Tier 2 Advanced Power Strips with Bluetooth® in Multifamily Residential Applications

Southern California Edison
Emerging Technologies Program
Data Analysis Summary

Source: embertec

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Disclaimer

EXECUTIVE SUMMARY

In support of California's strategic plan to accelerate the penetration of energy efficiency technologies, this report presents the results of data analysis collected through a field test of Tier 2 advanced power strips (APS) installed at residential audio/video (A/V) systems.

Project Goal: The primary goal for this project was to determine the energy savings and demand reduction of recent generation APS in residential A/V systems. Three to five weeks of power monitoring data were collected at 92 sites in November and December of 2016 by SCE, with APS units activated for the first half of the monitoring period. AESC performed analysis of the data provided by SCE to determine key metrics, such as energy and demand savings.

Project Findings: The data analysis found that the APS devices used in the study resulted in average annual energy savings of approximately 49% per site. Demand savings of approximately 60% per site were also achieved during DEER on-peak periods. Additionally, the projected annual energy usage calculated by the APS software aligned fairly well with actual energy usage measured in the study.

Table 1. Summary of Energy Savings and Demand Reduction

	Annual Energy Consumption (kWh/yr)	Annual Energy Savings (kWh/yr)	Peak Demand (W)	Peak Demand Reduction (W)
Baseline	487.4	-	88.85	-
Tier 2 APS with Bluetooth®	247.0	240.4	35.96	52.89

Conclusions and Recommendations: Although usage patterns were also found to vary significantly between the baseline and post monitoring periods, energy savings were still significant when normalized for A/V usage. The analysis determined that the Tier 2 APS units utilized in this study yielded measurable energy savings.

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ASSESSMENT OBJECTIVES

The primary objective of the analysis was to determine DEER peak demand reduction and annualized energy savings metrics associated with an SCE field evaluation of Tier 2 APS devices with Bluetooth® functionality installed in residential audio/video applications.

TECHNOLOGY DESCRIPTION

The Tier 2 Advanced Power Strip (APS) utilized in this study was the EmberStrip 8AV+, created by embertec. The APS monitors power consumption in controlled devices to recognize usage patterns and de-energizes controlled devices when they are not in use. The APS also de-energizes controlled devices when it does not detect infrared (IR) signals for a one-hour period. The EmberStrip APS also has a Bluetooth sensor, which allows users to monitor usage and control the APS via smartphone or tablet.

TECHNICAL APPROACH/TEST METHODOLOGY

AESC performed data analysis of 92 data files provided by SCE's Emerging Products division. AESC did not have control or knowledge of the experimental design or implementation of the measurement and verification effort. In SCE's study, Tier 2 Advanced Power Strips were installed with existing audio/visual (A/V) systems at 92 residential sites. Instantaneous power measurements were collected in five minute intervals for approximately two weeks before and after the Thanksgiving holiday, during November and December of 2016. Somewhat counterintuitively, the APS A/V controls were activated during the initial monitoring period and were subsequently turned off to estimate baseline usage during the second half of the testing period. In the following sections, the "Pre" case refers to the baseline without activated A/V controls, while the "Post" case refers to the APS with activated controls.

Compared to a simulated approach, this testing methodology provides a more comprehensive view of energy savings by including the effect of the user's interaction with the IR sensor in the activated APS Post state. Although this testing approach does not allow for significant variations in usage patterns, the effect of these differences in usage was minimized by extending the monitoring period to two weeks in the baseline and proposed cases.

AESC did not have visibility into test participant demographics or plug load device conditions. As a result, demand profiles and usage patterns are not ensured to be consistent with past studies.

RESULTS

Although 92 host sites participated in the study, only 46 sites had data that were deemed sufficient for inclusion in the analysis. While the median data collection interval was five minutes, most sites exhibited a few gaps of several hours or days in which no data was collected. The source of these data gaps is unknown. The data for the 46 usable sites were corrected by removing days with significant collection gaps, to avoid biasing results towards any particular time of day. Due to the prevalence of data gaps, removing days with only partial data dramatically decreased the effective monitoring period. To illustrate, the 46 sites used in the analysis were monitored for an average of 16.4 days in the baseline and 22.0 days in the post. However, after days with significant gaps were removed from the data, the average number of complete days for these sites was just 13.3 days in the Pre-installation case and 16.2 days in the Post-installation case.

TABLE 2 – AVERAGE MONITORING PERIOD

	Pre-Installation	Post-Installation
Observation Time [days]	16.4	22.0
Complete Days	13.3	16.2
Complete Weekday Days	9.4	11.4
Complete Weekend Days	3.9	4.8

For the purpose of maintaining consistency among the sampled group, weekdays and weekends were also differentiated in the analysis. To be included in the analysis, each site was required to have at least five complete weekdays and two complete weekend days' worth of data in both the Pre-installation and Post-installation monitoring periods. Using data from complete weekdays and complete weekend days, average energy impacts were calculated for both weekday and weekend days at each site. These site averages were scaled to determine energy savings over a standardized two-week period with exactly ten weekdays and four weekend days. A similar extrapolation was utilized to determine annual energy savings for each site. This method ensures that annualized results are not biased towards weekend or weekday data, despite gaps in usable data over the monitoring period. Please see Appendix A for observed energy usage trends between weekend and weekday periods.

