LBNL-46930

Field Surveys of Office Equipment Operating Patterns

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http://enduse.lbl.gov/Projects/OffEqpt.html

September 5, 2001

DRAFT
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This work was supported by the U.S. Environmental Protection Agency, Office of Air and Radiation, Climate Protection Division through the U.S. Department of Energy under Contract No. DE-AC03-76SF00098.

Abstract

This paper presents the results of 11 after-hours walk-throughs of offices in the San Francisco CA and Washington D.C. areas. The primary purpose of these walk-throughs was to collect data on turn-off rates for various types of office equipment (computers, monitors, printers, fax machines, copiers, and multifunction products). Each piece of equipment observed was recorded and its power status noted (e.g. on, off, low power). Whenever possible, we also recorded whether power management was enabled on the equipment. The floor area audited was recorded as well, which allowed us to calculate equipment densities.

We found that only 44 percent of computers, 32 percent of monitors, and 25 percent of printers were turned off at night. Based on our observations we estimate success rates of 56 percent for monitor power management and 96 percent for enabling of power management on printers.

Introduction

The U.S. Department of Energy (DOE) projects that office equipment will be the fastest-growing commercial end use between 1998 and 2020 (US DOE 1999). Energy use for personal computers in the commercial sector is expected to grow an average 2.9 percent per year during this period, and energy use for other office equipment is expected to grow 2.6 percent per year. This is on top of the steep growth that occurred during the 1990s. Norford et al. (1989) estimated 1988 office equipment energy consumption (including personal computers (PCs[1]), monitors, and input/output (I/O) devices[2]) at 25 TWh. Office equipment energy consumption has since grown to 74 TWh[3] (Kawamoto et al., 2000). This growth has drawn attention to the office equipment end use.

As the energy impacts of office equipment have become better understood, conservation policies have emerged that target this office equipment energy use. In 1993, the Environmental Protection Agency (EPA) launched an energy conservation program called ENERGY STAR®, which initially targeted energy use by computers, monitors, and printers. Copiers, fax machines, scanners, and multifunction devices (MFDs) were added to the program later. The program sought to use power management (PM) to reduce power use by office equipment that was sitting idle. PM was developed for laptop computers to prolong battery life; PM reduces consumption by slowing the computer's clock rate, turning off power to certain circuits, and spinning down the hard drive. The EPA believed that these and other similar strategies could be used to reduce power use in desktop computers and other office equipment. ENERGY STAR computers, monitors, printers, copiers, scanners, and MFDs now commonly enter a low-power mode or "go to sleep" after a period of inactivity.

As part of its ongoing support of EPA's ENERGY STAR Program, Lawrence Berkeley National Laboratory (LBNL) forecasts aggregate energy and carbon savings for each ENERGY STAR-labeled product. These forecasts are bottom-up estimates; that is, they begin with estimates of unit energy consumption, unit shipments, and device lifetimes and work "upward" to aggregate energy use and savings. Accurate unit energy savings estimates are essential to assessing program impacts.

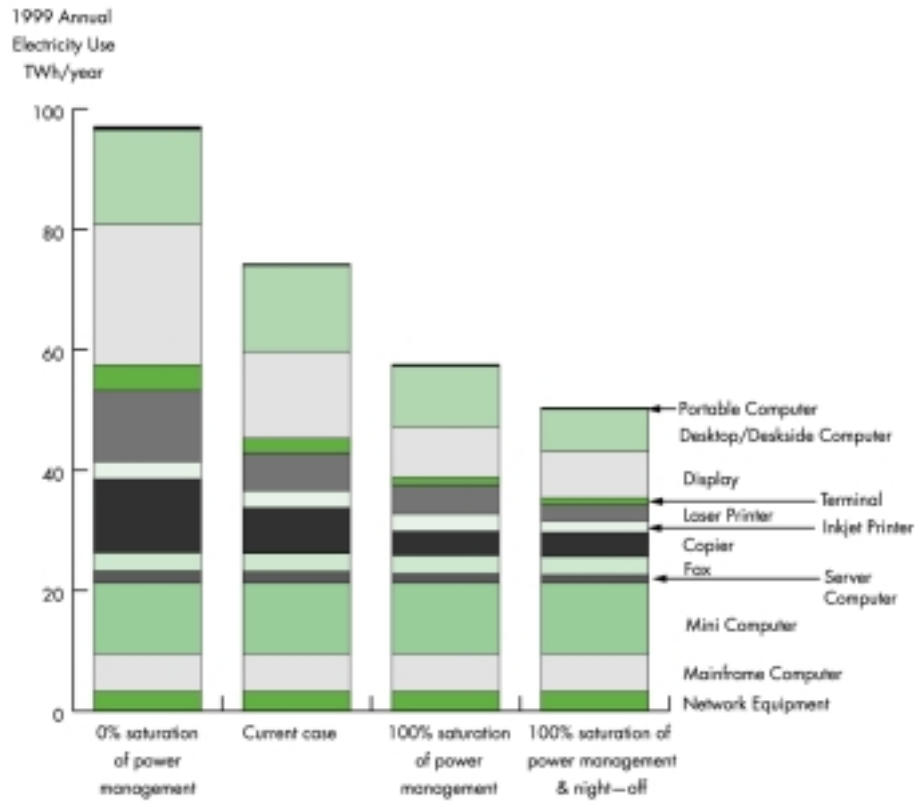
Office equipment energy use is dependent on the power consumption characteristics of a device, its built-in power management features (e.g., low power modes and auto-off), and user behavior. Figure 1 shows estimates for aggregate office equipment energy use for different degrees of power management saturation and rates of equipment turn-off (based on data from Kawamoto et al., 2000). The current case shown in the figure is based on assumptions about current power management use and turn-off rates. The 0-percent power management and 100-percent power management cases are extremes, but

[1] We use the term PC throughout the paper to refer to all personal computers, including both Apple and Windows/Intel devices (i.e. Macs and PCs).

[2] This includes printers and scanners but presumably not office equipment such as copiers and fax machines.

[3] Includes network equipment.

Figure 1. Annual Electricity Use for Office Equipment under Various Assumptions



Source: Chen, A. 2000. "EETD Study Explores Electricity Use of Office and Network Equipment." *Environmental Energy Technology Division News*, 2(2):1-3. Lawrence Berkeley National Laboratory.

they still hinge on assumptions about turn-off rates. The last case shown assumes both 100 percent saturation of power management and 100 percent night turn-off rates. As the figure shows, varying assumptions about power management use and turn-off rates has a large impact on energy use estimates.

Despite the importance of these assumptions, there is a great deal of uncertainty about turn-off behavior and the use of power management. Improving our understanding of user behavior is critical to creating accurate estimates of office equipment energy use and to assessing the impacts of policies like ENERGY STAR.

User behavior determines the number of hours per day during which a device is in use, the number of hours the device is turned on but idle, and the number of hours the device is off. User behavior may be influenced by the computing environment; hardware, operating systems, software, networking, back-up systems, and corporate culture vary widely. The characteristics of the individual user and the computing environment are important variables in determining the success or failure of power management.

Power status during non-business hours is an important determinant of energy use. In a 9-to-5 office, office equipment is used during less than 25 percent of the week. For personal office equipment (most computers, monitors, and personal printers), actual work hours are even fewer after holidays, vacation, sick days, travel, and meetings are taken into account. Equipment with multiple users (most copiers, fax machines and networked printers) have longer workdays and fewer idle days but nonetheless are unused for most of a typical week. During the course of a week, a computer left on 24 hours per day would consume four times the energy of one that is routinely turned off at the end of the work day. It is therefore impossible to characterize average energy use for office equipment without first knowing turn-off behavior.

