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Governor

OFFICE PLUG LOAD FIELD MONITORING REPORT

PIER FINAL PROJECT REPORT

Prepared For:
California Energy Commission
Public Interest Energy Research Program

Prepared By: Ecos

April 2011
CEC-500-2011-010

Prepared By:
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Portland, OR
Commission Contract No. 500-06-007

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California Energy Commission

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Acknowledgements

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Many people were involved with study design, site recruitment, and data collection for this study. The research team would like to thank everyone who contributed to the success of this research project. In particular, the research team would like to recognize:

- Alea German, RLW Analytics
- Amber Watkins, RLW Analytics
- Brad Hoover, RLW Analytics
- Brian Parker, Ecos
- Chris Calwell, Ecos
- Greta Melvin, Ecos
- John Stoops, RLW Analytics
- Nancy English, Ecos
- Vic Sanchez, ASW Engineering

Finally, the research team would like to extend its sincere gratitude to all of the California offices that allowed us to visit their offices, review their electricity bills, and inventory and meter their plug load devices. This study would not have been possible without your generous participation.

Please cite this report as follows:

Moorefield, L., B. Frazer and P. Bendt, Ph.D. 2011. *Office Plug Load Field Monitoring Report*. California Energy Commission, PIER Energy-Related Environmental Research Program. CEC-500-2011-010.

Preface

The California Energy Commission Public Interest Energy Research (PIER) Program supports public interest energy research and development that will help improve the quality of life in California by bringing environmentally safe, affordable, and reliable energy services and products to the marketplace.

The PIER Program conducts public interest research, development, and demonstration (RD&D) projects to benefit California.

The PIER Program strives to conduct the most promising public interest energy research by partnering with RD&D entities, including individuals, businesses, utilities, and public or private research institutions.

PIER funding efforts are focused on the following RD&D program areas:

- Buildings End-Use Energy Efficiency
- Energy Innovations Small Grants
- Energy-Related Environmental Research
- Energy Systems Integration
- Environmentally Preferred Advanced Generation
- Industrial/Agricultural/Water End-Use Energy Efficiency
- Renewable Energy Technologies
- Transportation

Lighting California's Future: Cost-Effective Demand Response is the final report for the Lighting California's Future project (Contract number 500-06-035 conducted by Architectural Energy Corporation, Adura Technologies, and California Lighting Technology Center. The information from this project contributes to PIER's Building End-Use Energy Efficiency Program.

For more information about the PIER Program, please visit the Energy Commission's website at www.energy.ca.gov/research/ or contact the Energy Commission at 916-654-4878.

Abstract

Office equipment and other miscellaneous plug loads consume more than 20 percent of electricity in California's offices. However, energy use per device and device usage patterns are not well documented for many of these plug loads.

In 2007 and 2008, Ecos Consulting and RLW Analytics conducted a plug load field monitoring study in commercial offices in California. Researchers visited 47 offices and compiled an inventory of all plug load devices found at each of the sites. The research team then installed plug load meters on a subset of devices in 25 of these offices. The meter files consisted of two weeks of data at one-minute intervals for each metered device. Researchers recorded power, current, voltage, and power factor with real-time time stamps. In total, the team inventoried nearly 7,000 plug load devices and collected meter data from 470 plug load devices. This is the first study to actually *measure* how products are used in the office environment.

Among office plug loads, computers and monitors accounted for the largest share of energy in the office plug loads study—66 percent. Office electronics—such as printers, faxes, multifunction devices, and computer speakers—accounted for 16 percent of plug load energy use. Miscellaneous devices—such as portable lighting, telephones, and coffee makers—made up the remaining 18 percent.

In the future, California will need to exploit every opportunity for office plug load energy reduction. These energy-reduction opportunities for California include:

- Aggressive consumer education on the energy use of office electronics.
- Promotion of office electronics whose power management features cannot be disabled.
- Promotion of highly efficient products and of highly efficient power supplies.
- Use of "smart" plug strips and other automatic controls.
- Consideration of office electronics in Title 20, California Appliance Efficiency.
- Consideration of switched outlets in Title 24, California Building Energy Efficiency Standards.

Keywords: Plug load, consumer and office electronics, office plug load, field study, plug load meters, office electronics

Table of Contents

List of Tables

List of Figures

Executive Summary

Introduction

Energy efficiency efforts designed for commercial buildings have traditionally targeted the building envelope; heating, ventilation, and air-conditioning systems; and hard-wired lighting. Recently, however, the energy effect of the plugged-in equipment in these offices has garnered attention as a result of the growing requirement for more electronic products that are faster and functionally more robust than their predecessors.

Today, office equipment and other miscellaneous plug loads consume more than 20 percent of electricity in California's offices. Previous research to understand the energy use of office products relied on lab measurements of power drawn in various modes of operation, which were then combined with educated guesses about the ways products are actually used. In 2007 and 2008, Ecos Consulting and RLW Analytics conducted a plug load field monitoring study in commercial offices in California on behalf of the California Energy Commission's Public Interest Energy Research (PIER) Program to record detailed data on how many and what types of plug loads are found in California's office, and how these plug loads are used.

Purpose

The overarching goal of this research was to collect and analyze detailed information on California's office plug loads to develop sound recommendations for near- and long-term strategies to reduce plug load energy consumption.

Project Objectives

The project's objectives were to document how many and what kinds of plug loads are in use today in a select group of Northern and Southern California offices, and then to record detailed data on device power demand by mode, power factor, energy consumption, and usage patterns. In addition, the team sought to collect qualitative information from study participants on their office's energy efficiency practices and procurement specifications, if any.

Project Outcomes

The meter logged power, current, voltage, and power factor with real-time time stamps at one-minute intervals for each of the metered devices. While the scale of this study was not large enough to be statistically valid for all of California, the findings provide detailed insights into how many and what types of plug loads are found in California's offices, how these devices operate in their everyday office settings, and how much energy they consume.

Among office plug loads, computers and monitors accounted for the largest share of energy in the office plug loads study. Office electronics such as printers, faxes, multifunction devices, and computer speakers accounted for 16 percent of plug load energy use. Miscellaneous devices such as portable lighting, telephones, and coffee makers made up the remaining 18 percent.

Conclusions

While the scale of our study was not large enough to be statistically valid for all of California, the findings provide detailed insights into how many and what types of plug loads are found in California's offices, how these devices operate in their everyday office settings, and how much energy they consume.

Among office plug loads, computers and monitors accounted for the largest share of energy in the office plug loads study. Office electronics such as printers, faxes, multifunction devices, and computer speakers accounted for 16 percent of plug load energy use. Miscellaneous devices such as portable lighting, telephones, and coffee makers made up the remaining 18 percent. Much of this energy is consumed on nights and weekends, when no one is working in these offices. In total, researchers estimated that California's office plug loads consume about 1,000 GWh annually, costing business owners over $140 million each year. The associated carbon dioxide emissions of these plug loads is more than 230,000 metric tons annually—equivalent to the carbon dioxide emissions of 46,000 cars during one year.

As the state strives to meet the California Public Utilities Commission's "Big, Bold Energy Efficiency Strategies," which include a net zero energy mandate for all new commercial construction by 2030, California will need to exploit every opportunity for office plug load energy reduction. These energy-reduction opportunities include:

- Aggressive consumer education on the energy use of office electronics.
- Promotion of office electronics whose power management features cannot be disabled.
- Promotion of highly efficient products and of highly efficient power supplies.
- Use of *smart* plug strips and other automatic controls.
- Consideration of office electronics in Title 20.
- Consideration of switched outlets in Title 24.

Benefits to California

California now has program and policy recommendations based on recent, detailed plug load performance information collected in the field. This data depicts how office plug loads are operated in their everyday settings and what changes would have the greatest effect on reducing plug load energy use. If needed, further analysis can be conducted using the detailed files recorded for each device in the study. In addition, the research team further refined the plug load field metering method that was developed for the team's 2006 PIER-funded residential plug load field metering study. This project's method and the analysis tools developed to support it can continue to be leveraged as the Energy Commission or others seek to conduct larger, statistically valid field monitoring studies.

<Authors' note: This report was originally completed and submitted to PIER in 2008. In 2010, the research team discovered an error in the analysis that affected annual energy use calculations for many products. Revisions to the analysis were completed in 2011; this 2011 revised report reflects those revisions. This version contains corrected annual energy use values where applicable, and corrections to all related values such as estimates for statewide plug load energy use in small offices. Power demand by mode and duty cycles were not affected by the analysis error and remain unchanged from the original 2008 report. >

1.0 Introduction

Energy efficiency efforts designed for commercial buildings have traditionally targeted the building envelope; heating, ventilation, and air conditioning (HVAC) systems; and hard-wired lighting. Recently, however, the energy impact of the plugged-in equipment in these offices has garnered attention as a result of the growing requirement for more electronic products that are faster and more robust than their predecessors.

In the *Annual Energy Outlook 2008*, the Energy Information Administration (EIA) classifies office equipment and personal computers as two of the three "fastest growing [electrical] end uses" (p. 59). (The third end use referenced is televisions.) In addition, the same report states that the "increased penetration of computers, electronics, appliances, and office equipment" is one of the significant "factors that influence growth in CO_2 (carbon dioxide) emissions" (p. 86).

Similarly, the most recent California Commercial End Use Survey (CEUS) also highlights office plug loads. According to this study, office equipment accounts for 18 percent of electricity in California's small and large offices, making it the third-largest end use behind HVAC and lighting. The CEUS miscellaneous category includes other plug loads not specified elsewhere. Separately, this category accounts for 5 percent of small and large office electricity use. (See Figure 1.) Findings from these two important studies highlight the urgency of addressing energy-reduction opportunities in office plug loads. As improvements are made to HVAC and lighting efficiency through Title 24, office plug loads, if not addressed, will account for an even larger share of commercial electricity consumption.

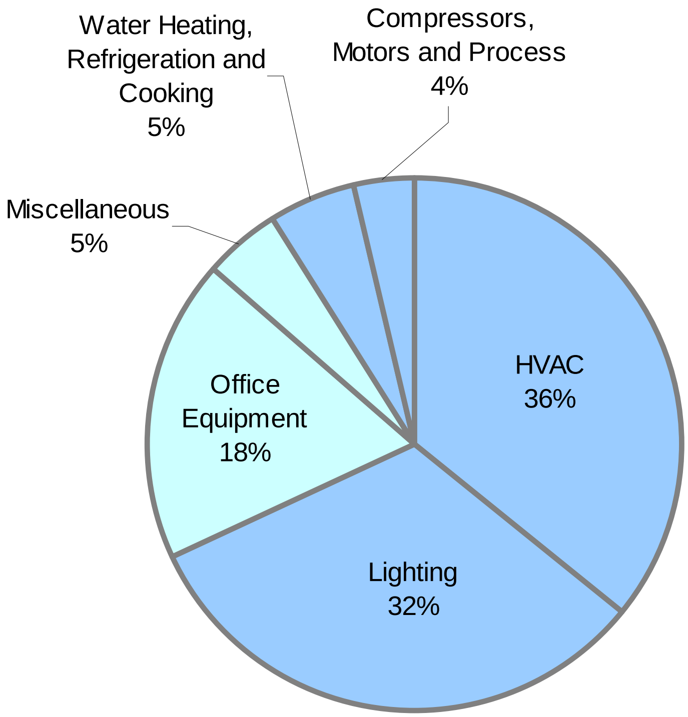

Figure 1. California's Office Electricity Consumption

Source: California Energy Commission, 2006

Previous research to understand the energy use of office products relied on lab measurements of power drawn in various modes of operation combined with educated guesses about the way the product was actually used in the field. This effort is the first study to actually *measure* how products are used in the office environment. Researchers visited 47 offices in California, inventoried and categorized all of the plug loads found, and then metered a subset of these devices for two weeks at one-minute intervals. In total, the research team inventoried nearly 7,000 plug load devices and collected 48 million metered data points from 470 plug load devices. The data reveal not only how much power is being drawn when office devices are on, off, or in standby, but also how many *hours* per day each device spends "on" and in its various low-power modes.

The primary goal of this research is not only to characterize office plug loads, but also to use the findings to recommend policy priorities for the Energy Commission, electric utilities, and other interested organizations so that growth of future commercial energy use can be reduced through voluntary market-based programs and energy efficiency regulations. As the state strives to meet the California Public Utilities Commission's "Big, Bold Energy Efficiency Strategies," which include a net zero energy mandate for all new commercial construction by 2030, California will need to exploit every opportunity for office plug load energy reduction.

This report begins with a review of the study method in Section 2, including scope and method of product measurement, office participant selection and recruitment, and analysis methods. The results, detailed in Section 3, compare energy-use profiles of business types, overall product categories, and individual products. Section 4 summarizes research and policy implications of the research.

2.0 Study Method

This report builds upon the method of the residential plug load field monitoring study conducted in 2006 by Ecos Consulting and RLW Analytics on behalf of the California Energy Commission's Public Interest Energy Research (PIER) program. (See Porter et al. 2006 for details.)

2.1. Plug Load Device Selection

Because the goal of the investigation is to identify and to prioritize the electronic end uses in commercial buildings that represent the best opportunities for reducing energy consumption, researchers considered only electrically powered office products that have not yet been thoroughly investigated and researched. Previous estimates and measurements of total stock and energy use enabled the research team to focus further by placing higher measurement priority on plug load products that the research team suspected had high overall energy use and lower measurement priority on plug loads with low overall energy use. The scope does not include large appliances (white goods), HVAC, or other hard-wired loads such as lighting or GFCI outlets. A full list of products covered in the scope can be found in the Appendix, section 5.3.Appendix. The product list was largely based on the taxonomy developed by Nordman and Sanchez (2006) in *Electronics Come of Age: A Taxonomy for Miscellaneous and Low Power Products.*

2.2. Participant Selection

A secondary goal of this research is to develop a sound methodology for conducting field measurement of plug loads in a commercial setting. Researchers are pioneering the practice of installing meters on a wide variety of electronic office products and use these data to characterize their energy use, but they must deal with difficult-to-anticipate challenges in participant recruitment, data collection, and analysis. For these reasons and because of the cost associated with the extended travel needed for a statistically valid sample, researchers elected not to undertake a sample statistically mapped to California as a whole. Instead, they attempted to diversify the participant sample as much as possible so that the data represented the range of possible California plug load energy use profiles.

The design of the participant sample considers three variables that are likely to have the most significant impact on plug load energy use profiles:

- **Geographic trends.** The sample includes both rural (Sonoma County) and urban (San Diego County) counties.[1] Selecting these counties enabled researchers to collect data from Southern and Northern California as well as from different utility territories.
- **Office type.** The three offices types represented in the sample are 1) legal, accounting, and tax services; 2) architectural and engineering; and 3) computer systems design.

1. These counties also have different climates, but because plug load usage is likely to be independent of climate, this is not necessarily significant.

These reflect a broad range of business types that are unlikely to have confidentiality concerns associated with a field team on premises.

- **Office size.** Both small (up to 9 employees) and large (10 or more employees) office sizes for each office type and county are included.

A total of 47 office participants, evenly distributed by the county, office type, and size variables outlined above were selected for site visits.

2.3. Recruitment

Researchers used a series of steps to recruit offices to participate in the study. First, letters from the research team and the Energy Commission went out describing the study goals and options for participation. A follow-up phone call to each potential participant enabled the research team to confirm the participant fit within the sampling plan and met other logistical criteria. Once deemed eligible, participants were offered a monetary incentive in exchange for their involvement in the study. In general, researchers offered larger incentives to participants with large offices and offices where the team expected to be on site for relatively long periods. Survey Sampling International, an agency specializing in providing "call-lists" for sales companies and research firms, provided office addresses and phone numbers.

2.4. Data Collection

Data collection occurred in two phases. During Phase 1, researchers conducted on-site walk-throughs of 22 office spaces to create an inventory of all plug load devices found in those spaces. Then the research team reviewed device inventories and prioritized devices for metering in Phase 2. Phase 2 visits occurred at 25 additional sites and consisted of the same kind of on-site walk-throughs as those of Phase 1. Based on the product prioritization that occurred after Phase 1, researchers installed individual plug load meters on a subset of the inventoried products and left the meters for two weeks to record time-series data. The team then analyzed the data to determine the time each product spent in each operating mode, the average power in each operating mode, and the estimated overall energy use for each product. Aggregating the data enabled the team to make recommendations on devices that are ripe for energy efficiency policy approaches and additional research.

