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FINAL PROGRAM REPORT

Plug Load Savings Assessment:

Part of the Evidence-based Design and Operations PIER Program

Prepared for: California Energy Commission

Prepared by: New Buildings Institute
Contact: Cathy Higgins, Research Director, NBI

nbi new buildings institute

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Prepared by:

Primary Author(s):
Cathy Higgins

New Buildings Institute
1601 Broadway
Vancouver, WA 98663
360-567-0950
www.newbuildings.org

Lead Researcher: Catherine Mercier / Laura Moorfield
Ecova

Contract Number: 500-08-049

Prepared for:

California Energy Commission

David Weightman
Contract Manager

Virgina Law
Office Manager
Energy Efficiency Research Office

Laurie ten Hope
Deputy Director
RESEARCH AND DEVELOPMENT DIVISION

Robert P. Oglesby
Executive Director

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- Catherine Mercier and Laura Moorfield Ecova – Lead Researchers
- Cathy Higgins NBI - Reseach Program Manager
- Craig Billingsley and Chris Calwell Ecova – Analysis and Policy Support
- Lia Webster, Erin Rowe, Eric Greensfelder and Mark Effinger PECI – Field Metering Leads
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For more information about the Energy Research and Development Division, please visit the Energy Commission's website at www.energy.ca.gov/research/ or contact the Energy Commission at 916-327-1551.

For information on this research please contact Catherine Mercier, ECOVA cmercier@ecosconsulting.com or Cathy Higgins, NBI higgins@newbuildings.org

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EXECUTIVE SUMMARY

This Project Report (Final Report) summarizes the findings for the Plug Load Savings Assessment project within the *Evidence-based Design and Operation* research program (Program) led by New Buildings Institute (NBI) and its subcontractors for the California Energy Commission's Public Interest Energy Research (PIER) program. The research period was October 2008 through March 2013 and included studies on plug load energy use and savings strategies.

Achieving California's ambitious energy and environmental goals and policies will depend in part upon achieving dramatic improvements in the energy efficiency of new and existing commercial buildings. The commitment to these goals is evidenced by the existence and progression of advanced building codes and appliance standards, and the proliferation of utility energy conservation incentive programs. However some recent studies on the actual measured energy performance of newer generations of commercial buildings (those designed for high energy efficiency) evidence a wide range of energy performance; some buildings are performing far below design expectations. For example, NBI's 2008 study of measured energy performance of Leadership in Energy and Environment Design –New Construction (LEED –NC) buildings[1] found average savings of 28% compared to national code, but energy use at 1/4 of the buildings was near or *higher* than the allowable code baseline level. This performance shortfall needs to be better understood and corrected so that efficiency "as designed" comes into alignment with efficiency "as measured."

NBI was the prime research investigator for the PIER Program and ECOVA led the Plug Load Savings Assessment research with PECI as the field investigator. The full technical study on plug load energy use in offices and the savings assessment along with related plug load meterics and case study information is available at www.newbuildings.org/pier-research.

Objective. The objective of the *Plug Load Savings Assessment* research project was to characterize the electricity consumption of office equipment plug load devices and identify opportunities for energy savings.

Background. Plug loads (miscellaneous electric devices that plug into wall outlets) are one of the largest and fastest growing electric end uses in commercial buildings in the United States[2]. In California, plug loads on average account for 13% of total electricity consumption in commercial buildings and 23% in offices specifically[3].

Approach. The research team first inventoried the type and quantity of plug load devices (n=726) in two recently LEED[4]-certified buildings in California. A subset (n=100) representing a

[1] Energy Performance of LEED® for New Construction Buildings, NBI 2008

[2] Energy Outlook Report

[3] California Commercial Energy Use Survey (CEUS), 2006.

[4] U.S. Green Building Council's Leadership in Energy and Environmental Design Program - LEED

diversity of office equipment was established. Sensors were used to track power use at one-minute intervals for one month; these measurements established the baseline energy use and load profile of the sample set. In the second phase the team implemented energy saving strategies and measures on a subset of the 100 devices (n=39), then monitored the energy use on those devices at one-minute intervals for a second month. This enabled the team to estimate the energy savings effects of each efficiency strategy by plug load device category and overall annual savings potential for each of the office building sites.

Results: Energy Use. The baseline office equipment energy use, as a percent of the studied set of plug loads, per device category was measured as: 1) Desktop Computers 70%, 2) Imaging Equipment 17%, 3) Monitors 9%, and 4) Miscellaneous loads 5%[5]. The first three items account for approximately 95% of the measured energy use. The average energy use intensity of the studied plug loads at the two buildings was 0.7-.94 kWh/ft^2/yr. These findings are significantly lower than those calculated from office buildings in the CEUS database, which indicates energy plug load energy intensities of 2.19 kWh/ft^2/yr for small offices[6]. Two factors may account for this difference. First, the CEUS office equipment category includes servers and air conditioning units dedicated to servers. Servers were excluded from this study due to the unique nature of their energy use and because of liability concerns. Second, the office equipment purchased at these particular sites was more energy efficient than would be considered typical. For each site, studied plug loads used about 6% of the building's total annual energy (electricity plus natural gas).

Results: Energy Savings Opportunities. The savings solutions employed and evaluated were based on three categorical approaches: 1) Software-related changes: set all equipment to manage power to optimize energy savings, or use power management controlled at the information technology (IT) department level, 2) Hardware additions or replacements: purchase and install advanced power strips and timers that automatically control loads after business hours and on weekends, and procure more energy efficient office equipment with only necessary capabilities during procurement, and 3) Information and reminders (prompts) for occupants: provide simple, easy-to-understand information that encourage users to change personal practices (behaviors) so equipment is not left operating unnecessarily.

Five key savings strategy areas that produced immediate plug load savings: 1) Power Management Changes: set more aggressive power management settings on imaging equipment, enable computer power management settings, 2) Advanced Plug Strips and Timers: apply advanced plug strips to stop power flow to peripheral equipment when the primary device is turned off. Set timers to turn equipment off at the end of the day and weekends, 3) Adjust Monitor Brightness: adjust the monitor brightness to meet user needs without defaulting to the maximum brightness, 4) Occupant Behavior: send notices to staff to turn off equipment at the end of the day and initiate office energy awareness campaigns or competitions, and 5)

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[5] The percent of energy use per device category was very similar at both sites.

[6] Itron Inc., 2006. *Note:* one of the sites was a library, which is not a separate category in CEUS; results for the library were compared to those for a small office, the most similar category.

Equipment Procurement: at the time of equipment upgrade, purchase the highest efficiency option (such as those listed through the TopTen[7] program).

Measures 1-4 are no- to low-cost savings opportunities, with power management settings accounting for the lion's share (71%). Advanced plug strips accounted for 16% of the savings from the no- to low-cost measures, and occupant behavioral approaches contributed another 10%. Although equipment procurement is an important savings strategy, which in this study demonstrated energy savings approximately twice that of the no-to low-cost measures, it is not cost-effective to implement for energy efficiency savings alone. When replacement is necessary, highly efficient equipment should be purchased. The incremental cost for energy efficient equipment is usually minimal.

The results of this study show it is possible to significantly reduce plug load energy use in high performance buildings. At the small office, measures installed on 24 devices reduced the energy consumption of the affected plug loads by 46%. At the library, measures installed on 15 devices reduced the energy consumption of the affected plug loads by 17%. Extrapolating these findings to estimate potential energy savings for a realistic scenario at each site, no- and low-cost energy savings strategies could save about 19% of total studied plug energy use at the library and 40 percent of the studied plug load energy use at the small office. Savings opportunities may be greater in buildings with higher plug load densities. Any strategies that successfully reduce plug loads will be critical for California to reach a policy goal of zero-net energy for newly constructed commercial buildings by 2030.

A number of issues exist related to study and quantification of savings strategies for plug load energy use, chief among them being the lack of a uniform definition for plug loads. Secondly, meters are sometimes configured in buildings such that several systems or building areas may be served by the same circuits. This makes device or device category energy use harder to determine over time, particularly given the existing lack of knowledge regarding individual device electric load profiles. Thirdly, submetering individual circuits is expensive, limiting the viability of doing it over extended time periods. As such, it is difficult to know with certainty if some of the strategies employed in this study will persist over time. These issues are discussed in the technical report, in addition to suggestions for topics meriting further investigation.

Market Connections. Several key items beyond the full technical report were produced as a result of this study. A *Plug Load Best Practices Guide for Offices* (*Guide*), a *Methodology for Reporting Office Equipment Plug Load Energy Use* (Methodology Paper) and accompanying *Case Study on Office Plug Loads* (Case Study), and a *Plug Load Policies: In Place, Pending or Possible* (Policy Paper) are located at www.newbuildings.org/pier-research. The *Guide* helps office managers, tenants and owners understand their plug loads with the aim of reducing energy use and cost; it is the nation's first market-based publication on this topic[8]. Nearly 20 industry entities included

[7] See www.toptenusa.com.

[8] The researchers did an internet and industry search for similar materials and could not locate any simple guide on the topic of plug load best practices aimed at the occupant or office manager.

references to the research results in their e-news, on their websites or in magazine articles in publications such as *Commercial Property Executive's* (which has a readership of over 80,000). Research results were shared at almost a dozen energy and industry events. The *Guide* is available from several California utilities and their program implementation contractors. The Methodology Paper and Case Study have been shared with the Consortium for Energy Efficiency (CEE) and with ASHRAE members to spur the dialog on consistency of metrics and measurements related to plug loads. The Policy Paper is available to code developers.

