PC and Monitor Night Status: Power Management Enabling and Manual Turn-off

Bruce Nordman, Alan Meier, Mary Ann Piette
Lawrence Berkeley National Laboratory

ABSTRACT

While office equipment accounts for about 7% of commercial building energy use, this reflects considerable energy savings from the use of automatic power management. Most of these savings were gained through the use of low-power modes that meet the criteria of the U.S. EPA's ENERGY STAR® program. Despite this success, there are large amounts of additional savings that could be gained if all equipment *capable* of power management were *enabled* and *functioning.* A considerable portion of equipment is not enabled for power management at all, enabled only partially, or is enabled but prevented from functioning. Additional savings could be gained if more equipment were turned off at night manually.

We compiled results from 17 studies from the office equipment literature addressing PCs and monitors. Some factors important for annual energy use, such as power levels, have been documented elsewhere and so are not covered. We review methods for estimating office equipment use patterns and energy use, and present findings on night status—power management and manual turn-off rates.

In early studies, PC power management was often found to function in 25% or less of the ENERGY STAR compliant units (10% of all PCs). However, recent assessments have found higher rates, and we estimate that for ENERGY STAR models, 35% of PC CPUs and 65% of PC monitors are enabled for power management. While the data lack statistical rigor, they can be used to estimate the magnitude of current and potential power management savings, which we did for major types of office equipment. The data also make clear that the topic of enabling rates, and the factors which influence them, deserve greater scrutiny.

Introduction

Office equipment is estimated (Koomey et al. 1995) to consume about 7% of electricity use in commercial buildings in the U.S., and an increasing share of residential electricity use. However, this figure is highly uncertain because we lack sufficient data on the status of these devices when they are not in use. Specifically, the use of automatic power management and manual turn-off greatly affects a computer's annual energy use. In this paper we review measurements of power management enabling rates and night status for PCs and monitors. Based on this, we propose "typical" rates for these factors.

Our analysis is limited to PCs and monitor night status (including enabling), as within the realm of office equipment, this topic holds the most extant data, uncertainty in energy use, and existing and potential energy savings.

Background

PC power management operates by the unit sensing when a specified time has passed with no 'activity' (usually from the keyboard or mouse) and initiating a sequence of low-power modes. Delay times usually range from a few minutes up to an hour. When activity occurs while the device is in a low-power state, it automatically wakes itself up and returns to the full-on state. Though not technically part of automatic power management, the degree to which people turn off equipment by hand can be as important to energy use and savings as power management. Ideally, power management would transparently and universally save office equipment energy, but a variety of factors can interfere with it being fully enabled and functioning (Nordman et al. 1997). Monitors can also be turned off automatically by an external "controlling device" [1] that monitors activity (keyboard/mouse or room occupancy) and turns the monitor power on and off as needed.

To illustrate the importance of night status[2], consider a sample personal computer (PC) and monitor which consume 45 W and 90 W when in active use, 25 W and 5 W when in a low-power (sleep) state, and 2 W each while switched off. This machine has 9.5 hours of on-time per workday, and that the user does not turn on their PC for 20% of workdays (due to absenteeism, meetings, travel, and vacations[3]). Figure 1 shows several scenarios, highlighting the dramatic effect of night status. "Disabled/Enabled" refers to power management functioning on both the PC and monitor. "On", "Low", and "Off" refer to the night status of the PC and monitor respectively. The last row reflects our best estimate of typical office night status (see Table 6 for a summary of the enabling and night status underlying this estimate).

