TIER 2 ADVANCED POWER STRIPS IN RESIDENTIAL AND COMMERCIAL APPLICATIONS

San Diego Gas & Electric
Emerging Technologies Program
Technology Assessment Report
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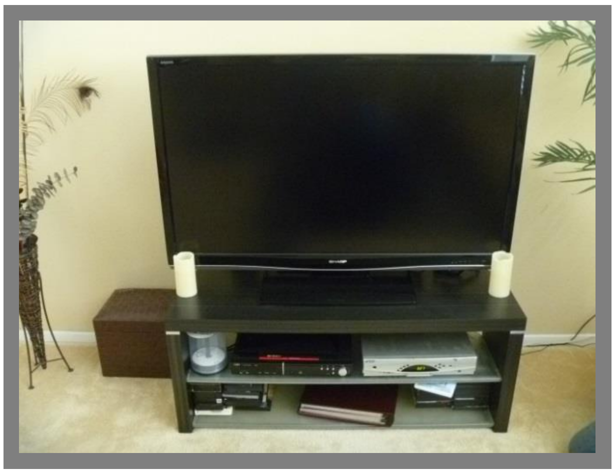

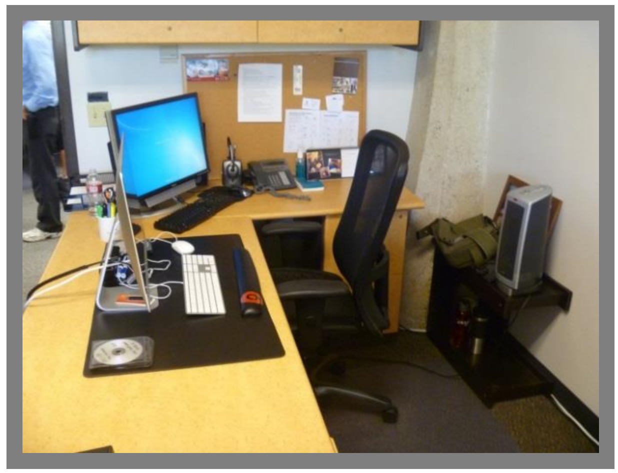

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EXECUTIVE SUMMARY

In support of California's strategic plan to accelerate the penetration of energy efficiency technologies, this report presents the findings of a field evaluation of Tier 2 advanced power strips (APS) installed at residential audio/video (A/V) systems and commercial office and computer lab workstations (PC). The work was executed by Alternative Energy Systems Consulting, for the San Diego Gas and Electric Emerging Technology program. RMS Consulting, CalPlug, CalTF, and the power strip vendor and manufacturer contributed additional direction, assistance, and field work in support of the project.

Technology Evaluation Description: The primary goal for this project was to determine the energy savings and demand reduction of recent generation advanced power strips in residential A/V systems and commercial PC workstations. Each Tier 2 APS controls power to the plug loads using inputs of aggregate system power and monitored user activity. A field trial was conducted at 42 residential A/V sites and 51 university PC workstations for an average of 13 days. The M&V approach used a CalPlug approved method that simultaneously collects baseline data and simulates the controlled state. Additionally, post-installation monitoring was performed at 9 residential A/V sites in order to gain insight into the behavioral effects not entirely captured by the CalPlug method.

Project Findings: The study found that the APS devices functioned as designed and operation was intuitive with simple, quick installation. Energy savings, demand reduction, and estimated simple payback from the CalPlug method are presented in Table 1.

TABLE 1 – RESULTS SUMMARY TABLE – AVERAGES ACROSS ALL HOST SITES

SETTING	BASELINE ENERGY [KWH/YR]	ENERGY SAVINGS [KWH/YR]	DEER ON-PEAK BASE DEMAND [W]	DEER ON-PEAK DEMAND REDUCTION [W]	COST [$]	ESTIMATED PAYBACK [YR]
Res A/V	463	234	65	35	$65	1.9
Com PC w/ vacant workstations	477	371	84	45	$65	1.2
Com PC w/out vacant workstations	476	336	91	40	$65	1.3

Conclusions and Recommendations: Tier 2 APS models have differences from past generations that should provide increased energy savings, demand reduction, and user acceptance. Both the A/V and PC models were successful in lowering energy consumption and demand profiles. Despite this, market penetration remains low and utility encouragement and programs should be considered for aiding the uptake of this emerging technology. Several correlations were found that could aid in the streamlining of programs development and evaluation. Customer acceptance and persistence after installation remains uncertain due to entrenched customer A/V and PC expectations and complications with IT protocols and software concerns in large commercial settings.

Additional study using a post-installation methodology could clarify some of the uncertainty surrounding behavioral effects. Vendors should work to address the IT concerns of large commercial customers in order to increase customer acceptance at valuable, high-volume implementations. Despite these uncertainties, it is expected that the total resource cost and benefits to society could be significant if a Tier 2 APS program is effective. One effective program approach using typical methods could be a direct install program free to residential and light commercial customers and with a buydown for larger commercial customers.

ABBREVIATIONS AND ACRONYMS

AESC	Alternative Energy Systems Consulting
APS	Advanced power strip
A/V	Audio/video – In general, refers to residential entertainment system
CalPlug	California Plug Load Research Center
CPUC	California Public Utilities Commission
DEER	Database for Energy Efficient Resources
EE	Energy efficiency
ET	Emerging technologies
IPMVP	International Performance Measurement and Verification Protocol
IR	Infrared
MFR	Multi-family residence
M&V	Measurement and verification
OS	Occupancy sensor
PC	Personal Computer – In general, refers to commercial (or residential) computer workstations
SDG&E	San Diego Gas and Electric
SFR	Single-family residence

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INTRODUCTION

This study was performed by Alternative Energy Systems Consulting (AESC) on behalf of San Diego Gas and Electric's (SDG&E) Emerging Technologies (ET) program. AESC is an energy engineering practice specializing in utility programs, technology assessments, demand side audits, and measurement and verification. SDG&E's ET program strives to increase the exposure and success of emerging and underutilized energy efficiency and demand side management technologies in the California marketplace. This field test technology assessment was designed to provide information on a management device for common consumer electronics plug loads. The assessment was performed in parallel to a scaled field placement pilot program being conducted by SDG&E.

Home and office electronics and plug loads account for a sizable portion of overall residential and commercial energy consumption. Although some home and office electronics are increasingly implementing control logic and EE designs to reduce consumption, there are few options for customers to reduce their energy footprint for existing plug load electronics equipment. One particularly unaddressed issue is the consumption of standby, "vampire" loads and the common occurrence of electronics left on unnecessarily.

Standby, vampire loads (sometimes called "phantom loads") are the electronic equipment demands that occur when the device is turned off by the user. Although the electronic device is turned off, manually or otherwise, it will still draw power. Televisions, coffee machines, computer monitors, DVD players, stereos, game consoles, cell phone chargers, printers, and desktop computers are only some of the common home and office devices that have standby loads. While each standby load is typically small, they are constant and can consume large amounts of energy over time, especially when one considers the huge number of consumer electronics now present in our everyday lives.

LITERATURE SURVEY – PLUG LOAD CHARACTERIZATION

Many studies have been performed to characterize plug loads and identify opportunities and barriers to EE measures, although the data for residential applications far outweighs that of commercial applications. A study of plug loads prepared for Southern California Edison in 2010 determined that about 91% of residential plug load energy consumption comprised of A/V and PC usage, after excluding kitchen appliances and most lighting (Peters, 2010). Figure 1 shows the percentages of each residential, plug load end use category. The other plug loads in the study were comprised of small appliances and several other end-uses. Figure 1 leads to the conclusion that residential A/V and PC plug loads are a good target for energy efficiency measures, since control strategies could perhaps affect a large number of equipment in each category with a simple measure while affecting a large fraction of the home plug load consumption.

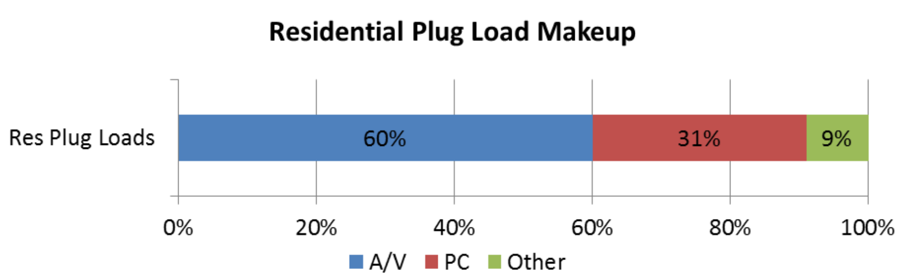

FIGURE 1 - RESIDENTIAL PLUG LOAD END-USES, EXCLUDING KITCHEN APPLIANCES AND MOST LIGHTING (PETERS, 2010)

Figure 2 and Figure 3 below show recent and projected residential and commercial plug load consumption for A/V and PC equipment, as reported by the U.S Energy Information Administration (Conti, 2014). The A/V numbers include data for televisions, set-top boxes, home theater systems, DVD players, and video game consoles, while the PC data includes data for desktop and laptop computers, monitors, and networking equipment. Note that printers are not included here.

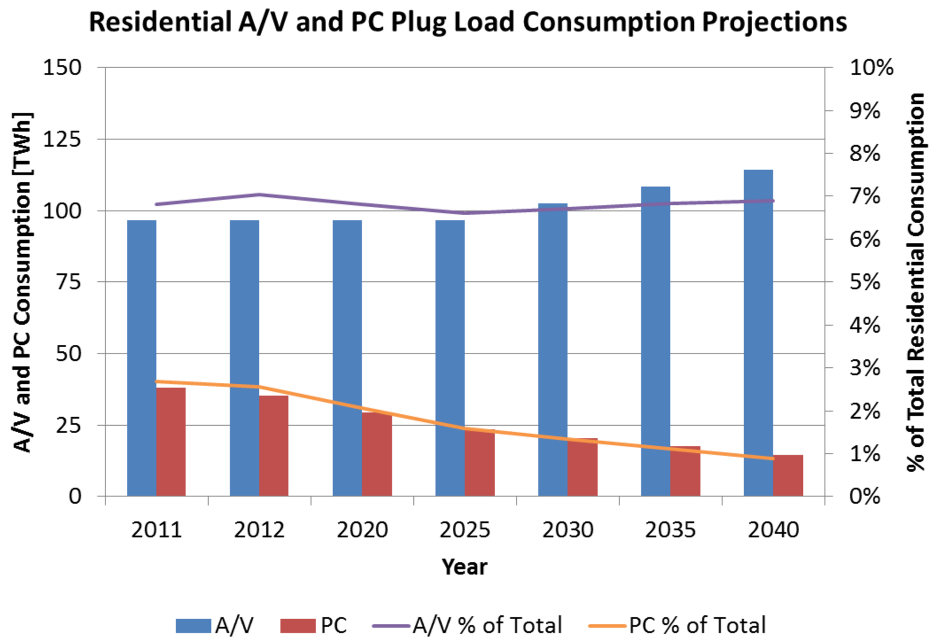

FIGURE 2 - RESIDENTIAL A/V AND PC PLUG LOAD CONSUMPTION TREND (CONTI, 2014)