2.4.1. Meter Selection

Researchers used a total of 120 Watts Up Pro ES meters to gather data on power demand, power factor, and time of use for individual plug load devices. Prior to selecting this meter, the team evaluated several meters in the lab for comparison. In addition, the Electric Power Research Institute (EPRI) conducted a meter evaluation in its lab to inform researchers' selection. Ultimately, researchers selected the Watts Up Pro ES meter because it had the following features:

- Ability to record and store data from a single plug load device rather than a circuit or electrical panel
- Ability to record data at one- or two-minute intervals

- Ability to store data for multiple weeks
- Ability to record true root means squared (r.m.s), which is a statistical measure of the magnitude of a varying quantity, watts, r.m.s. volts, r.m.s. amps, volt-amps, power factor, and add a date and time stamp for each interval recording
- User-friendly character (provided clear documentation, was easily programmed, and downloaded data quickly and accurately)
- Ability to record entire range of power for office plug load devices (<1 watt up to 1,800 watts) with same model meter
- Sufficient level of accuracy in specifications for this study. Meters evaluated in the research team's
- laboratory met the stated specifications.
- Desired price point
- Timely consumer availability (in 2007)

Researchers programmed the meters to record watts, volts, amps, volt-amps, power factor, and maximum wattage at one-minute intervals. With these settings, the team was able to record a maximum of 23,752 readings, or 16.5 days worth of one-minute interval data. The desired file length was 20,160 readings at one-minute intervals — exactly two weeks.

Figure 2. Watts Up Pro ES Meter

Photo Credit: www.WattsUpMeters.com

2.4.2. Phase 1 Data Collection

During Phase 1 site visits, researchers created plug load inventories of 22 offices. Two field surveyors visited each site. They first met with the site contact (often this was the IT or facilities manager) to answer questions about the study, explain the survey procedure, ask the site contact questions about the facility and the business's environmental procurement practices, and get sign-offs on an entrance agreement (required) and billing data release (optional). Field surveyors then walked through the office space together and created an inventory of every plug load device. This inventory included device name, device location (private office, production center, etc.), and type of power supply (internal, external, none, or unknown). Surveyors recorded screen size for monitors and televisions, and number or U-bolts along with the rack height for servers. If any device was unplugged or inaccessible for metering, the surveyor noted that as well. All information was recorded on site in a database template stored on a tablet PC. Once off site, surveyors could then upload the site data to a central database.

2.4.3. Phase 2 Data Collection

For Phase 2 sites, surveyors followed all of the above procedures to create the same plug load inventories of 25 new sites. Next, the research team selected a subset of the inventoried devices for time-series metering.

After all devices were logged into the database, surveyors determined the number of meters to be allocated to that site using the metrics explained in the meter allocation section below. They then entered the meter number into the database where a computer program assigned each meter to a specific device type based on the metering prioritization. The computer program selected device types to be metered, but not a specific device in a specific location. For example, the program may indicate that a desktop computer should be metered, but not that the desktop computer at the reception desk should be metered. This enabled the field surveyors to use professional judgment when selecting which devices to meter. In no case did researchers use a meter to record data from multiple devices connected to a plug strip. If a device selected for metering was plugged into a plug strip, the meter was installed between the device and the plug strip. See the photographs in Figure 3 for examples of how meters were installed in the field.

1. No plug strip: Device plugged into meter; meter plugged into wall outlet
2. Plug strip present: Device plugged into meter, meter plugged into plug strip, plug strip plugged into wall outlet.

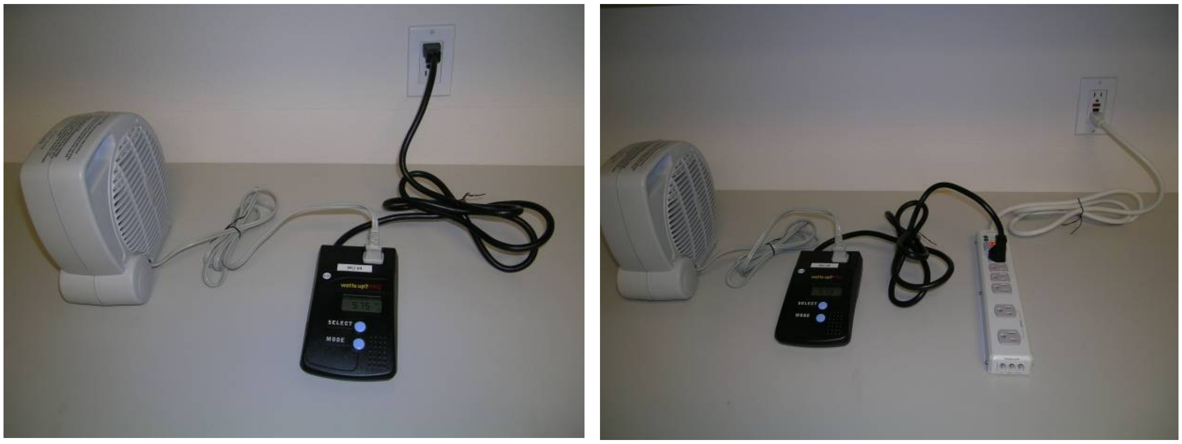

Figure 3. Sample Installations of Meter

Photo Credit: Ecos

Once all the meters had been installed at the site, surveyors arranged a time for meter pickup with the site contact. Meters were left on site 14 days, after which time surveyors returned to remove them. Off site, surveyors downloaded the meter files to their computers, and then uploaded all meter files to the central database. Figure 4 illustrates a meter connected to a computer for downloading data. Figure 5 depicts an example of two-week power data recorded from a desktop computer.

Figure 4. Meter Connected to Computer for Downloading Data

Photo Credit: Ecos

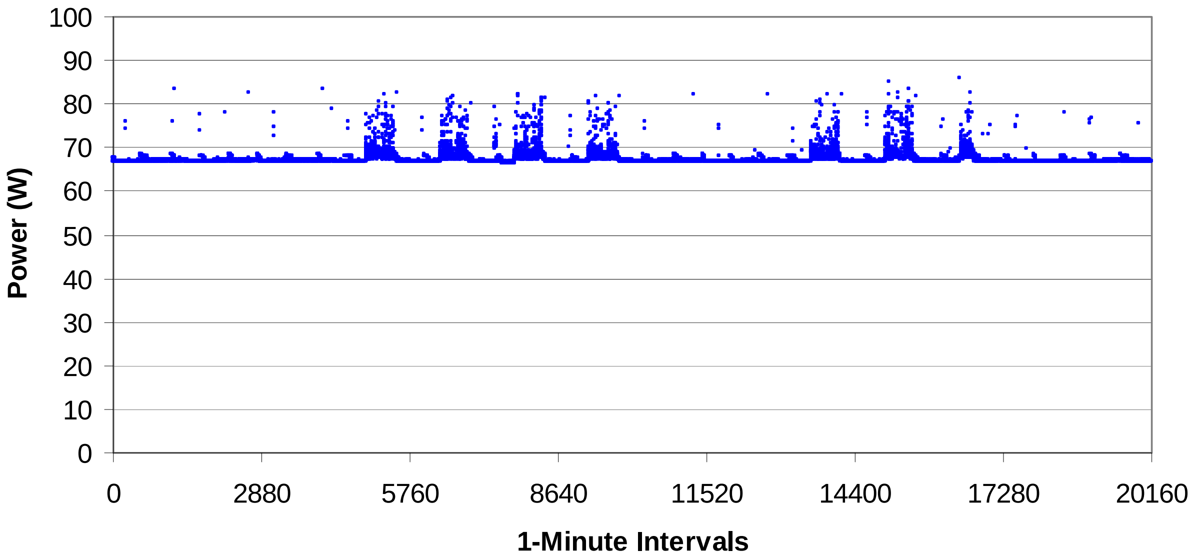

Figure 5. Desktop Computer Meter Data from Two-Week Metering Period

Source: Ecos

Metering Prioritization

Since the purpose of the study was to gather detailed information on office electronics, the research team wanted to meter as many traditional office electronics (e.g., computers, printers, etc.) as possible while collecting meter data on a wide variety of all plug load devices encountered. However, because it was not feasible to meter every device at every site, the team needed to develop a prioritization system for product metering. To do so, researchers determined three main areas of interest and categorized all of the devices in the product taxonomy accordingly. The three main areas of interest were:

1. Devices whose cumulative energy use is believed to be high.
2. Devices about which little is known (either duty cycle or energy consumption).
3. Devices whose energy consumption could be reduced through use of automatic controls.

The team assigned all of the products in the team's product taxonomy to one or more of the above categories, enabling systematic sorting of devices into *high*, *medium*, *low*, or *do not meter* categories to ensure capture of meter data from a targeted subset of encountered plug load devices.

While researchers decided some priorities on a case-by-case basis, in general, high-priority devices were those expected to be among the highest energy users, or which fell into more than one of the above categories. Devices that fell into the second or third areas of interest were ranked as medium priority. Low-priority devices were those that piqued some interest but did not fall solidly into the top three areas. Devices labeled *do not meter* were those that were very well understood and/or outside the scope of this study (e.g., white goods), hard to meter accurately (e.g., laptop docking station), or rejected due to difficulty or liability (e.g., servers). See Appendix, section 5.3, for device prioritization.

Meter Allocation

The goal was to have the majority of meters installed on high-priority devices, with medium- and lower-priority devices receiving fewer meters. Researchers used the following distribution to allocate meters at each site:

Table 1. Meter Allocation According to Prioritization

Priority for Metering	Meter Allocation per Site
High	60%
Medium	30%
Low	10%
Do Not Meter	0%

Source: Ecos

The team allocated meters to each site proportionally based on square footage and/or number of full-time employees. This enabled metering of multiple sites of different sizes during the same period. Researchers installed a minimum of 10 meters and no more that 40 meters at each site, first developing two metrics to determine the specific number of meters between 10 and 40. In the first metric, researchers divided the site square footage by 100 to arrive at the number of meters to be installed at that site. However, this metric was not always the best predictor of the number of plug loads at every site. For that reason, and to allow the field surveyors to exercise professional judgment at the sites, researchers developed an alternate metric—three meters for every full-time employee—to use if the first metric did not seem to yield an appropriate number of meters for a specific site.

Examples for determining an appropriate number of meters are as follows:

- Example for a 1,400-square-foot site: 1,400 divided by 100 = 14, so the site would get 14 meters.
- Example for an 800-square-foot site: 800 divided by 100 = 8. The minimum number of meters to be allocated to a site was 10, so this site would get 10 meters.
- Example for a site with eight full-time employees: 8 multiplied by 3 = 24. This site would be allocated 24 meters.

Billing Data Collection

Twenty-one sites — 10 sites in Pacific Gas and Electric's (PG&E) territory and 11 sites in San Diego Gas & Electric's (SDG&E) territory — allowed review of their electricity billing data from February 2007 through February 2008. In some cases, businesses that were tenants rather than owner-occupants did not have the authority to release their billing data. In other cases, the billing data covered an entire office complex, and billing data for the surveyed site could not be separated out.

Researchers asked every site contact who was willing (and able) to release billing data which equipment and office areas their electric bill covered. Because of the various ways commercial office buildings are metered, and the variety of arrangements that building tenants have with landlords, billing data did not necessarily cover the same portion of the office space that researchers surveyed; however, the research team collected billing data when sites were willing to get a general sense of the scale of plug loads within overall electricity consumption.

Typical Site Visits

For Phase 1, surveyors were typically at each site for one and a half hours. The smallest sites required only one hour; the largest took up to three hours. A typical Phase 2 visit took one-half to one hour longer than a Phase 1 visit to a site of similar size. The meter removal visit took one-half to one hour per site. During the course of the study, no equipment at participating sites was damaged, and to researchers' knowledge, only one meter was disabled by a study participant.

2.5. Data Analysis

As noted earlier in this report, the scale of this study does not allow its findings to be statistically significant for California. However, the in-depth case study approach provides a wealth of new data on how many and what types of plug load devices are found in California's offices and how these devices operate (and are operated by users) in their everyday settings. The study's findings can be used to characterize plug load energy use in offices across California (but not to predict it precisely), to identify products that warrant further research, and to shape future strategies for office equipment energy savings.

Researchers established five main goals for their data analysis methodology:

1. **Site plug load characterization.** Determine the number of and types of plug load devices at each of the 47 sites in the study.
2. **Average power demand by mode.** Determine the average power demand of each device type (e.g., laptop computer, inkjet printer) according to the mode of operation.
3. **Duty cycles.** Determine the percentage of time each device type spent in each of its operational modes during the two-week metering period. Use these percentages to predict annual duty cycles.
4. **Energy consumption.** Determine total energy consumed in each mode for each device type during the two-week metering period. Scale those findings up to predict the energy consumption by mode annually.
5. **Time of use.** Evaluate the real-time energy consumption of selected metered devices.[2]

The findings from the data analysis process, as well as lessons learned, will help the efficiency research community move closer to better understanding the energy impacts of plug load devices as well as how to study this topic effectively.

2.5.1. Processing the Meter Data

The first step in the meter data analysis was to review files for errors. File errors can occur for a variety of reasons in field studies, including meter malfunction, improper meter setup or data download, and interference in the field. Researchers reviewed the 470 time-series meter files for

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2. Load curve data collected during this study will be evaluated in follow-on Grid Impacts Assessment research to be completed in 2009.

file length and plausible power and voltage readings. In total, 40 files, or 8.5 percent, were eliminated. Fifteen of the eliminated files had less than one week's worth of data; 24 had unreasonable readings for power and/or voltage; and 1 file was an exact duplicate of another.

A small number of meter files were slightly shorter than two weeks, and a few were slightly longer. However, after the long files were trimmed not to exceed the two-week metering period, the product files ranged from 99.2 percent to 100 percent of the desired file length. Researchers then wrote and refined a program in Fortran for analysis of the meter data. The basic intent of the analysis was to determine for each device metered:

- The amount of time spent in each operating mode.
- The power demand in each of those modes.
- The energy consumed in each mode.

One of the challenges of the analysis was that there was not enough information to determine the operating "mode." The problem can be illustrated by the following typical definition of a "sleep" mode from the ENERGY STAR® Requirements for Computer Monitors v. 4.1:

> "The reduced power state that the computer monitor enters after receiving instructions from a computer or via other functions. A blank screen and reduction in power consumption characterize this mode. The computer monitor returns to On Mode with full operational capability upon sensing a request from a user/computer (e.g., user moves the mouse or presses a key on the keyboard)" (p.4).

In this case, the mode is defined by two quantities: power consumption and functionality. The meters recorded power consumption but not functionality, so from the outset, the research team had only half of the needed information.

To get around this, researchers first determined not the operating mode, but the *power state*. For the purposes of this report, a product is considered to be in a power state when it spends a significant and continuous period with its power consumption in a narrow range. An operating mode can include one or more power states, and may also include fluctuating power levels that are not considered power states. Fluctuating power levels are especially common in active mode. See Appendix, section 5.40, for a detailed description of the Fortran program used to sort meter data into power states.

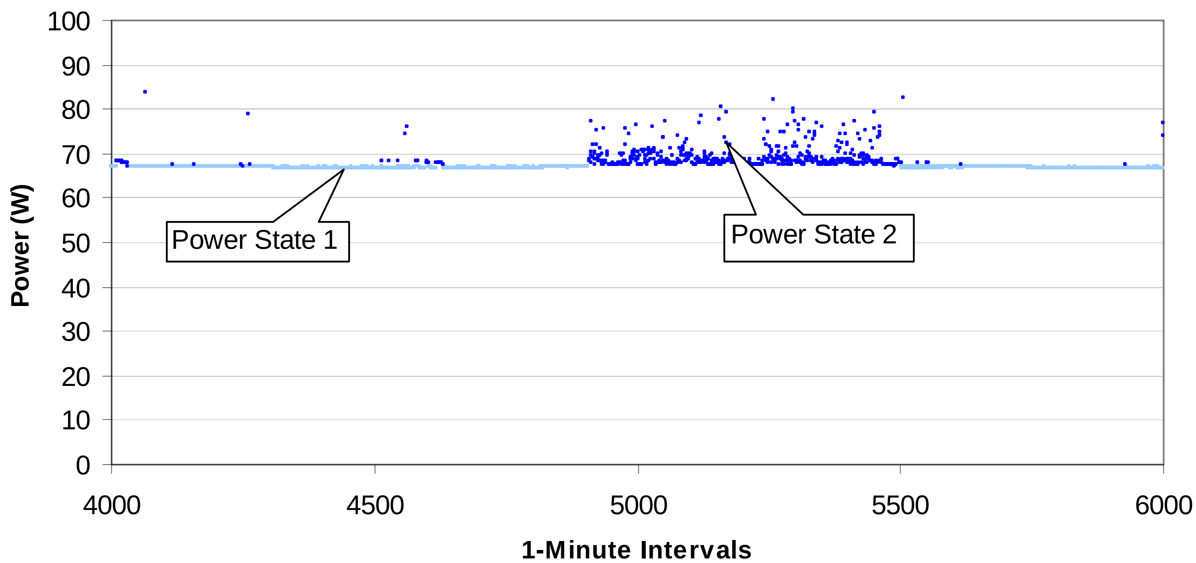

Figure 6. Desktop Computer Power Data Sorted Into Power States

Source: Ecos

The final step was to collect statistics on each power state and to assign each state to an operating mode. An analyst, who could include knowledge of the product's typical operation and power consumption patterns, made these assignments. Researchers used the following operational modes:

- **Disconnected.** No power recorded. Disconnect mode means that the device is not drawing any power. This could occur when a device was unplugged, turned off with a hard switch, or turned off via a surge protector or plug strip.
- **Standby.** Minimum observed steady power mode that was in the range of previously measured standby power values for the product type.
- **Sleep.** Steady low power mode between standby and idle. Power states were assigned to sleep mode only after idle and standby states were identified. This mode assignment was used only for product types where power-saving features are a know part of the products' design.
- **Idle.** Steady mode that falls below "active" mode. A product operates here when it is prepared to perform its intended function, but is not doing so.
- **Active.** Device is performing its intended function. In some cases, products may have more than one intended function and therefore a wide range of active mode power. For example, a multifunction device demands different power levels for scanning, printing, and copying; however, when it is performing any of these functions, the device is in active mode.