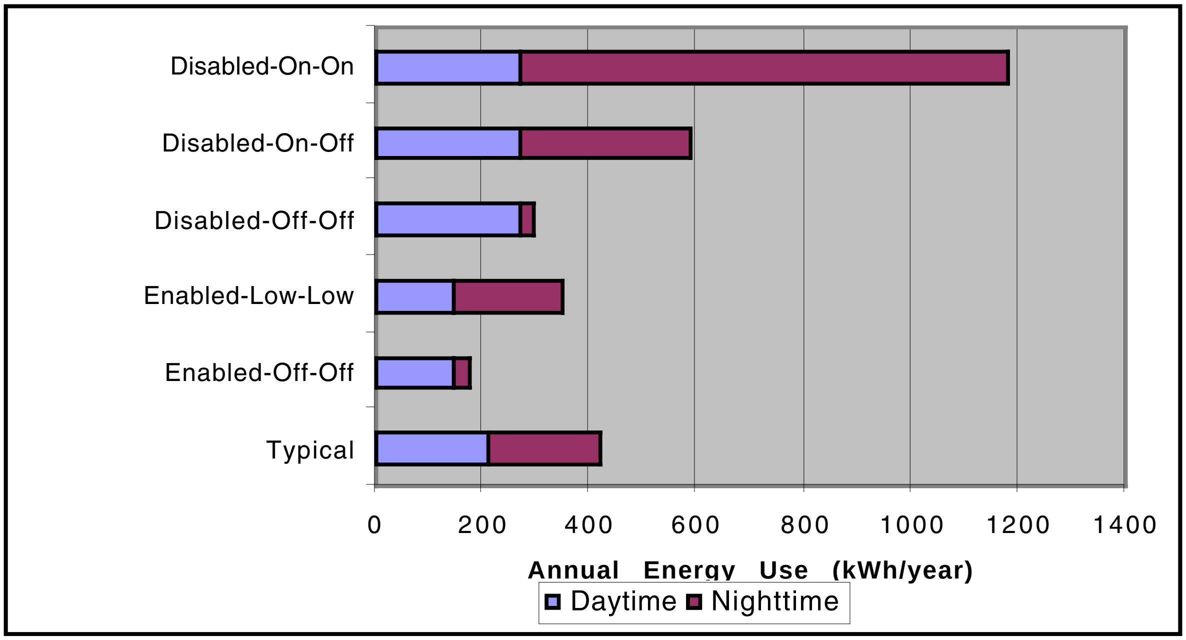


Figure 1. Effect of Night Status on Annual Energy Use of a PC / Monitor

Measurements of office equipment electricity use have been made for a variety of reasons. These include to:

- Assess the contribution of office equipment to national and international energy use;
- Assess current and potential savings from more efficient office equipment and controlling devices, and forecast future use or savings;
- Properly size building wiring and HVAC capacity; and
- Evaluate building energy use.

---

[1] A "controlling device" is an external hardware device that turns the power on and off to a piece of office equipment (most commonly a monitor but also printers and copiers) based on measures of activity such as keyboard / mouse activity or occupancy.

[2] "Night status" is used in this paper as a short-hand for both nights and weekends, and presumes that most equipment is used by staff who work during the day only.

[3] (Tiller & Newsham 1993) found that on one weekday in four, the typical PC is not turned on at all. (Szydlowski & Chvála 1994) found a similar result.

Most studies to date have concentrated on equipment power levels or results derived from that such as load shapes or annual energy use, often combined with factors such as equipment populations.

This paper takes a different approach, putting aside the issue of power levels entirely, to concentrate on equipment status at night—whether a device is fully on, in a low-power mode, or off. The goal is to arrive at our best estimate of the distribution among these modes to inform estimates of use and savings. With nights and weekends making up about 75% of the hours in each week, night status has a huge effect on annual energy use and current and potential savings from power management or manual turn-off of equipment. Despite this, it is typical for much less data collection effort to be invested for night status than for other factors.

Equipment night status is a function of two primary factors: the rate at which equipment is **manually turned off** by workers, and the rate at which equipment **power management** capabilities are operating. This second factor is in turn determined by the rates at which power management is enabled and at which it functions properly when enabled. The studies reviewed often take different approaches to what to measure and so the results are for the most part not strictly comparable. These studies span time and geography widely, and the data can be expected to vary across these dimensions. A study could be designed to justify a statistically-significant conclusion about leave-on and enabling rates for a particular region at a particular time, but it would be a considerable task and nothing resembling it has been done to date. However, assumptions about these factors must be included in policy and research analyses, so our goal is to review existing data to provide the best available estimate of these factors available.