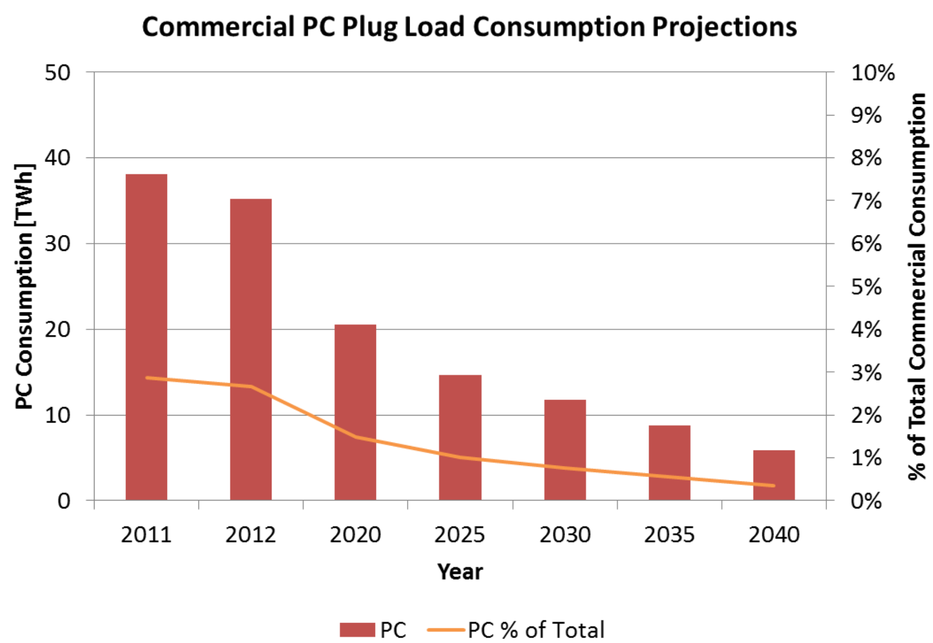

FIGURE 3 - COMMERCIAL PC PLUG LOAD CONSUMPTION TREND (CONTI, 2014)

As seen in the above figures, A/V consumption percentage stays relatively constant but increases in magnitude as A/V device usage continues to increase. On the other hand, PC plug load consumption is projected to decrease year-over-year in both the residential and commercial environments. Despite these trends, both end uses are large consumers of energy and are an obvious target for improved energy efficiency and new energy conservation measures.

A study by Fraunhofer USA estimated the number of A/V and PC devices in residences across the country, shown in Figure 4.

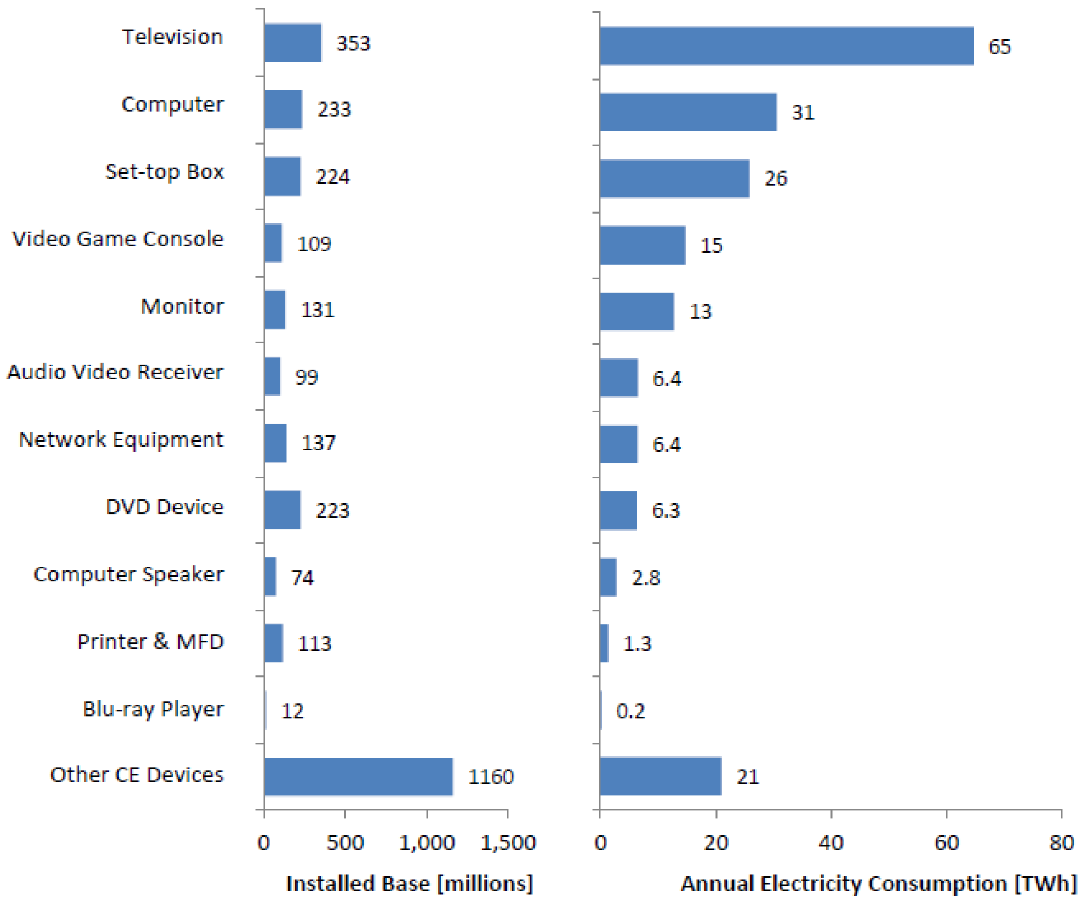

Figure 4 - Residential AV and PC plug load devices and consumption in the US (B. Urban, 2011)

A 2011 study performed by the New York State Energy Research and Development Authority determined the average number of A/V and PC plug load devices in the typical US home, as shown in Table 2.

TABLE 2 - A/V AND PC DEVICE FREQUENCY PER US HOME

DEVICE	AVERAGE FREQUENCY PER HOUSEHOLD
Television	2.9
Set-top Box	1.8
DVD, VCR, or BluRay	2.1
Video Game Console	0.6
Audio System	0.2
Desktop Computer	0.8
Laptop Computer	0.5
Computer Monitor	0.8
Printer	0.6
Fax Machine	0.2
Other PC & A/V devices	0.2

Finally, several studies have characterized average residential annual A/V energy usage. These studies have shown that the average California household uses about 685 kWh per year for A/V devices (Wang, 2014). In general, this figure includes televisions, stereos, set-top boxes, DVD players, and video game consoles.

EMERGING TECHNOLOGY MOTIVATION

As shown in Table 2, the average household has over 10 A/V and PC devices. Additionally, nearly every cubicle, desk, and workstation in the commercial world has a computer or laptop dock, monitor, and other PC peripherals. The market and opportunity for plug load management and energy savings is large and ubiquitous.

There is no current energy efficiency code that directly addresses home and office electronics plug load management in California. Various plug load devices may have Energy Star standards and energy efficiency measures built in, but no standards or code for management of these plug loads has been established. Utilities have developed some programs and efforts around certain types of home area network (HAN) measures, but none that directly and solely relate to A/V and PC plug load management.

Although no energy efficiency standards and programs related to this type of plug load management exist, there have been attempts at measures in the marketplace and encouragement from utilities, research institutions, and industry partner organizations. However, despite this encouragement and obvious need for energy efficiency improvement, the standard practice in the majority of homes and workplaces is to have a manually switched power strip which is almost never turned off. Thus, there is a need for emerging technologies that can provide energy efficiency control measures for this plug load management opportunity.

APS Background and Technology

As described in the preceding Introduction section, the largely unsolved issue of standby and wasted A/V and PC plug load consumption necessitates an emerging technology solution. One such solution developed by industry is the advanced power strip (APS), sometimes called a "smart power strip." An APS is a power strip which has several controlled plug load receptacles and may also have several uncontrolled receptacles. The controlled receptacles are energized or de-energized based on various conditions while the uncontrolled receptacles remain always energized.

Manufacturers and vendors have been offering APS devices for several years now. These APS devices come in several designs and can generally be categorized into first or second generation devices, also known as Tier 1 and Tier 2. First generation Tier 1 APS devices have had some utility, deemed programs designed around them throughout the country, but limited adoption rates in California have made it difficult to set up effective programs. In response to the results of this first generation of APS technology, manufacturers have designed and marketed new APS devices with differing control strategies. Second generation Tier 2 APS devices are the emerging technology under study in this report.

Literature Survey – Tier 1 APS Devices

The first generation APS devices generally utilize one of the following energy savings strategies to control the power state of the controlled receptacles:

- Timeclock programming
- Occupancy sensor (OS)
- Current sensing of a master device

The timeclock programmed power strip uses manually-programmed daily schedules to determine when controlled receptacles should be energized. This type of APS is best suited to a workstation that has a regular schedule of use. This strategy has potential for maximized savings when used at a location with a strict, regular schedule. However, there is potential for turning off computers while they are on, thus potentially losing unsaved data or damaging components. Additionally, if the equipment schedules deviate or change over time, savings will not be maximized and users may have to override the controls frequently.

The OS based approach uses an infrared (IR) sensor to determine when a user is present. When a user is detected, the equipment will remain energized for use, if desired. When no motion is detected for a certain amount of time (30 minutes, for example), all controlled equipment will be de-energized. This strategy would seemingly provide a good match between controlled times and active use times, but can be accidentally triggered by passers-by or pets. For example, the equipment could be energized as a co-worker passes by an empty workstation or if a pet passes by the television. This type of APS may also turn off equipment when it is still in use, thus losing unsaved information or damaging computer components.

The last and most common type of first generation APS is the current sensing, master/controlled design. This type of APS has a master receptacle which is monitored by current-sensing instrumentation. When the master device current drops below a certain threshold, it is assumed to be in standby or turned off. When this happens, the controlled receptacles are all de-energized. This strategy typically uses the television or computer as the master device and assumes that all peripheral devices are unused whenever the computer or television is off. Figure 5 shows a typical PC application of a master/controlled APS device. The modem and router are always energized, the computer is always energized and is monitored for current draw to determine the controlled state, while the PC peripherals are plugged into controlled receptacles and are de-energized when the computer is in a low-power standby or off state.

