Field Study of Tier 2 Advanced Power Strips

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Executive Summary

Background and objective

Plug load energy used by everything from computers to water coolers represents a relatively untapped energy savings resource in commercial buildings. And these loads, defined as all electric end uses that are not HVAC, lighting, or domestic hot water, are increasing (CBECS 2016). This is especially true in contrast to other end uses. There is a need for those in the commercial buildings industry to both identify and quantify strategies for reducing these loads.

Slipstream, in partnership with the Center for Energy and Environment and LHB, have completed a field research study to demonstrate and measure the savings from Tier 2 Advanced Power Strips (T2 APS) in office buildings. We also characterized the types of devices and baseline usage in those offices, and documented occupant acceptance, operational issues, and cost-effectiveness of the T2 APS.

We used what we learned to identify actions that utilities and policy makers could take, including increasing the impact of these strategies in Conservation Improvement Programs (CIPs) in Minnesota. We also put plug loads into context and established some best practices for building designers and operators.

Approach and initial measurement

This study is intended to be a supplement to a previous CARD funded plug load study completed in 2016. We selected a sample of three buildings for further field data collection. Baseline data was collected in each of those offices. Next, we implemented the T2 APS. We tested two different APS, an Embertec 8PC+ and a Tricklestar PC Advanced PowerStrip+, each separately. After these strategies were implemented, we collected more data, and surveyed occupants to gauge their satisfaction.

For the three offices that were monitored in detail, we found that the average workstation used 364.9 kWh per year. Slightly over half of that energy was generally consumed by the computer itself (whether laptop or desktop) and the remainder was consumed by monitors, electronics, and peripherals.

Energy savings

We implemented two different T2 APS devices in workstations and directly measured the energy savings from each. Each site received both power strips, however the same participant never received both power strips – randomly selected participant received either Device A or Device B. Based on the table above, and our lessons from the field, several conclusions can be drawn:

- Device A (Embertec 8PC+) saved on average 28% of a workstation's energy consumption or 98 kWh saved per workstation. From the 2016 study, this is comparable to computer power management.
- Device B (Tricklestar PC Advanced Powerstrip+) had lower savings across the board. There was some concern with whether the device was working at times. This device saved 8% of a workstation's energy consumption or 29.4 kWh saved per workstation.

Economics

The power strips we tested had costs of $99.99 (Embertec) and $69.99 (Tricklestar). We used life-cycle cost analysis to analyze the cost effectiveness of each strategy, using break-even cost as a key metric (the cost at which the installation makes financial sense). For a typical private organization, the break-even cost for Device A was found to be $147 per workstation, higher than it likely would cost most firms to implement this device. The break-even cost for Device B was $44, which is lower than it would cost most firms to implement the device. Simple paybacks for Device A and Device B were 7.6 and 14.2 years, respectively. (See Table 7 in the *Economics of plug load strategies* section for details.)

Participant satisfaction

Our survey of research participants suggests that their satisfaction with the T2 APS is very similar to what was found in the 2016 study for computer power management. Our key takeaway is that in most cases, users are not receptive to the computer power management strategy (whether it is implemented with a T2 APS or with a simple onboard settings). This strategy is typically the largest energy saving strategy that can be implemented at a workstation making continued efforts to improve acceptance worthwhile.

Recommendations

Results from our study suggest the following recommendations for Minnesota's CIPs:

- At a minimum, focus on implementing computer power management.
- Identify which technologies work best in specific environments.
- Provide incentives and technical support/assistance to increase adoption.
- Consider more innovative program approaches beyond a basic incentive.
- Integrate CPM or T2 APS into more holistic programs like retrocommissioning and turnkey small business programs.
- Incorporate plug load research lessons into new construction programs.
- Develop a strong relationship with IT departments.
- Inclusion in TRM should also cover performance specifications for the devices.

We also translated these lessons learned for office owners, operators, and designers. These stakeholders could benefit from working more closely with IT to improve T2 APS or CPM adoption. They should also know that the T2 APS strategy is most cost effective when adopted at the time a power strip needs to be purchased. Lastly, this study confirms findings from the 2016 study that show behavior is a critical component to computer power management and T2 APS. Users must be educated and encouraged to use the devices to increase acceptance and adoption of this technology.

Introduction

Workstation plug load energy used by everything from computers to space heaters remains a relatively untapped energy savings resource in commercial buildings. According to a recent building energy study, these loads, defined as all electric end uses that are not heating, ventilation, air conditioning (HVAC), lighting, or domestic hot water (DHW), are increasing (CBECS 2016). This trend is more apparent as energy use from other end uses such as HVAC and lighting have decreased, driven by energy code and technology advancements. In Minnesota, the average plug load energy use in office buildings was about 2% (or 2 kBtu/ft^2/year) in the 1970s and has grown to 15-25% (or 12-20 kBtu/ft^2/year) in an average building today. This percentage is expected to increase as energy use from other building end uses continues to decrease.

Plug load energy use is most critical in building projects that are striving for a much lower energy use intensity (EUI), based on targets such as LEED or Architecture 2030. These buildings are often being designed to attain building EUIs of below 40. With rising plug loads, it can mean up to 50% of that target EUI is consumed by plug load devices. In other words, uncontrolled plug load usage is making it increasingly difficult to meet energy performance goals for high performance buildings.

As a result, there is a need to both identify and quantify specific strategies for reducing these loads. A previous study sponsored by the Department of Commerce evaluated several energy saving strategies (Hackel 2016). Since the completion of the previous CARD study, a new Tier 2 Advanced Power Strip (T2 APS) product has come on the market and appears to offer increased energy savings. Currently, there is insufficient data to validate the savings potential of these devices in commercial buildings. This study supplements the previous study by providing savings data for T2 APS.

In this study we evaluated workstation plug load energy usage in office buildings in Minnesota. We installed and monitored two different T2 APS at 81 total workstations across three different commercial office buildings. The data from this study provides some of the first insights on the energy impacts of T2 APS in commercial office buildings.

Objective

The primary objective of the study was to demonstrate and measure the savings from T2 APS in commercial buildings. In addition to testing T2 APS in a sample of buildings and measuring the energy impacts, other objects of the study included:

- Characterizing the electricity consumption and type of plug load devices in Minnesota offices
- Identifying key savings strategies for plug load reduction in such buildings
- Documenting occupant acceptance, operational issues, and cost-effectiveness of the installed strategies

- Understanding plug load energy usage in the broader context of building design and operation (as compared to other end uses, total building energy, and other design and code considerations)
- Identifying actions that utilities and policy makers could take based on the results of the study including inclusion of this strategy in Conservation Improvement Programs (CIPs) in Minnesota

The remainder of this report presents the approach and results of our broad field study and subsequent analysis, as well as qualitative lessons learned from the occupant and operational observations. We close with some conclusions pertaining to utility CIPs as well as building owners and operators.

Literature Review

The study of plug load energy use in commercial office buildings has only been significant in the recent past. One study (Dirks 2012) developed several theories as to why plug loads have not been at the forefront of building research. Plug loads were found to be an undefined problem with few clearly identified solutions, and therefore less likely to get research funding. The high cost of metering plug loads was also identified, especially compared to the possible savings. The study concluded that better understanding of plug load usage was needed both to justify and appropriately allocate resources. Despite these barriers, plug load research has increased in recent years, and we were able to review about 30 separate studies.

One of the earliest comprehensive field studies (Sanchez 2007) audited 16 U.S. office buildings and documented all miscellaneous and office equipment end uses. The number of units were counted, energy usage was estimated, and "turn-off rates" were determined. The study also calculated the plug load use as a percentage of total building energy usage and found ranges of 11-19%. This did not correlate well with other recent estimates that nearly 50% of total office building electricity was consumed by these end uses. This discrepancy led us to conclude that the method of modeling plug loads needed to be examined in more detail and that bottom up determination of plug load energy usage has limitations.

Two studies focused on the design of field metering studies such as ours. In one (Lanzisera 2013), researchers attempted to determine the breadth of a field study required to obtain quality data. Based on one building over an 18-month period, their conclusion was that inventorying 50% of the area for devices, and metering 10-20% of key devices over a two-month time period at one-minute intervals would generate the most representative data. The second study (Brown 2010), tested metering methodologies at four national labs and ten buildings. Multiple meters were tested, and one was even developed within the lab for the project. The primary outcome of this study is a series of recommendations suggesting further development of data collection methodologies, continued and expanded data collection, improvements in metering technology and utilization of the collected data. Both of these studies informed the experimental method for our study.

The availability of commercial test data for T2 APS is limited to one publicly available study published by San Diego Gas and Electric. Results of this field evaluation of T2 APS devices showed annual energy savings of 336-371 kWh for office and computer lab workstations (SDG&E 2015). Twenty-six computer lab workstations and 25 office workstations were tested. Workstations were in use for about 31 hours per week.

Our study takes the research further by involving a variety of office types in Minnesota buildings and introducing the power strips to a larger number of workstations than previously studied. In addition, our study is conducted primarily at the workstation level, measuring energy usage and savings of the entire workstation, as well as satisfaction of each workstation occupant with plug load control.

Research Method

The research design for this project involved:

- identifying 3 offices in Minnesota for participation - drawn from the 2016 study,
- collecting baseline data from these offices,
- implementing T2 APS in those offices,
- measuring energy reduction resulting from the T2 APS and surveying occupants on their experience and satisfaction

Discovery

Sites to study

Three buildings were selected for on-site measurement from the characterization survey respondents in the 2016 study. To be eligible for our field study, the office had to have more than 40 workstations (for statistically significant results) and be willing to participate. Because there is a large diversity in office types there was no ability to make the sample statistically representative of Minnesota offices; there is therefore selection bias in our subset of buildings for the field study. We did attempt to make the sample diverse; it included all types of offices: public and private, owned and leased, small and large, standalone and connected to other building types (e.g. labs, service buildings, etc.). Two of the field study sites were in the Twin Cities Metropolitan area of Minnesota, though in different communities within that area. The third site was in Duluth, Minnesota. The three office spaces we chose for deeper study are described in Table 1.

Table 1. Characterization of the eight office spaces chosen for in-depth study and full measurement.

Location	Name (used in report)	Conditioned area (ft^2)	Space ownership	How organization pays for utilities	Occupants	Organization type	Activity / program of the space studied
Site A	Architecture	34,135	leased	Part of rent	122	Private	Architecture and engineering
Site B	City office	78,000	owned	part of rent	340	Public	Public service in city government
Site C	Engineering	78,000	leased	part of rent	265	Private	Engineering department in architecture firm

Installed saving strategy

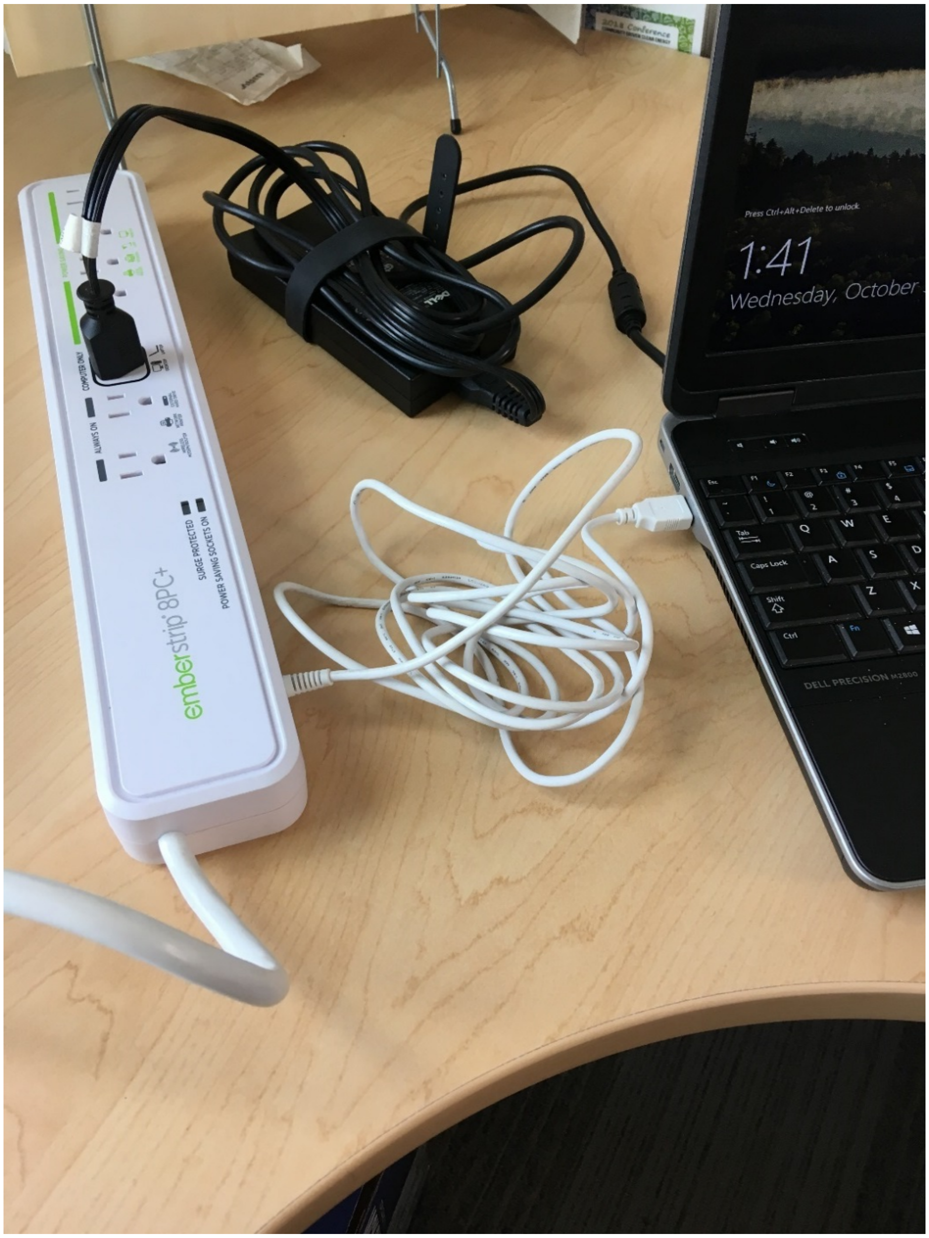
This study utilized two different T2 APS manufacturers; Embertec and Tricklestar. This report will refer to these as Device A and Device B.

- Device A: Embertec 8PC+, Model: Emberstrip Computer (PC) ESUSPC8-ET-10, Software Version: 2_0_00_62
- Device B: Tricklestar PC Advanced PowerStrip+, Model: 181SS-US-7XXX-N, Occupancy Sensor TS1910, Model: 188LV-XX-MSIT-XCTBQ

These two T2 APS devices are currently available on the market, although other devices may be available at the time of this report. The T2 APS technology incorporates both the standard T1 APS technology – which powers down select outlets on the power strip when the workstation is not in use, with computer power management (CPM). The power strip saves energy when a workstation is not in use in two separate ways. First, it puts the computer into computer power management, which decreases computer consumption. Second, at the same time, it also switches off outlets which peripheral devices would be plugged into – eliminating stand by energy consumption from peripheral devices. Both devices feature on online portal where an administrator can download logged data (to determine energy savings) or alter the power saving settings of the power strips.

While Device A and Device B both implement the T2 technology (CPM and outlet control), they do so in different ways. Device A includes a 3rd party software which is installed on the PC. The software can be installed by an IT department (pushed to multiple computers at one time) or can be installed manually on individual computers. This software provides the user multiple pieces of control. First, it allows a user to adjust the time delay to which the computer is put into computer power management and which the controlled outlets are switched off. It also allows the user to set a schedule, where the power strip can be forced to “stay on” for any period of time. This is very useful in cases where a user might need to remotely log into and control their computer. This power strip senses mouse movement and keyboard strokes to determine when a computer is active or being used. The power strip is connected to the computer via a USB cable. Device A also has onboard monitoring capabilities and can be set to record energy savings through a pre/post monitoring period. Figure 1 shows Device A connected to a laptop.

Figure 1: Device A connected to laptop.



Device B uses an occupancy sensor to determine when there is activity. The occupancy sensor delay can be set from 10 minutes to 30 minutes, in 5-minute increments. The occupancy sensor is typically mounted to the monitor via two-sided tape and is connected to the computer via USB cable to control the computer power management settings. When the occupancy sensor does not sense activity, it puts the computer into computer power management mode (communicating through the USB cable). When the computer is put into computer power management, the power strip senses a reduce power draw from the computer and shuts off the controlled outlets. This device should be plug and play out of the box. However, to have this device added to the online portal (where an administrator could view energy savings or turn on/off the energy saving mode), the device must be set up using Wi-Fi connection.

Figure 2 shows Device B connected to a laptop and Figure 3 shows the associated occupancy sensor used with Device B, connected to the laptop and mounted on the monitor.

Figure 2: Device B connected to laptop.