The purpose of this study was to observe and record turn-off behavior in the field in order to refine ENERGY STAR energy savings calculations. Our goal was to observe a total of 1,000 computers/monitors in 10 different offices. Other office equipment (printers, copiers, etc.) were also recorded, but we set no explicit target number of units to audit. In the audit, we recorded each device's power mode, and, for printers, whether the device had power management enabled. These data allowed us to calculate power management enabling and/or success rates in addition to turn-off rates for certain types of equipment. We distinguish the power management success rate from the enabling rate because it is possible, as the result of a number of factors, for a device with power management enabled to fail to enter a low-power state.[4] It is often easier to calculate success rates because they can be based on observation of only the state of the equipment's power, not the PM settings. Success rates are also more useful in calculating energy use.

Previous Work

The most complete review of power management and turn-off literature is by Nordman et al. (2000). They compiled 17 research studies of computer and monitor power management and manual turn-off; fourteen of these studies address night status. Although that paper focuses on computers and monitors, some of the studies also addressed printers and copiers. Table 1 summarizes the literature relevant to the current study, including 14 of the studies surveyed by Nordman et al. and one additional paper that addresses turn-off rates for copiers.

Researchers used night audits, daytime audits, surveys, and continuous power or status monitoring (noted as time series data in Table 1) to assess user behavior. Of these methods, night audits and continuous monitoring provide the most reliable indications of night status. Survey data are less reliable although the relevant questions (do you turn off your computer at night/on weekends/when you go on vacation?) are straightforward. Daytime audits provide only limited information about nighttime status.

Nine of the 15 studies described in Table 1 were done in the U.S. (six in California). Two were done in Canada, and the rest were from Thailand, Sweden, Denmark, and the Netherlands. Governmental organizations and national laboratories are disproportionately

[4] For example, network activity often interferes with computer power management, and printers in error mode typically do not enter low power mode.

Table 1. Literature Addressing Turn-Off Rates

Study	Data	Method	Description
Syzdlowski & Chvala (1994)	1990-92	Time-series data	Six Pacific Northwest National Laboratory buildings, Richland WA
Tiller & Newsham (1993)	1992	Time-series data	3 Canadian federal government buildings in the Ottawa area
IHEM (1994)	1994	Survey, Daytime Audit	Survey of LBNL employees, 861 responses. Berkeley CA
Nordman et al. (1996)	1995	Day and night audits	LBNL, 1 building, Berkeley CA
LBNL-Forrestal[a]	1996	Night audit	The U.S. Department of Energy's Forrestal Building, Washington DC
CADDET (1999)	1996	Day and night audits	Ministry of Environment and Energy, Toronto, Canada, 1 building
Arney & Frey (1996)	1996	Time-series data	Architectural Energy Corporation's offices in Boulder CO
Mungwititkul & Mohanty (1997)	1996	Not specified	"Several" office and university buildings including a private office, a state enterprise, and an academic institution, Thailand
Schanin (1997)	1997[b]	Night audit	45 sites in San Francisco Bay Area (CA); All but 5 were private companies.
Becht et al. (1998)	1997	Surveys	400 user questionnaires were completed; the number of companies represented was not reported. The Netherlands.
Bryntse & Enoksson (1998)	1997	Surveys	14 sites (5 government/9 private; 5 small/6 medium/3 large organizations); Sweden
Nordman et al. (1998)	1997	Day and night audits	Most of LBNL, 3 municipal office buildings, a federal office building, two large corporate offices, 1 hospital; San Francisco Bay Area CA
Nielsen (1998)	1997-98	Surveys	Survey of PC users and IT[c] managers (118 user and 255 manager responses), Denmark
Picklum et al. (1999)	1997-98	Day and night audits	City of San Francisco CA, 7 sites
Nordman (2000)	1999	Day and night audits	City of San Diego CA, 1 building

[a]Designation is from Nordman et al. (2000) for an otherwise unpublished LBNL study.
[b]These data were collected by Bayview Technologies, Inc., a manufacturer of control devices for plug loads (including monitors), as a part of their marketing efforts. The report was available on the Bayview website in 1997, but the data may have been collected earlier.
[c]IT= Information Technology

represented. Not all the studies were specific about the number of buildings represented and whether the buildings were government-owned, but for the studies where that information was provided well over half of the buildings were government-owned (federal, state or municipal). (By comparison, government buildings make up only 8 percent of all buildings in the U.S., US DOE 1998.)

Tables 2 through 5 summarize the results of these studies for PCs, monitors, printers, and copiers, respectively. The sample sizes vary widely, from 13 to more than 20,000. Some of the studies tracked whether a device was in low-power mode. Turn-off rates vary widely among the studies, ranging from 0 to 91 percent for computers and from 55 to 93 percent for monitors.

Table 2. PC Night Status[a]

Study	Sample Size	On	Low	Off
Syzdlowski & Chvala (1994)	182	18 %	--	82 %
Tiller & Newsham (1993)	94	20 %	--	80 %
IHEM (1994)	30	47 %		53 %
Nordman et al. (1996)	70	26 %	6 %	69 %
LBNL-Forrestal	~200	10 %		90 %
CADDET (1999)	307	>99 %	<1 %	0 %
Arney & Frey (1996)	20	25 %	--	75 %
Nielsen (1998)	373	11 %		89 %
Picklum et al. (1999)	904	17 %	9 %	73 %
Nordman (2000)	154	9 %	0 %	91 %

[a]Adapted from Nordman et al. (2000).

Table 3. Monitor Night Status[a]

Study	Sample Size	On	Low	Off
Nordman et al. (1996)	70	24 %	19 %	57 %
LBNL-Forrestal	~200	10 %		90 %
Schanin (1997)[b]	>20,000	45 %		55 %
Becht, Pleijster, & De Vree (1998)	~400	7 %		93 %
Bryntse & Enoksson (1998)	~140	18 %		82 %
Picklum et al. (1999)	882	16 %		64 %
Nordman (2000)	154	8 %	4 %	88 %

[a]Adapted from Nordman et al. (2000).
[b]These data were collected by Bayview Technologies, Inc., a manufacturer of control devices for plug loads (including monitors), as a part of their marketing efforts.

Table 4. Printer Night Status

Study	Sample Size	On	Low	Off
Arney & Frey (1996)	13	38 %	23 %	38 %
Schanin (1997)	not spec.	75 %		25 %
Becht, Pleijster & De Vree (1998)	202	20 %		80 %
Bryntse & Enoksson (1998)	a	66 %		34 %
Nielsen (1998)	not spec.	38 %		62 %
Picklum et al (1999)	211	50 %	23 %	27 %
Nordman (2000)	45	27 %	31 %	42 %

[a] Bryntse & Enoksson surveyed 150 workers at 14 different sites. 100 percent of respondents reported using a printer, but it is not clear how many different printers were represented by the responses.

Table 5. Copier Night Status

Study	Sample Size	On	Low	Off[a]
Mungwititkul & Mohanty (1997)	19	0 %	0 %	100 %
Schanin (1997)	138	84 %		16 %
Becht, Pleijster, & De Vree (1998)	not spec.	19 %		81 %
Nordman et al. (1998)	223	29 %	38 %	33 %
Nielsen (1998)	not spec.	18 %		82 %
Picklum et al. (1999)	54	13 %	19 %	69 %

[a]Includes manual and auto-off.

Methodology

Our study involved night audits of nine San Francisco Bay Area sites and two Washington DC sites. Our interest was primarily in night status; for computers and monitors, we restricted ourselves primarily to recording that information ("on," "low power," or "off"). Because printers and copiers were fewer in number, we took the time to write down the manufacturers and model numbers. Whenever possible, we also checked the power management settings.[5] Some types of information—vintages, for example—were not collected because of the time that would have been required. Collecting other information, e.g., power management settings for computers and monitors and operating systems of computers, would have required computer access. This would have been difficult in environments where most computers were password protected or locked and significantly more intrusive than simply observing power status, both of which would have made obtaining permission even more difficult than it already was.

