Reducing Office Plug Loads through Simple and Inexpensive Advanced Power Strips

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ABSTRACT

As efficiency gains are made in building lighting and HVAC systems, plug loads become a greater percentage of building energy use and must be addressed to meet energy goals. HVAC and lighting systems are targeted because they are typically the highest energy end uses, but plug load reduction and control should be considered as part of a comprehensive approach to energy reduction. In a minimally code compliant office building, plug loads typically account for 25% of the total electrical load. In an ultra-efficient office building, plug loads are typically one of the last end uses to be considered for energy conservation and, as a result, can account for more than 50% of the total electrical load (Lobato et. al, 2011). Plug load efficiency strategies are different than other building efficiency strategies because they involve relatively small loads distributed throughout a building. These loads typically move around in the building when office configuration changes are made, so these loads may shift between circuits over time. Commercially available advanced power strips (APS) can be used to mitigate wasted energy from most plug loads and, in many cases, can have a return-on-investment of approximately two years or less. In recent technology demonstrations, data from occupancy sensors tracking plug load reductions with occupancy have shown energy-saving potential for both business and nonbusiness hours. Also, dense panel-level sub-metering has been used to quantify whole-building receptacle circuit energy consumption, energy savings, and return on investment for the whole building. Receptacle-level metering has been used to show the plug load energy consumption of individual devices and workstations. This paper documents the process (and results) of applying advanced power strips with various control approaches.

INTRODUCTION

Advanced power strips (APS) have been tested in numerous demonstration projects and wide-scale deployments. Basic mechanical schedule timers have been commercially available for a long time, while newer electronic, logic-based controls have started becoming commercially available over the past three to five years. There are an abundance of APSs that offer a variety of complexity, control strategies, data collection abilities, and costs. Some APSs come with a web-based dashboard that allows users to implement and change control strategies, as well as look at the real-time energy consumption of plug loads in their buildings. This centralized, web-based approach to plug load management is novel because conventional plug strips typically have to be configured and controlled locally.

Plug load energy savings are achieved when the device is either transitioned to a low-power state, or it is de-energized to eliminate the power draw. Both can be executed either manually or automatically. A low-power state is between a de-energized state and a ready-to-use state, such as standby, sleep, hibernate, and "off" state with parasitic power draw. A de-energized state is when electricity is not being provided to the device, such as physically disconnecting or unplugging the power cord from an electrical outlet.

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Commercially available APSs offer a variety of control approaches, including manual control, automatic low-power state, schedule timers, load-sensing, occupancy, and vacancy. This paper describes each control approach in more detail and presents multiple case studies demonstrating plug load controls.

Manual Control

Built-in power buttons, shutdown procedures, or switched power strips are among the most common manual controls for plug loads. Switches, whether built into a device or on a power strip, provide a quick and easy manual method of powering down electronics. Other devices, such as computers, may have a shutdown procedure that users must perform to shut down the device. For some devices, manual control is the best or only method. The energy savings potential for this type of control depends entirely on user behavior.

Automatic Low-Power State Control

Built-in automatic low-power state functionality, such as standby or sleep, can often be a very effective energy saving approach. Idle time can be monitored by internal processes, causing the device to power down to a low-power state when it has been idle for a given period of time. Automatic low-power states provide limited control but are often the most accessible (and inexpensive) and effective when configured correctly. The prime example of this type of control is a computer entering a “sleep” mode. One hurdle with low-power state control is ensuring that the information services departments are enabling the appropriate settings and utilizing newly available updating techniques (such as wake-on LAN) to enable both low-power states and effective business operations.

Schedule Timer Control

Certain devices are used during the same times each day or at regular intervals, causing them to have predictable load profiles. Predictable plug loads can be effectively managed with schedule timers, which apply user-programmed schedules to de-energize and energize the device to match its pattern of usage. A schedule timer control can take multiple forms, such as electrical outlet timers, power strips, or centralized circuit controls. Schedule timer controls are generally straightforward, consistent, and reliable, but target only the energy that is wasted during nonbusiness hours.