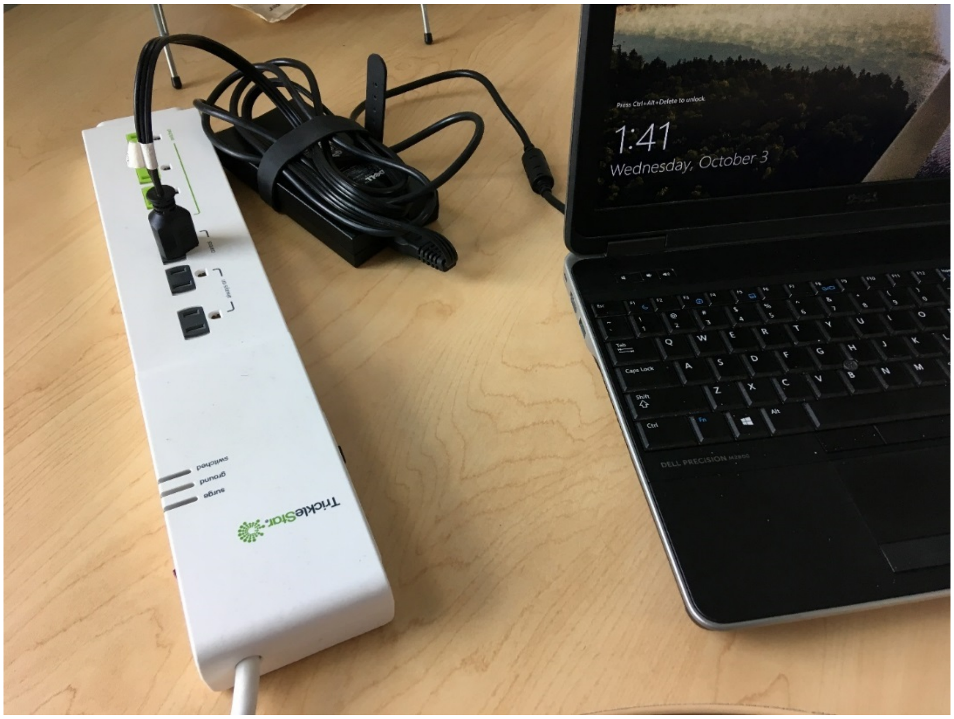


Figure 3: Device B occupancy sensor connected mounted to monitor and connected (via USB) to laptop.

Computer power management settings

Across the three sites participating in the study, there was no company-wide implemented CPM policy. At two of the sites, users were allowed to make changes to the CPM settings, however in our experience, the majority of users do not manually implement CPM. By implementing the T2 APS devices, we are implementing a CPM policy at the participating workstations. While the T2 APS manufacturers each have specific recommendations for CPM settings, (Device B recommends 10-15 minutes) our study chose to follow the ENERGY STAR guidelines for implementing CPM – which recommends a 30 minute delay to activating CPM. This decision was based on our experience in the 2016 study that more aggressive CPM settings can lead to user acceptance and persistence issues. Table 2 summarizes the initial CPM settings and T2 APS device CPM settings.

Table 2: Summary of pre-T2 APS and post-T2 APS CPM settings.

Site	Initial Setting	Setting implemented via T2 APS
Architecture	No CPM policy	30 minute delay to activate CPM
City Office	No CPM policy	30 minute delay to activate CPM
Engineering	No CPM policy	30 minute delay to activate CPM

The primary energy saving feature of the T2 APS devices is CPM. If any of the sites used a CPM policy that was less than 30 minutes, we would have implemented T2 APS devices with a CPM setting that matched or was more aggressive than what was initially found. Using a T2 APS CPM setting longer than what was initially found would likely lead to increased energy consumption.

Data collection

We collected data on energy use at the three building sites both before and after implementing the plug load reduction strategies. We also collected qualitative feedback on occupant satisfaction.

Site inventory and measurement

On-site data collection included inventory, baseline usage, and testing of energy reduction strategies, in progressive measurement periods. To facilitate these periods, participating sites were three times over the course of the study. Each visit had a different purpose:

- In the first visit we installed monitoring equipment and collected device inventories.

- In the second visit we checked on our monitoring equipment and data, and then installed the T2 APS devices at select workstations.
- In the third visit we downloaded data and removed the monitoring equipment, concluding data collection at that site.

We implemented the T2 APS strategy (see *Installed saving strategy* in more detail below) and its corresponding equipment as closely as possible to how we felt an owner or contractor would implement it in an existing office as part of an energy efficiency program.

The pre-strategy measurement that is described in *Analysis* below refers to measurements taken between the first and second visits, and the post-strategy measurement describes measurements taken between the second and third visits. These pre- and post-treatment measurement periods were all approximately one month. This was based on previous research in which measurement periods of at least four weeks were shown to reasonably reduce variability (Lanzisera 2013).

We targeted a total of 40 workstations to study at each site. This represented a balance between budget and estimated statistical significance. A control group of approximately one-third of the monitored workstations at each site allowed for correction of seasonal and other temporal variation, or other unknown factors affecting the pre-versus post-treatment comparison. This control group did not receive a T2 APS. Assignment to treatment group versus control group (versus exclusion from the study) was randomized. The desired sample size of 27 T2 APS and 13 controls at each office was independent of the total number of subjects available.

All visits were done outside of normal business hours to minimize the disruption of any individual's work activities and to mitigate our influence on the office occupants. Occupants were informed of our work in enough detail that their daily routine would not be adversely affected. A primary site contact at each site was important for addressing any questions or concerns by participants.

Baseline measurement

Prior to the first visit, we selected the 40 workstations to be monitored using a random sampling tool. These selections were marked on copies of the building floor plans that were then used by the project team. The sample included all types of workstations: individual offices, shared offices and cubicles. Unoccupied workstations were excluded, as were workstations where a person had a specific reason not to be involved in the study (there were only one or two of these at a typical office site).

For most of the installations, four people worked together on the inventory and installation so that visits took about three hours; visit time was minimized due to our need to be escorted in the offices after hours. One person on each of two teams took a detailed inventory of each workstation, including a description of each device with a plug, the type of computer(s), number and size of monitors, while the other member of each team connected the monitoring devices and counted plugs to ensure the inventory was complete.

We placed a single monitoring device at each workstation. All plug loads at the workstation were routed through this monitoring device. Figure 4 shows how we set up the metering equipment. All of the plug devices in the workspace are connected through a single data logger (Onset UX120-018) which recorded voltage (V), current (A), real power (W), energy (kWh), apparent power (VA) and power factor (PF) at one-minute intervals. These loggers have approximately six months of memory at these settings. A power strip is connected to this data logger which powered all devices at the workstation.

Figure 4. Metering configuration at a typical workstation.

Equipment measurement

Prior to the second visit, we used the randomization tool described above to divide the sampled workstations into treatment and control groups. The control group allowed us to account for environmental effects such as season, day length, and even changes in office work schedules between data collection periods of four weeks. In our second visit we implemented one of the two T2 APS at each of the treatment workstations. As previously stated, the treatment group was randomly selected. To assign the APS devices (A and B) to the treatment group, the group was divided in half (by selecting every other participant). In rare circumstances, participants who indicated that they would need the ability to log into and operate their work computer remotely were assigned the Device A which includes software which allows the user to schedule periods when the computer will remain on.

Again, four people worked together on the installation. These visits generally took about two hours. During this visit the teams also validated the original inventory of each workstation and noted any cases where the monitoring setup had been changed. In some cases, we also had communications from our site contact of any changes by participants.

Occupant satisfaction survey

Approximately one week after the final treatment was removed from each site, a post-treatment survey was sent to each participant who had a strategy installed at their workstation. This survey asked participants to evaluate each strategy installed at their workstation or on common equipment. The survey consisted of three questions and a comment section that participants could use to further describe their experiences with the technology. The survey was only delivered to those receiving a T2 APS and was the same regardless of whether the participant received Device A or Device B. From the three sites studied, 46 participants responded.

Results from the Participant Satisfaction Survey are summarized below in the *Survey results* section. The participant satisfaction survey instrument is included in Appendix B.

Analysis

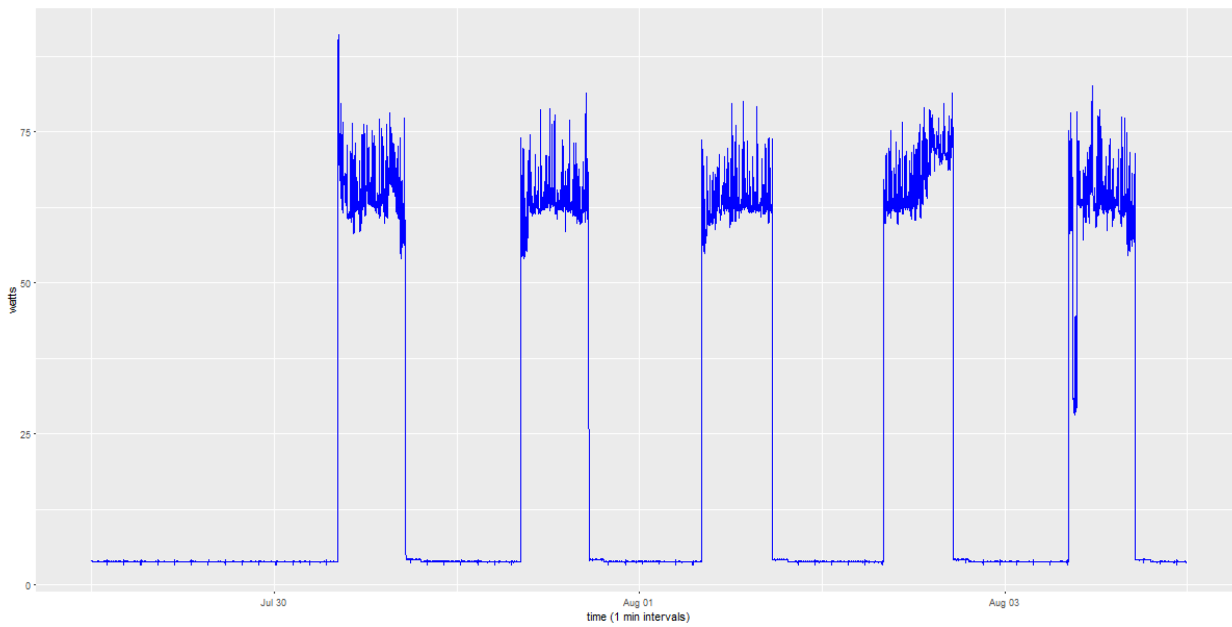
The pre- and post-strategy measurements were both checked for quality and analyzed to determine the amount of energy usage in a typical year as well as typically-expected savings.

Data quality and control

All field data and calculations from the project were compiled and organized according to individual workstations. Data were first checked for gaps and extreme outliers (negative energy usage, for example). From there, basic statistics were examined for each workstation, including the average energy usage for each day of the week, the percentage of workstation usage from computer(s) in total and during each day type, the peak workstation usage, and the peak computer usage.

Each workstation's data was then visually examined to check for data quality. Those with statistics that differed significantly from average values were investigated in even more detail, to determine why they deviated. Generally, the data exhibited a robust relationship between computer and workstation energy, and clear indication of days of the week, making it possible to quickly identify bad or missing data. Figure 5 is an example of such a visualization; data for this laptop workstation clearly represents a weekend followed by five distinct weekdays of operation.

Figure 5. Typical visualization of workstation plug load energy for quality control purposes.



Where questionable, bad, or missing data was found, it was either resolved by more detailed investigation or the workstation was removed from the set in cases where significant issues were found or large portions of data was missing.

Calculation of energy savings

The first step in analyzing the clean data was to determine the typical energy usage for each workstation or common area device. We were only able to measure each workstation for about a month, so we first extrapolated to a typical year. A primary element of variance was temporal variance across a week, from weekend to weekday to holiday, to even the type of week (for example, Fridays generally lead to less energy usage than Tuesdays), so our extrapolation was done by day type. If *E* is the energy usage of a given workstation, and *i* is a given day type, then we extrapolated to the typical annual energy usage for each workstation in a year by:

$$E_{annual} = \sum_{i=Sunday}^{Saturday} \left[E_i \times \frac{N_{i,annual}}{N_{i,measured}} \right]$$

where $N_{i,annual}$ is the number of days of type *i* in an average year, and $N_{i,measured}$ is the number of days of type *i* in our measurement period. Note that for day types we individually broke out all seven days, Saturday through Sunday, plus federal holidays as an eighth type of day. We recorded the average of E_{annual} per workstation for each site, as well as the average across all sites, and various other categories (e.g. all workstations with two monitors).

The next major metric to calculate was energy savings. We repeated the energy savings calculations below separately for each of the energy reduction strategies that we tested. The energy savings from a given strategy *S* were calculated for each workstation *j* as:

$$S_j = E_{annual,post-strategy} - E_{annual,pre-strategy}$$

where *post-strategy* denotes expected annual usage extrapolated based on measurements in the period after the strategy was applied and *pre-strategy* is based on the period before the strategy was applied. At this point we calculated and noted the standard deviation of S_j at each of the eight sites, as well as the standard deviation of S_j across all sites of a given strategy. These standard deviations were used to calculate confidence intervals for energy savings stated throughout this report.

In the initial study design, we proposed to use workstations in the "control" group to adjust calculated savings from the T2 APS to account for office-wide seasonal changes in energy consumption between months. For example, if there were significantly more vacations taken in the treatment phase than the baseline phase of the study in an office, we would expect that average usage to go down slightly regardless of where a group of workstations were using a T2 APS in the treatment period. Subtracting significant seasonal usage changes seen in the control group from the treatment groups would allow us to estimate net savings that are corrected for seasonal variations in use. However, in this study, we did not see any statistically significant changes in usage by control groups between the baseline and treatment phases of the study in each office. Given the small sample sizes in this study (n = ~10 for each treatment group), we also observed that adjusting the gross savings based upon the small changes in month-to-month usage from control groups would produce relatively large effects on the overall savings results and mask the significant change in usage caused by the T2 APS installations. For these reasons, the control group's usage data was not used directly in savings calculations.

Results

The results of the study follow the progression of the research method. First, we discuss the results of characterizing plug load devices in Minnesota offices. Then we report the baseline energy usage of devices we measured in the field and the energy impacts from reduction strategies in terms of both energy and economics. Then, results of the participant satisfaction survey are given. Finally, we close with some broader context, comparing these results to broader building energy usage. In all cases, we often draw comparisons between these results and those from a much broader study of plug load usage and savings that we completed in 2016 (of eight different Minnesota offices).

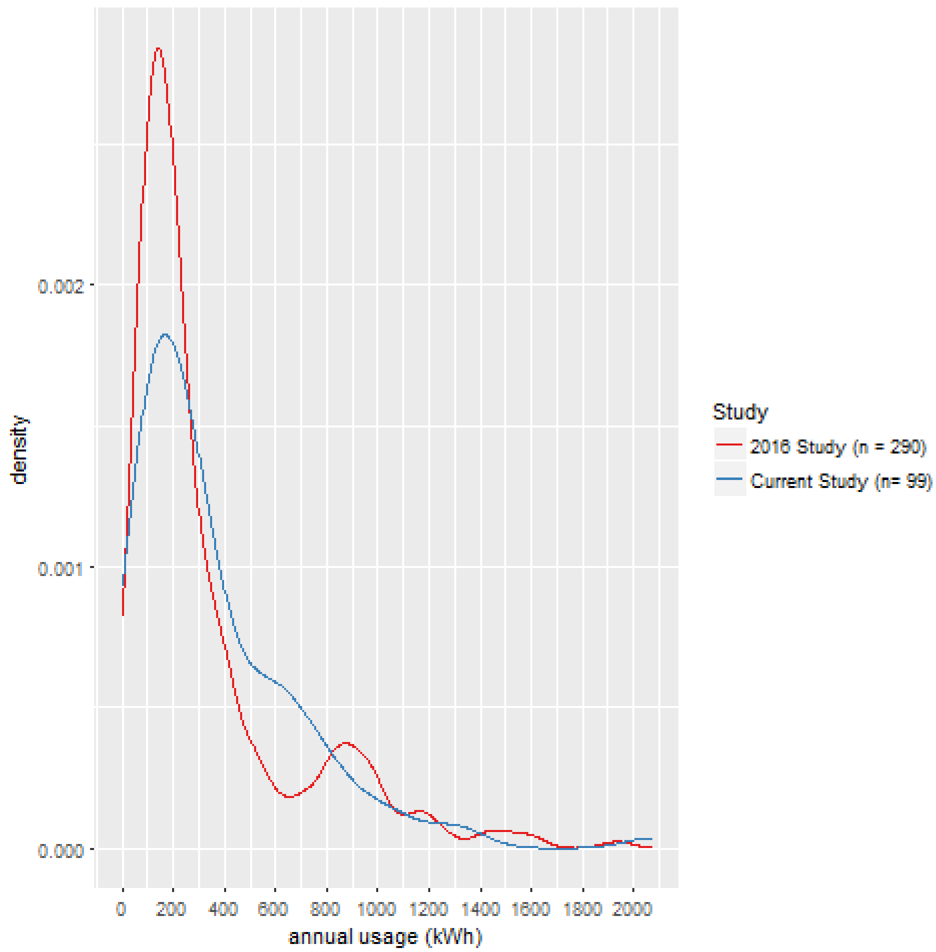
Plug load energy usage and potential for savings

Plug load energy usage is highly variable with business type, IT approach, and user behavior. We were able to measure the baseline usage of 94 workstations (36 control and 58 treatment) after statistical outliers were removed. Though not necessarily statistically representative of all offices in Minnesota, we can see some relevant trends with a sample of this size.