2.5.2. Averaging and Scaling the Meter Data

After sorting the meter data for each device into operational modes, the research team used the sorted data to calculate the following for each metered product:

- Average power demand by mode
- Total time spent in each mode during the two-week metering period
- Total energy consumed in each mode during the two-week metering period

The above findings were used to develop the following summary information for each device type (e.g., inkjet printer, notebook computer):

- Average power demand by mode
- Average percentage of time spent in each observed mode
- Average device energy consumption per mode for each device type

Next, researchers used the average device energy consumption findings from the two-week metering period to predict the average annual energy consumption per mode for each device type. Scaling the data from two weeks to one year was relatively straightforward for two reasons. The first is that the meter files were quite uniform in length. Files that were too long were trimmed to be exactly 20,160 intervals (or minutes, for a total of 14 days) long. Of the few files that were shorter than 20,160 intervals, none were more than 0.8 percent short. The second reason is that, with the exception of space heaters and possibly portable fans, the research team did not expect seasonal variations in office plug load energy use.

Finally, researchers multiplied the average annual energy for each device type by the total number of those devices inventoried during the study. This enabled an understanding not only of the energy impact of individual device types, but also the cumulative energy impacts of all devices in the study. Energy findings reported in the next section are derived from metered devices and scaled up to all inventoried devices. For example, if researchers metered 5 telephones but inventoried 80, the cumulative energy impact of telephones would be the average of the annual energy use of the 5 metered phones multiplied by 80. If researchers inventoried six answering machines but did not meter any, the findings section would not report any energy use for answering machines. See Appendix, section 5.3, for a complete list of all metered and inventoried items in this study.

3.0 Results

As noted in the methodology section, the sample size was not large enough to be statistically valid for California. Readers should view the findings as characterizations of the sites studied rather than as a representative sample of all of California's offices. High-level results are in alignment with previous research on commercial plug loads and therefore are very likely to be indicative of plug load energy use in most offices. The following section discusses researchers' findings about the businesses surveyed as well as the plug load devices found in them. Finally, the report presents a comparison of the research team's findings with previous research.

3.1. Business Type Results

In total, researchers visited 47 sites. Almost half of these had fewer than 10 full-time employees; the rest ranged in size from 10 to 275 full-time employees. The square footage of the sites visited ranged from 350 to 38,000 square feet.[3] Researchers inventoried a total of 6,943 plug load devices and had usable two-week meter files from a subset of 430 of the inventoried devices. In addition, the team collected one year of electricity billing data from 21 offices as well as limited qualitative information on the purchasing and IT practices at each business. See Appendix, section 5.2, for a complete listing business types, location, square footage, and number of full-time employees for each site visited.

3. In the CEUS report (2008, p.8, Table E-1) small sites are <30,000 square feet and large sites are ≥ 30,000 square feet. All except one of the sites were small according to this CEUS classification.

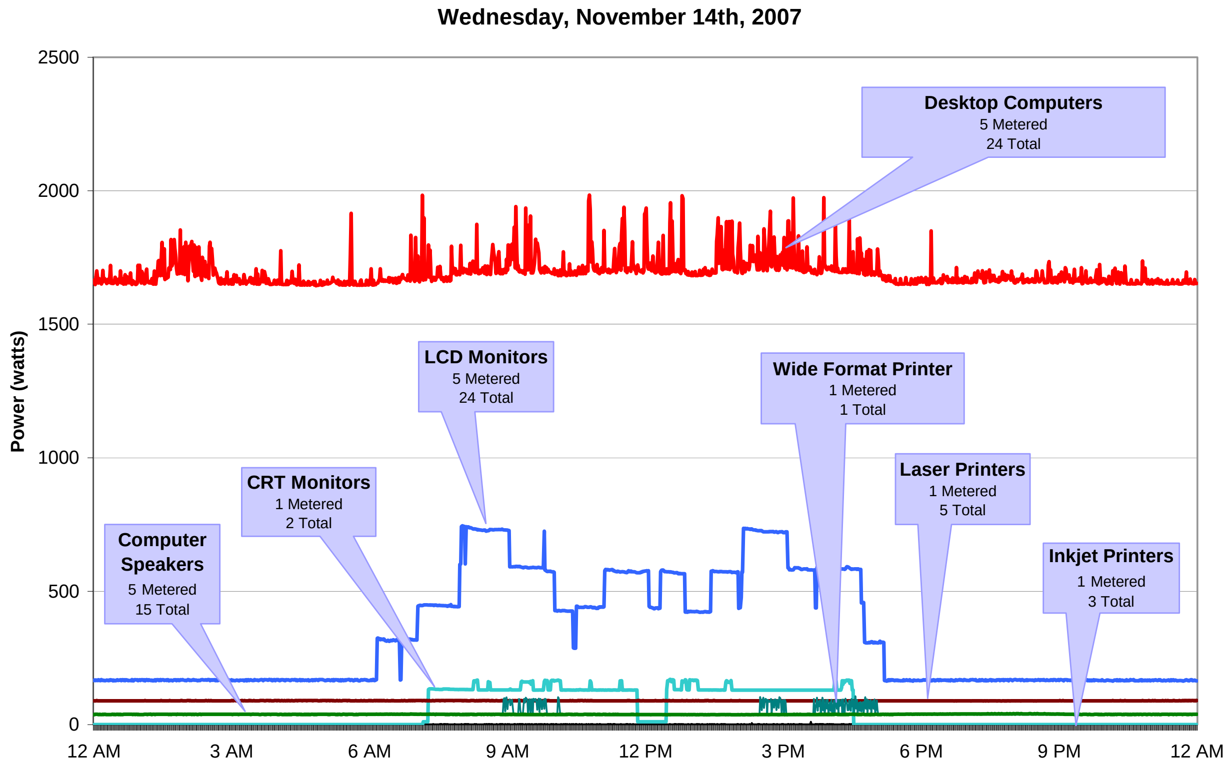

Figure 7. 24-Hour Snapshot of a Metered Site
Source: Ecos

Energy Findings

On average, plug loads consumed about 20 percent of total office electricity in the sites that participated in the study. This was calculated by dividing the average annual plug load energy per square foot by the annual energy reported in the electricity billing data collected from the participating sites. Because researchers did not receive billing data from all of the surveyed businesses and did not have precise information on what building systems the utility bills covered, the annual energy reported in the billing data may not include heating, cooling, and/or lighting in some cases. However, the findings are only slightly lower than those reported in the most recent Commercial End Use Survey (CEUS) report, where researchers concluded that plug loads consume approximately 23 percent of total electricity usage for small offices (Itron Inc. 2006).

Within the Ecos study, the plug load energy use documented translates to an average of 2.0 kWh per year per square foot. The plug load energy density findings align well with the findings in the most recent CEUS report. Researchers found that office electronics consumed 2.19 kWh per year per square foot in small offices (<30,000 square feet). Miscellaneous plug loads add an additional 0.78 kWh per year per square foot (Itron 2006, Table E-3, p.12). The office with the lowest energy use per square foot was an architectural/engineering business, while the office with the highest energy use per square foot was a computer systems design business. (See Figure 8 and Figure 9.) Interestingly, the computer systems design business with the highest energy use per square foot had one of the lowest energy usages per full-time employee. This business occupied only 350 square feet but had 22 full-time employees. One explanation may be that many of these employees worked from remote offices.

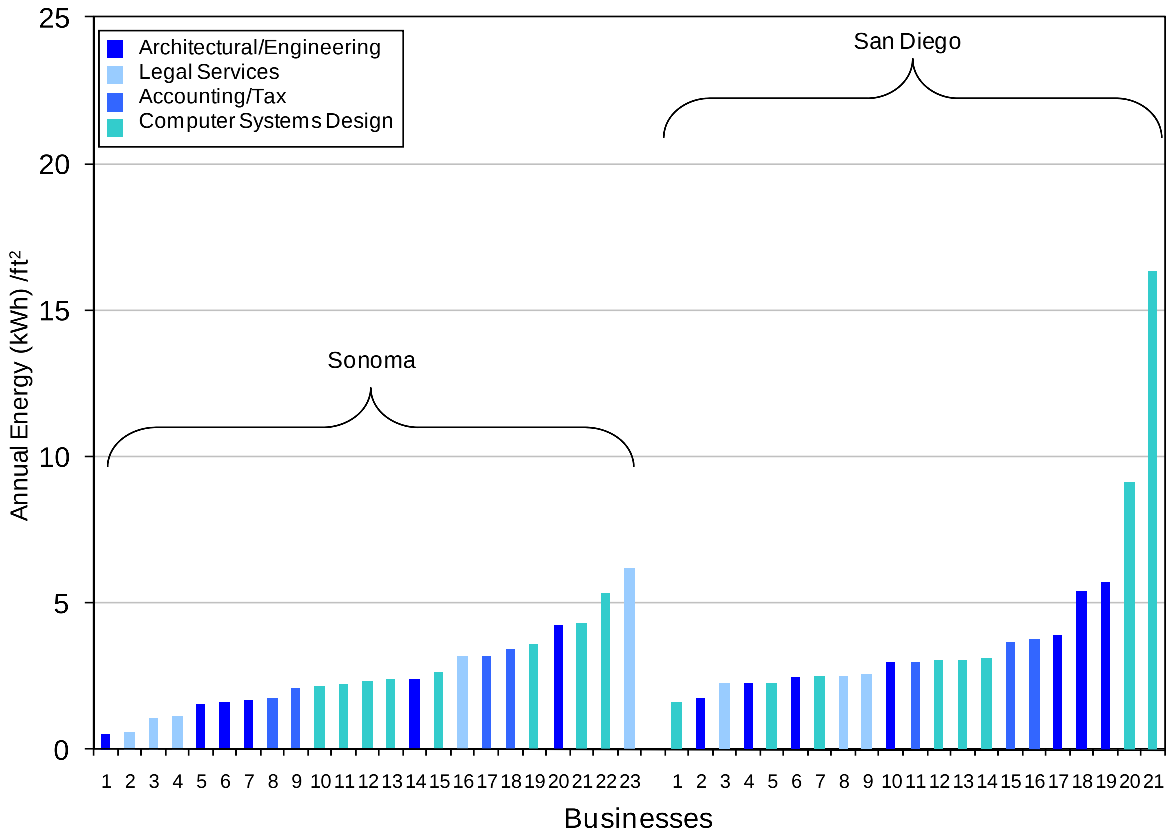

Figure 8. Annual Energy Use per Square Foot

Source: Ecos

These same plug load energy findings meant that study participants used 499 kWh per year per full-time employee, or 477 kWh per year for all employees (full- and part-time). The U.S. Census Bureau's 2002 California Economic Census recorded that there were 1,164,306 total employees working in the professional, scientific, and technical services sector (the NAICS category of all Ecos study participants) at that time. Based on the census employee data, researchers estimate that plug loads in this sector alone consume nearly 600 million kWh per year. Using census data for all business types that are likely to make up the majority of California's small offices (NAICS codes 51 through 56), researchers estimate that office plug load energy use for these businesses could exceed 720 million kWh annually. These findings are slightly lower than the 2006 CEUS study (Itron 2006) where office electronics and miscellaneous plug loads were estimated to consume 1,076 GWh (1.08 billion kWh) per year in small California offices. At $0.13 per kWh, this equates to electricity expenses for office plug loads of more than $140 million each year.

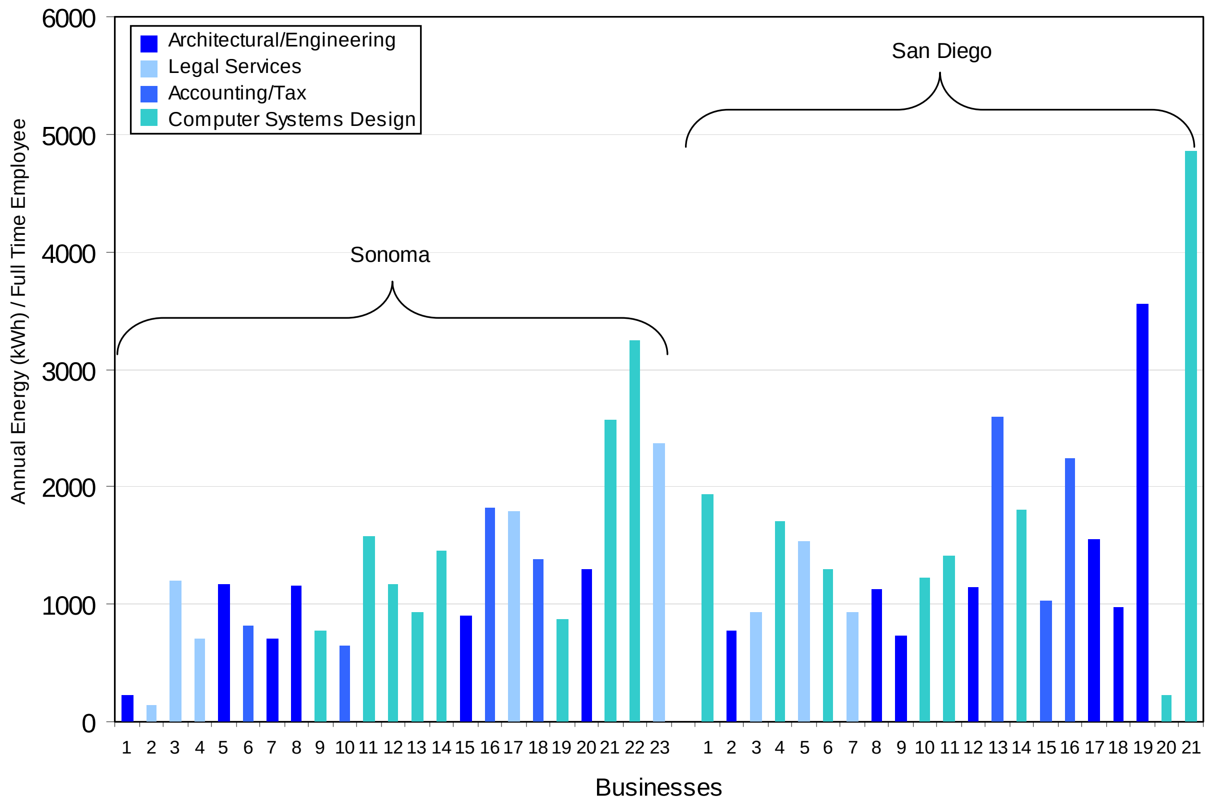

Figure 9. Annual Energy Use per Full-Time Employee

Source: Ecos

While researchers encountered a range of plug load energy use, no decisive patterns in office energy use emerged according to Ecos' business categories. For example, computer systems design businesses had by far the two highest energy densities; however, many computer systems design businesses fell right around the average.

The surveyed offices contained an average of seven devices per employee (full- and part-time). The survey also revealed that, on average, there are 30 plug load devices for each 1,000 square feet of office space.[4] These results indicate that approximately 30 million plug load devices may currently be in use in California's offices.

Energy Efficiency Measures

Researchers learned the following qualitative information about the energy saving and other "green" practices of the surveyed businesses:

- Four percent stated that their IT equipment is set to manage power use — that is, to automatically drop into a lower power state when a device is not in use.

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4. The 2006 CEUS study (Itron, page 8, Table E-1) reported that California's small and large offices total 1,022,013,000 square feet.