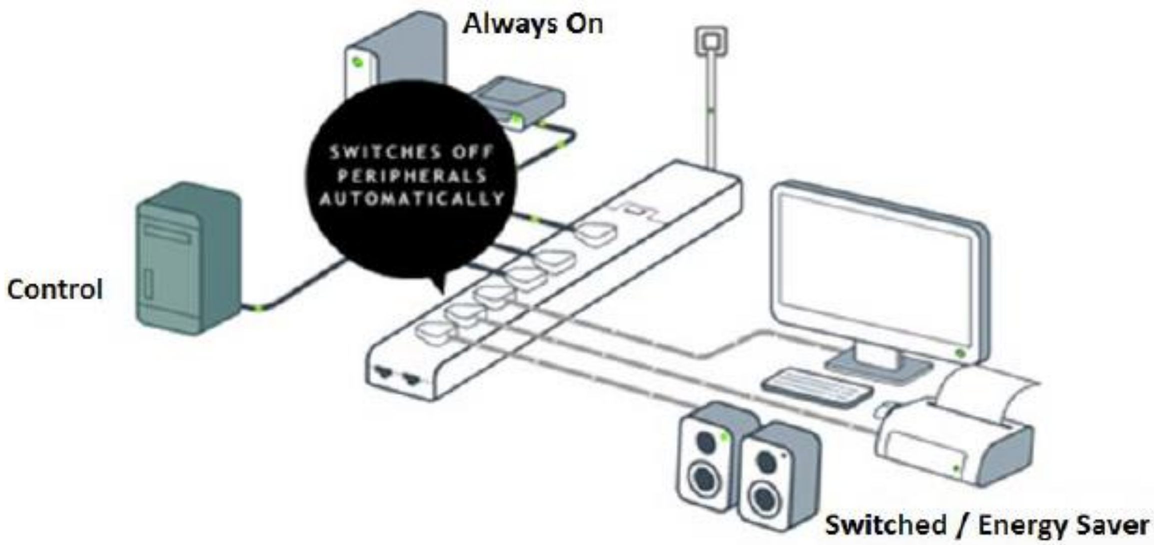

FIGURE 5 - MASTER/CONTROLLED APS DESIGN (MALIK L. A., 2011)

The master/controlled type of APS will not turn off the computer or television while they are still in use and will not disrupt any unsaved processes or computer components. However, there are several downsides to this control strategy:

- The current threshold which determines when peripherals should be energized or de-energized may not align with actual power draw of the master device during active and standby modes. Although this threshold is sometimes adjustable by a dial or switch, it may not be well suited to the particular master television or computer. For instance, a plasma TV will have varying power across the color spectrum and a computer may have very low power even if it is performing user or critical processes. For this reason, Tier 1 APS models are often not well-suited for laptop computer setups.
- The master device will never be automatically de-energized using the control strategy. Since televisions and computers often use the most energy of these PC and A/V devices, this is a significant downside to this strategy.
- Energy at the peripherals will only be saved when the master device is turned off by the user or built-in setting. If the computer or television is left on when not in use, all the peripheral devices can remain on, as well. For this reason, one of the major wasteful energy states of A/V and PC systems is not addressed.

Previous studies and utility deemed values in various settings have identified savings ranging from 23 to 89 kWh/year for these types of smart strips. An NREL study identified savings from 4 to 26% in office workstation settings.

Table 3 lists the savings results for each of the sources found in the literature survey. The values span home A/V, home PC, and commercial PC settings and almost exclusively use the master/controlled APS type. Many studies commented on large variation in savings from strip to strip due to the large variability associated with combinations of possible connected equipment and uncontrollable user behavior, such as moving plugs.

TABLE 3 - LITERATURE SURVEY OF FIRST GENERATION APS SAVINGS

SOURCE	APS TYPE	APPLICATION	SAVINGS [KWH]
(SDG&E, 2013)	Master/Controlled	Res PC	25
(Malik L. a., 2011)	Master/Controlled	Res PC	34
(Kessler, 2011)	Master/Controlled	Res PC	31
(BPA, 2013)	Master/Controlled	Res PC	23
(SDG&E, 2013)	Master/Controlled	Res A/V	26
(Malik L. a., 2011)	Master/Controlled	Res A/V	34
(BPA, 2013)	Master/Controlled	Res A/V	43
(Kessler, 2011)	Master/Controlled	Res A/V	75
(BPA, 2013)	Master/Controlled	Res A/V	43
(Malik L. , 2012)	Master/Controlled	Omitted	89
(Malik L. , 2012)	Master/Controlled	Omitted	75
(BPA, 2013)	Occupancy Sensor	Omitted	67

Source	APS Type	Application	Savings
(I. Metzger, 2014) (Spam, 2012)	Master/Controlled	Com PC	4%
	Schedule Timer	Com PC	26%
	Occupancy Sensor	Com PC	21%

LITERATURE SURVEY – TIER 2 EMERGING TECHNOLOGY APS DEVICES

There have been limited studies on the emerging technology APS devices as of this report. Additionally, these APS devices have only one savings strategy each for A/V and PC control, thus far. These two strategies are detailed in the next section.

Several studies have been performed to estimate the savings potential of the emerging technology APS devices. Table 4 lists the results of these tests which vary between about 250 to 350 kWh saved per year. Note that they all used the same methodology and instrumentation to test a single APS vendor's PC and A/V models. This methodology was developed and proposed by CalPlug at the University of California, Irvine as a solution for standardization of Tier 2 APS testing with appropriate rigor and technical defensibility (Wang, 2014).

TABLE 4 - LITERATURE SURVEY SECOND GENERATION APS SAVINGS

SOURCE	APS TYPE	APPLICATION	SAVINGS [KWH]
(BPA, 2013)	IR and Load Sensing	Res A/V	321
(EnergyConsult, 2012)	IR and Load Sensing	Res A/V	258
	IR and Load Sensing	Res A/V	280
(Wang, 2014)	IR and Load Sensing	Res A/V	348
	Software and Load Sensing	Com PC	350

EMERGING TECHNOLOGY DESCRIPTION

The emerging technology devices under study are two APS models designed for A/V and PC use. The A/V model is marketed to residential customers who can save energy at their A/V systems by reducing standby power and automatically turning off A/V equipment when they are not in use. The PC model is marketed to both residential and commercial customers who can save energy at their computer workstations by reducing standby power and turning off PC peripherals when not in active use. Each model uses a more sophisticated control algorithm than the timer, occupancy sensor, or master/controlled APS models.

There are two options for each model: a wall pack that plugs into a two-receptacle wall outlet and sits flush with the wall or a power strip version. The wall pack model has three always energized receptacles and a single controlled receptacle that a controlled power strip can be plugged into. The power strip model has two always energized and six controlled receptacles.

FIGURE 6 - A/V WALL PACK MODEL AND EXAMPLE ARRANGEMENT

A/V Model

The A/V model uses a combination of remote control signals and power monitoring to determine when the A/V equipment should be de-energized. The A/V model has two modes of saving, standby savings and accidental active savings:

The APS will monitor the collective power of the controlled devices and determine when equipment is in use by observing fluctuations and power levels. When the television is turned off, for instance, the power will go to a lower, constant state and the APS will recognize that the user is finished using the A/V equipment for the time being. When the APS sees that the user is finished, an LED light will blink for 1 minute, signaling that the controlled devices will be de-energized. After 1 minute, the electrical relay opens, de-energizing all controlled devices and thus saving standby loads and turning off any peripherals that may have been left on.

A small IR sensor monitors remote control activity for any nearby device and will recognize most volume, power, channel, and other button presses. Whenever a remote control signal is observed, the LED light flashes in response. It has mechanical shielding and filtering to prevent false readings from lightbulbs and sunlight. If no remote control activity is observed for 1 hour while the A/V equipment is on, the APS will signal the user that it is planning on de-energizing the controlled devices. The APS assumes that since there has been no IR activity for 1 hour, the user must have left the A/V equipment on accidentally, such as when the user leaves the room or falls asleep on the couch. The LED light will blink for 10 minutes, alerting the user that de-energizing is imminent and that if the A/V equipment is still in use, a quick remote control signal should be sent to avoid shutdown. This is based on studies that have shown that the interval between remote control clicks is usually less than 10 minutes (Wang, 2014). If the user presses a remote control button, the APS timer will be reset; otherwise, the A/V system will turn off, thus saving energy of controlled devices that were accidentally left on. The timer setting, in the tested case, can be set to 1 hour, 2 hours, or a temporary, one-time 8 hours.

When the user wants to turn on the television or any other A/V device, the APS relay must be closed to re-energize the controlled devices. To do this, the user simply presses any remote control IR button to signal to the APS that it should re-energize the controlled receptacles. When the APS sees an IR signal, the relay closes and all the devices are energized and can be turned on as normal. The remote control can be for any of the devices, TV or otherwise, can be any button (power, volume, channel, etc.) and any device can be turned on independently. For instance, a CD player can be turned on using a remote control without having to turn on the TV.

PC Model

The PC model uses monitoring of computer processes to determine when PC equipment should be de-energized. Software is installed on the computer in conjunction with the APS that communicates with the PC via a USB cable. The PC model has two methods of energy savings, de-energizing peripheral devices and putting the computer into a low-power standby state.

The PC model monitors background and user computer processes to determine when the user is and is not actively using the PC equipment. When the PC equipment is inactive, a timer counts down towards zero and if no user process or activity resets the timer, peripheral devices are de-energized and the computer is put into standby, thus avoiding any lost unsaved data. The APS software alerts the user whenever a shutdown is imminent and can be overridden on the screen, if the computer is still being used.

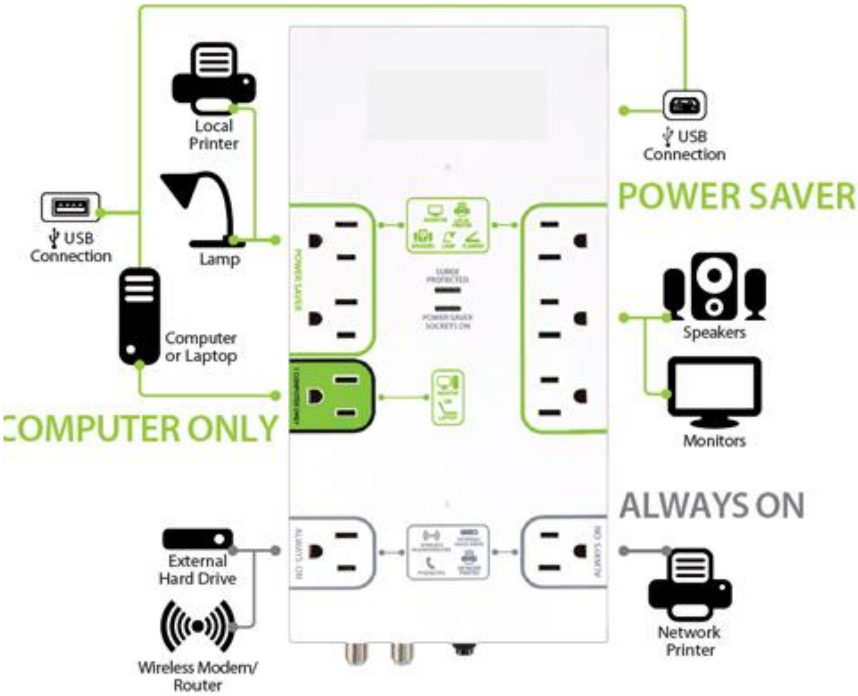

FIGURE 7 - PC POWER STRIP MODEL AND EXAMPLE ARRANGEMENT

APS Application and Barriers

The estimated useful life (EUL) for an APS is about 8-10 years, according to a presentation by Bonneville Power Administration (BPA, 2013) and DEER estimates[1]. With a cost of about $65, payback well under the EUL is assured with even a modest amount of energy savings. According to the manufacturer, the weakest link in APS devices that is most likely to fail is the mechanical or electrical relay due to frequent switching cycles. The model used in this study employs an electrical relay which is rated up to 100,000 switching cycles, thus rendering this concern moot.

These APS devices are well suited to many environments, wherever A/V or PC systems are installed. The best applications would be at large scaled placements that have many A/V or PC systems, such as a commercial office building, schools, dormitories, or hotels. However, since the market for this technology is so large, single-family residences (SFR), multi-family residences (MFR), and small commercial customers are all viable candidates for this measure.

Competing manufacturers and vendors of Tier 2 APS devices include Bits Limited, Embertec, and TrickleStar.