In defining the scope of our study, we recognized that individual behavior was not the only driver of operating patterns. Turn-off rates can be driven by company policy (e.g., network back-ups), remote access (including telecommuting), and corporate culture. Consequently, it was not sufficient simply to get a large sample of devices; we also needed a large sample of sites. We set a goal of ten sites with an expectation of observing about 100 computers per site.

We recruited 11 sites primarily through personal contacts although we made some cold calls to facilities departments at target companies. We provided a description of the study, including exactly what we would do, how long it would take, and how the data would be used. Eleven sites are not a large sample from a statistical perspective, but they represent fairly diverse industries and, as we discovered, equipment user behavior. Table 6 lists the sites audited by business type. Company names have been omitted for privacy reasons.

Several companies declined to participate for security reasons (a software firm cited fear of industrial espionage, a brokerage expressed concerns about client confidentiality, and another company was concerned that our study was a first step toward EPA regulatory oversight of computing practices, despite our reassurances to the contrary). In most cases, our contact acted as guide and chaperone, but in a few cases we were unescorted.

Most of the audits were done on weeknights, beginning after 6 p.m. In most cases only a few employees remained in the office at that hour. Site 4, an internet infrastructure company, was still quite busy when we arrived at 6 p.m. We bypassed inhabited cubicles on the first round of observations at this site and then made a second pass through the

[5] Larger laser printers usually have a liquid crystal display and user-accessible menus that can be checked for power management enabling. Smaller laser printers and inkjet printers usually have no indication of power status and thus offer no means of checking whether power management is enabled. Copiers have quite complicated menus, sometimes requiring pass codes; for most copiers, we were unable to directly observe the power management settings.

Table 6. Sites Audited

Site	Industry
1	Health Insurance
2	Restaurant Chain (Administrative Offices)
3	Medical Devices
4	Internet Infrastructure
5	Independent Policy Institute
6	Financial Software and Services
7	Energy
8	Software Development
9	Health Maintenance Organization (Administrative Offices)
10	Medical Research Center
11	Research Institution (Administrative Offices)

building to visit the cubicles we had missed. Three sites were audited on weekends. A typical audit employed two staff members and took two to three hours to complete; we averaged slightly more than 100 computers per site.

Wherever possible, we used a floor plan of the building or floors inspected to track our progress. We obtained estimates of the floor area from the building manager or computed estimates from the floor plan. For each site, we recorded characteristics of the computing environment: operating systems used, network issues that might affect turn-off (such as network backups), and power management policies.

During the walkthroughs we recorded the type of equipment and its power status. Computers were identified as PC (meaning DOS/Windows/Intel devices), Mac, laptop (or portable), workstation, or server. At some sites, docking stations were common; we noted their presence as well as the status or absence of the associated laptop. Each computer's power status was recorded as "off," "on," or "low power" (usually indicated by a flashing green light on the front panel). Unfortunately, many computers have no external indicator of low-power mode. Because we could only observe external indicators, some computers recorded as being "on" may actually have been in a low-power mode. *Our data can therefore only be used to estimate a lower bound for computer power management enabling rates or success*.

Monitors typically indicate low-power mode with an amber light (or occasionally a blinking green light).[6] Unless the monitor appeared very old, we assumed that if the computer was off and the monitor was blank, the monitor was in low-power mode. (We checked vintages on several monitors when we were in doubt and found several from 1992 or earlier. These were assumed to be full on.) A visible display on a monitor always indicates full power.

[6] We often found that a row of Post-It® notes stuck to the bottom of the monitor obscured the power status indicator. However, because such notes usually obstruct the power button as well, their presence virtually guaranteed that the user had not turned off the monitor.

Inkjet printers do not generally have a separate low-power mode (their idle power is usually sufficiently low to qualify as an ENERGY STAR low-power mode); therefore, they were recorded as simply "on" or "off." Printers with menus (mostly laser printers) normally indicate when they are in low-power mode ("powersave" on HP printers). For all printers with menus, we examined the menus to ascertain whether the devices had power management capability, if it was enabled, and how long a delay was set. Most fax machines have no visible indication of low-power mode. A few models specifically indicated their power state, and their status was recorded as indicated. One device receiving a fax at the time of the audit was noted as on. Only one fax machine was turned off. The power status of copiers was relatively easy to obtain. However, efforts to ascertain power management enabling for copiers were difficult because of these machines' complex and idiosyncratic controls. Besides the above primary types of office equipment, various miscellaneous devices were also noted: computer speakers, "zip" drives, CD writers, personal audio equipment, etc. For all device types, we noted whether an ENERGY STAR label was displayed.[7]

Appendix B contains a more extensive discussion of audit methodology, including information and advice for performing other types of audits, such as daytime audits.

Results

Figure 2. Power Status by Equipment Type

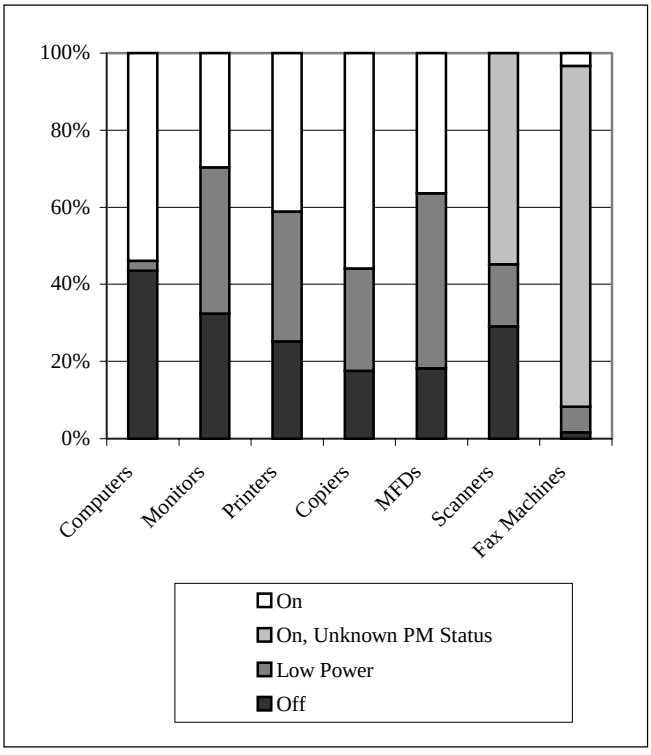


Figure 2 summarizes power status breakdown of the devices we observed. Computers had the highest average turn-off rates, while fax machines had the lowest, as one might expect. Detailed results are shown in Table 7. We surveyed 1,280 desktop and deskside computers, significantly more than our goal of 1,000 computers. The number of monitors was even higher, reflecting the large numbers of docking stations found at some sites. The number of personal computers per site ranged from 57 to 199, and the number of monitors ranged from 75 to 203. Computer turn-off rates ranged from 2 to 91 percent with an average of 44 percent, lower than in most previous studies. The range for

[7] Most ENERGY STAR office equipment is not labeled (more fax machines and copiers are labeled than computers monitors and printers). This information was not collected to get an accurate count of ENERGY STAR equipment but rather as feedback for EPA's marketing and branding efforts for the label.