- Seven percent said that they discourage the use of screen savers; the same percentage allows employees to change computer power management settings themselves.
- Twelve of the businesses surveyed stated that they have sustainable energy procurement guidelines in place.
- Five of these businesses specified that their sustainable energy procurement practices include the purchase of ENERGY STAR® computers and monitors.
- Seventy-five percent of the businesses surveyed said that they participated in some environmental stewardship activities with 97 percent of these describing environmental stewardship as only recycling.
- One business mentioned using San Diego Gas & Electric's energy conservation program.
- Another business produced its own green power with photovoltaic panels.

While the majority of businesses in this study stated that they strive for environmental stewardship, to almost all of them, this consisted mainly of recycling. In addition, only five businesses mentioned procurement of ENERGY STAR computers and monitors. These findings indicate that there is still a need for consumer education on the energy impacts of office plug loads. In addition, because power management on IT equipment typically was not tightly regulated, another energy reduction approach in offices would simply be to activate automatic power management settings.

3.2. Analysis of Plug Load Product Categories

To assess the overall impacts of the varieties of plug loads found in offices, researchers multiplied the average annual energy consumption of each device type metered (e.g., inkjet printers, LCD monitors, etc.) with the total number of each device type inventoried in all offices in this study. This enabled researchers to expand upon the metered data findings to estimate the annual energy consumption of all plug loads encountered in the study. Researchers then categorized all of plug loads in this study into one of three groups: Computers and Monitors, Office Electronics, and Miscellaneous Plug Loads. Figure 10 illustrates the distribution of cumulative annual energy use per product category at the 47 sites visited.

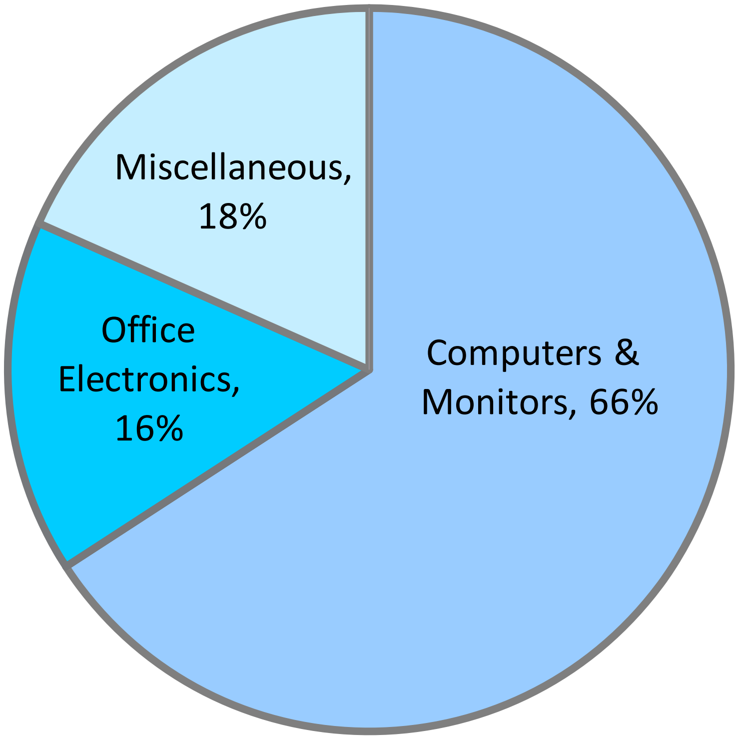

Figure 10. Office Plug Load Categories with Percentages of Total Energy Use

Source: Ecos

As expected, the Computers and Monitors category was by far the largest category, accounting for 66 percent of all plug load energy use at the offices in the study. This category includes desktop, laptop, and thin client computers as well as CRT and LCD monitors. This suggests that programs and policies targeting these two most basic of office electronics stand to have the greatest energy reduction.

The other two categories, Office Electronics and Miscellaneous, account for 16 and 18 percent of plug load energy use, respectively. Office Electronics includes imaging equipment (e.g., printers, copiers, and multifunction devices) as well as computer peripherals such as computer speakers, external drives, and hubs and switches. Devices such as paper shredders, adding machines, and portable desk lamps fall into the Miscellaneous category. Miscellaneous also includes telephony equipment and small kitchen appliances like coffee makers and toaster ovens. (White goods such as dishwashers and refrigerators are outside the scope of this study and therefore not included in the above categories.)

3.3. Product Level Results

This section discusses the study's findings in detail by presenting results on average power demand by mode, duty cycle, and estimated annual energy use on a product by product basis.

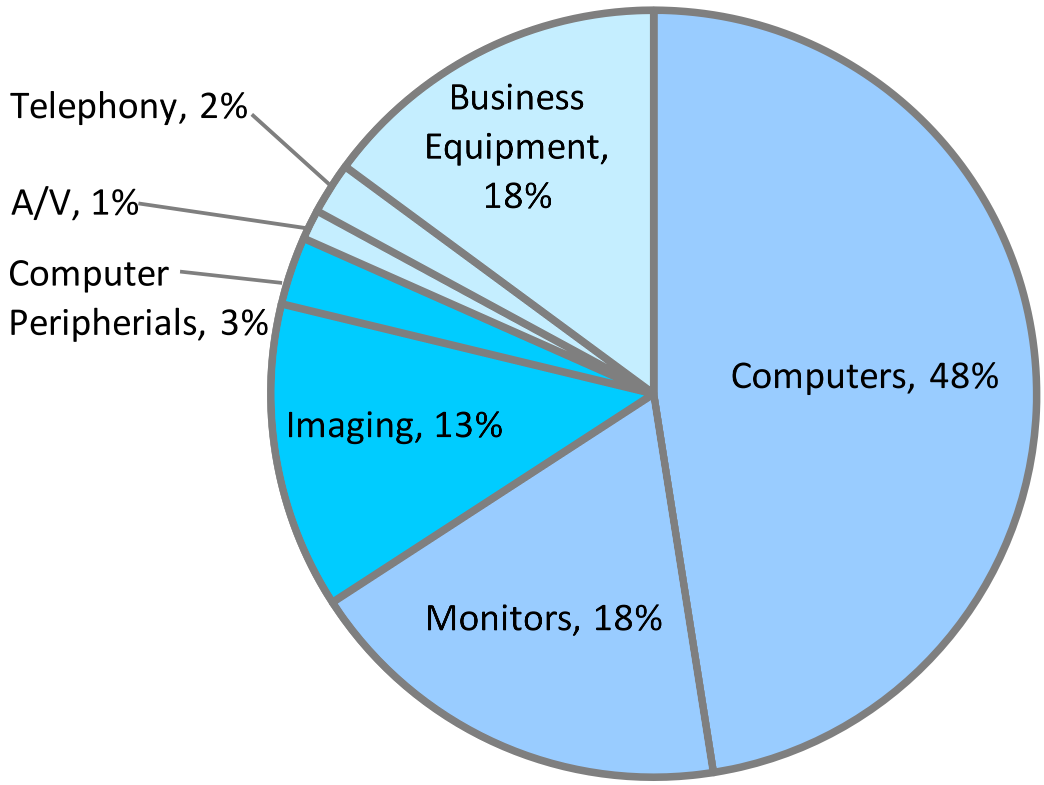

Figure 11. Percentage of Office Energy Consumed by Product Types

Source: Ecos

3.3.1. Computers and Monitors

Computers were the single largest office plug load end use. Their energy consumption alone accounted for 48 percent of total office plug load energy use in the study. Researchers collected meter data on 61 desktop computers, 20 notebooks, and six thin client computers.

Power Demand by Mode

The low power modes (sleep and standby) of desktop and notebook computers in the study were similar, typically less than 3 watts. All of the computers metered demonstrated low standby power values (0.9 to 2.6 watts), indicating that efficiency standards targeting standby mode have effectively lowered standby power in computers.

Active mode power was also similar for these two technologies. The gap between notebooks and desktops has significantly decreased from Ecos' previous residential plug load (Porter, et al. 2006) study to only a 4.2 watt difference. Desktop computers averaged 79 watts in active mode while notebooks averaged 75 watts in active mode. However, when comparing desktop and notebook computer power, it is important to keep in mind that desktop computer power demand does not include power attributed to its display while notebook power demand is likely to include power attributed to the display. Laptop power demand may also include power drawn to charge the battery.

Idle mode power in both desktop and notebook computers warrants some discussion. Average desktop idle power was 46 watts, while notebook idle power averaged 30 watts. Thin client idle power was 31 watts on average. ENERGY STAR Version 4.0 maximum idle power levels range from 50 watts to 95 watts for desktops and 14 watts to 22 watts for notebooks depending on the class of the computer.

Study findings for average idle power were somewhat lower than expected given that the Tier 1 ENERGY STAR program requirements for computers became effective July 20, 2007. In addition, while the 80 PLUS[5] program for computer internal power supplies has very likely contributed to industrywide improvements in computer power supply efficiency, the 80 PLUS program manager at Ecos Consulting estimates a 3 percent to 5 percent penetration rate for 80 PLUS power supplies in California (personal communication, Rasmussen, October 13, 2008). While this is a significant achievement, it cannot solely account for the study's low idle power findings. The most plausible explanation is that, as previously discussed, the research methodology used in this study to sort metered power data into power states used a somewhat different approach to identify idle mode than did previous research, including ENERGY STAR's. ENERGY STAR defines idle mode as a set of functions whereas in this study, researchers recorded only power values, not function. Therefore, what is categorized as idle mode here is likely to be the steady, lower end of the range of power values that would be considered an idle mode as defined by a set of functions. The discrepancy between computer idle power findings from this study and previous research is due to different approaches of categorizing data rather than from discrepancies in the data itself.

Nonetheless, previous PIER research indicates that idle power in computers can be reduced below the power levels researchers identified as well as the ENERGY STAR levels. In "How Low Can You Go: A White Paper on Cutting Edge Commercial Desktop Computer Efficiency" (Beck et al. 2008), researchers found that desktop computer idle power can be reduced to 30 watts with off-the-shelf components and to just 19 watts with best-in-class computer components. Given this, idle mode presents a ready opportunity for computer power reduction.

For thin client computers, note that idle power is higher than active power. The reason is that only three of the six metered thin client computers metered exhibited an idle mode. In addition, two of these three computers had much higher active power (44 watts each) than the other four models (15 watts, 15.7 watts, 16 watts, and 23 watts). While the high active power of the outlier models was averaged in with lower active power of all six thin client computers, the idle mode depicted in the graph is representative of only those three thin client computers that had an idle mode.

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5. See http://www.80plus.org/ for details on the 80 PLUS program.

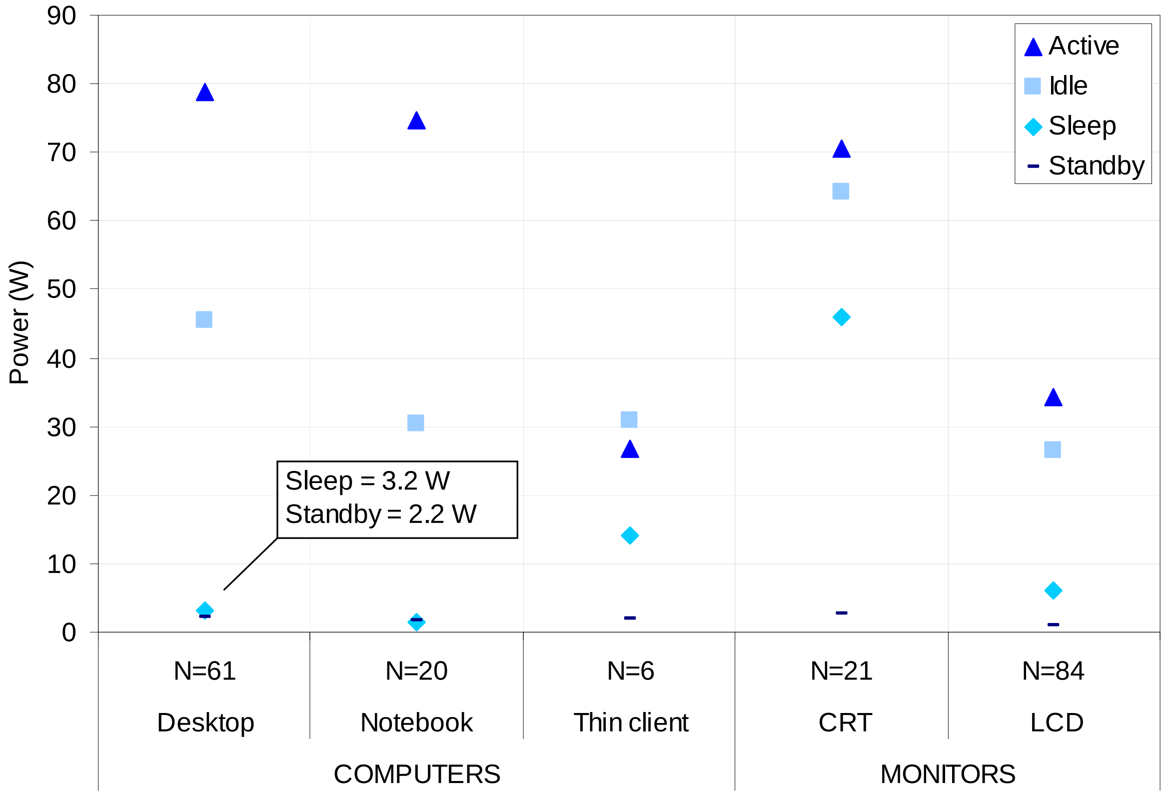

Figure 12. Computer and Monitor Power Demand by Mode

Source: Ecos

The power data for monitors was derived from meter files from 21 CRT monitors and 84 LCD monitors. This is representative of the distribution of all monitors inventoried. As expected, LCD monitors drew less power than CRT monitors in every mode, with significant differences in every mode except standby.

Within the monitor category, CRTs used 14 to 49 percent more power than LCDs in each mode. CRTs used an average of 71 watts in active, while LCDs used an average of only 34 watts in active. The average power for CRTs in sleep mode was 46 watts while the average power for LCDs in sleep mode was just over 6 watts. Of the 955 monitors inventoried in the 47 offices in this study, 79 percent were LCDs, indicating that consumers are already making the shift to the more-efficient technology.

Duty Cycles

Standby mode was the predominant mode for all computers occupying between 39 percent (for thin client computers) up to 56 percent (for notebook computers) of the two-week metering period. On average, desktop computers spent one-third of the two-week metering period in active mode. Thin client computers had a similar amount of time devoted to active mode. In contrast, notebook computers spent only 10 percent of time in active mode. Idle mode was utilized the most by thin client computers. Desktops and notebooks used idle mode less frequently at 13 percent and 6 percent of time, respectively. Sleep mode was not utilized often in any of the computers metered. Time spent in disconnect ranged widely—from 1 percent for thin clients to 26 percent for notebooks. Disconnect mode could indicate that the computer was unplugged. More likely is that the computer was powered down with a hard off switch or turned off via a plug strip. Because thin client computers are often used as small servers, their low percentage of time in disconnect makes sense.

Table 2. Computer and Monitor Duty Cycles

Product	Number Metered	Average Time in Active	Average Time in Idle	Average Time in Sleep	Average Time in Standby	Average Time in Disconnect
Desktop Computer	61	30%	13.4%	0.4%	50%	7.2%
Notebook Computer	20	10%	6%	2%	56%	26%
Thin client	6	29%	29%	2%	39%	1%
CRT Monitor	21	17%	2%	0.4%	48%	32.6%
LCD Monitor	84	18%	8%	2%	50%	22%

Source: Ecos

CRT and LCD monitors had very similar duty cycles. LCDs spent more time in idle mode than did CRT monitors, but researchers found that CRT monitors were in disconnect mode for 10 percent more time than LCD monitors. Disconnect mode for monitors is likely to indicate that the monitor is powered down with a hard off switch.

Energy Use by Mode

Results from this study indicate that the average desktop computer consumes 266 kWh per year compared to 58 kWh per year for the average notebook computer. These annual energy findings for desktop computers are lower than Energy Star Category B computers, but higher than high-efficiency computers investigated in a previous PIER research study (Beck et al. 2008). The average CRT monitor consumes approximately 128 kWh per year, and the average LCD monitor consumes 80 kWh per year. CRT and LCD monitors, and desktop and notebook computers consumed the majority of their energy in active mode. The energy use difference between LCD and CRT monitors in this study was not as large as the team expected. One explanation is that LCD monitors tend to be larger than CRT monitors. Also, they spent more time in idle and sleep modes than did CRTs and were turned off less often. LCD monitor energy use could be reduced by decreasing the time spent in idle mode on nights and weekends.

