also because school buildings in general experience more 'after-hours' per year than other buildings, computer labs present a target for energy-efficiency efforts in schools.

Laptop Computers

There are 50 laptop computers in our sample, and we recorded information on the power state of 37. Of those 37, all but two (or 95%) were plugged in, either through their power cord or a docking station. Nine (or 24%) of the 37 laptops were clearly on; i.e., their display showed a desktop, application, or login screen.

Sixty percent (60%, or 21) of the 35 laptops that were plugged in were plugged into docking stations.[2] Of 107 docking stations found, 20% (21) were 'full', i.e., contained laptops, while 80% (86) were 'empty,' or without laptops. Those empty docking stations are evidence of at least 86 more laptops that were absent at the time of our visit. In addition, we found 35 power cords with ILPSs that we identified as "laptop charger, empty" (which we consider in the 'power' category of ME). Combined with 50 laptops and 86 empty docking stations found, we conclude that at least 171 laptop computers are in use among our sample of buildings. Of course, this number does not include (and we did not attempt to estimate) the number of people who take both their laptop and its power cord/battery charger home or lock them up at night.

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[2] Docking stations are in our 'peripheral' miscellaneous equipment category; laptop computers are office equipment.

If we compare this minimum number of laptop computers to the total number of non-server computers in our sample, from Table 3 (1,453 desktops + 45 ICSs, + 171 laptops = 1669 total), laptops comprise approximately 10% of non-server computers found in our survey; again, this is a conservative estimate.

Some offices appear to have largely switched from desktop to laptop computers. Table 4 shows that in two (of six) offices in our sample – one large and one medium office – the sum of laptop computers, empty docking stations and empty laptop battery chargers (ILPSs) outnumbered the desktop computers found.

Table 4. Ratio of Laptop to Desktop Computers at Two Sites

Site	no. of desktop computers	number of laptop computers			
		laptops found	empty docking stations	empty laptop chargers	**estimated total**
E	**20**	4	11	9	**24**
M	**41**	26	40	9	**75**

Monitors

The average turn-off rate among 1,329 CRT monitors was 32%; it ranged from 17% at Site E (medium office) and N (university) to 62% at Site D (high school). 71% of CRT monitors that were not off were in low power. Among the 269 LCD monitors in Table 3 the turn-off rate was 18% and the PM rate was 75%.

Assigning a unique number to each computer/monitor workstation enabled us to analyze the relationship between computer power state and monitor power state. Table 5 shows the results of that analysis. (Note: Table 5 does not include monitors connected to more than one computer.)

Table 5. Analysis of Monitor Power Management by Computer Power State

Computer	Computer Power state	No.	Monitor Power State: Off	Monitor Power State: Low	Monitor Power State: On	Monitor Power Management *: Monitor PM Rate (computer is off or in low power)	Monitor Power Management *: PC-initiated Monitor PM Rate (computer is on)
Desktop	Off/no signal	433	184	244	5	98%	
	Low	59	4	53	2	96%	
	On	689	154	286	249		53%
Laptop **	Absent or empty docking station	55	13	42	0	100%	
	Plugged-in or in docking station	23	4	15	4	79%	
Server	On	32	14	10	8		56%

*Monitor Power Management is the percent of monitors *not off* that are in low power
** These data refer to external monitors connected to laptop computers, not to the laptop display.

Computers can initiate low power modes in ENERGY STAR monitors. Power management settings in the computer operating system (OS) control panels determine if and when the computer sends a signal to the monitor that causes the monitor to enter low power. If an ENERGY STAR monitor is attached to a computer that is on, it will enter low power only if it receives this signal. "PC-initiated monitor PM rate" refers to the share of systems in which the computer signals the monitor to initiate PM, and the monitor responds. We can infer this rate only among systems in which the computer is on and the monitor is not turned off.

An ENERGY STAR monitor can also enter low power if there is no video signal from the computer, either because the computer is off, it is in low power, or the monitor is disconnected from the computer. "Monitor PM rate" refers to the share of monitors that power manage in the absence of a signal from the computer.

Among monitors that were not turned off, those connected to computers that were off or absent had monitor power management rates of 98% (with desktop computers) and 100% (with laptops); monitors not off and connected to desktop computers that were in low power had a 96% monitor PM rate. In the remaining cases, the monitor may have been incapable of power managing (i.e., it was non-ENERGY STAR). Monitors not off and connected to desktop or server computers that were on had PC-initiated monitor PM rates that were much lower: 53% (for desktop computers) and 56% (for servers). Clearly, monitors that depended on a computer signal to initiate power management were much less likely to enter low power.

In our 2000 study we did not uniquely identify each workstation and so could not conduct this analysis. However, our 2003 monitor "PC-initiated PM rate" differs from the monitor "PM enabling rate" of another recent but unpublished study. In 2001, researchers at Energy Solutions in Oakland CA (O'Sullivan 2003) used **EZ Save** software[3] to remotely obtain (via local area networks) the PM *settings* of over 7,000 computer monitors at 17 commercial and institutional sites in the San Francisco Bay area. They found that monitor PM settings in the computer OS control panel were enabled for 44% of monitors. We would expect the share of monitors that *actually* power manage when the computer is on to be lower than the share of computers *enabled* to power manage their monitors (because some monitors may not be ENERGY STAR, there may be network interferences with PM, etc). However, our "PC-initiated PM rate" of 53% for desktop computers is higher than the 44% "PM enabling rate" found by Energy Solutions. There are several possible explanations for this:

1) Energy Solutions' 2001 sample contained significantly more computers using the Windows NT OS (which does not support PM and is no longer supported by Microsoft) than LBNL's 2003 sample,
2) Newer computers may be more successful at initiating monitor power management, and newer computer equipment (like newer buildings) may be over-represented in our 2003 sample,
3) Our PC-initiated PM rate is calculated from a subset of monitors (those left on and attached to a PC left on), while Energy Solutions' enabling rate represents all monitors. If turn-off and enabling rates are not independent (i.e., if people who leave their devices on at night are more likely to enable than those who turn their devices off), that could explain part or all of the discrepancy.
4) PC-initiated monitor PM rates actually have risen, as individuals and organizations respond to ENERGY STAR or other educational programs about the energy savings potential of monitor PM, or
5) Our 2003 sample includes a wider variety of commercial building types and locations, and so is more representative than data collected only from office buildings in California,.

In any case, the ability of computers to power manage monitors deserves further scrutiny and improvement.

In the report on our 2000 office equipment field surveys (Webber, Roberson et al. 2001) we speculated that monitors in low power might be thought by users to be off. Among buildings in this report, Site M, a large office, offers anecdotal evidence regarding user (mis)interpretation of monitor power state. According to the facility manager, this company's strict policy is that employees turn their monitors off before leaving, and security personnel turn off any monitors found left on. Our data show that only 4% of monitors were on, but only 29% were actually off; the remaining 65% were in low power mode. This confirms our field observations that if a display is black or blank, users often assume the monitor is off, even though the front panel power indicator (which is amber and/or blinking when the unit is in low power) indicates otherwise.

LCD monitors were not even mentioned in the report on our 2000 field surveys of office equipment, but in 2003, LCDs were 17% of all monitors. As shown in Table 6, at three sites (including two high schools, D and F) we found no LCD monitors, but at two sites (E, medium office; A, university building), LCD monitors outnumbered CRT monitors, and at three others (B and H, both medium offices; and J, health care) LCDs were over 25% of all monitors found.

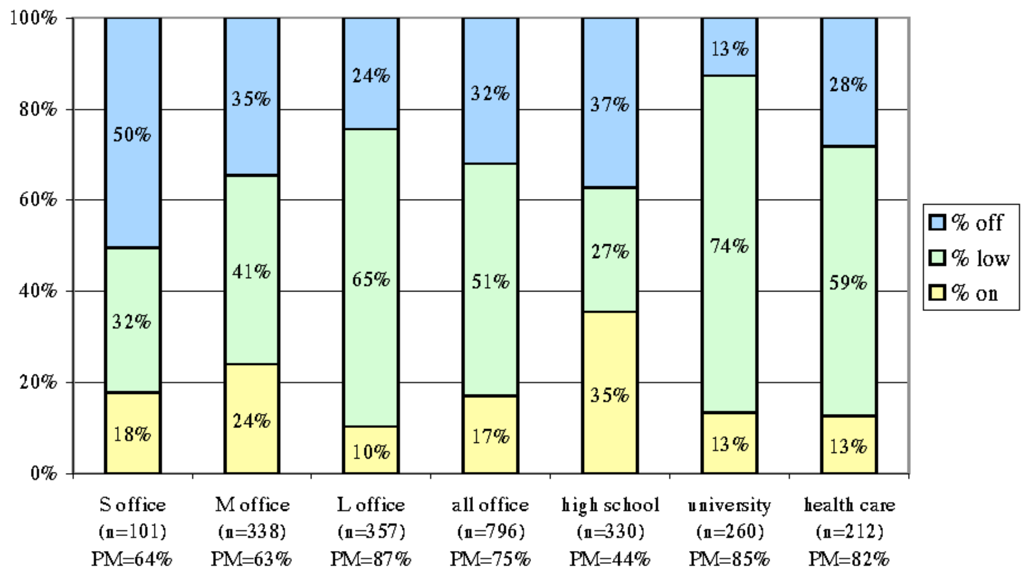
[3] **EZ Save** software was developed by the Department of Energy and adapted by the EPA ENERGY STAR program.

Table 6. Number and Percent of LCD Monitors, by Site
sorted by percent of LCD monitors

site	D	F	C	M	G	K	N	J	H	B	A	E	all
LCDs	0	0	2	4	12	14	13	18	40	66	96	21	286
CRTs	89	248	254	97	162	88	76	46	104	111	79	12	1366
total	89	248	256	101	174	102	89	64	144	177	175	33	1652
% LCDs	0%	0%	0%	4%	7%	14%	15%	28%	28%	37%	55%	64%	17%

While our building sample is not large enough to draw reliable conclusions about office equipment power management based on building type, we did some analysis within our sample. Figure 4 shows the after-hours power status of monitors (both CRT and LCD) based on building type. (A similar analysis for desktop computers and ICSs is not shown here because almost all the computers found in low power were in a single (health care) building, which may be anomalous.)

Figure 4. Monitor After-hours Power Status, by Building Type

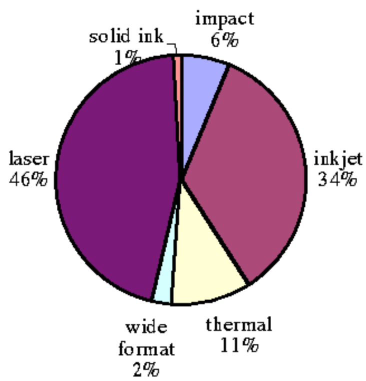


In our sample, monitor PM rates were by far the lowest in high schools (44%) and highest in university buildings (85%) and large offices (87%). Monitor turn-off rates were lowest in university buildings (13%) and highest in small offices (50%). In addition to the low monitor PM rate, a relatively high number (35%) of monitors were on in high schools, where all monitors found were CRTs, which use significantly more power when on than LCDs (Roberson, 2002). This strengthens the evidence that there is significant energy savings potential among office equipment in computer classrooms, and particularly those in high schools.

Printers

We categorize printers based on imaging technology: laser, inkjet, impact, thermal, wide format, solid ink.[4] Figure 5 shows the composition of our sample. Of 385 printers, 45% (174) were laser, 34% (132) were inkjet, 11% (41) were thermal, 6% (25) were impact, 2% (8) were wide format, and 1% (4) were solid ink.

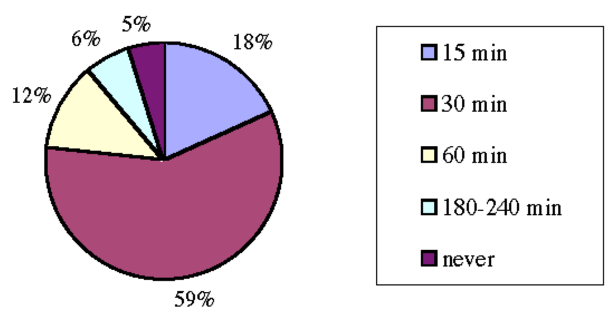
Figure 5. Printer Sample, by Technology



Of 158 laser printers in our sample, 15% were off, and 60% of those not off were in low power mode. Among the 123 inkjet printers the turn-off rate was 30%; we found no inkjet printers in low power. Of 38 thermal printers, which do not power manage, the turn-off rate was 18%. Of four solid ink printers none were off, but three (75%) were in low power.

For laser printers we tried to record "powersave" (i.e., low power) delay settings and whether or not they were networked. We did not record delay settings for laser printers that were off, or for those that did not have user interactive menus. Of 78 laser printers for which we actually recorded delay settings, 18% (14) were set to 15 minutes, 59% (46) were 30 minutes, 12% (9) were 60 minutes, 6% (5) were 180-240 minutes, and 5% (4) were set to "never" or off. Figure 6 displays this graphically.

Figure 6. Laser Printers: Powersave Delay Settings



[4] Wide-format is not an imaging technology, but rather an ENERGY STAR category for printers that accommodate 17"x 22" or larger paper. Of 8 wide format printers in our sample, 7 used inkjet, and one used impact technology.

Among printers for which we recorded the presence or absence of a network connection, 63% of laser printers but only 7% of inkjet printers were networked.

Only 60% of laser printers not off were actually found in low power (see Table 3). Not all laser printers can power manage (i.e., they are not ENERGY STAR), and so do not have powersave delay settings. Among laser printers that can power manage, there are several reasons they might be found on during our survey: (1) the printer has a long (3-4 hour) powersave delay setting, which had not elapsed, (2) the printer was recently used, and (3) the printer is in error mode, which effectively prevents it from entering low power.

Multi-Function Devices

The ENERGY STAR Office Equipment program distinguishes 'digital copier-based MFDs,' which are covered by their MFD program, from printer- and fax-based MFDs, which are covered by their printer program. In this study, we identify any multi-function device as an MFD, and distinguish between them on the basis of imaging technology (inkjet or laser), which we think is most relevant to power consumption.

Many units of office equipment that we identified in the field as copiers, fax machines, or printers turned out, on later examination of their specifications, to actually be multi-function devices. Among the 80 MFDs eventually identified, 80% (64) used laser technology, and the remaining 20% (16) were inkjets. Turn-off and PM rates were similar for laser and inkjet MFDs. Of 63 laser MFDs in Table 3 the turn-off rate was 21%, and 28% of those that were not off were in low power. Of 16 inkjet MFDs (at least some of which can power manage) the turn-off rate was 19%, and 31% of those not off were in low power.