Table 7. Night Audit Results

Site Number	1	2	3	4	5	6	7[a]	8	9	10	11[a]	Total Sample
Computers												
On	75 %	72 %	56 %	71 %	87 %	95 %	9 %	55 %	65 %	35 %	32 %	54 %
Low	1 %	2 %	5 %	0 %	0 %	3 %	0 %	4 %	7 %	3 %	3 %	3 %
Off	24 %	26 %	40 %	29 %	13 %	2 %	91 %	40 %	28 %	63 %	66 %	44 %
# of Units	87	57	81	125	67	100	146	193	111	199	114	1,280
Monitors												
On	51 %	36 %	30 %	21 %	60 %	72 %	3 %	17 %	44 %	16 %	14 %	30 %
Low	28 %	47 %	28 %	47 %	9 %	12 %	62 %	41 %	20 %	55 %	35 %	38 %
Off	21 %	17 %	42 %	32 %	31 %	16 %	35 %	42 %	36 %	29 %	51 %	32 %
# of Units	145	88	96	169	75	109	146	198	116	203	113	1,458
Printers												
On	54 %	56 %	53 %	27 %	50 %	50 %	49 %	40 %	47 %	30 %	35 %	42 %
Low	32 %	40 %	29 %	64 %	46 %	50 %	9 %	20 %	32 %	44 %	34 %	33 %
Off	14 %	4 %	18 %	9 %	4 %	0 %	42 %	40 %	21 %	26 %	31 %	25 %
# of Units	37	25	17	11	26	10	69	35	34	121	62	447
Copiers												
On	0 %	100 %	100 %	100 %	100 %	100 %	83 %	0 %	25 %	40 %	50 %	56 %
Low	100 %	0 %	0 %	0 %	0 %	0 %	17 %	100 %	38 %	60 %	0 %	26 %
Off	0 %	0 %	0 %	0 %	0 %	0 %	0 %	0 %	38 %	0 %	50 %	18 %
# of Units	1	2	2	1	1	1	6	1	8	5	6	34
MFDs[b]												
On	0 %	NA	NA	NA	50 %	100 %	NA	NA	NA	20 %	NA	36 %
Low	0 %	NA	NA	NA	50 %	0 %	NA	NA	NA	60 %	NA	45 %
Off	100 %	NA	NA	NA	0 %	0 %	NA	NA	NA	20 %	NA	18 %
# of Units	1	0	0	0	4	1	0	0	0	5	0	11
Scanners												
On	100 %	100 %	100 %	50 %	100 %	NA	0 %	33 %	100 %	56 %	100 %	71 %
Off	0 %	0 %	0 %	50 %	0 %	NA	100 %	67 %	0 %	44 %	0 %	29 %
# of Units	3	2	3	2	1	0	2	3	3	9	3	31
Fax												
On	0 %	14 %	0 %	0 %	0 %	0 %	0 %	0 %	0 %	8 %	0 %	3 %
On or Low	100 %	86 %	100 %	100 %	100 %	33 %	86 %	100 %	100 %	75 %	100 %	88 %
Low	0 %	0 %	0 %	0 %	0 %	67 %	14 %	0 %	0 %	8 %	0 %	7 %
Off	0 %	0 %	0 %	0 %	0 %	0 %	0 %	0 %	0 %	8 %	0 %	2 %
# of Units	8	7	2	5	2	3	7	2	6	12	6	60

[a]Audits 7 and 11 both occurred during "stage 2" electricity alerts in the region. That is, power demand was high, and the state electrical system operator had warned of brownouts. The two sites audited on those days would have been particularly aware of that situation (one was an energy company, and the other is known to inform employees of power alerts, so turn-off behavior at these two sites may have been affected.

[b]Because of the purpose of our work, we use the definition of MFD used by EPA's ENERGY STAR Program, which equates MFDs with digital copiers. Printer-based MFDs are included in the printer category.

monitors was narrower, from 16 to 51 percent with an average of 32 percent. Again, this was lower than in previous studies.

Computers

Of the 1,280 computers audited (desktop and desksides only; does not include servers or portables) 44 percent were off, 3 percent were in low-power mode, and the remaining 54 percent were on (these numbers do not total 100 percent because of rounding). As noted

above, there is not always a clear indication that a computer is in low-power mode. The reader should therefore use caution in drawing conclusions about power management use in computers based on these results although we can conclude that *at least* 5 percent of the computers left on were in power management mode.

Microsoft® Windows NT was the predominant operating system in several of the offices audited. NT does not support PC or monitor power management without additional software (this is also true of other less popular operating systems, such as Linux). Because the market share of operating systems changes over time, our results provide only a snapshot of a dynamic market. Windows 2000 (Microsoft's successor to the NT operating system) does support power management, which may increase the feature's success in the future.

In addition to the desktop/deskside computers, there were 161 docking stations. Of these, 91 were empty. Of the 70 laptops that were present, 16 were off, and 3 were obviously active (we observed screen savers or heard the hard drive). There were 22 laptops not associated with a docking station. Of these, four were off, 11 appeared to be in low-power state, and four appeared to be using full power. We were unable to determine the status of the remaining three laptops.

Monitors

Of the 1,458 monitors audited, 32 percent were off, 38 percent were in low-power mode, and 30 percent were on. Based on the split between low power and full on, we calculate a power management success rate of 56 percent.

If a monitor was on and displaying information, we noted what the monitor was displaying. This information was recorded for 358 active monitors (the information was not recorded for site 1). The most common displays were screen savers (106), log-in screens (51), dialog boxes indicating that the computer was "locked" (33), and other dialog boxes or messages (18). Of the other dialog boxes, nine said something like "It is now safe to turn off your computer," indicating that the user had initiated the shutdown process but failed to actually turn off the computer (or the computer failed to turn itself off). Four of the monitors were identified as pre-1993 models and therefore were assumed to have a power management option. Together these monitors accounted for about 60 percent of active monitors observed.

Because the turn-off rate for monitors was so much lower than expected, the question arose: has widespread power management for monitors reduced turn-off rates? That is, do people leave their monitors on, thinking that they will "turn themselves off" (and not realizing the power differential between low power and off)? The speculations in these two questions are clearly not the case for the 30 percent of monitors that were full on because the vast majority of these had an active display (desktop, screensaver, etc.). The 38 percent of monitors in low-power mode, however, might have been thought by the user to be "off." Two of the studies cited above addressed this question by identifying ENERGY STAR devices and calculating a separate turn-off rate. Nordman et al. (1996)

audited 34 ENERGY STAR monitors and 36 non-ENERGY STAR monitors. The turn-off rate for ENERGY STAR monitors was 53 percent; for non-ENERGY STAR monitors, it was 61 percent. Picklum et al. (1999) reports results for 882 monitors, 768 of which were ENERGY STAR. The turn-off rate was the same, 64 percent, for both ENERGY STAR and non-ENERGY STAR monitors. From these data, we can conclude that the difference, if any, in turn-off rates between the two types of monitors is small.

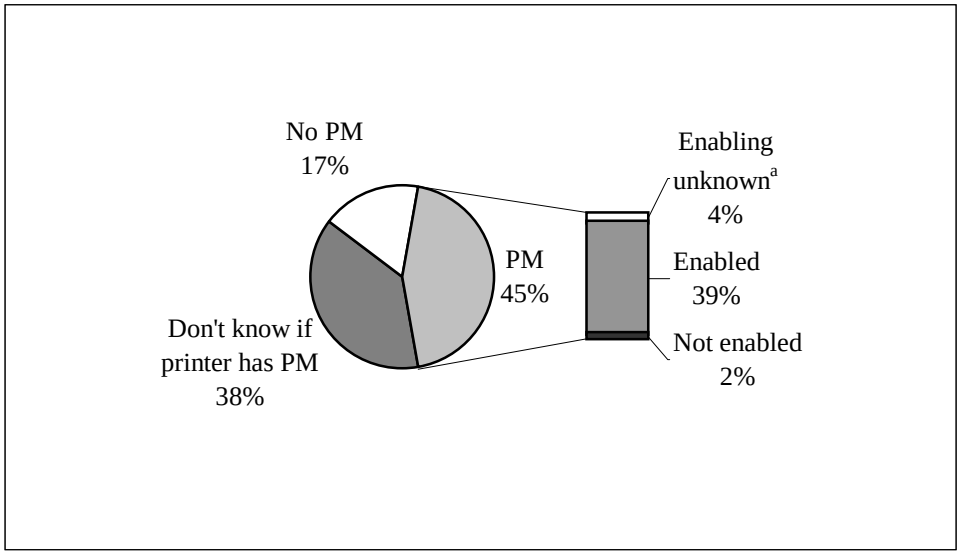
Printers

We divided the printers according to whether the models did or did not have power management or if this feature was unknown. We further divided the devices with power management according to whether the feature was enabled. The resulting designations are shown in Figure 3.