Baseline usage of workstations

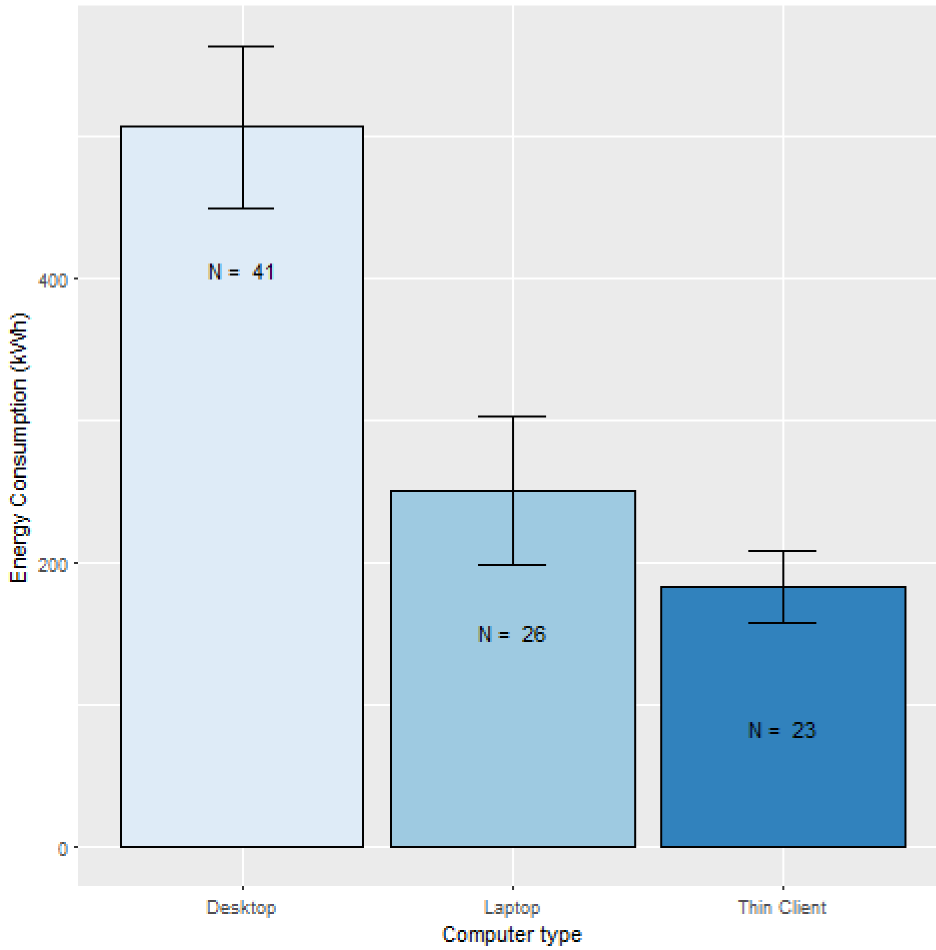
At the workstation level, energy usage varies significantly from user to user. The highest user in our study used energy at a rate of 2073 kWh/year, for a single workstation. This compares closely to our broader 2016 study, for which the highest user used 1936 kWh/year. In both cases, these users were architects with significant performance requirements at their workstation for design work. On the other end of the spectrum, there were a number of users who barely used their computing equipment; many of these users spend almost their entire day away from their workstation. In the middle, the average workstation used energy at a rate 365 kWh/year, and 70% of all workstations used less than 400 kWh/year. The (extrapolated) annual energy usage of each workstation we measured is shown in Figure 6. The data from the 2016 study is also overlaid on Figure 6.

Figure 6: 2016 study baseline data overlaid with current study baseline data.



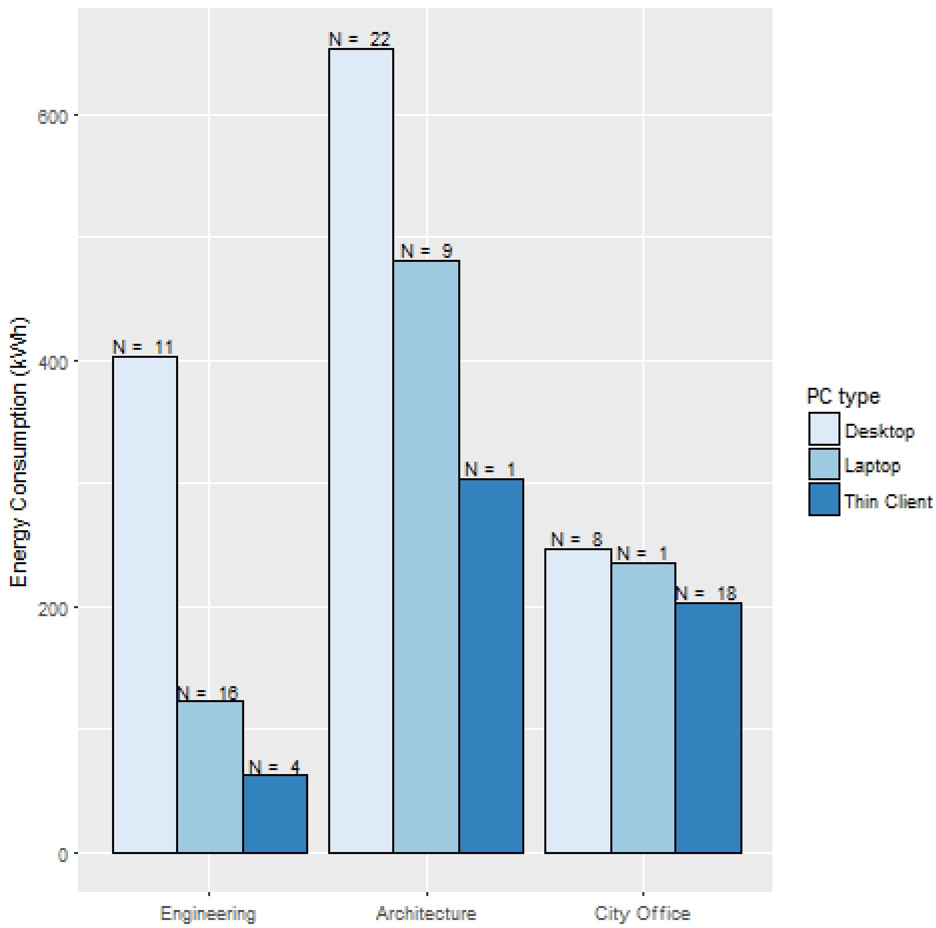
In the 2016 study we found that a workstation's total energy consumption is driven primarily by the computer, which contributed approximately 66% of the workstation's total consumption for desktops and 30% of the workstation's total consumption for laptops. In cases where the user is preforming computationally intensive tasks, the computer will contribute a larger portion of the workstation consumption. Figure 7 shows average total workstation energy consumption sorted by the type of computer configuration at each workstation.

Figure 7. Baseline total workstation consumption of desktop, laptop, and thin client workstations.



Desktop workstations use more energy regardless of activity type (engineering, architecture, city office) both because they have larger, more energy intensive components and because they are less likely to have integrated power management software. This trend is seen in Figure 8.

Figure 8: Baseline total workstation consumption of desktop, laptop and thin client workstations, sorted by office type.



From our inventory, we were able to characterize the types of other devices found at each workstation, including the computer itself. Figure 9 shows the number of desktops, laptops and thin clients found at each site for both the current study and the 2016 study. Unlike the 2016 study, our study found a larger sample of thin clients. Many of the other devices found during our inventory mirrored those found during the 2016 study; including multiple space heaters and fans. One device which increased in prevalence from the 2016 study is a device charger. We found significant numbers of these devices at each site, as shown in Figure 10.

Figure 9: Count of desktops, laptops and thin clients at each site for both the current study and the 2016 study.

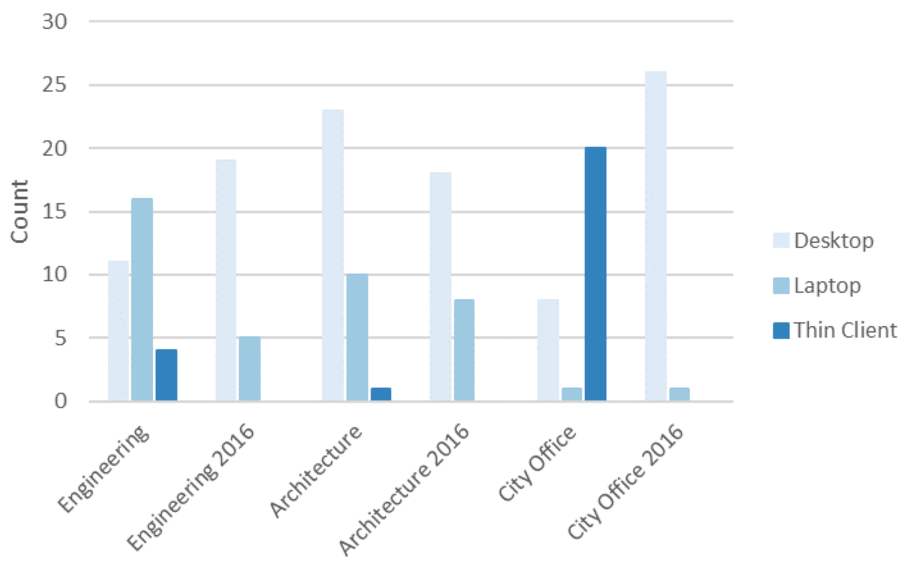
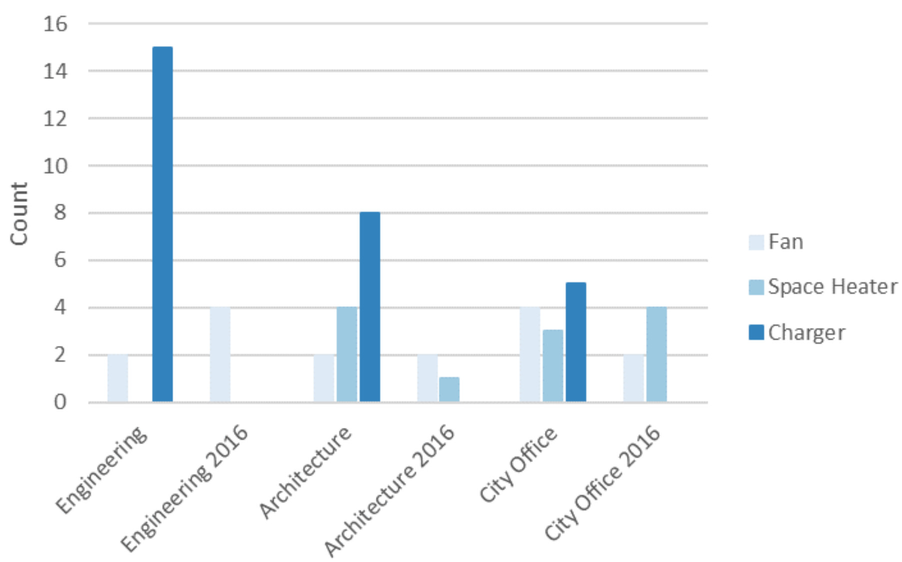
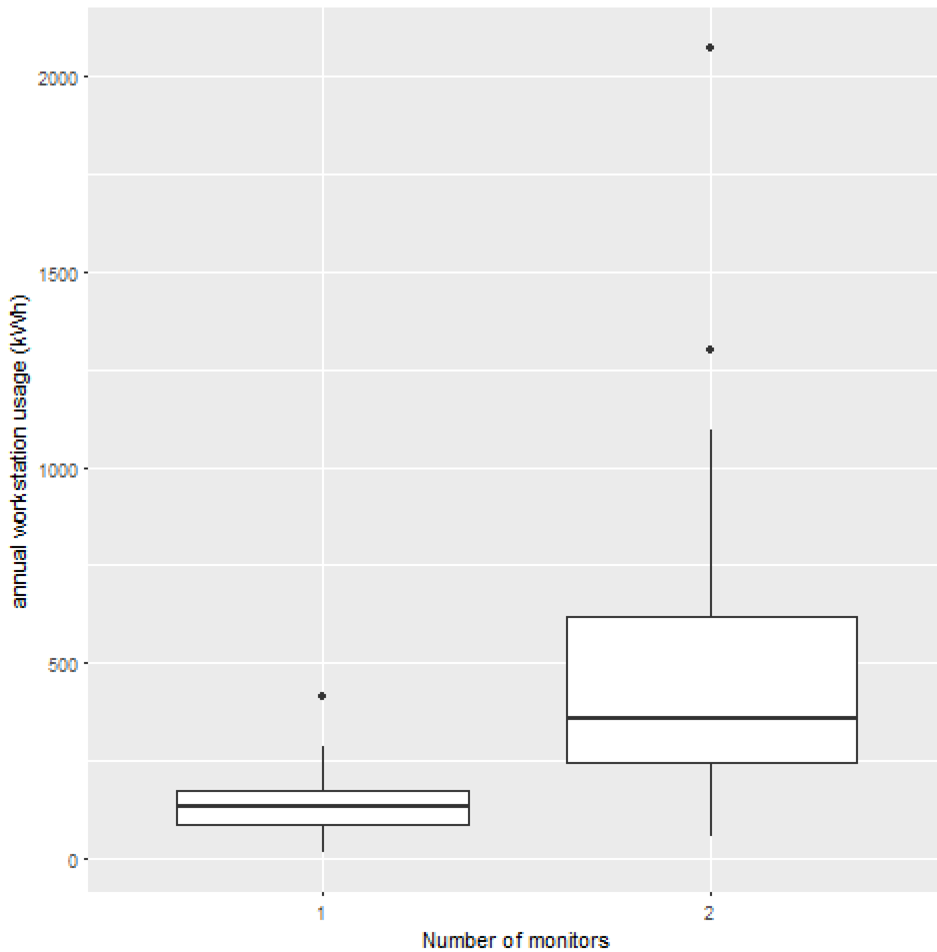


Figure 10: Count of device chargers, fans and space heaters at workstations across roughly 40 workstations at each site for both the current study and the 2016 study.



In the 2016 study, we found that workstations with multiple monitors tended to have increased energy savings, often enough to offset energy savings from the general shift from desktop computers to more laptops and thin clients. In this study, we again inventoried the number of monitors present at a given workstation. In alignment with 2016 findings, workstations with two monitors had a greater baseline usage than those with a single monitor, shown in Figure 11. There were also two workstations which had three monitors.

Figure 11: Baseline annual workstation consumption sorted by number of monitors.



We also considered the energy usage in workstations temporally, to understand how much energy usage is occurring during a typical working day, versus overnight, versus on the weekend. Figure 12 shows the energy usage over the course of an average weekday for each office, and Figure 13 shows the same for an average weekend day.

Figure 12. Workstation energy usage in a typical weekday for each office.

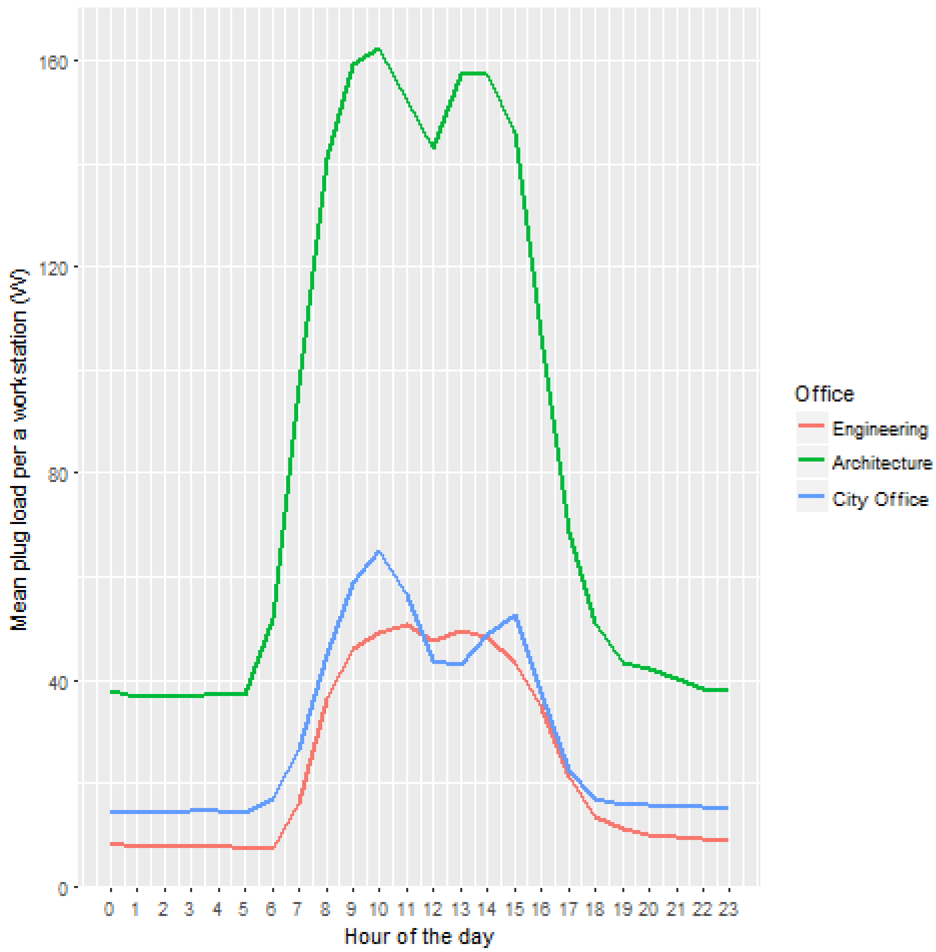
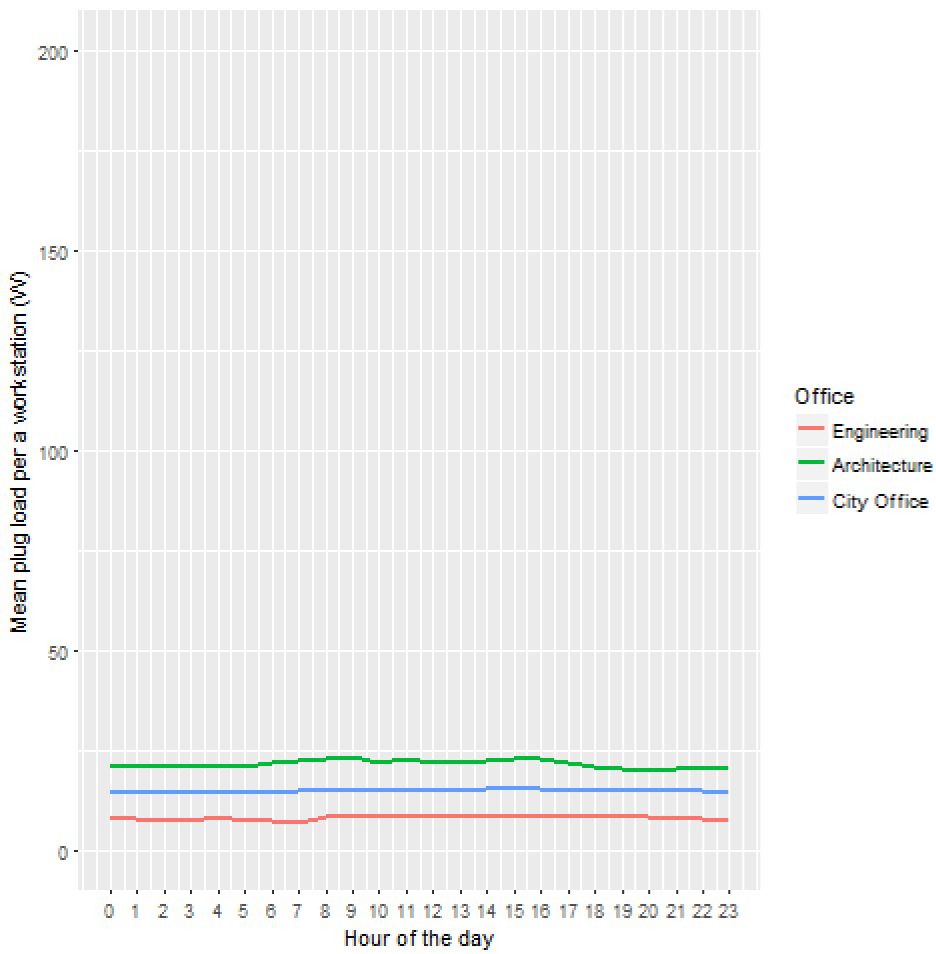


Figure 13. Workstation energy usage in a typical weekend day for each office.



