Office Space Plug Load Profiles and Energy Saving Interventions

Brad Acker, Carlos Duarte and Kevin Van Den Wymelenberg,
University of Idaho

ABSTRACT

This paper presents the findings from a two-year project to characterize space level plug load profiles and explore load reductions interventions and their effects on load shapes in typical commercial office spaces. A total of six office spaces were studied comprising 48,500 square feet (SF) and inventorying 1,360 plugged devices. Baseline plug load profiles are presented along with load profiles and savings data for spaces after plug load reduction interventions were implemented. Interventions included occupancy sensor plug strips, load sensing plug strips, educational and behavior based strategies, and replacement of legacy equipment with ENERGY STAR® equipment. A total of 121 plug strips were installed across two spaces. One space utilized 33 occupancy sensor plug strips while the other installed 88 load sensing plug strips. The behavior based intervention comprised education of plug load impacts and reminder e-mails to turn off unused equipment. Average saving of 0.60 kWh/SF*Yr were found with plug strip interventions and 0.76 kWh/SF*Yr from ENERGY STAR ® equipment upgrades. Practical issues and policy implications regarding these interventions are discussed. The energy saving potential for server level control of individual computer stations is also discussed. The paper provides guidance to utility program specialists aiming to develop incentives for plug load efficiency measures, and to energy efficiency researchers and energy modelers when estimating plug load intensities and profiles in offices. This paper is based on a more detailed report, "Plug Load Profiles" (Acker, B. et. al. 2012).

Literature Review

Previous plug load studies, ranging from 2001 to 2011, were reviewed. A series of papers by Lawrence Berkley National Laboratory (LBNL) examined ENERGY STAR® programs and the use of power saving setting on office computers. (Heaters, Roberson, et al. 2004, Sanchez et al. 2007, Webber et al. 2001) These studies reported the 1) power status and turn-off rates of computers and general office equipment and 2) general surveys of office equipment densities and with a focus on after-hours energy use and turn-off rates and documented sleep mode power levels. In the 2007 LBNL report, Sanchez looked at 4,000 units of office equipment (OE) and 6,000 units of miscellaneous equipment (ME) in 16 buildings located throughout San Francisco, Pittsburgh, and Atlanta. The research took place after-hours. The study recorded the number and power status of OE and ME. OE was defined as units plugged in (not hard wired) in categories of computers, monitors, printers, fax machines, copiers, scanners, and multi-function units. ME included all items plugged in (not hardwired) but not included in the OE list. Examples of ME were desk lamps, heaters, personal coffee warmers, radios, and clocks. The average equipment density found was fourteen pieces of ME and nine pieces of OE per 1,000 square feet. This represents a much lower percent of total electric use in ME (4-9%) than reported in the 2006 Annual Energy Outlook report (37%) (EIA, 2006).

Two studies (Moorefield, 2008, Moorefield, L. & Mercier, C., 2011) were found that directly measured power use of individual plug loads. Moorefield (2008) conducted detailed energy logging of individual office equipment in California and attributed 30% (3.3 kWh/sf*yr) of whole building annual energy use to plug loads. However, the paper was not explicit as to whether all energy consumption was accounted for, thus this figure may be overstated. Some confirmation is provided by Itron (2006) in a California Energy Commission report which reported plug loads as 23% of whole building energy consumption based upon surveys and energy end use models. Moorefield (2008) reported computer and monitor loads separately from other OE. Computers and monitors represented 66% of the total plug load energy consumed, while other OE represented 17% and ME represented 17%. With regard to total building energy use index (EUI), computer and monitors represent 20% of whole building energy while OE and ME represent 5% each. A table of comparison finding from past research can be found in the Moorefield study (2008).

The literature review revealed a knowledge gap with regard to aggregate plug load profiles within a building because most existing research focused on profiles of individual equipment. Plug loads, monitored at the distribution panel level, will reveal the scale of total plug loads and their associated profiles over time. Longitudinal plug load consumption data have not been presented in previous research. Of specific interest are peak demand and baseline power levels, associated times, and after-hours power levels. The 2009 KEMA study suggested that 15-minute interval plug load data be collected and that this would improve the overall energy end use characterization (KEMA, 2009). In addition to providing load profile shapes, better data is needed for energy modelers on a plugged W/SF and schedule basis. The literature also suggested a need for data examining the effect of smart plug strips and occupancy sensors to control outlet power and the implementation of user education campaigns to raise awareness of the total power contribution of plug loads. No aggregate building or space level research was found on plug load reduction strategies.