Load Sensing Control

A device, such as a computer, may operate in conjunction with other devices, such as a monitor or other peripherals. Load-sensing control automatically energizes and de-energizes secondary devices (e.g., monitor or other peripherals) based on the “sensed” power load of the primary device (e.g., computer). If the primary device goes into a power state below a given threshold, the load-sensing control can power down the secondary devices. Load-sensing control may save more energy than scheduling control because it can reduce energy use during business and nonbusiness hours. However, it is a more complex control approach and relies on the built-in automatic low-power state functionality in the primary device.

Occupancy Control

Plug load energy savings are accomplished when devices are de-energized or transitioned into a low-power state when not in use, which for many instances, can be determined by whether or not the occupant is in the vicinity of the device. Occupancy control energizes plug loads only when users are present and de-energizes them when the space is vacant. This approach pinpoints the main source of wasted energy at workstations and has a high energy savings potential because it reduces energy use during business and nonbusiness hours. However, it is a more complex control, and depends on proper sensor placement and sensitivity.

Vacancy Control

Currently, vacancy control is not commercially available for plug loads but is commonly implemented in lighting controls because it effectively reduces energy. Vacancy control is a slight modification to occupancy control; it energizes a plug load when it receives manual input from a user and de-energizes the plug load automatically based on lack of occupancy. Plug loads that are needed only when users are present (e.g., task lights, monitors, and computers) would be good applications of vacancy control. This approach also has the highest potential for energy savings at workstations because the plug load will stay in a de-energized state until a user manually energizes the device, thus eliminating the wasted energy associated with false positives.

OCCUPACY CONTROL CASE STUDY

A demonstration project of plug load occupancy control was conducted at the U.S. Environmental Protection Agency (EPA) Region 8 Headquarters located in Denver, Colorado, from February 2011 to June 2011. This research study was undertaken in an effort to identify effective ways to reduce plug load energy. A centralized occupancy control approach was implemented on a sample of 126 occupant workstations in the building, to de-energize circuits feeding groups of six or eight cubicles. An automated energy management system de-energized the circuits when all cubicles in a group were unoccupied for a given period of time. This demonstration project also examined the influences of behavioral change on plug load energy consumption, which is not discussed in this paper.

A four-week baseline was established to quantify normal operating conditions. Occupancy controls were enabled to de-energize plug load circuits after 15 minutes of no occupancy in a group of cubicles. Energy savings of the occupancy controls were quantified by comparison to the baseline.

Energy Savings Results

The study found that the occupancy control was an effective method for reducing plug load energy consumption. Figure 1 shows workstation occupancy rates were found to be significantly less than building occupancy rates, contributing to the high energy savings potential of occupancy controls during business hours.