Inkjets and personal laser printers made up most of the printers for which we could not determine whether power management was a feature. Most inkjets do not have a low-power mode, but they consume very little power in their normal idle mode and so usually meet ENERGY STAR guidelines without a separate low-power mode. The printers without power management included many older models, among them 38 HP LaserJet IIs and IIIs and 9 older LaserJet 4's (HP introduced power management in the middle of LaserJet 4 production; only some of these models have power management).

Based on the printers that we know had power management, we can estimate a power management enabling rate. Using only the devices with known PM settings, we found that 96 percent of printers capable of power management had this feature enabled. If we assume that all of the devices with unknown PM settings were enabled, that figure increases to 97 percent. If we assume that none of the devices with unknown PM settings were enabled, the rate falls to 88 percent.

Figure 3. Printer Power management (PM) Distribution



[a] Most of these devices were off.

Table 8. Printer Status by Printing Technology

	Monochrome Laser Printers	High-end Color Printers	Inkjet Printers	Impact Printers	Wide-Format Printers	Total[a]
On	36 %	33 %	67 %	69 %	29 %	42 %
Low Power	40 %	52 %	2%	0 %	14 %	33 %
Off	24 %	15 %	31 %	31 %	57 %	25 %
Total Units[c]	331	27	55	13	7	447

[a]The total includes 14 printers that we were unable to classify.

We did not record whether a printer was shared or personal (partly because this is often unclear from observation alone). However, we did record model numbers and separated our sample according to printer technology—monochrome laser, inkjet (including color), high-end color (laser and thermal), wide format, and impact—, and it is possible to draw some inferences from the data. All the high-end color printers and wide-format printers were located in common areas (copy rooms or aisles, but most of the inkjets and impact printers were located in individual offices. Table 8 shows the results of the audit by technology. Wide-format printers were the most likely to be turned off. These are specialized devices and generally used infrequently. As noted above, most of the inkjets and impact printers seemed to be personal printers and had similar turn-off rates. The overall turnoff rate of 25 percent may be slightly high for shared printers and slightly low for personal printers.

Hewlett-Packard (HP) printers dominated our sample, and monochrome laser printers and inkjets were especially common. Of 331 monochrome laser printers, 315 were HP, as were 47 of the 55 inkjets. In contrast, only 12 of 27 high-end color printers, one of seven wide-format printers, and none of the impact printers were manufactured by HP.

Copiers

Because copiers typically have longer power management delay times than computers, monitors, and printers (two to three hours compared to a typical 30 minutes for other types of equipment),[8] our evening audits may have been taken place too early for some copiers to have initiated power management. A later evening or weekend audit might have found higher rates of copiers in low-power mode or turned off (auto-off).

Our copier sample is quite small compared to our computer, monitor, and printer samples. Most of the offices only had one or two copiers per floor. Because of our small sample size and the timing of the audits, Nordman et al. (1998) remains a better source than the current paper for copier turn-off and power management data (see Table 5).

Multi-function Devices

Multi-function devices include a wide range of equipment that combines printing, copying, scanning, and/or faxing in a single machine. We include only digital copiers in

[8] The difference is attributable largely to copiers' long warm-up time.

this category because EPA only covers copier-based MFDs under the ENERGY STAR MFD program; printer- and fax-based MFDs are covered under the ENERGY STAR printer program. We used this guideline in dividing MFDs between the printer and MFD categories in Table 7.

Fax Machines and Scanners

For most fax machines it is impossible to distinguish "on" and "low-power" modes by visual inspection. A few devices have lights or liquid crystal displays (LCDs) indicating power status; these were recorded as being in the state indicated. The vast majority of devices, however, were on and idle, and their power level was unknown. These are shown as "on or low" in Table 7. One device was receiving a fax, and one other had a low-power light that was not lit; these were characterized as "on." One fax machine was reported as off; we were unable to verify whether it was actually in use.

We do not distinguish "on" and "low-power" modes for scanners.

Equipment densities

For each site audited, we obtained or estimated the audited floor space. We also estimated the total number of workers at the each site based on our observations of office configurations and, in some cases, floor plans that listed the personnel assigned to each office. From these sources, we calculated the density of each type of equipment. Table 9 shows the number of desk workers and equipment densities per desk worker at each site. Computer density (for desktop and deskside computers) ranged from 0.61 per worker at the health insurer's offices to more than two per worker at the software company's offices. The low density at the health insurance company reflects the large number of employees using docking stations. (A docking station and laptop typically replace a desktop computer and the docking stations were not included in our density calculations.)

Table 9. Equipment Densities per Worker

Site Number	1	2	3	4	5	6	7	8	9	10	11	Total Sample
# of Desk Workers	143	92	91	167	68	96	126	92	118	204	81	1,278
Audited floor area (m^2)	2,600	2,900	2,300	3,000	1,200	1,400	3,500	1,500	3,000	3,100	1,800	26,100
Computers/worker	0.61	0.62	0.89	0.75	0.99	1.04	1.16	2.10	0.94	0.98	1.41	1.00
Laptops[a]/worker	0.41	0.34	0.18	0.29	0.01	0.13	0.00	0.11	0.05	0.01	0.00	0.15
Monitors/worker	1.01	0.96	1.05	1.01	1.10	1.14	1.16	2.15	0.98	1.00	1.40	1.14
Printers/worker	0.26	0.27	0.19	0.07	0.38	0.10	0.55	0.37	0.29	0.59	0.77	0.35
Copiers/worker	0.01	0.02	0.02	0.01	0.01	0.01	0.05	0.01	0.07	0.02	0.07	0.03
MFDs/worker	0.01	0.00	0.00	0.00	0.06	0.01	0.00	0.00	0.00	0.02	0.00	0.01
Scanners/worker	0.02	0.02	0.03	0.01	0.01	0.00	0.02	0.03	0.03	0.04	0.04	0.02
Faxes/worker	0.06	0.08	0.02	0.03	0.03	0.03	0.06	0.02	0.05	0.06	0.07	0.05

[a]In this case, laptops include observed stand-alone laptops and docking stations (the laptop used with the docking station may or may not have been present at time of audit). This total does not represent a full count because some laptops may have been out of the office leaving behind no observable telltale signs for our auditors.

Table 9 also reports the floor area audited, but these data should be used with caution in relation to national estimates of office floor area, which include indoor parking facilities, basements, lobbies, etc. (USDOE, 1998); our audits, in contrast, generally excluded such public areas (although we included hallways and other non-office space immediately within the office areas audited). Any equipment densities calculated based on our floor space data will therefore be biased compared to national estimates.

Conclusions

Table 10 highlights some of the key results of this study. Perhaps most importantly, the turn-off rates we found for computers and monitors were lower than reported in previous studies. These results may represent in part differences in the factors that affect turn-off behavior at governmental/quasi-governmental organizations and the private sector (our study looked primarily at private-sector offices; previous studies focused heavily on governmental and similar offices). Another possibility is that turn-off rates have been decreasing over time. Most of the previous computer studies cited were done in 1996 or earlier, and most of the monitor studies were done in 1997 or earlier.

Monitor power management success rates in this study were lower than the 80 percent rate of power management enabling previously used in LBNL's ENERGY STAR forecasts for EPA. Several factors seem to be reducing the use of monitor power management, primarily screen savers and operating systems that are incompatible with power management.

The lower turn-off rates found for computers and monitors lead to higher overall energy use estimates for these products than have previously been calculated. Lower turn-off rates also result in higher potential savings from power management because a power-managed device left on overnight will generally drop into low-power mode. Incorporating the results of this study into the ENERGY STAR savings forecasts therefore increases the estimated unit energy savings for computers and monitors.