Plug load savings

Of the installed 81 devices, we were able to test and measure the impact of two different Tier 2 APS devices on the workstations that we studied, using a pre-/post- test of these devices across 58 workstations (23 data points were removed because the data was a statistical outlier or the user self-uninstalled the equipment). The results of the energy savings test are laid out in the following section.

As previously stated, the study tested two different power strips in the field, which are identified in this report as Device A and Device B. These devices are outlined below.

- **Device A:** Embertec 8PC+, Model: Emberstrip Computer (PC) ESUSPC8-ET-10, Software Version: 2_0_00_62
- **Device B:** Tricklestar PC Advanced PowerStrip+, Model: 181SS-US-7XXX-N, attached to Occupancy Sensor TS1910, Model: 188LV-XX-MSIT-XCTBQ

Prior to implementing the T2 APS device at each workstation, we surveyed for any baseline plug load control, including existing advanced power strips or computer power management. (Computer power management is one of the primary energy saving features in T2 APS devices.) We found that none of these offices had *widely* implemented the best-practice CPM settings on their computers prior to our arrival, though some stations had chosen some degree of power management. Furthermore, none of the workstations where we implemented T2 APS had existing advanced power strips.

The energy savings results for implementing T2 APS Device A at each office are given in Table 3. The average for all workstations tested is highlighted at the right, with the 95% confidence interval for that average and percent savings given next to it. As previously discussed, the T2 APS devices implemented a 30 minute computer power management policy, consistent with ENERGY STAR recommendations.

Table 3. Energy savings results for T2 APS Device A.

	Engineering	Architecture	City Office	Median	Average	95% CI
Base usage (kWh)	263.5	647.8	197.5	NA	364.1	
Device A (kWh)	94.4	150.1	54.0	31.2	98.0	48.8
Device A (%)	36	23	27	NA	27	10
N, Device A	10	10	11	31	31	

Results of the field test found that on average Device A saves 27% ± 10% of workstation energy. We would recommend using as a representative savings figure for the T2 APS technology. In terms of energy savings, Device A had a savings of 98.0 kWh ± 48.8 kWh. The largest savings found at a workstation was 450.3 kWh (56% energy savings) and the largest percent energy savings found at a workstation was 61.7% (70.4 kWh savings).

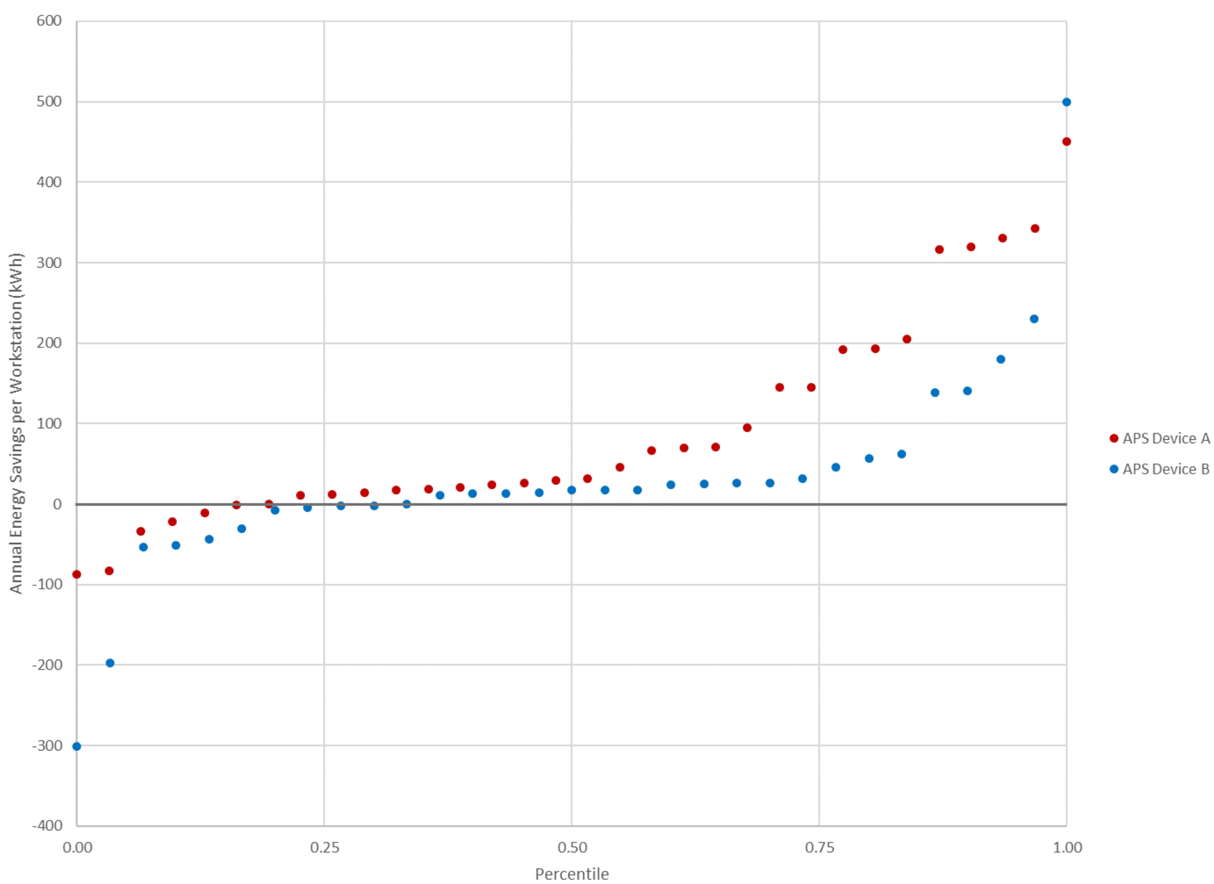
The energy savings results for implementing T2 APS Device B at each office are given in Table 4. The average for all workstations tested is highlighted at the right, with the 95% confidence interval for that average and percent savings given next to it. The T2 APS devices implemented a 30 minute computer power management policy. Device B saved 8% ± 6% of workstation energy on average, equating to 29.4 kWh ± 30.8 kWh of workstation energy saved. There were issues with the operation of this device in the field. When analyzing the data, there were workstations where this device appeared to have issues with putting the workstation computer to sleep. This trend was very noticeable as power usage overnight or over the weekend was still relatively high and as a result, energy savings for these workstations were very low. We did find that Device B worked well and saved energy at certain workstations however. The largest savings found at a workstation was 230.2 kWh (21% energy savings) and the largest percent energy savings found at a workstation was 51.1% (138.8 kWh savings).

Table 4: Energy savings results for T2 APS Device B.

	Engineering	Architecture	City Office	Median	Average	95% CI
Base usage (kWh)	121.2	669.7	236.0		382.9	
Device B (kWh)	10.8	53.7	14.2	17.9	29.4	30.8
Device B (%)	9	8	6		8	6
N, Device B	7	11	9	27	27	

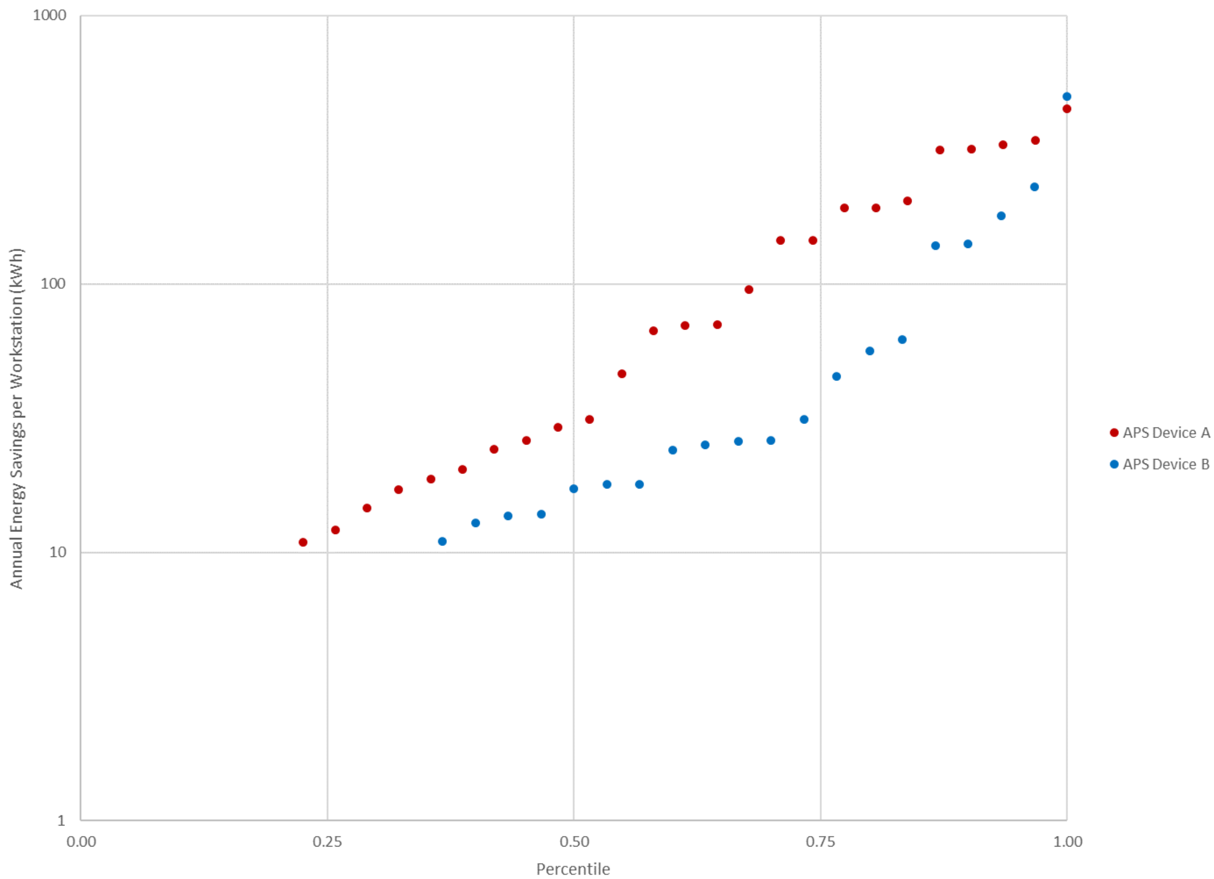
Figure 14 shows the energy savings at every workstation that we measured, sorted from least to most savings, with the percentile given on the x-axis. The workstations above the 70th percentile represent the majority of the energy savings found for these devices.

Figure 14: Distribution of energy savings for each APS.



Above the 50th percentile, Device A sees larger energy savings. For savings at or below the 50th percentile, Device A also saved more energy than Device B, which is seen when plotted on a logarithmic axis (Figure 15).

Figure 15: Distribution of energy savings for each APS, plotted on a logarithmic axis.



We also looked at the comparative impact between workstations with desktops, laptops and thin clients. Figure 16 compares savings between laptops, desktops and thin clients at each site. The broader 2016 study found that desktops typically had greater energy savings from the implementation of computer power management. This study finds similar saving trends, with desktops yielding greater savings compared to laptops and thin clients (note that the city office laptops which saved approximately 150 kWh had a sample size of 1). Figure 17 shows the savings for all sites combined, confirming the trend found in the 2016 study between energy savings and computer type.

Figure 16. Energy savings sorted by laptop, desktop and thin client workstations. The number of samples is recorded above each bar.

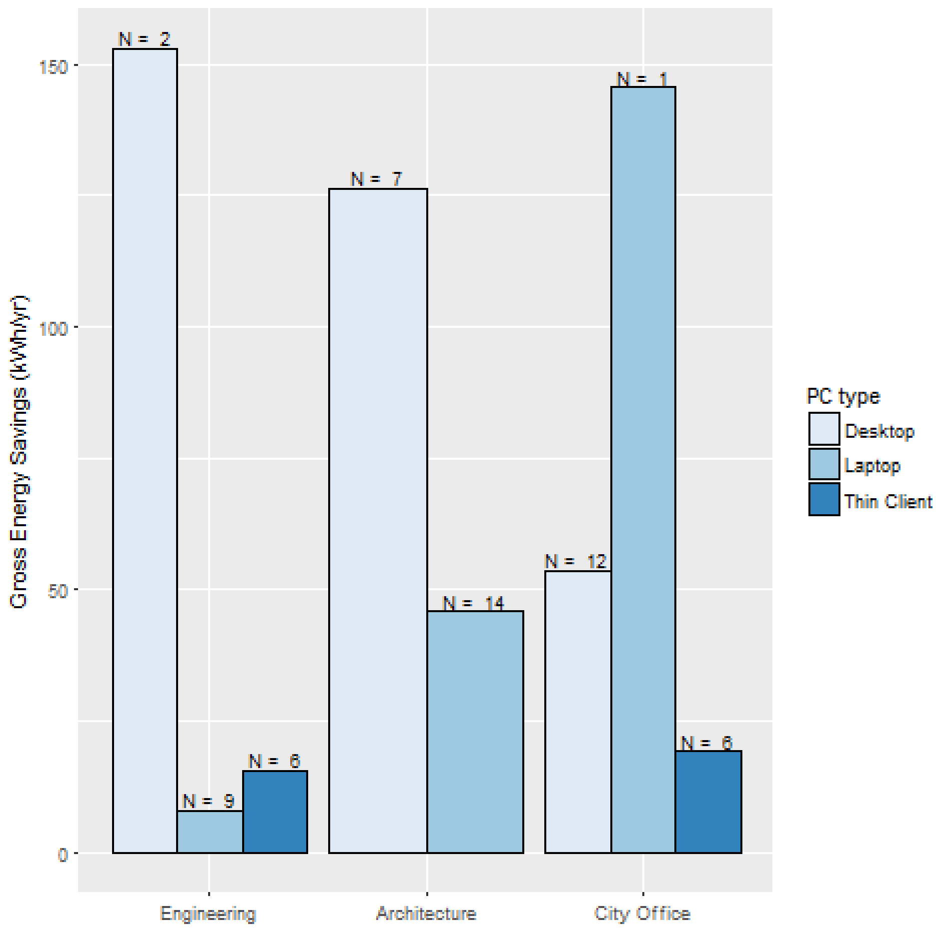
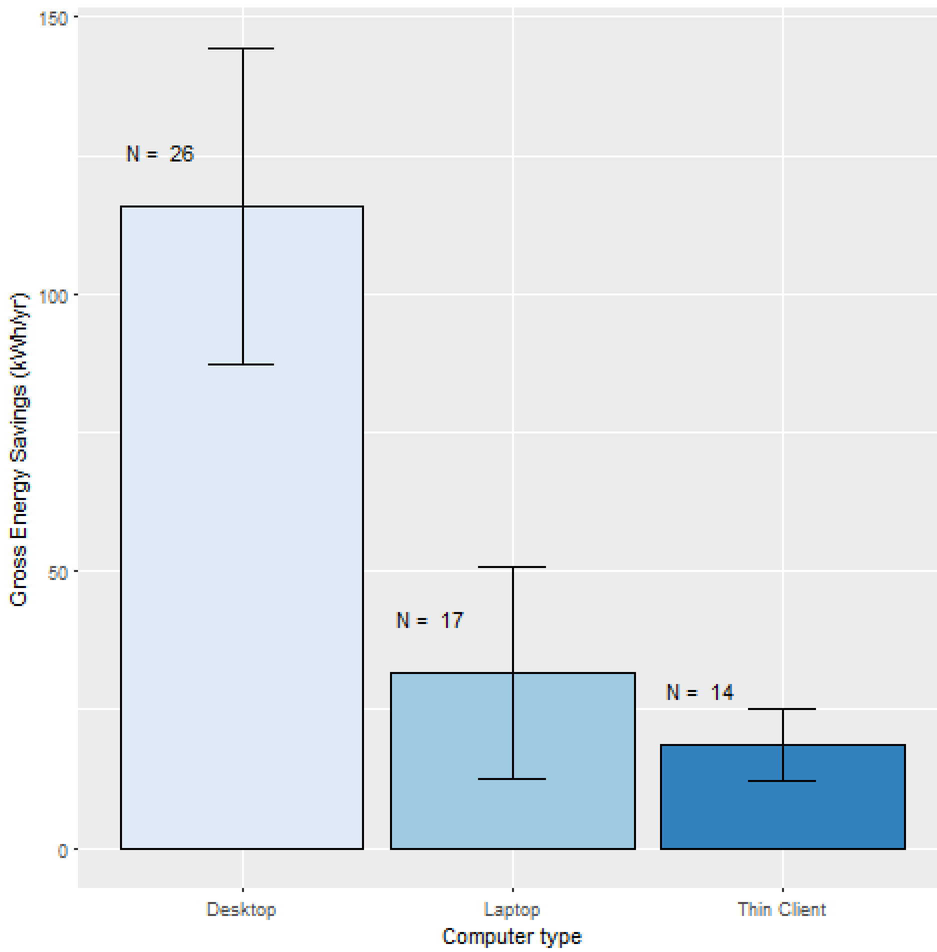


Figure 17: Energy savings sorted by desktop, laptop and thin client for all sites.