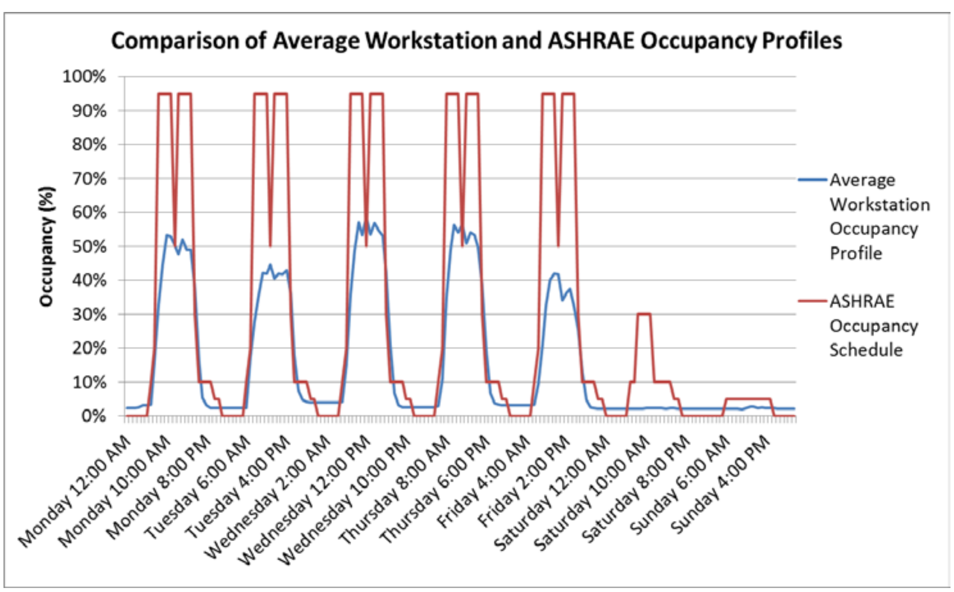

Figure 1 Comparison of the average workstation occupancy rates observed during the demonstration project compared to the ASHRAE occupancy profiles for buildings. (Credit: Ian Metzger, NREL)

The measured occupancy rates of approximately 50% during business hours confirm that control devices with the ability to track occupancy will have a higher energy saving potential at workstations. Other studies conducted by the U.S. General Services Administration (GSA) show that occupants are only at their workstations approximately 30% of the day during business hours. Energy savings for the occupant controls relative to the baseline for the 126-person test group are presented in **Table 1**.

Table 1. Occupancy Control Energy Savings Results

Plug Load Control Approach	Percent Energy Reduction from Baseline
Occupancy Control	21%

Energy savings were found to be significant during both business and nonbusiness hours. Occupancy control was found to have higher energy savings than the behavioral change methods examined in the demonstration project. It is important to note that only workstations were examined in this demonstration project. Shared equipment in common areas (e.g., kitchens, break rooms, print rooms, conference room, etc.) were not included in this study. Higher energy savings are conceivable if all office plug loads are controlled appropriately.

Lessons Learned

Collecting occupancy data can be a sensitive issue, which may require protocols to be followed that would ensure occupant anonymity could be maintained. Anonymity is typically required for field research and should be included in dashboard interfaces for displaying data.

Installation of the control and submetering system took longer and was more costly than expected. The wired installation of the control system and communications were very cumbersome and complex. Wireless communications and controls with "plug and play" installation are expected to have less complexity, are quoted at lower costs, and are currently commercially available. However, wireless communication reliability can be an issue and cyber-security at federal facilities will be a hurdle for all dashboard and data storage submetering systems. It is often more efficient to set up an independent wireless network for the submetering system.

Developing the appropriate plug load management process can have a significant influence on the success of energy reduction goals. This may include behavioral change mechanisms, control systems, or other policies. Establishing a program champion, developing a business case, benchmarking, identifying occupant needs, selecting equipment, controlling equipment schedules, institutionalizing reduction measures, and promoting occupant awareness can all be critical steps in the process.

SCHEDULE TIMER AND LOAD-SENSING CASE STUDY

A demonstration project of plug load schedule timer and load-sensing control with APS was conducted by GSA's Mid-Atlantic Region. According to several energy assessments of GSA's buildings conducted by the National Renewable Energy Laboratory (NREL), plug loads account for approximately 21% of the total electricity consumed within a standard GSA office building (Metzger et al., 2012). This project tested the effectiveness of two types of plug load control strategies: schedule timer control and load-sensing control. An APS that provided both control approaches and submetering was deployed in seven GSA field offices.

This study aimed to measure the holistic energy consumption of an office, including shared equipment and common areas, such as break rooms and print rooms. Overall, 295 devices were monitored during the study, which consisted of a baseline and two subsequent test periods, each 4 weeks long.

Energy Savings

The study found that the schedule timer control was an effective method for reducing plug load energy consumption in all space types, but most notably in the common areas, such as print rooms and break rooms. **Table 2** shows the energy savings from schedule timer controls for different space types in a typical office environment.