This analysis consisted of examining the night-time operating status and the status of the power management equipment that have been reported in published and gray literature. Data on office equipment night status are not regularly reported in any standard venue such as government statistics, refereed journals, or even building energy audits. Most of our sources are research reports by building energy efficiency professionals assessing office equipment, plus surveys by an equipment manufacturer. We also have benefited from our own experience in measuring office equipment energy use, particularly in conducting night-time audits.

Data Sources

We limited our scope to studies that included at least ten devices of a given type (PC, monitor, printer, or copier), as we felt that fewer than ten devices constituted an anecdote and so would be insufficiently indicative of general trends in night status. For some sources, the same measurement approach was taken at several sites but is reported here only in aggregate.

We did not use data collected after some intervention was made to change energy use patterns, such as user education, power management enabling, or use of controlling devices. An example of a study we could not include due to this criterion is (Katipamula 1996) which had the goal of quantifying the savings from enabled ENERGY STAR computers, so before the measurement was done all the devices were enabled and their prior status (enabled or not) was not reported.

Table 1 lists the studies we include in this paper. Some cover all the devices with others covering only one. The studies are listed in order of the date of data collection, to give a sense of the evolution in the data over time. Studies referenced as simply “LBNL” are data collected by LBNL but not previously published.

Table 1. Studies Included In This Paper and Methods Used

Study	Reference	Data	Method
PNNL	Syzdlowski & Chvála 1994	1990-92	Time-series data
NRC	Tiller & Newsham 1993	1992	Time-series data (activity)
LBNL1	LBNL	1994	Daytime audit
LBNL2	IHEM, 1994	1994	Survey; Daytime audit
LBNL3	LBNL	1994	Daytime audit
MIT	Norford & Bosko 1995	1995	Daytime audit
LBNL4	Nordman, Piette & Kinney 1996	1995	Daytime audit; Night audit
LBNL5	LBNL	1996	Night audit
Defender	Julinot, Fogg & Julinot 2000	1996	Daytime audit; Night audit
AEC	Arney & Frey 1996	1996	Time-series data
Thai	Mungwititkul & Mohanty 1997	Prob.1996	Not specified
Bayview	Schanin 1997	1997	Night audit
EIM	Becht, Pleijster & de Vree, 1998	1997	Surveys
Dalarna	Bryntse & Enoksson, 1998	1997	Surveys
DEFU	Nielsen 1998	1997-98	Surveys
LBNL6	Nordman, Picklum & Kresch 1999	1997-98	Daytime audit; Night audits
LBNL7	Nordman 2000	1999	Daytime audit; Night audit

Night status was not necessarily a goal of these studies. They had diverse goals and used a variety of methods to address night-status. The methods include.

- *Surveys.* Written or verbal surveys of office workers and/or IT (Information Technology) staff about computer usage habits and power management enabling[4]. (LBNL2, EIM, Dalarna, DEFU)
- *Daytime Audits*. Audits of the power management enabling and daytime use patterns. A daytime audit can help indicate which offices are in use at all to better interpret night-time data[5]. Power management enabling of PCs is often easier to check during the day, and users can be queried about their equipment and reasons for turn-off and power management enabling decisions. (MIT, LBNL1, LBNL2, LBNL3, LBNL4, LBNL6, LBNL7)
- *Night Audits*. Audits of equipment status—as on/off, or on/low/off. It is also possible (though cumbersome and rare) to check PC enabling at night, so most night audits report only power status, not enabling status. Equipment observed in a low-power mode can be concluded to be enabled for power management, though equipment that is fully on or off does not lead to any hard conclusion about enabling. (CADDET, LBNL4, LBNL5, Bayview, LBNL6, LBNL7)
- *Time-Series Data*. Continuous power or status monitoring of energy use over time (typically several days to several months). Time-series data provide a detailed picture of the energy use of a device, with night status a side-benefit of such studies. Averages of time-series data (e.g. daily average loadshapes) can result in night status for a device

[4] It is unknown how reliable of a data source surveys are for power management enabling or manual turn-off. For the former, people need to have a sufficient understanding of what power management is and to recognize it occuring. In one of the survey studies (Nielsen 1998), only 31% of IT staff and 20% of others reported recognizing ENERGY STAR. One might expect recognition of the label to be easier to come by than knowledge of power management, and this low rate of recognition gives us pause. The ENERGY STAR program is confident that as of 1999, the ENERGY STAR program has achieved at least 30% "brand awareness"—that at least 30% of U.S. consumers recognize and understand the ENERGY STAR label (Abelson, 2000).