Methods

This study collected approximately 12 months of baseline consumption in order to detect if seasonal differences exist in plug load profiles and equipment densities. Furthermore, four plug load reduction strategies were investigated, 1) occupancy sensor plug strips, 2) load sensing plug strips, 3) behavior based interventions through an educational campaign, and 4) installation of ENERGY STAR® equipment. In this study, computers, monitors and periphery equipment are reported separately from ME and other OE. The peripheral equipment category included speakers, head phones, small routers (not network based) and external USB hard drives. OE is largely comprised of printers, plotters, fax, and multifunction machines. ME included desk lamps, fans, heaters, mini fridges, radios and other similar equipment.

The occupancy sensor plug strips selected were WattStopper Isole IDP-3050. This plug strip incorporates six outlets that are switched and two uncontrolled outlets. The occupancy sensor uses passive infrared (PIR) technology. The plug strip turns power off to all devices plugged into the controlled outlets when the sensor does not detect occupancy. Any plug load devices other than computers or shared printers were controlled. An adjustable delay is provided from 30 seconds to 30 minutes, and 10 minutes was used.

The load sensing plug strips selected were the BITS Limited model SCG3E. This product has one control outlet, four switched outlets and two always powered outlets. The load sensing plug strips turn off ‘switched’ plugs based on the power draw state of the device plugged into the ‘control’ outlet. In this study, the computer monitor was plugged into the control outlet. The plug strip then sensed when the monitor transitioned to sleep mode and this reduction in current triggered the switched outlets to turn off. The individual computer setting for monitor sleep mode time delays were not adjusted, rather site-specific IT Department settings were retained.

In one facility a behavior-based intervention was investigated instead of a plug strip intervention. E-mail was sent to all employees by the companies’ Human Resources department. The e-mail explained the project and the impact of plug load devices in overall building energy use and encouraged employees to turn off any unused plug load items and shutdown computers at the end of the day. Three follow up e-mail reminders were sent, one per week, for a total of four e-mails over the course of one month. Data were collected during the intervention and for three months afterwards to examine persistence.

In one facility that did not have any other interventions, the effect of replacing existing desktop computers with ENERGY STAR® equipment was studied. This was done in a small office building with six actively used workstations, and four of the workstations were fitted with new equipment.

Finally, two spaces were studied for baseline power and inventory data only. No interventions took place in these two spaces.

Site Selection

Six office spaces were studied as described in Table 1. Within the limitations of a small convenient sample, an effort was made to achieve a range of office types according to size, business type, and public/private ownership.

Table 1. Study Sites

Site Number	Full Time Employees	Private / Public Sector	Square Footage	Business Type	Intervention Used
1	31	Public	4,544	Land Records	Occupancy Sensor Plug Strips
2	90-97	Private	13,688	World Wide Logistics	Load Sensor Plug Strips
3	6	Private	1,288	Architect	ENERGY STAR ® Eq.
4	7	Public	1,550	Elections Office	None
5	49	Public	13,072	Regulatory Agency	E-mail Campaign
6	100 (est.)	Private	13,688	Investment Analytics	None

All offices are located in Boise, Idaho and were suites within a larger building except for one stand-alone building (Site 3). For this study, a large office is considered to have 50-100 employees, a medium office has 20-50 employees and a small office has fewer than 20 employees. Two large offices, two medium offices and two small offices and a mix of private and public offices were studied. Sites 1, 4 and 5 are public agencies. Sites 2, 3, and 6 are private firms. Of the private firms, site 3 is a small firm working locally while site 2 and 6 are both large corporations doing business globally. The total sample comprises 48,500 SF of office space. Interventions were applied as described in Table 1.

Site Surveys

Five sites were surveyed via walkthrough, once during a winter period and a once during a summer period. This was done to ascertain any seasonal differences in plug load equipment, such as space heaters during winter or fans during summer. Additionally, these data helped to explain changes in load patterns independent of load reduction interventions. Data were collected on the number of occupants, business type, office area, and equipment data were recorded including the number of computers, monitors, peripheral equipment, office equipment (copiers, printers, etc), and miscellaneous equipment (radios, personal electronics, coffee warmers, etc). Seasonal variation in occupant and equipment densities was recorded. One site did not allow detailed surveys.

Metering Methodology

Total plug load energy was logged at the distribution panel level in order to obtain aggregate plug loads and profiles over time. Data logging equipment were placed at the panel feeders to record true power and energy values every 15 minutes. If the panel contained non-plug load circuits such as lighting or HVAC equipment, current loggers were used to monitor these draws and were subtracted from the total current of the panel, leaving just the plug load data. In some panels, there were fewer circuits containing plug loads than those without plug load circuits, and in these cases the individual plug load circuits were logged directly.

Analysis Methodology

Data were organized and checks done to ensure the quality of the data for each download period. Incomplete data and data with quality problems were removed from the data set. Data removal was not often needed, with the occasional exception of logger battery failure. Loggers were typically downloaded every two to three months. Data were analyzed in spreadsheets using pivot table methods with the data organized by pre and post intervention categories. Data were further categorized and evaluated on month, week, and day types, and on a time of day basis. Data are presented on a weekday, weekend and holiday basis. In the case of e-mail interventions, data were examined during and after business hours on weekdays.