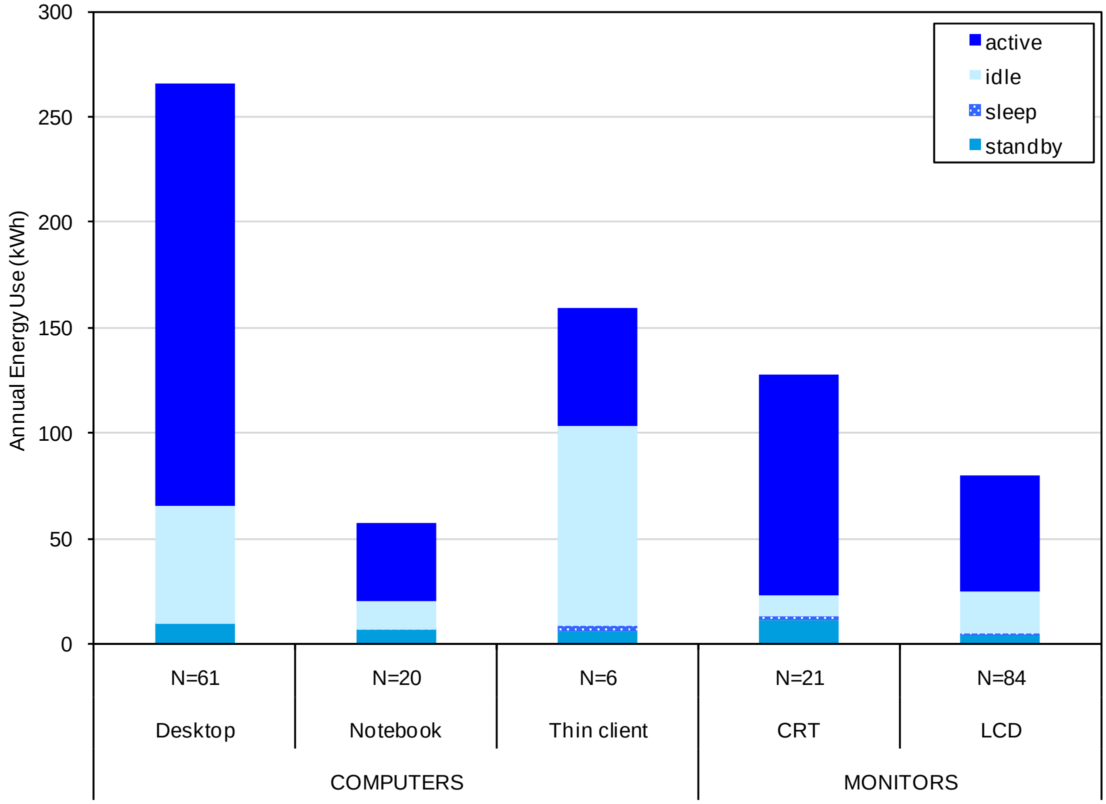

Figure 13. Computer and Monitor Energy Annual Energy Use per Device

Source: Ecos

Time of Use

Because computers made up such a significant share of office plug load energy use, researchers conducted an additional time-of-use analysis on desktop and notebook computers to better understand how and when computers operate. Figure 14 and Figure 15 illustrate the average hourly energy use per mode of notebook and desktop computers, respectively. The energy levels represented in these graphs is the weekday hourly average of the 20 notebook and 61 desktop computers metered. Note how active mode is concentrated during working hours for notebooks but continues throughout the evening for desktops. Active energy use by computers during nonworking hours is often indicative of screen savers. Sleep mode accounts for very little energy and is rarely used.

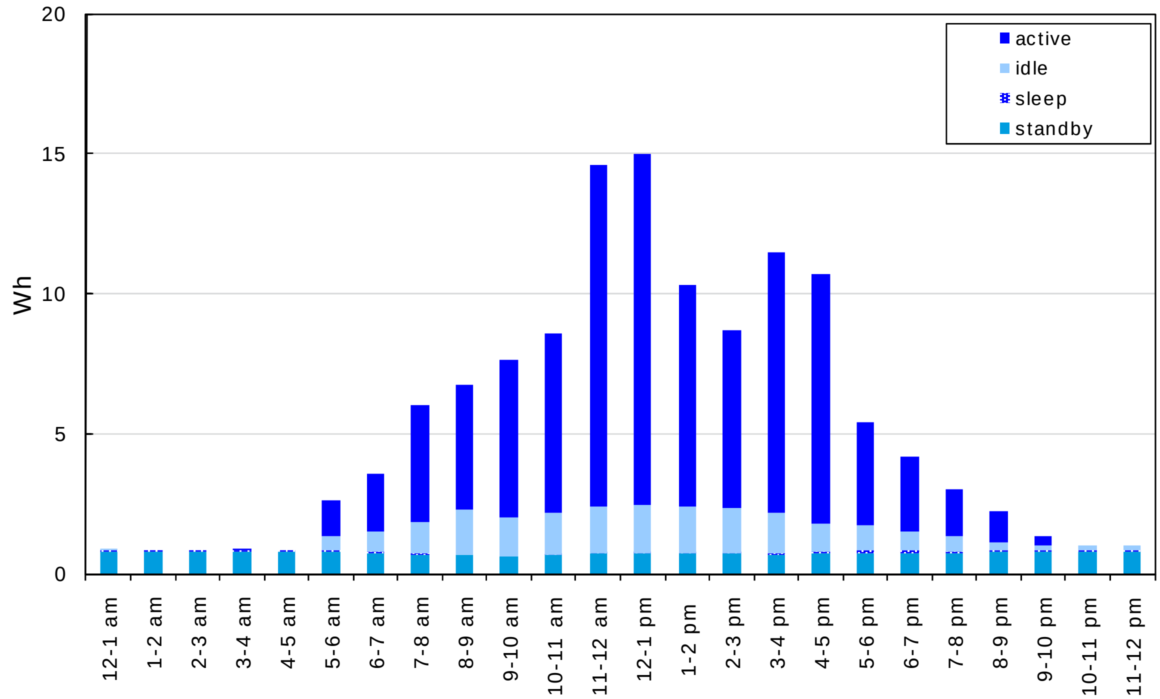

Figure 14. Average Hourly Notebook Computer Energy Use (Weekday)

Source: Ecos

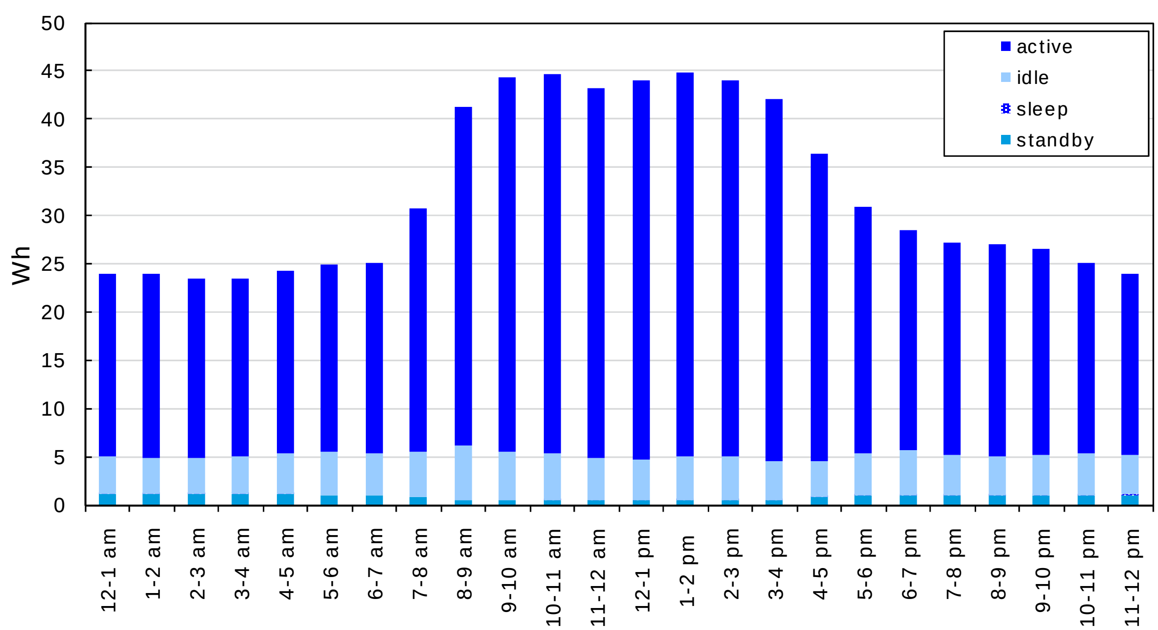

Figure 15. Average Hourly Desktop Computer Energy Use (Weekday)

Source: Ecos

3.3.2. Office Electronics

In this study, the office electronics category consisted of imaging equipment and computer peripherals. Printers, fax machines, scanners, and multifunction devices were all considered imaging equipment and made up 13 percent of plug load energy use in the offices that participated in the study. In total, researchers metered 77 imaging devices and inventoried 232. Laser printers accounted for more than half of all the imaging equipment in the study.

Computer peripherals metered in this study consisted mostly of computer speakers, but also included external drives and Ethernet and USB hubs and switches. These devices accounted for 3 percent of office plug load energy use.

Power Demand by Mode

Most of the imaging devices metered operated in standby, idle, and active modes throughout the two-week metering period; however, a sleep mode was also apparent in some samples (but not all) of two device types: inkjet printers and laser multifunction devices. As expected, active mode power was higher in laser devices than in inkjet devices. An exception was the wide format printers, which are typically inkjet. The laser printer had the highest active power demand at 130 watts, followed by the wide format printer active power of 87 watts and the laser multifunction devices' average active power of 76 watts. The process of fusing ink onto paper utilized in laser printers is energy-intensive because it requires a great deal of heat. Therefore, a laser printer has higher active power than a laser multifunction device because the fuser is needed for every print job but is not needed for faxing and scanning.

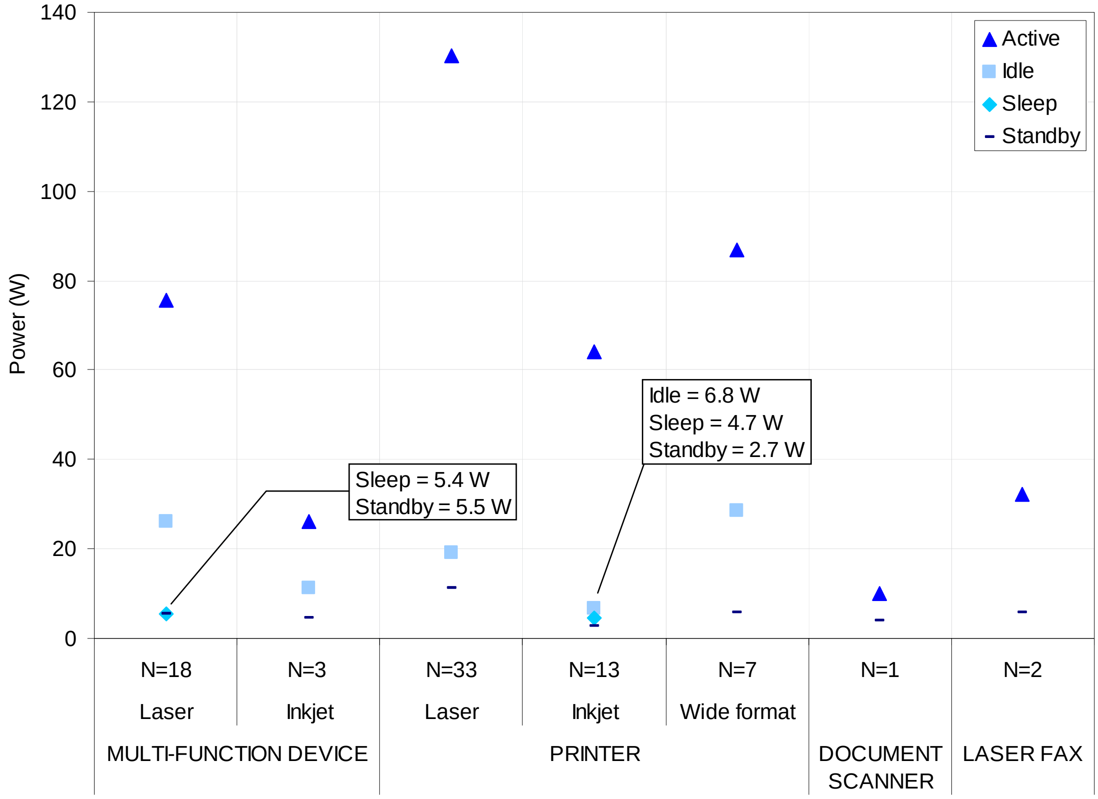

Figure 16. Imaging Equipment Power Demand by Mode

Source: Ecos

Across the range of imaging equipment, idle mode power was well below active, but on average more than three times higher than standby. This indicates potential for power reduction and ultimately energy savings by enabling device power management features to automatically move the device into a low power mode instead of remaining in idle mode indefinitely.

Note that only one scanner and two fax machines were metered. While these files reveal useful data about the metered devices, they can in no way be considered to be representative samples for these technologies.

All of the computer peripheral devices metered had active power demands of fewer than 30 watts with the exception of two samples of computer speakers. Eighteen of the 20 computer speakers metered had active power in the range of 7 to 8 watts. This finding was consistent with the computer speaker data recorded in the 2006 residential plug load field research (Porter et al. 2006). The two outlier computer speakers had active power values of 78 watts each. These high active measurements were surprising but probably recorded from computer speaker systems that often include multiple speakers and a subwoofer all linked together in one system. While such high-power computer speakers are not likely to be found in many office settings, they are evidently present in some. Researchers chose to separate out the higher power readings along with those of traditional computer speakers for clarity. Standby mode was 3 watts or fewer for every device in this category.

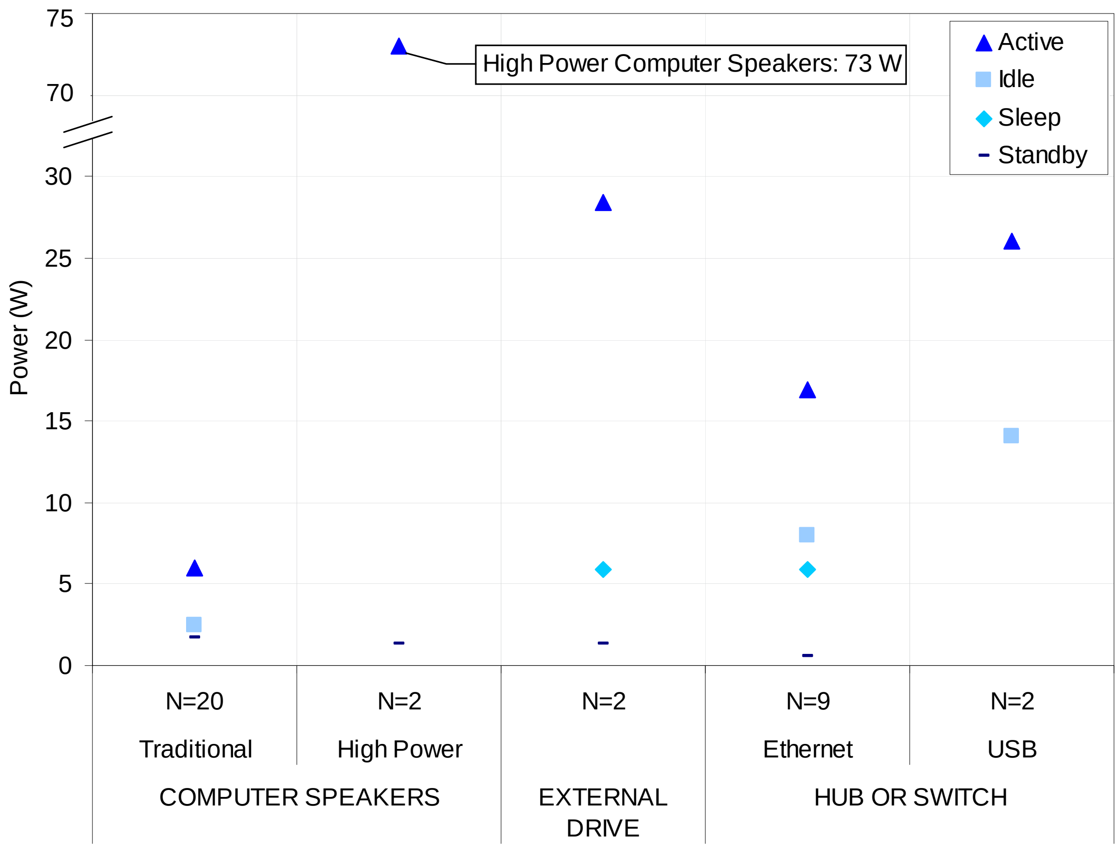

Figure 17. Computer Peripheral Power Demand by Mode

Source: Ecos

Duty Cycles

Standby mode dominated all of the imaging equipment devices metered. However, laser multifunction devices, laser printers, inkjet printers, and wide-format printers all showed time in disconnect mode. These devices can have hard off switches; it appears that in several instances, these devices were actually turned off. Laser multifunction devices and laser printers showed the highest percentage of the two-week metering period in active mode—14 percent each. These two products along with wide-format printers had the highest percentage of time in idle mode as well. Sleep mode was very rarely used— only the inkjet printers exhibited this mode.