ENERGY SAVINGS:

The average baseline and savings for the corrected dataset are shown in Table 3. The 90% confidence intervals for baseline energy consumption and energy savings are 487 ± 48 kWh and 240 ± 30 kWh, respectively.

TABLE 3 – AVERAGE ENERGY SAVINGS RESULTS FOR THE A/V TRIAL

# of Sites	Baseline Annual Usage [kWh]	Baseline Standard Deviation [kWh]	Annual Savings [kWh]	Annual Savings Standard Deviation [kWh]
46	487.4	197	240.4	122

Overall, energy savings per site were found to be well correlated with baseline energy consumption. The corrected baseline and energy savings for each of the 46 sites are plotted in Figure 1. Baseline usage and savings are fairly linear across the range of sites monitored, indicating that annual baseline usage and savings are related.

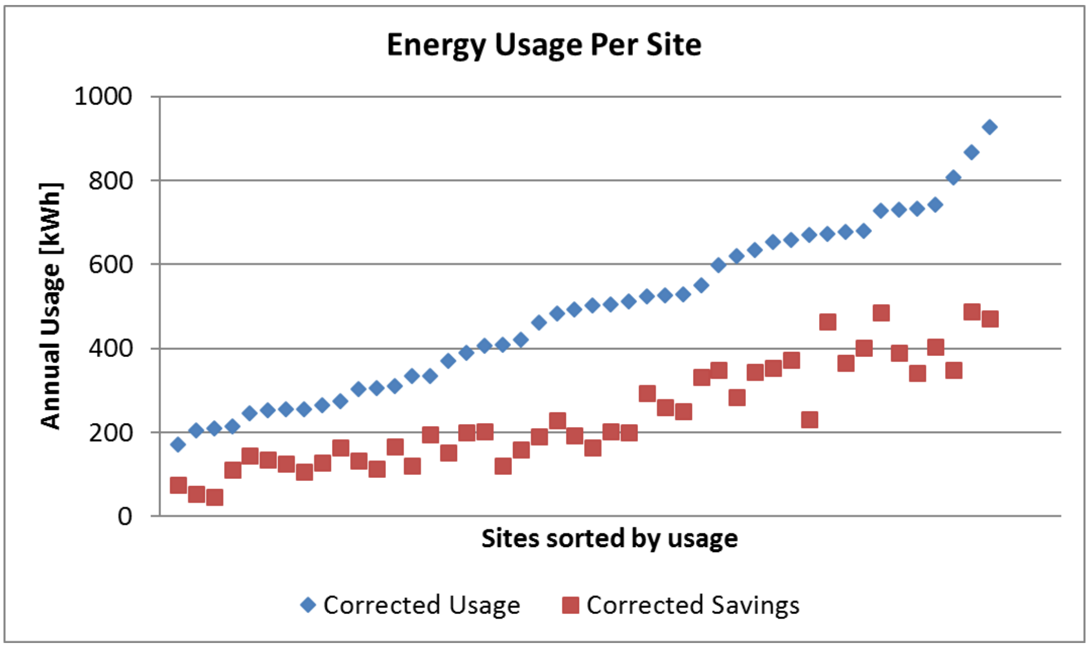

FIGURE 1: ENERGY USAGE AND SAVINGS BY SITE

Figure 2 plots the annual, calculated savings as a function of annual usage. Note that the good fit, linear trendline has a slope of about 0.5, or approximately 50% savings.