1. Plug Load Savings Assessment Final Report

1.1 Background

This report summarizes the findings from Project 3: *Plug Load Savings Assessment* within the PIER program "Evidence-based Design and Operations." The research occurred from 2010-2012 and was led by Ecova[9] and supported by PECI for field monitoring and New Buildings Institute (NBI) as project manager and market connections lead.

Plug loads (devices that plug into wall outlets) are one of the largest and fastest growing electric end uses in commercial buildings in the United States[10]. Although efficiency improvements are occurring at the equipment and appliance levels, such as EnergyStar standards for copiers and monitors, the growing number of office electronics coupled with the need for faster, more powerful equipment has resulted in an overall increase in plug load energy consumption.

On average, plug loads account for 13% of total electricity consumption in California commercial buildings and 23% of office building electricity[11]. Office equipment alone is about 74% of the plug load energy for such things as computers, monitors, imaging equipment and various peripherals (things such as computer speakers). Plug loads, unlike building design and major energy systems such as lighting, heating and cooling equipment, are not subject to statewide energy codes. This is because of the challenge of regulating energy use that occurs through occupant choices after the issuance of the building permit. This further drives the need to better understand the energy impact of these growing loads and identify methods to meet occupant needs with less energy intensity and demand.

This research characterizes the electricity consumption of office equipment plug load devices in two recently LEED-certified buildings in California and identifies opportunities for plug load energy savings that may be transferable to offices throughout California.

1.1.1 Objectives

The project objective was to estimate the potential to save energy use by employing strategies effecting plug load device consumption which included changes to hardware, software and through deploying information designed to change occupant behavior.

The primary research objectives were to determine the energy used by office equipment plug load device category and to assess the most effective approaches to reduce plug load energy for these devices in office buildings. For the successful energy reduction strategies, a secondary goal was to refine and focus the findings so that utility programs and occupants/owners will

[9] While the lead researchers remained consistent throughout the project, Ecos changed mid-project when it was acquired by Ecova. All work on this project is now attributed to Ecova.

[10] U.S. Energy Information Agency 2008 Energy Outlook Report.

[11] Itron Inc. study resulting in the California Energy Use Survey (CEUS), 2006.

adopt them to create energy savings in California's commercial office buildings. The commercial office category for purposes of this study includes a variety of occupancy types.

1.1.2 Approach

The plug load research team performed the majority of the research at two California buildings - a 95,000 square foot (ft^2) public library in San Mateo and a 14,000 ft^2 small office in Oakland. Both of these buildings were designed for high energy and environmental performance relative to their peer buildings. The design of this study included the following two phases:

1. **Inventory, Identify and Meter Existing Equipment:** Inventory all plug load equipment and identify the subset most applicable across offices. This represented 726 plug load devices. Meter a subset of 100 of the devices representing a diversity of equipment types and uses; placing the highest priority on computers, monitors, imaging equipment and computer peripherals[12] for one month at one-minute intervals. This step established the energy use baseline for these 100 devices.

2. **Apply Energy Reduction Strategies:** Reduce the energy use of a subset of the metered devices by applying energy efficiency technologies or approaches to the end use and re-metering the altered device to determine the savings potential of the strategies. The saving strategies fell into four major categories:

    a) **Power Management Changes**: Computer and imaging equipment have power management settings which can be enabled to reduce energy use

    b) **Advanced Plug Strips/Timers:** Advanced plug strips stop power flow to peripheral equipment when the primary device is turned off. Timers can be set to turn equipment off at the end of the day if it will not be used during the night.

    c) **Adjust Monitor Brightness:** Adjusting monitor brightness to meet user needs without defaulting to the maximum brightness saves energy.

    d) **Occupant Behavior (via education and prompts):** These approaches include sending notices to staff to turn off equipment at the end of the day and end of the week and energy awareness information or campaigns.

1.1.2.1 Measurement Methodology

The team identified plug load devices with high energy use and installed meters on 100 of them. Left in place for one month, the meters measured and recorded volts, power, power factor, current and volt amps each minute. Then, 39 of the 100 devices were selected for energy efficiency hardware and software upgrades. 39 of the 100 devices were then metered for a second month.

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[12] Determined as the most numerous devices at the two sites and which use the most significant amounts of plug load energy (Mercier, C. and Moorefield, L. Ecova, et al., 2011).

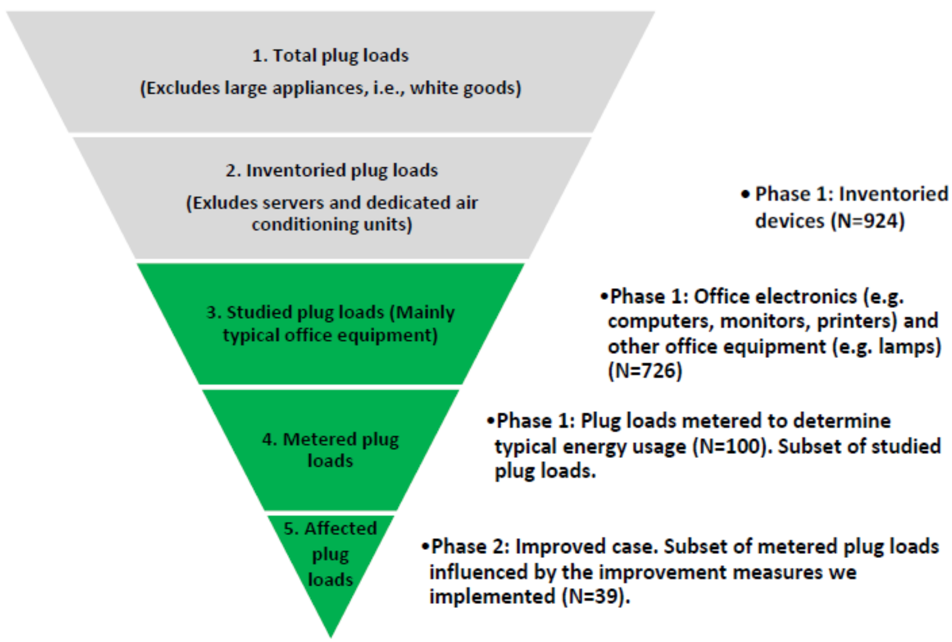
Once the second month of metering was completed, the team compared the energy use of the 39 affected (upgraded) plug loads to the 61 unchanged (control) plug load devices. Both months included 31-day periods with the same number of work and non-work days.

Figure 1 summarizes the tiers of plug load quantities at each step. The total in the top tier includes items subject to California Title 20 Standards for Non-Residential Appliances, such as refrigerators. Refrigerators, and other white goods, were not part of this study.

The second level top to bottom is the inventoried equipment; including all of the unregulated plug load devices, a total of 924 plug in devices at the two offices. This figure excluded servers and any dedicated systems to servers. Data centers and server closets have very specific energy use profiles and were not a part of this research. Data centers are a unique category of plug loads studied in other PIER research. [13]

The third tier are the plug loads identified as primarily office equipment; the subject of this study (726 devices). The metered devices are shown as the fourth tier and the fifth tier shows the 39 plug load devices for which savings strategies were employed.

Figure 1: Overview of Study Scope and Methodology



1.2 Technical Outcomes and Findings

The full details of this research discussed here are available in the final Commercial Plug Load Savings Assessment Report[14]. In addition to this report, a Plug Load Metering Plan (Metering

[13] See NRDC report on server energy use and savings at www.nrdc.org and Department of Energy Data Center energy information at www.eere.energy.gov/manufacturing/datacenters/about.html.

[14] Mercier, C. and Moorefield, L. Ecova, et al., 2011

Plan) was a deliverable developed in this project. The Metering Plan can be used in future plug load related research to guide inventory and assessment protocol in field studies. Other related items were also developed to facilitate these findings reaching the market or influence State energy policy and are described in the Section on Market Connections.

The Metering Plan describes: a) the method for conducting base-case metering, b) the preparation steps taken prior to the site visits c) a list of items that were taken to the sites, d) interview questionnaire, e) a description of the walk-through survey approach, f) detail on how meter tracking was installed g) a description of how data was downloaded and transferred from the devices and lastly) a description of how plug load devices were reconnected. To summarize, the Plug Load Metering Plan provided full metering detail, inventory lists, surveys and templates. , This plan can serve as a model that can be applied in future plug load inventory and metering studies that involve field data collection.

1.2.1 Commercial Plug Load Savings Assessment

The Savings Assessment Report describes the primary technical finding from the study. It includes data and information on:

- Baseline energy use for the building and for plug load device type categories
- Specific descriptions of the energy savings strategies
- Estimated savings for each energy savings strategy employed in the study
- Total plug load energy savings estimates for each site
- A discussion regarding issues that need to be considered when interpreting the data findings (Data Interpretation Issues)

1.2.1.1 Energy Use – Phase 1

The first step in the study involved determining baseline energy use of a select group of device categories. Savings were investigated in phase II of the study. To increase confidence that the metered data collected from the sample was representative of general office equipment energy use, this data was compared with measurements taken in previous PIER research on office plug devices by (Ecova) the lead research team on this project.