Survey and metered data were analyzed and are presented in several forms. Average densities of equipment per 1,000 SF, miscellaneous equipment populations, power densities of plug loads per square foot (W/SF), densities of computer equipment, OE, and ME. In addition, densities are reported on a full-time employee (FTE) basis, along with the number of plug load devices per FTE.

Data were collected over approximately a 15-month period at each site. Interventions were applied to four of the six sites. For the plug strip and e-mail interventions approximately a 12-month period was used to establish the baseline energy use profile and interventions were logged for approximately three months. In the case of the ENERGY STAR® intervention, baseline data were logged for approximately three months and post data for approximately12 months.

Summarized Results

Results of the site surveys are presented first, followed by baseline load profile data and finally energy and demand savings due to interventions. Additional information can be found in the detailed report (Acker, B. et. al. 2012).

Survey Results

The survey results show a wide range in most types of equipment when normalized per 1,000 SF as seen in Figure 1. This spread within a small sample makes it difficult to generalize these data. Computer monitors show an interesting and challenging trend in plug load use. Older CRT monitors were not often found and newer more energy efficient LCD models prevailed. While newer LCD models use approximately half the energy of an older CRT monitor (Moorefield, et. al., 2008), many workstations had two LCD monitors. This apparent step forward in energy efficiency has been balanced in part by an increase in monitor count.

Figure 1. Plug Load Equipment Distribution, All Sites

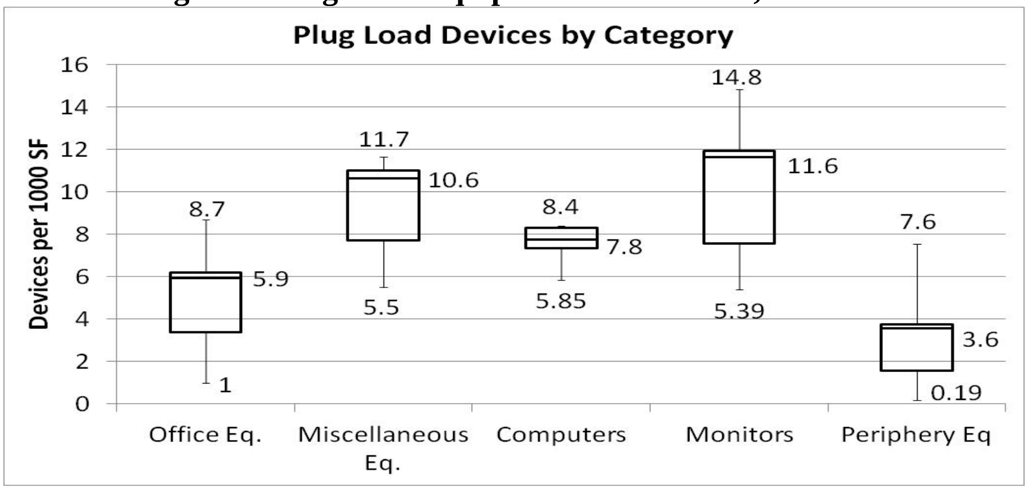

Figure 2 shows the more common ME found during the surveys. Several items were found infrequently, including coffee warmers, voice recorders, digital picture frames, fountain pumps, handheld vacuums, massage chairs, humidifiers, sign tickers, and a shoe polisher, and these were excluded from Figure 2. A large distribution in ME is shown; again making it difficult to generalize office plug load densities.

With regard to personal comfort devices, fans were found more often than personal heaters but neither occurred frequently. A total of eight heaters were found across two sites. Fans were found in four of the surveyed sites. Seasonal variation was not significant.