Table 2. Schedule Timer Control Energy Savings Results by Space Type

Space Type	Percent Energy Reduction from Baseline
Workstation	26%
Print Rooms	50%
Break Rooms	46%

Load-sensing control was only found to be moderately effective at reducing plug load energy consumption. The low energy saving results at workstations was attributed to the fact that GSA computers were being controlled by a centralized computer power management system. Computer power management is an example of automatic low-power state control. This centralized system was already putting computers and monitors into low-power states, therefore limiting the energy savings potential for this demonstration project. It should be noted that this can be a low/no-cost measure that, properly implemented, can effectively control computer power consumption. **Table 3** shows the energy savings from load-sensing control for different space types in a typical office environment.

Table 3. Load-Sensing Control Energy Savings Results by Space Type

Space Type	Percent Energy Reduction from Baseline
Workstation	4%
Print Rooms	32%
Break Rooms	N/A

Lessons Learned

Although schedule timers were found to have higher energy savings, they were only able to achieve energy savings during nonbusiness hours. In contrast, load-sensing control was able to achieve energy savings during both nonbusiness and business hours, but relied on good occupant behavior or the proper computer power settings to put the computer in sleep mode. In general, schedule timer and load-sensing controls are effective in saving energy for office equipment and can be economical if applied properly. The deployed APS had a manufacturer's suggested retail price (MSRP) of $120 per plug strip. However, there are advanced plug strips on the market that incorporate these technologies and have an MSRP of approximately $20 to $60, although these less expensive APSs typically do not provide submetering capability.

Submetering data are valuable in spotting wasted energy use, informing the future procurement of low-energy equipment, and identifying equipment that is behaving erratically (which is often a precursor to equipment failure). These data are also valuable to building energy modelers, allowing them to more accurately model plug loads in a building. However, the increased cost is typically not economical unless data are actively managed by onsite personnel. It was difficult to set the load threshold for some equipment, such as computers and monitors. The complexity of the load-sensing control resulted in instances where the equipment was being de-energized when the occupants needed them to be energized. Occupant feedback indicated a lack of training/instruction with the devices leading to limited understanding of their operation in some instances. Schedule timer controls are simple and easy to understand for users, which led to larger energy savings in this study. Load-sensing control is more complicated and difficult to understand, leading to complaints and disabling in some instances, which resulted in limited energy savings. More detailed training and maintenance could have made load-sensing control more effective.

INEXPENSIVE SCHEDULE TIMER CASE STUDY

A demonstration project of simple inexpensive schedule timer control with APS was conducted at an office building in Honolulu, Hawaii, from November 2012 through May 2013. The deployed APS could only be controlled locally, each device had to be programmed individually, and no built-in submetering capability existed. Therefore, the programmed schedule timer control was set to be more conservative to accommodate the schedules of different users. This project tested the effectiveness of schedule timer control deployed on a whole building rather than a small sample size as in other demonstration projects. APSs were deployed throughout the entire building, capturing all plug loads.

This study aimed to measure the whole building energy consumption of office plug loads using dense panel-level submetering and calculated energy savings associated with inexpensive schedule timer controls. A total of 689 plug load devices were monitored during the study, which consisted of baseline and test periods, each 4-6 weeks long.

Energy Savings

The study found that the schedule timer control is an effective method for reducing plug load energy consumption in all space types and for all occupant types. Plug loads at the demonstration building are estimated to account for approximately 22% of the whole building energy consumption. **Figure 2** shows the whole building plug load average daily usage profile, comparing the baseline to the schedule timer control. Energy savings are achieved only during nonbusiness hours. Some variation is observed during business hours, which is not attributed to the control devices but an indication that occupant behavior varied between the uncontrolled and controlled phases of the project. Occupancy and behavior are uncontrolled variables; however, occupancy data was collected and used to normalize the energy data in an attempt to remove the variability between the two phases.