Table 10. Key Results

Turn-off Rates	
Computers	44 %
Monitors	32 %
Printers	25 %
Monochrome Laser	24 %
High-End Color	15 %
Inkjet	31 %
Impact	31 %
Wide Format	57 %
Copiers	18 %
MFDs	18 %
Scanners	29 %
Fax Machines	2 %
Monitor PM Success Rate	56 %
Printer PM Enabling Rate	96 %

Our overall printer turn-off rate aligns closely with that found by Nordman et al. (1998), the most credible of the earlier studies in terms of methodology (night audits) and number of units observed (211). We found printer power management enabling rates to be 96 percent. This figure is higher than the 90 percent enabling rate assumed in earlier ENERGY STAR forecasts. Unlike monitor power management, printer power management does not commonly fail. Failure tends to occur when the device experiences an error or shifts into user

attention mode (a paper jam, for example)—a temporary condition. This is the first study we know of to measure turn-off rates for MFDs, fax machines and scanners. Past studies of copiers did not distinguish analog copiers and digital copiers (MFDs). ENERGY STAR savings estimates for MFDs used the same assumptions as for analog copiers. The results of this study support this approach: the turn-off rates for analog copiers and MFDs were both 18 percent. Most energy use estimates for fax machines assume that they are turned on 100 percent of the time. Our study largely confirms this assumption: we found only one unit (2 percent of the sample) turned off. Although the sample size for these devices is relatively small, this work represents a good start in assessing operating patterns.

Future Work

Several of the drivers of turn-off rates and power management use have changed significantly over time. The immense increase in networking since the ENERGY STAR Program was introduced in 1993 is an important factor because network activity can keep computers from entering low-power modes. Networking also facilitates back-ups, remote access, and telecommuting, which require that a computer be left on after hours. Continuing audits of office equipment energy use in the future will allow us to increase our sample size and thus improve the reliability of the data, and ultimately should provide a basis to assess changes in turn-off rates and power management enabling rates over time.

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Appendix A. Description of Audit Sites

Site 1

Health insurance offices
San Francisco CA
May 28, 2000
Sunday afternoon, 2-4 p.m.
Floor area: 2,602 m^2
Notes: The area audited was primarily occupied by information services. Employees are instructed to leave their computers on at night for software installs. Employees are also instructed not to turn off their monitors, apparently because of complaints of switch failure. Computer power management may have been disabled to facilitate remote access (program: Tivoli). Almost everyone runs Windows NT. An estimated 98 percent of desktop computers and docking stations were manufactured by Compaq. An estimated 98 percent of printers were Hewlett-Packard. Monitors were a mix of NEC and Compaq dating back to at least 1992, so some were non-ENERGY STAR. Many monitors displayed a log-in screen. Our guide's computer was one of these: she leaves her computer on at night in compliance with policy but restarts her computer each evening (because leaving it on for long periods without rebooting destabilizes the operating system).

Site 2

Headquarters for a Restaurant Chain
San Francisco CA
June 12, 2000
Monday evening 7-8:30 p.m.
Floor area: 2,881 m^2
Notes: At some point, employees were instructed to leave their computers on on Monday evenings to update virus software. Although that policy was no longer in effect, there might have been some holdovers still adhering to the old policy.

Site 3

Medical Device Company
Alameda CA
July 19, 2000
Wednesday evening, 6-8 p.m.
Floor area: 2,258 m^2
Notes: The building is about 5,017 m^2 and includes a laboratory, warehouse, offices, meeting rooms, and manufacturing. Only office areas, about 45 percent of the total floor area (based on visual inspection of the floor plan), were audited, adding up to a total audited floor area of 2,258 m^2.

Site 4

Internet Infrastructure Company
San Francisco CA
July 24, 2000
Monday evening, 6-8 p.m.
Floor area: 2,974 m^2
Notes: According to an IT person, the office runs Windows 98, Windows NT 4.x, and Linux. There is no uniform policy on turning off equipment. Back-ups do not take place at the work station level.

Site 5

Independent Policy Institute
Washington DC
July 12, 2000
Wednesday evening, 6:30 p.m.
Floor area: 1,166 m^2
Notes: The company has 200 employees, 150 in the DC location. The company uses computers running both the Macintosh and Microsoft operating systems; NT 4.0 is the primary Microsoft OS. Purchases are made by IT staff to take advantage of vendor relationships, and machines are installed and configured by IT staff. Employees are instructed to leave CPUs on overnight, to facilitate network back-up and anti-virus activities, but to turn monitors off.

ENERGY STAR is not a factor in purchase decisions, nor is it a standard element of the installation/configuration process for new PCs. The company had experienced problems with power-managed computers losing network connections, as well as some software incompatibilities. These issues were resolved by disabling the sleep mode.

There had been employee complaints when printer or copier services were not available when needed (e.g., the first person to arrive in the office in the morning not being able to print because the printer wasn't turned on, or the copier taking too long to warm up before making a copy). As a result, printers and copiers are left on at all times. ENERGY STAR power save mode is activated on all new printers installed although the settings may be subsequently changed by users.

Site 6

Financial Software and Services Office
Berkeley CA
July 31, 2000
Wednesday evening, 6:30 p.m.
Floor area: Appx. 1,394 m^2
Notes: The first floor housed administrative personnel; the second and third floors housed development, research, and production activities.

Every PC ran Windows NT. The company has a formal policy of leaving PCs on at night for virus checking. The desktop machines are not backed up. Turning off the monitor at night is at the user's discretion. It appeared that most people left their monitors on.

Because this is a software development firm, many cubicles had two PCs (generally with two monitors, not a switchbox), and we encountered several servers in the cubicles (there was also a large computer room, which we did not audit). There were also a few Unix workstations on desktops. This office is probably not typical of most office environments.

Site 7

Electric and Gas Utility
Concord CA
August 1, 2000
Tuesday evening, 5:45-8:00 p.m.
Floor area: 3,457 m^2
Notes: Two years ago the company committed to a 15-percent reduction in energy use in the building by the end of 2000. They have used a three-pronged approach:
(1) Perform a benchmark audit
(2) Educate employees
(3) Educate building managers

One year ago the company instituted a program to turn off monitors (our contact said "off," not "standby," but most of the monitors were in standby).

A Stage 2 power alert was issued the day of the audit, which might have affected user behavior.

Site 8

Software Development Company
San Jose CA
August 12, 2000
Saturday, 8:30-11:00 a.m.
Floor area: 1,524 m^2
Notes: Most offices had at least two computers. In most cases each computer had its own monitor. The computers were primarily a mix of PCs and Macs.

Site 9

Health Maintenance Organization Headquarters
Oakland CA
September 9, 2000
Saturday, 10:00 am-12:30 p.m.

Floor area: 3,011 m^2
Notes: The audit covered the 13th and 14th floors of the building, which house the nutritional services, health education, government affairs, computer services, divisional parking, divisional security, planning and analysis, allocation and planning, management information, and program performance assessment functions. The office uses mainly Windows 98 and Windows NT, with a few instances of MacOs and Linux. Users are instructed to leave their computers on for "pushes" -- software updates over the network using Tivoli (IT management software). Health Education does its own software updates. Desktop machines are not backed up; C drives are apparently disabled and users save their work to network drives. Most of the computers are by Compaq and most are less than a year old and were purchased for Y2K compliance. Monitors were replaced at the same time.

Site 10

Medical Research Company
Washington DC
September 21, 2000
Thursday evening, 6 p.m.
Floor area: 3,104 m^2 audited
Notes: Heterogeneous computing environment. Most equipment, operating system, and software decisions are left to users. Printers are installed by an outside contractor and are left with their factory default settings.

Site 11

Research Institution
Berkeley CA
June 27, 2000
Tuesday evening, 6:00-8:30 p.m.
Floor area: 1,766 m^2
Notes: Three floors were audited, containing the offices of information systems, budget and administration, administrative services, and travel.