Barriers to the market penetration of APS devices primarily derive from customer resistance, variability in customer A/V and PC use, and high cost relative to standard power strips. It is easy to imagine that a typical customer would not spend much time or effort thinking about and installing a power strip when the typical, manual toggle power strip is such an engrained default practice. Customer acceptance of APS devices will highly depend on the usability and simplicity of the technology. It is

[1] DEER EUL ID: Plug-OccSens

likely that only simplified APS models that do not impede or slow A/V and PC use will be widely accepted. Users will likely resist spending money and time learning how to use yet another device that has no obvious and immediate benefit to them.

This customer resistance has led utilities to explore direct install and give away demand side management (DSM) program options. However, this type of DSM approach has its own questions and barriers. The rapidly changing electronics market, consumer behavior, variability in user patterns and APS acceptance, and unpredictable user interaction with APS devices all add uncertainty to the design and implementation of utility programs (N. O'Neill, 2010).

ASSESSMENT OBJECTIVES

The goal of this technology assessment is to identify the demand reduction, energy savings, and operational benefits of a Tier 2 APS device used in residential A/V and commercial PC environments. The Tier 2 APS under study has an algorithm that uses remote control IR signals, power sensing, and masterless control in A/V settings and power sensing with additional computational algorithms in desktop and laptop commercial PC settings. To this end several objectives were established:

- Measure and verify energy and demand savings of the A/V and PC APS models selected at residential and commercial applications.
- Perform a qualitative evaluation of the APS devices by considering user interaction, acceptance, and installation ease.
- Perform a quantitative evaluation of the APS devices by performing a statistical analysis of the collected data to determine energy and demand savings and identify trends and correlations with various parameters, should they exist. These results informed a workpaper submitted to the CPUC in December 2014.
- Generate a technology assessment report that follows the International Performance Measurement and Verification Protocol, Option B (IPMVP).
- Complement the concurrent scaled field placement pilot program.

In order to accomplish these objectives, APS simulation devices were installed at 53 residential host sites for A/V operation and 51 personal workstations and computer lab stations at a single commercial host site for PC operation. Note that only 42 of the residential A/V sites were used in the analysis for reasons described later. Additionally, 13 residential sites were selected for post-installation measurement to gain a better understanding of the impacts of the selected measurement and verification (M&V) simulation instrumentation and to collect further data from a different M&V approach. Of the 51 installed PC workstations, 13 were observed to be largely unused, vacant computers. Results are presented for both the isolated 38 active PC workstations and the total population of 51 active and vacant workstations combined.

A/V Measurement and Verification Plan

The M&V plan for the A/V and PC emerging technology assessment was based around the concurrent scaled pilot program and a field trial. The M&V plan opted to use an instrumentation and APS simulation system designed by CalPlug with industry input and approved by the California Technical Forum (CalTF). The instrumentation is the same one utilized in the referenced, previous APS studies which found average savings of 250-350 kWh per year for this type of APS. These previous studies were independently conducted by IOU's and regional bodies through various consultants, under the guidance of CalPlug's methodology developed in concert with APS industry input.

This instrumentation and M&V approach was agreed upon by all involved parties: AESC, SDG&E, CalTF, CalPlug and the vendor supplying the APS devices and instrumentation system.

Additionally, a small sample group from the population was selected for traditional pre and post measurement to supplement the main M&V approach.

A/V Host Sites

The participating host sites for the A/V field trial were volunteers that responded to email solicitations from AESC and SDG&E. The original M&V plan intended on gathering volunteer participants from the larger pilot program. Unfortunately, the pilot program start date was delayed and the M&V field work had to begin regardless. Thus, solicitations were sent to individuals in the AESC and SDG&E ET professional and personal network. These solicitations included details on the goals the project, instrumentation to be installed, field visit details, and a description of the technology and its purpose. Although it was hypothesized that SDG&E employees could potentially skew results due to energy conscious behavior, a statistical analysis showed that this effect was small with low level of significance. This is detailed in the Appendix.

Once volunteer interest was established, host site A/V characteristics and demographics were determined and a field demonstration agreement between SDG&E and each participant was executed. Host sites were located throughout SDG&E territory in the greater San Diego metropolitan area.

Figure 8 - Example host site A/V systems

Of the 53 installed sites, 4 sites had to be de-installed due to data transmission issues, instrumentation at 3 sites was not initialized correctly, and 4 sites had irreconcilable data errors. This resulted in a final total A/V population of 42 host sites. Upon initial screening and site visits, demographic data was collected and plug load devices (television, game console, etc.) were noted and recorded. Table 5 summarizes some of the demographic data of the host sites.

TABLE 5 - HOST SITE DEMOGRAPHICS

Location (Zipcode)	Host Site Frequency (% of total)
Central San Diego (92103, -08, -10, -17, -22, -23, -24, -20)	10 (24%)
La Mesa, El Cajon (91941, -42, -77, 92020, -21, -71)	8 (19%)
Escondido (92025, -27, -29, -69, -78)	7 (17%)
Poway, North San Diego (92064, 92126, -28)	5 (12%)
Encinitas, Solana Beach (92007, -24, -75)	4 (10%)
Carlsbad, Vista (92009, -10, -81)	3 (7%)
Chula Vista (91910)	3 (7%)
Fallbrook (92028)	1 (2%)
Coronado (92118)	1 (2%)

Self-reported weekly TV hours	Host Site Frequency
10-19	8 (19%)
20-29	13 (31%)
30-39	9 (21%)
40-49	6 (14%)
50-59	3 (7%)
60-69	0 (0%)
70-79	3 (7%)

# of Residents	Host Site Frequency
1	5 (12%)
2	10 (24%)
3	13 (31%)
4	10 (24%)
5	2 (5%)
6	2 (5%)

Devices at main TV	Host Site Frequency
2	8 (19%)
3	11 (26%)
4	8 (19%)
5	10 (24%)
6	4 (10%)
7	1 (2%)

Children Present in Household	Host Site Frequency
Yes	16 (38%)
No	26 (62%)

Building Type	Host Site Frequency
SFR	30 (71%)
MFR	12 (29%)

A/V Instrumentation

The plan utilized a proprietary savings verification system that was designed by the vendor for the measurement and calculation of APS savings based on CalPlug metering requirements. The instrumentation monitors and records A/V system voltage and current along with remote control IR activity to establish the baseline usage patterns. Simultaneously, the instrumentation and backend simulate the energy savings strategy by calculating when the controlled A/V system devices would have been powered off. This approach reduces testing timelines, eliminates user acceptance issues, and eliminates short-term usage variations by simultaneously capturing baseline and proposed performance.

However, simulation of the controlled state internally and on the backend without actually turning any A/V devices off introduces uncertainty. This is because the M&V approach does not capture user interaction effects that could potentially alter actual savings. The instrumentation mitigates this issue by flashing an LED light whenever the device believes that the A/V system is not in use. When the user signals with the remote that the A/V devices are still being used, the simulation resets its use timer. This is similar to the actual APS device function where the user is supposed to react to the flashing LED in order to reset the shutdown timer.

It should be noted that the alternative pre-post methodology has its own uncertainties, largely associated with varying use patterns between the pre and post timespans.

FIGURE 9 - A/V APS INSTRUMENTATION, LED LIGHT, AND INSTALLED INSTRUMENTATION

The instrumentation collects the following data points for all the connected plug loads, combined:

1. Real time
2. IR activity
3. Shutdown timer
4. Mains voltage
5. Current
6. Instantaneous power (actual)
7. Instantaneous power saved (simulated case)
8. Cumulative energy consumption (actual)
9. Cumulative energy saved (simulated case)

Data is logged every 1 second and transmitted to vendor servers every 8 hours via cell phone networks. The final, raw data result is a file of timestamps, A/V power parameters, cumulative energy consumption, IR activity, the shut down timer value, simulated relay state, and cumulative energy savings. The simulation uses the default 1 hour shutdown timer setting, although a 2 hour and once-off 8 hour setting is available.

The instrumentation accuracy was verified using an independent, calibrated HOBO plug load logger in series with the instrumentation unit. This was done at 3 sites, but only one of the three transmitted data correctly. Figure 10 shows the comparison of the custom instrumentation and calibrated HOBO plug load logger. The accuracy as compared to the HOBO logger is as follows:

- Average absolute error: 0.421 Watts
- Average absolute percent error: 1.69%

This observed measurement error is well within acceptable bounds and should serve as validation of the instrumentation's accuracy.

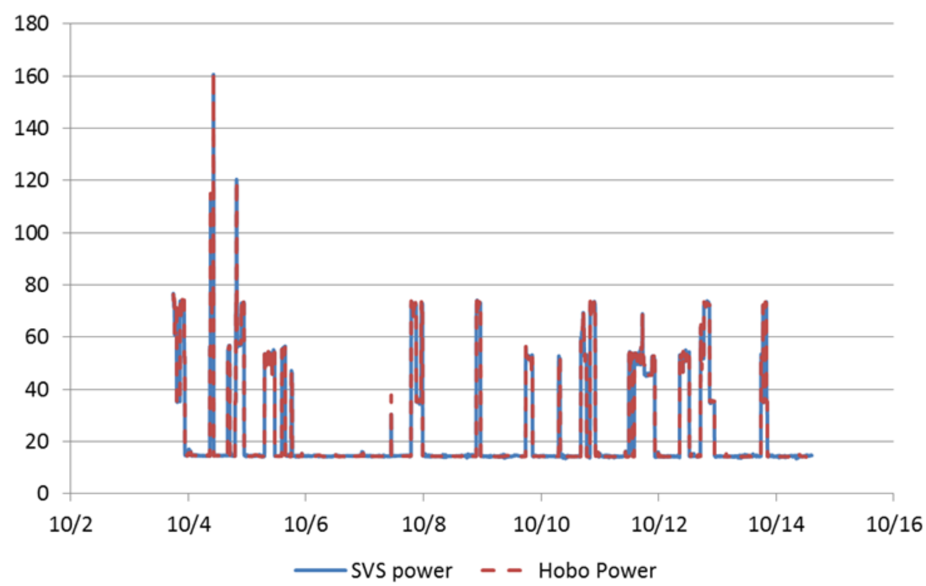

FIGURE 10 - A/V APS INSTRUMENTATION DATA COMPARED WITH CALIBRATED PLUG LOAD LOGGER

A/V Timeline and Party Roles

The field testing and data collection spanned 9 weeks from September 2 to November 10, 2014. The host sites were installed in two phases with the set of 25 instrumentation systems, with each host site monitored for an average of 16 days. Justification for this relatively short measurement period is presented in the Appendix.

AESC coordinated all field work and participated in every installation with assistance from the vendor at various host sites. Removal of the instrumentation and installation of the actual APS device for those who opted-in was completed by AESC and the vendor.

FIGURE 11 - INSTALLED A/V APS DEVICE AFTER REMOVAL OF INSTRUMENTATION

Data was transmitted to vendor servers where it was compiled, compressed to 90-second intervals, and delivered to AESC for analysis.

A/V Analysis

The analysis of the baseline and controlled plug load energy usage utilized a simple before and after energy savings calculation over the duration of the deployment.

$$Energy\ Savings\ (kWh) = Baseline\ Energy\ Usage\ (kWh) - Controlled\ Energy\ Usage\ (kWh)$$

Peak demand reductions were determined by isolating the data during peak hours.

$$Peak\ Demand\ Reduction\ (kW) = Baseline\ Peak\ Load\ (kW) - Controlled\ Peak\ Load\ (kW)$$

The data used relied on the monitored baseline demand and energy consumption and the calculated controlled state. In the simulated controlled state, savings were realized when the shutdown timer reached zero.