Table 3. Imaging Equipment Duty Cycles

Product	Number Metered	Average Time in Active	Average Time in Idle	Average Time in Sleep	Average Time in Standby	Average Time in Disconnect
Laser MFD	18	14%	14%	0%	66%	6%
Inkjet MFD	3	1%	2%	0%	97%	0%
Laser Printer	33	14%	17%	0%	51%	18%
Inkjet Printer	13	2%	4%	5%	68%	21%
Wide-Format Printer	7	6%	34%	0%	33%	27%
Document Scanner	1	3%	0%	0%	97%	0%
Laser Fax	2	4%	0%	0%	96%	0%

Source: Ecos

In contrast, many computer peripherals spent the majority of the metering period in idle mode. Computer speakers operated in idle for 84 percent of the time, and hubs and switches, both Ethernet and USB, operated in idle for 55 percent of the time. Standby was the dominant mode for the two external drives metered.

Table 4. Computer Peripheral Duty Cycles

Product	Number Metered	Average Time in Active	Average Time in Idle	Average Time in Sleep	Average Time in Standby	Average Time in Disconnect
Traditional Computer Speakers	18	1.5%	89%	0%	4%	5.5%
High-End Computer Speakers	2	30%	0%	0%	7%	63%
External Drive	2	10%	0%	4%	86%	0%
Ethernet Hub or Switch	9	16%	53%	0%	20%	11%
USB Hub or Switch	2	2%	55%	4%	39%	0%

Source: Ecos

Energy Use

Wide-format printers, laser printers, and laser multifunction devices had the highest annual energy use per device. This makes sense because these are the same devices that had the highest active and idle power demands as well as the highest percentages of time in both of these modes. Laser printers in the study consumed 170 kWh per year on average. Laser multifunction devices followed suit, consuming 171 kWh per year. Wide-format printers consumed 212 kWh per year; however, because these printers are typically employed in only architectural and engineering offices, they do not represent a typical load for many offices.

Both inkjet printers and multifunction devices use less than a quarter of the overall energy use of their laser counterparts. However, in the study's product inventory, laser printers and multifunction devices outnumbered inkjet printers and multifunction devices by three to one. A simple energy savings strategy would be to utilize inkjet technology instead of laser technology whenever possible.

With the exception of the laser printer, standby energy use was below 40 kWh per year for products in this category. For the 33 laser printers that metered, the average annual standby energy was 50 kWh. This energy use in standby mode alone is more than what a normally operated[6] 40-watt light bulb would consume over the course of one year.

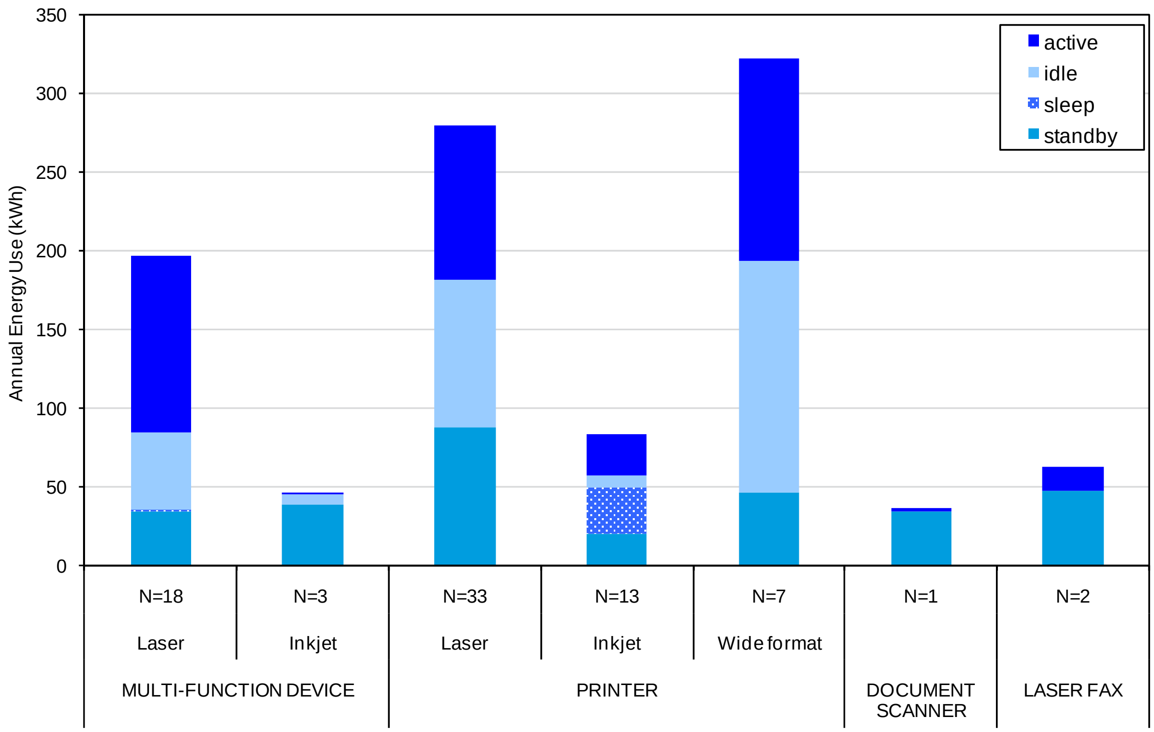

Figure 18. Imaging Equipment Annual Energy Use per Device

Source: Ecos

Low power modes account for a significant share of energy use in many computer peripherals. Much of this energy consumption could be eliminated through the use of "smart" plug strips. These devices use a timer, load sensor, occupancy sensor, or some combination thereof to shut off power to selected devices. In an office setting, a smart plug strip could be used to cut power to the monitor and computer peripherals when the computer enters a sleep, standby, or disconnected mode. Alternatively, a smart plug strip with an occupancy sensor could be programmed to power down selected devices when no occupant is present. A timer-controlled plug strip would be an effective energy reduction solution for devices that do not need to draw

6. Assumes 1,000 hours of operation per year

power at night and on weekends. Through any of these methods, significant energy savings could be realized in most computer peripherals through responsive "smart" controls.

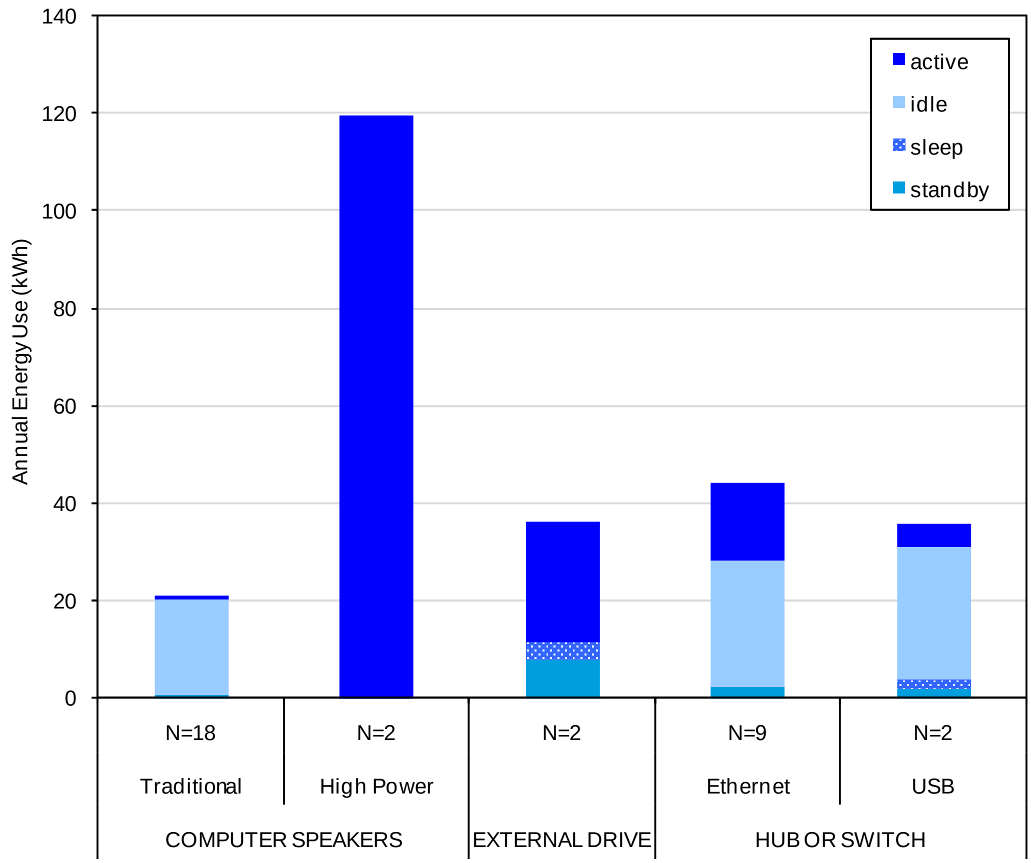

Figure 19. Computer Peripheral Annual Energy User per Device

Source: Ecos

Time of Use

Researchers conducted a time-of-use study for laser printers to better understand the time-of-day energy use by these devices. While the printer energy use peaks during the expected time frame, energy consumed in all modes remained relatively high overnight. Sleep mode was not utilized for these devices. Given this data, laser printers appear to be a ready target for after-hours energy reduction programs.

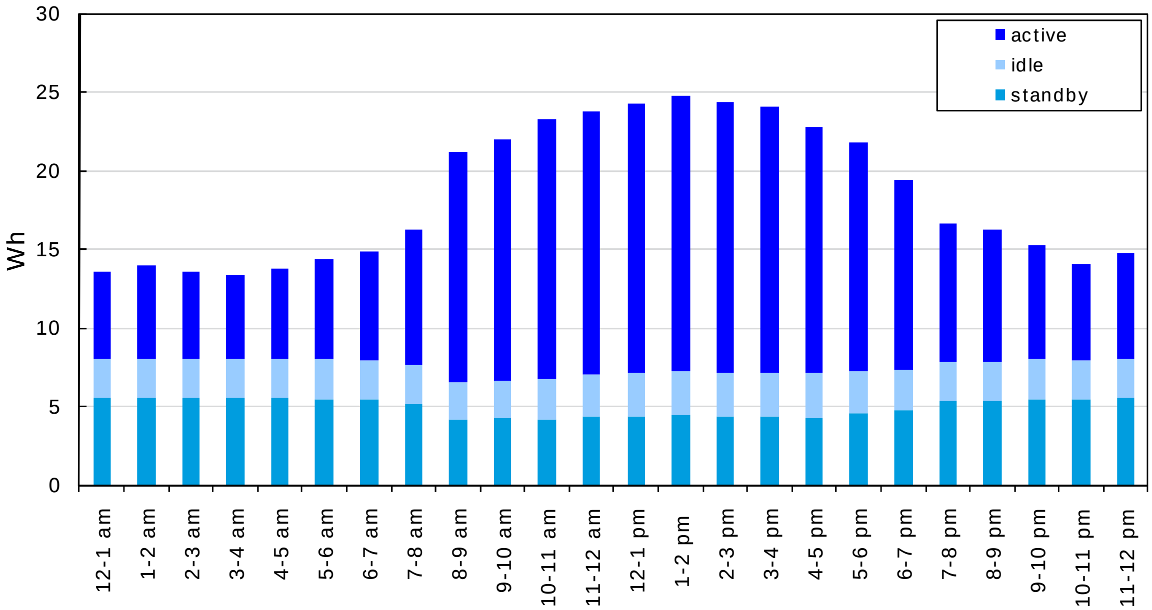

Figure 20. Average Hourly Laser Printer Energy Use (Weekday)

Source: Ecos

3.3.3. Miscellaneous

Energy use by all devices in the Miscellaneous category accounted for 18 percent of plug load energy use for the offices in the study. The Miscellaneous category includes audio/visual equipment, telephony, and general business equipment such as paper shredders, adding machines, portable lamps, and coffee makers. Energy use of audio/visual equipment accounted for only 1 percent of office plug load energy use while telephony accounted for 2 percent. General business equipment was the largest share of the Miscellaneous category and accounted for 15 percent of office plug load energy use.

Because the Miscellaneous category comprises many disparate devices, in this section the authors discuss only the devices with the highest cumulative energy consumption: coffee makers, portable lighting, and paper shredders. Detailed findings for all devices in this category are available in the Appendix, sections 5.5 through 5.7.

Surprisingly, coffee makers were the largest energy consumer (cumulatively) in this category. Based on two weeks of meter data, researchers estimated that these devices consume 400 kWh per year per device – equivalent to a standard refrigerator. Coffee makers in this study had an average active power demand of 464 watts. This is likely due to the fact that, while many offices have single-pot coffee makers typically found in homes, many models in offices are the larger, commercial variety. These coffee makers may brew two pots at one time, or brew coffee directly into stationary containers where coffee is then dispensed through spouts. In addition, researchers observed that while some coffee makers had an intermediate "keep warm" power level, other models simply cycled a high-power heating element on and off to keep the coffee at the appropriate temperature throughout the day. The study's inventory included a total of 50 coffee makers.

Portable lighting was the second-largest cumulative energy consumer in this category. Researchers recorded meter data from 156 table lamps and 236 desk attachment lamps. Desk attachment lamps include lamps clamped to desks or cubicle walls, or plug-in fixtures installed under office cabinets. While researchers did not record lamp technology in the field, their standby power and power factor findings indicate that a variety of technologies — incandescent, fluorescent tubes, compact fluorescent lights, line-voltage halogen, and low-voltage halogen — are all in use in portable office lighting. Annual energy for individual lamps, both table and desk attachments — approximately 80 kWh — was relatively low; however, the prevalence of portable lighting in offices accounts for the notable energy impact.

Electric paper shredders were the third-largest energy end use in this category. Individually, these devices consume 165 kWh per year, and researchers recorded 60 of them in the plug load inventory. As illustrated in Figure 22, active mode energy dominates the total energy use of these devices.

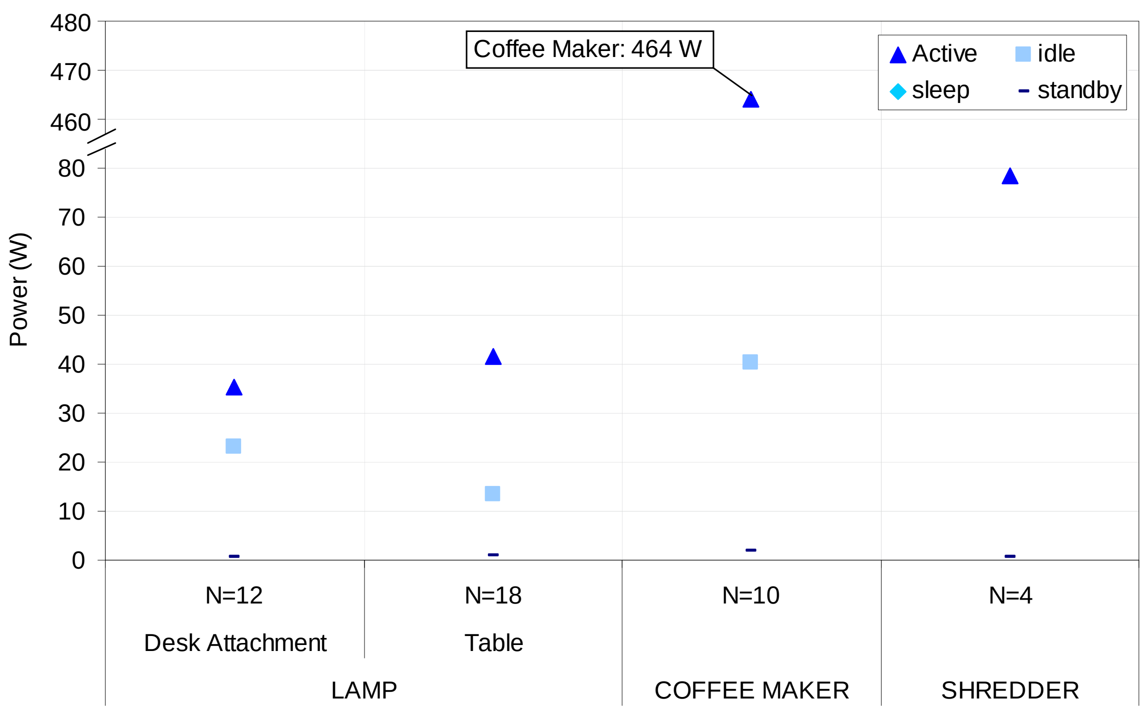

Figure 21. Miscellaneous Equipment Power Demand by Mode

Source: Ecos

Table 5. Miscellaneous Equipment Duty Cycles

Product	Number Metered	Average Time in Active	Average Time in Idle	Average Time in Sleep	Average Time in Standby	Average Time in Disconnect
Desk Attachment Lamp	9	20%	1%	0%	9%	70%
Table Lamp	16	14.5%	1.5%	0%	4%	80%
Coffee Maker	10	25.5%	16%	0%	46%	12.5%
Shredder	4	25%	0%	0%	43%	32%