Figure 2. Summary of Miscellaneous Equipment

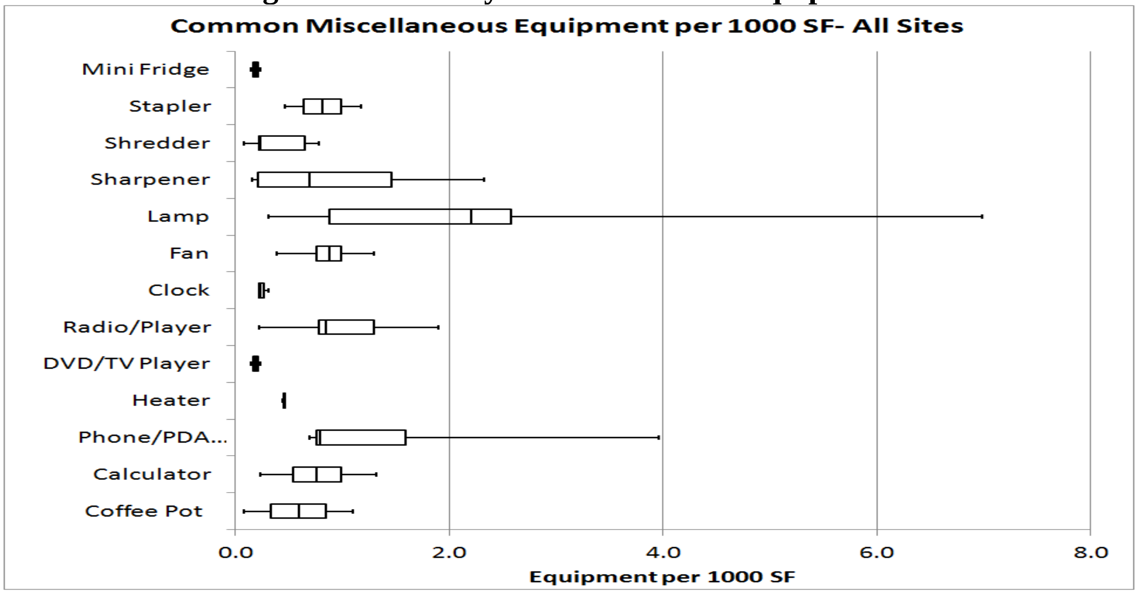

Table 2. Summary of Survey Results

	Site 1	Site 2	Site 3	Site 4	Site 5	Site 6
Characteristic	Standard, Med	Standard, Large	Standard, Small	Standard, Small	Computer Intensive	Computer Intensive
Office SF	4,544	13,688	1,288	1,550	13,072	13,688
FTE	31	94 (avg.)	6	7	49	100 (est)
SF/FTE	147	146	215	221	267	137
Total PL Devices	216	359	50	67	275	392 (est)
Devices/SF	0.05	0.03	0.04	0.04	0.02	0.03 (est)
Devices/FTE	6.97	3.82	8.30	9.60	5.61	3.92(est)
Baseline Avg. Weekday W/SF	0.87	0.36	0.84	0.36	0.48	1.75
Baseline Avg. Weekday kWh/SF*ry	5.15	2.18	5.06	2.18	2.86	10.5

Table 2 shows summary results of device densities and baseline power densities in the study spaces. Two sites (2, 4) shared the lowest energy intensity of 2.18 kWh/SF*Yr and this value agrees well with some of the previous research that reported 2.19 kWh/SF*Yr (Iron Inc., 2006). However, two other sites (1, 3) had over twice this value and one site (6) had almost five times this value. Note that both site 5 and 6 are categorized as computer intensive. These are both businesses that do extensive computer analytics. These data do not contain server rooms, only personal computers. The sample size is obviously too small to draw conclusive results about the computer intensive categorization, however it is interesting to note that one computer intensive site (5) was near the lower end of energy intensities found while the other site (6) was the highest. Regressions between several moderating factors and plug load energy use were examined but proved difficult to establish.

Monitoring Period Baseline Energy Use

Baseline load profiles were generated on a weekday, weekend and holiday basis. Information that can be drawn from load profile graphs includes day type peaks, unoccupied power draw, and operation hours of the space. Evaluating a load profile of an individual space, including after-hours use, can provide insight regarding the most effective energy efficiency measure for that site. Figure 3 shows the baseline profile of Site 2 and includes the full year-long baseline data. Site 5 had a similar peak as Site 2 but the after-hours load was 4.75 kW. All spaces had similar profile shapes with differences being in base load and peak values. Graphs of all sites are available elsewhere (Acker, B. et. al. 2012). The large unoccupied draw was determined to be in part due to an IT policy prohibiting employees from turning computers off on weekday evenings to allow network maintenance. Table 3 shows the relevant parameters of the load profiles of the study sites.