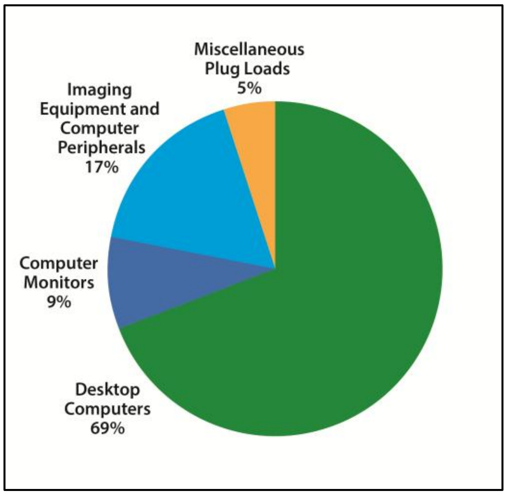
Annual energy use by device type was estimated by multiplying the average device category energy use from the one-month metering period in Phase 1 by the total number of those devices inventoried extrapolated for 12 months.

Four categories of office equipment energy use monitored for this study: 1) desktop computers, 2) imaging equipment and peripherals (primarily computer speakers), 3) computer monitors. and miscellaneous loads. Figure 2 shows the percent of the studied plug load's energy use[15] at

[15] As shown in Figure 1, the studied energy use is the energy use for the subset of plug load items determined to be office equipment after excluding servers, dedicated air systems and appliances. For this research the studied energy use represented 726 devices (590 at the library and 136 at the office).

the Oakland office site per each device category. The San Mateo library site results were similar (within 2-5% on each of the three dominant categories).

Figure 2: Percent of the Studied Plug Load Energy Use by Device Category – Office



Desktop computers (70%) used the majority of the energy in the study sample. When monitors are added to the desktop energy profiles, the energy usage was just under 80% of all office equipment plug load that was measured. Imaging equipment and computer peripherals energy use was 17%. Computer monitors used 9% of subject energy. Miscellaneous items (electric staplers, coffee makers, projectors, etc.) accounted for the remaining 5%.

From device inventories at each site and energy use recordings from the metered devices, the estimated plug loads energy intensities were measured at 0.7 kWh/ft^2 per year for the public library and 0.94 kWh/ft^2 per year for the small office. These findings are significantly lower than those calculated from the most recent California Energy Use Survey (CEUS). CEUS shows 2.19 kWh/ft^2 per year for small offices (Itron Inc., 2006)[16]. Two factors may account for the differences between the study samples and the database. First, the CEUS office equipment category includes servers. Servers were excluded from the current study as noted earlier, due to the unique nature of server energy

Second, both the library and small office had lower-than-average densities of office equipment (about 2 PCs/1000 ft^2 at each site). Additionally, interviews with occupants indicated that the office equipment purchased at these particular sites was more energy efficient than what would be considered typical. Studied plug loads at both sites used about 6% of each building's total annual energy (electricity plus natural gas)[17].

[16] Note that libraries are not a separate category in the CEUS analysis; results for the library were compared to the most similar category, small office.

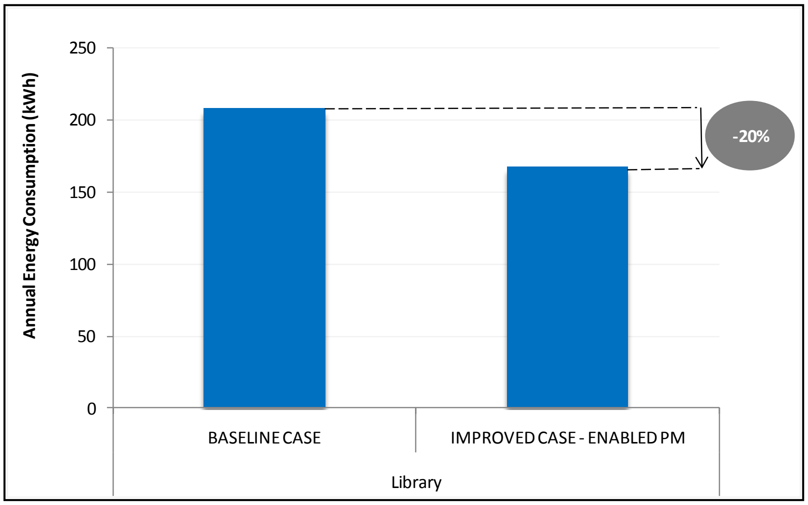
[17] See section **Error! Reference source not found.** on Data Interpretation Issues - this discusses the hallenges of definitions and percent of building energy use for plug loads.

1.2.1.2 *Energy Saving Strategies – Phase 2*

The research team organized the savings solutions into three areas: software, hardware and occupant behavior.

Software — Using aggressive power management settings on all equipment (i.e., keeping the time delay prior to powering down to a lower power mode as short as possible) or using power management software that is controlled by Information Technology (IT) departments and built-in settings that will save energy. If power management software is already installed on the devices as part of the equipment purchase, this solution can be implemented at no cost. This strategy yielded the largest energy savings for no-to-low-cost choices. An example of possible power management energy savings at the library is illustrated in Figure 3 where this strategy yielded a 20% reduction in energy use on a printer.

Figure 3: Savings from Setting Aggressive Power Management (PM) Settings on One Printer



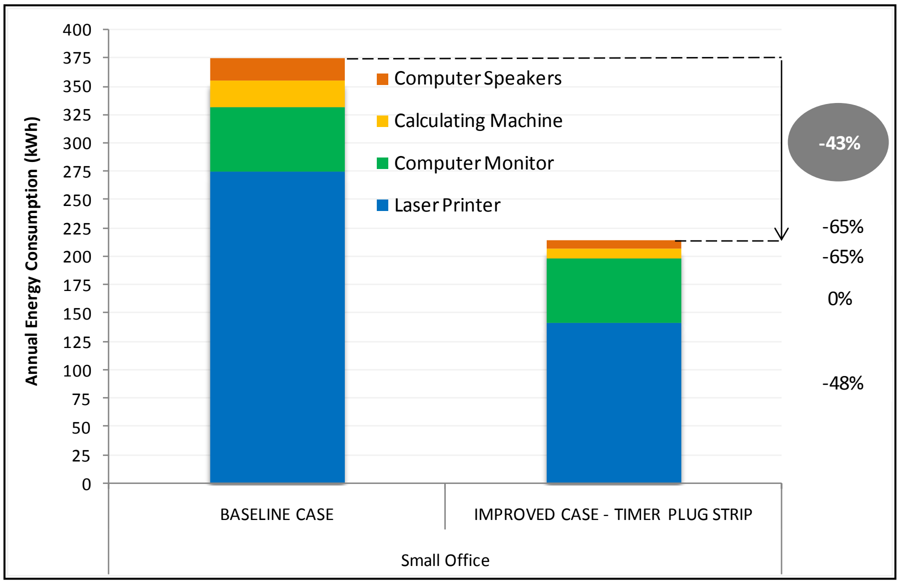
Hardware — There are multiple hardware-related options. The first option employed in this study was to purchase and install advanced power strips and timers for certain devices. These hardware options are a fairly low cost solution.

The largest energy savings came from upgrading existing equipment by replacing the equipment via purchase of more energy efficient models of devices. This only makes financial sense when equipment upgrade is necessary for other reasons besides energy. In that case this high first cost is already a planned expense in the procurement schedule. In this research, one extreme example of least (old) versus most efficient (new) equipment was the replacement of an older inefficient desktop computer with a new micro-sized desktop. The new unit featured basic functionality and was preset or designed to use ultra-low relative power including aggressive power management settings. This action reduced the electricity use of an occasionally used desktop by over 95%.

Another example of a hardware savings approach used on several of the devices in this study was the Digital Timer Plug Strip (DTPS). Timer plug strips provided a programmed 'off' period. They are a good option for devices that do not need to draw power at night and on weekends.

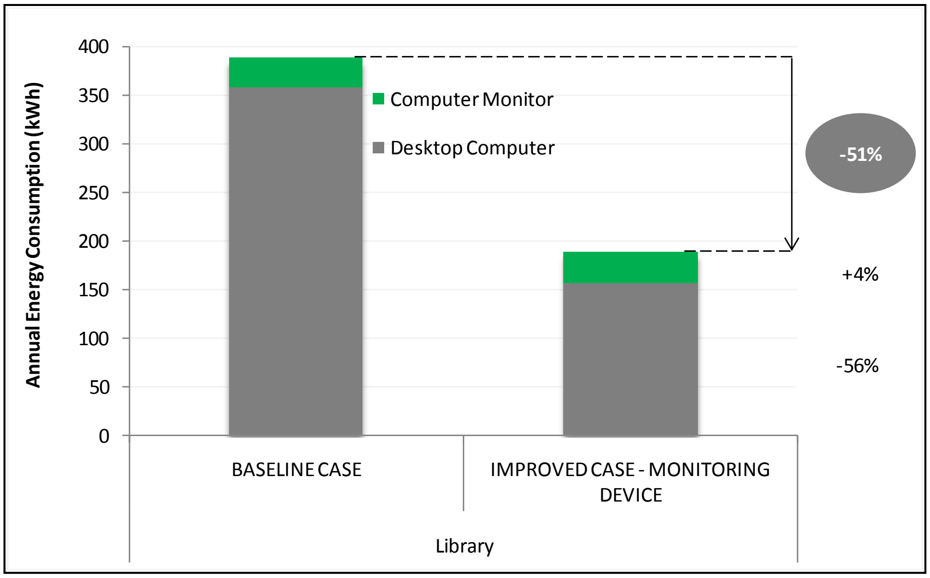
Figure 4 shows a 43% percent reduction in energy use from a set of devices as a result of DTPS employed at the small office site.