Copiers

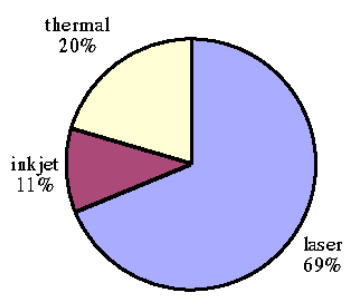
Of the 33 copy machines in Table 3, 48% were off and 29% of those that were not off were in low power. This low PM rate may be due in part to the fact that copiers often have powersave delay settings of two hours or more, and some of the copiers that we found on would eventually have entered low power.

Our 2000 field surveys of office equipment included 34 copiers and 11 'digital copier-based MFDs,' which yields a copier to 'digital copier-based MFD' ratio of 3:1. Our current sample includes 33 copiers and 64 laser or 'digital copier-based MFDs,' which yields a 2003 copier to 'digital copier-based MFD' ratio of 0.5:1. These numbers confirm our field observations that MFDs are replacing copiers in the marketplace.

Fax Machines

It can be difficult to tell whether a fax machine is on or in low power. Also, many units meet ENERGY STAR's low power requirement when on but idle or 'ready', and so do not need a separate low power mode. In this study, unless a fax machine gave a visual indication that it was in low power, we recorded it as being on. Of the 47 units in our sample and in Table 3, none were off and 6% (3) were in low power. Of the 44 fax machines whose technology we were able to determine, 69% (30) were laser, 20% (9) were thermal, and 11% (5) were inkjet. Figure 7 displays this graphically.

Figure 7. Fax Machine Technology



Scanners

Of the 34 scanners in Table 3, 41% were off and 60% of those that were not off were in low power. Of the total 37 scanners in our sample, 76% (28) were flatbed scanners, 14% (5) were specialized document scanners, 5% (2) were wide format, and 5% (2) were slide scanners. Among flatbed scanners only, 18% (5) were on, 43% (18) were in low power, 29% (8) were off, and 11% (3) were unplugged. All five document scanners were off; both wide format scanners were found in the same room, and were on.

Office Equipment: Comparison of 2000 and 2003 Turn-off and PM Rates

A primary goal of this study is to update information on office equipment turn-off and power management rates from previous studies, and to broaden the range of buildings in which this data is collected. Table 7 compares the office equipment turn-off and PM rates from this series of surveys to those from our 2000 field surveys of office buildings in California (Webber, Roberson et al. 2001).

In most cases, our 2003 field data yield turn off and PM rates that are virtually the same as those found in 2000. Notable exceptions are that monitor PM rates were higher (72% in 2003 c.f. 56% in 2000) and MFD PM rates were much lower in 2003 than in 2000 (29% in 2003 c.f. 56% in 2000). Also, copier and scanner turn-off rates were higher in 2003 than in 2000.

Table 7. Office Equipment Turn-off and Power Management Rates

			Turn-off Rate		PM Rate	
Category	**Type**	**no. in 2003**	**2000**	**2003**	**2000**	**2003**
computers	desktop + ICS	1,498	44%	37%	5%	7%
	desktop	**1,453**		**36%**		**6%**
	ICS	45		60%		61%
monitors	**all**	**1,598**	**32%**	**29%**	**56%**	**72%**
	CRT	1,329		32%		71%
	LCD	269		18%		75%
printers	all	353	25%	23%	44%	31%
	monochrome laser		24%		53%	
	high-end color		15%		61%	
	laser	**158**		**15%**		**60%**
	inkjet	**123**	**31%**	**30%**	**3%**	**0%**
	impact	22	31%	27%	0%	0%
	thermal	38		18%		0%
	wide format	8	57%	75%	32%	0%
	solid ink	4		0%		75%
MFDs	**all**	**79**	**18%**	**20%**	**56%**	**29%**
	inkjet	16		19%		31%
	laser	63		21%		28%
copiers	all	33	18%	49%	32%	28%
fax machines	all	47	2%	0%		6%
scanners	all	34	29%	41%		60%

For computers, the 2003 PM rate of 6% is similar to the estimated 2000 rate of 5%, but the 2003 turn-off rate of 36% for desktop computers is lower than the 2000 turn-off rate of 44% for all computers.

The 2003 turn-off rate of 32% for CRTs matches the 2000 turn-off rate for all monitors, but the 2003 turn-off rate of 18% for LCD monitors is much lower. In 2003 we found a much higher PM rate for both CRT and LCD monitors (71% and 75%, respectively) than the 56% PM rate reported for all monitors in 2000.

For all laser printers (of which <2% are color) our 2003 turn-off rate of 15% is lower than the 2000 rate of 24% for monochrome laser printers. The 2003 turn-off rates for inkjet (30%) and impact (27%) printers are similar to the 2000 rates for both (31%). Among our small sample of 8 wide format printers in 2003, the 75% turn-off rate is significantly higher than the 57% reported in 2000. The 2003 turn-off rate of 0% for (a sample of four) solid ink printers is lower than the 2000 turn-off rate of 15% for high-end color printers.

The 2003 PM rate of 60% for laser printers is similar to the 2000 rate of 61% for "high end color" printers. In 2000 some inkjet and wide-format printers were in low power, but in 2003 we found none.

The 2000 study did not report on thermal or solid ink printers, probably because few or none were found. Solid ink is not a widespread printer technology; in 2003 we found four, all in the same building. Of 41 thermal printers in our 2003 sample, only 15% were found in offices; another 15% were in education buildings, but 70% were found in health care buildings. For thermal printers the 2003 turn-off rate is 18%; for solid ink printers it is 0%. The 2003 PM rate for thermal printers is 0%; for solid ink it's 75%.

In 2003 we distinguish between laser and inkjet MFDs, but their turn-off rates (19 and 21%, respectively) are similar to the 2000 rate of 18% for all MFDs. However, in 2003 the PM rate for both inkjet and laser MFDs (31 and 28%, respectively) are significantly lower than the 2000 rate of 56% for all MFDs.

Copiers had a much higher turn-off rate in 2003 (49%) than in 2000 (18%), but their PM rate in 2003 (28%) is slightly lower than in 2000 (32%). Because of confusion about fax machine power state, no PM rate was reported in 2000; however, in 2003, at least 6% of fax machines were in low power. For scanners, the turn-off rate rose from 29% in 2000 to 41% in 2003; the 2003 PM rate was 60%.

Miscellaneous Equipment

Miscellaneous Equipment: Numbers and Density

Miscellaneous equipment outnumbered office equipment in all buildings except one (a university, site A); at one medium office (site E), the ratio of miscellaneous equipment to office equipment exceeded 4:1. For all buildings combined, if external power supplies are included as miscellaneous equipment, the ratio of miscellaneous equipment units (7,668, Appendix D) to office equipment (3,934, Table 2) is almost 2:1.

For all buildings combined, the most numerous equipment types in each ME category are as follows:

audio/visual:	television (27% of audio/visual category), VCR (23%), overhead projector (14%)
food/beverage:	microwave oven (16%), undercabinet refrigerator (15%), coffee maker (12%)
portable hvac:	8-16" diameter fan (35%), heater (21%), < 8" diameter fan (20%)
laboratory:	scale (24%), spectrophotometer (18%), tabletop centrifuge (13%)
lighting:	fluorescent undercabinet lamp (60%), 13W compact fluorescent lamp (15%)
medical:	oto-opthalmoscope charger (25%), exam light (18%), x-ray light box (12%)
networking:	switch (30%), hub (22%), modem (14%)
office misc.:	clock and/or radio (22%), compact audio system (18%), pencil sharpener (17%)
peripheral:	computer speaker pair (52%), laptop docking station (12%), PDA dock (11%)
power:	lighted power strip (36%), plug-in power supply (35%), in-line power supply (8%)
telephony:	powered phone (42%), headset with network box (13%), conference phone (11%)
maintenance:	vacuum cleaner (21%), floor polisher (14%), clothes washer or dryer (12%).

Appendix D lists the number of miscellaneous equipment units, by category, found in each building. For all sites combined, the most numerous miscellaneous equipment categories are power (including external power supplies, which are discussed in the following section), lighting, and computer peripherals. The least numerous categories of plug-load miscellaneous equipment are money exchange and security. Figure 8 shows the relative numbers of each category of miscellaneous equipment, by type of building, and Figure 9 shows the density of each equipment category, in number of units per 1000 ft^2 of floor area surveyed.

Figure 8. Miscellaneous Equipment Numbers, by Category and Building Type

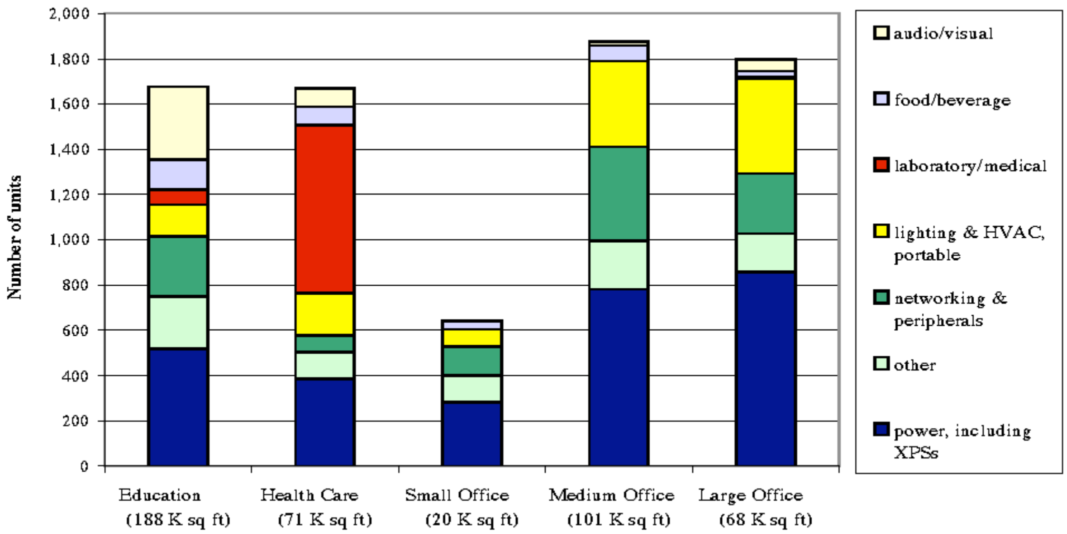
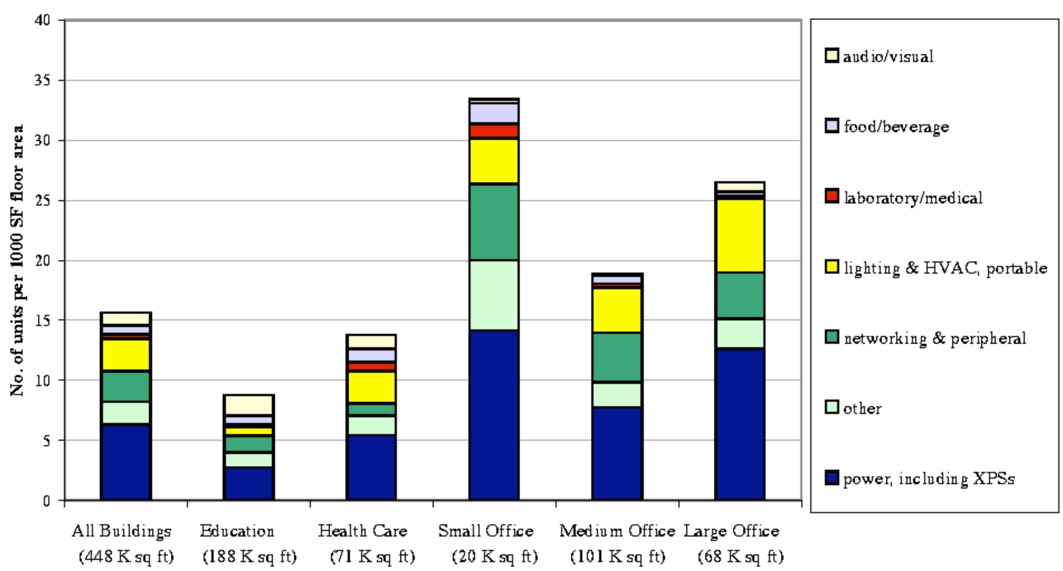


Figure 9. Miscellaneous Equipment Density, per 1000 ft^2 Floor Area



In Figures 8-11, some miscellaneous equipment categories have been combined for easier comparison. Specifically, we combined laboratory with medical and medical specialty, portable lighting with portable HVAC, and networking equipment with computer peripherals; 'other' combines the categories of money exchange, office miscellany, security, telephony, and utility/maintenance.

Not surprisingly, laboratory and medical equipment is the largest miscellaneous equipment category (in terms of number of units) in health care buildings, and audio/visual equipment is a significant category in education buildings. Networking equipment appears to be a smaller category in large offices; however, this result may be because we did not have access to network closets in the two large offices in our sample.

Miscellaneous Equipment: Relative Energy Consumption

An inventory is a necessary starting point, but does not reveal the relative total energy consumption (TEC) of ME found in our survey. For that we must first estimate the typical UEC of each type of equipment, which, when multiplied by number of units found, yields an estimate of TEC. We were able to estimate the UEC and TEC for over 70% (230 of 321 types) of ME found among buildings in this survey.

Typical unit energy consumption is the sum of the products of the power consumed in each power state (unplugged, off, on, active) and the likely number of hours per year (or percent time) spent in each state. We used data from previous metering projects and other available sources to estimate both parameters. In some cases we found UEC estimates in the literature. To estimate power consumed in each power state, we relied primarily on metering data by LBNL and others, online and published sources, and comparison to similar devices for which we have data (AD Little 1996, Cadmus 2000, USDOE 1995, Wenzel 1997).

In all cases, for both power levels and usage patterns, we recorded the basis of our estimates in order to facilitate subsequent evaluation and revision of our estimates based on new information or assumptions. To estimate the portion of time each type of miscellaneous equipment typically spends in each power state, we used data on as-found power states collected in this survey, supplemented by educated guesswork and personal experience. Here are some examples:

- we assumed that refrigerators, freezers, and refrigerated vending machines are always on,
- we estimated that microwave ovens in office lunchrooms are used 5 hours/week on average,
- 80% of VCRs found were on; we assume they are always on and estimated additional 10% usage,
- 60% of over 450 computer speaker pairs in our survey were found on; we used that data without adjustment, assuming that speakers found off during our survey were virtually always off.

Of course, for each type of equipment, usage and UEC may vary depending on the setting in which it is found. For example, a TV in a high school classroom is likely to be used less often that it would in a home. Similarly, a coffee maker is likely to be used more often in a typical office than it would in a typical home. Our UEC estimates apply to the buildings that we surveyed and do not necessarily apply in other situations.