[5] (Szydlowski & Chvála 1994) also reported the 'FOT' (Fraction on-time) from day and night audits of PCs to calibrate annual energy use estimates to a particular site.

being a percentage distribution among each mode rather than a simple on/low/off[6]. (PNNL, NRC, AEC)

Many studies incorporated data collection methods beyond those listed here; only those methods that contributed data to this paper are listed. The purposes of these studies varied, but fell into the following general categories:

- Document office equipment ("plug load") energy use patterns. (PNNL, AEC).
- Collect data to evaluate measures to reduce office equipment electricity use (NRC, LBNL1, LBNL2, Thai).
- Collect data to evaluate reduction measures and also to estimate current use. (LBNL3, LBNL4, LBNL5, LBNL6, LBNL7).
- Evaluate the performance of ENERGY STAR computers. (MIT, LBNL1)
- Assess knowledge of office equipment energy efficiency and test educational messages among different groups (e.g. users, buyers, or IT staff). (EIM, Dalarna, DEFU).
- Estimate the savings from installation of controlling devices only. (LBNL2, Defender, Bayview)

Results

The discussions of PCs and monitors are necessarily intertwined as the studies often do not distinguish between them and the monitor is dependent on the PC to initiate low-power modes.

Often the terms "ENERGY STAR", "power management capable", and "efficient" are used interchangeably in the studies, though there are distinctions among them. For example, some computers and printers use electricity at a sufficiently low rate when active that a separate low-power level is not present or required to meet ENERGY STAR criteria. Some equipment has power management capability, but the low-power levels do not meet the ENERGY STAR criteria.

Computers and monitors are the most complicated pieces of office equipment regarding power management, with two pieces that are typically independently powered (with separate on/off switches), and distinct power management mechanisms. Another reason they are difficult to evaluate is that computers and monitors can have power management that is enabled but fails to function (Nordman et al. 1997) due to a software or hardware problem.

Tables 2 through 5 list the key findings of each of the studies. **In many of the studies, it was not specified if it was the PC, the monitor, or the combination that was being described.** It may be that at those sites the two parts were generally powered on and off together[7]. However, this remains a key uncertainty in much of the data. In the tables, sources which did not differentiate between the PC and monitor are listed in the PC tables. While monitor status is most apparent when conducting a night audit, we assumed that both the PC and monitor were in the state reported.

In many of the studies we reviewed, it was not specified if a device being "on" at night meant that it was in its full-on state or also that it could be in a low-power state. We generally assumed that if low-power modes were not specifically referred to, that "on" included both full-on and low-power modes.

All of these sources are based on data from public institutions (some level of government or a public university/national laboratory) except the survey data and most of the Bayview data. We have heard anecdotal evidence that the private sector has lower rates of night turn-off than does the public sector, but other than the high leave-on rates in the Bayview data we are unable to confirm or deny this.

---

[7] This is facilitated on those devices that have the monitor plugged into an outlet on the back of the PC and switched off with it, a capability which is becoming less common.

When data were reported separately for the ENERGY STAR subset of the devices, we report that in parentheses following the full dataset. Note that we do not report the non-ENERGY STAR subset explicitly, as there are probably some ENERGY STAR models in the full set. That is, it is much easier to be confident that a device is ENERGY STAR compliant than to be certain that it is not. Also, many studies did not even attempt a differentiation so that the full dataset almost certainly contains ENERGY STAR models.

In cases in which enabling was not reported directly, we inferred the enabling rate by calculating the percentage of units reported to be in a low-power mode at night from the total units left on at night (that is, assuming no correlation between power management enabling and manual turn-off behavior).