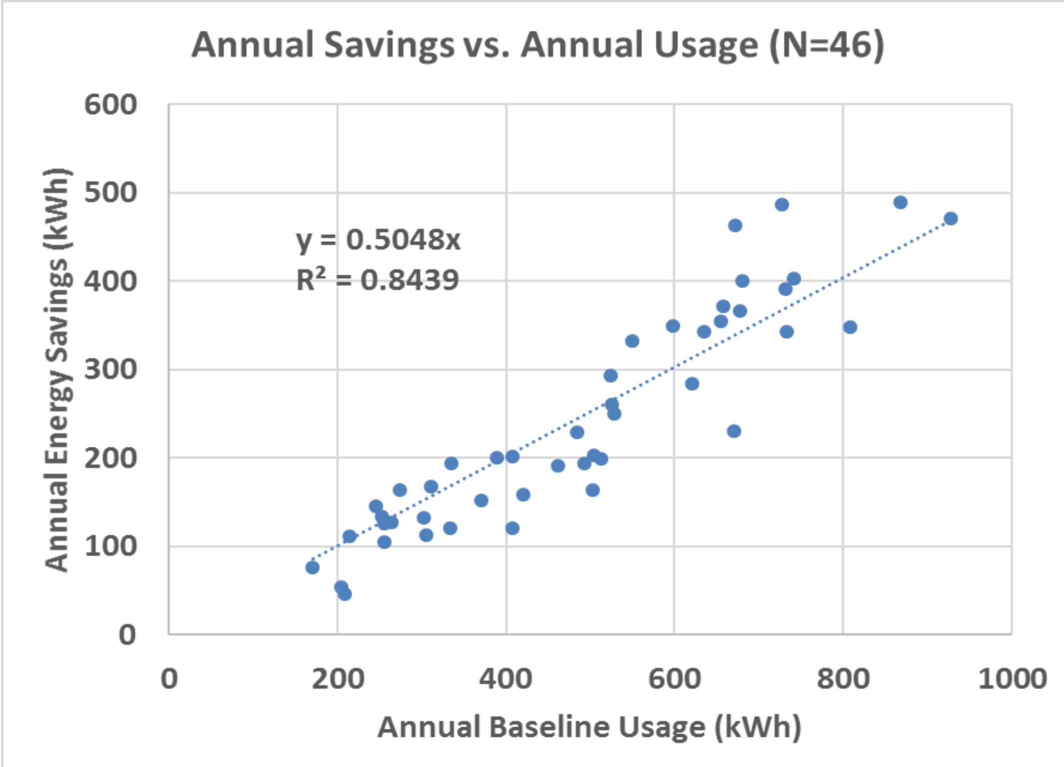

FIGURE 2: ANNUAL ENERGY SAVINGS AS A FUNCTION OF BASELINE ENERGY USAGE

However, the percent savings do not have a correlation with baseline energy use and are dictated primarily by user behavior which is highly variable. The percent savings for all the sites was between 22% and 69%, with an average percent savings per site of 48%. Figure 3 shows the percent savings of the corrected dataset by baseline usage, showing no correlation between percent savings per site and annual baseline usage. Although sites with larger baseline energy usage generally achieved greater energy savings, the realized percent savings was not proportional to annual baseline usage.

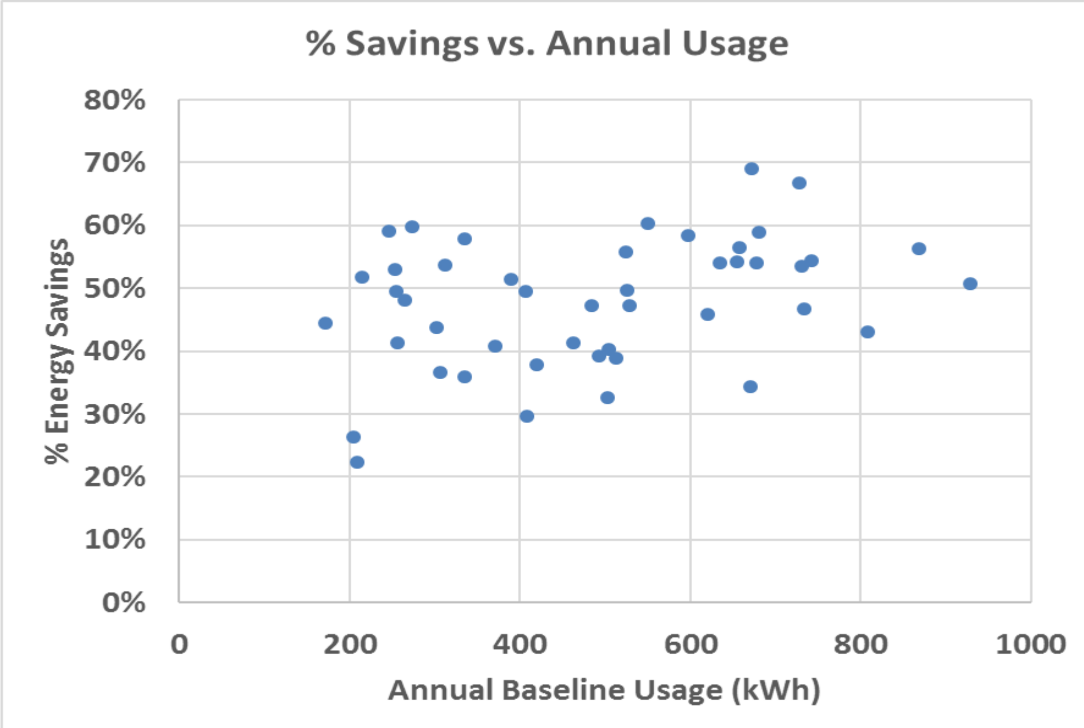

FIGURE 3: ANNUAL PERCENT SAVINGS AS A FUNCTION OF BASELINE ENERGY USAGE

The histograms for the baseline usage and energy savings are shown in Figure 4. Energy savings per site ranged from a minimum of 47 kWh/year to a maximum of 489 kWh/year.