A new data point from this study was how thin clients respond to computer power management and plug load controls. Thin clients typically consume less energy than a laptop, as these devices are optimized for cloud-based computing. We would expect energy savings to be available, but likely less than those seen with a laptop.

We also considered evaluating the energy savings of various workstations based on other equipment found in workstations during the inventory. This serves to answer the question, which workstations should energy managers and programs target with the T2 APS devices. One metric that could be used to determine which workstations should be targeted is the number of devices present at a station. Figure 18 shows the energy savings for each APS device sorted by number of devices present at a workstation. For Device A, our data does not show a clear trend of more savings from more devices. This is likely because the computer is the primary driver of energy consumption at a workstation. Saving generated from the T2 APS computer power management settings overshadow savings from controlling peripheral devices. Device B does show a trend with increasing devices, however, based on the savings and error bars, we found that it is not a statistically significant trend.

Figure 18: Energy savings sorted by number of devices inventoried at each workstation.

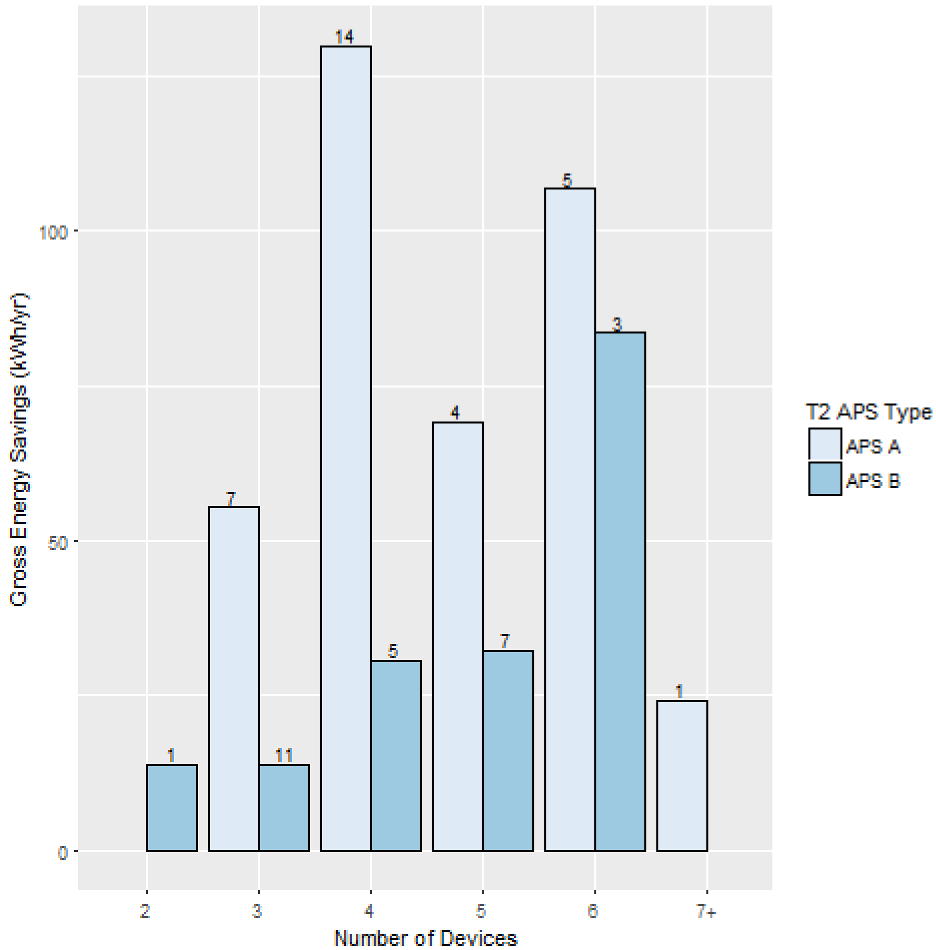
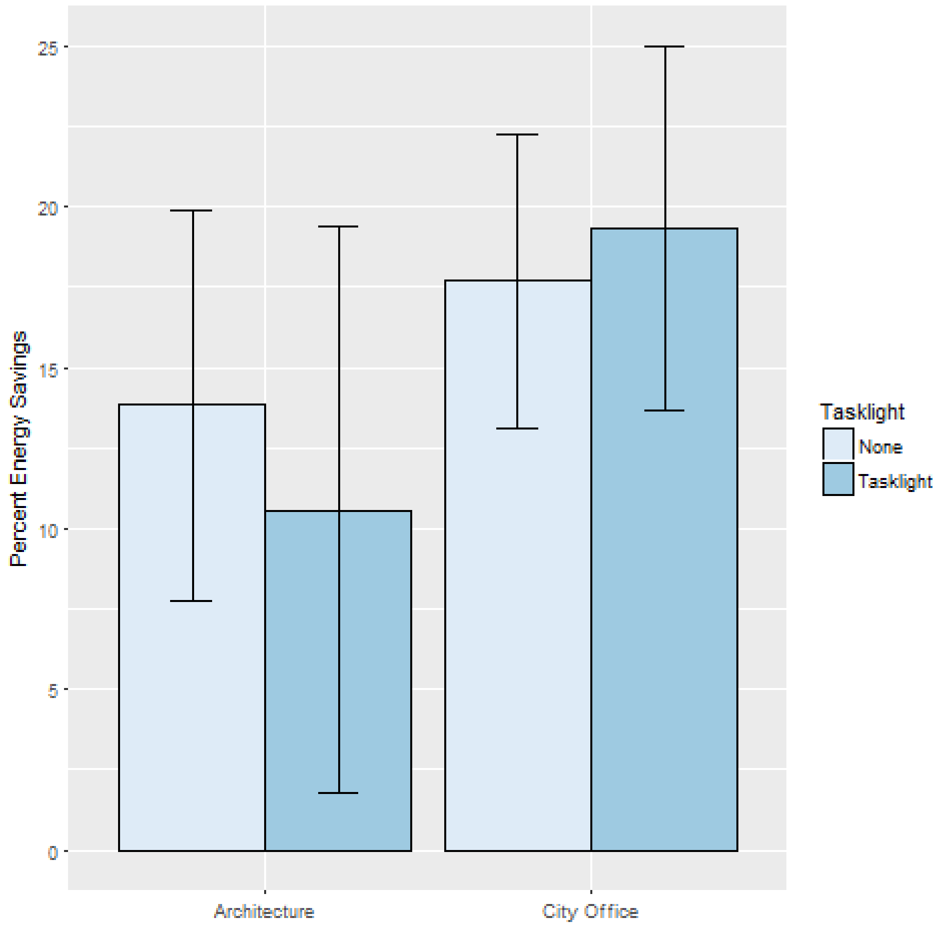


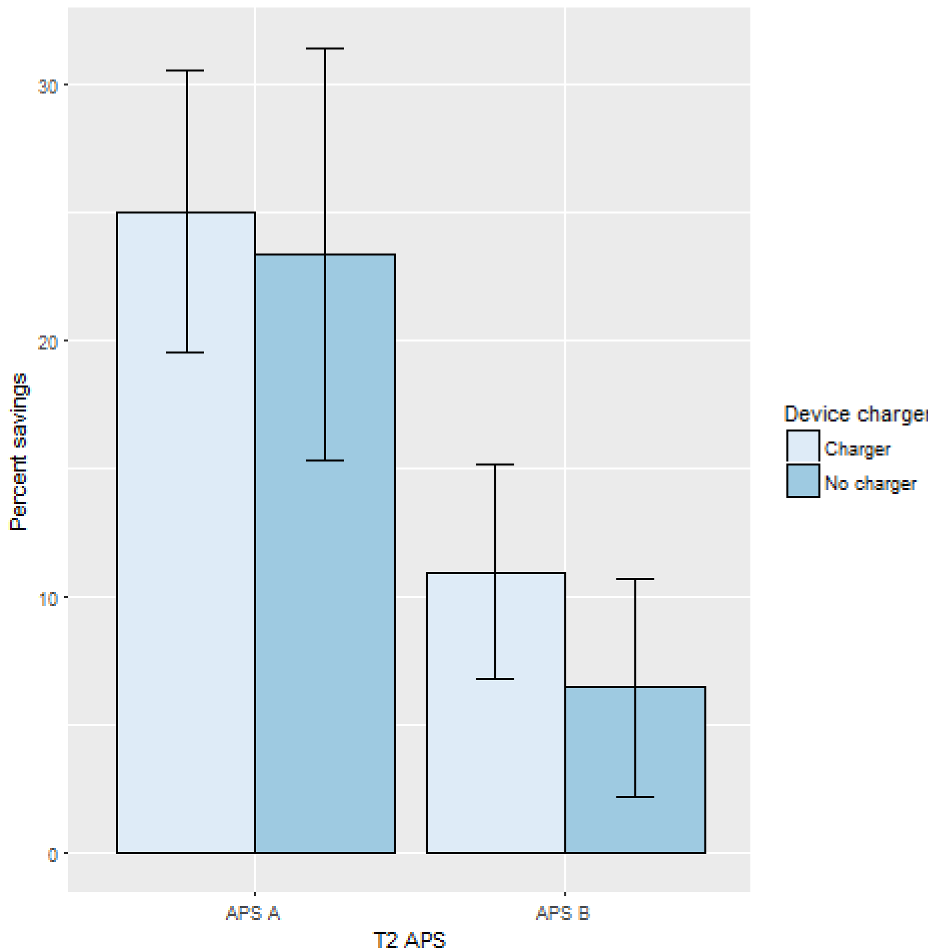
Figure 19 shows the energy savings for workstations with task lights and without task lights for both the architecture office and city office. The engineering office had one task light in the treatment sample and was excluded. Based on the data collected, no clear correlation can be drawn on whether workstations with a task light can save more energy by being equipped with a T2 APS device. It is possible that these results would show more savings for workstations with task lights if this study had collected data during the winter season, where daylight hours are significantly shorter. In this scenario it is likely that individuals are more likely to use their task lights in the morning and evenings.

Figure 19: Percent energy savings between workstations with and without a task light.



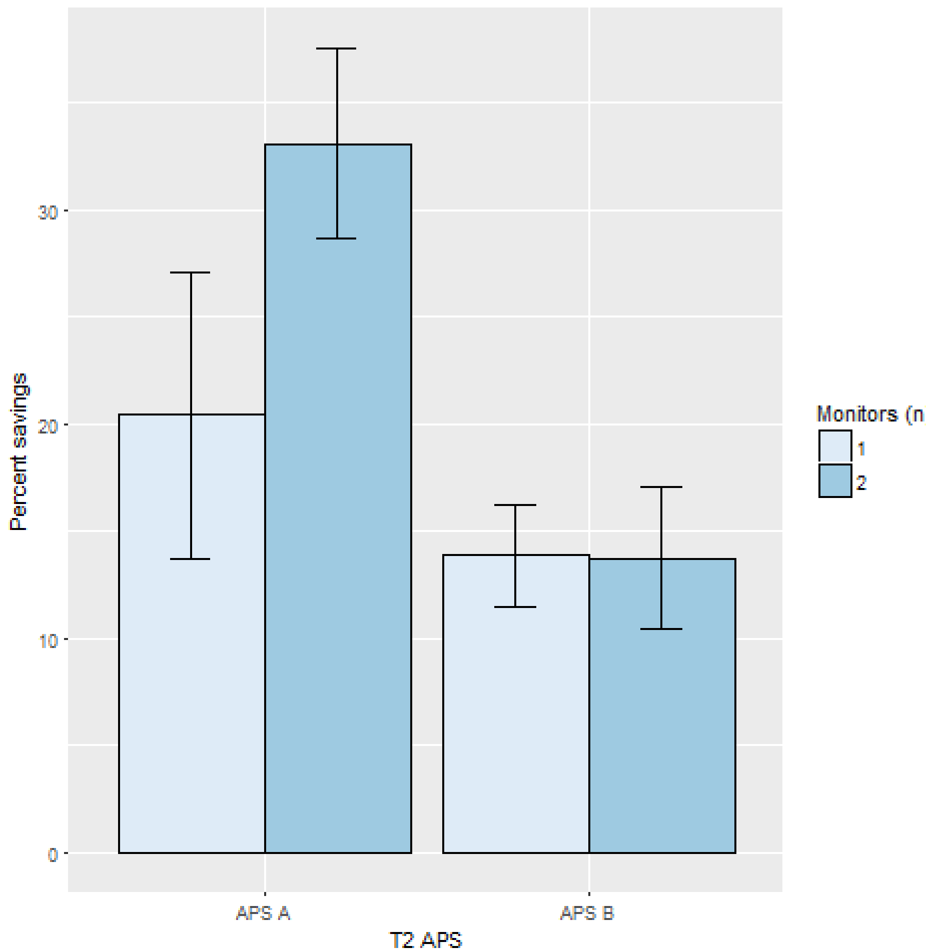
Another inventory item device that workstations were grouped by (and savings analyzed) was whether the workstation had a device charger present. The inventory conducted during this study found large numbers of device chargers, likely an indication of the increasing amount of plug in personal device such as tablets and cell phones. When sorting the savings by whether a device charger is present, a slight trend appears to show more savings for stations with a device charger. This is seen in Figure 20.

Figure 20: Energy savings for each power strip sorted by whether a device charger is present.



We also analyzed the impact of the number of monitors on the energy savings. Figure 21 shows the energy savings sorted by number of monitors. There were two stations with three monitors and one station without a monitor (laptop only); these were excluded. The results for Device A correlate with the 2016 study – stations with multiple monitors or large monitors present additional energy saving opportunity. Device B did not exhibit this trend, likely due to the power strips' operational issues.

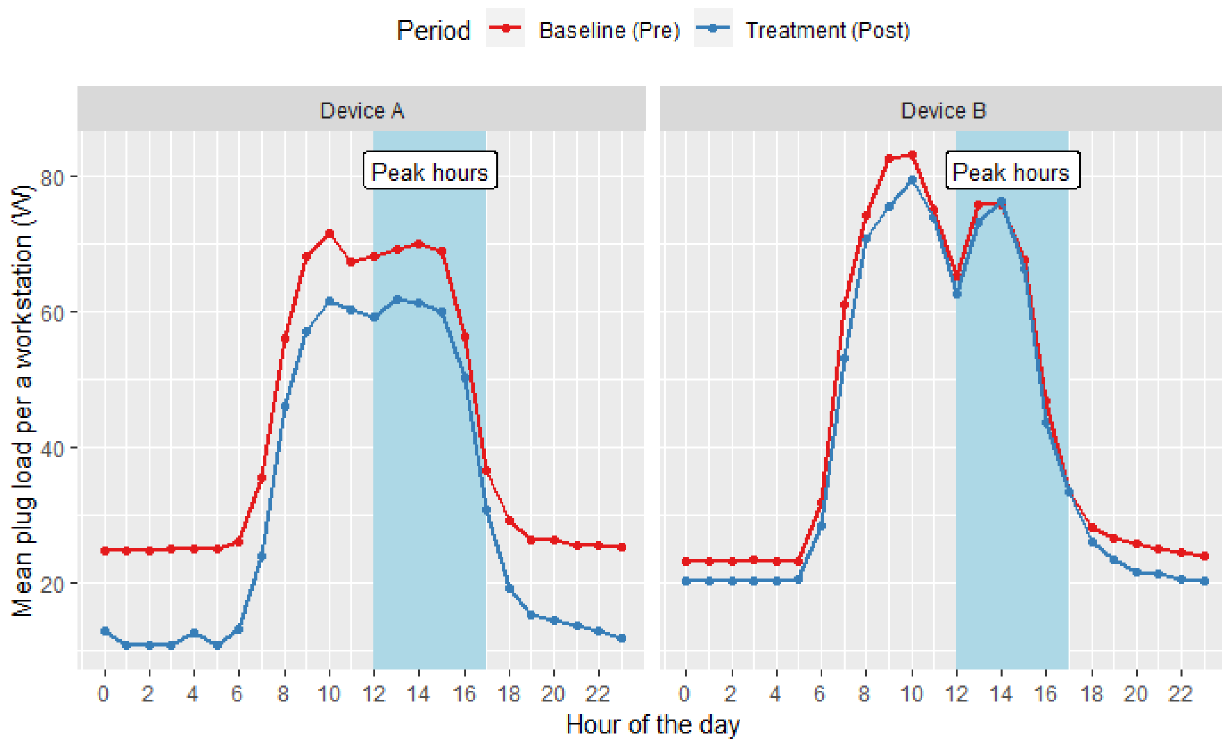
Figure 21: Energy savings for each APS device sorted by number of monitors.