Results were annualized by using a ratio of measured hours to hours in a calendar year. This approach assumes that usage patterns over the measurement period are representative of average behavior over the long term.

$$Annual\ Energy = \frac{8760\ hours}{Monitored\ Hours} * Measured\ Energy$$

The complete dataset was statistically analyzed to determine variability, trends, factors, and any correlations between savings and factors such as demographics or plug load types.

Similar to the actual APS device, the custom instrumentation was limited to measurement of the aggregate connected A/V load rather than individual devices. The instrumentation did not measure the power and state of individual A/V devices, but rather than collection as a whole. Due to this, analysis could not easily parse out effects and consumption of individual A/V devices. For this reason, analysis methods treated each A/V system as a collection that could not be separated into individual components. The data and analysis could not be used to verify and support the methods used in a previous SDG&E APS workpaper which approached savings calculations from the perspective of each, individual connected plug load device (SDG&E, 2013).

A/V Post-Installation Measurement

In addition to using the instrumentation that simulated energy savings after collecting baseline per CalPlug methodology, 13 sites were selected for additional post-installation monitoring. This additional M&V was performed in order to supplement the primary M&V approach and to provide further data for evaluation. In general, both methods have limitations due to their treatment of various uncontrollable, independent test variables relating to user behavior and usage patterns. As such, results from both methods complement each other by controlling for independent behavioral variables differently.

These sites were post-monitored with HOBO plug load data loggers after the actual APS had been installed upon removal of the CalPlug method instrumentation. Unfortunately, conditions changed in 4 of the 13 sites, resulting in a post-installation dataset of 9 homes for comparison with the simulation M&V approach. The 9 post-installation sites were monitored for 21 days, on average.

The relevant differences between the CalPlug and pre-post monitoring approaches that motivated the use of both methods are as follows.

CalPlug method advantage
Eliminates variability in usage patterns between pre and post timespans

CalPlug method disadvantage
May not fully account for user interaction with APS when system is turned off (since simulated)

Pre-post monitoring advantage
Includes all user interaction effects and feedback with APS controls when A/V devices are turned off.

Pre-post monitoring disadvantage
Cannot control variability in usage patterns between pre and post timespans without prohibitive, long-term monitoring.

PC MEASUREMENT AND VERIFICATION PLAN

The M&V plan for the PC emerging technology assessment was based around a field trial. Similar to the A/V approach, the M&V plan opted to use an instrumentation and APS simulation system built by the APS vendor using CalPlug-designed methodology and metering requirements.

PC Host Sites

The participating host site for the commercial PC field trial was a local university. The university volunteered for participation in the PC trial after becoming familiar with the benefits and workings of the PC APS technology. The university volunteered to have the test instrumentation installed in various office workstation and computer lab spaces. Twenty-six computer lab stations and 25 office workstations were selected for the field trial by the host site. Workstations were selected based on host site criteria, accessibility, and IT concerns. The office workstations were permanent locations with daily work schedules, as with any typical commercial workstation. For this reason, they generally represent a typical commercial application.

FIGURE 12 - EXAMPLE OFFICE WORKSTATION AND COMPUTER LAB LOCATIONS

Of the 51 installed PC workstations sites, 13 appeared to be unused, vacant workstations[2]. Since vacant workstations are sometimes present in typical installations, results are presented for both the 38 active workstations and the combined 51 active and vacant workstations.

PC Instrumentation

The PC APS instrumentation was similar to the A/V instrumentation. However, instead of using the custom instrumentation boxes, actual PC APS devices and software were modified to execute the same M&V strategy. Again, the instrumentation did not actually turn off the PC peripherals or put the computer into standby after the de-energizing timer reached zero. Rather, the device was used to

[2] Defined as less than 10 hours of active use per week of monitored time.

simultaneously acquire baseline data and calculate savings from the proposed controlled state on the backend. Additionally, the instrumentation only logged and transmitted data when the computer was on.

The instrumentation was created by installing custom software onto the host site computers and flashing the APS device hardware. By doing this, the vendor was able to make the PC APS devices function as CalPlug method instrumentation, using the PC as a data transmitter via the host site's internet connection.

Similar to the A/V M&V approach, this simultaneous baseline and calculated savings method eliminated user interaction effects and short term usage variation complications. However, the behavioral uncertainty associated with this M&V approach raises fewer questions than in the A/V approach. In the PC version, the control algorithm relies on computer process status rather than user signals, as in the A/V case. Although the PC version does prompt the user if a shutdown is imminent, in the commercial space, there is likely less chance that a user would be inactive while still using the computer. Additionally, computer processes may be a more robust and reliable measure of activity than remote control IR signals, with less variability.

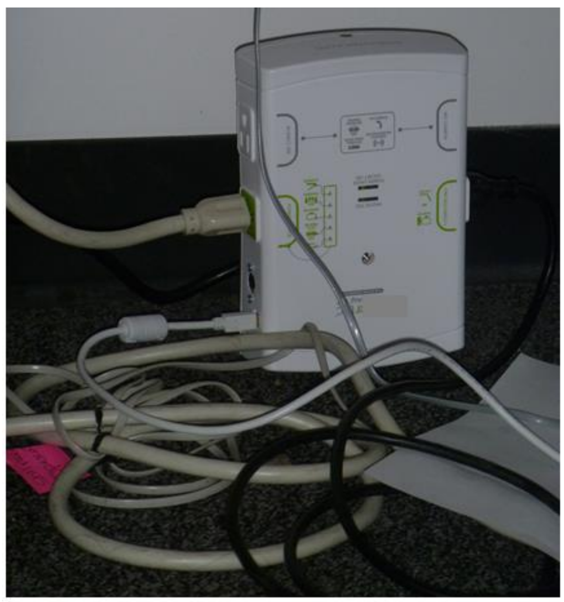

FIGURE 13 - MODIFIED PC APS FOR INSTRUMENTATION USE IN COMMERCIAL FIELD TRIAL

The instrumentation collected the following data points for all the connected plug loads, combined:

1. Real time
2. Mains voltage
3. Current
4. Shutdown timer
5. Instantaneous power (actual for computer and peripherals, separated)
6. Instantaneous power saved (simulated case)
7. Cumulative energy consumption (actual)
8. Cumulative energy saved (simulated case)

Data is measured every 1 second and transmitted to vendor servers every 8 hours via university network connections. The final, raw data result is a file of timestamps, A/V power parameters, cumulative energy consumption, the shutdown timer value, simulated relay state, and cumulative energy savings.

PC Timeline and Party Roles

The vendor and host site coordinated and managed all PC APS instrumentation installations and uninstallations. This was necessary as the installed software and server connectivity required the host site IT department participation and oversight. AESC was present during several of the installs.

Data was transmitted to vendor servers through university network connections. It was then compiled and delivered to AESC for analysis.

PC Analysis

The basic method for savings calculations followed the same methods of the A/V analysis. The analysis of the baseline and controlled plug load energy usage utilized a simple before and after energy savings calculation over the duration of the deployment.

$$Energy\ Savings\ (kWh) = \ Baseline\ Energy\ Usage\ (kWh) - Controlled\ Energy\ Usage\ (kWh)$$

Peak demand reductions were determined by isolating the data during peak hours.

$$Peak\ Demand\ Reduction\ (kW) = Baseline\ Peak\ Load\ (kW) - Controlled\ Peak\ Load\ (kW)$$

The data used relied on the monitored baseline demand and energy consumption and the calculated controlled state. In the simulated controlled state, savings were realized when the shutdown timer reached zero.

Results were annualized by using a ratio of measured hours to calendar year hours. This approach assumes that usage patterns over the measurement period are representative of average behavior over the long term.

$$Annual\ Energy = \frac{8760\ hours}{Monitored\ Hours} * Measured\ Energy$$

The complete dataset was statistically analyzed to determine variability, trends, factors, and any correlations. The analysis was limited by the data collection capabilities of the instrumentation such that only the aggregate load and consumption of the total PC system could be considered, rather than individual pieces of PC equipment. For this reason, analysis methods similar to those performed in a previous SDG&E APS workpaper (SDG&E, 2013) was not possible.

A/V RESULTS

The field trial of the A/V Tier 2 APS devices was conducted using the instrumentation and methods described in the M&V plan above. After some necessary correction of the datasets, average demand and energy savings were calculated for each host site. These were combined into a single average savings value that is assumed to be representative of SDG&E territory population. Summarized A/V findings are presented in Table 6 and Table 7. The total dataset includes the 42 host sites with usable data. Additionally, the post-installation monitored dataset includes 9 host sites from additional monitoring.

TABLE 6 – AVERAGE ENERGY SAVINGS RESULTS FOR THE A/V TRIAL

METHOD	# OF SITES	BASELINE ANNUAL USAGE [KWH]	STD DEV [KWH]	ANNUAL SAVINGS [KWH]	STANDARD DEVIATION [KWH]	% SAVINGS	STANDARD DEVIATION
CalPlug	42	463	317	234	183	50%	14%
Pre-Post	9	461	160	134	57	32%	14%

Of 46 participating A/V hosts, 10 declined to install or keep the APS device at the end of the test due to A/V equipment setup incompatibilities or personal preferences. Installation of the A/V devices is straightforward and uncomplicated. Setup takes about 5-10 minutes, depending on the complexity of the A/V system. The most time is spent locating and isolating plugs for each piece of equipment. Less than 5 minutes is needed to understand the operation by reading the manual and testing after installation.

TABLE 7 - AVERAGE DEMAND SAVINGS RESULTS FOR THE A/V TRIAL

Avg baseline demand [W]	53.0
Avg demand savings [W]	27.6
Avg DEER on-peak baseline demand[3] [W]	64.8
Avg DEER on-peak demand savings [W]	34.6

Baseline demand and demand reduction is also presented on an hourly basis.

There was no correlation between % savings and any site variables, suggesting that the 50% (or 32%) savings value is a consistent, average across all prospective sites. This confirms previous findings of the same nature. Additionally, there were relatively robust correlations between baseline consumption and average savings with active A/V system power. For every watt of average, A/V system power, the annual baseline usage and savings increases about 2.4 and 1.2 kWh, respectively. Note that this correlation applies only to the CalPlug results (50% savings) and to A/V equipment that are controlled plug loads. These findings may prove useful for programs development and evaluation.

[3] DEER on-peak defined as 2 PM to 5 PM (CPUC, 2013).

RAW A/V DATA AND PROCESSING

All raw 1-second data was reviewed by AESC for device functionality analysis and performance verification. It was then requested that this data be compressed by the vendor to 90 second intervals for data processing reasons. Each site's raw data took the form shown in Figure 14 with three of the variables plotted.

The green series is the "OffTimer" which sets to 1 hour whenever the A/V system is switched on or whenever an IR signal is seen. As long as no IR signal is seen and the A/V system is on, the timer counts down to zero. If the timer counts to zero, the instrumentation and backed calculations assume a simulated open relay state and accumulates energy savings. Additionally, whenever the A/V system is off, all standby power results in accumulated energy savings.