Figure 4: Savings from Digital Timer Plug Strips (DTPS)



Occupant [measures intended to change] use-related Behavior. Simple, easy to-understand, real-time feedback on energy consumption can affect user behavior that will reduce energy consumption. An email reminder to turn off equipment employed in this study reduced desktop computer electricity use by 6% on average. Another feedback method/message saved a projected 51% of the annual electricity used at each workstation at the library (Figure 5). This message reminded occupants to shut off their computers when they were not working at the office. Other efforts include encouraging users to flip the switch on power strips, turn off devices when not in use and increasing awareness of efficiency settings.

Figure 5: Savings Example from Employing Strategies to Remind Users to Shut off Computers Nights and Weekends (Monitoring Feedback)



The next section discusses some of the key findings for using and combining the savings approaches as applied to the four major energy use device categories used in this study: 1. Desktop Computers, 2. Computer Monitors, 3. Imaging Equipment/Peripherals and 4. Miscellaneous, followed by graphs and tables providing examples of savings details.

1. Desktop Computers

Desktop computers are the largest energy use of the studied plug loads at both sites, representing 68% and 69% at the library and the small office respectively. Hardware upgrades, software settings and behavior change all appear to be promising strategies for reducing the energy consumption from computers. While many of the desktop computers metered were the same model, energy consumption among the individual units ranged widely. This suggested that energy consumption variance was due to differences in user behavior. Unit power management settings (or lack thereof) were also a factor. The primary opportunity for reducing computer energy use at both sites was to insure that power management settings were enabled.

Enabling and properly programming power management settings is a significant savings opportunity; however, there are some barriers that need to be addressed to ensure energy savings results. User lack of information and education and conflicting practices in IT management policies, can impede energy savings. Power management of some devices can be automated at the IT level with to centrally control power to devices during nights and weekends such as products from Verdiem, 1E WakeUp and many others. Although deploying these software solutions was not part of the scope of this study, the team estimated that this strategy could save 5,540 kWh at the library and 3,270 kWh per year at the small office.

Behavioral-related information measures such as sending email reminders to encourage employees to turn off computers at night and on weekends are worthy of consideration.

However, given the timeframe of this study, persistent energy saving from this strategy could not be confirmed.

Finally, as with many electronic devices, significant savings are possible by replacing older computers with highly efficient newest models. The example described above under Hardware, involved replacing an inefficient desktop with a micro-sized unit that contained basic functionality, ultra-low power use and enabled power management settings. In this case power use was reduced by saved 95%. While these computers cannot replace all desktops because of applications capabilities, these computers used only for relatively straightforward tasks like email, word processing and internet browsing are suitable candidates for greatly improved systems at the time upgrades via procurement schedules.

2. Computer Monitors

Computer monitors metered at the sites typically consumed somewhat more electricity per year than today's most efficient models. The majority of the monitors were in standby or 'off' mode after business hours and on weekends at both sites, suggesting that power management settings were enabled on most of them, or that users routinely turn off monitors at the end of the day. Standby power use on monitors metered in this study was typically less than 2 watts. The key monitor savings opportunities at both sites were achieved by adjusting brightness settings in to properly account for ambient light levels and also upgrading equipment at replacement.

3. Imaging Equipment and Computer Peripherals

Most imaging equipment and computer peripherals, such as computer speakers, were used rarely but drew power continuously. The solid-ink multifunction device[18] (MFD) consumed significantly more energy than other devices. By itself it used 6% of total studied plug load energy at the small office, and nearly 40% of the electricity used in the all imaging equipment category at one of the sites.

An external control device can be incorporated on printers without power management settings so power can be reduced when the device is not in use. These add-on devices are an easy, low-cost way to eliminate the energy used by often-forgotten computer peripherals and imaging equipment. Timers and timer plug strips were the most effective at saving energy and saved up to 43% per workstation and are good options to control imaging equipment that is rarely used outside of normal business hours.

4. Miscellaneous Plug Loads

Miscellaneous plug loads such as projectors, coffee makers and vending machines were not numerous, but many of those that were monitored consumed did scale power consumption to usage.

[18] A Multifunction Device (MFD) combines printing, coping, scanning and/or faxing and are becoming the standard over separate equipment for each of these office needs.

Personal space heaters were frequent at the research sites and high winter energy users. To discourage the use and the need for personal space heaters, the HVAC system should be maintained so that it provides adequate and evenly distributed heat throughout the office. It can be challenging to maintain the desired temperature for all employees given the wide range of user preferences, heat gain or loss from windows, and proximity to vents and thermostats in different areas of a typical office building. If the findings of recent automotive research are any guide, it may prove more energy efficient to heat or cool the seat in which individuals are sitting than the air around them, given how readily the air circulates from one cubicle space to another in open floor plans.[19] Reducing these occupant-driven plug loads for thermal comfort is an important part of moving office spaces to low energy.

1.2.1.3 Savings by Measure

The research team applied individual energy saving measures and actions to those areas identified as high energy users. Table 1 shows the percent saved from the original measurement and as a lifetime potential based on data from EnergyStar. The final column shows the estimated payback in years resulting from implementing the measure or practice based on typical California commercial electricity rates.

Many of the software and behavior measures in Table 1 have short or immediate payback periods. Simple things such as adjusting the onboard computer power settings take little time and have large impacts. Hardware approaches incur more cost, particularly for some of the higher tech equipment so these investments should be leveraged with other procurement needs to reduce the incremental costs.

The dozen measures summarized in Table 1 are grouped by the three strategy categories of hardware, software and behavior. The pre (Baseline) and post (Improved) energy use for the device is shown, followed by the estimated annual energy use and savings.

Table 1: Summary of Measured Plug Load Energy Savings and Paybacks at the Small Office

Type	Energy Saving Measure	Plug Loads Affected (N=24)	Baseline Case Energy Use (kWh per year)	Improved Case Energy Use (kWh per year)	Measured Energy Savings Opportunity (kWh per year)	% Savings	Payback Period at $0.1342 per kWh (years)
	Replace existing monitor with Top-Ten monitor	LCD monitor	20.0	11.5	8.5	43%	Immediate

[19] See: http://blogs.edmunds.com/strategies/2006/09/keep-your-cooland-perhaps-save-some-gas.html and http://www.sciencedaily.com/videos/2006/0901-cool_car.htm Additional investigation of personal thermal applications are being conducted at Lawrence Berkeley Lab www.lbl.gov and at University of California Berkeley Center for the Built Environment http://cbe.berkeley.edu/.

Type	Energy Saving Measure	Plug Loads Affected (N=24)	Baseline Case Energy Use (kWh per year)	Improved Case Energy Use (kWh per year)	Measured Energy Savings Opportunity (kWh per year)	% Savings	Payback Period at $0.1342 per kWh (years)
Hardware - New Equip.	Replace existing monitor with Top-Ten monitor with automatic brightness control	LCD monitor	42.4	21.2	21.2	50%	51
Hardware - Plug Strips and Timers	Install load-sensor plug strip on workstation	LCD monitor, laser printer and computer speakers	113.6	61.4	52.2	46%	4.3
	Install remote control plug strip on workstation	Laser printer	49.5	22.4	27.1	55%	9.7
	Install timer plug strip on workstation	LCD monitor, laser printer, computer speakers and calculator	375.6	214.3	161.3	43%	1.2
	Install timer on imaging equipment	Laser multifunction device	38.9	24.7	14.1	36%	10.5
Software	It to centrally enable computer power management settings through the IT department	Desktop computers	The IT administrator did not implement this measure because some staff access their computer remotely.				
	Turn down brightness settings of computer monitors	LCD monitor	56.5	53.0	3.5	6%	Immediate
			48.3	35.3	13	27%	Immediate
Behavior	Send Outlook reminders to turn off computers	Desktop computer	103.7	96.6	7.1	7%	Immediate
			90.7	103.6	-13.1	-14%	Immediate
			90.7	62.4	28.3	31%	Immediate
			75.4	74.2	1.2	2%	Immediate
	Install feedback monitoring device on workstation	LCD display, computer, computer speakers	115.4	80.1	35.3	31%	6

Type	Energy Saving Measure	Plug Loads Affected (N=24)	Baseline Case Energy Use (kWh per year)	Improved Case Energy Use (kWh per year)	Measured Energy Savings Opportunity (kWh per year)	% Savings	Payback Period at $0.1342 per kWh (years)
	Provide energy report with action steps to reduce desktop computer energy use	Desktop computer	355.6	153.1	202.5	57%	Immediate
Combination	Replace desktop computer with micro-sized desktop and enable power management settings	Computer	485.1	23.5	461.5	95%	Immediate

Figure 6 shows the estimated kWh savings due to implementing these various measures and separates out the no- to low-cost items. It further shows the portion of all savings for the activity or measure. For example, enabling power management settings accounted for 71% of the no- to low-cost savings, advanced plug strips contributed 16% and occupant behavior approaches another 10%. The graph also shows that replacing 90% of desktops with highly efficient desktops accounted for 71% of the office equipment plug load energy saved in the building.