Peak demand reduction potential

In addition to reducing energy consumption (kWh), some utilities are also concerned with reducing peak demand (kW) in their service territory. As a result, we calculated the peak demand reduction of the tier 2 advanced power strip devices. We used the same experimental and analytical methodology that was used for the energy consumption analysis, with the new metric being average demand at five different hours of the day (12:00 PM – 5:00 PM). This time range is the typical time in which office buildings experience their peak demand and the timeframe in which most utilities are concerned with capacity and demand. Figure 22 plots the average baseline demand for workstations at all three offices and also the average demand after the Tier 2 APS devices were implemented.

Figure 22: Demand reduction for Device A and Device B averaged across the 3 offices.



Like the previous study, we found that CPM (either implemented through a Tier 2 device or onboard program) reduces demand across all hours of the day. On average, the peak demand reduction was 7.7 W for Device A and 1.6 W for Device B. Due to the sample size and error bars, these reductions are not statistically significant.

Economics of plug load strategies

The two T2 APS devices have significantly different price points. Device A has a cost of $115 per workstation (including labor) while device B has a cost of $85 per workstation (including labor). In addition, the devices have different purchasing options. Device A must be purchased through the manufacturer while Device B is readily available from multiple retailers. In our study, we procured our devices directly through the manufacturer without any issue. Table 5 lists these costs in detail, based on labor and equipment costs that we incurred in setting up our tests.

Table 5. First costs, per workstation, for implementing each strategy.

	Equipment	Labor	Total
Device A	$100	$15	$115
Device B	$70	$15	$85

Since it's not obvious whether the first cost is justifiable based on energy savings for all scenarios, we have completed a life cycle cost assessment based on the benefit of the energy cost saved. This does not include some other potential cost impacts such as incentives, increased productivity, carbon credits, etc. This assessment is valid for building design teams or owners considering incorporating the technology, and also for utility program personnel in Minnesota who need cost information to implement and evaluate these programs.

We conducted life cycle cost analysis in accordance with the procedures of the Federal Energy Management Program (FEMP) (NIST 1995). The inputs to this analysis are shown in Table 6.

Table 6. Inputs and assumptions for economic analysis.

	Value	Basis
Electricity cost	$0.1058 / kWh	Average commercial electric rate in MN, based on EIA 2017 data.
General inflation	1.5%	Difference between 20-year treasury bills, inflation adjusted and not
Fuel inflation, electricity	2.2%	FEMP 10-year outlook
Total tax rate	45%	Nominal federal business tax rate + MN corporate tax rate
Depreciation of equipment	20 years	Straight-line depreciation
Discount rate	5-9%	9% for the corporation scenario, 5% for an institutional scenario
Life cycle cost timespan	20 years	Estimated lifespan of a power strip

We considered two categories of building owners, corporation and institution, and the economic outcome of these owners choosing plug load reduction strategies in Minnesota. Corporations are assumed to use a higher discount factor of 9% and pay corporate tax rates typical of Minnesota businesses. Institutions are assumed to pay no taxes and use a lower discount factor of 5%. Following FEMP guidelines to decide whether to adopt a technology, these organizations would need to determine whether the net present value of the technology was positive or negative.

Because the installed costs (device cost plus labor cost) of these power strips can vary, we first calculate the cost at which the owner would break even (have a net present value of zero). This break-even cost is a function of energy savings and economic parameters (inflation, energy cost, etc). Two scenarios were evaluated for the simple payback of these devices: one in which an existing workstation with a functional power strip has an APS added and another in which a new workstation is being constructed or added and needs a power strip. For new workstations, only the additional incremental cost is used for the cost of an APS beyond that of a standard power strip.

For our average values of energy savings, this results in the break-even costs for corporations shown in the first row of Table 7. Though we recommend that decision-makers consider this break-even cost as the primary metric (because it includes all financial elements), some will still be interested in simple payback. This is reported in the second row of the table.

Table 7. Economic analysis results for corporate owners.

	Device A new workstation	**Device A** exist. workstation	**Device B** new workstation	**Device B** exist. workstation
Break-even cost	$147	$147	$44	$44
Simple payback	7.6 years	8.8 years	14.2 years	17 years

Since the economic parameters are often different for institutions, we presented a separate scenario for institutions in Table 8.

Table 8. Economic analysis results for institutional owners.

	Device A new workstation	Device A exist. workstation	Device B new workstation	Device B exist. workstation
Break-even cost	$159	$159	$48	$48
Simple payback	9.2 years	11.1 years	20.9 years	27.3 years

For new workstations, Device A is the most cost effective, with a break-even cost of $147 for corporations and slightly higher for institutions. Most offices should be able to implement Device A for below this cost. Simple payback is on the order of 7.6 to 9.2 years. Device B has a significantly lower break-even cost of $44-48 per workstation, which exceeds the installed cost of the device itself. For existing workstations, the economics of the T2 APS devices change slightly. For corporations, the break-even costs remain the same, however, the simple payback increases from 7.6 to 8.8 years for Device A and 14.2 to 17 years for Device B. Similar increases are seen for institutions as well.

The economics are considerably better if we consider the possibility of an incentive (upstream or downstream) for each device. In some large utility programs, a $20 incentive is available for APS devices. When accounting for this, the simple payback time for Device A and Device B decreases significantly for a corporation and institution. These results are shown in Table 9 for corporations and in Table 10 for institutions.

Table 9: Economic analysis results for corporate owners assuming a $20 per device incentive.

	Device A new workstation	Device A exist. workstation	Device B new workstation	Device B exist. workstation
Break-even cost	$147	$147	$44	$44
Simple payback	6.2 years	7.6 years	10.9 years	14.2 years

Table 10: Economic analysis results for institutional owners assuming a $20 per device incentive.

	Device A new workstation	Device A exist. workstation	Device B new workstation	Device B exist. workstation
Break-even cost	$159	$159	$48	$48
Simple payback	7.2 years	9.2 years	15.3 years	20.9 years

Occupant acceptance and operational issues

We surveyed participants to gauge their satisfaction with the plug load reduction strategies implemented. We also observed and recorded operational issues encountered.

Survey results

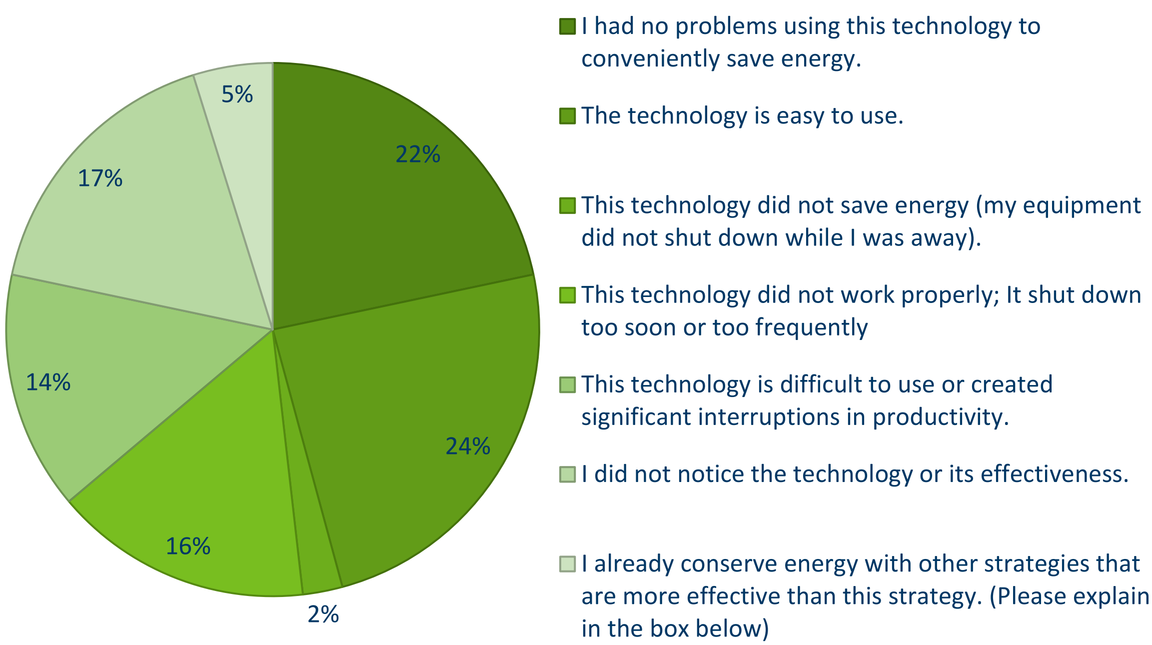
Participants in the treatment groups at each site were given a follow-up survey to gauge their satisfaction and opinion with each T2 APS device and associated CPM settings. The same questions were used for Device A and Device B and the results were anonymous (we were unable to sort feedback by device type). We received surveys from approximately two-thirds of the group across all sites. Participants gave mixed responses overall.

Participants perception of the T2 APS technology

This question rated the opinions each user felt about the APS device itself. A user was able to respond with multiple choices if they felt like it more accurately described their experience.

Figure 23 summarizes the responses and opinions about the technology as a whole.

Figure 23: Survey results for a question for how easy to use the technology is, for all participants.



About equal portions gave positive and negative responses, 46% and 47% respectively. This is somewhat negative relative to similar surveys we've implemented with technologies in the past. This is representative of the number of issues are each site, specifically with non-desktop setups. A common problem we experienced at each site was that:

> "IT found that the surface pro would cycle between "docked" and "undocked" when plugged into the sensing/switching portion of the power strip. He moved it to the "always on" receptacle to alleviate the problem."

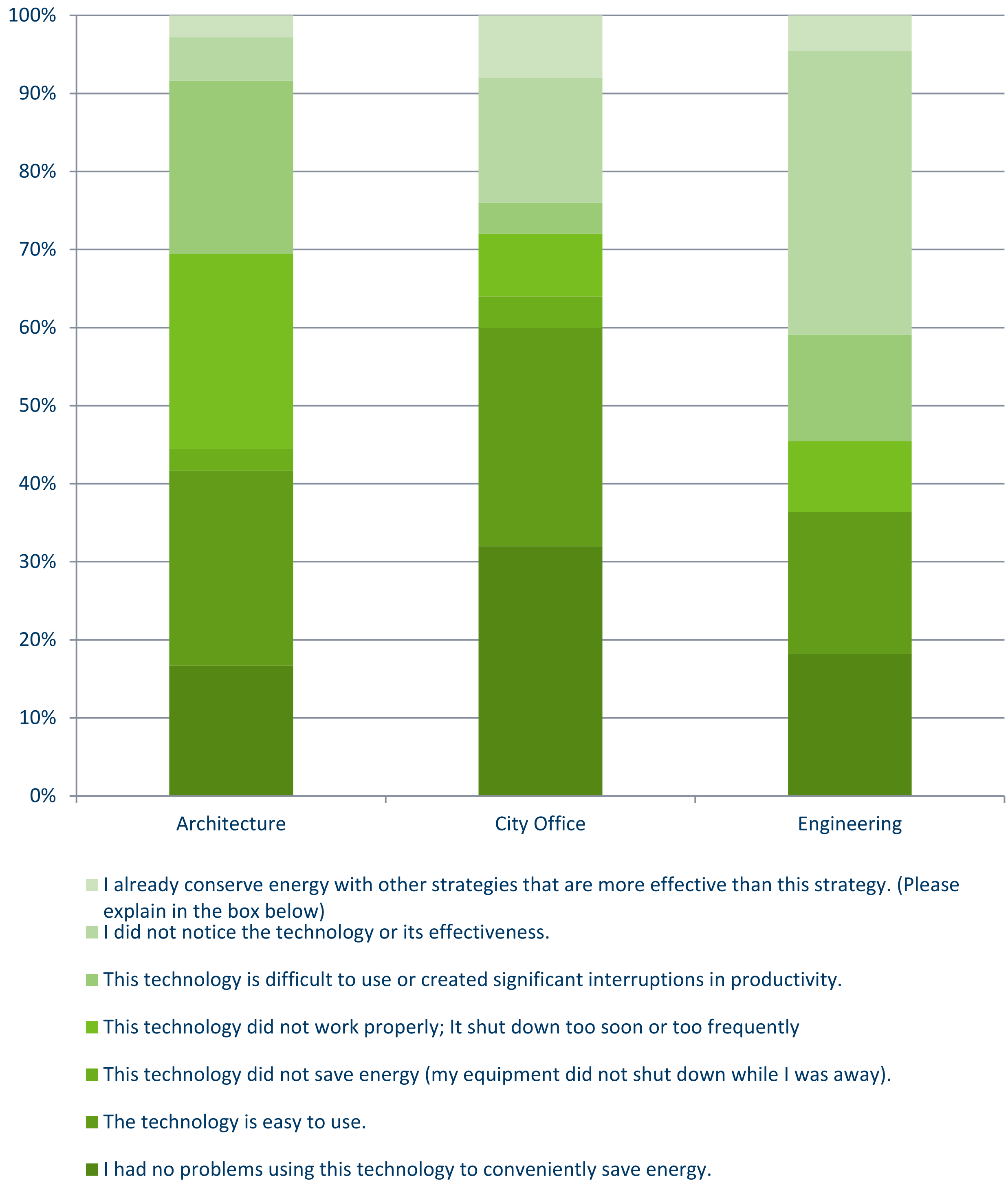
Many laptops and thin client setups utilized this work-around, lowering the savings and increasing the frustration of those users. A few users responded with statements that this work around actually caused what seemed to be more usage during the day than their existing settings. This led to a few responses in 'This technology did not save energy' where in the last study, no one answered this way.

In the traditional desktop setups, the APSs more often worked as expected. We had respondents at each site talk about how they never or rarely noticed the technology as they worked and were happy when it shut down over lunch and at night. For some offices, this could be more than just a hardware change, but it necessitates a behavior change as well. At the same time, we did have several users who at times experienced difficulty adopting this technology:

> "I greatly appreciate this study and recognize its importance. Often I did not even notice it. Other times however, I would be in the middle of reading through an email or drawing (and not moving my mouse) and the screen would turn off to conserve power. It seemed excessively conservative at times and would need some further calibration to be practical. It would be great if the results of the study could be shared with the study group so we have a better understanding of the magnitude of energy savings."

Breaking this down by site, we can see how the inventory and operation of an office changes the application of T2 APSs. Figure 24 breaks down the opinions by site.

Figure 24: Survey results for a question for how easy to use the technology is, sorted by site.

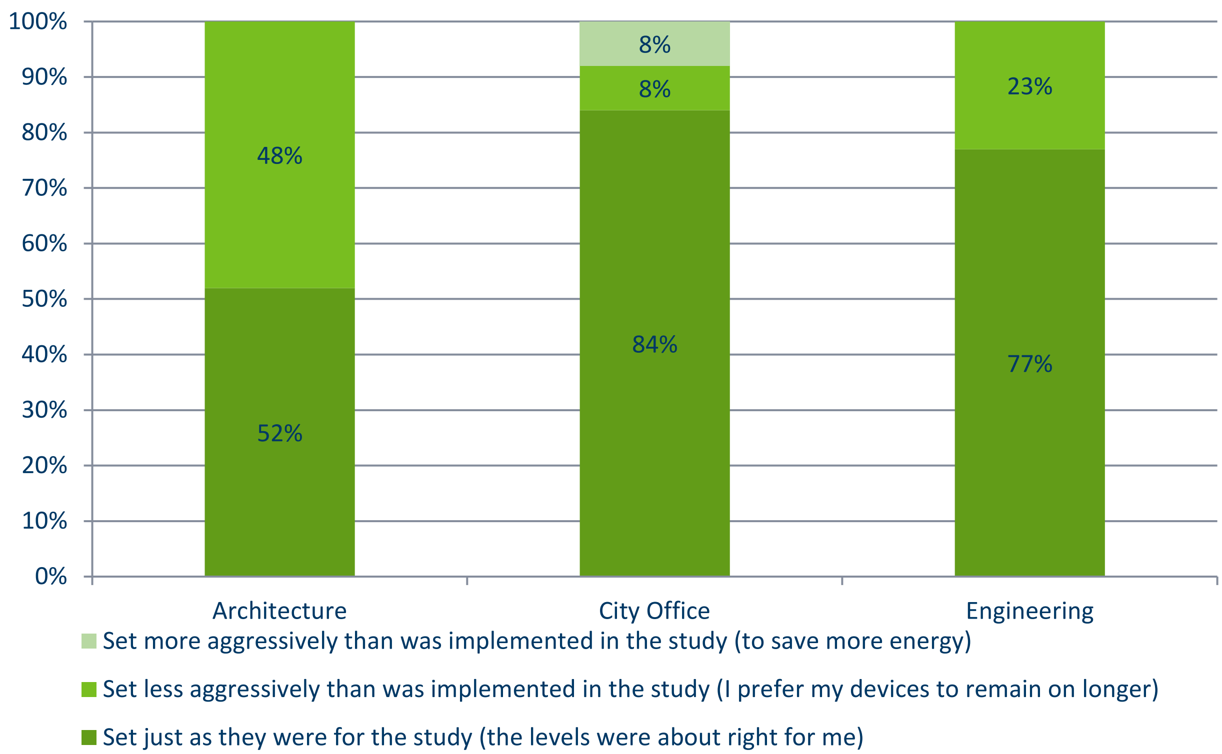


This break down was initially perplexing to the project team. During the study, the city office site reported the most problems and the engineering office reported very few. However, as shown above the opinions of the technology at the city office are the most positive and at the engineering site, the most negative. It is possible that the users who had negative experiences at the city office chose not to complete the survey. A key takeaway is that issues/negative experiences can go unreported.

Response to computer power management

By definition, Tier 2 APS devices interact directly with computer's power settings. So we also surveyed the participants regarding their experience with the computer settings that the T2 APS pushed to their computer. Through all three sites, most answered that they liked the CPM settings put in place for the study. About a third reported that they would have preferred that their devices stay on longer. We received more positive responses than negative, but they did vary dramatically by site. We had received a similar response during the 2016 study to this question; it is clear that computer power management settings must be applied with some forethought regarding the specific site and what they will put up with. Figure 25 shows the breakdown of responses.