We prioritized the considerable effort of estimating UECs by focusing on the most numerous and most energy-intensive equipment types. Miscellaneous equipment for which we do *not* have UEC (and therefore TEC) estimates include some specialized medical equipment and other equipment we could not meter and for which we could find no power specifications. That we do not have estimates of power use for some equipment does not mean that their consumption is insignificant, only that we were unable to estimate it at this time. Examples of equipment for which we have no estimate (with the number of them found) are:

- audio/visual category: video switch (9), power distribution & lighting system (5),
- food & beverage category: hot beverage dispenser (4), steam trays (3),
- peripheral category: keyboard/video/mouse (KVM) switch (27), pen tablet (17)
- power category: battery backup system (3), power amplifier (2)

For the 230 types of miscellaneous equipment for which we have estimates of both power consumption and time spent in each power mode, it is a simple matter to calculate typical unit energy consumption and (multiplying UEC by the number of units found) to calculate their total energy consumption. Obviously, any error in the UEC estimate is compounded (multiplied) by the number of units found. Also, the more power consumed and the more time spent on, the larger the potential error in our (absolute kWh) estimates.

Our UEC estimates ranged from 1 kWh/yr for pencil sharpeners to 7,008 kWh/yr for kilns; TEC estimates ranged from 1 kWh/yr (e.g., for one shaver) to almost 80,000 kWh/yr for 24 refrigerated vending machines.

Networking equipment in our survey, primarily ethernet hubs and switches, ranged from 1 to 80 ports each. Our inventory distinguishes these equipment by the number of ports (e.g., we list the number of 12-, 16-, 24-, 48-, and 80-port hubs separately), but our estimates of UEC and TEC are based on the sum of all ports, regardless of unit configuration. We found a total 2,120 ethernet switch ports and 451 ethernet hub ports.

Of the miscellaneous equipment for which we have UEC and TEC estimates, Table 8 shows the total energy consumption of miscellaneous equipment according to our categories. The top 50 in unit energy consumption are listed in Table 9 and the top 50 in total energy consumption are listed in Table 10.

The food & beverage category appears to dominate miscellaneous equipment in terms of *unit energy consumption*; eleven of the top 15 equipment types in terms of UEC are in the food & beverage category, which are shaded in Tables 9 and 10. The food & beverage category also dominates in terms of *total energy consumption*, accounting for half (50%) of total energy consumed. Table 10 shows that among our survey of commercial buildings the top ten types of food & beverage equipment in terms of TEC are:

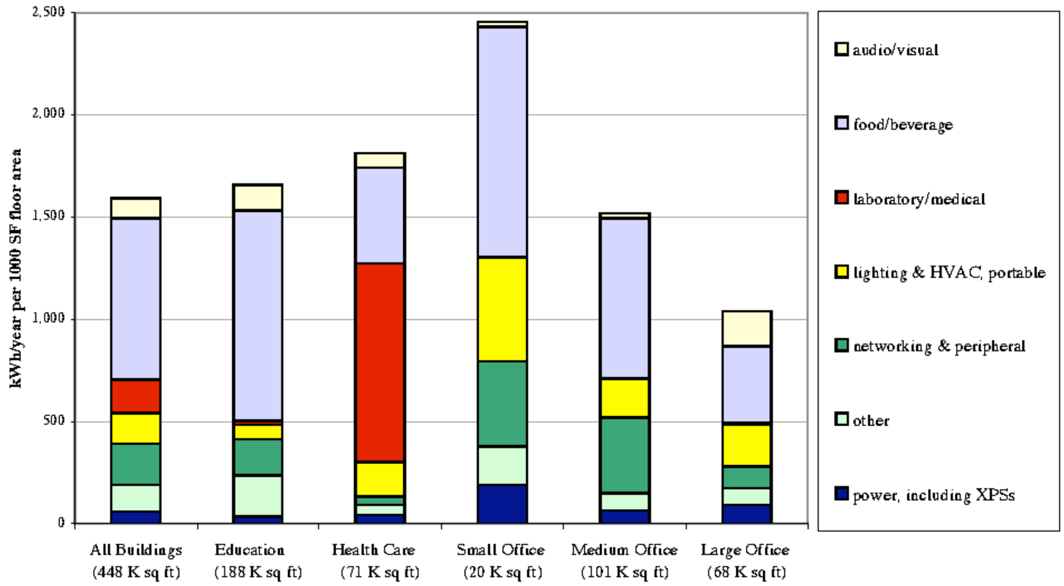
1) refrigerated vending machines
2) commercial refrigerators
3) commercial freezers
4) microwave ovens
5) coffee makers, commercial or specialty
6) hot food cabinets
7) coffee makers, residential models
8) small (undercabinet) refrigerators
9) room temperature vending machines
10) visi-coolers

While each ethernet switch port has a UEC of just 17 kWh/yr, the over 2,000 units have a collective TEC of over 35,000 kWh/year, which suggests this equipment is a good target for energy efficiency measures. We estimate that computer speaker pairs collectively account for almost 10,000 kWh/yr in these buildings; because these units are seldom used, their consumption represents a considerable energy savings potential.

Table 8. Total Energy Consumption of Miscellaneous Equipment, by Category

Miscellaneous Equipment Category	TEC (kWh/yr)	% of Sum
food/beverage	354,406	50%
laboratory/medical	72,583	10%
networking	53,775	8%
audio/visual	43,036	6%
lighting, portable	42,417	6%
computer peripherals	35,549	5%
other (money exchange, security, specialty, utility/maintenance)	38,285	5%
hvac, portable	26,731	4%
power, including XPSs	26,079	4%
office miscellany	13,114	2%
telephony	7,616	1%
All Miscellaneous Equipment Found in Survey	**713,591**	**100%**

Figure 10. TEC of Miscellaneous Equipment, Normalized by Floor Area (kWh/yr per 1000 ft²)



Figures 8-10 show that although small offices have the lowest numbers of miscellaneous equipment, they have the highest *density*, in both numbers and TEC, in all categories except audio/visual. This is consistent with Figure 2, in which small offices have the highest density of both office and miscellaneous equipment.

Figure 11. TEC of Miscellaneous Equipment, as Percent of Building Type

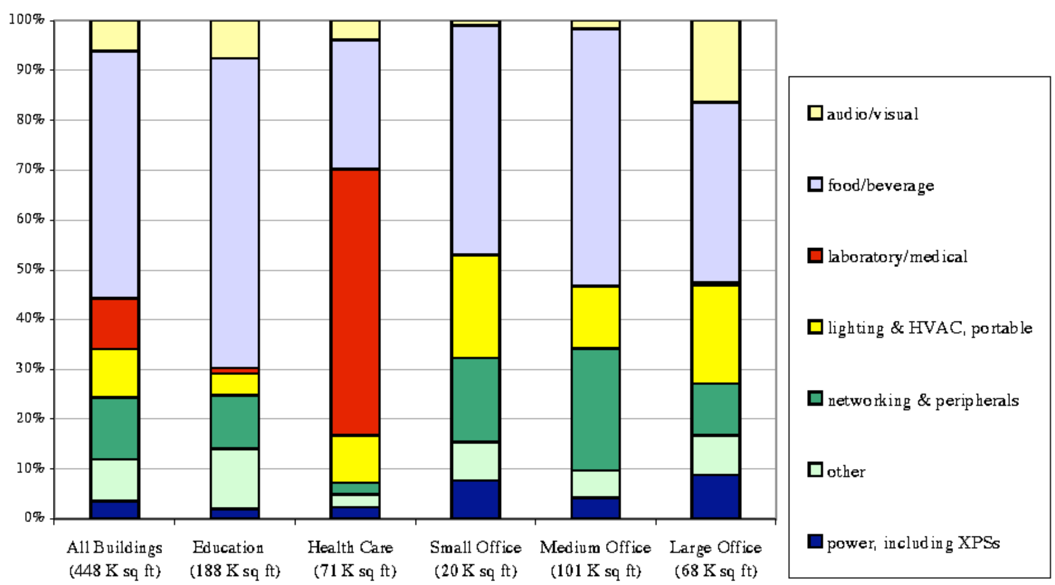


Table 9. Top 50 Miscellaneous Equipment Types, by Unit Energy Consumption

Note: Shading indicates equipment in the food & beverage category
Note: * indicates equipment for which we found and used published UEC values.

	Miscellaneous Equipment		Power Use (W)		Estimated Usage (percent time)			Unit Energy Consumption (UEC) kWh/yr
	Category	Type	On	Off	On	Off	Unplugged	
1	specialty	kiln	8000		10%	0%	90%	7,008
2	food & beverage	fryer						* 5,884
3	food & beverage	freezer, commercial						* 5,200
4	food & beverage	hot food cabinet						* 4,700
5	food & beverage	refrigerator, commercial						* 4,300
6	laboratory	autoclave	1500	0	30%	50%	20%	3,942
7	food & beverage	visi-cooler						* 3,900
8	food & beverage	vending machine, cold beverage						* 3,318
9	food & beverage	ice maker						* 2,167
10	food & beverage	vending machine, room T snack	205		100%	0%	0%	1,796
11	food & beverage	coffee maker, commercial or specialty	2595		6%	74%	20%	1,349
12	laboratory	drying oven or steam incubator	300	0	50%	50%	0%	1,314
13	food & beverage	refrigerated case						* 1,214
14	audio/visual	LED display sign, networked	135	15	100%	0%	0%	1,183
15	food & beverage	soda fountain pump or smoothie maker	100	0	100%	0%	0%	876
16	networking	switch, fiberoptic, 24 port	96		100%	0%	0%	841
17	food & beverage	bottled water tap, hot & cold						* 799
18	food & beverage	water cooler, hot & cold						* 799
19	HVAC, portable	air cleaner						* 761
20	utility/maintenance	clothes washer						* 704
21	food & beverage	refrigerator, L (full-size)						* 701
22	food & beverage	refrigerator/freezer						* 701
23	peripheral	external drive, tape backup	100		80%	10%	10%	701
24	audio/visual	system control, rack-mount	79	5	100%	0%	0%	692
25	audio/visual	power/volume controller	79	5	100%	0%	0%	692
26	HVAC, portable	room air conditioner						* 630
27	utility/maintenance	clothes dryer						* 622
28	specialty	bookshelves, mobile	70	0	100%	0%	0%	613
29	utility/maintenance	pump, water treatment chemical	70	0	100%	0%	0%	613
30	food & beverage	refrigerator, M (apt-size)						* 567
31	utility/maintenance	exhaust fan, industrial	125	0	50%	50%	0%	548
32	laboratory	refrigerator, S	60	0	100%	0%	0%	526
33	laboratory	freezer	60	0	100%	0%	0%	526
34	lighting, portable	incandescent tracklight, 50 lamps each	2000	0	3%	97%	0%	520
35	telephony	phone/PBX centrex system	55.5		100%	0%	0%	486
36	food & beverage	coffee maker, residential model	865	0	6%	69%	25%	450
37	food & beverage	microwave oven	1620	3	3%	97%	0%	447
38	medical specialty	charger, suction pump	50	3	100%	0%	0%	438
39	peripheral	disk array	50		100%	0%	0%	438
40	networking	tape drive	100		50%	50%	0%	438
41	medical specialty	sterilizer, hot bead	90		50%	50%	0%	394
42	audio/visual	digital video camera	70	3	60%	40%	0%	378
43	networking	router	40		100%	0%	0%	350
44	peripheral	external drive, other	50		80%	20%	0%	350
45	medical specialty	charger, defibrillator	50	3	75%	25%	0%	335
46	HVAC, portable	heater	750		5%	48%	48%	329
47	peripheral	external drive, hard disk	50		67%	25%	8%	292
48	food & beverage	refrigerator, S (undercabinet)						* 277
49	networking	video processor, rack-mount	30		100%	0%	0%	263
50	lighting, portable	incandescent studio lamp, 500W	500	0	6%	94%	0%	260

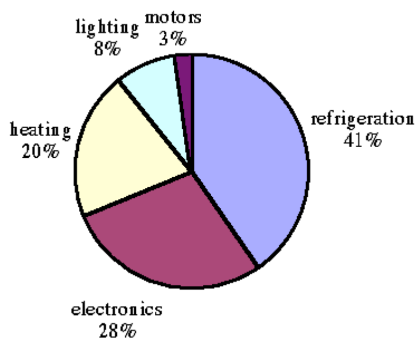
Finally, we characterized the top 50 miscellaneous equipment types in Table 10 according to these broader end-use or technology categories: electronics, heating, lighting, motors, and refrigeration. For equipment that could belong in more than one of these categories, we categorized it based on its primary technology or consumption. For example, refrigerated vending machines are a 'refrigeration' end use, while room temperature vending machines are 'lighting;' microwave ovens and computer projectors are categorized as 'electronics' although they might alternatively be categorized as 'heating' and 'lighting,' respectively. Figure 12 shows the relative consumption of equipment in Table 10 according to these end-use categories.