Figure 6: Summary of Savings at the Small Office

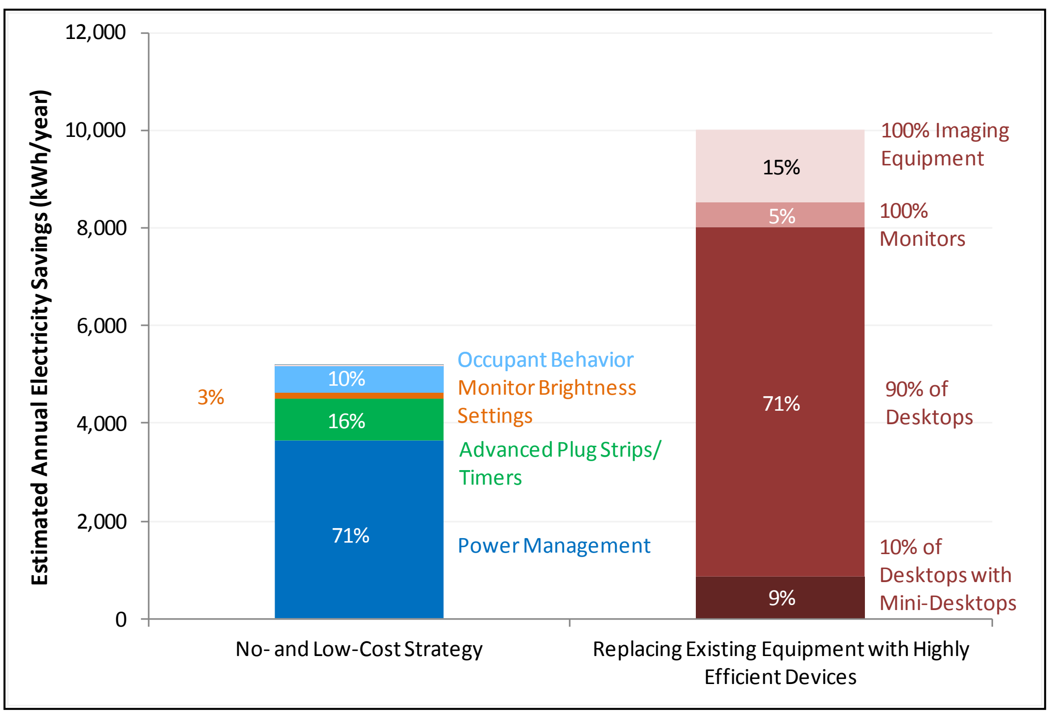


Table 2 is a summary of the total energy savings opportunities. It presents the number of devices studied at each sites, along with the percent of the devices that would be impacted by each savings strategy. The measured savings opportunity from both sites is shown in the right-hand column. An individual measure with high savings can be less valuable than one with a modest savings depending on the number of devices and the baseline energy use for the devices. An important caveat is that this research represents a very small sample size, reducing the ability for broad claims of specific achievable savings at other buildings. The findings do, however, demonstrate consistency in the order of importance of approaches and the key devices to be addressed (see **Error! Reference source not found.**) that are transferable to most ffice spaces.

Table 2: Summary Plug Load Energy Savings Opportunities by Individual Strategy

Type	Strategies	Studied Devices		Opportunity[1]		Measured Savings (%)[1] per Device Type
		Library	Small Office	Library	Small Office	
Replace	Replace existing monitors with comparable best-in-class models	218	33	100%	100%	43%
Replace	Replace existing monitors with comparable best-in-class models with Automated Brightness Controls	218	33	100%	100%	37%-50%
Replace	Replace inefficient MDFs, mailing machines, and laser and inkjet printers, with comparable best-in-class models	40	15	100%	100%	79% Small Office[3] 74% Library[3]
Replace	Replace existing desktop computer with comparable best-in-class models	203	37	100%	100%	88%[4]
Replace	Replace desktop computers by mini-desktops and enabled PM	203	37	20%[4]	10%[4]	95%
Hardware	Load sensor plug strip with computer laser and computer speakers	17 computers speakers/ 28 laser printers/ 82 private monitors	20 computer speakers 9 laser printers 33 monitors	8/17 of computer speakers 11/28 of laser printers 11/82 monitors	15% of computer speakers 3/9 of laser printers[5] 3/33 monitors	46%

Type	Strategies	Studied Devices		Opportunity[1]		Measured Savings (%)[1]
Hardware	Install remote control plug strip with laser printer	12 private laser printers	9 laser printers	11/12 of private laser printer	5/9 of laser printers	55%
Hardware	Load sensor plug strip with laser printer and computer monitor in public space of library	16 public laser printers 136 public monitors	n/a	100% public laser printers 16/136 monitors	n/a	14%
Hardware	Use timer plug strip with computer peripherals and laser printers	17 computer speakers 28 laser printers 82 private monitors	6 calculators 20 computer speakers 9 laser printers 33 monitors	8/17 of computer speakers 11/28 of laser printers 11/82 monitors	3/9 of laser printers 3/33 of monitors 5/20 computer speakers and 5/6 calculators	43%
Hardware	Use timer plug strip and timers with imaging equipment	5 laser MFD 28 laser printers 5 Inkjet printers 2 laser fax	9 laser printers 1 mailing machine 4 Laser MFD 1 Solid Ink MFD	100% imaging equipment	63% laser printer 100% mailing machine, laser MFD and solid ink MFD	10%-36%
Hardware and IT	Enable power management settings for computer or install centralized software method	203	37	13%	62%	50% per inefficient computer
Behavior	Enable more aggressive power management settings for imaging equipment	5 laser MFD 27 laser printers 5 Inkjet printers 2 laser fax	9 laser printers 1 mailing machine 4 laser MFD 1 solid Ink MFD	100%	100%	20%
Behavior	Adjust brightness settings of computer monitors	218	33	100%	100%	12%

Type	Strategies	Studied Devices		Opportunity[1]		Measured Savings (%)[1]
Behavior	Outlook reminders to encourage manually unplugging computers	203	37	64/203	100%	6%

Notes on table data:

[1] Savings opportunities are based on measured savings, except in a few cases where we used assumptions from previous commercial studies.

[2] The "Total Estimated Savings" is the number of inventoried devices multiplied by the measured average energy consumption for each device type, the opportunity percentage or the percentage of total inventoried devices that could be affected by this measure, and the measured savings opportunity per device type (%).

[3] This is a weighted average of estimated savings opportunities based in inventoried imaging equipment.

[4] Such computers are by no means intended to replace all desktop applications in an office, but desktop computers that are only employed for relatively straightforward tasks like email, word processing, and internet browsing, could be easily replaced with much less powerful computers.

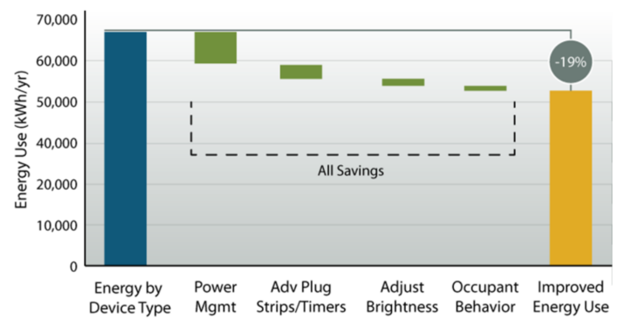
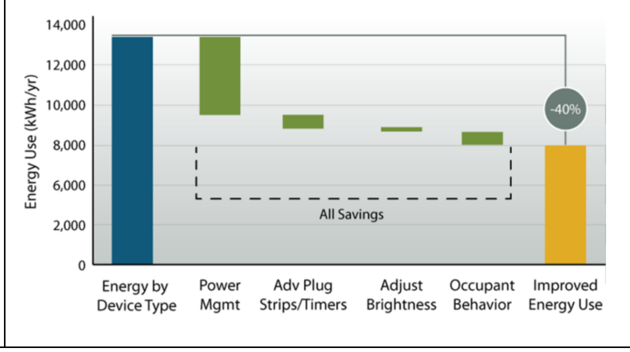
[5] Load-sensor plug strips can only be installed on printers connected to an individual computer. Also, savings will only be achieved if the computer is powered down by the user or automatically at night and on weekends.

1.2.1.4 Total Energy Savings: Studied Plug Loads

The applied strategies and measures showed strong energy reduction opportunities even at these sites that had already adopted green practices and building design. The sum of the applied measures reduced the total studied baseline plug loads by 19% at the library and by 40% at the office, as shown in

Figure 7 provides the share that each major savings category contributed to the total reduction of studied plug load energy use. Power management (which includes simple modifications to the settings on desktop computers, monitors or imaging equipment) is the greatest contributor to savings at both sites. For both sites, the second area of greatest savings is Advanced Plug Strips and Timers. The other two key areas - Adjustments to Monitor Brightness and Occupant Behavior approaches – contribute less and vary slightly between the two sites but are still two of the four primary methods for savings.