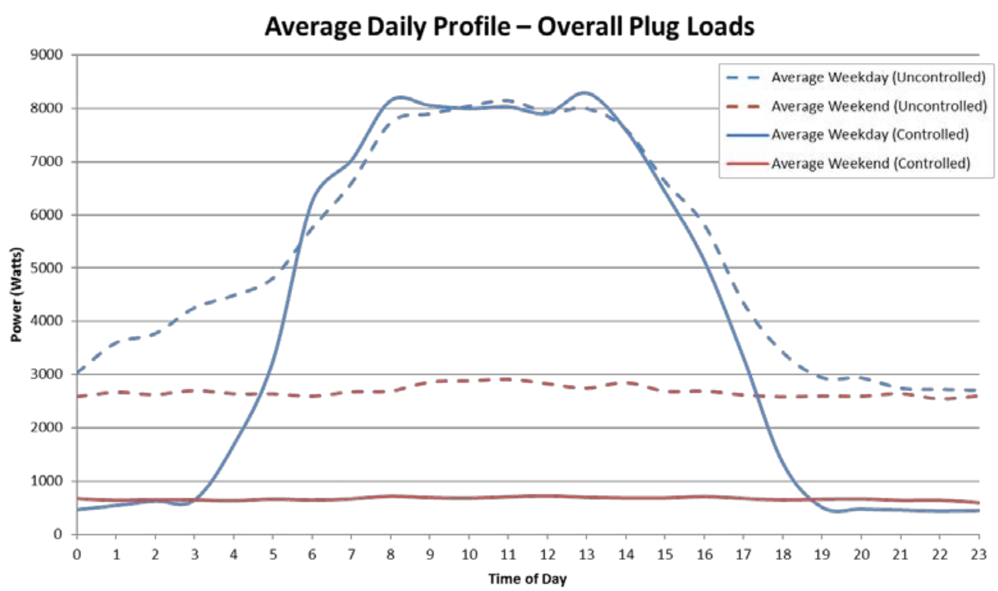

Figure 2 Baseline and APS schedule timer control plug load energy consumption profiles. (Credit: Michael Sheppy, NREL)

Energy savings were analyzed by space type to identify applications with the highest energy savings, for prioritized deployment. **Figure 3** shows the energy savings by space type. Print rooms, open offices, and hallways were found to have the highest energy savings.