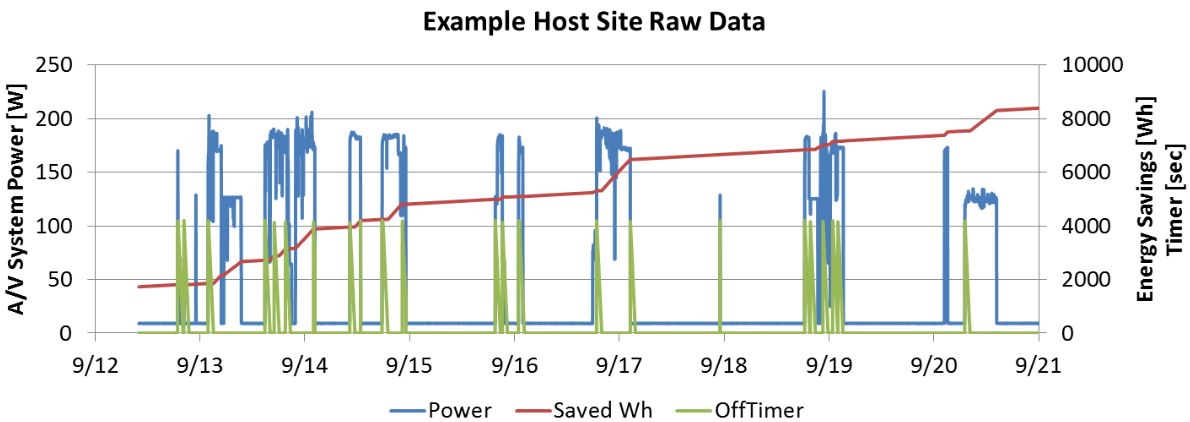

FIGURE 14 - RAW DATA EXAMPLE WITH THREE OF THE SERIES SHOWN

The data series were truncated so that the final corrected data spanned multiples of 24 hours, without weighting the timeframe towards any particular time of day.

Some of the raw data had periods with missing data due to failures of the cellular network transmission or accidental IR sensor movement. As a result, energy savings accumulated faster or slower than it should have during these time periods for these host sites. The following table lists the number of sites with and without these issues. Where possible, corrections were made by eliminating data that had instrumentation faults as long as the remaining set still spanned enough time.

TABLE 8 - NUMBER OF HOST SITE RESULTS THAT REQUIRED AND DID NOT REQUIRE DATA CORRECTION

No data correction necessary	22
Data correction necessary	20
Intractable data issues[4]	4

[4] Several sites had data issues that could not be corrected since the resultant data timeframe would be too short for an accurate representation.

The following figures present four cases, which represent a case without necessary correction, a correction that resulted in a lower final energy savings, a correction that resulted in a higher final energy savings, and an example with intractable data collection issues that rendered the host site unsable.

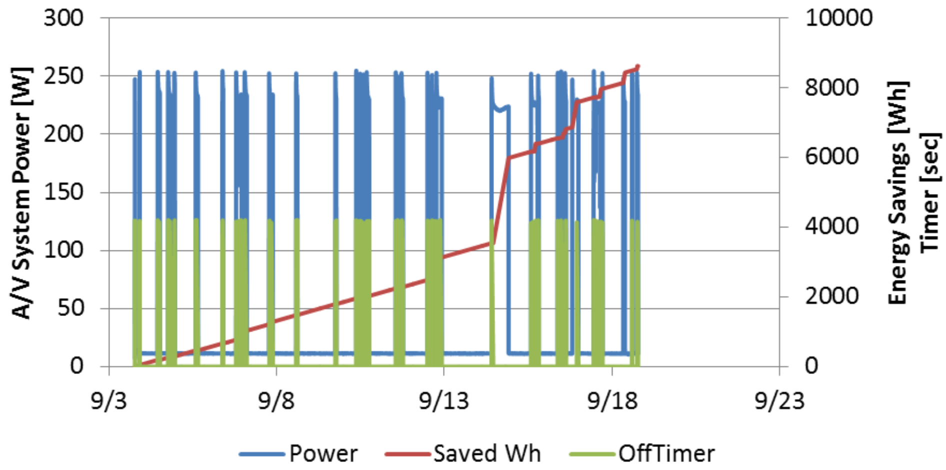

FIGURE 15 - EXAMPLE HOST SITE DATA FOR A SITE THAT DID NOT REQUIRE DATA CORRECTION (INSTRUMENTATION ID 26.1)

Figure 16 shows a host site with improper OffTimer and IR sensor data collection throughout the duration of the test, resulting in inaccurate results. This was most likely due to the IR sensor being accidentally moved to a location outside of the remote control line of sight. Host sites with data like this were considered unusable since corrected data would not span a representative timeframe.

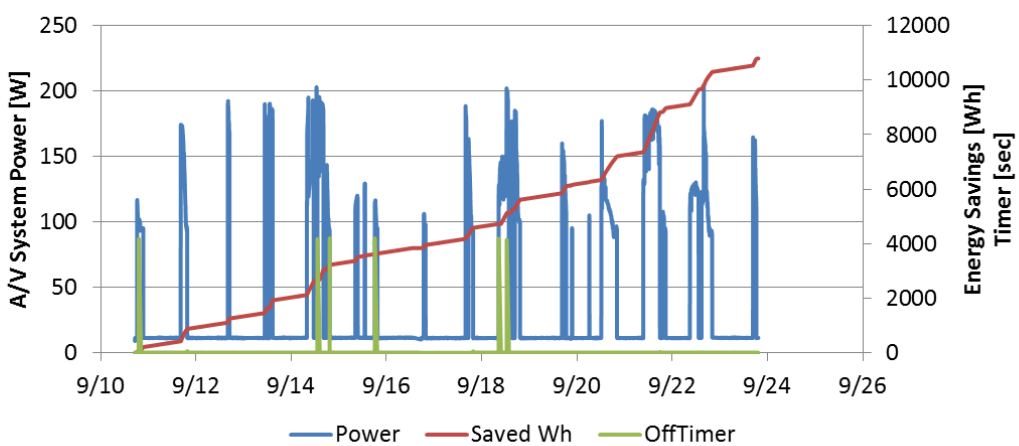

FIGURE 16 - EXAMPLE HOST SITE DATA FOR A SITE THAT HAD INTRACTABLE DATA ISSUES (INSTRUMENTATION ID 15.1)

Figure 17 shows a host site with faulty OffTimer and IR sensor collection during middle of test, resulting in an inaccurate, high energy savings accumulation. The following figure shows the raw, problematic data and the corrected version in two plots.

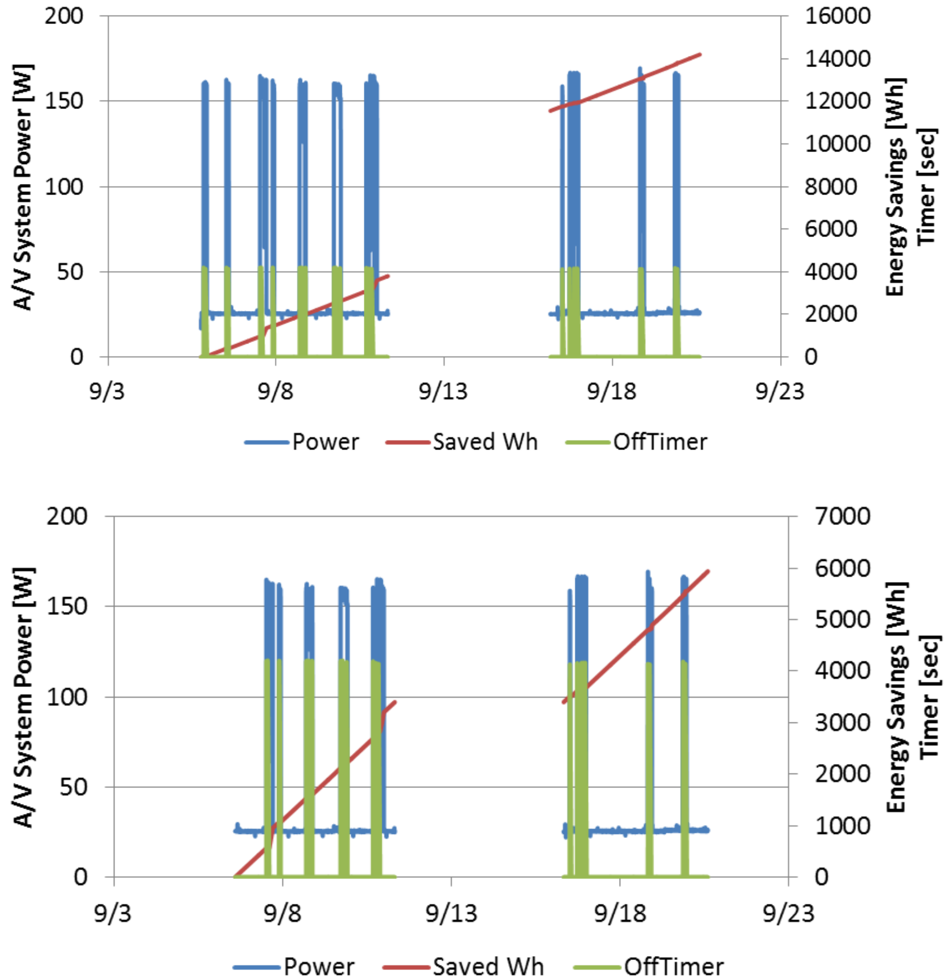

FIGURE 17 - EXAMPLE HOST SITE DATA FOR A SITE THAT DID REQUIRE DATA CORRECTION (INSTRUMENTATION ID 20.1)

Figure 18 shows a host site with faulty OffTimer and IR sensor collection during beginning and middle of test, resulting in an inaccurate, low energy savings accumulation. The following figure shows the raw, problematic data and the corrected version in two plots.

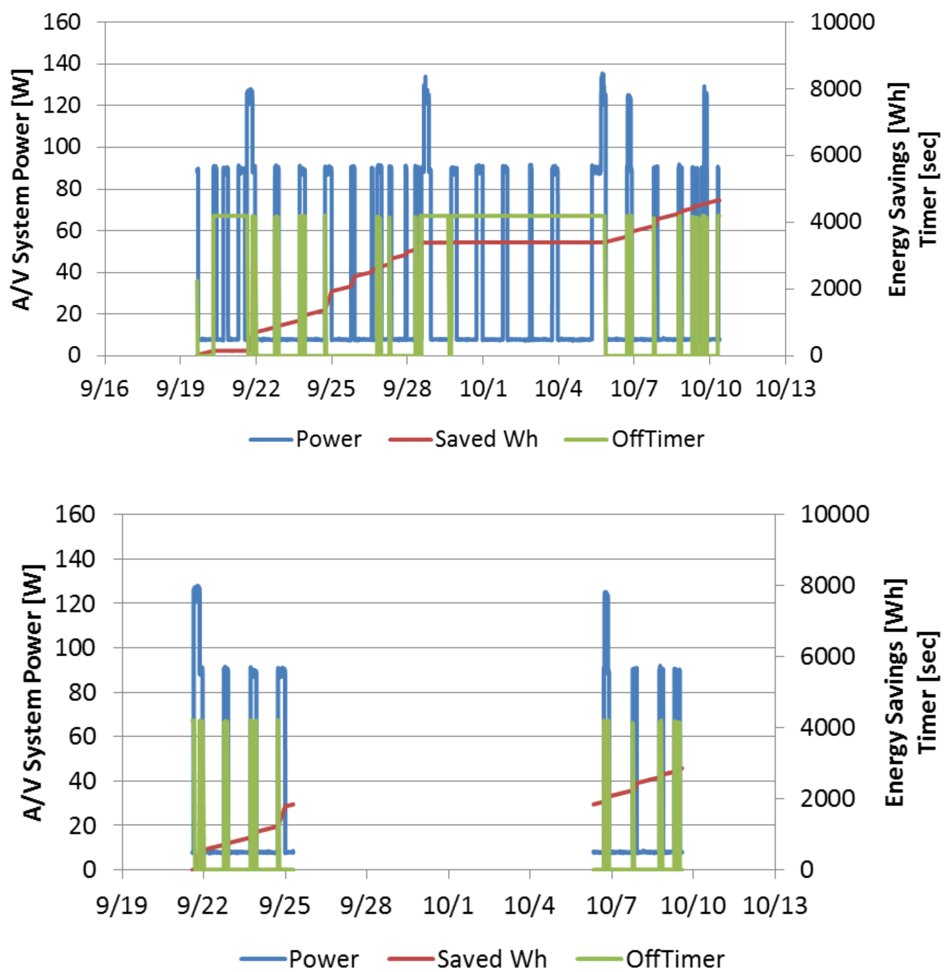

FIGURE 18 –EXAMPLE HOST SITE DATA FOR A SITE THAT DID REQUIRE DATA CORRECTION (INSTRUMENTATION ID 55.2)

The data for the 42 usable host sites were corrected by removing the faulty collection periods in multiples of days in order to avoid biasing results towards any particular timeframe. Additionally, the start and end points of the data collection were aligned, such that the total recorded data spanned multiples of 1 full day.