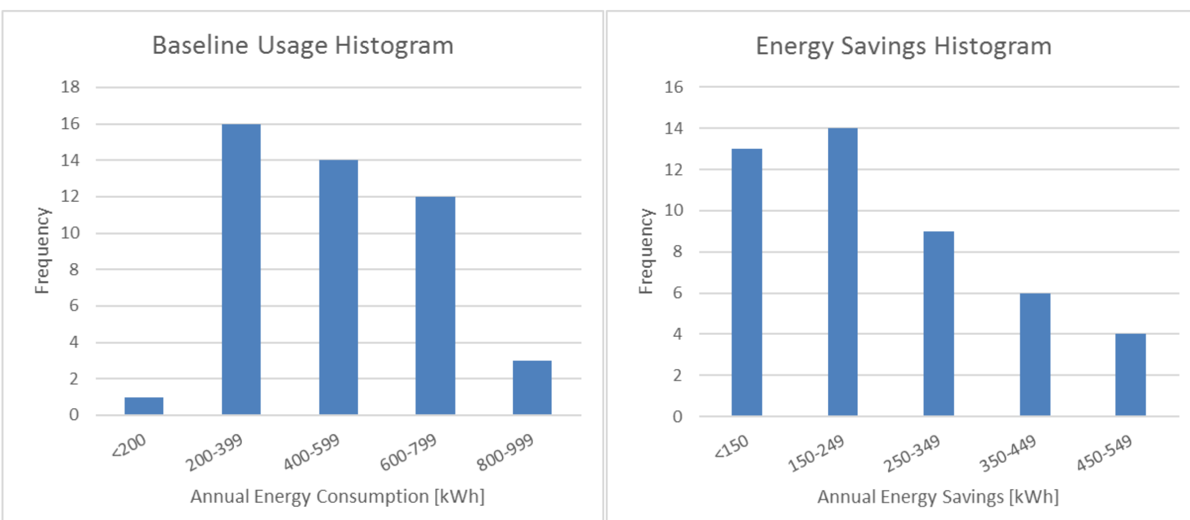

FIGURE 4: HISTOGRAMS OF ANNUAL BASELINE USAGE AND ENERGY SAVINGS

DEMAND REDUCTION:

In addition to energy savings, the APS devices tested in this study also achieved some demand reduction.

In both the pre-installation and post-installation cases, the demand profile experiences a brief dip that roughly coincides with the DEER peak demand period of 2:00-5:00pm. This trend suggests that many participants in the study were away from home during on-peak hours. The associated demand savings are most likely due to standby demand reduction rather than turning off equipment that had been accidentally left on.

Figure 5 plots the daily baseline demand profile, post-installation daily demand profile (including weekday and weekend), and demand reduction, as averaged across all complete host sites over the measurement period. Note that the baseline demand fluctuates throughout the day, but peaks at 7am, 2pm and at 8pm. This daily demand profile differs from previous studies that reported a lone baseline demand peak at around 9pm. This inconsistency with previously reported findings suggests that demographics or APS usage characteristics in this analysis may differ from other studies.

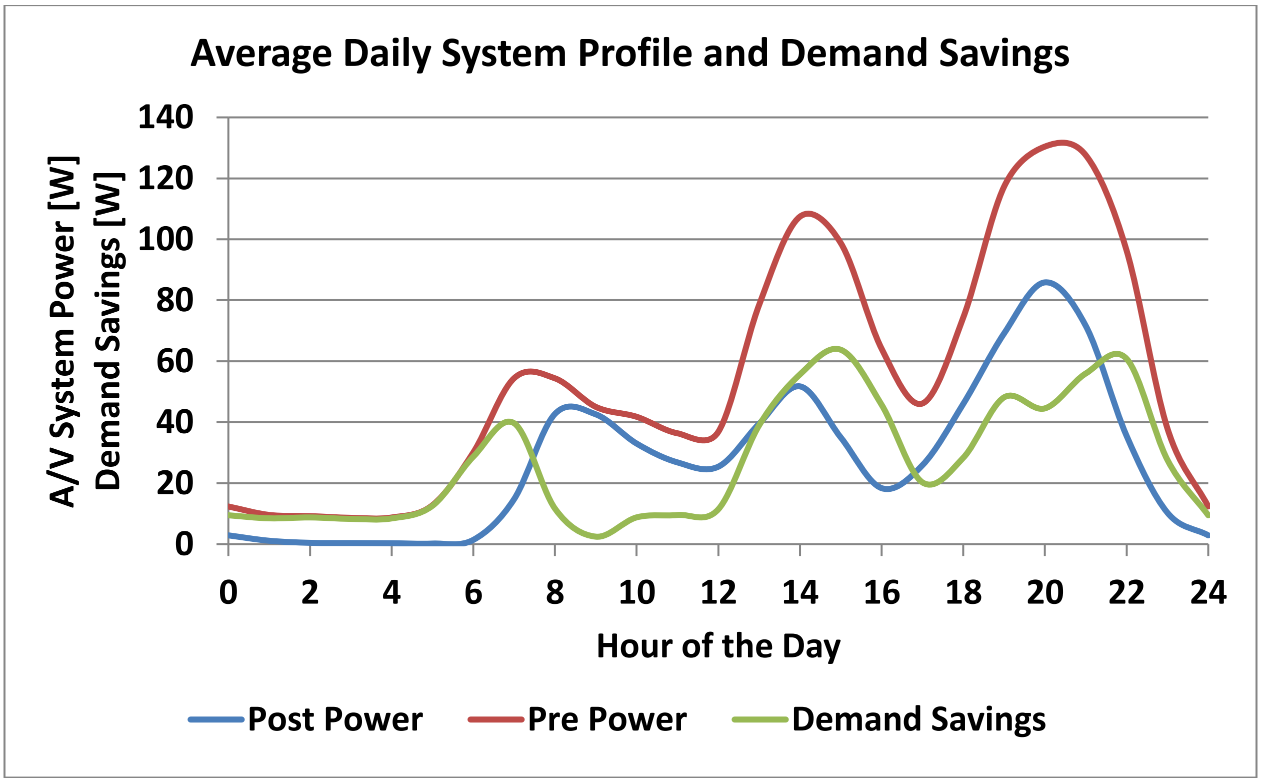

FIGURE 5: AVERAGE HOST SITE SYSTEM LOAD PROFILE, INCLUDING DATA FROM WEEKDAYS AND WEEKENDS

As the above chart illustrates, on average, positive demand savings were achieved for each hour of the day, with a maximum savings of approximately 64W occurring at around 3pm. It should also be noted that the demand savings is about 10W during off hours. Average demand savings across the entire day were about 27W. For separate demand profiles of weekdays and weekend days, please see Appendix A.