Appendix B. Audit Methodology

The activities that make up an audit of office equipment depend on the purpose of the exercise. For the audits included in this report, we were primarily interested in night and weekend power status (on, low power, off). The audits were therefore performed after regular office hours (during evenings or weekends). Because PCs and monitors are typically personal equipment (that is, they usually have a single user) and may contain private or sensitive information, we took a hands-off approach to these devices. We collected only data that could be observed without touching the device. We adopted this approach because we feared that obtaining permissions for more intrusive information-gathering would be prohibitively difficult. We were less circumspect with copiers, printers, and fax machines, and, whenever possible, we directly observed the power management settings for these devices. These devices are not sensitive in the ways that computers can be and are usually located in common areas for access by multiple users.

The goals of an audit can range from equipment counting/inventory to estimating potential or actual energy savings; audit procedures vary accordingly. Procedures also vary according to the type of equipment audited. Computer and monitor procedures differ greatly from those for imaging devices (printers, copiers, and fax machines). Below, we provide audit advice and procedures gleaned from these and earlier audits (Nordman et al. 1996, Nordman et al. 1998, Picklum et al. 1999, Nordman 2000).

General Auditing Issues

It is common for the senior personnel in an office setting to have enclosed offices with doors on them. For nighttime audits, locked doors may prevent checking the equipment in these offices if auditors don't have a master key. For most of the audits included in this report, we did not have a master key and were restricted to observing equipment in cubicles and unlocked offices. Fortunately for our data collection, cubicles far outnumbered offices at the sites we audited. For daytime audits, locked offices can also be a problem if the office occupant is not present. The most complete audits are those done at night with a master key.

Workers are often suspicious of equipment auditors/enablers. Most people have never met researchers concerned about office equipment energy use and so may doubt an auditor's explanation about who s/he is and what his/her purpose is. Even in our after-hours audits, we encountered a few people working late (we worked during one conference call taking place on a Sunday). Letters from management personnel whom employees recognize and defer to are often helpful or necessary to reassure workers and to get and maintain access to office areas and particular equipment. It was usually the case that our contact remained in the building for the duration of the audit, either as an escort or working in his/her office while we performed the audit. We usually skipped occupied offices and returned at the end of the audit, by which time the occupant had, in most cases, left for the evening.

Daytime audits have several advantages. Occupants can be queried about whether certain equipment is used much or at all. People can be asked if it would be acceptable to them to enable or change power management on a device, or if there is a company policy of active enabling, or if there is any reason to *not* enable power management. On some copiers, configurations cannot be checked while the machine is warming up; daytime audits, during which the copiers are likely to be on already, can avoid this delay. Daytime audits should be conducted during regular work hours, not too early or late in the day, and should avoid time periods that may be anomalous near holidays.

Nighttime audits have other advantages. For PCs, night audits should be conducted at least half an hour (preferably a full hour) after workers have left for the day to insure that power management delays will be over before auditors observe the equipment. For imaging devices, reliable data can only be taken after at least two (preferably three) hours because these devices have longer delay times before power management takes effect. It may be helpful if auditors promise to not make any changes to equipment configurations to alleviate any fears of the person authorizing the audit and to avoid blame for problems with equipment subsequent to the audit.

The nomenclature used for power management varies among brands and types of equipment; “sleep,” “suspend,” “energy saver,” and “power saver” are all common terms.

Some suggested “rules of thumb” for quick and effective auditing follow:

- If equipment is unplugged from power, assume that it is not in use and don’t include it in your inventory.
- Consider how you will treat equipment that is exceedingly old or broken but still plugged in. We typically included these devices in our audits, particularly if they were obviously using energy (for example, the monitor in standby mode that was in a vacant office not connected to a computer).
- Be prepared for equipment such as laptops (possibly without a power cord), and laptop docking stations, with or without the laptop present.
- Computers operated as servers usually operate 24 hours/day, 7 days/week and so should be counted for total electricity use but should not be included with regular PCs as servers are not to have power management opportunities. (Unfortunately it is not always apparent which computers are used as servers.)
- Be prepared for anomalous situations, such as the aforementioned monitor that was plugged in to the wall and in standby but not connected to a PC.

PC and Monitor Auditing

Some barriers to effective auditing of PCs and monitors include:

- Windows “Log-on” and screensaver passwords can prevent access to BIOS screens or control panels to check or change power management settings.
- Glare screens on monitors often cover the power indicator and/or the switch. Post-It® notes stuck along the bottom of the monitor can have the same effect. This can reduce the likelihood that users manually power off their monitors or notice monitors remain

on at some level (whether full on or in low power). These phenomena also make auditing more difficult.

- Some PCs may be turned around so the backs of the devices face outward (perhaps because accessing the hardware is more important to the user than accessing the power switch or floppy drives), which means the auditor must crawl under a desk (if possible) to observe the power button. For obvious reasons, these computers are virtually never turned off.
- PCs without brand-name indications (either home built or put together by small companies from components) provide little information for an auditor. Vintage and processor type may not be detectable from the outside. Similarly, major components of machines can be replaced, giving them markedly different characteristics than appears on the outside. In some cases, only the case is reused, and that the whole interior of the machine is different from what appears to the outside observer.

For more detailed information on PC and monitor power management, please refer to the *User Guide to Power Management in PCs and Monitors* (Nordman et al. 1997). This guide provides an introduction to auditing of PCs and monitors, with far more detailed audits than those included in this paper.

Printer, Copier, and Fax Machine Auditing

Auditing of imaging devices (printers, copiers, and fax machines) for power management status is in some ways easier and in other ways more difficult than auditing of PCs and monitors. It is generally easier to identify the brand and model of an imaging machine and easier to determine whether it is ENERGY STAR compliant. It is often more difficult to find power management controls without having the instruction manual to refer to, but the manual is more likely to be available than it is for PCs or monitors. Imaging devices are more likely than PCs—but less likely than monitors—to indicate their power management status. Delay times on printers and copiers can be up to several hours, so night audits of these devices need to take place later than for PCs and monitors. Finally, unique among office equipment, copiers can turn themselves entirely off, so that it can be impossible to tell if whether the machine was manually turned off or turned itself off.[9]

Imaging devices are generally shared among users rather than being used solely by one person, so behavioral influences are more complicated than for PCs used by a single person. However, the internal functioning of power management for imaging devices is simpler than it is for PCs and so less likely to fail when properly configured. We are unaware of an imaging device failing to manage power when this feature is enabled except when the machine is experiencing an error, such as a paper jam or an open door. Imaging devices that are more than eight years old are more common than very old computers, and "odd" devices are also more common, such as large- format printers or copiers, or microfilm printers.

Exploring the controls for imaging devices almost always reveals previously unknown features or information and so is well worth the effort. For example, many fax machines

[9] A few PCs can turn themselves off at specific times but this feature is not known to be widely used.

have a feature to automatically reduce incoming documents to fit on the page, which avoids using excess paper when faxing between countries that use a different standard paper size. Many copiers have a feature that automatically turns them on or off according to a timer, varying with the day of the week. Printing out configuration or test pages can also reveal interesting information. For example the "HP Copyjet Self Test Page" reports the number of "Power Cycles" that the machine has gone through, which, combined with the date of purchase, can help the auditor determine how often the machine is turned off.

Fax Machines

In the audits of office equipment at the City of San Francisco, no ENERGY STAR fax machines were found to have power management disabled. Fax machines are the most difficult imaging devices to audit, and we were unable to verify the status of many of the machines we saw. So, although we cannot definitely conclude based on this audit that fax machine power management is generally not disabled, it does appear that disabling of power management is much less of a problem with fax machines than it is with printers and copiers.

Inkjet or thermal fax machines don't have the fuser roll that takes considerable power to keep ready in laser-based fax machines. As a result, these types of machines generally meet low-power requirements without any active power management and so would not have any power management controls to enable or check. Thus, only laser-based machines need to be scrutinized closely.