Table 2. PC Enabling Status

Study	% Enabled	Sample Size	Comments
LBNL1	17%	30	Daytime audit
LBNL2	20%	20	Daytime audit
MIT	0%	>1,150 (>350)	Night audit
LBNL3	90%	10	Daytime audit
LBNL4: CPU	10% (25%)	70 (28)	Night audit; Daytime audit
Thai	10%	not spec.	Not specified
EIM: CPU	40%	99	Survey
DEFU: CPU	5%	255	Survey
LBNL6: CPU	35% (44%)	904 (697)	Night audit
LBNL7: CPU	0%	154	Night audit

Notes: Enabling status was only checked directly in LBNL1, LBNL2, LBNL3, and LBNL4; on all others it is inferred from night status. Values in parentheses are for the subset of ENERGY STAR equipment. For MIT, machines were not individually checked. For LBNL4, the figures are for power management functioning; enabling rates were higher, about 50%. For LBNL1, an additional 14 machines in a library all had power management disabled. In DEFU it is stated that "almost no one has power management in the central unit" which we took as 5% enabling. In studies marked 'CPU' are ones in which it is clearly the processor (not the monitor) that was assessed.

Table 3. Monitor Enabling Status

Study	% Enabled	Sample Size	Comments
LBNL4	40% (75%)	70 (34)	Night audit; direct exam.
Defender	<1%	307	Night audit
Dalarna	76%	150	Survey
DEFU	43%	118	Survey
LBNL6	55% (63%)	882 (768)	Night audit
LBNL7	0%	154	Night audit

Notes: Enabling status was only checked directly in LBNL4; on all others it is inferred from night status. Values in parentheses are for the subset of ENERGY STAR equipment. For LBNL4, figures are for power management functioning; enabling rates were higher, about 50%. For Dalarna, the users reported having monitor power management capability; we assumed that the users would only know about power management if it was enabled and functioning.

In Tables 4 and 5, "On" means fully on, "Low" means that it is in some low-power mode, and "Off" means switched off. When low-power modes were not separately reported, we show those spanning the "On" and "Low" columns.

The three studies in which ENERGY STAR 'off' rates are reported separately from the total suggest that users typically do not leave PCs and monitors on more often when they know that the device will enter a low-power mode. However, there are clearly not enough data to draw such a conclusion with statistical significance. If such a difference did appear, it is possible that total energy use would be greater with power management. More likely is that night leave-on rates will rise, but independently of the presence of power management.

Table 4. PC Night Status

<table>
<tr><th>Study</th><th>On</th><th>Low</th><th>Off</th><th>Sample Size</th></tr>
<tr><td>PNNL</td><td>18%</td><td>—</td><td>82%</td><td>182</td></tr>
<tr><td>NRC</td><td>20%</td><td>—</td><td>80%</td><td>94</td></tr>
<tr><td>LBNL2</td><td colspan="2">47%</td><td>53%</td><td>30</td></tr>
<tr><td>LBNL4: CPU</td><td>26%</td><td>6% (14%)</td><td>69%</td><td>70 (28)</td></tr>
<tr><td>Defender</td><td>>99%</td><td><1%</td><td>0%</td><td>307</td></tr>
<tr><td>AEC</td><td>25%</td><td>—</td><td>75%</td><td>20</td></tr>
<tr><td>LBNL5</td><td colspan="2">10%</td><td>90%</td><td>~200</td></tr>
<tr><td>Bayview</td><td colspan="2">45%</td><td>55%</td><td>>20,000</td></tr>
<tr><td>DEFU: CPU</td><td colspan="2">11%</td><td>89%</td><td>373</td></tr>
<tr><td>LBNL6: CPU</td><td>17% (16%)</td><td>9% (12%)</td><td>73% (72%)</td><td>904 (697)</td></tr>
<tr><td>LBNL7: CPU</td><td>9%</td><td>0%</td><td>91%</td><td>154</td></tr>
</table>

Notes: Values in parentheses are for the subset of ENERGY STAR equipment. For PNNL and NRC, power management was not applicable, as it was not yet present in desktop PCs. For PNNL, it was noted that monitors were turned off more frequently than PCs, but this was not quantified. For AEC data, 4 of original 24 PCs were excluded as it was unclear what their night status was. The Bayview audits covered about 45 distinct sites. For DEFU, the figure is a composite of IT staff and regular users though the difference was small.