Figure 7: Studied Plug Load Energy Savings from all Strategies and Measures

At the Library	At the Office
	

The important takeaway here is that the three strategies of Power Management, Plug Strips/Timers and Adjusting Monitor Brightness achieve the lion's share of low- to no-cost savings opportunities and should be the first things addressed by any office. Approaches to Behavioral strategies do need to be a part of improvements, but changes can be simple (a prompt or reminder sign) or more complicated (ongoing employee engagement, varying methods of prompts, rewards), so the persistence and cost is highly variable.

What is less obvious, but important to remember, is that percent savings is deceptive and cannot singularly be used to rank savings opportunities. For example the library has only a 19% savings, while the office showed a 40% savings. Library actual savings were over 12,000 kWhs/year due to its >65,000 kWhs/year annual studied plug load energy use, while the office savings were just over 5,000 kWhs/year –40% of approximately 13,000 kWhs/year energy use for the studied plug loads.

1.2.1.5 Data Interpretation Issues

A number of data interpretation issues arose during this research. These include lack of definition of plug loads, plug load metering issues, the impact of the IT structure of the office (cloud vs. in-house server), and that as other building loads decrease, plug loads become a greater percentage of building energy use. These four issues are briefly defined below.

1. **Lack of Definition.** Plug loads have historically been outside the purview of code-setting bodies, and the number of office equipment devices and personal technologies changes quickly. As a result, there is no industry definition of "Plug Loads." Table 3 shows how three different references (CBECS, CEUS and PIER) account for plug energy use in offices. The two most commonly referenced sources for baseline energy use – CEUS (California) and CBECS (national) - differ significantly in how they categorize plug energy use. A third reference, a 1999 PIER study that contributed to the 2003 PIER Impact Assessment study and this NBI/Ecova study, shows yet another categorization. Due to these varying definitions and percent references, the industry is perplexed and inconsistent when presenting plug load energy use. For the purpose of this study, the

research team clearly defined the set of devices (office equipment) and the relationship of those devices to the total plug load items in the building (see Figure 1).

Table 3: Variations in Plug Load Energy Use in Buildings References

CBECS	• Office equip., computers and 'other' • All commercial bldgs – 20% • All non-mall bldgs - 12%
CEUS	• Office equip., misc. equip. • All commercial bldgs – 13% • All offices – 23% (office equip: 20%, misc: 3%)
PIER	• 2003 Impact Assessment Office Equipment – 6% • 2011 Small Oakland office all plug loads – 30% • 2011 Small Oakland office plugs after server closet – 8%

Source: C. Higgins 2011, NBI, PIER Metering and Review of Data Sources

2. **Plug Load Metering Issues.** In standard commercial building electrical wiring the major energy uses and equipment - such as heating, cooling and primary lighting circuits - are isolated at the panel. This allows metering of their energy use by attaching monitoring equipment at the isolated circuit in the panel. The plug loads, however, are blended into other circuits that typically mix many items onto the circuit making it difficult to monitor them as a set. The approach used in this study to overcome this metering complexity is described below in Section 1.2.1.6.

3. **The Office IT Structure.** The two primary IT factors that impact how much energy an office will use are the a) type of centralized computing equipment (server closet vs. data center, etc.) and b) whether the company computing is performed in-house or remotely (referred to as 'cloud computing'). These affect the study, actual use and strategies and direction of energy use trends. Changes in these two factors make the representation of plug loads challenging. This study, as was anticipated, investigated IT software but was unable to do field tests due to participant agreements not to impact the IT systems.

4. **The Problem with 'Percent'.** Percent is always relative while energy savings targets and outcomes are absolute. Without common definitions and industry understanding of the issues presented here, references to percent have less meaning. Percent problems for plug loads come in three forms:

    a. Percent of Building Use. As the energy use of other systems is reduced due to improved design and operations (as is the case with the high performance buildings selected for this study) plug loads naturally represent a larger percent of the load and are often the remaining efficiency to be pursued. The percent of plug loads can seem distorted when compared to the traditional, dated and conflicting references in CBECS and CEUS (Table 3). For example, total 'plug loads' of the studied office was 30% of building energy use. This certainly seems large, but when the studied office equipment alone is determined this number drops to 6% of total building energy use (see Section 1.2.1.6 below and Figure 8).

b. Measure Savings. To be relevant, savings must have a scale of measures impacted and baseline assumptions of time and energy. Representing the savings potential of a single measure using a percentage is incomplete. This study cross-referenced all savings against the number of devices impacted and the measured baseline energy.

c. Targets are Absolute. Energy targets – at the project and the policy level – are typically based on actual savings and outcomes. Saving 40% of a small energy use device is only valuable if that device is prolific and the savings widely implemented.

1.2.1.6 The Whole-Building Perspective

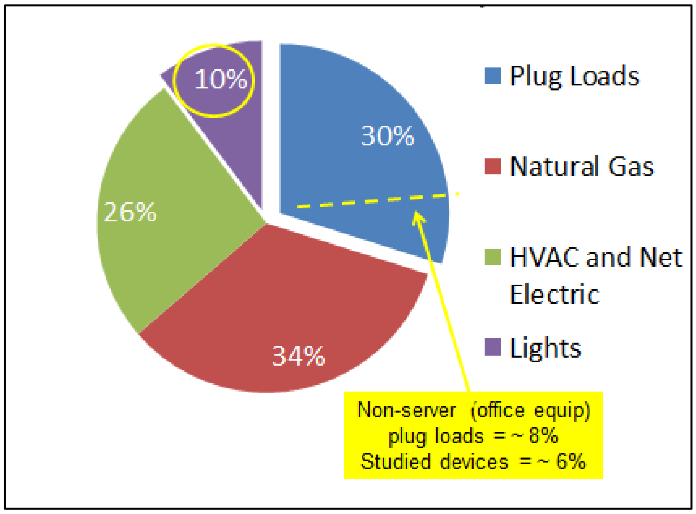
The research approach for assessing energy use and savings potential was a very precise 'bottom-up' method which included an inventory of all equipment, elimination of IT-based items (server closet and associated plug in air-conditioner) and major appliances, and direct device monitoring of all remaining items.

In parallel with this Ecova-led device-level assessment, NBI worked at the small office site on a 'top-down' analysis for Project 2 – Key Performance Indicators of High Performance Buildings. This work started with whole-building total energy use and metering at the panel for subsystems to identify the gross plug loads, followed by submetering the server closet and associated air conditioner. This 'deductive' method (starting from total building energy and removing known amounts per metered system) helped identify and verify the plug load portion of the whole-building energy use and the allotment of 'office equipment' plug loads studied for savings strategies. From this 'top-down' metering approach the overall energy use categories were determined.

At the small office Figure 8 shows this building's relatively low percent of lighting energy use (10%[20]). The plug loads in turn are much higher than the lighting load – representing 30% of total energy load for the building and reflecting the trend discussed above: when primary loads are reduced (such as lighting), plug loads become a larger percent. The 30% attributed to Plug Loads in Figure 8 is based on the system metering NBI installed. This total is predominantly the energy use of the server and its direct plug-in air conditioning unit. The non-server plug load energy use is assessed to be 8% of the total at this building, while the studied office equipment plug loads devices represent a smaller subset of 6% of the whole building after appliances are removed, as shown below.

[20] Average California office lighting = 28% according to CEUS.

Figure 8: Plug Loads as a Percent of Whole-Building Energy - Small Office



Source: C. Higgins, NBI, 2012, PIER Metering and Review of Data Sources

Combining the whole-building and system-level metering from Project 2 with Ecova's device-level pre- and post-efficiency strategy metering helps show the bigger picture of office equipment impact. The amount identified in this research of 'office equipment' was 6% of whole-building energy use and, coincidentally matches the 6% 'office equipment' figure from the 2003 PIER California Impact Assessment (Table 3).

Given this whole-building information, the team determined the savings from the applied measures at each site as a portion of the two buildings' total energy use. The findings of potential energy savings at each site found that these savings represent 1% and 2.5% of the total building energy use at the library and the small office, respectively as shown in Table 4. When these buildings are ready to upgrade equipment, additional savings could be achieved by replacing those desktop computers that do not require large memories or processor speeds with micro-sized desktops and by replacing other desktop computers, monitors and imaging equipment with the most efficient models.

Table 4: Summary of Energy Use and Savings for Studied Plug Loads (Office Equipment)

	Energy Use					Savings			
Study Sites in CA	kWh/sf	Total kWh	Btus/sf	% of Whole Bldg Energy Use (all fuels)	% of Whole Bldg Electricity	Total kWh from low-no-cost savings approaches	kWh sf/yr	As a % of Studied Plug Loads per Ecova	As a % of Bldg Total Energy Use per NBI
Library	0.70	66,300	2.4	6%	8%	12,270	0.13	19%	1.1%
Small Office	0.94	13,100	3.2	6%	12%	5,180	0.37	40%	2.5%

1.3 Market Connections

In addition to the two technical products identified in the original research targets and described earlier – the Plug Load Metering Plan and the Savings Assessment Report - three market-centric products were developed: 1) the *Plug Load Best Practices Guide for Offices* (*Guide*), 2) a *Methodology for Reporting Commercial Office Plug Load Energy Usage* Paper (Reporting Methodology Paper) and 3) a Case Study on Office Plug Loads (Case Study). Each provides market value in different ways. The *Guide* helps office managers, tenants and owners understand their plug load energy use with the aim of reducing energy use and cost. The Methodology Paper has a program and policy focus. It suggests the metrics, terminology and metering methods of office plug loads based on this research and can be a tool for discussion and resolution of industry inconsistencies and gaps. The Case Study provides a real-world example of the application and outcomes of both the *Guide* and Methodology Paper recommendations at an office space. Each of these is described below, followed by sections on specific market connections and adoptions.