Figure 3. Site 2 Baseline Load Profile

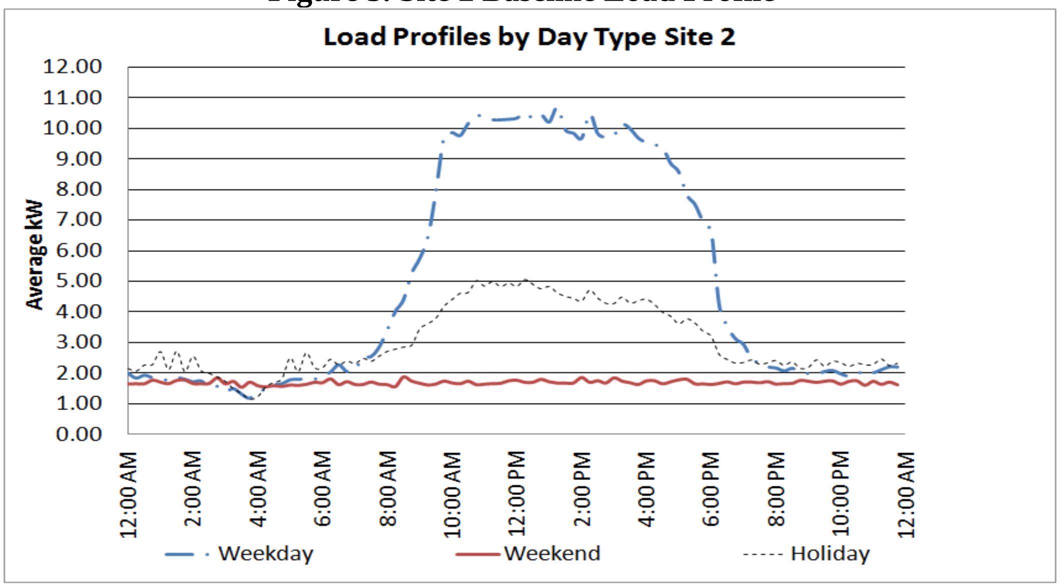

Table 3. Summary Baseline Load Profiles

	Site 1	Site 2	Site 3	Site 4	Site 5	Site 6
Peak hours	6am-6pm	7am-6pm	8am-5pm	7am-5pm	8am-5pm	7am-6pm
Weekday kW Peak	6.25	10.50	1.5	1.25	9.5	28.00
Weekday Unoccupied kW	2.75	2.00	0.75	0.25	4.75	22.00
Weekend kW Peak	2.00	1.75	0.60	0.35	2.5	21.00
Holiday kW Peak	3.00	5.00	0.50	0.35	3.5	23.00

Monitored Period Energy Savings

This section provides data on the energy and demand saving of the four interventions used in the study sites. Interventions included load sensor plug strips, occupancy sensor plug strips, Energy Star® equipment and behavior based. Various metrics are used in order to normalize the data on a per square foot basis.

Plug Strip Interventions

After the baseline period was recorded, an intervention of occupancy sensor plug strips were installed at Site 1, and load sensing plug strips at Site 2. At Site 1 a total of 33 occupancy sensor strips were installed, covering every cubical in the study space with 124 total plugged devices controlled. At Site 2, a total of 88 load sensing plug strips were installed controlling 77 plugged devices. At Site 2 it may seem strange that 88 plug strips are used and only 77 devices were controlled. There are two reasons for this. The first reason is because with load sensing plug strips the computer monitor was plugged into the control outlet and not counted as a switched device. The other reason is that Site 2 has fewer miscellaneous equipment due to human resource polices which limiting equipment in the M.E. category. Therefore, 39 of the 88 plug strips had no devices controlled. At Site 2, per plug strip analysis was conducted on the 49 strips with controlled devices. Table 4 summarizes the baseline and savings data from the plug strip interventions.

Table 4. Summarized Plug Strip Baseline and Savings

	Load Sensing	**Occupancy Sensing**
Total Average Savings	6565 kWh/yr	5396 kWh/yr
Baseline Weekday Average	0.36 W/SF	0.87 W/SF
Savings per device controlled	85 kWh/yr	50 kWh/yr
Plug Strips, used	49	33
Controlled Devices	77	108
Uncontrolled devices in space	269	113
Controlled devices per strip	1.57	3.27
Savings per plug strip	134 kWh/yr	163 kWh/yr
Saving per device controlled	85.4 kWh/yr	49.8 kWh/yr

Figure 4 shows pre/post intervention load profiles and percent saving line for Site 1. Again, the year-long baseline and 3-month intervention period data underlie the graph. Note that energy savings occur in both occupied and unoccupied hours. Site 2 showed a similar saving profile with detailed results in Table 6 and summarized results in Table 4. Detailed savings data are shown in Tables 5 and 6. Savings are presented for weekend and holiday periods.

Figure 4. Site 1 Weekday Load Profile (occupancy sensor plug strip intervention)