On-peak demand and demand savings were calculated by averaging the demand between 2pm and 5pm on complete weekdays. Nearly all surveyed sites exhibited savings during this DEER peak period, although two sites showed a slight increase in energy consumption during the period, likely due to varying use patterns. Overall, there was significant variation in peak demand period savings, ranging from -8W to 155W. The demand impacts are summarized in Table 4.

TABLE 4: AVERAGE WEEKDAY ON-PEAK PERIOD SAVINGS

	Average	Standard Deviation
DEER on-peak baseline demand [W]	88.85	48.41
DEER on-peak demand savings [W]	52.89	43.40
DEER on-peak % demand savings	50%	27%

AGREEMENT OF PREDICTED ENERGY SAVINGS WITH MEASURED SAVINGS:

Each installed APS unit was equipped with an algorithm that predicted Annualized Projected Energy of the system. This predicted annualized value was generally found to align well, but not exactly, with measured energy usage, as illustrated in the charts below.

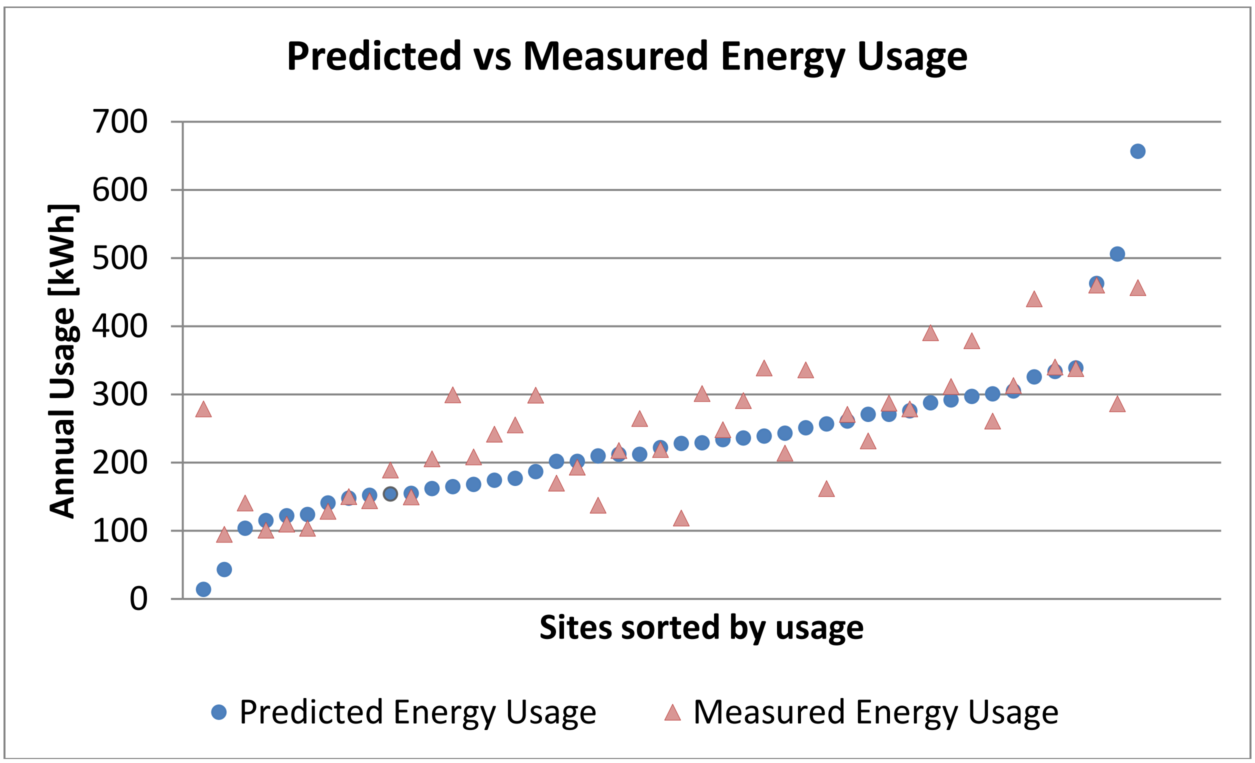

FIGURE 6: AGREEMENT OF SIMULATED ENERGY SAVINGS WITH MEASURED ENERGY SAVINGS BY SITE

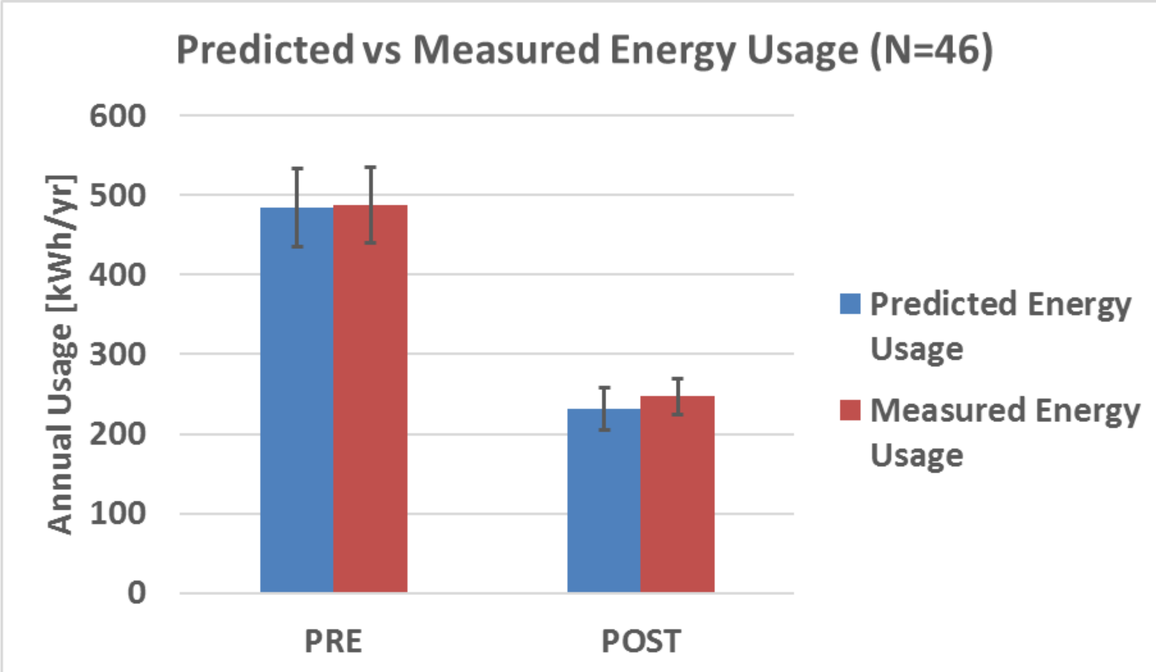

FIGURE 7: OVERALL AGREEMENT OF SIMULATED ENERGY SAVINGS WITH MEASURED SAVINGS

Note that the bracketed range represents the 90% confidence interval of the population mean. Overall, the average predicted energy consumption was within the 90% confidence interval of the measured energy usage.