Energy Savings and Demand Reduction

The average baseline and savings for the corrected dataset are shown in Table 9. The 90% confidence interval for baseline energy consumption and energy savings is (381,544) kWh and (187,280) kWh, respectively.

Table 9 - Total dataset baseline annual usage and savings

# of Sites	Baseline Annual Usage [kWh]	Std Dev [kWh]	Annual Energy Savings [kWh]	Standard Deviation [kWh]	% Savings	Std Dev	Avg Monitored Time [hr]
42	463	317	234	183	50%	14%	322

In comparison to the raw instrumentation data, average baseline usage is about the same and average annual savings are slightly less. The Appendix shows the comparison between the raw and corrected results. Annual percent savings is reduced from 53% to 50%, when the data is corrected as described above.

The corrected baseline and energy savings for each of the 42 sites are plotted in Figure 19. Baseline usage and savings are fairly linear across the range of sites monitored, with the exception of two sites at the highest end of the usage spectrum, on the right side of the plot. These two sites had unique A/V setups that utilized more than the average amount of energy and both opted to not use the APS at the end of the project.

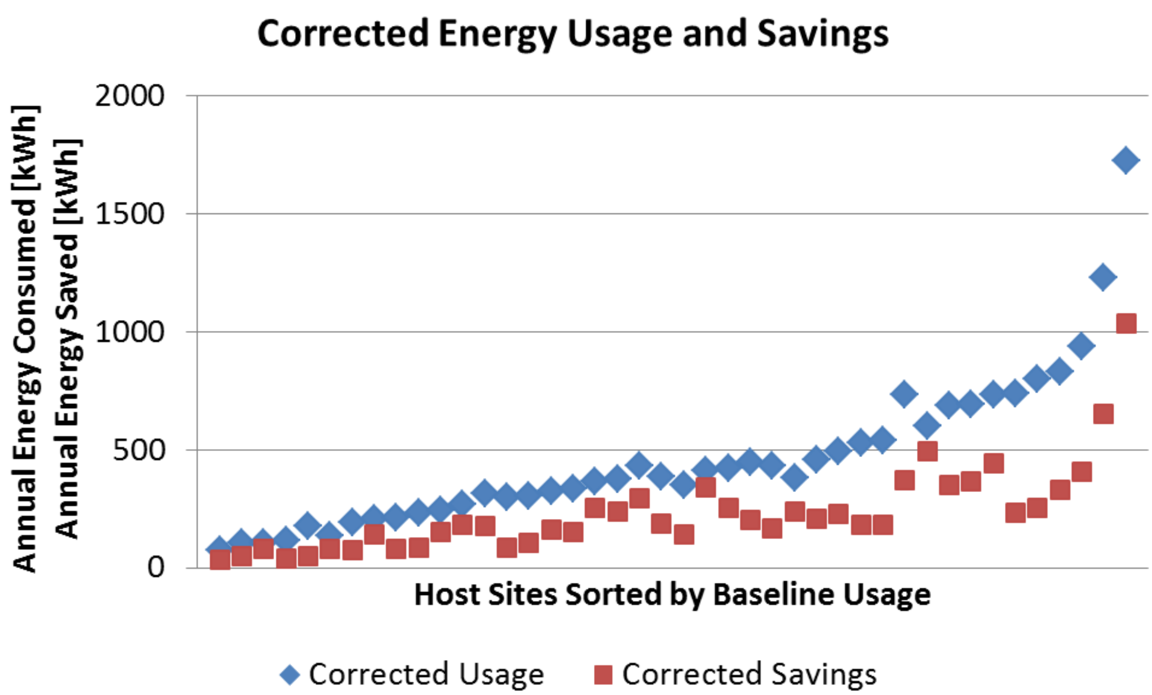

Figure 19 - Corrected dataset baseline annual usage and savings

Figure 20 plots the annual, calculated savings as a function of annual usage. Note that the good fit, linear trendline has a slope of about .5, equating to about 50% savings.

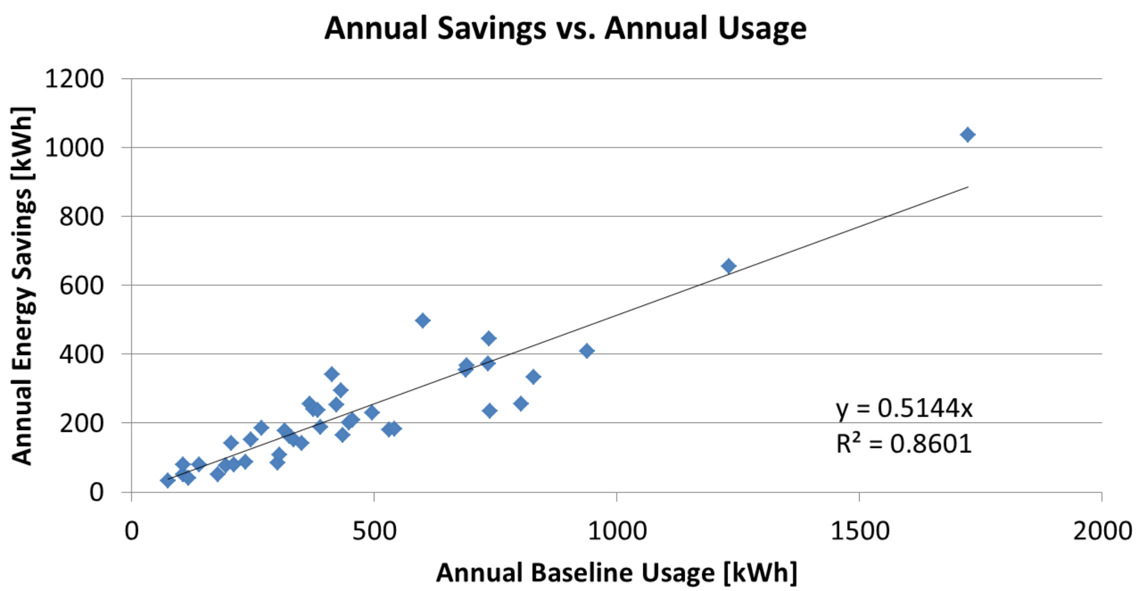

FIGURE 20 - ANNUAL SAVINGS AS A FUNCTION OF ANNUAL USAGE

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 28% and 83%, with an average of 50%. This finding is consistent with the previous studies referenced earlier. Figure 21 shows the percent savings of the raw and corrected datasets, sorted by increasing baseline usage, showing no correlation between % savings and annual baseline usage.

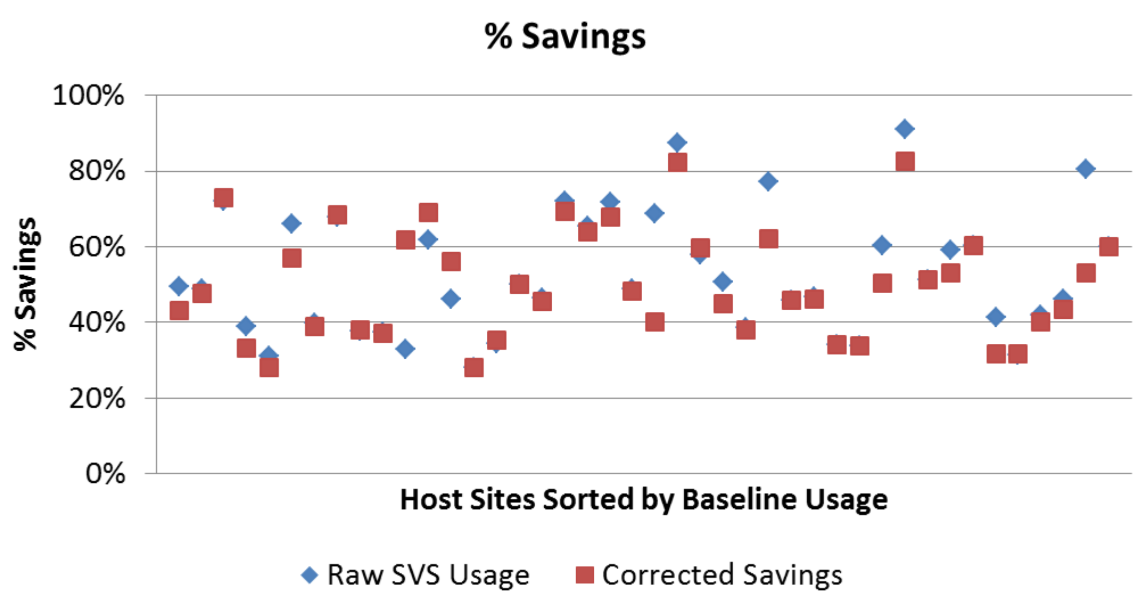

FIGURE 21 - PERCENT SAVINGS FOR THE RAW AND CORRECTED DATASETS, SORTED BY BASELINE USAGE

The histograms for the baseline usage and energy savings are shown in Figure 22. High users and savings of 500 kWh and above are relatively rare.

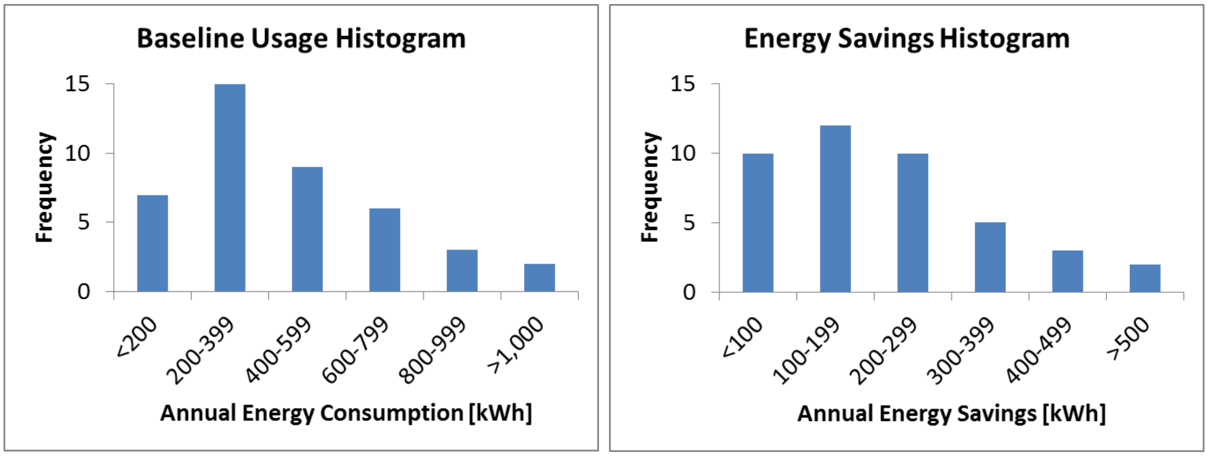

FIGURE 22 - HISTOGRAMS OF ANNUAL BASELINE USAGE AND ENERGY SAVINGS

Demographic Correlations

It would be useful to determine whether energy savings have any correlation to site characteristics in order to inform utility program design or market potential predictions. Unfortunately, few robust correlations were found in the monitored population of 42 host sites. The strongest observed correlation that could be useful was the relationship between average active A/V system power and the annual consumption and estimated savings. This was a surprise as it is reasonable to assume that usage patterns would dominate effects of average A/V power.