Table 5. Monitor Night Status

<table>
<tr><th>Study</th><th>On</th><th>Low</th><th>Off</th><th>Sample Size</th></tr>
<tr><td>LBNL3</td><td>24% (16%)</td><td>19% (35%)</td><td>57% (53%)</td><td>70 (34)</td></tr>
<tr><td>LBNL5</td><td colspan="2">10%</td><td>90%</td><td>~200</td></tr>
<tr><td>EIM</td><td colspan="2">7%</td><td>93%</td><td>~400</td></tr>
<tr><td>Dalarna</td><td colspan="2">18%</td><td>82%</td><td>~140</td></tr>
<tr><td>LBNL6</td><td>16% (13%)</td><td>20% (23%)</td><td>64% (64%)</td><td>882 (768)</td></tr>
<tr><td>LBNL7</td><td>8%</td><td>4%</td><td>88%</td><td>154</td></tr>
</table>

Notes: Values in parentheses are for the subset of ENERGY STAR equipment.

Table 6, Figures 2, and Figure 3 present our estimates for power management enabling and night status. The “Enabled” column is the fraction that is both enabled *and* functioning. The Night Status is the average found during nights and weekends after power management capabilities have had sufficient time to reach their final state. Given the data these are based on, they are necessarily a matter of judgement. Estimates of annual energy use and savings can be made with the enabling and manual turn-off rates in combination with assumptions about the fraction of work days during which each device is turned on, the length of work days, hours of use per day, and activity distribution. Among these factors, power management enabling and night status clearly have the most effect on annual energy use and savings, both with respect to the amount of uncertainty, and the potential to increase savings through more enabling and manual turn-off.

Table 6. Summary of Enabling Rates and Night Status Estimates

	Power Mgmt.	Night Status		
Device	**Enabled**	**On**	**Low-Power**	**Off**
PC	25% (35%)	25%	10%	65%
Monitor	60% (65%)	15%	20%	65%

Notes. Values in parentheses are for ENERGY STAR compliant models only.

Figure 2. Power Management Enabling

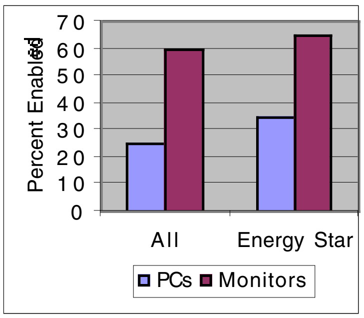
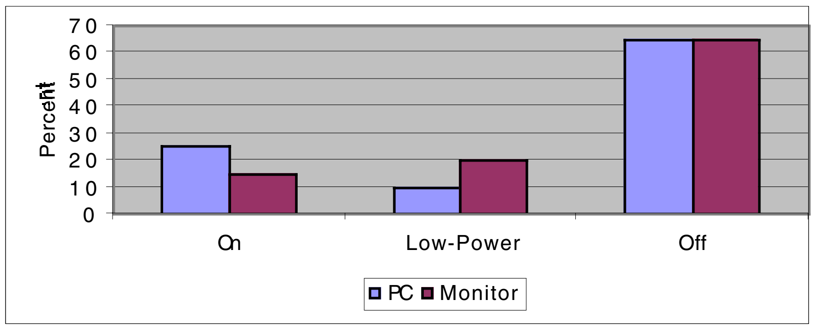


Figure 3. Night Status



Discussion

As these results show, the enabling and night status vary markedly from site to site. The underlying factors determining the rates are diverse, complex, and generally not presented in the reports in any detail. Our confidence in survey results is less than that for audit data, as people may not correctly or fully understand how their machine works, or give the answer they believe is wanted rather than what is actually true. For the most part, the hardware and software implementations of power management have improved over time, and rates of ENERGY STAR compliance of the entire PC and monitor markets and equipment have risen sharply over time. For these reasons, we have taken the more recent audit data and assumed a slight improvement since then.

A significant counter trend is the Windows NT 4.0® operating system. As shipped, it does not allow for power management of the processor or monitor. It is possible to obtain software from the CPU manufacturer or a third-party to implement either or both of these functions, but it takes special effort and is likely done only rarely on desktop PCs. Windows 2000® is supposed to support robust power management capability as-shipped, but how well this works broadly in practice has yet to be seen.