Table 10. Top 50 Miscellaneous Equipment Types, by Total Energy Consumption

Note: Shading indicates equipment in the food & beverage category

	Miscellaneous Equipment		number	Energy Consumption, kWh/yr	
	Category	Type	found	per Unit	Total
1	food & beverage	vending machine, cold beverage	24	3,318	79,632
2	food & beverage	refrigerator, commercial	18	4,300	77,400
3	networking	switch, ethernet, total no. of ports	2120	17	35,285
4	food & beverage	freezer, commercial	5	5,200	26,000
5	food & beverage	microwave oven	53	447	23,675
6	specialty	kiln	3	7,008	21,024
7	lighting, portable	fluorescent undercabinet lamp, ave 24"	626	33	20,833
8	food & beverage	coffee maker, commercial or specialty	15	1,349	20,241
9	laboratory	autoclave	5	3,942	19,710
10	food & beverage	hot food cabinet	4	4,700	18,800
11	food & beverage	coffee maker, residential model	39	450	17,542
12	food & beverage	refrigerator, small (undercabinet)	50	277	13,860
13	food & beverage	vending machine, room T snack	7	1,796	12,571
14	food & beverage	visi-cooler	3	3,900	11,700
15	HVAC, portable	heater	33	329	10,841
16	power	plug-in power supply (PIPS), attached	878	11	9,999
17	peripheral	computer speakers (pair)	464	21	9,836
18	food & beverage	refrigerator, M (apt-size)	17	567	9,641
19	food & beverage	bottled water tap, hot & cold	12	799	9,588
20	food & beverage	ice maker	4	2,167	8,668
21	HVAC, portable	air cleaner	11	761	8,371
22	networking	router	23	350	8,059
23	lighting, portable	incandescent desk/table lamp, 75W ave	99	78	7,722
24	peripheral	external drive, tape backup	11	701	7,709
25	audio/visual	VCR	113	64	7,214
26	audio/visual	LED display sign, networked	6	1,183	7,096
27	medical specialty	charger, defibrillator	21	335	7,036
28	audio/visual	TV (all sizes)	130	53	6,941
29	audio/visual	projector, overhead	68	96	6,524
30	peripheral	projector, computer	32	204	6,523
31	food & beverage	fryer	1	5,884	5,884
32	laboratory	refrigerator, S	11	526	5,782
33	power	UPS (uninterruptible power supply)	137	36	4,983
34	medical	exam table w/ heated drawer	38	130	4,940
35	networking	hub, ethernet, all sizes, total no. ports	451	11	4,938
36	office miscellany	adding machine	81	58	4,730
37	medical	charger, oto/opthalmoscope	116	39	4,573
38	telephony	phone, powered	98	42	4,116
39	peripheral	external drive, hard disk	13	292	3,796
40	office miscellany	typewriter	32	116	3,700
41	medical specialty	vital signs monitor	24	153	3,679
42	specialty	bookshelves, mobile	6	613	3,679
43	HVAC, portable	fan, medium (8-16" diam)	56	62	3,495
44	audio/visual	system control, rack-mount	5	692	3,460
45	food & beverage	refrigerator, L (full-size)	4	701	2,803
46	medical specialty	sterilizer, hot bead	7	394	2,759
47	medical	exam light	87	31	2,714
48	networking	video processor, rack-mount	10	263	2,628
49	laboratory	drying oven or steam incubator	2	1,314	2,628
50	peripheral	external drive, other	7	350	2,450
				SUM	607,780

Figure 12. End-Use Breakdown of Top 50 Miscellaneous Equipment Types, by TEC

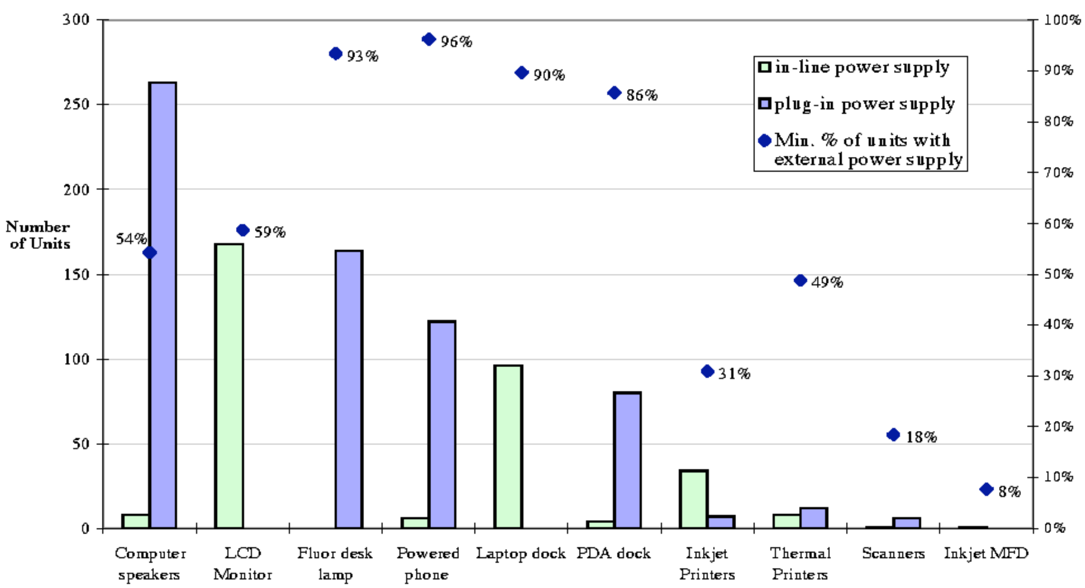


External Power Supplies

Figure 13 shows the types of equipment we found with external power supplies, the number of units of each equipment type that had an XPS, the type of power supply (ILPS or PIPS), and the minimum percent of each equipment category that had an XPS. It is a minimum value because although we tried to record every occurrence of an XPS, we did not capture all of them.

The most numerous XPSs were among computer speakers, LCD monitors, fluorescent desk lamps (whose PIPS included a magnetic ballast), powered phones (including conference and speaker phones), laptop and PDA docking stations. The highest percentage of units with XPSs were among powered phones, fluorescent desk lamps, laptop and PDA docking stations. ILPSs were prevalent among LCD monitors and laptop docking stations, while PIPSs prevailed among computer speakers, fluorescent desk lamps, powered phones and PDA docks. Equipment among which we found both ILPSs and PIPSs (though not on the same unit) were computer speakers, powered phones, PDA docks, inkjet printers, thermal printers, and scanners.

Figure 13. External Power Supplies: Number, Type and Frequency



Conclusions

For all buildings combined, the average plug-load equipment density in *units per 1000 gross ft²*, was about 9 for office equipment and 14 for miscellaneous equipment, for a sum of about 23 units per 1000 gross ft². Educational buildings, where large floor areas are devoted to classrooms, had the lowest density of both office and miscellaneous equipment. However, two-thirds of computers and monitors found in educational buildings (and thus most of the energy savings potential) were concentrated in computer-based classrooms.

Among offices only (for which we were able to estimate number of employees, or occupants), the average equipment density, in *units per employee*, was approximately 3 units of office equipment and 6 units of miscellaneous equipment per employee, for a sum of about 9 electrical plug-load devices per employee; note that this includes equipment found in common areas such as kitchens, print centers, and utility closets. Because we have not attempted to estimate equipment density before, these data represent a baseline for reference and comparison with future data.

Office Equipment

A good overview of our results regarding office equipment power states is provided by Figure 3 (page 10), which allows a visual comparison of the percent of units found on, in low power, or off, by equipment type. Power management, indicated by the middle segment of each bar, is most successful among monitors and laser printers; and least successful among desktop computers, inkjet printers, copiers, and fax machines. Turn-off rates, indicated by the right segment of each bar, are highest (≥ 40%) among integrated computer systems, copiers, and scanners; and lowest (≤ 20%) among laser printers, LCD monitors, and MFDs.

This is the first field study in which we analyzed the effect of computer power state on monitor power state. Only 6% of desktop computers in this study of commercial buildings were found in low power, and only 53% of those that were on successfully initiated power management in monitors. Computers in homes (where fewer are networked) may have higher enabling rates, but we have no data from residences. Clearly there is significant room for improvement in power management of computers, and more data are needed to identify the parameters that affect the ability of computers to power manage themselves and their monitors.

In contrast, 96-98% of monitors connected to computers that were not on were found in low power, so a very high proportion of monitors are ENERGY STAR compliant, or capable of power managing themselves.

This report presents evidence of the growing use of laptop computers. Because of their inherent portability, accounting for laptops is difficult, especially during an after-hours survey, but our conservative estimate is that laptops comprise at least 10% of the non-server computers in our sample. We also estimate that laptops outnumbered desktop computers at two sites: one medium and one large office. To the extent that relatively energy-efficient laptops are replacing desktop computers, significant electrical energy is saved. However, more work is needed to characterize laptop usage patterns and energy consumption, which can vary widely depending on how often they are used when plugged in and how often the battery is charged. Laptop power state data from this survey can be useful in developing a typical unit energy consumption for laptop computers, but needs to be supplemented by data not available from after-hours surveys.

LCD monitors, which use significantly less energy when on than CRT monitors, are also penetrating the market. They outnumbered CRT monitors at two of the twelve sites in our sample: a medium office and a university classroom building. In contrast, we found no LCD monitors at three sites: two high schools and a large office. We expect the market share of LCD monitors to continue to grow as older CRT monitors are replaced and LCD monitor technology improves and becomes more affordable due to economies of scale.

For both types of education buildings in our sample (high schools and university classroom buildings), two-thirds of computers and monitors found were in "computer labs," or classrooms with a 1:1 ratio between computer workstations and chairs.[5] Some university computer labs had LCD monitors, but all the high school computer labs we visited had CRT monitors, many of which were found on after-hours. With so many workstations located in one room, and (presumably) controlled by one or very few instructor(s), we suggest efficiency efforts in high schools focus on reducing power consumed by equipment in these rooms.

Among our sample of printers, 46% were laser and 34% were inkjet. The turn-off rate was twice as high (30%) for inkjet printers as for laser printers (15%); inkjet printers are more likely to be turned off than laser printers because they are much less likely to be networked. Among laser printers, 77% had power management delay settings of 30 minutes or less, and only 5% were disabled (i.e., set to "never"). This indicates a high market penetration for ENERGY STAR laser printers; however, for reasons discussed above (including error messages and after-hours network use), the actual PM rate for laser printers is lower than indicated by PM delay settings. Nevertheless, the 2003 PM rate of 60% for laser printers is higher than the 2000 PM rate of 53% for monochrome laser printers, suggesting improvement in actual PM rates.

Eighty percent (80%) of multi-function devices that we found used laser imaging technology; the other 20% were inkjet. For both types, the average turn-off rate was about 20%, and the average PM rate was 30%, significantly lower than the 56% PM rate for MFDs observed in 2000. Power management rates among MFDs are important because MFDs appear to be replacing copiers in the workplace; the ratio of digital copier-based MFDs to copiers rose from 1:3 in our 2000 survey of office equipment to 2:1 in the 2003 survey reported here. However, while most MFDs can also fax, print, and scan, we did not observe a corresponding decrease in the relative number of fax machines, printers and scanners.

Miscellaneous Equipment

The inventory and energy consumption estimates of miscellaneous plug-load equipment presented in this report represent a first step toward characterizing the electrical demand of this large end-use category. Miscellaneous equipment outnumbered office equipment in our sample by a factor of almost two to one. While some energy-intensive devices, such as commercial refrigeration equipment, have been the target of efficiency efforts, including ENERGY STAR labeling, other less consumptive but more numerous devices, such as networking equipment and external power supplies, may offer significant energy savings potential.

According to our system of taxonomy, by far the most numerous category of miscellaneous plug-load equipment was 'power,' including power strips, surge suppressors, and external power supplies. The second most numerous category was 'lighting,' particularly undercabinet and compact fluorescent lamps, and the next most numerous category was computer 'peripherals,' 52% of which were computer speaker pairs. However, the numbers of each type of equipment do not necessarily reflect their relative energy intensity. The next step was to estimate typical unit energy consumption for the most common types of miscellaneous equipment, and begin to sort out their relative contribution to plug-load end use.

We were able to derive UEC estimates and calculate TEC for just over 70% of the types of ME found in our survey. Among miscellaneous equipment for which we have TEC estimates, equipment types with the top 50 TEC account for 85% of the total TEC—about 608K of 714K kWh/year, respectively. The food & beverage category accounts for 50% of the estimated (714K kWh/yr) TEC for all miscellaneous equipment devices. This category includes refrigeration equipment (freezers, refrigerators, vending machines) that are always on, as well as ubiquitous and frequently-used devices such as coffee makers and microwave ovens.

[5] We do not necessarily assume a 1:1 ratio between chairs and people; occupancy rates may vary between classes.

Future Work

The low rate of power management in desktop computers causes concern and deserves further investigation to ascertain barriers to computer power management as well as the most effective ways to mitigate them. One possibility would be to conduct more in-depth case studies in several types of buildings to identify specific institutional or technological impediments and evaluate the efficacy of various counter measures. Increasing power management among PCs would yield significant savings in both computers and monitors.

The increasing use of laptop computers makes it important to characterize their unit energy consumption. This would likely involve visiting offices during working hours and asking laptop users about their usage patterns, including how often the laptop is powered from a wall outlet and how often the battery is charged. It would also be useful to estimate the extent to which laptops are used in addition to or instead of desktops.

Results of this study point to the savings potential among computers and monitors in computer classrooms. We should improve our assessment of computer usage patterns in schools and develop effective strategies for realizing these savings. It would then be possible to implement prospective energy-saving measures in several computer classrooms and schools, and conduct follow-up surveys to evaluate their relative efficacy.

It would be useful to supplement these survey results with automated, network-based collection of data regarding usage patterns and power management settings of computers, printers, fax machines, and MFDs. While the former provides more detail, the latter yields significantly more data over longer periods of time.

Now that we have UECs for most common types of miscellaneous equipment, it would be possible to calculate their relative energy intensity among all buildings in our sample, or between types of buildings. Given utility bills for an individual building, we could work with building managers to estimate the portion of building energy load attributable to miscellaneous plug-load and to identify energy saving opportunities.

Additional after-hours building surveys could improve our understanding of office equipment usage and miscellaneous plug loads. Surveying a single building more than once (e.g., at weekly, monthly intervals) would help us to assess the robustness of the results from a single survey. The representativeness of our office equipment sample would be improved (compared to CBECS, for example) by visiting more large offices, and the completeness of our miscellaneous equipment inventory could be improved by ensuring that we survey their common or service areas such as network, phone and other utility closets. Furthermore, now that we have a baseline inventory of miscellaneous equipment, additional surveys and device metering would enable us to track changes in numbers and types of miscellaneous equipment, as well as their after-hours power status, and begin to characterize the typical ‘plug-load profile’ for various types of buildings.

References

AD Little. 1996. *Energy Savings Potential for Commercial Refrigeration Equipment.*

Cadmus. 2000. *Product Testing and Analysis of Water Dispensers.* Memo prepared for EPA's Energy Star Program. February.

EIA. 2003. *Annual Energy Outlook 2003 with Projections to 2025,* Dept of Energy, Energy Information Administration, Washington DC.

EIA/CBECS. 2002. *Computers and Photocopiers in Commercial Buildings.* Energy Information Agency, Commercial Building Energy Consumption Survey. US Dept of Energy (DOE), Washington DC.

EPA/DOE. 2003. *History of Energy Star.* http://208.254.22.7/index.cfm?c=about.ab_history

McCarthy, Kathryn, and R.E. Brown. 2002. (Draft) *A Field Method to Quickly Detect Power State in Plug-in Devices.* LBNL-54169. Lawrence Berkeley National Laboratory, Berkeley CA.

O'Sullivan, Terry, of Energy Solutions, Oakland CA. 2003. *Personal Communication*, November 30: Monitor power management enabling rates determined by EZ Save software.

Roberson, Judy A., G.K. Homan, A. Mahajan, B. Nordman, C.A. Webber, R.E. Brown, M. McWhinney, J.G. Koomey. 2002. *Energy Use and Power Levels in New Monitors and Personal Computers.* LBNL-48581. Lawrence Berkeley Lab, Berkeley CA. 36 pgs. http://enduse.lbl.gov/Info/Pubs.html

Rosen, K. and A. Meier. 1999. *Energy Use of Televisions and Videocassette Recorders in the U.S.* LBNL-42393. March. Lawrence Berkeley National Laboratory, Berkeley CA.

Roth, Kurt, Goldstein, Kleinman. 2002. *Energy Consumption by Office and Telecommunication Equipment in Commercial Buildings Volume 1: Energy Consumption Baseline.* Arthur D Little Reference No. 72895-00. US DOE

US DOE. 2003. *Energy Savings Estimates of Light Emitting Diodes in Niche Lighting Applications.* Office of Energy Efficiency and Renewable Energy, Building Technologies Program. November.