Fax machines controls usually make it difficult to check a machine's configuration without using the manual. One possible shortcut on some models is a feature that allows the machine to print out a page of menu commands, which this can indicate how to find power management controls if there are any. Some models can print a page of configuration settings, which may indicate whether a power management control is present, and perhaps how to get to it. These conclusions are based on only a few models, so auditors may find machines that don't fit any of the patterns described.

Pre-ENERGY STAR fax machines are not known to have power management, so the topic is not addressed in manuals for these machines. At least one ENERGY STAR model we checked (Canon 7000/7500) did not mention power management at all but was confirmed to move into a low-power mode, so we assume that this feature cannot be disabled. Another family of models (Panafax UF-550, -560, -770, -880) specifies the power management control with a "Start" and "End" time during which power management operates; most of the models we examined were set to start at 00:00 and end at 00:00. We confirmed that power management on these models always operates; we presume that this is the default setting. One fax machine (actually a small MFD) showed "SLEEP" on the display when audited and operated with a delay timer to initiate the low-power mode (the delay timer was set to zero minutes and presumably operated satisfactorily or it would have been changed). Other devices had an LED indicator for low-power modes. However, most fax machines do not give any outward indication of low-power modes.

Because the ENERGY STAR program specifies a five-minute delay before most fax machines (those <= 14 ppm[10]) goes into low-power mode, a power meter could be fairly easily used to determine power status. For some devices (such as the Canon 7000/7500 mentioned above, this might be the only way to determine power status.

Some multi-function devices are based on fax machine designs[11] and so are likely to have similar characteristics to ordinary fax machines except that they might have longer delay times before entering power management modes.

Printers

Inkjet printers use little power when not actively printing, so most meet ENERGY STAR low-power requirements without changing to a different power mode. Some larger inkjet printers do need to manage power, and one model we saw (HP 1200C) had power management on a small "DIP" switch with unrelated configuration settings. Most inkjet printers have an indicator light to signal that they are on; they typically do not call attention to themselves (with noise, etc.) so much as laser printers. The delay time for an inkjet printer to wake up is short and so not so much of a deterrent to manual turn-off.

For laser printers, different power modes are always needed. Larger printers with alphanumeric displays generally indicate a low-power mode, but the increasingly common "personal" laser printers do not have such a display. The ENERGY STAR maximum delay time before entering power management modes in printers "as-shipped" ranges from 15 to 60 minutes, depending on printer speed. In our examination of printer delay times, we often found a large variety of delay times for printers of the same model, suggesting that someone had actively changed the times since the machines had been purchased.

The largest manufacturer of laser printers is Hewlett-Packard (HP), so a review of power management controls in their printers is useful; other manufacturers' product lines may follow a similar pattern. Most HP laser printers use the "LaserJet" name. Early LaserJet printers had no power management capability (none of the IIs and IIIs had power management capability and only some of the 4s did[12]). All larger HP printers share a similar control structure, with one button to cycle through different "menus" and another one to cycle through different "items" within each menu. Items may hold a switch, a value, or, when selected, cause an action. When auditing, it is an easy, though somewhat tedious, matter to cycle through the various menus and items to locate the power management setting (usually called "POWERSAVE"). Unfortunately, the location has changed over time. It is in the "Configuration" menu in the 4000N, 5si, and 5M(color); in the "Printing" menu in the 5N; and in the "Job" menu in the 4plus, 4si, and 4MV. To audit the setting, use only the "menu" and "item" keys. To change it, use "+" or "-" with

[10] Pages per minute.

[11] These are covered under the ENERGY STAR printer and fax label, not the MFD label (for copier-based multi-function).

[12] Our audits turned up examples of the LaserJet 4, 4 plus, and the 4 Si with and without power management capability, suggesting that HP introduced the feature in the middle of the production of those series.

the “value” key, then “Select” to set it. You may need to take the printer explicitly off line before starting, and manually put it back on line afterwards (some require this, and some don’t).

Examination of one Lexmark model (an Optra SC 1275) found a similar setup to the HPs, though a different way of using the keys. The “menu” key cycles through the menus, and “select” causes the menu key to cycle through the items in the menu. Once the desired item is found, “select” is used to check or edit the item, and “menu” used to adjust the value, followed by “return” to end the process. The term “Power Saver” is used. Other Lexmark Models (N and Lxi) use a common menu system; next to the LCD display are four buttons, selecting the button next to “Menus,” and then selecting “Setup Menu” followed by “Power Saver” accesses the power management delay timer.

A final example is the Tektronix Phaser 360 Color Printer. The “menu” key is used like the “select” button in the Lexmark example; the “<---” and “--->“ keys cycle through menus and selections; and “OK” makes a change permanent (use “Exit” if you don’t want to make a change). The power management control is called the “Energy Star Timeout,” and it displays “Energy Star Mode” when managing power.

Some printers allow the control panel to be “locked,” restricting access to the controls, but this feature seems to be used only rarely.

Copiers

Copiers have the largest range of power management controls and indicators of any type of office equipment. Part of this is the result of the wide range of copier sizes as well as the fact that power management has been present in some copier models for many years. Also, some copiers have very limited displays, and most have some controls designed only for service technicians or specially trained “key operators.”

Because copiers usually take a long time to warm up from low-power or off modes, they usually indicate those states. On some, a low-power indicator light turns on or flashes, and the main display commonly dims or turns off. Copiers with an alphanumeric or graphic display often use words to indicate low-power status on the display. Copiers with just a numeric display for copy count and zoom magnification usually have the most obscure controls for power management.

It is often helpful to have the copier manual to refer to; the manual may be located on the sides, back, or inside of the copier. Sometimes there are separate “user” and “key operator” manuals; it is useful to check both.

Copiers with complex displays are more likely to have power management controls that can be easily located without a manual. Examination of the manual may be fruitful, as in the case of key operator codes. On some copiers, the default is no password code, even if one is can be set. On others, the default password is listed in the manual and often has not been changed. On many copiers, the only setting is the delay prior to low power

and/or auto-off. On a few models, the degree of low power can be set. Many copiers have clocks and can be set to turn on or off at specific times of day, and this can often vary by day of the week. These timers are rarely used but should be checked just in case.

Some copiers with an auto-off feature actually move the power switch so that its position is indistinguishable from that of a switch that has been manually turned off. On others, a "soft switch" has the same effect. However, some models leave the switch in a position that is different during auto-off from where its position for manual turn-off, so the two states can be distinguished.

For any copier, a good test of its status is so press the "start" key and measure how long it takes to make a copy or to become ready. The longer the recovery time, the lower power the mode the copier was in.

When a copier is on, default duplex is easy to see from the controls; however, if the copier is not in default duplex, try putting a sheet in the document feeder as a few models will only default to duplex when not copying off the glass.

In the San Francisco project, all of the copiers audited had some power management enabled. However, some of them had the auto-off feature enabled, but the accompanying low-power feature disabled. Nordman et al. (1998) similarly found a mix of enabling. Of 81 ENERGY STAR copiers observed, 22 were found on in the night audits. Of those, 13 were verified to have auto-off disabled. Three of the copiers observed had auto-off enabled but low-power mode disabled.

Duplexing rates (the percent of images that are produced as double-sided copies[13]) may also be of interest to auditors. Making double-sided copies reduces paper demand and saves energy used in paper production. Nordman et al. (1998) estimate that 16 watt-hours of production energy are embodied in each sheet of copy paper. Many copiers have counters for the number of double-sided copies made in addition to the universal counters of total images. Combining these two allows calculation of the "duplexing rate." Duplex counters on some models note one count for each duplexed copy; others note two copies. It is easy to determine how to read the meter: take a reading, make a double-sided copy, and take another reading to determine how many copies were noted.

For both counting copies and checking power management, it is often helpful to talk to a service technician, who can often either show how to get at the right controls, or if s/he is reluctant to tell you how to gain access to a service mode, may offer to report results to you.

[13] Here "copy" refers to the paper while "image" refers to what is copied onto the paper. One double-sided copy has two images, one on the front and one on the back.