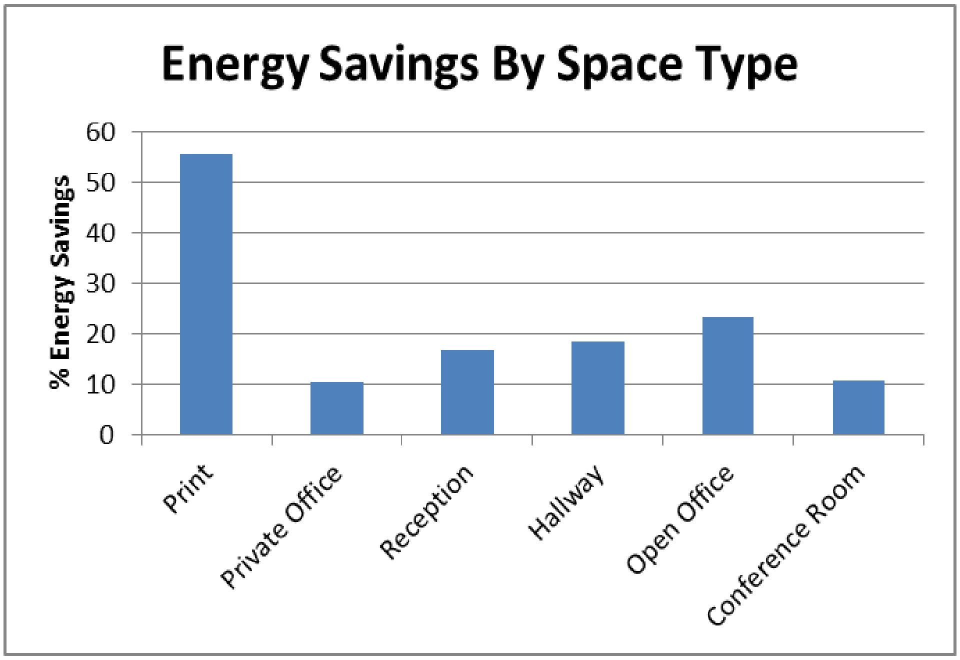

Figure 3 Energy savings by space type. (Credit: Michael Sheppy, NREL)

Measured data was extrapolated to predict annual energy savings using eQUEST energy simulation software developed by the U.S. Department of Energy. Reduction in plug load energy consumption is expected to reduce the energy required for the air conditioning system. **Table 4** shows the modeled energy savings from schedule timer controls for different energy systems.

Table 4. Schedule Timer Control Energy Savings Results by Space Type

Energy System Type	Percent Energy Reduction from Baseline
Plug Loads	28%
Air Conditioning	5%
Whole Building	***8%***

Lessons Learned

Simple and inexpensive schedule timer APSs can be effective in whole building deployments. However, schedule timers are unable to capture energy savings during business hours when occupants are not at their workstations. These devices are easy for the occupants to understand and operate, resulting in higher acceptability in wide-scale deployments. Schedule timer APSs are typically inexpensive, approximately $20 or less MSRP, and can result in payback periods of less than 2 years if applied properly.

CONCLUSION

Advanced power strips with various control approaches are commercially available and have been proven to save energy. However, selecting the appropriate control approach is critical to achieving maximum energy savings. Different equipment types require different control approaches. For example, control approaches that track occupancy, such as load-sensing, occupancy, and vacancy controls, should be applied to equipment found at workstations, such as computers, monitors, and task lights. Schedule timers should be applied to shared equipment, such as printers, coffee makers, and water coolers, but can also be effective at workstations as an alternative to automated computer power settings. However, it is also very important to understand the built-in capabilities of a device, such as automatic low-power states, and how the built-in capabilities may interact with the control approach (e.g., load-sensing). In all cases, it is important for the occupant to understand the purpose and operability of any APS. Therefore, education is paramount when considering the deployment of advanced power strips.

Potential barriers for APSs include: occupant acceptance, communications, lack of personnel time for analysis, and complex controls in some instances. These devices may require operation and maintenance to update controls, manage data, and troubleshoot incorrect operations and communication failures on a regular basis. All control strategies should provide manual override to accommodate atypical times when a plug load device would not normally be in use (e.g., using a device outside normal business hours). APSs may create a parasitic load, which must be included in the analysis of total costs savings potential.

There is the opportunity for significant energy savings through appropriate deployment of APSs. These savings can achieve very attractive returns on investment due to the low cost of certain APS devices. This has been proven with schedule based control in two case studies discussed here. There is significant opportunity for more precisely tuned control of the plug and process loads utilizing occupancy or vacancy control, but a commercially available system that accomplishes this effectively (both in effort and cost) has not been perfected.

Sub metering data are valuable in spotting wasted energy use and identifying equipment that is behaving erratically, but the increased cost is typically not economical unless data are actively managed by onsite personnel. A more effective feedback loop to the end users than the currently available web dashboard approach will be necessary to achieve higher levels of savings for submetering.

Research has been conducted on appropriate control approaches for different types of equipment and published resources are available, such as Assessing and Reducing Plug and Process Loads in Office Buildings (NREL, 2012) and Selecting a Control Strategy for Plug and Process Loads (Lobato et al, 2012). These documents provide a methodical approach to assessing and determining the appropriate control mechanism for different plug loads. Selecting the appropriate control approach and considering lessons learned from the presented case studies will help to make future deployments more effective and increase plug load energy reduction in office buildings.

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