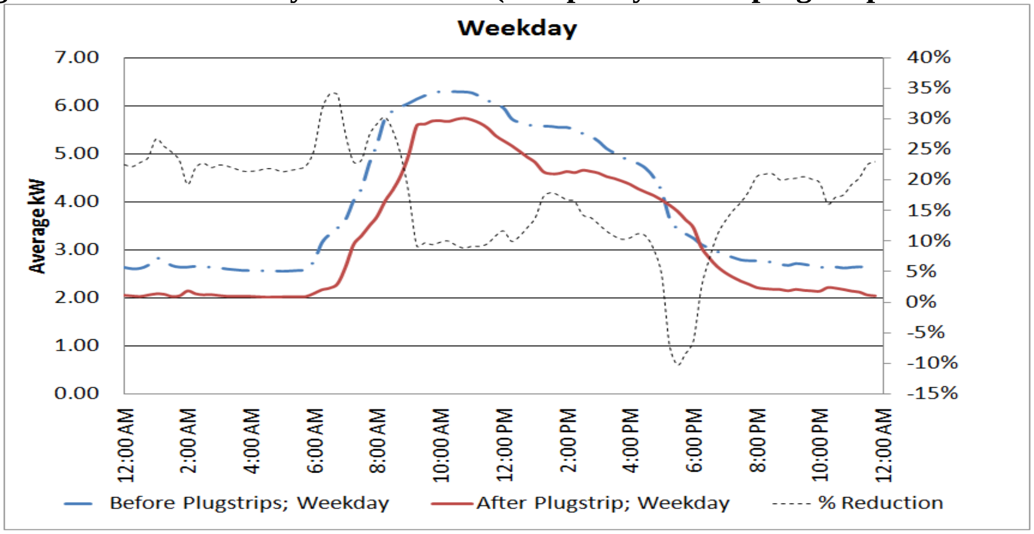

Table 5. Occupancy Sensor Plug Strip Energy Savings

Weekday Demand and Energy Savings						
	Percent	kW	W/SF	kWh/year	kWh/SF *Year	kBTU/SF * Year
Median	19.21%	0.55	0.12	3,317.09	0.73	2.49
Average	16.97%	0.63	0.14	3,760.02	0.83	2.82
Weekend Demand and Energy Savings						
	Percent	kW	W/SF	kWh/year	kWh/SF *Year	kBTU/SF * Year
Median	28.61%	0.57	0.13	1445.15	0.32	1.09
Average	28.39%	0.57	0.13	1431.91	0.32	1.08
Holiday Demand and Energy Savings						
	Percent	kW	W/SF	kWh/year	kWh/SF *Year	kBTU/SF * Year
Median	35.14%	0.72	0.16	173.90	0.04	0.13
Average	36.22%	0.86	0.19	205.33	0.05	0.15

Table 6. Load Sensing Plug Strip Savings

Weekday Demand and Energy Savings						
	Percent	kW	W/SF	kWh/year	kWh/SF *Year	kBTU/SF * Year
Median	18.03%	0.64	0.05	3815.42	0.28	0.95
Average	19.75%	0.87	0.06	5196.44	0.38	1.30
Weekend Demand and Energy Savings						
	Percent	kW	W/SF	kWh/year	kWh/SF *Year	kBTU/SF * Year
Median	23.51%	0.42	0.03	1054.09	0.08	0.26
Average	25.14%	0.42	0.03	1069.94	0.08	0.27
Holiday Demand and Energy Savings						
	Percent	kW	W/SF	kWh/year	kWh/SF *Year	kBTU/SF * Year
Median	41.69%	1.00	0.07	240.40	0.02	0.06
Average	38.41%	1.25	0.09	300.31	0.02	0.07

Behavior Intervention

This intervention consisted of the human resources manager sending out a preliminary e-mail informing the staff of the importance of turning off unneeded equipment and the energy impacts of current practices. The e-mail also contained information about the study being performed and contained a graph of the baseline plug load profile. After the initial e-mail was sent a reminder e-mail was delivered once a week for a period of four weeks. Very modest energy savings can be seen in unoccupied hours during the post-intervention period in Figure 5. However, there was also an increase in peak occupied energy use. Therefore, data were analyzed on a weekly basis starting just two weeks before the intervention and continuing 12 weeks afterwards. It appears that the trend for adding more plugged equipment likely continued into the post-intervention period, confounding the results. No discernible trends could be found relating to persistence of savings. It is possible that the email campaign had an unintended reverse effect during occupied hours, however the slight reduction in after-hours consumption does not necessarily support this interpretation since it appears occupants were receptive to the campaign in their end of day behavior.