These results can be compared to assumptions used in forecasting estimates. For example, (Koomey et al. 1995) assumes 100% enabling of power management and a night leave-on rate of about 20%, though the paper was written before the problem of low enabling rates was widely known.

Confounding Factors

There are many factors in this assessment which lead us to be cautious in drawing quantitative conclusions. These include:

- The studies rarely collected data that are strictly comparable, and none collected all desired data. Ideally, for each device we would know if it was enabled for power management, if it was functioning, if it was ENERGY STAR compliant, whether it is usually turned off at night or left on continuously, and what operating system the relevant PC was using. It would also be helpful to have a standard protocol describing audit considerations such as what time to begin night audits, what equipment (e.g. servers) to exclude or count separately, and how to treat devices in error or other anomalous modes.

- A PC may be ENERGY STAR compliant, but incapable of low-power modes due to software or hardware problems, or have high active power levels (a parameter not covered by ENERGY STAR). Either of these occurrences can make calling the equipment 'efficient' misleading.
- Auditing office equipment fully can be a daunting task, and many studies make simplifications such as combining low-power modes in with the full-on mode, or failing to record whether power management is enabled or not. Equipment identification, (including ENERGY STAR compliance and power management details) is often difficult to do, even with experience. Our earliest study (Tiller & Newsham 1993) reported that many devices were unauditable due to PCs having moved during the study period; data files corrupted; user removal of monitoring program; or password protection inhibiting data access. Auditing complexities have only increased since then.
- Equipment characteristics and usage patterns vary over time, with evolving information infrastructures and contexts, and changes in hardware, software, and user use and expectations. The factors underlying these changes are diverse and not all moving in the same direction (e.g. towards more or less night-time energy use).
- Many assumptions must be made in the course of auditing night-status in a building, and it is rarely feasible to anticipate or document all of these. For example, an office may appear to be unused, making it less impressive that the PC and monitor in it are off. Equipment may be broken or obsolete and yet still present in the office. Some people may work late and overlap with the audit activity and so have their PC recorded as on even if it ends up in a low-power or off mode eventually. These and other confounding factors are discussed in a document "Office Equipment Auditing" prepared along with (Picklum, Nordman, & Kresch1999) and available at http://eetd.LBL.gov/BEA/SF.
- These studies rarely include mobile ("laptop") computers, as they are often not present when an audit is done, or are locked up for security concerns.

These caveats don't make the data cited useless, but help illustrate that considerably more and better data would be necessary to be able to draw hard quantitative conclusions.

Outlook

Perhaps the most promising way to collect data on equipment night-time status is 'network auditing' — checking the power status and power management configuration over the computer network from a single computer rather than having to physically visit each device. This has some great advantages for auditing, potentially bypassing barriers of space and time. Printer status and configuration is most commonly accessible electronically today, with printer driver software often reporting printer status and management software from major manufacturers providing the ability to check and change configuration readily. Some PCs can be configured to allow remote management, but this seems to be used less frequently. Copiers are not accessible electronically at present, but will be as they become multi-function devices. While it is not inevitable, no technological barrier prevents the quick and comprehensive assessment of power management in an office from a single computer.

A related development is device "self-monitoring". This was the monitoring method of the very first study reported here (Tiller & Newsham 1993), was incorporated in printer controlling devices in the early 1990s, and could be readily developed for current computer platforms. Self-monitoring means that the device itself tracks the device activity patterns and/or the amount of time it spends in each power mode, and possibly the savings gained from power management, or the savings obtainable if it were to be enabled.

Conclusions

The amount of available good quality data on PC and monitor night status (including enabling rates) is not large, but some estimate must be made for assessing existing energy use levels and for potential for reducing it. We have reviewed all the relevant data we could find and made estimates for these factors based on it. Power management enabling rates appear to be rising, and if manual turn-off of equipment declines in the future, power management will only become more important. Some conventional monitoring and auditing is necessary to track these factors, but the promise of electronic gathering of night status data over networks may hold the key to low-cost collection of large sets of night status data.