Figure 25: Computer power management preferences, sorted by site.



Reactions from the city office and engineering sites positively reflect the settings implemented. These figures align with the feedback received for CPM in the 2016 study. The architecture site had significantly lower feedback, with just over 50% positively receiving the CPM settings. Across the entire study, 30% of the respondents indicated that the settings were too aggressive for their work and typical usage. One participant provided the following feedback:

> "It would be nice to be able to have three settings to choose from on a daily/hourly basis. Low/Med/High as to the aggressiveness of the power saving. I as a technician am actively using my PC most of the day, how much difference does it make to shut down my PC over a lunch hour? End of the day, absolutely."

The energy efficiency aspects of the devices and the CPM were received well by sites – most participants were open to the technology. Owners, managers and IT departments should expect some additional time spent by staff adjusting to the technology (mostly driven by CPM). Workstations/sites with slower computers may experience additional acceptance problems as well – users who struggle with long computer start up times will have further difficulties as computer power management powers down their computers more frequently.

Operational issues

In addition to seeking feedback from users, we observed and recorded operational issues with the device installation and ongoing operation. We especially took note of complaints from occupants, difficulties while working with IT systems, and issues brought up by the install team.

Hardware integration

Integration of the T2 APS devices themselves resulted in a few reoccurring issues:

- The dimensions of the APS are larger than a standard power strip. This caused issues with some office furniture.
- The APS devices require a USB port for full functionality; this was initially perceived to be a constraint but was not encountered at any workstation in this study.
- Both devices' energy saving features can be easily deactivated by unplugging the USB cable – an easy way for a user to "opt out."
- The control port on Device B had a threshold sensor to determine whether the computer at the workstation had gone to sleep or not, indicating that the occupant was away and allowing the remainder of the power strip to shut down. These sensors were tuned well to traditional desktops sleep mode. Laptops with docking stations or hubs, all in one monitors, and low energy use slim towers like thin clients had different levels of power use in sleep mode for which the threshold did not fit. As a result, a workaround was needed to overcome this. The proposed workaround is to plug the computer into the always on outlet and to plug the monitor into the control outlet. A drawback to this configuration is the monitor remains in standby mode during unoccupied periods instead of being powered down by the switched outlets.
- On Device B, an attached occupancy sensor determined control. Placement of the occupancy sensors was very important to the success of the device. If placed with too much line of sight the sensor can pick up movement in spaces adjacent to the intended workspace which results in equipment being on at unnecessary times. Or, if the sensor doesn't have enough line of sight, it cannot sense movement at the intended workstation and shuts equipment down prematurely.

IT integration

By definition, Tier 2 APS devices interact directly with computer's power settings. This necessitated that we worked closely with local IT departments to maintain high levels of productivity for each of the users in the study even while their computers power was being managed.

Device A required more attention by IT because it involved installing software on the computers. At the architecture and engineering offices, the IT department tested the software for Device A beforehand to make sure that there were not any issues with their systems. At the city office, where we had the least amount of contact with the IT staff, the software install was done by the IT department at the request of our site contact without much testing. At the architecture and city offices, the IT departments used a silent install to install the software to the participant's computers. This works very well and would be easy to do for a large install across many computers. The engineering site had the users self-install the software, which also worked without issue.

At each site we had to mitigate initial concerns about CPM and the effects of the device. In each case we pitched this as a one-month test in which any setting changed could be reverted at the end of the study. Phrasing it this way allowed us to gain support among the IT departments.

Some IT concerns and barriers to implementation were encountered; generally in one of the following areas:

Third-party software and CPM. There are two separate considerations for software and CPM. First, not every business will be open to implementing CPM, whether through a T2 APS device or through onboard CPM settings. In our previous 2016 study, several of the sites were resistive to implementing CPM, however, after working with key IT personnel, we were often able to overcome these challenges. Figure 26 outlines initial barriers and final outcome at each of the eight sites. In conclusion, six of the eight sites implemented CPM. One site was not open to CPM due to an IT policy that computers must run 24/7.

Figure 26: Initial response by each site to implementing CPM as well as final decision after working through any potential concerns/issues.

	CPM as found	Concerns / barriers posed	Open to improvement	Improved	Network policy used	
Architecture	None	Large	■	■	■	Nearly all concerns overcome
City public works	User-controlled	None	■			Lack of a test not due to IT
Engineering	None	Moderate	■			
City office	None	Small	■	■	■	Remote desktop was only barrier
Real estate	User-controlled	None	■	■		Fully outsourced IT
Prod. develop.	Weak settings	Small	■	■	■	
County office	None	Large				IT: computers must run 24/7
Energy non-profit	User-controlled	Small	■	■	■	

The second concern is 3rd party software. The three sites in this study did not have issues implementing a 3rd party software for CPM. In the previous study, we did not survey the eight sites for any barriers to a 3rd party software. However, we do believe this is a valid concern and that some fraction of businesses will not be open to using a 3rd party software. When implementing CPM or a 3rd party software, a discussion/relationship must be had with the IT department as initial concerns can often be overcome.

Remote access. The first IT consideration at each site was which users needed the ability to access their computers remotely (e.g. log-in in the evening to work). Some of the treatment set-ups we investigated caused issues for users who wished to remote-in. Remote access was not possible when the computer was put to sleep or off altogether. This was a problem at each site both with the individual users and the system that the IT department used to allow their workers to remote-in. There were solutions that allowed us to overcome this barrier:

- Device A allowed users to set active times and sleep times according to a schedule, thus allowing those few who wanted to remote-in a method to disable the CPM during certain time periods or for specific nights of the week. Outside of those specified time periods, the device would still function to save energy.
- Another work around would be to use a Wake on LAN setup that utilizes software on the local network to wake computers that are needed based on some communication. This was looked into but ultimately never used.
- Those who remote-in often could simply be passed over in implementation of APSs. When we received a list of users in the study who were marked as remote-in users we put a small portion of them into the Device A treatment group to study how the scheduling system behaved, and the rest we did not assign an APS to.
- Server connections like VPN eliminate the need for remote access. This allows users to access their files, without logging on to the computer itself and eliminates most of the remoting in problems. Unfortunately, whether a company uses this configuration is not likely to be driven solely by the desire for a specific CPM. But as more employees shift toward laptops and thin clients, more companies are shifting toward server-based approaches to remote access anyway.

Software. Some types of software do not behave properly when the computer automatically goes into sleep mode (e.g. they may not save all data properly or lose network connection). This was mainly retroactive and able to be fixed on a case by case basis. As in the first study, this issue came up only a handful of times and was mainly attributed to the different sleep cycle causing network disconnections. Only once did we have to amend a workstation because of this issue.

IT labor requirements. Each device required a certain level of the IT department's time at each site. The Device B device required a WiFi connection (for portal registration, can be used without registering into the portal) and the Device A device required a software download. Solutions included:

- The Device A software download was a necessity for the treatment phase of the study at each site. The usually solution here was to work with the IT department prior to initial install to make sure that there were no issues from having this software downloaded when it needed to be. This was achieved by a few phone calls in the weeks leading up to install.

- The Device B needs to be programmed over Wi-Fi in order to register each device into the online portal. This may or may not be important, depending on if energy savings are tracked. The two solutions for this were to bring a hotspot with us or to pre-program the device and swap the devices on site. The latter option was chosen to cut down time on-site.

Pushing updates. At various times throughout the study, IT staff need to push software updates to users in the study. CPM and T2 APS' are perceived to hinder this in some scenarios as these they cannot be pushed to a computer that is asleep. We found one primary solution:

- The most common recourse was to allow the update to be pushed the next time the computer was on and awake. Originally this led to some misplaced complaints that the APS devices were causing the computer to restart in the morning when they started working. Once users understood the computer restarts were due to computer updates, the complaints were solved.

Other Priorities. IT departments are tasked with maintaining many operations of a business that are critical to productivity. This productivity often dwarfs the energy savings generated from APS and CPM, so it is difficult to make these measures a priority. This is an important concern to take into account when changing group settings or acquiring new hardware. We developed some thoughts on this issue:

- Slow, incremental change may aide in an IT department that is low on bandwidth.
- Another solution to this problem is for the directive to come from management, as opposed to from an outside source (like a program) or a single individual within the IT department. If saving energy is seen as a priority alongside other business priorities, IT staff are more likely to be successful in implementation.

As an additional test of the usability of these devices, at the end of the study the participants had the choice to keep the power strip or remove it. The IT departments at each site were accepting of the technology and allowed their users to keep the APS if they wanted.

Conclusion and Discussion of Results

Implications for plug load strategies in CIP's

The results of our field study indicate that 1) there is still significant energy being used by basic plug loads in most Minnesota office workstations, and 2) the T2 APS devices can reduce plug load energy consumption. A measure using T2 APS devices has an estimated statewide savings potential of between 8-44 million kWh annually.

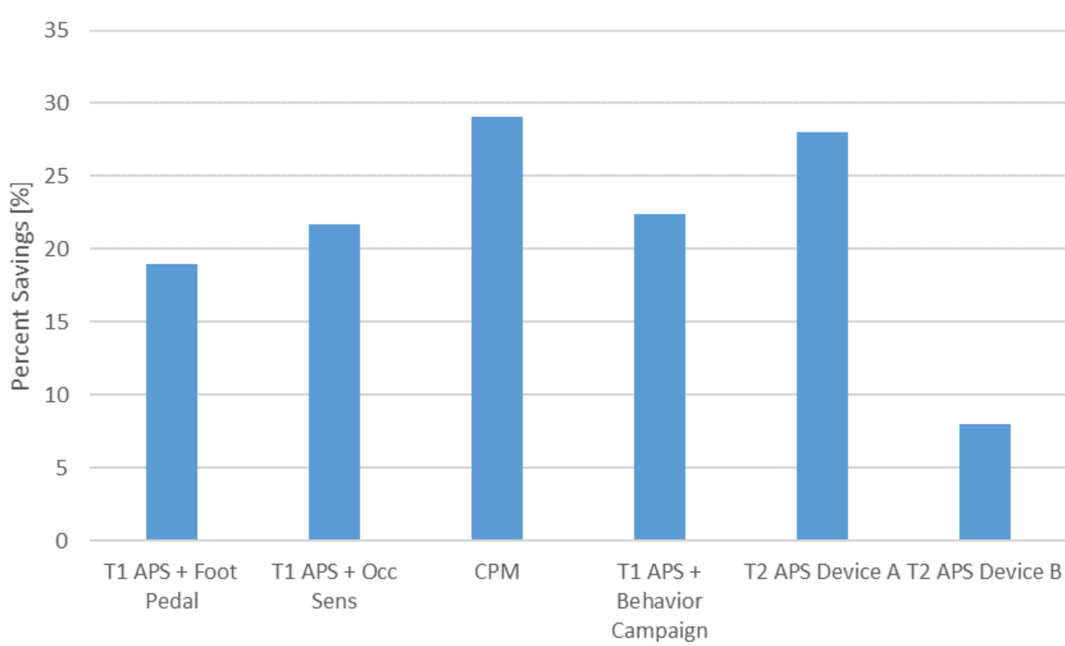
Guidance for CIP personnel

At the time of this report, no CIPs in Minnesota offer incentives for T2 APS devices. There is potential for all utilities to capture savings from this end use, though it is certainly more cost effective in certain scenarios than others. We recommend that any program designed around implementing T2 APS devices also develop a set of performance criteria to ensure the T2 APS used in the program offering deliver the savings found in this study.

At a minimum, focus on implementing computer power management.

Consider the impact of the T2 APS versus the other plug load reduction strategies tested in the 2016 study. Figure 27 shows the energy savings from the all of these strategies.

Figure 27: Percent savings for strategies tested in the previous study as well as the T2 APS devices.



Device A has savings of similar magnitude to the computer power management (CPM) strategy tested in the previous study. This is intuitive, because the majority of the energy consumption at a workstation is driven by the computer and both strategies impact computer power settings as a primary function. Our current study suggests that computer power management settings still have not been widely adopted. As the computer is the largest energy consuming device at a workstation, the most energy savings can be found by implementing controls that reduce computer run time when not in use.

There are many ways to implement CPM. The 2016 study essentially utilized Microsoft's implicit features to push settings to all computers in a network, which carried no additional cost beyond the labor costs for implementation. This was an effective way to save approximately 30% of workstation energy. There are also third-party software packages that can be utilized to implement CPM, but these carry upfront costs in addition to the labor required to implement them.

Another option is to use a T2 APS to implement CPM, as described in this report. Based on the current research, these devices also are effective in reducing computer run time and workstation energy consumption.

One drawback of the T2 APS devices compared to traditional CPM settings or software is that the T2 APS devices can more easily be manually overridden by users. With both devices, the user can unplug the device to deactivate CPM, while continuing to use the power strip. We discuss the importance of user buy-in and education below, which is critical to successful results from the T2 APS devices.

Identify which technologies work best in specific environments.

There are many different environments in the commercial building world, ranging from office buildings with large workstation/computer densities to primary schools with much smaller workstation/computer densities. The approaches tested in the 2016 study and in this supplemental study present a variety of strategies which can be successfully implemented to save energy.

In new construction, retrofit or other scenarios where users are purchasing new power strips, T2 APS devices may be a more attractive option. The economics for T2 APS devices are more favorable when a power strip already needs to be purchased. In cases where the user has a functioning standard power strip, implementing on-board CPM might be a more cost-effective option.

In large retrofit installs, such as a high-rise office building, we would recommend using the on-board computer power management settings. This will reduce the installed costs of the devices yet still achieve most of the available energy savings.

For small business, it may be advantageous to install a piece of hardware which automatically implements CPM. In these scenarios, T2 APS devices are an ideal fit. Buildings that have staff who are interested in energy efficiency or operators/owners who are targeting a low building EUI, the T2 APS would also be an ideal fit.

Provide incentives and technical support/assistance to increase adoption.

Regardless of which technology is selected (CPM or T2 APS), we still recommend providing an incentive to increase user adoption. In many cases, the small incentive makes the economic outlook significantly more favorable which can often sway a potential customer.

In addition to providing an incentive, it is critical to provide technical assistance and support. In both studies, computer power management (both on-board and through a Tier 2 device) was the most challenging strategy to implement and generated negative feedback where not implemented correctly, or where implemented too aggressively. CIPs can work with ENERGY STAR's Low Carbon IT Campaign to have instructional materials available, and provide backup support (ENERGY STAR can provide some support at no cost).

Consider more innovative program approaches beyond a basic incentive.

Based on our recent research, optimal computer power management settings (whether through a software program or through a T2 APS device) are not widely adopted. Different program approaches may be required to widen adoption of these measures because they are directed at an audience that isn't used to looking for utility rebates or thinking about energy. A few potential approaches that could be considered:

- A **direct install approach** offering to install a T2 APS where they make the most sense. This would also lead to high quality installations and user satisfaction. Such a program could also implement a T1 APS with on-board CPM (using typical Group Policy template approaches for example). This may be an especially pertinent approach for small and medium business programs.
- An **upstream** rebate program leveraging outreach and marketing from product manufacturers through collaboration. Office furniture manufacturers could also participate in such a program.
- A **behavioral** campaign could be used to impact savings in several ways. First, educating users about T2 APS devices will increase user acceptance of the device and decrease the likelihood that they'll manually override the settings. Greater acceptance and use of the device increases savings. Secondly, educating users about CPM can drive self-adoption of this strategy or encourage users to implement more aggressive settings if CPM is already active. Either approach could be included with energy management or retrocommissioning programs, or as a standalone behavioral program. Behavioral elements could also be added to simpler prescriptive offerings for T2 APS or CPM, to both increase user satisfaction and savings.

Integrate CPM or T2 APS into more holistic programs like retrocommissioning and turnkey small business programs.

Either CPM or T2 APS could presumably be included in a prescriptive (i.e. standard) or custom program. But other more holistic program types could consider including these strategies as well. Retrocommissioning programs could include CPM as a low-cost, software-based measure. Implementers would need to add a small IT skillset, but such an offering could remain limited to basic approaches. Small business programs that are attempting to expand scope could potentially add every strategy that we tested here to their offerings. Other holistic programs such as energy management should consider these strategies as well.

Incorporate plug load research lessons into new construction programs.

New construction programs have historically ignored potential for energy reduction through plug load impacts, and in fact generally assume plug loads are a relatively static element in a building design. The fact that the new Minnesota code requires some amount of plug load control may lead to these assumptions decreasing only slightly, but then remaining static.

New construction programs in Minnesota could begin to recommend plug load reduction strategies be implemented in every office area, including the T2 APS technology. New construction presents an opportunity where users are already purchasing power strips. As mentioned in this study, this helps improve the economic outlook of the T2 APS devices. Of course, savings potential in this program type may be curtailed somewhat by the new code, but there is still potential beyond that. They could also provide behavioral information at time of occupancy.

Develop a strong relationship with IT departments.

As plug loads increase over time and become a higher percentage of building energy use, facility managers and building designers will have less influence on energy saving strategies. Instead, IT personnel will be at the forefront of managing plug loads as well as server or data center usage. IT could even be involved with lighting controls as they grow more complex and building automation software in addition to their interaction with workstations (and plug load controls).

CIPs need to have staff in place to interact with IT personnel in companies of different sizes as well as at third party IT consulting firms. They need to be able to understand all of their needs and constraints, and have some basic influence to drive some of the savings strategies that we studied here (as well as some server energy savings strategies documented by others). CIPs should also begin targeting more outreach at IT personnel. They can consider talking with both the IT department and sustainability leadership in a firm to establish opportunities. This combination provides more internal motivation for plug load reduction and worked well for our study.