Figure 5. Site 5 Weekday Load Profile, Behavior Intervention

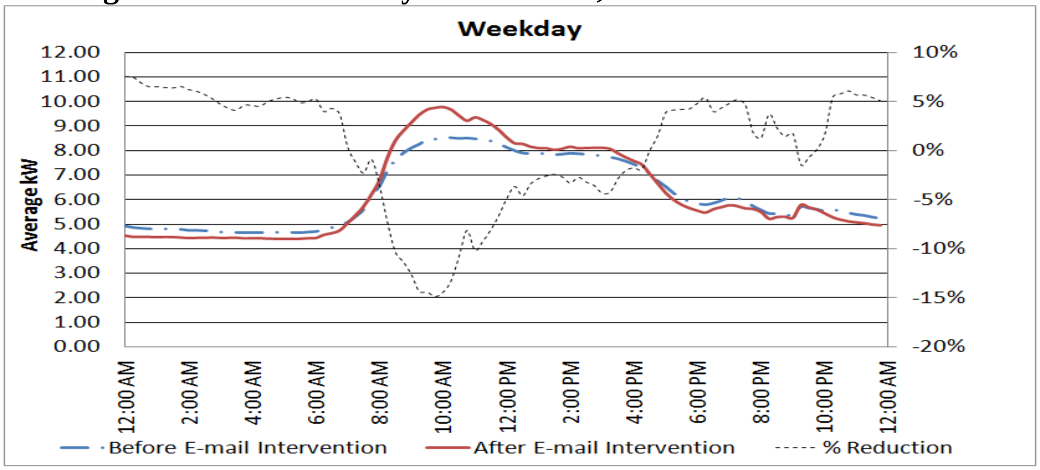

Table 7. Site 5 Weekday Unoccupied Saving, Behavioral Intervention

	Percent	kW	W/SF	kWh/year	kWh/SF *Year
Median	4.76%	0.23	0.02	877.12	0.06
Average	4.14%	0.21	0.02	795.67	0.06

ENERGY STAR® Equipment

At Site 3, four older computers were replaced with ENERGY STAR® models. This space had an inventory of ten computers, but only six people were employed during the study. The remaining four computers were seldom used, and were observed off during inventories. Therefore the replacement of four of the six actively used computers represents about two-thirds replacement. The baseline period for this site was three months, relatively short compared to other sites in this study, but is still longer than most plug load studies (Moorefield, L., et. al. 2011, Itron, 2006). The post-logging period was 12 months. The load profiles can be seen in Figure 6 and tabulated savings in Table 8.

Figure 6. Site 3 Weekday Load Profile, ENERGY STAR®

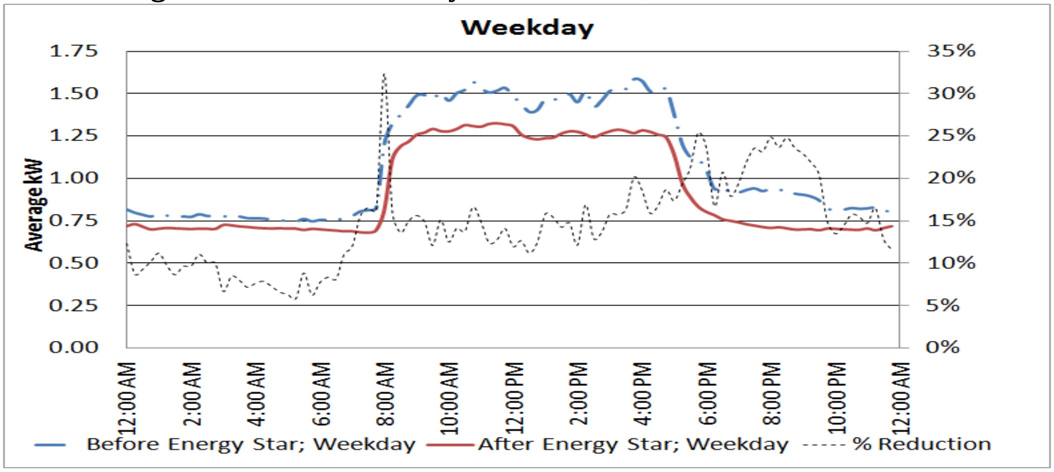

Table 8. Site 3 Weekday Savings, ENERGY STAR®

	Percent	kW	W/SF	kWh/year	kWh/SF *Year
Median	14.27%	0.21	0.16	1234.96	0.96
Average	14.49%	0.16	0.13	972.63	0.76

Conclusions

This report supports the energy savings potential of each of the studied interventions and provides substantial results for two energy saving plug strip technologies. Occupancy sensor plug strips saved 49.8 kWh/yr*device controlled and load sensor plug strips saved 85.4 kWh/yr*device controlled. This research gives insight to utility analysts on realistic implementation savings of these technologies. For example a recent study reported selective workstation savings of 43% with load sensor plug strips (Moorefield, L., et. al. 2011). However, this paper shows space-wide savings in the range of 20%, which may be closer to what a utility analyst might expect over a diverse population. These differences can be attributed to user rejection of the technology and limited or no devices available for control at some workstations. Cost effectiveness may still be a concern for utility program evaluators as the current price for occupancy sensor plug strips is approximately $90.00 and load sensor plug strips cost approximately $30.00, while standard plug strips with similar surge protection specifications cost approximately $15-$20. While the retail price is quite different between the two technologies, either may face challenges meeting cost effectiveness tests. This research provides sufficient data to support and refine the concurrently established unit energy savings (UES) values recently adopted by the Northwest Power and Conservation Council's, Regional Technical Forum (RTF). The RTF deemed a UES of 100 kWh with a minimum of one device controlled for load sensing plug strips (NWPCC-RTF, 2011). This research shows lower savings for load sensing strips on a per device basis (85.4 kWh/yr) but higher on a per strip basis (134 kWh/yr). Site surveys may prove important when attributing energy saving to this technology.