Source: Ecos

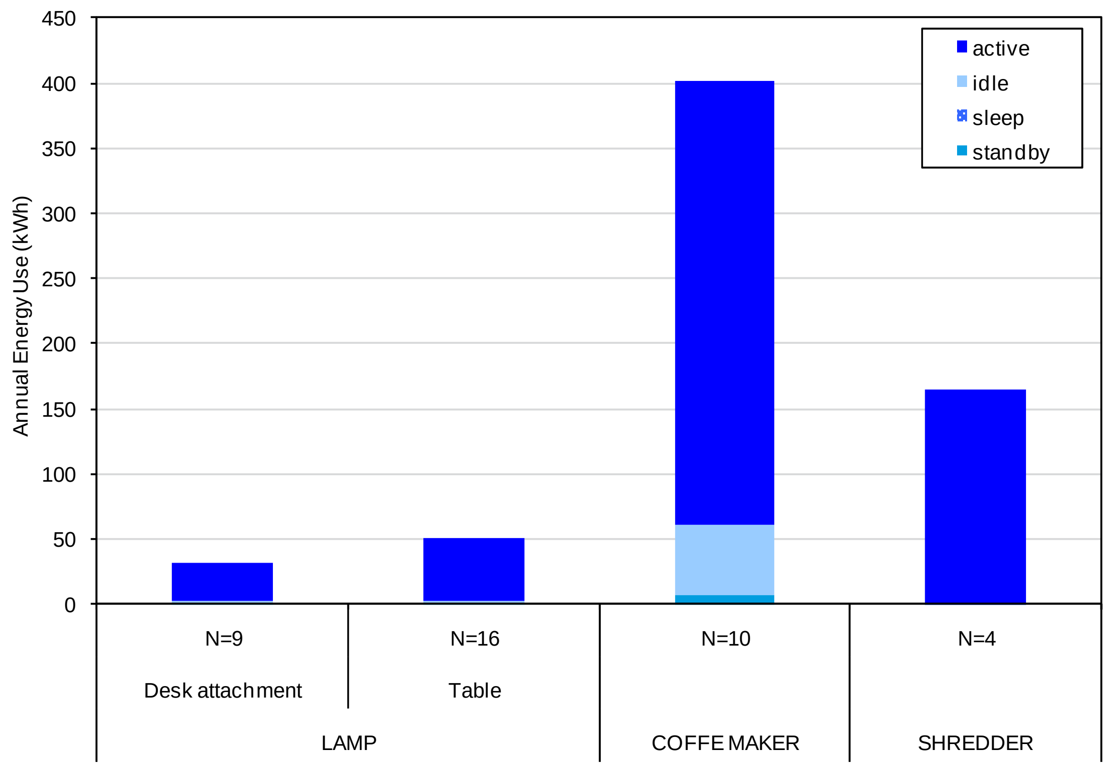

Figure 22. Miscellaneous Office Equipment Annual Energy Use by Mode

Source: Ecos

3.4. Comparing Results With Other Studies

As noted above, the study's high-level findings are slightly lower than the 2006 CEUS report (Itron 2006) for share of total small office energy consumed by plug loads, small office plug load energy density, and total California energy consumed by office plug loads in small offices. Because the study was not large enough to be statistically significant, some variances from previous research in this area were expected.

The 2007 LBNL study *Space Heaters, Computers, Cell Phone Chargers: How Plugged In Are Commercial Buildings?* (Sanchez et al. 2007) reported similar to or slightly lower results than the

Ecos study did. In this report, researchers found that the plug loads accounted for 11 percent to 19 percent of total electricity consumption in the buildings they audited. One explanation for this difference in findings is that the LBNL sites were in San Francisco, Atlanta, and Pittsburg, whereas all of the Ecos study sites were in California. Because California has a mild climate and many building efficiency standards, it is reasonable that the share of office plug load energy use is higher in this state than in states with fewer regulations and greater heating and cooling loads. In the *Annual Energy Outlook* (2006), the EIA found that 14 percent of commercial electricity was attributable to PC and non-PC office equipment. This lower percentage is expected because the Ecos study focused specifically on offices, not the entire commercial sector, where office electronics and other plug loads are likely to be more prevalent. Similarly, the 2006 PG&E report *Consumer Electronics: Market Trends, Energy Consumption, and Program Recommendation* (Chase et al 2006) reported that in 2005, electronics represented 18 percent of small business and residential electricity consumption in PG&E's territory. Regarding the number of devices per square foot, LBNL reported 23 plug load devices per 1,000 square feet for all the commercial buildings it surveyed, whereas Ecos recorded 30 devices per 1,000 square feet. However, the average number of devices for small, medium, and large offices in the LBNL study is 31.5 devices per 1,000 square feet (Sanchez et al. 2007).

Table 6. Comparison of Selected Findings with Previous Research

	Study Annual kWh/product	LBNL Annual kWh/product (Kawamoto et al 2001)	LBNL Annual kWh/product (McWhinney et al 2004)	LBNL Annual kWh/product (Sanchez et al 2007)	US DOE Annual kWh/product (Roth 2002)
Desktop Computer	266	213	n/a	n/a	297
Laptop/Notebook Computer	58	24.6	n/a	n/a	32
Inkjet Printer	36	74	52	n/a	92
Laser Printer	170	283	620[7]	n/a	735
LCD Monitor	80	n/a	n/a	n/a	23
CRT Monitor	128	205	n/a	n/a	306
Inkjet MFD	43	n/a	73	n/a	n/a
Laser MFD	171	n/a	n/a	n/a	n/a
Computer speakers	21	n/a	n/a	74	n/a

Source: Eccos

7. Includes data from black-and-white and color laser printers

4.0 Conclusions and Next Steps

The purpose of this study was to gain detailed insights into the plug loads currently in use in California's offices and to inform future energy efficiency policies, programs, and research. Researchers inventoried how many and what kinds of plug loads are in use in 47 California offices and recorded detailed meter files to determine which modes products operate in, what the average power demand is for each identified mode, and how products operate and are operated by consumers in their everyday office settings.

Furthermore, using simple, scenario-based calculations from study findings, researchers believe that, in some circumstances, energy use by office plug loads could consume more than four times the energy of the hard-wired office lighting. Consider a hypothetical 10-foot-by-12-foot private office. Depending on the efficiency of the devices in use and the efficiency of the hard-wired lighting, traditional office plug loads could consume up to three times more energy than high efficiency hard-wired office lighting. However, if high efficiency plug load devices were used, they could consume less energy than high efficiency hard-wired lighting.

Table 7. Comparison of Plug Load and Hard-Wired Lighting Energy Use[8]

Office Equipment			
	Active Power (W)	**Energy (kWh)/year**	**Energy (kWh) per year per ft^2**
Traditional			
Desktop Computer	79.0	266	2.2
CRT Monitor	71.0	128	1.1
Computer Speakers	7.0	21	0.2
Telephone	4.8	20	0.2
Desk lamp: 60 W incandescent	60.0	75.0	0.6
Total	**161.8**	**510**	**4.3**
High Efficiency			
Laptop	75.0	58	0.5
Computer Speakers	7.0	21	0.2
Telephone	4.8	20.0	0.2
Desk lamp: 15 W LED	15.0	19	0.2
Total	**101.8**	**118**	**1.1**
Hard-Wired Lighting			
	Active Power (W)	**Energy (kWh)/year**	**Energy (kWh) per year per ft^2**
Traditional			
Two 4x2 Troffers, 3 standard T-12 lamps each	**178.0**	**445**	**3.7**
High Efficiency			
Two 4x2 Troffers, 1 efficient T-5 lamp each	**70.0**	**175**	**1.5**

Source: Eccos

4.1. Consumer Implications

Office occupants can begin saving energy immediately by simply turning devices off that are not in use. This is a no-cost energy savings strategy. Another would be to prohibit the use of screen savers that can cause computers and monitors to operate in active mode. Researchers found that many devices were often left to operate in active or idle mode overnight and on

8. These are hypothetical scenarios. Notes and assumptions:

- Plug load power and energy data are findings from commercial plug load field research.
- Desk lamps assumed to operate for five hours per day, five days per week, 50 weeks per year.
- Hard-wired lighting assumed to operate for 10 hours per day, five days per week, 50 weeks per year.
- Hard-wired lighting equipment estimates provided by Stan Walerczyk, LC, Lighting Wizards

weekends. Offices could implement their own awareness campaigns to educate occupants of the importance of powering down their office equipment — just as they switch off the lights — before heading home for the evening. Alternatively, offices could implement networked power management systems that allow IT managers to power networked devices on and off as required for updates. Offices should also consider replacing worn-out or inefficient devices with high-efficiency models. Notebook computers use less than one-fourth of the energy consumed by desktops. LCD monitors use far less power in active than do CRT models, but at sites surveyed, they were often left on during nonworking hours. No matter how efficient any technology is, few devices need to be in an active mode when no one is there to use them. Finally, while it is neither practical nor feasible for most businesses to upgrade all equipment, offices could establish new procurement procedures with a focus on plug load energy reduction.

4.2. Utility and Policy Implications

Utilities can look to these findings to inform new programs and policies in their territories. Rebates could be designed for office electronics that ship with automatic controls enabled to power the device down to a low power mode when not in use. Another program opportunity for utilities is promotion of and rebates for "smart" plug strips. "Smart" plug strips vary in design but typically employ some combination of load sensors, remote controls, occupancy sensors, and timers. These inexpensive devices power down designated plug loads when the control load is turned off by the user. The burden of responsibility to power down electronic devices is thereby taken away from the consumer. Additional research is underway to quantify the energy reduction potential from these devices.

Results of this study can also inform policy makers about priority products ready for new mandatory standards or voluntary specifications. California has led the nation in mandating power supply efficiency, but for certain products, the bar could be raised even higher through widespread implementation of power supply efficiency programs such as ENERGY STAR, 80 PLUS, and Climate Savers. Title 20 could address some commercial plug loads that are increasingly ready for standards consideration. Title 24 could consider a requirement for switched outlets. For example, private offices and conference rooms could be required to have a certain percentage of their wall outlets controlled by a single switch located near the room entrance. Automatic controls, already effectively used with hard-wired lighting, could be required to operate some wall outlets as well.

While voluntary programs and mandatory regulations have had a vital role in improving the energy efficiency of office plug loads, the increased reliance on office electronics coupled with a growing need for faster, higher-power, higher quality equipment has resulted in an overall increase in plug load energy consumption. Significant opportunities for energy savings remain untapped.

4.3. Future Research

Further research needs to be conducted to estimate the energy savings potential of all of the measures noted above including automatic controls such as "smart" plug strips, other timer or occupancy sensing outlet controls, and widespread use of devices' own power management settings. In addition, while harder to quantify, future research should also explore the potential for plug load energy reduction through consumer education campaigns.

One important and growing end use that warrants further investigation is servers and data centers. Ecos included these devices in the product inventory but did not meter them due to concerns about disruption of service. For this reason, the study's cumulative office plug load energy use may be too low.

Finally, future research should leverage the methodologies developed during this study. A study of this nature requires significant efforts to design the research plan, recruit participants, visit sites, install and remove meters, transfer and review the meter files, and analyze the data. A subsequent study scaled up to a sample size that is statistically valid for all of California's offices could build upon our many successes and lessons learned.

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5.0 Appendices

5.1. Methodology Design Matrix

Table 8. Study Design Prioritization

Considerations	Priority Level low ⟶ high	Rationale
Number of Participants		Sample size needed for statistical significance too large for project budget. Sample size designed to include variety of offices.
Climate Zone Distribution		Representation from both Northern and Southern CA desired. Significant variations in plug load energy use due to climate not expected.
Building Type Distribution		Plug load energy use not expected to be heavily dependent on building type.
Demographics of Employees		Plug load energy use not expected to be heavily dependent on employee demographics.
Business Types		Targeted three business types in to investigate plug load energy use variances among businesses with different functions.
Number of Devices Metered		Goal was to create as large a data set of office plug loads as possible within the parameters of the study.
Number of Days Metered		Intent was to gather weekday and weekend data; two weeks and two weekends would smooth out any daily irregularities.
Interval of Meter Files		Since a main goal of the study was to understand how office plug loads are operated in the field, 1-minute metering intervals would provide detailed resolution on product operation.

Source: Ecos

5.2. Study Participant Data

Table 9. Study Participant Data

Business Type	NAICS	Square Footage	Full-Time Employees	Surveyed	Metered	Sonoma	San Diego
Legal Services	5411	5000	20	X	X		X
Legal Services	5411	38000	275	X	X	X	
Legal Services	5411			X			X
Legal Services	5411	3000	10	X	X		X
Legal Services	5411	800	3	X		X	
Legal Services	5411	6967	20	X	X	X	
Legal Services	5411	3000	7	X	X		X
Legal Services	5411	13000	32	X		X	
Legal Services	5411	1500		X		X	
Legal Services	5411	3000	4	X	X	X	
Accounting/Tax preparation/etc.	5412	1300	7	X		X	
Accounting/Tax preparation/etc.	5412	1100	3	X		X	
Accounting/Tax preparation/etc.	5412	4389	24	X			X
Accounting/Tax preparation/etc.	5412	8000	26	X	X	X	
Accounting/Tax preparation/etc.	5412	1700	3	X			X
Accounting/Tax preparation/etc.	5412	750	2	X	X		X
Accounting/Tax preparation/etc.	5412	1574	6	X	X	X	
Architectural/Engineering	5413	1780	7	X			X
Architectural/Engineering	5413	4200	16	X		X	
Architectural/Engineering	5413	6000	20	X	X		X
Architectural/Engineering	5413	800	2	X	X		X
Architectural/Engineering	5413	1000	4	X	X		X
Architectural/Engineering	5413	6500	16	X	X	X	
Architectural/Engineering	5413	4200	14	X	X		X
Architectural/Engineering	5413	2000	16	X			X
Architectural/Engineering	5413	4700	25	X			X
Architectural/Engineering	5413	10000	45	X		X	
Architectural/Engineering	5413	4850	11	X	X	X	
Architectural/Engineering	5413	1200	6	X		X	
Architectural/Engineering	5413	25000	100	X	X	X	
Architectural/Engineering	5413	5500	16	X		X	
Computer Systems Design	5415	5000	12	X	X	X	

Business Type	NAICS	Square Footage	Full-Time Employees	Surveyed	Metered	Sonoma	San Diego
Computer Systems Design	5415	3700	12	X		X	
Computer Systems Design	5415	1100	3	X		X	
Computer Systems Design	5415	7500	20	X			X
Computer Systems Design	5415	1100	7	X	X	X	
Computer Systems Design	5415	5000	16	X	X		X
Computer Systems Design	5415	3000	13	X	X	X	
Computer Systems Design	5415	17000	48	X			X
Computer Systems Design	5415	350	22	X	X		X
Computer Systems Design	5415	400	2	X			X
Computer Systems Design	5415	6000	25	X		X	
Computer Systems Design	5415	1000	3	X	X		X
Computer Systems Design	5415	4983	6	X	X		X
Computer Systems Design	5415	1000	2	X	X		X
Computer Systems Design	5415	4650	13	X		X	
Computer Systems Design	5415	3324	9	X	X	X	

Source: Ecos

5.3. Device List With Metering Prioritization

Table 10. Device Prioritization with Number of Devices Counted and Metered

Product Name	Number of Surveyed Items	Number of Metered Items	Prioritization Level
Computer, desktop	780	61	1
Computer, integrated-LCD	6	0	1
Computer, notebook	120	20	1
Computer display, CRT	203	21	1
Computer display, LCD	752	84	1
Projector, video	18	4	1
Copier	27	0	1
Multifunction device, inkjet	19	3	1
Multifunction device, laser	64	18	1
Printer, inkjet	71	13	1
Printer, laser	232	33	1
Printer, thermal	1	0	1
Printer, solid ink	0	0	1
Printer, wide format	21	7	1
Minicomputer/Thin client	44	6	1
External drive (CD, DVD)	58	2	1
Whiteboard, digital	2	0	1
Phone, switchboard	24	0	1
Audio minisystem	0	0	2
Charger, digital music player	18	0	2
Speakers, powered	73	6	2
Stereo, portable	46	1	2
Subwoofer	15	1	2
Charger, bar code scanner	0	0	2
Bar Code Scanner (no battery charger)	0	0	2
Television, LCD	7	2	2
Television, plasma	6	0	2
Television, rear projection	0	0	2
Television, CRT	21	0	2
Television/VCR Combination	2	0	2
Scale, digital	16	0	2
Fax, inkjet	8	0	2
Fax, laser	16	2	2
Fax, thermal	0	0	2
Mailing machine	28	0	2
Scanner, document	34	1	2
Scanner, flatbed	19	0	2
Scanner, slide	0	0	2