US DOE. 1995. *Technical Support Document: Energy Efficiency Standards for Consumer Products: Refrigerators, Refrigerator-Freezers & Freezers.* DOE/EE-0064.

Webber, Carrie A., R.E. Brown, A. Mahajan, J.G. Koomey. 2002. *Savings Estimates for the Energy Star Voluntary Labeling Program: 2001 Status Report.* LBNL-48496. Lawrence Berkeley National Laboratory, Berkeley CA. 29 pgs.

Webber, Carrie A., J.A. Roberson, R.E. Brown, C.T. Payne, B. Nordman, J.G. Koomey. 2001. *Field Surveys of Office Equipment Operating Patterns.* LBNL-46930. Lawrence Berkeley National Laboratory, Berkeley CA http://enduse.lbl.gov/Info/Pubs.html

Wenzel et al. 1997. *Energy Data Sourcebook for the U.S. Residential Sector.* LBNL-40297. Lawrence Berkeley National Lab, Berkeley CA.

Appendix A: Building Descriptions

Site A

University classroom building, Atlanta GA
Urban, downtown campus; 4-story, circa 1970
Area surveyed includes chemistry and computer laboratory/classrooms, faculty offices, lecture hall, lobby, and storage.

Site B

Medium office, Pittsburgh PA
Headquarters of a national non-profit organization
Suburban office park, 3-story, new in 2002
Area surveyed includes computer lab/shop, conference, cubicles, custodial, kitchen, lounge, network closet, offices, print/copy centers, reception, server room, shipping & receiving.

Site C

Large office, Atlanta GA
National headquarters of an internet company
Midtown office building, 8-story, circa 1970s
Area surveyed includes customer call center, computer classrooms, break room, conference, cubicles, .offices, and print/copy centers.

Site D

Urban high school, CA
3-story main building, new in 2001
Area surveyed includes administrative offices, audio/visual studio, bookroom, classrooms, computer classrooms, conference, library, teachers lounge, network closet, print/copy center, utility/mechanical.
Most computers are found in a few rooms, including computer classrooms and the library.

Site E

Medium office, Atlanta GA
Branch office of an international consulting firm
One floor of a 1990s suburban office tower
Area surveyed includes break room, conference, cubicles, lounge, offices, print/copy centers, server room.
This office had a high percentage of laptop computers, which must be locked up or taken home at night.
Only administrative staff have desktop computers, which are left on at night for backups and updates.

Site F

Urban high school, Pittsburgh PA
3-story main building, remodeled in 1990s
Area surveyed includes auditorium, cafeteria, classrooms (including art, band, language, computer classrooms, conference, library, teachers lounge, network closet, offices, storage, and A/V workroom.
Most computers are found in a few classrooms and the library.

Site G

Outpatient clinic, San Francisco CA
10-story urban medical campus building
Area surveyed includes conference, cubicles medical labs, library, lounges, exam rooms (including E/N/T, general medicine, ophthalmology, pediatric), nurses stations, offices, patient registration, phone bank, medical utility, treatment rooms, and waiting. Each exam and treatment room had a computer/monitor.

Site H

Medium office, Atlanta GA
Information services department of a university
6-story urban campus building, circa 1970s
Area surveyed includes break room, conference, copy/print center, cubicles, custodial, lounge, network closet, offices, server room , and utility/mechanical.

Site J

Medical office building, Pittsburgh PA
Suites of physicians in private practice
5-story suburban building,
Area surveyed includes break room, conference, exam rooms (including cardiology, E/N/T, endocrinology, ophthalmology, sleep disorders, urology), kitchen, labs, offices, server room, storage, utility, and waiting.

Site K

Small office, Pittsburgh PA
5 small businesses in 3 different suburban buildings
Area surveyed includes break room, conference, copy/print center, cubicles, electronics shop, network closet, offices, server room , and storage.

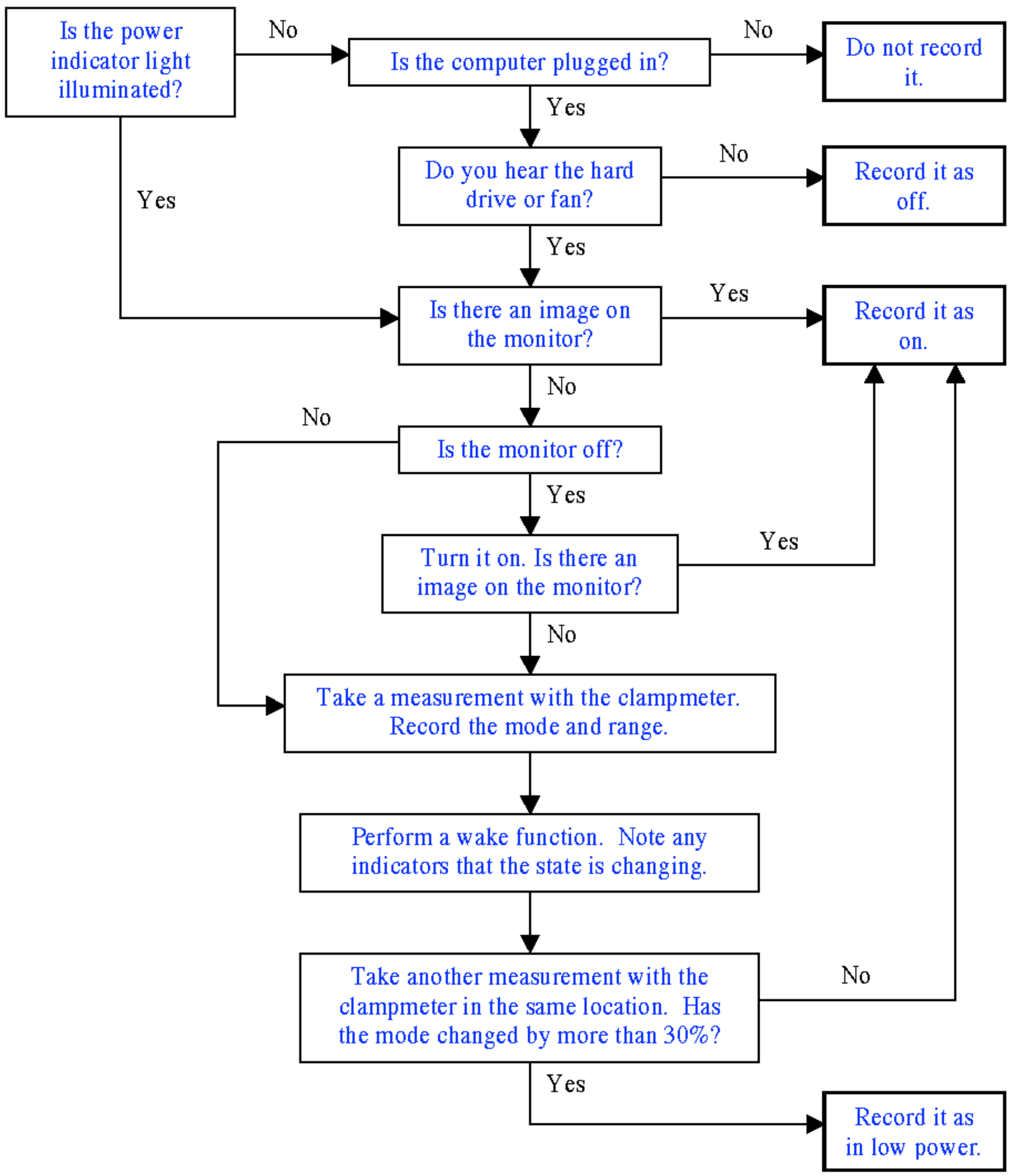
Site M

Large office, Pittsburgh PA
Corporate headquarters of a major manufacturer
Urban downtown office building, 6-story, new in 2001
Area surveyed includes conference, copy/print centers, cubicles, kitchen, lounge, health center, offices. Many employees in this office use laptop computers. Company policy is to turn monitors off at night (to prevent fires); special permission is required to bring in or use small appliances (fans, heaters, lamps, etc).

Site N

University classroom building, Atlanta GA
Urban, downtown campus; 4-story, circa 1960
The area surveyed included computer laboratories and classrooms, other classrooms, and offices of faculty, staff, and graduate students.

Appendix B: Flowchart for Auditing Desktop Computer Power State



Appendix C: Miscellaneous Equipment Taxonomy

Category	Equipment Type (not an exhaustive list)
audio/visual	television, video cassette player/recorder, overhead projector, audio amplifier, compact disk audio device, digital video disk device, slide projector, video monitor, audio mixer, audio tape device, LED display sign, receiver, speaker, tuner, digital video camera, video conferencing device, microfilm viewer, scan converter, public address system, set-top box
food & beverage	microwave oven, refrigerator (all sizes), coffee maker, toaster/toaster oven, vending machine, hot/cold bottled water tap, hot pot/kettle, water cooler, freezer, hot beverage dispenser, hot food cabinet, ice maker, coffee grinder, drinking fountain, fryer/griddle, steam trays, visi-cooler, meat slicer, mixer, soda fountain pump, blender, refrigerated case
hvac, portable	fan, heater, air cleaner, room air conditioner
laboratory	scale, spectrophotometer, tabletop centrifuge, temperature monitor, lab refrigerator, microscope, autoclave, shaker/stirrer, lab freezer, hot plate/warmer, drying oven, timer
lighting	fluorescent undercabinet lamp (by size), desk/table/floor lamp (by lamp type and power use), incandescent spotlight or studio lamp, decorative lamp, strand or cable lights, fluorescent light box, incandescent or halogen track light or recessed lamp, exterior fluorescent sign
medical	oto-opthalmoscope charger, exam light or headlamp, x-ray light box, exam chair or table, body scale, hospital bed, utensil sterilizer, blood pressure monitor, IV cart
medical specialty	vital signs monitor, respirator, defibrillator charger, EKG machine & accessories, pulse oxymeter, eye chart projector, lensmeter, glucometer charger, hot bead sterilizer, suction pump charger, hearing test device, retinal scanner, fundus camera, hyfrecator, sonoscope
money exchange	credit card reader, cash register, bar code scanner, change or stamp vending machine
networking	modem, router, hub, printer hub, switch, print controller/server, video processor, wireless access point, audio/video modulator, tape drive, broadband distribution amplifier, driver
office miscellany	clock and/or radio, boombox or compact audio system, pencil sharpener, adding machine, shredder, typewriter, stapler, postage meter or scale, hole punch, laminator, time stamper, binding machine, microfiche reader
peripheral	computer speakers (pair), laptop docking station, personal digital assistant dock, computer projector, keyboard/video/mouse switch, external drive (CD, zip, hard disk, tape backup), pen tablet, digital whiteboard,
power	power strip, surge protector, PIPS, ILPS, uninterruptible power supply, charger (for laptop computer, cell or cordless phone, power tool), power conditioner, battery backup system
security	badge reader, book demagnetizer, shoplifting sensor, article surveillance system
specialty	pottery wheel, mobile bookshelves, oscilloscope, shrinkwrapper, bench wheel, soldering iron
telephony	conference or speaker phone, answering machine, intercom, phone switch, phone jack or box, dictation machine, PBX phone line converter, voice control box, switchboard phone, integrated voice server
utility/maintenance	vacuum cleaner, floor polisher, dishwasher, ultrasonic cleaner, water purifier, clothes washer or dryer

Appendix D: Miscellaneous Equipment Numbers, by Category and Site

Sorted in descending order

site code	G	M	C	H	F	K	E	J	B	A	D	N	All
bldg type	medical	L office	L office	M office	school	S office	M office	medical	M office	school	school	school	
ME Category													**sum**
power	114	220	205	174	57	167	87	64	139	36	44	86	**1393**
lighting	85	226	179	158	70	52	172	51	15	8	10	20	**1046**
plug-in power supply	92	123	221	111	34	84	76	35	88	60	24	42	**990**
peripheral	13	104	150	125	85	82	87	9	118	36	30	44	**883**
audio/visual	58	28	24	8	144	7	8	27	2	65	90	23	**484**
office miscellany	28	68	6	34	38	86	18	56	86	9	33	19	**481**
medical	393	5						76					**474**
in-line power supply	25	72	16	69	27	32	29	56	10	95		13	**444**
food/beverage	29	9	15	31	71	33	14	51	24	19	30	14	**340**
networking	27	8	8	48	43	46	31	21	6	4	11	11	**264**
telephony	5	76	15	26	49	10	20	8	12	3	1	8	**233**
medical specialty	149	3			2			70					**224**
hvac, portable	41	1	13	24	7	24	5	11	6	3	20	4	**159**
laboratory	44	1						10		63			**118**
utility/maintenance	3			2	14	4	2	2	4	9	8	4	**52**
specialty	1	2			13	14			3	1	9	1	**44**
money exchange	12	1			3	3		2	6	3	3		**33**
security		1	1		1				1		2		**6**
sum	**1119**	**948**	**853**	**810**	**658**	**644**	**549**	**549**	**520**	**414**	**315**	**289**	**7668**

Note; Plug-in and in-line power supplies are listed separately, but are actually part of the power category

NATIONAL RENEWABLE ENERGY LABORATORY

Reducing Office Plug Loads through Simple and Inexpensive Advanced Power Strips

Preprint

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Reducing Office Plug Loads through Simple and Inexpensive Advanced Power Strips

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ABSTRACT

As efficiency gains are made in building lighting and HVAC systems, plug loads become a greater percentage of building energy use and must be addressed to meet energy goals. HVAC and lighting systems are targeted because they are typically the highest energy end uses, but plug load reduction and control should be considered as part of a comprehensive approach to energy reduction. In a minimally code compliant office building, plug loads typically account for 25% of the total electrical load. In an ultra-efficient office building, plug loads are typically one of the last end uses to be considered for energy conservation and, as a result, can account for more than 50% of the total electrical load (Lobato et. al, 2011). Plug load efficiency strategies are different than other building efficiency strategies because they involve relatively small loads distributed throughout a building. These loads typically move around in the building when office configuration changes are made, so these loads may shift between circuits over time. Commercially available advanced power strips (APS) can be used to mitigate wasted energy from most plug loads and, in many cases, can have a return-on-investment of approximately two years or less. In recent technology demonstrations, data from occupancy sensors tracking plug load reductions with occupancy have shown energy-saving potential for both business and nonbusiness hours. Also, dense panel-level sub-metering has been used to quantify whole-building receptacle circuit energy consumption, energy savings, and return on investment for the whole building. Receptacle-level metering has been used to show the plug load energy consumption of individual devices and workstations. This paper documents the process (and results) of applying advanced power strips with various control approaches.