1.3.1 Plug Load Guide – Best Practices for Offices

This is the nation's first market-based guide on this topic[21]. The information is organized around the five key themes shown to the right. Objectives included increasing the recognition of plug loads as a major energy use, providing measured data on the use and savings potential, and putting actionable guidance on reduction methods in the hands of occupants and efficiency programs. The *Guide* outlines no- and low-cost measures for reducing the energy and costs associated with office equipment plug loads such as computers, monitors and imaging equipment. Office managers, who are the key decision makers in regard to office equipment operations and purchasing, are the primary audience for the *Guide*. Additional audiences are tenants and building owners or brokers (who could incorporate the guide as part of a green leasing package or promotion).

5 Steps for Managing Plug Load Energy Use in Offices:

1. **Review.** Identify your needs, inventory your equipment and focus on the devices that use the most energy—usually, that's the equipment you use the most.
2. **Remove.** Eliminate or unplug unnecessary devices.
3. **Replace.** When it's time to replace, purchase the most energy-efficient devices for the job.
4. **Reduce.** Turn it off or power it down when not in use.
5. **Retrain.** Engage staff. Make sure they understand why, when and how to power down.

1.3.2 Plug Load Methodology Paper

The Methodology Paper offers new suggestions and guidance to establish a metering and metrics protocol for office plug loads and includes the results of office metering focused on plug loads. It is largely based on lessons from this PIER research combined with NBI's Office of the Future field findings and other research experience. The Methodology Paper was provided to program and policy entities as a reference for discussions, decisions and adoption on common methods and definitions for plug load energy use and savings representations.

[21] The researchers did an internet and industry search for similar materials and could not locate any simple guide on the topic of plug load best practices aimed at the occupant or office manager.

1.3.3 Plug Load Case Study

The Case Study is based on applying the Methodology Paper metrics and recommended approach to assessing the energy savings and outcomes at the PECI office in Portland, Oregon. The PECI office served as a test bed for the metering method, metrics, and to add greater data on the plug load approaches and measured performance for energy efficiency. The Case Study provides owners or office managers of validation of the recommended strategies and outcomes through an applied example in a typical office space. The Case Study can also serve as a supporting document or reference for the program and policy audience in support of the Methodology Paper.

1.3.4 Research Promotion and Outreach

The Savings Assessment Report results and the *Guide,* received attention through the research teams outreach to targeting a variety of users (e.g., building owners, utilities, cities) and approaches (e.g., media releases, announcements from NBI and its allies, articles and presentations). A list of the known publications, entities and utilities promoting this PIER research is shown below; considering the extent of the outreach and the interest, there are undoubtedly others that have picked up on the media and extended the information across additional conduits.

- **Media release**, blog postings and Twitter feeds promoting the *Guide* in July 2012 were shared by ESource, The Kresge Foundation, The Institute for Market Transformation, Healthcare Performance Engineering, CB Richard Ellis Green, Rocky Mountain Institute, Natural Resources Defense Council and PAE Engineers.
- **Industry articles** on, or citing, the results were in *Commercial Property Executive* (CPE), *Real Estate Rama*, *Building Operating Management*, *Environmental Building News*, *Smart Energy Universe*, *The Power Factor, Ecova Insider and the Northwest Conduit*
- **A feature article on commercial plug load trends** titled "The Next Frontier" appeared in the September issue of *Commercial Property Executive* magazine (CPE); it references the *Guide* and includes an interview with a staff member[22]. CPE has a subscription base of over 30,000 top-level commercial real estate executives, including a mix of investors, developers, financiers and service providers from across the nation and spanning the major property types.
- **Presentations** were made at multiple venues. The Savings Assessment Report findings were a part of presentations at the 2011 and 2012 Behavior Energy and Climate Conference (BECC) meetings in Washington D.C. and Sacramento respectively, and at the October 2012 California Emerging Technology Summit meeting in Irvine. In March 2012 the findings were presented as part of a panel at the ASHRAE High Performance Conference in San Diego and at the ACEEE Market Transformation Conference in Washington D.C. in March 2013.

[22] A copy of the article can be found at: http://digital.cpexecutive.com/publication/?i=119254

- **Webinars** highlighted this work in two important presentations. First to a group of 35 NBI stakeholders, mostly utilities and public-purpose providers interested in advancing their efforts to incentivize plug load control measures. Second, to over 200 participants comprised primarily of utilities, consultants, program implementers, and architects and engineers, through a webinar co-hosted by E-Source. Both webinars addressed questions from the attendees and generated a number of follow up inquiries and connections to the research.

1.3.5 Public Programs and Market Adoption

Plug Load Guide. Use of the *Guide* by utilities and the market is facilitated through its design, which provides blank areas on the front and back for co-branding. The *Guide was* co-funded with support NBI, the Northwest Energy Efficiency Alliance and BC Hydro. CEC recognition was required in all cases of use within and beyond California. Specific uses of the *Guide* include:

- **Utilities.** The *Guide* was, or is in the process of being, co-branded for distribution to thousands of office building owners and tenants throughout California through several major utilities (LADWP, SMUD and SCE). PG&E and Sempra received the *Guide* and associated files for customization and are considering its use and distribution through their programs.
- **The Cities of San Francisco and Berkeley**. Both are working on branded versions for distribution to their constituency and through city efficiency and disclosure programs.
- **Ecology Action.** A PG&E program implementer for small and medium commercial buildings in seven Northern California counties, Ecology Action has over 12,000 commercial retrofit projects completed. Approximately 40% of their work to date is in offices where they plan to put the Guide in the hands of owners and tenants on behalf of PG&E.
- **Real estate brokers** through **Waypoint** Buildings Group. Waypoint works as a real estate specialist in sustainability and energy efficiency for commercials buildings. They plan to use the *Guide* with clients interested in green tenant leases, and through local chapters of BOMA.
- **CB Richard Ellis** (CBRE).The world's largest manager of commercial real estate, CBRE, has its office of Sustainability in San Francisco. The researchers provided the Director of Sustainability the *Guide* as a tool for their tenants.
- **Consortium for Energy Efficiency (CEE)**. The research team delivered the Methodology Paper to CEEE - a key conduit to the utility industry for program research and alignment on energy efficiency issues and measures - as a topic for their committee work measured performance.
- **ASHRAE.** ASHRAE considers and makes recommendations on metrics and protocols for energy efficiency. The Methodology Paper is in the hands of staff at ASHRAE.

- **NBI PIER Research Site**. The results of all the key research products are publically available on the NBI website and through its Advanced Buildings® Program. NBI's site receives over 45,000 site visits annually seeking information on commercial building energy efficiency.

1.4 Benefits to California

As represented in the research, specific energy savings potential are highly variable by office, and the estimates from this research are based on a very small sample set. Nonetheless, the research did demonstrate that a 19-40% reduction in the studied office equipment plug loads was achieved at these two high performance California buildings. To provide some order of potential impact, on a conservative basis, an estimate of just a 10% reduction to office equipment energy for office buildings translates into an annual California savings of 316 GWh. When this is applied to all commercial building types – recognizing that office equipment plug load energy potential exists in the majority of commercial buildings[23] - the savings becomes 478 GWh.

In addition, several non-energy benefits accrue, including: extended equipment life (and therefore reduced landfill volume and reduced cost for California offices), improved office comfort due to reduced heat and noise, the potential to downsize HVAC systems due to less heat from equipment, and the opportunity for space savings due to the typically smaller size of efficient equipment as compared to their non-efficient counterparts.

The results of extrapolating the savings across buildings in California are shown in Table 5 below.

Table 5: Potential Impact of Office Equipment Plug Load Energy Efficiency in California

	Energy Savings Due to Applying a Percentage Savings to California Office Buildings Plug in Office Equipment (GWh)	
Percent Reduction	**Offices Only**	**All Commercial Buildings**
10%	316	478
25%	790	1196

The research team has worked to put the results in the hands of the office owners and managers, utilities and policymakers; these are groundwork steps toward making potential savings a reality. The next and final section outlines recommendations for continued progress toward California's goals of low- and zero-energy buildings in the area of Plug Loads.

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[23] Office equipment is typically found in less density in commercial buildings that aren't offices, but the estimate is made as an example and is simply an extrapolation of the conservative 10% reduction across all California commercial buildings.