DISCUSSION

The results of this study should be tempered by the fact that the average number of uses declined sharply from the pre-installation to post-installation period. Note that a "use" was defined by the analysis as a continuous period with greater than 50W of power consumption. While the total time in use would be expected to decrease since the APS is designed to turn off devices that are not in use, the total number of uses per day would be expected to remain constant. The data shows that both the average time of use and average number of uses per day decrease significantly from the baseline to the post period.

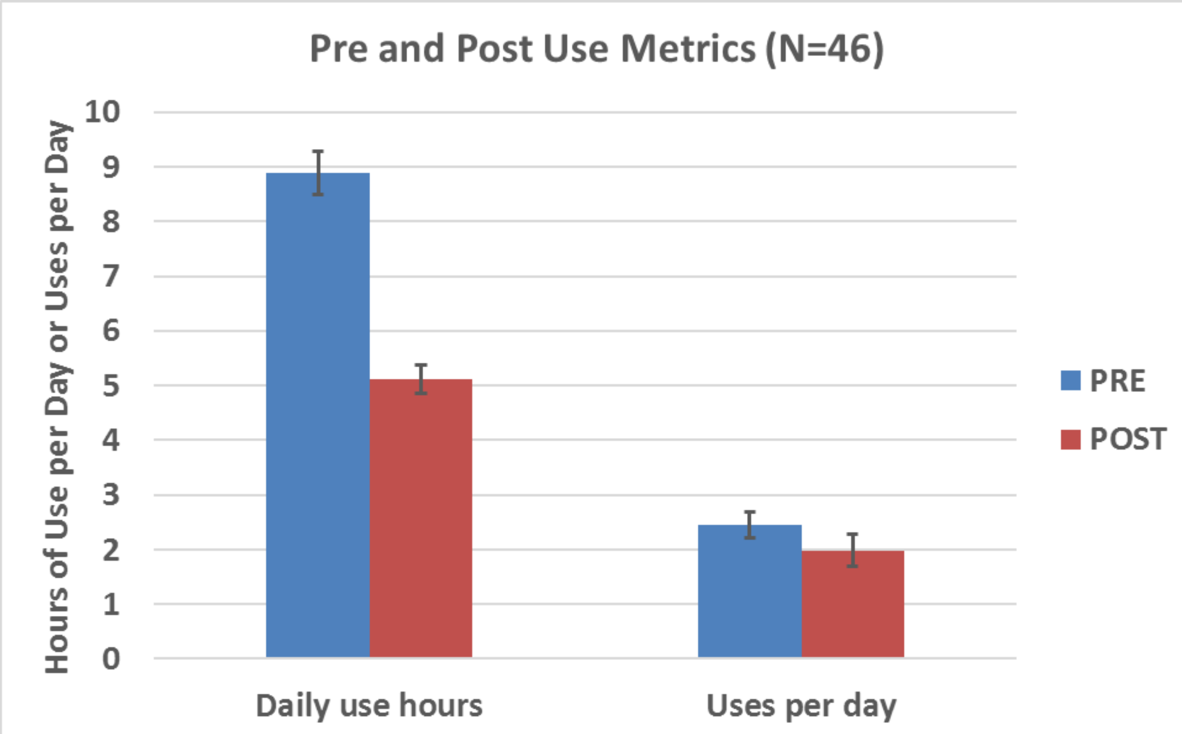

FIGURE 8: DECLINE IN A/V USAGE BETWEEN PRE AND POST MONITORING PERIODS

This significant change in A/V usage may have resulted from the fact that pre- and post-installation periods were collected over nearly identical 2-3 week periods at all 46 sites. As a result, it is possible that more popular television programming was scheduled during the pre-installation period, which led to an increase in A/V operation during this period. These results highlight the fact that it is difficult to control for changes in usage patterns when conducting any monitoring study, and this issue can be best addressed by extending the monitoring period in future studies.