INTRODUCTION

Advanced power strips (APS) have been tested in numerous demonstration projects and wide-scale deployments. Basic mechanical schedule timers have been commercially available for a long time, while newer electronic, logic-based controls have started becoming commercially available over the past three to five years. There are an abundance of APSs that offer a variety of complexity, control strategies, data collection abilities, and costs. Some APSs come with a web-based dashboard that allows users to implement and change control strategies, as well as look at the real-time energy consumption of plug loads in their buildings. This centralized, web-based approach to plug load management is novel because conventional plug strips typically have to be configured and controlled locally.

Plug load energy savings are achieved when the device is either transitioned to a low-power state, or it is de-energized to eliminate the power draw. Both can be executed either manually or automatically. A low-power state is between a de-energized state and a ready-to-use state, such as standby, sleep, hibernate, and "off" state with parasitic power draw. A de-energized state is when electricity is not being provided to the device, such as physically disconnecting or unplugging the power cord from an electrical outlet.

Ian Metzger, Michael Sheppy, and Dylan Cutler are engineers at the U.S. Department of Energy National Renewable Energy Laboratory, Golden, Colorado.

Commercially available APSs offer a variety of control approaches, including manual control, automatic low-power state, schedule timers, load-sensing, occupancy, and vacancy. This paper describes each control approach in more detail and presents multiple case studies demonstrating plug load controls.

Manual Control

Built-in power buttons, shutdown procedures, or switched power strips are among the most common manual controls for plug loads. Switches, whether built into a device or on a power strip, provide a quick and easy manual method of powering down electronics. Other devices, such as computers, may have a shutdown procedure that users must perform to shut down the device. For some devices, manual control is the best or only method. The energy savings potential for this type of control depends entirely on user behavior.

Automatic Low-Power State Control

Built-in automatic low-power state functionality, such as standby or sleep, can often be a very effective energy saving approach. Idle time can be monitored by internal processes, causing the device to power down to a low-power state when it has been idle for a given period of time. Automatic low-power states provide limited control but are often the most accessible (and inexpensive) and effective when configured correctly. The prime example of this type of control is a computer entering a "sleep" mode. One hurdle with low-power state control is ensuring that the information services departments are enabling the appropriate settings and utilizing newly available updating techniques (such as wake-on LAN) to enable both low-power states and effective business operations.

Schedule Timer Control

Certain devices are used during the same times each day or at regular intervals, causing them to have predictable load profiles. Predictable plug loads can be effectively managed with schedule timers, which apply user-programmed schedules to de-energize and energize the device to match its pattern of usage. A schedule timer control can take multiple forms, such as electrical outlet timers, power strips, or centralized circuit controls. Schedule timer controls are generally straightforward, consistent, and reliable, but target only the energy that is wasted during nonbusiness hours.

Load Sensing Control

A device, such as a computer, may operate in conjunction with other devices, such as a monitor or other peripherals. Load-sensing control automatically energizes and de-energizes secondary devices (e.g., monitor or other peripherals) based on the "sensed" power load of the primary device (e.g., computer). If the primary device goes into a power state below a given threshold, the load-sensing control can power down the secondary devices. Load-sensing control may save more energy than scheduling control because it can reduce energy use during business and nonbusiness hours. However, it is a more complex control approach and relies on the built-in automatic low-power state functionality in the primary device.

Occupancy Control

Plug load energy savings are accomplished when devices are de-energized or transitioned into a low-power state when not in use, which for many instances, can be determined by whether or not the occupant is in the vicinity of the device. Occupancy control energizes plug loads only when users are present and de-energizes them when the space is vacant. This approach pinpoints the main source of wasted energy at workstations and has a high energy savings potential because it reduces energy use during business and nonbusiness hours. However, it is a more complex control, and depends on proper sensor placement and sensitivity.

Vacancy Control

Currently, vacancy control is not commercially available for plug loads but is commonly implemented in lighting controls because it effectively reduces energy. Vacancy control is a slight modification to occupancy control; it energizes a plug load when it receives manual input from a user and de-energizes the plug load automatically based on lack of occupancy. Plug loads that are needed only when users are present (e.g., task lights, monitors, and computers) would be good applications of vacancy control. This approach also has the highest potential for energy savings at workstations because the plug load will stay in a de-energized state until a user manually energizes the device, thus eliminating the wasted energy associated with false positives.

OCCUPACY CONTROL CASE STUDY

A demonstration project of plug load occupancy control was conducted at the U.S. Environmental Protection Agency (EPA) Region 8 Headquarters located in Denver, Colorado, from February 2011 to June 2011. This research study was undertaken in an effort to identify effective ways to reduce plug load energy. A centralized occupancy control approach was implemented on a sample of 126 occupant workstations in the building, to de-energize circuits feeding groups of six or eight cubicles. An automated energy management system de-energized the circuits when all cubicles in a group were unoccupied for a given period of time. This demonstration project also examined the influences of behavioral change on plug load energy consumption, which is not discussed in this paper.

A four-week baseline was established to quantify normal operating conditions. Occupancy controls were enabled to de-energize plug load circuits after 15 minutes of no occupancy in a group of cubicles. Energy savings of the occupancy controls were quantified by comparison to the baseline.

Energy Savings Results

The study found that the occupancy control was an effective method for reducing plug load energy consumption. Figure 1 shows workstation occupancy rates were found to be significantly less than building occupancy rates, contributing to the high energy savings potential of occupancy controls during business hours.

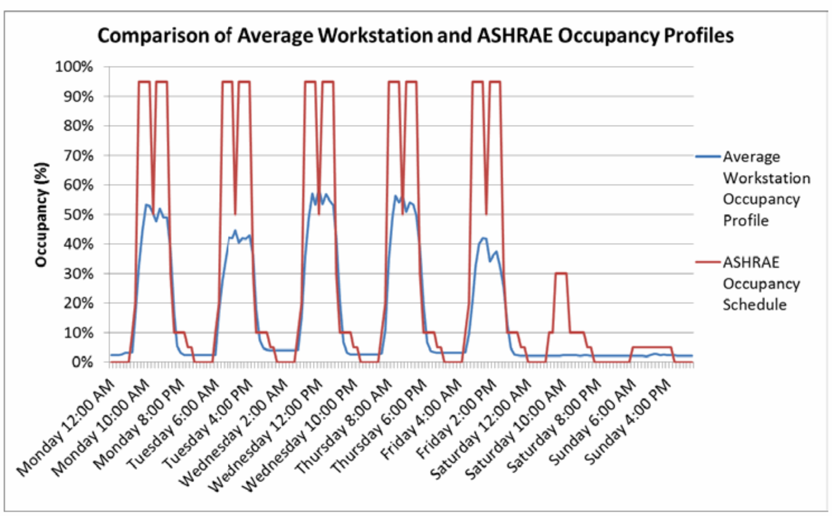


Figure 1 Comparison of the average workstation occupancy rates observed during the demonstration project compared to the ASHRAE occupancy profiles for buildings. (Credit: Ian Metzger, NREL)

The measured occupancy rates of approximately 50% during business hours confirm that control devices with the ability to track occupancy will have a higher energy saving potential at workstations. Other studies conducted by the U.S. General Services Administration (GSA) show that occupants are only at their workstations approximately 30% of the day during business hours. Energy savings for the occupant controls relative to the baseline for the 126-person test group are presented in **Table 1**.

Table 1. Occupancy Control Energy Savings Results

Plug Load Control Approach	Percent Energy Reduction from Baseline
Occupancy Control	21%

Energy savings were found to be significant during both business and nonbusiness hours. Occupancy control was found to have higher energy savings than the behavioral change methods examined in the demonstration project. It is important to note that only workstations were examined in this demonstration project. Shared equipment in common areas (e.g., kitchens, break rooms, print rooms, conference room, etc.) were not included in this study. Higher energy savings are conceivable if all office plug loads are controlled appropriately.

Lessons Learned

Collecting occupancy data can be a sensitive issue, which may require protocols to be followed that would ensure occupant anonymity could be maintained. Anonymity is typically required for field research and should be included in dashboard interfaces for displaying data.

Installation of the control and submetering system took longer and was more costly than expected. The wired installation of the control system and communications were very cumbersome and complex. Wireless communications and controls with "plug and play" installation are expected to have less complexity, are quoted at lower costs, and are currently commercially available. However, wireless communication reliability can be an issue and cyber-security at federal facilities will be a hurdle for all dashboard and data storage submetering systems. It is often more efficient to set up an independent wireless network for the submetering system.

Developing the appropriate plug load management process can have a significant influence on the success of energy reduction goals. This may include behavioral change mechanisms, control systems, or other policies. Establishing a program champion, developing a business case, benchmarking, identifying occupant needs, selecting equipment, controlling equipment schedules, institutionalizing reduction measures, and promoting occupant awareness can all be critical steps in the process.

SCHEDULE TIMER AND LOAD-SENSING CASE STUDY

A demonstration project of plug load schedule timer and load-sensing control with APS was conducted by GSA's Mid-Atlantic Region. According to several energy assessments of GSA's buildings conducted by the National Renewable Energy Laboratory (NREL), plug loads account for approximately 21% of the total electricity consumed within a standard GSA office building (Metzger et al., 2012). This project tested the effectiveness of two types of plug load control strategies: schedule timer control and load-sensing control. An APS that provided both control approaches and submetering was deployed in seven GSA field offices.

This study aimed to measure the holistic energy consumption of an office, including shared equipment and common areas, such as break rooms and print rooms. Overall, 295 devices were monitored during the study, which consisted of a baseline and two subsequent test periods, each 4 weeks long.

Energy Savings

The study found that the schedule timer control was an effective method for reducing plug load energy consumption in all space types, but most notably in the common areas, such as print rooms and break rooms. **Table 2** shows the energy savings from schedule timer controls for different space types in a typical office environment.

Table 2. Schedule Timer Control Energy Savings Results by Space Type

Space Type	Percent Energy Reduction from Baseline
Workstation	26%
Print Rooms	50%
Break Rooms	46%

Load-sensing control was only found to be moderately effective at reducing plug load energy consumption. The low energy saving results at workstations was attributed to the fact that GSA computers were being controlled by a centralized computer power management system. Computer power management is an example of automatic low-power state control. This centralized system was already putting computers and monitors into low-power states, therefore limiting the energy savings potential for this demonstration project. It should be noted that this can be a low/no-cost measure that, properly implemented, can effectively control computer power consumption. **Table 3** shows the energy savings from load-sensing control for different space types in a typical office environment.

Table 3. Load-Sensing Control Energy Savings Results by Space Type

Space Type	Percent Energy Reduction from Baseline
Workstation	4%
Print Rooms	32%
Break Rooms	N/A

Lessons Learned

Although schedule timers were found to have higher energy savings, they were only able to achieve energy savings during nonbusiness hours. In contrast, load-sensing control was able to achieve energy savings during both nonbusiness and business hours, but relied on good occupant behavior or the proper computer power settings to put the computer in sleep mode. In general, schedule timer and load-sensing controls are effective in saving energy for office equipment and can be economical if applied properly. The deployed APS had a manufacturer's suggested retail price (MSRP) of $120 per plug strip. However, there are advanced plug strips on the market that incorporate these technologies and have an MSRP of approximately $20 to $60, although these less expensive APSs typically do not provide submetering capability.

Submetering data are valuable in spotting wasted energy use, informing the future procurement of low-energy equipment, and identifying equipment that is behaving erratically (which is often a precursor to equipment failure). These data are also valuable to building energy modelers, allowing them to more accurately model plug loads in a building. However, the increased cost is typically not economical unless data are actively managed by onsite personnel. It was difficult to set the load threshold for some equipment, such as computers and monitors. The complexity of the load-sensing control resulted in instances where the equipment was being de-energized when the occupants needed them to be energized. Occupant feedback indicated a lack of training/instruction with the devices leading to limited understanding of their operation in some instances. Schedule timer controls are simple and easy to understand for users, which led to larger energy savings in this study. Load-sensing control is more complicated and difficult to understand, leading to complaints and disabling in some instances, which resulted in limited energy savings. More detailed training and maintenance could have made load-sensing control more effective.

INEXPENSIVE SCHEDULE TIMER CASE STUDY

A demonstration project of simple inexpensive schedule timer control with APS was conducted at an office building in Honolulu, Hawaii, from November 2012 through May 2013. The deployed APS could only be controlled locally, each device had to be programmed individually, and no built-in submetering capability existed. Therefore, the programmed schedule timer control was set to be more conservative to accommodate the schedules of different users. This project tested the effectiveness of schedule timer control deployed on a whole building rather than a small sample size as in other demonstration projects. APSs were deployed throughout the entire building, capturing all plug loads.

This study aimed to measure the whole building energy consumption of office plug loads using dense panel-level submetering and calculated energy savings associated with inexpensive schedule timer controls. A total of 689 plug load devices were monitored during the study, which consisted of baseline and test periods, each 4-6 weeks long.

Energy Savings

The study found that the schedule timer control is an effective method for reducing plug load energy consumption in all space types and for all occupant types. Plug loads at the demonstration building are estimated to account for approximately 22% of the whole building energy consumption. **Figure 2** shows the whole building plug load average daily usage profile, comparing the baseline to the schedule timer control. Energy savings are achieved only during nonbusiness hours. Some variation is observed during business hours, which is not attributed to the control devices but an indication that occupant behavior varied between the uncontrolled and controlled phases of the project. Occupancy and behavior are uncontrolled variables; however, occupancy data was collected and used to normalize the energy data in an attempt to remove the variability between the two phases.

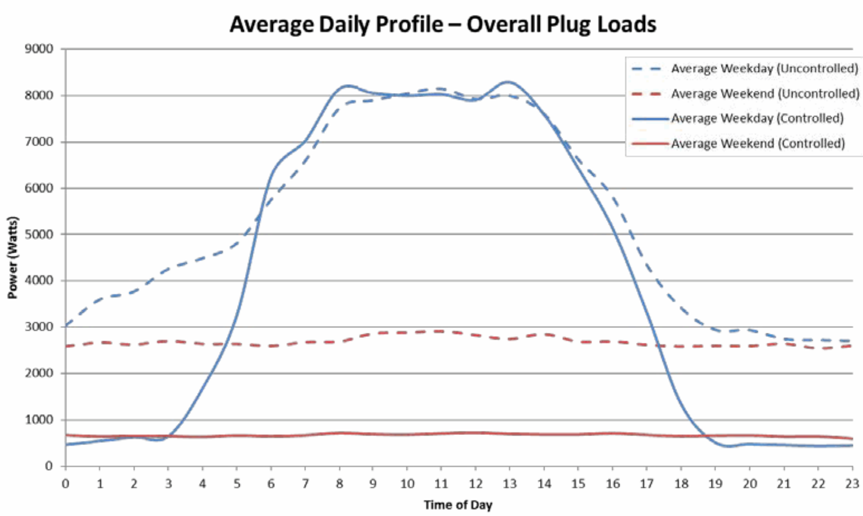


Figure 2 Baseline and APS schedule timer control plug load energy consumption profiles. (Credit: Michael Sheppy, NREL)

Energy savings were analyzed by space type to identify applications with the highest energy savings, for prioritized deployment. **Figure 3** shows the energy savings by space type. Print rooms, open offices, and hallways were found to have the highest energy savings.