Because the IT infrastructure varies from firm to firm, and IT infrastructure is so critical to every firm, CIPs should also collaborate with IT personnel in testing different strategies. Significant testing will be important in the early life of a CIP offering to ensure that user productivity is not negatively impacted, which would quickly lead to removal of any strategy put in place.

TRM inclusion

At the time of this report, the Minnesota Technical Resource Manual (MN TRM) includes a section on Tier 2 Advanced Power Strip savings. These savings are based off estimates from other studies in other states. Based on the findings of this research, we plan to recommend updates to the savings figures included in the MN TRM.

Based on the savings shown in Table 3 in the *Plug load savings* section, the average savings for Tier 2 Advanced Power Strips per workstation is 98 kWh (Device A). This is a reduction from the current TRM value of 125 kWh. In addition, the average demand savings between 12:00 PM and 5:00 PM was found to be 7.7 W (Device A) as discussed in the *Peak demand reduction potential* section. This is a reduction from the current TRM value of 11 W. The measure life should remain at 8 years and the unit participant incremental cost should be $100. We would recommend adding an additional unit participant incremental cost of $80, which represents the reduced cost scenario if a new power strip purchase was required.

Based on the discrepancy in savings between the two products tested, we recommend developing a specific performance specification or criteria for T2 APS devices to ensure that power strips achieve the high level of performance displayed by the Embertec device in this study. These criteria can help push the market and entice manufacturers to enhance their products to meet these specifications. These specifications could be related to product safety and longevity as well as energy and performance. At this time, we are unaware of any other state TRMs that include performance criteria for commercial Tier 2 Advanced Power Strips.

Guidance for building operators and designers

The results of our field study indicate that office operators can implement cost-effective and non-disruptive strategies to reduce plug load energy usage. Some reduction strategies can be effectively implemented at any time in existing offices. Others are best implemented by office managers when purchasing new equipment or by design professionals at the time of office build-out.

Implement low-cost software and hardware strategies in existing offices.

Office operators have several cost-effective options for plug load reduction strategies including CPM and T2 APS. Both of these strategies resulted in cost-effective energy savings with minimal or no disruption to office worker comfort or productivity.

Computer power management could be a good starting point, especially in cases where power strips do not need to be replaced or purchased. CPM had only a two-year payback and can be readily implemented using existing software in most offices to save energy on both monitors and computers when not actively being used. Operators will need to work closely with their IT departments or consultants. These two sides will often need to overcome a few barriers together. Office operators may contact ENERGY STAR for no-cost support.

For cases where power strips need to be purchased (such as new construction, retrofits, buildouts, etc.), T2 APSs are an option, saving energy from all non-computer plug loads at workstations and implementing CPM. With utility incentives, this approach can have a payback of about six to seven years. For large offices, this approach will be more challenging to implement than solely using on-board computer power management. For high performance buildings with low EUI targets, T2 APS devices are an effective way to control plug loads.

Save energy by influencing staff behavior in a positive way.

The actions of individual office staff can have a significant effect on plug load energy use. A behavior change campaign can be an effective method for offices to not only conserve energy but educate employees about the significance of plug loads. Campaigns should maintain a positive message and be communicated by those close to the staff (as opposed to a remote corporate office or third party). If executed correctly staff can respond positively to behavior messaging. No- and low-cost campaign elements can include identifying an office sustainability champion, sending email reminders, and providing candy or small gift cards as incentives for those observed saving energy. A campaign may be more effective when used in conjunction with a technology measure (e.g. an APS installation) as in our study. Including behavioral elements can significantly increase the savings of these hardware and software strategies.

As previously mentioned, user acceptance is a critical component for operators and designers relying on a T2 APS device to implement CPM. Users can deactivate CPM by unplugging either the USB connecting the power strip to the computer or the occupancy sensor USB cable connected to the computer. A positive campaign to engage users will increase acceptance and minimize self-uninstalls.

Implement strategies at the time of new construction or tenant build-out.

Design professionals and office owners need to be aware of the significance of plug loads in new office construction, renovation, and tenant build-out. If teams that are developing new offices are interested in high performance, plug loads could make up a large portion (up to 55%) of their project’s energy usage. Teams could also use the metrics from *Baseline usage of workstations* to more accurately size all kinds of building systems that are often oversized for plug loads. When selecting new workstation furniture, look for options that either include or easily allow integration of plug load control and monitoring. New electrical systems may include built-in solutions for energy reduction with occupancy sensors at receptacles (see *Code implications*) as well as plug load sub-metering to track performance.

Conclusions for manufacturers

Improving product design and development is somewhat outside the scope of our study, but we did document a few issues that could only be dealt with through redesign by a manufacturer.

In our discussions with the manufacturers, they are both aware of the potential acceptance issues with these devices. Both manufacturers stressed the importance of working with IT departments and future users to educate and provide technical assistance to increase acceptance and energy savings.

One general issue related to form factor. When installing the T2 APS devices, there were multiple instances encountered where the new T2 APS was larger than a standard power strip. This sometimes made the devices difficult to install in workstations that were small or had a lot of equipment. At one site in particular, the low-profile wall plug of the APS hindered the device being plugged into the wall.

We also have some specific conclusions and recommendations about the devices individually.

Embertec

The Embertec 8PC+, Device A, performed well in the field. However, there are a few key improvements or changes we recommend. First, the software uses specific keywords during the install to assign power strips into different "departments" in the online portal. If these keywords during the install are incorrectly entered, the install will not place the power strip into the correct department, which would prevent an administrator from adjusting that power strip in the portal. Second, moving power strips from one department to another cannot be done by the administrator of the account. This is problematic if a power strip user needs custom settings that differ from the other users in the department. The Embertec device also does not support Apple computers.

Tricklestar

We encountered the following issues with the Tricklestar PC Advaced PowerStrip+, Device B. A primary issue was the load sensing outlet ("Control" outlet where the PC is typically plugged into). Typically, the Tricklestar device deactivates the controlled outlets by sensing when the PC is asleep based on its power usage at any given time. Unfortunately, new laptops have power draws which can be very low at times, causing the device to power off the switched outlets even though a user is working at their computer. This can even lead to frequent on and off cycling, turning all devices plugged into the switched outlets on and off (monitors, task lights, etc). This creates a major disruption at a workstation. Tricklestar does have a workaround for this scenario, in which the computer is plugged into the "Always On" outlet and the monitor is plugged into the "Control" outlet. When the monitor goes into standby mode, the load sensing outlet will switch off the switched outlets. The main drawback from this is that the monitor never is turned fully off; it remains in standby mode. It would be ideal to be able to keep the monitors plugged into the switched outlets.

We also encountered some issues with the occupancy sensors attached to this device. If the Tricklestar power strip and occupancy sensor must be moved, the two-sided tape loses the ability to hold the occupancy sensor to the monitor. In an instance where the power strip is moved to a new workstation, the occupancy sensor may fall off the monitor.

The Wi-Fi connection for registering a device into the online portal can be a slow process if many devices are to be installed: each device must be individually activated via Wi-Fi. Registering the devices is not required – this step can be avoided if an administrator does not want to control the devices in the online portal or download the energy saving data. The time-delay to sleep also must be set individually on each occupancy sensor. If users could self-install, this time issue becomes less of a problem.

Product updates

Both products have received updates since our 2018 field test. Device B (Tricklestar) received firmware updates to the occupancy sensor. These updates optimized the detection area (range and spread) and also improved the logic which the occupancy sensor sends sleep commands to the computer. Device A (Embertec) has also had updates to the software that is used. New software features were implemented based on feedback and are primarily focused on improving the user experience, however several IT updates such as the ability to do a silent central installation on Windows 8 and 10 or the ability to disable energy monitoring/logging (if a user/company is not interested in recording individual device savings). In each case, we did not test the new software and cannot comment on how the updated devices performed in the field test.

Future scope

This supplemental study to the larger 2016 plug load study has tested multiple strategies to control and reduce plug loads. We believe that any future research should focus on how to successfully implement the largest energy saving measures. We have found that CPM, which can save up to 30% of workstation energy use, is not necessarily widely implemented. We would recommend a behavior study to determine the best behavior strategies to increase the acceptance and adoption of CPM (either software based or T2 APS). Behavior strategies to increase savings could also be studied as well.

This supplemental study had a relatively small sample size for T2 APS devices. Pulling together more data points in addition to this study will help minimize the uncertainty of the savings figures for these devices. These data points could be pulled from different territories/states and programs.

Lastly, a small business pilot could be tested using the T2 APS devices. The primary area of interest would be the delivery method of the typical program approach. Instead of a hands-on approach as seen in this study, the pilot would be more hands off, to determine how feasible it is to integrate these devices in the standard program environment.

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Appendix A: Device operation handouts

The following handout was used for participants receiving an Embertec device:

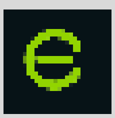
As part of a field study to investigate the potential to save energy in offices throughout Minnesota, your workstation has been randomly chosen to be outfitted with an advanced power strip. Thank you for taking part in this important research.

The power strip is connected to your computer via a white USB cable. If you have a laptop, this is connected to your docking station. If you have a desktop, this is connected to your desktop. Please do not disconnect this USB cable.

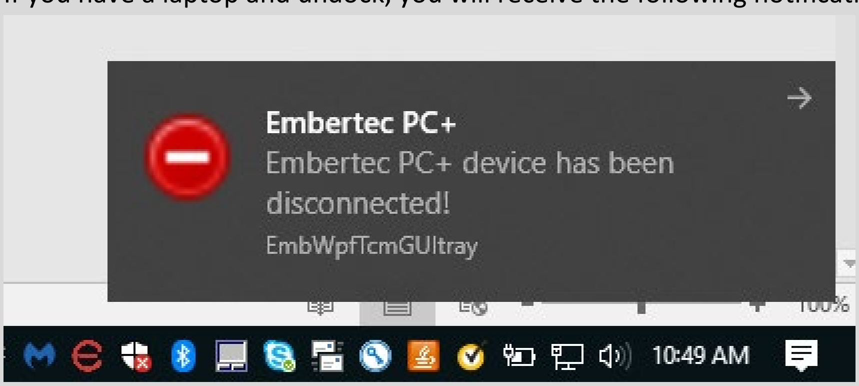
The power strip installed at your workstation has two primary energy saving functions:

- It senses computer use (via keystrokes or mouse movement). When the computer is not in use, it will put your computer to sleep after 30 minutes of inactivity.
- When the computer is not in use, it will also toggle power on/off to all plugged in devices at your work station – with the exception of the computer itself, which will always remain plugged into a powered outlet.

You will see the following icon on your taskbar; when this is green it indicates that the device is working.



If you have a laptop and undock, you will receive the following notification and the icon will turn red.



The device should not require any interaction from you; whenever you are at your workstation it should make power available to all your equipment. If you have any questions at all, please contact _______, who is our contact for the research.

The following handout was used for participants receiving an Embertec device who also needed to schedule remote work times:

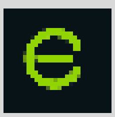
As part of a field study to investigate the potential to save energy in offices throughout Minnesota, your workstation has been randomly chosen to be outfitted with an advanced power strip. Thank you for taking part in this important research.

The power strip is connected to your computer via a white USB cable. If you have a laptop, this is connected to your docking station. If you have a desktop, this is connected to your desktop. Please do not disconnect this USB cable.

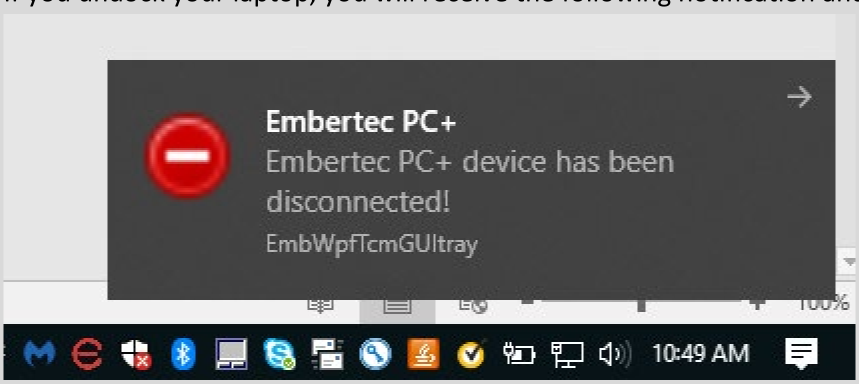
The power strip installed at your workstation has two primary energy saving functions:

- It senses computer use (via keystrokes or mouse movement). When the computer is not in use, it will put your computer to sleep after 30 minutes of inactivity.
- When the computer is not in use, it will toggle power on/off to all plugged in devices at your work station – with the exception of the computer itself, which will always remain plugged into a powered outlet.

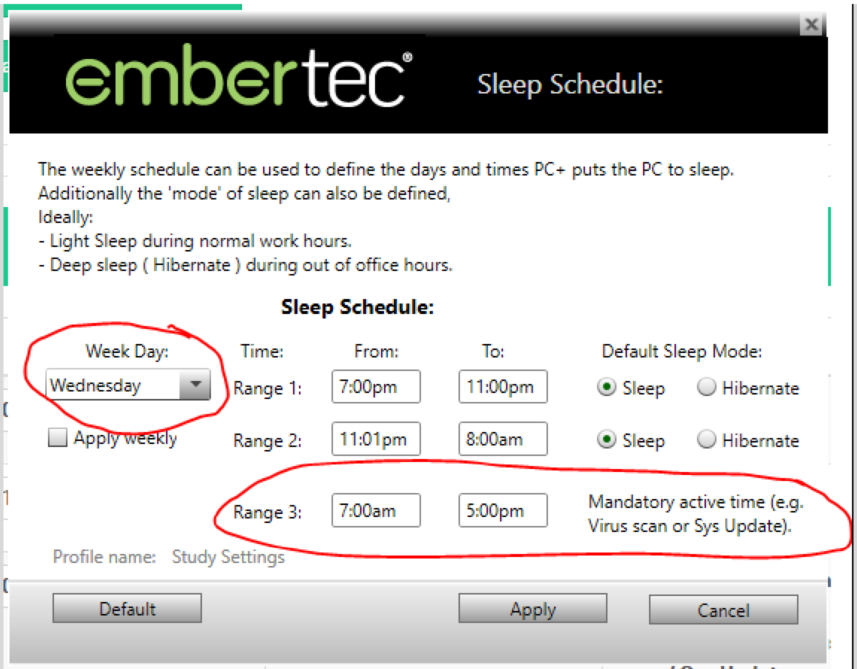
You will see the following icon on your taskbar, which when green indicates that the device is working.



If you undock your laptop, you will receive the following notification and the icon will turn red.



Remote workers - If you need to log into your work PC remotely from a different PC, you will want to set the sleep schedule. If you are taking your work PC home and using VPN, you do not need to set the sleep schedule. To set the sleep schedule (forces your computer to stay awake), right click on the "e" icon on your taskbar, then select "Sleep Schedule". The following window will appear:



There are two fields to complete. The first field is “Week Day” which specifies the day of the week which you may need to log in remotely. The second field is “Range 3” which specifies the time frame in which you may need to log in remotely. In the above example, the user has set their remote work schedule for Wednesday from 7 AM to 5 PM. This process can be repeated for any other day or time slot required for remote work. If there are two different periods for remote work, such as a morning and evening period on the same day, you would set Range 3 to span the entire day.

If you have questions about setting the sleep schedule or any other difficulties, please contact _______, who is our contact for the research.

The following handout was used for participants receiving a Tricklestar device:

As part of a field study to investigate the potential to save energy in offices throughout Minnesota, your workstation has been randomly chosen to be outfitted with an advanced power strip. Thank you for taking part in this important research.

The power strip is connected to your computer via a black USB cable. If you have a laptop, this is connected to your docking station. If you have a desktop, this is connected to your desktop. Please do not disconnect this USB cable.

The power strip installed at your workstation has two primary energy saving functions:

- It senses computer use (via an occupancy sensor). When the computer is not in use, it will put your computer to sleep after 30 minutes of inactivity.
- When the computer is not in use, it will also toggle power on/off to all plugged in devices at your work station – with the exception of the computer itself, which will always remain plugged into a powered outlet.

The occupancy sensor will show a blue light when operating and flash a red light when no motion is detected. You can manually put your computer to sleep by pressing the button on the right side of the occupancy sensor.

The device should not require any interaction from you; whenever you are at your workstation it should make power available to all your equipment. If the device has any difficulty sensing you, or you have any questions at all, please contact ______, who is our contact for the research.

Appendix B: Participant satisfaction survey instrument

As part of a field study to investigate the potential to save energy in offices throughout Minnesota, we have implemented tests of some technologies at your workstation. In the last month or so we tested an advanced power strip with built in computer power management. **We have just two questions for you about these tests.** Thank you for taking part; your feedback will be important in developing programs to save energy in Minnesota offices.

1. Regarding the power management settings for your computer and monitor: would you prefer them to be…
    a. Set less aggressively than was implemented in the study (I prefer my devices to remain on longer)
    b. Set just as they were for the study (the levels were about right for me)
    c. Set more aggressively than was implemented in the study (to save more energy)

2. Regarding the advanced power strip technology:
What is your opinion of this energy saving technology after using it for some time (check 1-3 statements that best describe your opinion)?
    - I had no problems using this technology to conveniently save energy.
    - The technology was easy to use.
    - This technology did not save energy (my equipment did not shut down while I was away).
    - This technology did not work properly; it shut down too soon or too frequently.
    - This technology was difficult to use or created significant interruptions in productivity.
    - I did not notice the technology or its effectiveness.
    - I already conserve energy with other strategies that are more effective than this strategy. (Please explain in the box below)

3. Please give us any other opinions you have, or tell us about specific problems or benefits you encountered from using plug load reduction technologies.