If post-installation annual energy consumption is normalized to consider this change in average daily uses, the energy savings impact of the technology is decreased, as shown in Table 5.

TABLE 5: ADJUSTED ANNUAL ENERGY SAVINGS TO CONSIDER CHANGES IN USAGE PATTERNS

	Unadjusted Energy Consumption (kWh)	Average Daily Uses	Adjusted Energy Consumption (kWh)
Pre-Installation	487.4	2.4	487.4
Post-Installation	247.0	2.0	305.2
Savings	240.4		182.1
% Reduction	49%		37%

However, even after adjusting for usage, the energy impacts measured in this study were significant. Annual energy usage was observed to decrease significantly in all 46 analyzed sites. Although the observed DEER Peak demand reduction per site was more variable, the aggregate demand reduction of many installed sites could provide significant value to utilities and electrical grid management.

APPENDIX A

In the analysis, data for weekend and weekday energy usage were evaluated separately to minimize usage differences. The following figure illustrates the observed difference between weekday and weekend energy usage:

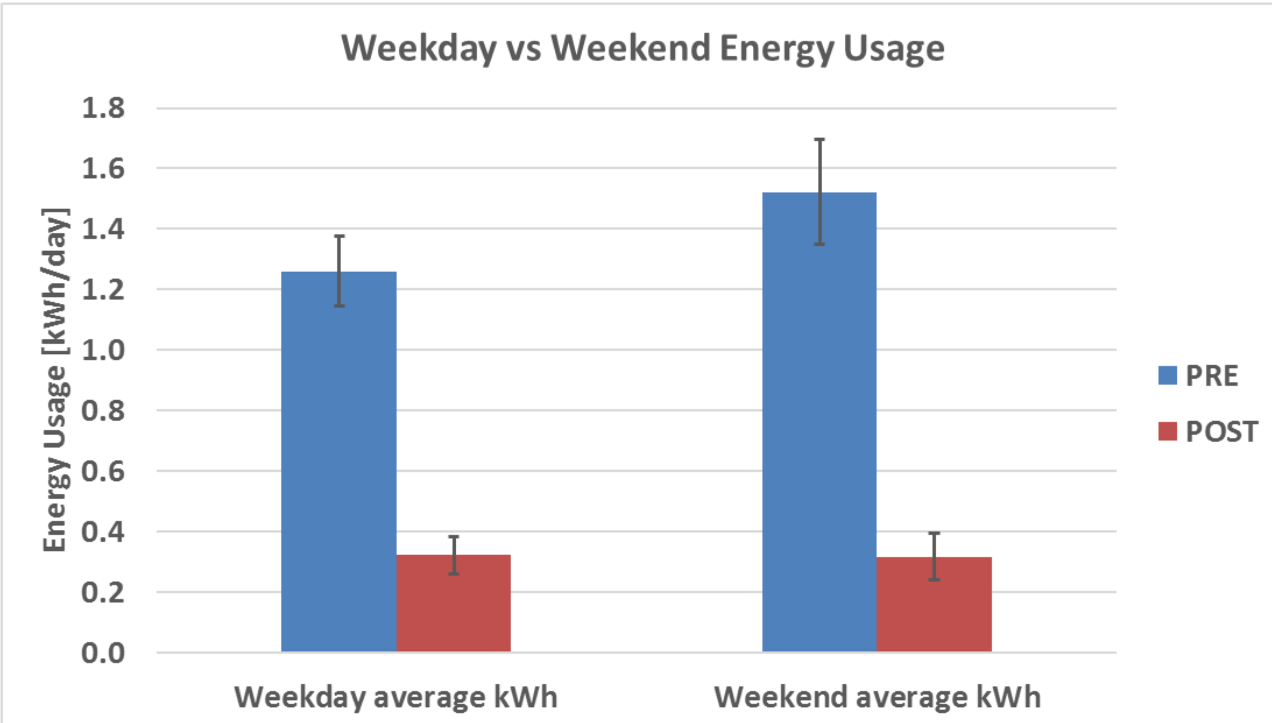

FIGURE 9: WEEKDAY VS WEEKEND ENERGY USAGE

Note that the bracketed range represents the 90% confidence interval of the population mean. In general, baseline energy consumption was observed to be higher during weekend days, while activated APS energy consumption was found to be relatively consistent between weekend and weekday periods. However, due to the very small sample size of weekend days, these results should be replicated in additional studies before conclusions are drawn.

Weekend and weekday energy usage was observed to follow differing hourly usage schedules, as shown in the below figures.