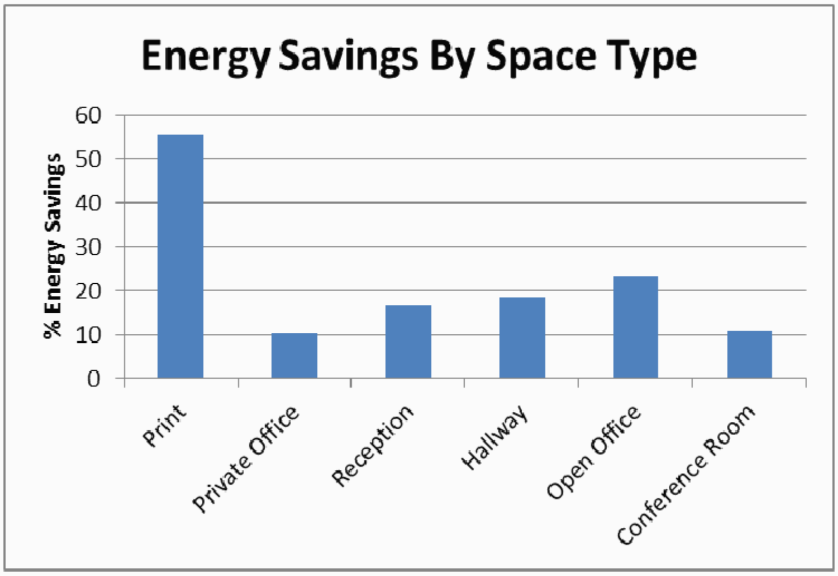


Figure 3 Energy savings by space type. (Credit: Michael Sheppy, NREL)

Measured data was extrapolated to predict annual energy savings using eQUEST energy simulation software developed by the U.S. Department of Energy. Reduction in plug load energy consumption is expected to reduce the energy required for the air conditioning system. **Table 4** shows the modeled energy savings from schedule timer controls for different energy systems.

Table 4. Schedule Timer Control Energy Savings Results by Space Type

Energy System Type	Percent Energy Reduction from Baseline
Plug Loads	28%
Air Conditioning	5%
Whole Building	***8%***

Lessons Learned

Simple and inexpensive schedule timer APSs can be effective in whole building deployments. However, schedule timers are unable to capture energy savings during business hours when occupants are not at their workstations. These devices are easy for the occupants to understand and operate, resulting in higher acceptability in wide-scale deployments. Schedule timer APSs are typically inexpensive, approximately $20 or less MSRP, and can result in payback periods of less than 2 years if applied properly.

CONCLUSION

Advanced power strips with various control approaches are commercially available and have been proven to save energy. However, selecting the appropriate control approach is critical to achieving maximum energy savings. Different equipment types require different control approaches. For example, control approaches that track occupancy, such as load-sensing, occupancy, and vacancy controls, should be applied to equipment found at workstations, such as computers, monitors, and task lights. Schedule timers should be applied to shared equipment, such as printers, coffee makers, and water coolers, but can also be effective at workstations as an alternative to automated computer power settings. However, it is also very important to understand the built-in capabilities of a device, such as automatic low-power states, and how the built-in capabilities may interact with the control approach (e.g., load-sensing). In all cases, it is important for the occupant to understand the purpose and operability of any APS. Therefore, education is paramount when considering the deployment of advanced power strips.

Potential barriers for APSs include: occupant acceptance, communications, lack of personnel time for analysis, and complex controls in some instances. These devices may require operation and maintenance to update controls, manage data, and troubleshoot incorrect operations and communication failures on a regular basis. All control strategies should provide manual override to accommodate atypical times when a plug load device would not normally be in use (e.g., using a device outside normal business hours). APSs may create a parasitic load, which must be included in the analysis of total costs savings potential.

There is the opportunity for significant energy savings through appropriate deployment of APSs. These savings can achieve very attractive returns on investment due to the low cost of certain APS devices. This has been proven with schedule based control in two case studies discussed here. There is significant opportunity for more precisely tuned control of the plug and process loads utilizing occupancy or vacancy control, but a commercially available system that accomplishes this effectively (both in effort and cost) has not been perfected.

Sub metering data are valuable in spotting wasted energy use and identifying equipment that is behaving erratically, but the increased cost is typically not economical unless data are actively managed by onsite personnel. A more effective feedback loop to the end users than the currently available web dashboard approach will be necessary to achieve higher levels of savings for submetering.

Research has been conducted on appropriate control approaches for different types of equipment and published resources are available, such as Assessing and Reducing Plug and Process Loads in Office Buildings (NREL, 2012) and Selecting a Control Strategy for Plug and Process Loads (Lobato et al, 2012). These documents provide a methodical approach to assessing and determining the appropriate control mechanism for different plug loads. Selecting the appropriate control approach and considering lessons learned from the presented case studies will help to make future deployments more effective and increase plug load energy reduction in office buildings.

REFERENCES

"Greening EPA." U.S. Environmental Protection Agency: http://www.epa.gov/greeningepa/facilities/denver-hq.htm. Accessed July 26, 2011.

Lobato, C.; Pless, S.; Sheppy, M. (2011). Reducing Plug and Process Loads for a Large Scale, Low Energy Office Building: NREL's Research Support Facility. NREL/CP-5500-49002. Golden, CO: National Renewable Energy Laboratory. Accessed June 28, 2012: http://www.nrel.gov/docs/fy11osti/49002.pdf.

Metzger, I.; Kandt, A.; Van Geet, O. (2011). Plug Load Behavioral Change Demonstration Project. NREL/TP-7A40-52248. Golden, CO: National Renewable Energy Laboratory. Accessed June 28, 2012: http://www.nrel.gov/docs/fy11osti/52248.pdf.

"Work Place Matters." U.S. General Services Administration. Accessed January 13, 2013: http://www.gsa.gov/graphics/pbs/WorkPlace_Matters_FINAL508_lowres.pdf.

"About the Mid-Atlantic Region." U.S. General Services Administration. Accessed June 27, 2012: http://www.gsa.gov/portal/category/21451.

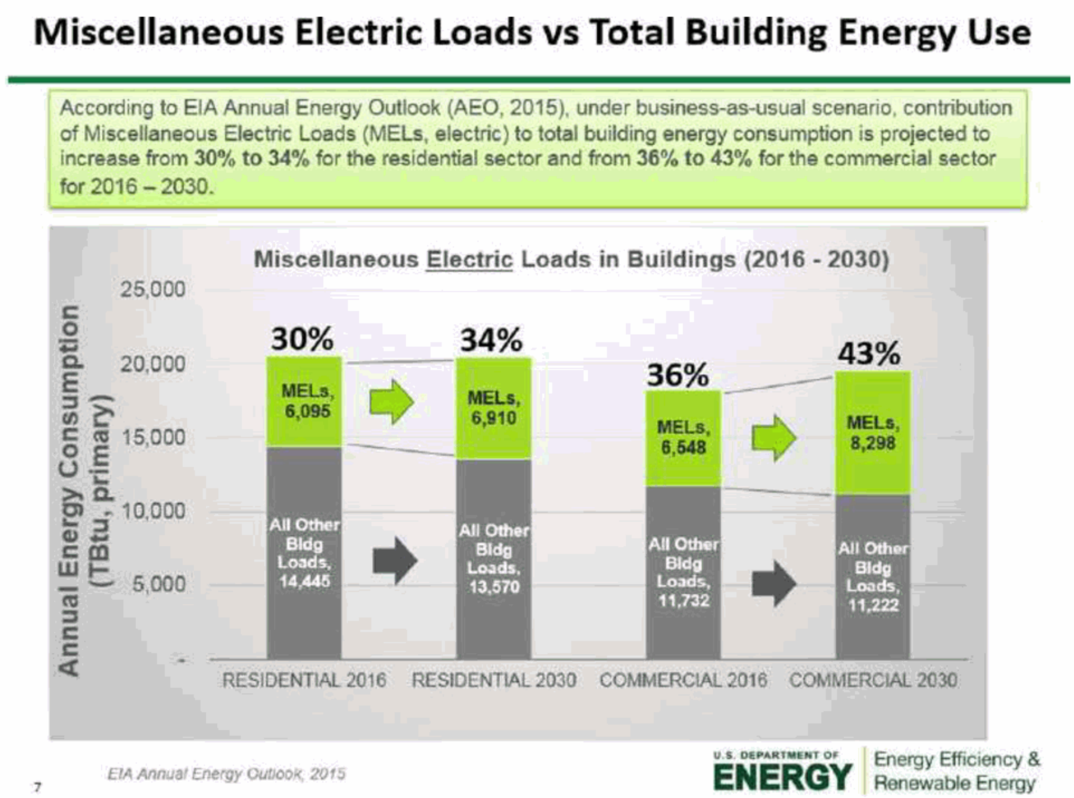
Metzger, I.; Cutler, D.; Sheppy, M. (2012). Plug-Load Control and Behavioral Change Research in GSA Office Buildings. NREL/TP-7A40-55780. Golden, CO: National Renewable Energy Laboratory. Accessed January 12, 2013: http://www.nrel.gov/docs/fy13osti/55780.pdf.

Lobato, C.; Sheppy, M.; Brackney, L.; Pless, S.; Torcellini, P. (2012). Selecting a Control Strategy for Plug and Process Loads. NREL/TP-5500-51708. Golden, CO: National Renewable Energy Laboratory. Accessed January 12, 2013: http://www.nrel.gov/docs/fy12osti/51708.pdf.

National Renewable Energy Laboratory (2012). Assessing and Reducing Plug and Process Loads in Office Buildings. NREL/BR-5500-51199. Golden, CO: National Renewable Energy Laboratory. Accessed January 12, 2013: http://www.nrel.gov/docs/fy11osti/51199.pdf.

Although commercial buildings continue to decrease their energy use through more efficient lighting, mechanical, and domestic water systems, the Miscellaneous Electrical Loads (MELs) energy segment continues to rise. More and more electrical power consuming devices are being plugged into building electrical systems. Some, such as fans, space heaters, printers, monitors, plug in lamps are left on, when spaces are unoccupied. Other devices may be left plugged in and continue to draw power even when inactive or in standby modes. This wastes energy and is counter to the energy efficiency aim of the IECC.

For more than eight years, other energy efficiency codes have included automatic receptacle control provisions to reduce the wasted energy including CA Title 24, Washington State Energy Code, Florida Energy Code, and ASHRAE 90.1. The Annual Energy Outlook of 2015 from the US EIA, indicate that these load categories will grow from 36% of a commercial buildings energy use, to 43% over the next 15 years.



This provision simply assures receptacle loads that are not needed when building occupants leave high receptacle load use areas, are automatically turned off, saving the energy that would otherwise be wasted. It requires that controlled receptacles clearly be marked as required by NFPA 70, to eliminate user confusion of proper use, and provides good practice exceptions where controlling receptacles would endanger safety and security, or areas of continuous operation.

Expressed safety concerns where extensive use of extension cords and plug strips would be used are unfounded. There are no documented studies validating this problem exists. Although there are no requirements for receptacle density in commercial buildings, a design professional will ensure there is an appropriate distribution of receptacles to effectively accomplish the mission of the building. There's no evidence that the distribution of receptacle outlets and controlling some of them has any adverse impact on the utility of this requirement.

Enforceability of this provision is straight forward for building departments and their inspectors. Construction drawings indicate which receptacles are controlled and which are uncontrolled. Onsite inspection will clearly show complying labelled receptacles and operation is easily varied with the shut-off controls already in place with the lighting system.

There have been a considerable number of studies over the years that share the viability and cost effectiveness of automatic receptacle control. Some noted here.

1. One study demonstrated effectiveness (e.g. Zhang2012) with simply payback on this type of equipment between 1.5 and 9 years for small and large offices. This considers the most comprehensive information on office plug load types, installation densities, usage patterns, and power states based on field surveys and monitoring (Kawamoto 2000, 2001; Moorefield, Frazer & Bendt 2011; Roberson 2002, 2004; Roth 2002, 2004; Sanchez 2007; Webber 2001, 2005).

2. A CASE initiative study for CA Title 24-2013 found that smaller office buildings (10,000 sqft) had an annual electrical savings of 4,900 kwh/year and a demand savings of 1.97 kW based on installed costs and utilization of lighting control system elements already installed. The simple payback was 4.2 years. For larger office buildings (175,000 sqft) the annual electrical savings were 107,000 kwh/year and a demand savings of 23.6 kW for a simple payback of 2.4 years.

3. A GSA Green Proving Ground Program study conducted in 8 buildings with monitored receptacle control found "Results underscored the effectiveness of schedule-based functionality, which reduce plug loads at workstations by 26%, even though advanced computer power management was already in place, and nearly 50% in printer room and kitchens." In the study buildings, receptacle loads averaged 21% of building energy use and monitored more than 295 devices over three different test periods to validate the findings. It found payback through timer scheduled control of kitchens of 0.7 years, printer rooms of 1.1 years and miscellaneous devices in 4.1 years. At workstations, the payback was 7.8 years.

4. A study done on "Office Space Plug Load Profiles and Energy Savings Interventions" at the University of Idaho and presented at the ACEEE summer Study in 2012 found that average savings of 0.60 kWh/SF Yr. with plug strip control interventions. This study provided guidance for utility programs to assist with development of plug load efficiency measures and was based on a more detailed report, "Plug Load Profiles" (Acker, B. et. al. 2012).

5. The DOE Better Buildings program issued a December 2015 "Decision Guides for Plug and Process Loads Controls" to help educate and guide decision processes for effective receptacle-based load control. It highlights that "Plug and Process Loads" account for 33% of the total energy consumed by commercial buildings. It sites seven decision strategies including that of integrated plug load controls with other building systems as one of the largest for energy savings across most building types for whole-building retrofit and new construction categories.

6. A study performed “Advancing the Last Frontier: Reduction of Commercial Plug Loads” presented at the ACEEE summer study of 2016, indicated field study results demonstrating savings of 19% when deploying plug in control strategies in office workstation environments.