1.5 Conclusions and Next Steps

This research provided the evidence-based data that can be leveraged for market, program and policy objectives relating to plug load energy use and savings. This research was also valuable for highlighting data interpretation issues and providing some clarifications and suggestions for resolution. Some key takeaways are:

- Plug load devices are rapidly growing in offices and are unregulated, so their absolute energy use is increasing.
- Server closets and data centers are very large and discrete energy uses requiring specific approaches.[24]
- This research showed effective approaches to significantly reducing energy use of this set of office equipment. Although the impacts appear small when seen as a percent of whole-building energy in this sample, the plug load strategies and opportunities will likely be greater in other buildings compared with these 'green' buildings.
- The savings levels, in these sites was 1-3% of total building energy use, represent an important and largely untouched area of savings. The integrated approach necessary to achieve the low and zero-net energy building targets across California must include these savings.

The clear identification of the following easy-to-communicate sets of three findings are a leap forward in understanding and progress on the sources of plug load energy use and what should be done to reduce it:

- Office equipment plug load energy use in order:
    1. Desktop Computers
    2. Imaging Equipment and Peripherals
    3. Computer Monitors
- Approaches to save energy:
    1. Software
    2. Hardware
    3. Occupant Information and Promos
- Priority no–low cost strategies and technologies[25]:
    1. Aggressive Power Management Settings
    2. Plug Strips and Timers
    3. Occupant Information and Prompts

This is the high level of information that benefits California's efforts to communicate effectively to the chain of parties responsible and engaged in plug load energy use. NBI has initiated this

[24] www.nrdc.org/energy/saving-energy-in-server-rooms.asp

[25] Note: Replacing equipment with low-energy models is a high saving strategy and is low or no cost the time of planned replacement.

information disbursement, but the findings remain available and valuable for use by a wide range of California entities.

1.5.1 Next Steps

The results of this research open new avenues for utility programs and necessitate policy formation. These results also open the door for additional research that will validate and expand upon what was found in this research effort. The next steps and recommendations are presented in three topic areas that align with different audiences: 1) Program Priorities, 2) Regulatory Approaches and 3) Future Research.

Program Priorities. Utility and public entities such as cities or government offices should consider the following within their voluntary efficiency programs:

- **Technology Incentives**. Incent advanced plug strips, timers and/or occupancy sensors focused on computers, monitors and imaging equipment and. IT energy management software programs.

- **Occupant Engagement Methods**. Include occupant engagement strategies such as enabling existing energy management settings, disabling unused equipment, education and awareness campaigns for staff about efficient behaviors and usage patterns, auto prompts to occupants to turn off equipment, and tenant competitions for low energy use.

- **Education and Promotion.** Promote the *Guide* and establish public education based on the recommendations.

- **Targeted Procurement**. Allow only the top efficient office products to be eligible in the program and inform office managers about the Top Ten list and site (www.toptenusa.org). Although EnergyStar labels identify higher efficiency equipment, the Top Ten list, developed by a national consortium of efficiency organizations, helps refine the attributes that make an appliance or equipment in the top ten of its class. Public programs could target, incent or promote the top ten, not just use broad labels such as 'buy EnergyStar'.

- **Cloud Computing.** Encourage strategies to move office computing to the 'cloud'. There are a range of possible outcomes for efficiencies to be realized by switching to virtualization and cloud computing alternatives if done correctly. A recent report by the National Resources Defense Council (NRDC) determined that "running a computer application in the cloud is generally more energy and carbon efficient than running it in your server room because cloud commuting can serve more customers at the same time, achieving economies of scale" (*Is Cloud Computing Always Greener* 2012[26]).

Regulatory Approaches. The regulatory approaches that could be pursued are highly dependent on the type of equipment and current mechanisms available. Within this research NBI wrote a brief paper titled "Plug Load Policies: *in Place, Pending or Possible"* (Policy Paper) to

[26] www.nrdc.org/energy/cloud-computing-efficiency.asp

present the methods underway in California and nationally to reduce plug load energy use and recommend next steps.

The major policy areas and current status in California are:

- **Switched Outlets (Control through the Receptacle).** This approach requires that a minimum number of receptacles in a building be on an independent circuit that is capable of being switched off through the use of a controller. In all cases these controlled receptacles are required to be easily distinguishable by occupants from the other, non-controlled receptacles. The three major codes or Standards – ASHRAE, IgCC (within the IECC), and Title 24 – have some requirements that fall under this approach.
  - *Title 24 2013*[27]: At least one controlled receptacle is to be installed within six feet of each uncontrolled receptacle in all buildings. Hotels and motels are required to have at least half of the receptacles in each guest room be controlled.
- **Appliance Standards (Title 20).** Appliance standards are set forth in the National Appliance Energy Conservation Act (NAECA), Energy Policy Act (EPAct) and the Energy Independence and Security Act (EISA). In California appliances must meet the minimum efficiency requirements of Title 20. Title 20 should continue to move toward technologically feasible lower power limits for appliance standards and expand to include electronics that feature standby, sleep and idle modes of operation – particularly for large plug contributors such as computers.
- **Wiring & Metering Approaches**. . The following energy codes and standards feature requirements, based on use thresholds for the wiring and metering of circuits associated with plug load energy use. These can facilitate the ability to access plug load data and, in turn, make that data visible to commercial building occupants. This 'feedback' loop is a major premise of this research.
  - *Title 24 2013*: There are four different energy thresholds with varying levels of disaggregation requirements for plug load circuits. All commercial buildings with a plug load service between 50 kVA and 250 kVA need to aggregate plug loads separately from other loads in the building. Buildings with a plug load service exceeding 250 kVA need to separate plug loads by floor, type or area. In addition, groups of plug loads exceeding 25 kVA in an area less than 5,000 square feet also need to be on a separate circuit.
- **Task Lighting**. When accounted for in a larger lighting design, task lighting – portable lights plugged in at individual work areas - can be an effective way to reduce overall space lighting energy use by putting the lumens at the work surface. Task lights fall into the plug load category and are therefore difficult to "touch" from a policy perspective.
  - *Title 24 2013* requires all portable lighting systems to be accounted for in the lighting power density (LPD) space limit but provides a budget of .3 watts per

[27] The Title 24 2013 Standard is scheduled to go into effect January 1, 2014.

square foot for task lighting. The Energy Code of Canada also requires that "supplemental interior lighting provided by movable or plug-in luminaires" be accounted for when determining compliance with installed lighting power limits.

- **Outcome-based Codes Approach.** A code approach that relies less on addressing the building in the construction phase, but more in the operational phase is referred to as an Outcome-Based Code (OBC). Outcome-based codes rely on demonstration of the building meeting a specific target for energy consumption, usually based on at least 12 months of measured energy use data. The targets can be set by building energy simulations or derived from surveys such as CBECS or CEUS.

  Though this code approach is only now in the pilot phase at a few municipalities[28] it offers significant promise in the medium to long term to address the most significant issues around plug loads – their variability among buildings and inability to be regulated in the construction phase. Several hurdles need to be addressed, chief among them the question of enforcement mechanisms available long after the building has been occupied.

- **Reach (or Stretch) Codes.** California's CalGreen has been adopted by over 100 jurisdictions and requires an energy saving level beyond the base energy code (Title 24). Similar actions are underway in Massachusetts and Oregon. At this point, none of the requirements for plug loads in these Reach Codes exceed those in ASHRAE 90.1-2010 or Title 24, but the Reach Codes provide a mechanism for implementing plug code requirements on less than, or in advance of, a full statewide mandatory basis.

[28] Seattle is in the process of having an Outcome-based code pilot program and other cities are considering the approach.

Table 6 summarizes the items currently in regulation in California and by other state and national codes and standards related to reducing plug load energy use.

Table 6: Plug Load Related Items in Codes and Standards

	Switched Outlets	Wiring/Metering	Task Lighting	Energy Star	Relevant Jurisdiction(s)
Title 24 2013	X	X	X		California
ASHRAE 2010	X	X		X	Maryland
IgCC 2012	X	X		X	Rhode Island[29]
Oregon Reach Code		X			Oregon

Summary of these policy-related recommendations for California:

1. Develop and set energy use targets through existing regulatory (Title 24), possible new pathways (outcome based) and voluntary (Reach, Stretch or Green) codes for commercial buildings.
2. Set minimum efficacy ratings for task lighting to encourage emerging technologies such as light-emitting diodes (LEDs)
3. Set default task lighting densities for compliance with Title 24 lighting power densities.
4. Move toward lower power and standby power limits in Title 20 requirements and expand to include electronics.
5. Maintain and enhance appliance efficiency programs while piloting outcome-based approaches.

Future Research. While thorough, this research raises many additional potential areas which, if pursued, will provide valuable insights and needed foundations to achieve California efficiency and zero-net energy targets. Research recommendations include:

- Expand the field investigation of plug load efficiency strategies and savings outcomes in order to increase the set of data samples.
- Include additional building types in next stage of research.
- Include additional types of plug loads with specific research focus divided into:
  - Office equipment
  - Servers and server closets
  - Task lights

[29] Adopted for Public Buildings only

- Perform Designing for Meterability (DFM) field studies and other methods for system-level metering to isolate the plug load energy use in new and existing buildings.
- Investigate the savings potential from behavioral changes and items as energy use and feedback displays.
- Determine the financial impacts and benefits of plug load measures and especially the incremental cost of measures.
- Identify the specific demand energy impacts.
- Research the latest in equipment and technology improvements.
- Identify the optimum outreach, education and behavioral efforts and impacts.

The Plug Load Savings Assessment research findings and the market connection products are valuable resources for today's work in energy efficiency in California and to build on for tomorrow's ongoing efforts.