Product Name	Number of Surveyed Items	Number of Metered Items	Prioritization Level
Scanner, wide format	1	0	2
Amplifier, ethernet broadband distribution	0	0	2
Hub or Switch, ethernet	134	9	2
Hub or Switch, USB	40	2	2
Firewall device	15	0	2
Modem, cable	3	0	2
Modem, DSL	8	0	2
Wireless access point	38	0	2
Charger, PDA	30	2	2
Speakers, computer	188	18	2
Tablet, pen (powered)	2	0	2
Charger, mobile phone	71	3	2
Dictation machine	0	0	2
Intercom	4	0	2
Phone, conference	21	0	2
Phone, corded (powered)	363	12	2
Phone, cordless	10	0	2
Phone, cordless with answering machine	0	0	2
DVD player	3	1	2
DVD recorder	0	0	2
VCR	6	0	2
VCR/DVD	4	0	2
Adding, machine	143	12	2
Shredder	60	4	2
Time stamper	0	0	2
Mug warmer (powered)	9	0	2
Oven, microwave	45	2	2
Air cleaner, portable	0	0	2
Air conditioning, window mounted	0	0	2
Evaporative cooler, window mount	0	0	2
Fan, portable	152	6	2
Fan, window	0	0	2
Humidifier	0	0	2
Space heater, portable	44	4	2
Lights, holiday	0	0	2
Lamp, table	156	16	2
Lamp, floor	0	0	2
Lamp, desk attachment	236	9	2
Water dispenser, bottled	28	0	2
Charger, battery	67	2	2
Charger, cordless power tool	0	0	2

Product Name	Number of Surveyed Items	Number of Metered Items	Prioritization Level
Refrigerator, mini	39	3	2
Charger, smart phone	0	0	2
Amplifier	0	0	3
Cassette deck	0	0	3
CD player	13	3	3
CD player, portable	27	7	3
Equalizer (audio)	0	0	3
Radio, table	24	2	3
Receiver (audio)	6	0	3
Speakers, wireless (base station)	0	0	3
Speakers, wireless (speakers)	0	0	3
Computer, integrated-CRT	4	0	3
Game console, portable	0	0	3
Printer, impact (dot matrix and other)	0	0	3
Scanner, business card	1	0	3
Scanner, receipt (with external power supply)	0	0	3
Modem, POTS	0	0	3
Modulator, audio/visual (powered)	0	0	3
Tape drive	4	0	3
Set-top box, digital cable	1	0	3
Set-top box, digital cable with PVR	0	0	3
Set-top box, game console	0	0	3
Set-top box, game console with internet	0	0	3
Set-top box, internet	0	0	3
Set-top box, PVR	0	0	3
Set-top box, satellite	0	0	3
Set-top box, satellite with PVR	0	0	3
Answering machine	1	1	3
Caller ID unit	0	0	3
Charger, still camera	2	0	3
Charger, video camera	0	0	3
Videocassette rewinder	0	0	3
Game console, commercial	0	0	3
Typewriter, Electric	24	1	3
Clock	4	1	3
Clock, radio	21	4	3
Coffee maker	50	10	3
Espresso maker, residential	4	1	3
Vacuum, rechargeable	9	0	3
Light box	3	0	3
Light, illuminated table	2	0	3
Charger, hedge trimmer	0	0	3

Product Name	Number of Surveyed Items	Number of Metered Items	Prioritization Level
Charger, weed trimmer	0	0	3
External power supply	4	0	3
Charger, wheelchair or golf cart	0	0	3
Charger, bicycle light	0	0	3
Tuner	0	0	3
Dock, notebook	77	4	
Projector, slide	0	0	
Printer, photo	0	0	
Printer, receipt size (mini)	0	0	
Router, Ethernet	11	0	
Server, desktop-derived	79	0	
Server, rack	54	0	
Mainframe	0	0	
Network equipment, IP telephone adaptor	0	0	
CD recorder	0	0	
Security system	9	0	
Set-top box, analog cable	0	0	
Binding machine (electronic)	1	0	
Hole punch (powered)	3	0	
Laminator	1	0	
Pencil sharpener	130	3	
Stapler	52	2	
Automatic griddles	2	0	
Blender	6	0	
Coffee grinder	5	2	
Corn popper, air	0	0	
Corn popper, hot oil	0	0	
Hot plate (kitchen)	1	0	
Kettle, electric	6	0	
Toaster	16	0	
Toaster oven	18	1	
Vacuum, standard	19	0	
Aquarium	4	0	
Dehumidifier	0	0	
Fan, range hood	0	0	
Night light, interior	3	0	
Timer, exterior (plug powered)	0	0	
Timer, interior (plug powered)	1	0	
Garbage disposal	2	0	
Refrigerator, wine cooler	0	0	
Trash compactor	0	0	
Vending machine, cold	3	0	

Product Name	Number of Surveyed Items	Number of Metered Items	Prioritization Level
Vending machine, hot	1	0	
Vending machine, room temperature	1	0	
Fountain, indoor	8	0	
Air freshener (plug in)	4	0	
Curling iron	0	0	
Hair dryer	0	0	
Home medical equipment	0	0	
Water softener	0	0	
Power strip	1027	0	
Surge protector	0	0	
Uninterruptible power supply, desktop	46	0	
Uninterruptible power supply, server	70	0	
Floor polisher	0	0	
Power tool, corded	6	0	
Clothes dryer, electric	0	0	
Clothes dryer, gas	0	0	
Clothes washer, horizontal axis	0	0	
Clothes washer, standard	0	0	
Cooktop, electric	0	0	
Cooktop, gas	0	0	
Dishwasher	4	0	
Freezer	1	0	
Oven, electric	0	0	
Oven, gas	0	0	
Refrigerator/Freezer	26	0	
Other	149	0	
Charger, miscellaneous	52	1	

Source: Ecos

5.4. Determination of Power States

The power states for a product were determined using the following process. First, the data was put through a 15-minute sliding average low pass filter. This has two effects: It averages out much of the noise (which is usually about 0.2 W but can be 0.6 W or more for switch-mode power supplies at low power levels). The sliding window also has the property that it remains constant only if the power level stays constant for mode than 15 minutes. This was used to impose the requirement of a continuous period. The second step was to identify those samples for which the sample value was the same as the 15-minute average (within 0.15 W). If the power level fluctuated, there would be occasional chance hits, but steady power consumption would generate a large number of hits. The next step was to form a histogram of the hits, using the data resolution of 0.1 W, and then scan the histogram for peaks. The requirement is that it must have at least 40 hits, have more hits than the surrounding eight points, and have more hits than the sum of the second, third, and fourth points on either side. This last requirement means the peak must be narrower than about 0.2 W (half width at half maximum). These conditions combined effectively impose the requirement of a narrow power range. The 40 hit minimum imposes the requirement that the product spends a significant amount of time (at least 40 minutes) in each power state.

This process was quite reliable for picking out power states. Power states that were used for only one hour in the two week metering period were identified, yet the process was quite immune to both noise and all the erratic behavior of products in active mode. If the active mode included stable power states, this process did pick them out. Common examples were a battery charger whose power decreased as the battery charged and eventually settled into a steady maintenance mode. This process identified the maintenance mode separate from the charging mode. Another example was a computer that spent much of its active time in the idle loop. When the computer was actually processing, the power consumption rose briefly to a higher (and variable) level, and then dropped back to idle. This procedure picked out the idle loop power state as distinct from the higher power level of computations.

Next, each sample was assigned to a power state according to the following criteria. A sample was assigned to the “disconnected” mode if it was one of at least 10 contiguous samples with zero power. A reading (minute) was assigned to a power state if it was within 0.2 W of that power state. Power readings were assigned to “active” mode if they were above the highest stable power state. This left gaps of data samples that were not yet assigned. Next, a data point which was immediately before or after a power state and is within 0.4 W of that state is assigned to it. Finally, a gap that has the same state at both ends and every point between is within 0.6 W of that state is assigned to the state. This left the very occasional data point with substantial noise (which are too few to matter in the energy analysis) and those data that are clearly between power states. These points were generally samples that were between two power states in active mode. They were assigned to the next-higher state to ensure that they did not confuse a standby or low-power mode.

5.5. Average Power by Mode

Table 11. Average Power Use by Mode

		Product Name	Number	Active (W)	Idle (W)	Sleep (W)	Standby (W)
Computers & Monitors	Computers	Desktop Computer	N=61	78.92	45.58	3.22	2.21
		Notebook Computer	N=20	74.72	30.33	1.56	1.59
		Minicomputer/Thin client	N=6	26.67	31.01	14.04	1.83
		Notebook Dock	N=4	26.29			1.11
	Monitors	CRT Display	N=21	70.56	64.18	45.86	2.60
		LCD Display	N=84	34.24	26.43	6.19	0.88
Office Electronics	Imaging	Laser MFD	N=18	75.73	26.13	5.44	5.45
		Inkjet MFD	N=3	26.04	11.14		4.66
		Laser Printer	N=33	130.14	18.99		11.37
		Inkjet Printer	N=13	64.00	6.75	4.68	2.69
		Wide Format Printer	N=7	86.80	28.58		5.62
		Document Scanner	N=1	10.13			4.03
		Laser Fax	N=2	32.28			5.71
	Computer Peripherals	Computer Speakers	N=18	5.95	2.43		1.66
		High Power Computer Speakers	N=2	73.05			1.35
		External Drive	N=2	28.43		10.73	.95
		Ethernet Hub or Switch	N=9	16.96	7.97	5.87	1.29
		USB Hub or Switch	N=2	26.03	14.05	5.92	0.56

		Product Name	Number	Active (W)	Idle (W)	Sleep (W)	Standby (W)
Miscellaneous	Audio / Visual	Television, LCD	N=2	58.17			3.14
		DVD player	N=1				1.28
		Video Projector	N=4	181.9		9.76	4.56
		CD player	N=3	8.26			2.06
		Portable CD player	N=7	17.95	2.95		1.27
		Speakers	N=6	32	10	3	1
		Portable Stereo	N=1	7.5	3.31		0.88
		Subwoofer	N=1	0	6.96		
		Table Radio	N=2	2.78			1.4
	Telephony	Charger, mobile phone	N=3	2.12	0.65		0.15
		Phone, corded (powered)	N=12	4.85	2.43		
	Business Equipment	Adding, machine	N=12	3.58	3.57		1.58
		Battery charger	N=2	3.37	0		1.26
		Clock	N=1		1.4		
		Clock, radio	N=4	5.37	2.99		4.04
		Coffee grinder	N=2		1.25		0.21
		Coffee Maker	N=10	464.01	40.25		1.77
		Espresso maker, residential	N=1	369.38			2.24
		Fan, portable	N=2				0.63
		Lamp, desk attachment	N=9	35.35	23.21		0.57
		Lamp, table	N=16	41.7	13.38		0.91
		Shredder	N=4	78.36			0.77
		Space heater, portable	N=4	937.65			1.03
		Stapler	N=2	1.73	0.81		1.22
		Toaster oven	N=1	1057.9			0.03
		Typewriter, Electric	N=1	7.13			3.38

5.6. Average Annual Energy Year per Mode per Device

Table 12. Average Annual Energy Used per Mode per Device

		Product Name	Devices metered (#)	Active (kWh)	Idle (kWh)	Sleep (kWh)	Standby (kWh)	Total (kWh)
Computers & Monitors	Computers	Desktop Computer	61	201	55.8	0.112	9.2	266
		Notebook Computer	20	37.3	13.4	0.271	6.61	57.6
		Minicomputer/Thin client	6	55.5	94.8	3	5.9	159
		Notebook Dock	4	8.91			2.1	11.0
	Monitors	CRT Display	21	105	10	1.54	11.1	128
		LCD Display	84	55.1	19.6	0.623	4.17	79.5
Office Electronics	Imaging	Laser MFD	18	111	29.8	0.0381	31	172
		Inkjet MFD	3	1.58	2.23		38.7	42.5
		Laser Printer	33	91.2	28.1		50.4	170
		Inkjet Printer	13	16	1.77	2.19	16.1	36.1
		Wide Format Printer	7	109	83.1		19.9	212
		Document Scanner	1	2.38			34.3	36.7
		Laser Fax	2	14.7			47.9	62.6
	Computer Peripherals	Computer Speakers	18	0.76	19.6		0.629	21.0
		High Power Computer Speakers	2	119			0.537	120
		External Drive	2	24.7		3.58	8.08	36.4
		Ethernet Hub or Switch	9	16	25.8	0.11	2.37	44.3
		USB Hub or Switch	2	4.87	27.1	2.01	1.91	35.9

Source: Ecos

		Product Name	Devices metered (#)	Active (kWh)	Idle (kWh)	Sleep (kWh)	Standby (kWh)	Total (kWh)
Miscellaneous	Audio/Visual	LCD Television	2	80.1			9.41	89.5
		DVD player	1				11.2	11.2
		Video Projector	4	25		4.24	25.7	54.9
		CD player	3	1.65			17.1	18.8
		Portable CD player	7	16	2.3		8.26	26.6
		Speakers	6	9.37	19.4	0.404	4.85	34.0
		Portable Stereo	1	2.14	3.2		6.59	11.9
		Subwoofer	1		61			61.0
		Table Radio	2	3.88			9.51	13.4
	Telephony	Mobile Phone Charger	3	0.3	0.0139		0.716	1.03
		Phone, corded (powered)	12	0.0285	19.5			19.5
	Business Equipment	Adding machine	12	2.42	16.3		3.35	22.1
		Battery Charger	2	0.284			5.4	5.68
		Clock	1	12.3				12.3
		Clock, radio	4	3.17	18.9		8.89	31.0
		Coffee Grinder	2		4.96		0.46	5.42
		Coffee Maker	10	340	54.7		7.01	402
		Espresso Maker	1	152			18.7	171
		Portable Fan	6				0.919	0.919
		Lamp, desk attachment	9	29.7	1.56		0.461	31.7
		Lamp, table	16	48.4	1.7		0.328	50.4
		Shredder	4	164.2			0.588	165
		Portable Space Heater	4	53.9			0.04041	53.9
		Stapler	2	0.00521	3.38		5.32	8.71
		Toaster oven	1	49.2			0.0834	49.3
		Electric Typewriter	1	0.0443			29.4	29.4

Source: Ecos

5.7. Miscellaneous Category Duty Cycle Data

Table 13. Miscellaneous Category Duty Cycle Data

Product	Number Metered	Average Time in Active	Average Time in Idle	Average Time in Sleep	Average Time in Standby	Average Time in Disconnect
Television, LCD	2	16%	0%	0%	34%	50%
DVD player	1	0%	0%	0%	100%	0%
Video Projector	4	6%	0%	5%	64%	25%
CD player	3	5%	0%	0%	95%	0%
Portable CD Player	7	5%	9%	0%	75%	11%
Speakers	6	7%	37%	2%	40%	14%
Portable Stereo	1	3%	11%	0%	86%	0%
Subwoofer	1	0%	100%	0%	0%	0%
Table Radio	2	16%	0%	0%	84%	0%
Mobile Phone Charger	3	2%	.25%	0%	33.75%	64%
Corded Phone	11	0%	92%	0%	0%	8%
Answering Machine	2	0%	100%	0%	0%	0%
Adding Machine	12	5%	54%	0%	25%	16%
Battery Charger	2	1%	0%	0%	49%	50%
Clock	1	0%	100%	0%	0%	0%
Clock Radio	4	6%	72%	0%	22%	0%
Coffee Maker	10	25.5%	16%	0%	46%	12.5%
Coffee Grinder	2	0%	45%	0%	25%	30%
Espresso Maker	1	5%	0%	0%	95%	0%
Lamp, Desk Attachment	9	20%	1%	0%	9%	70%
Lamp, Table	16	14.5%	1.5%	0%	4%	80%
Shredder	4	25%	0%	0%	43%	32%
Space heater, portable	4	1%	0%	0%	99%	0%
Stapler	2	0%	48%	0%	50%	2%
Toaster Oven	1	1%	0%	0%	33%	66%
Typewriter, Electric	1	0%	0%	0%	100%	0%
PDA Charger	2	1%	44%	0%	50%	5%

Source: Ecos