National Electrical Manufacturers Association

A NEMA Wiring Devices Section White Paper WD ARCP 1-2016

Automatic Receptacle Control to Meet ASHRAE 90.1-2010 and California Title 24

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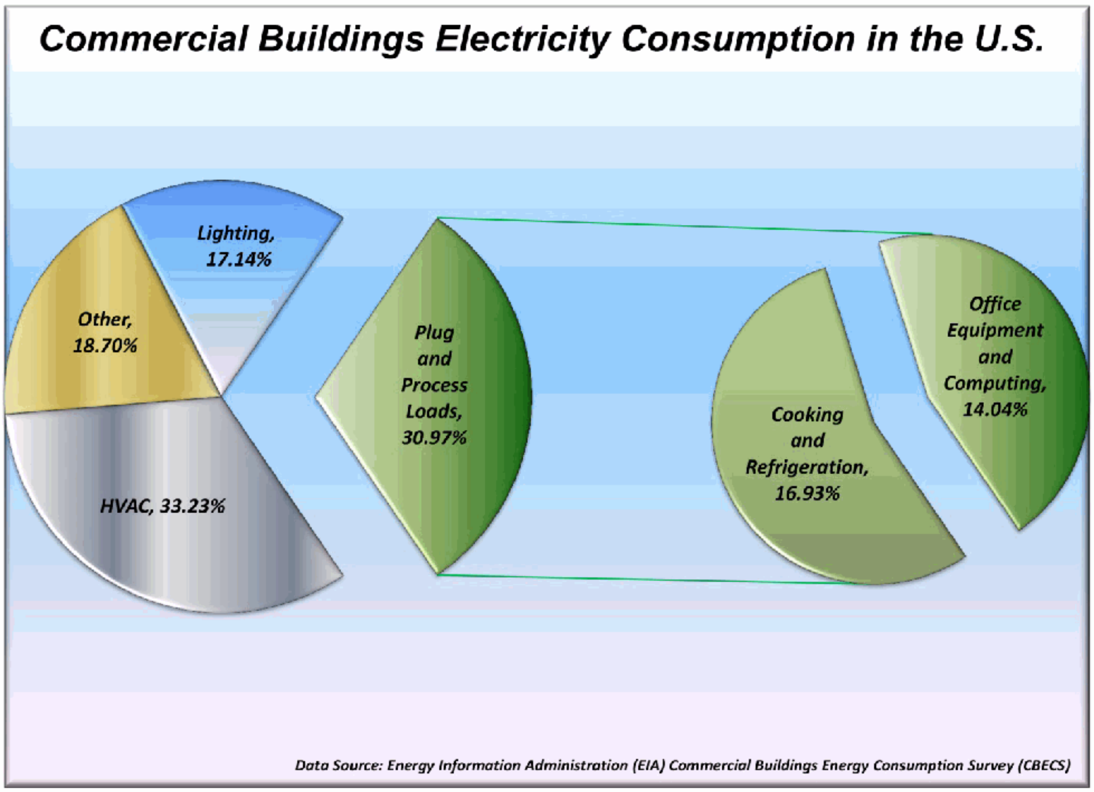
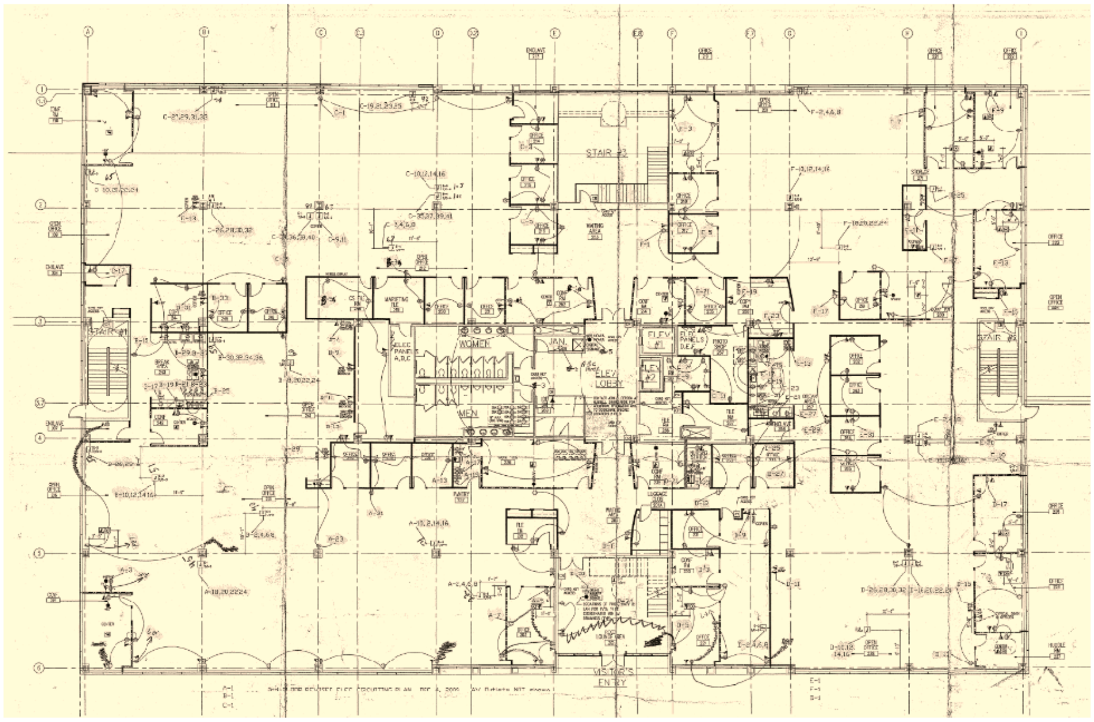
Automatic Receptacle Control to Meet ASHRAE 90.1-2010 and California Title 24

Advances in building construction methodology and product technology have allowed for greater energy efficiency in building design than ever before. In the recent past, HVAC and lighting presented the greatest opportunities to reduce power consumption and conserve energy. Designers and manufacturers have been implementing solutions targeting these systems. Office equipment, appliances, and plug-in lighting loads are the next major area for potential reduction of energy use through management and control. Today, much of what is plugged into a convenience receptacle is uncontrolled. Based on data from the Energy Information Administration Commercial Buildings Energy Consumption Survey of 2012, approximately 30% of the energy used in buildings is by loads that are plugged in.



Both ASHRAE 90.10 and California Electric Code (CEC) Title 24 have identified receptacles as an area requiring energy management and have incorporated explicit requirements for automatic control. They target spaces in a building and require that half (50 percent) of the receptacles are controlled by an automatic shutoff device. Most commonly, these are receptacles in personal offices, conference rooms, and cubicle spaces. (Code excerpts shown at the end of the paper)

Below is a typical commercial office building floorplan.



In this example, 80 percent of the receptacles are required to be controlled; 20 percent are exempt. Further analysis shows that most receptacles are located in the furniture systems or cubicles and conference areas of offices. Receptacles are most often used to control task lighting, followed by computer peripherals and personal devices (e.g., portable electronics, chargers, radios, heaters, fans, etc.). The energy standard requires some receptacles to be controlled. The intent is for the controlled receptacles to provide power when needed by the occupant—that is, when the occupant is present—and minimize wasted energy. Uncontrolled receptacles continuously supply power to equipment, requiring them to be energized at all times. Most computer equipment utilizes a “sleep mode” to optimize energy efficiency. Since the energy consumption on such a mode is very low, it is suitable to keep these devices plugged in to uncontrolled receptacles. Other, more discretionary plug-in items such as fans, heaters, and radios, if used, should be on only when the occupant is in the area, which results in minimum power use.

Circuit Design: Good, Better, Best

ASHRAE 90.1 and CEC Title 24 require automatic shutoff control by a time-of-day device, an occupant sensor, or an automated signal from another control or alarm system. It is up to the designer or building engineer to select the most appropriate technique to comply with the standard. Effectiveness and flexibility varies for each of these techniques, as do the types of buildings.

To better understand plug load, it is critical to examine how a particular building is used. Most commercial buildings serve as work locations, which come alive with people and activity throughout the day. Every building has prime use times (for example, 8 a.m. to 5 p.m.), with a reduction at night and then a slight increase if nighttime cleaning is performed. With a 24/7 work environment, it may be common to have variable hours, with people working earlier or later—not to mention weekends, holidays, and occasional exceptions. Many of today's buildings need to be more responsive to the individual worker and modern work schedule.

A hardwired load controller can be placed in a series with a branch circuit at the breaker panel to control power to the circuits according to preset schedules. Such a controller can be added to the building with minimal changes to the method currently used in circuit design. Either a remotely controllable circuit breaker or remotely controllable relay in a box outside the panel can serve this purpose. Circuits are typically routed conveniently through the building, properly sized to electrical needs and to maximize the number of outlets on a circuit. As a result, however, one circuit may be used for multiple offices and hallways, possibly unrelated to the way they need to be controlled. Office furniture is typically multi-circuited, with at least two circuits per work area, sometimes using isolated ground for computer use. In this instance, using time-based control would facilitate area control but may limit the flexibility of set times.

A sensor-based system, such as is commonly used for keeping lights off in unoccupied areas, can turn-off plug loads when the area is unoccupied. Since one person may be at work late or on a weekend when others are not present, ideally this occupant detection should resolve to a single person, not an entire floor or work group. Typical receptacle circuit design may need to be altered for maximum occupant benefit by limiting it to just a single-person area of use (i.e., only in the office or at the desk where the occupant works). As a result, the power circuit may need to have fewer receptacles, requiring more circuits. For new building construction, more branch circuits can be installed to enable greater control flexibility. For retrofitting existing buildings, wirelessly controlled receptacles can deliver this flexible control.

Open cubicle areas require a different design. As open areas need to be controlled as a group, typically a multiple-circuit control makes sense, similar to a time-based system. It can also be triggered by an overhead sensor, adding flexibility if the worker stays late or comes in on the weekend. Again, individually controlled receptacles, rather than controlled branch circuits, provide maximum flexibility and the best user experience.

Two Approaches for New Construction Applications

Controlled branch circuits may offer the use of two circuits for each duplex receptacle, where one receptacle is on one circuit and the other receptacle is on a second circuit ("split wiring"). In this situation, a wired load controller can control one receptacle, while the other receptacle is only controlled by the circuit breaker (i.e., always left on and not controlled). Using split wiring for every duplex receptacle will give the user the ability to plug into either a controlled or non-controlled outlet in the same location. The occupant will have choice of continuous power or a controlled circuit in the same location.

Choosing to run two circuits and control every other receptacle is another technique. The requirement is that a non-controlled receptacle be within 6 feet of a controlled receptacle.

In either case, concern for user convenience needs to be considered to make sure there are enough outlets to meet the plug-in needs of the occupant. Location is key.

Receptacle Markings

NEC has chosen the symbol ⏻ to indicate an automatically controlled receptacle. As non-controlled receptacles never had an identifier, none is required. Both ASHRAE and the CEC require receptacles to have a permanent marking. The installer may choose to add a permanent marking during construction. There are pre-marked receptacles available from several manufacturers that comply with permanent marking requirements.

The overall intent of the energy code and requirement is to minimize wasted energy and maximize efficiency. The directive is to control plug loads through the management of selected outlets. How this is done is left up to the property owner. It is impossible to say whether minimum compliance or a totally integrated building management system is appropriate without understanding the building and its use. Correct sizing in the design is paramount to proper automatic receptacle control.

Code Excerpts

ASHRAE 90.1-2010 and 2013

8.4.2 Automatic Receptacle Control
The following shall be automatically controlled:

a) At least 50% of all 125 volt, 15 and 20 ampere receptacles in all private offices, conference rooms, rooms used primarily for printing and/or copying functions, break rooms, classrooms, and individual workstations
b) At least 25% of branch circuit feeders installed for modular furniture not shown on the construction documents

This control shall function on

a) a scheduled basis using a time-of-day operated control device that turns receptacles off at specific programmed times—an independent program schedule shall be provided for controlled areas of no more than 5000 ft2 and not more than one floor (the occupant shall be able to manually override the control device for up to two hours);

b) an occupant sensor that shall turn receptacles off within 20 minutes of all occupants leaving a space; or
c) an automated signal from another control or alarm system that shall turn receptacles off within 20 minutes after determining that the area is unoccupied.

All controlled receptacles shall be permanently marked to visually differentiate them from uncontrolled receptacles and are to be uniformly distributed throughout the space.

Plug-in devices shall not be used to comply with section 8.4.2.

Exceptions: Receptacles for the following shall not require an automatic control device:
a) Receptacles specifically designated for equipment requiring continuous operation (24 hours/day, 365 days/year)
b) Spaces where an automatic control would endanger the safety or security of the room or building occupant(s)

California Electric Code (CEC) Title 24 Section 130.5

(d) Circuit Controls for 120-Volt Receptacles.
In all buildings, both controlled and uncontrolled 120 volt receptacles shall be provided in each private office, open office area, reception lobby, conference room, kitchenette in office spaces, and copy room. Additionally, hotel/motel guest rooms shall comply with Item 5. Controlled receptacles shall meet the following requirements, as applicable:

1. Electric circuits serving controlled receptacles shall be equipped with automatic shut-OFF controls following the requirements prescribed in Section 130.1(c)(1 through 5); and
2. At least one controlled receptacle shall be installed within 6 feet from each uncontrolled receptacle or a splitwired duplex receptacle with one controlled and one uncontrolled receptacle shall be installed; and
3. Controlled receptacles shall have a permanent marking to differentiate them from uncontrolled receptacles; and
4. For open office areas, controlled circuits shall be provided and marked to support installation and configuration of office furniture with receptacles that comply with Section 130.5(d) 1, 2, and 3; and
5. For hotel and motel guest rooms at least one-half of the 120-volt receptacles in each guest room shall be controlled receptacles that comply with Section 130.5(d)1, 2, and 3. Electric circuits serving controlled receptacles shall have captive card key controls, occupancy sensing controls, or automatic controls such that, no longer than 30 minutes after the guest room has been vacated, power is switched off.
6. Plug-in strips and other plug-in devices that incorporate an occupant sensor shall not be used to comply with this requirement.

EXCEPTION 1 to Section 130.5(d): In open office areas, controlled circuit receptacles are not required if, at time of final permit, workstations are installed, and each workstation is equipped with an occupant sensing control that is permanently mounted in each workstation, and which controls a hardwired, nonresidential-rated power strip. Plug-in strips and other plug-in devices that incorporate an occupant sensor shall not be used for this exception.

EXCEPTION 2 to Section 130.5(d): Receptacles that are only for the following purposes:

i. Receptacles specifically for refrigerators and water dispensers in kitchenettes.
ii. Receptacles located a minimum of six feet above the floor that are specifically for clocks.
iii. Receptacles for network copiers, fax machines, A/V and data equipment other than personal computers in copy rooms.
iv. Receptacles on circuits rated more than 20 amperes.

National Electrical Code® Article 406

(E) Controlled Receptacle Marking. All nonlocking-type, 125-volt, 15- and 20-ampere receptacles that are controlled by an automatic control device, or that incorporate control features that remove power from the outlet for the purpose of energy management or building automation, shall be marked with the symbol shown in Figure 406.3(E) and located on the controlled receptacle outlet where visible after installation.

Figure 406.3(E) Controlled Receptacle Marking Symbol.

Exception: The marking is not required for receptacles controlled by a wall switch that provide the required room lighting outlets as permitted by 210.70.

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