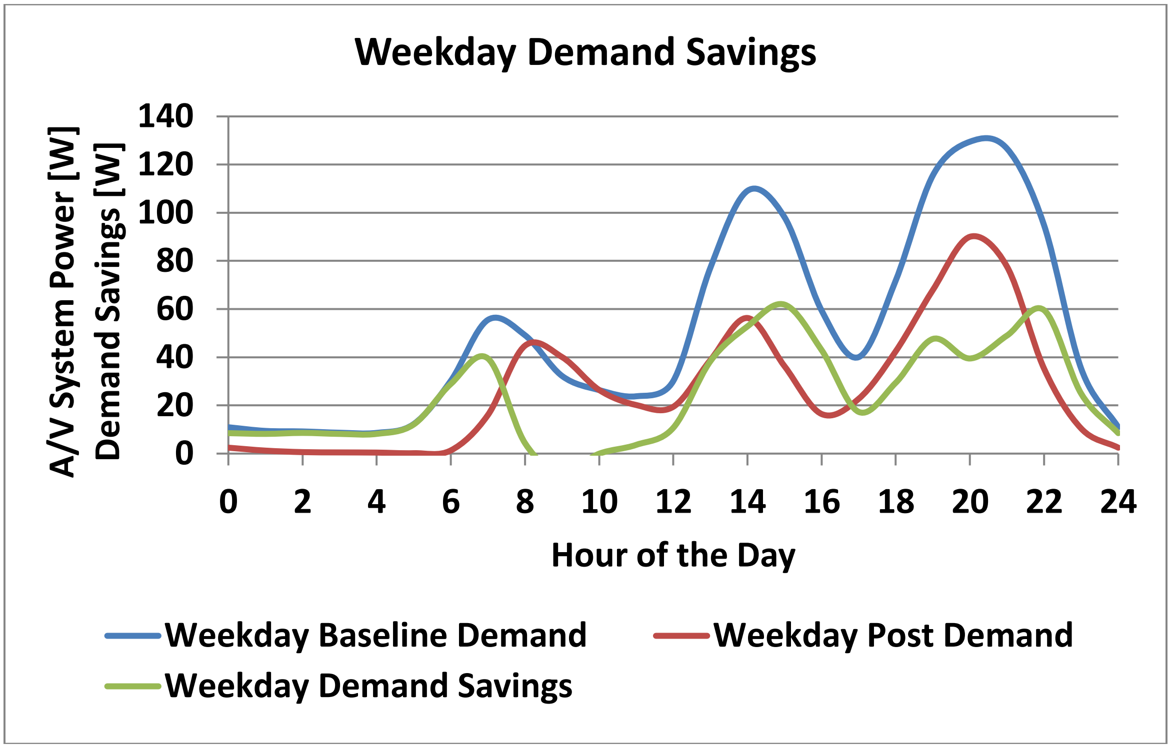

FIGURE 10: AVERAGE WEEKDAY DEMAND SAVINGS PROFILE

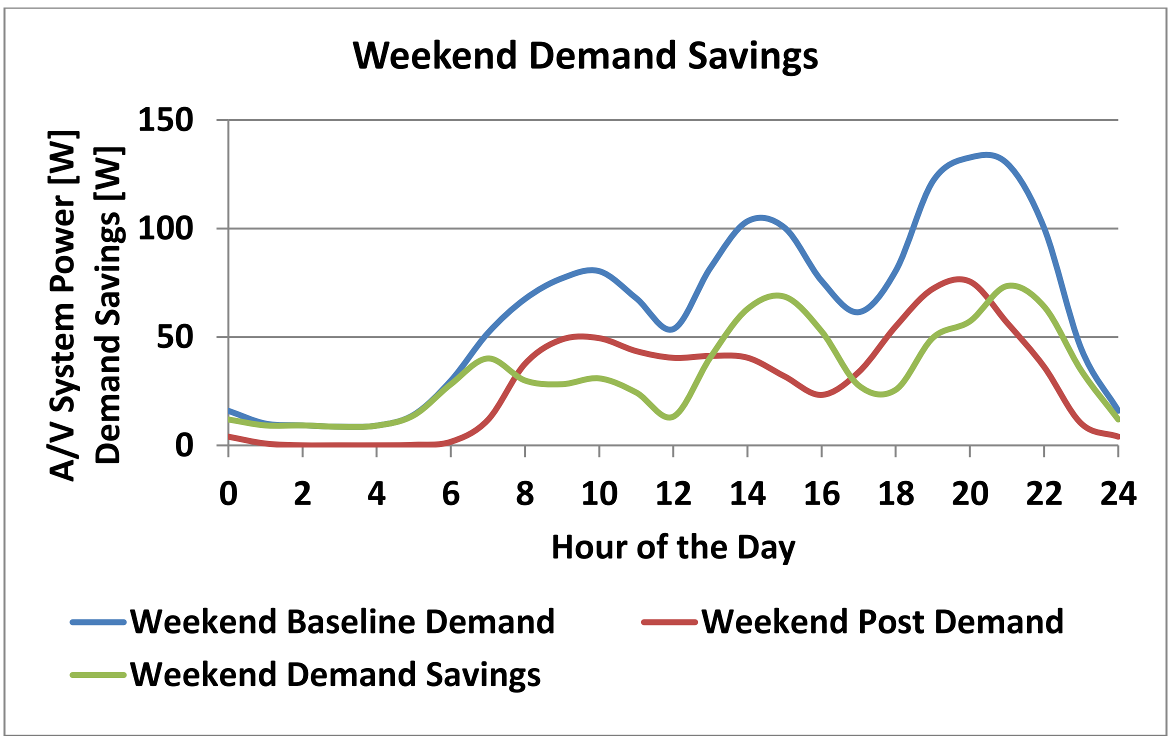

FIGURE 11: AVERAGE WEEKEND DEMAND SAVINGS PROFILE

Since these data were collected in the two weeks preceding and three weeks following the Thanksgiving holiday, the observed differences between the weekend and weekday demand profiles are minimal. The only noticeable difference is an increase in weekend demand between the hours of 8:00am and 12:00pm.