Further work is needed to better define the saving potential of behavior-based interventions given the limited sample of this investigation and the confounded results due to changes in plugged device counts pre and post intervention. Nonetheless, a 4% after-hours savings was shown, suggesting occupants were engaged. Additionally, to support aggressive net-zero energy research it would be useful to understand the savings from a combination of educational and technological intervention strategies. Server control of workstation computers has also shown savings potential and warrants investigation. An example of this can be seen in the high after-hours load profile in Figure 5, which is due to an IT policy requiring computers be powered constantly during weekdays to support network/software maintenance. Site 5 showed approximately a 4.5 kW draw while the average of sites 1-4 was approximately 2.1 kW.

Personal comfort devices such as fans and space heater were not common or consistent across sites, and no statistical difference was observed in seasonal inventories. While personal thermal comfort questionnaires were not conducted, it is believed that finding a substantial count of such devices would indicate poor HVAC control, airflow or envelope issues. On a case-by-case basis, the energy use caused by a high number of personal comfort devices could be considered in the economic analysis of HVAC or envelope energy conservation measures.

Another interactive affect involving plug loads is the trend for lighting designs with lower installed lighting power density (highly regulated by codes) resulting in increased task lighting loads (not typically regulated by codes). While studies have shown plug loads to be a signification portion of energy end use (Moorefield 2008) the practice of reducing installed lighting power densities in favor of task lighting (plug loads) can serve to increase plug use, increasing the potential benefit of plug load reduction strategies. Finally, one of the inputs to energy modeling software is plug load densities and schedules, and the shift to increased plug loads and less lighting loads adds more variability to this already challenging aspect of energy simulation. However, this study provides some guidance. Energy modelers should take note that average energy densities due to plug loads was found to be 0.77 W/SF, as little as 0.58 W/SF with the high outlier (1.25 W/SF) removed.

References

Acker, B., Duarte, C., Van Den Wymelenberg, K., (2012). Office Plug Load Profiles*;* Technical Report 20100312-01 Integrated Design Lab, University of Idaho, Boise, ID. www.idlboise.com/papers

Chetty, G., Bernheim Brush, A.J., Meyers, B.R., Johns, P., (2009). Its Not Easy Being Green: Understanding Home Computer Power Management. CHI 2009, April 4-9, 2009, Boston, MA. (ACM 978-1-60558-246-7/09/04)

EIA. (2006). Annual Energy Outlook 2006. Department of Energy, Energy Information Administration, Washington DC.

Heaters, Computers, Cell Phones Chargers: How Plugged In Are Commercial Buildings? (LBNL-62397). Berkley CA. Lawrence Berkeley National Laboratory

Itron Inc. (2006) California Commercial End-Use Survey. California Energy Commission, CEC-400-2006-005

Jackson, M., (2000). Are you sleeping? Understanding hibernation, standby, and other power management features. [on-line]. Available: http://articles.techrepublic.com.com/5100-10878_11-1056082.html

KEMA, (2006). End-Use Load Data Update Project Final Report. Phase 1: Cataloguing Available End-Use and Efficiency Measured Load Data.

Moorefield, L., Frazer, B., Bendt, P. (2008). Office Plug Load Field Monitoring Report. Durango, CO: Ecos

Moorefield, L., Mercier, C., (2011). Commercial Office Plug Load Savings Assessment. PIER Program: Evidence-based Design and Operations, CEC #500-08-049. Durango, CO:Ecos

NWPCC-RTF, (2011). Unit Energy Savings Measure - Commercial: Smart Plug Power Strips, [online] Available: http://www.nwcouncil.org/energy/rtf/measures/measure.asp?id=113

Roberson, J.A., Webber, C.A., McWhinney, M.C., Brown, R.E., Pinckard, M.J., Busch, J.F. (2004). After-hours Power Status of Office Equipment and Energy Use of Miscellaneous Plug-Load Equipment. (LBNL-53729-Revised). Berkley CA. Lawrence Berkeley National Laboratory

Sanchez, M., Webber, C., Brown, R., Busch, J., Pinckard, M., Roberson, J. (2007). Space Heaters, Computers, Cell Phones Chargers: How Plugged In Are Commercial Buildings? (LBNL-62397). Berkley CA. Lawrence Berkeley National Laboratory

Webber, C., Roberson, J.A., Brown, R.E., Payne, C.T., Nordman, B., Koomey, J.G. (2001). Field Surveys of Office Equipment Operating Patterns. (LBNL-46930). Berkley CA. Lawrence Berkeley National Laboratory