References

Abelson, Jill (U.S. Environmental Protection Agency). 2000. Personal communication to author.

Arney, W.M., and D.J. Frey. 1996. *Energy-Efficient Office Technologies Performance Evaluation*. EPRI TR-107140, 2890-23. Palo Alto, Calif.: Electric Power Research Institute.

Becht, R., F. Pleijster, and R. de Vree, 1998. *The energy consumption of office machines: knowledge, purchase behaviour and use*. Zoetermeer, The Netherlands: EIM.

Bryntse, G., and E. Enoksson. 1998. *Energy Efficient Office Equipment*. P 1440 GT. Dalarna, Sweden: Dalarna University College.

IHEM. 2000. *Energy Management Study For Personal Computers*. LBNL In-House Energy Management. Berkeley, Calif.: Lawrence Berkeley National Laboratory.

Julinot, B.J.S., G. Fogg, and H. Julinot. 2000. Who's In Charge Of Powering Down Idle Computer Monitors?. . *In Proceedings of the ACEEE 2000 Summer Study on Energy Efficiency in Buildings*. Washington, D.C.: American Council for an Energy-Efficient Economy.

Katipamula, S., T. Allen, G. Hernandez, M.A. Piette, R.G. Pratt. 1996. Energy Savings from Energy Star Personal Computer Systems. *In Proceedings of the ACEEE 1996 Summer Study on Energy Efficiency in Buildings*, 4:211-18. Washington, D.C.: American Council for an Energy-Efficient Economy.

Koomey, J., M. Cramer, M.A. Piette, and J.H. Eto. 1995. *Efficiency Improvements in U.S. Office Equipment: Expected Policy Impacts and Uncertainties*. LBNL-37383. Berkeley, Calif.: Lawrence Berkeley National Laboratory.

Mungwititkul, and B. Mohanty. 1997. "Energy Efficiency of Office Equipment in Commercial Buildings: The Case of Thailand". *Energy* 22(7):673-80.

Nielsen, T.B. 1998. *Pilot-Project Concerning User-Information on Energy Efficient Office Equipment*. TR-402E. Lyngby, Denmark: Research Association of Danish Electric Utilities (DEFU).

Nordman, B., M.A. Piette, and K. Kinney. 1996. "Measured Energy Savings and Performance of Power-Managed Personal Computers and Monitors". *In Proceedings* *of the ACEEE 1996 Summer Study on Energy Efficiency in Buildings*, 4:267-278. Washington, D.C.: American Council for an Energy-Efficient Economy.

Nordman, B., 1999. *Office Equipment Auditing*. Lawrence Berkeley National Laboratory. Available at: http://eetd.LBL.gov/BEA/SF.

Nordman, B., M.A. Piette, K. Kinney, and C. Webber. 1998. *User Guide to Power Management for PCs and Monitors*. LBNL-39466. Berkeley, Calif.: Lawrence Berkeley National Laboratory.

Nordman, B. 2000. *Ridgehaven Building Office Equipment Assessment*. Berkeley, Calif.: Lawrence Berkeley National Laboratory.

Norford, L.K., and K.L. Bosko. 1995. *Performance of Energy Star Compliant Personal Computers and Monitors*. Cambridge, Mass.: Massachusetts Institute of Technology.

Picklum, R., B. Nordman., and B. Kresch. 1999. *Guide To Reducing Energy Use In Office Equipment*. Berkeley, Calif.: Lawrence Berkeley National Laboratory.

Schanin, D.J. 1997. *Plug Loads — The Fastest Growing Consumer of Commercial Power*. San Carlos, Calif.: Bayview Technologies, Inc. (acquired in 1997; may be older)

Szydlowski, R.F., and W.D. Chvála. 1994. *Energy Consumption of Personal Computer Workstations*. PNNL-9061. Richland, Wash.: Pacific Northwest Laboratory.

Tiller, D.K., and G.R. Newsham. 1993. *Desktop Computers and Energy Consumption: A Study of Current Practice and Potential Energy Savings*. CEA 9101 U 829. Montréal, Québec, Canada: Canadian Electrical Association.