The active A/V system power was defined as the power level of the A/V system whenever the equipment was in use. The relatively robust correlation could potentially be used to evaluate the potential of individual sites without requiring extended monitoring. A quick spot measurement of the A/V system power under normal operating conditions as defined by the host customer could provide a quick metric for estimating baseline consumption and probable savings upon installation. Figure 23 shows the correlations between average active A/V system power and annual baseline consumption and savings.

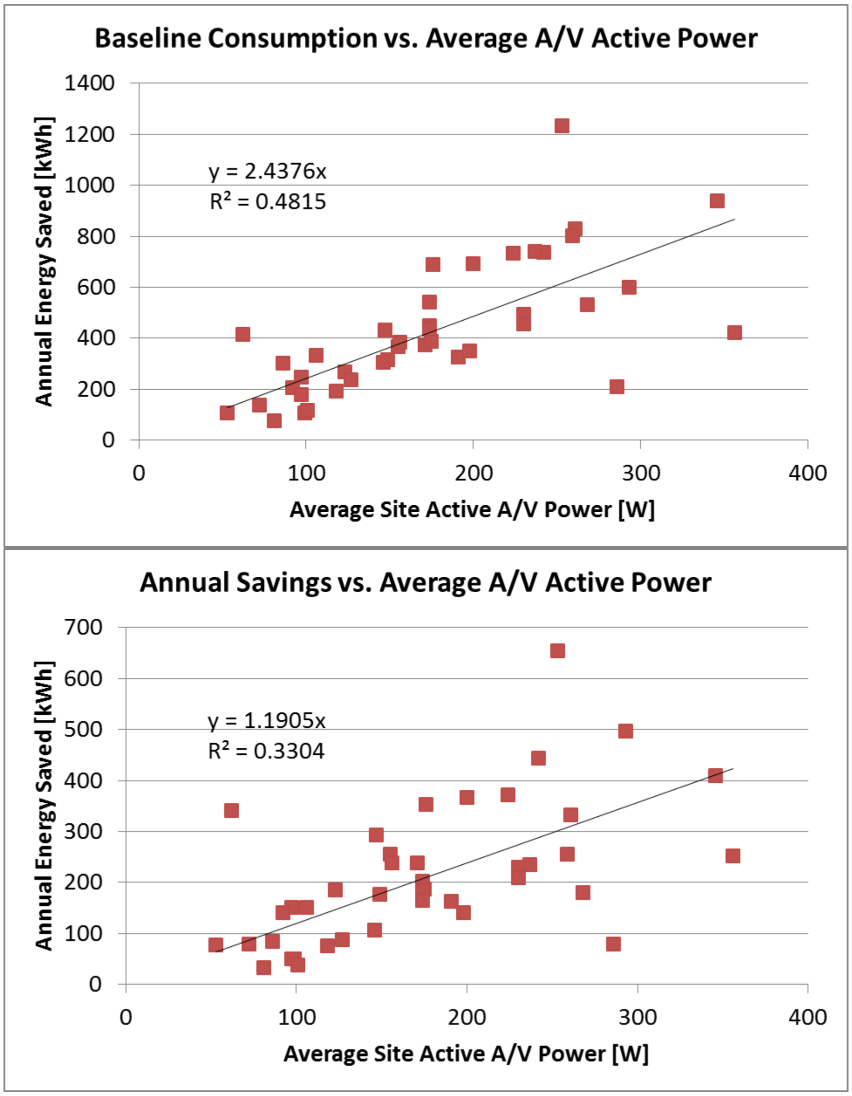

FIGURE 23 - A/V USAGE AND SAVINGS CORRELATION WITH A/V ACTIVE POWER

These two correlations may provide a solid foundation for simplifying program development and evaluation. The correlation suggests that annual baseline usage and savings at an A/V site can be estimated by spot measuring the typical controlled A/V system power at installation or by using well-documented equipment power from the available literature. The correlation suggested that there is about 2.44 kWh annual baseline consumption per A/V system watt and 1.19 kWh annual savings per A/V system watt. In this situation, the A/V system is comprised of only the controlled devices and should not consider any equipment not controlled by the APS.

Several demographic questions were asked of the participants during volunteer solicitation and during site visits. These demographic data were used to search for correlations with energy savings. No correlation was particularly strong or significant. Households with or without children, number of residents, SFR versus MFR, self-reported TV usage, cable subscription status, number of A/V devices, and renting versus owning all had no significant correlation. This was unexpected, as it was assumed that savings would have a strong relationship with some of these factors.

Demand Reduction

In addition to energy savings, the APS devices also achieved some demand reduction. Since most customers are likely away from home during on-peak hours, demand savings during that timeframe are almost assured. However, these demand savings are most likely largely standby demand reduction rather than turning off equipment that had been accidentally left on.

Although the average demand reduction for any given host site is likely relatively small, the aggregate demand reduction of many installed sites could provide significant value to utilities and electrical grid management.

Figure 24 plots the daily baseline demand profile, post-installation demand profile, and demand reduction as averaged across all host sites over the measurement period. All data came from the custom instrumentation that simultaneously measured baseline and calculated the post-installation savings state. Note that the demand reduction increases as the day progresses past 9 AM before peaking and rapidly decreasing at 9 PM.

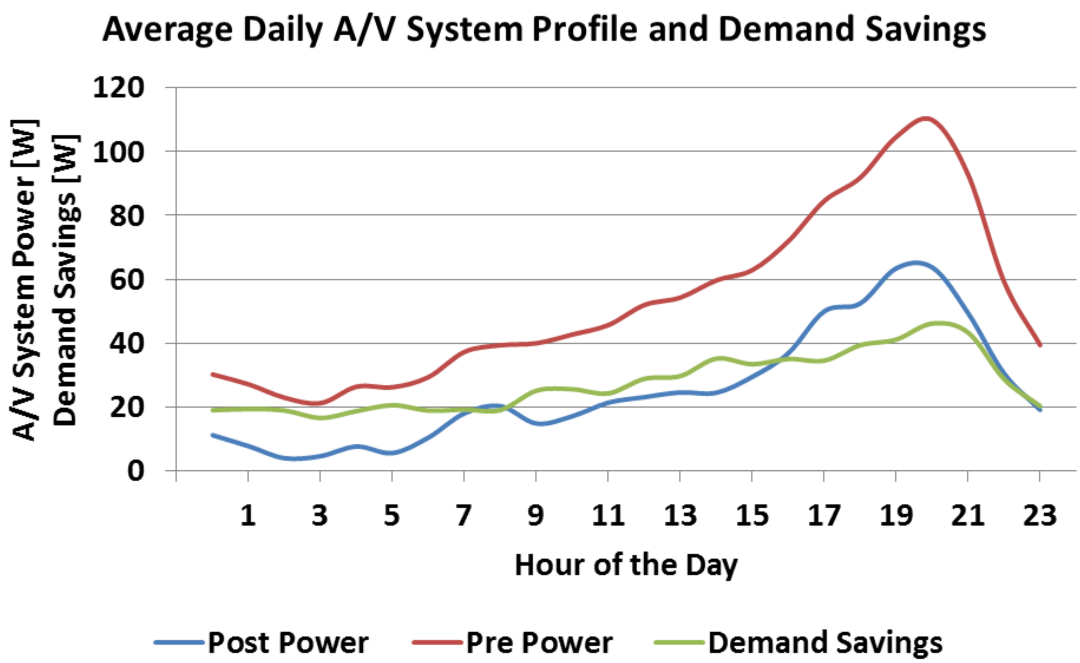

FIGURE 24 - AVERAGE HOST SITE A/V SYSTEM LOAD PROFILE AND DEMAND SAVINGS ON WEEKDAYS

A table of the hour-by-hour demand and demand savings can be found in the Appendix section.

Note that the demand savings is about 20 W during off hours, which could be in line with the savings level of about 30 kWh/year for previous generation powerstrips which saved standby energy during times the master device is turned off.

Average demand savings across the entire day were about 28 Watts and about 35 Watts during on-peak demand hours and listed in Table 10.

TABLE 10 - AVERAGE WEEKDAY A/V DEMAND SAVINGS

Avg baseline demand [W]	53.0
Avg demand savings [W]	27.6
Avg % demand savings	52%
Avg baseline on-peak demand[5] [W]	61.6
Avg on-peak demand savings [W]	31.6
Avg on-peak % demand savings	51%
Avg DEER on-peak baseline demand[6] [W]	64.8
Avg DEER on-peak demand savings [W]	34.6
Avg DEER on-peak % demand savings	53.4%

POST-INSTALLATION MONITORING SAVINGS

As discussed, the CalPlug instrumentation and analysis approach introduces uncertainty by removing the normal APS user interaction. Since the custom instrumentation only simulates the controlled state and does not turn off A/V devices, it may not accurately portray what the user would do if shutdown occurred. In order to mitigate this effect, the instrumentation uses a flashing LED light to alert the host site users as the actual APS device would, in order to illicit a remote control response. However, if the test subject did not respond to the M&V instrumentation's LED light but would have turned the TV back on in an actual APS application, results will be skewed.

AESC and SDG&E decided that a sample of the host sites should undergo some additional monitoring after the APS had been installed. Thirteen sites were selected for this post-installation monitoring. HOBO plug load loggers were installed in series with the actual A/V APS device upon removal of the custom instrumentation units. The timer was set to 1 hour as in the simulation. Although no remote control data was collected during this post-installation period, it was previously determined that annual usage estimates reach a steady state fairly quickly (see Appendix).

Not all of the 13 sites selected for post-installation monitoring yielded results that could be compared to the pre-monitoring. Four of the sites had to be excluded due to changes in conditions that would have yielded unfair comparisons. These included change in cable subscription, additional occupants moving in, and setting the APS timer to 2 hours instead of 1. The remaining 9 sites were deemed to have similar operating conditions as the previous M&V phase and were used for comparison with calculated savings from the custom, simulation instrumentation.

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[5] On-peak defined by the timeframe of 11 AM to 6 PM.

[6] DEER on-peak defined as 2 PM to 5 PM (CPUC, 2013).

The baseline consumption, corrected simulated savings, post-installation monitored savings, and percent savings for each of the 9 sites are plotted in Figure 25. The average percent energy savings were 32% of the baseline, whereas the simulation instrumentation found an average of 50% savings.

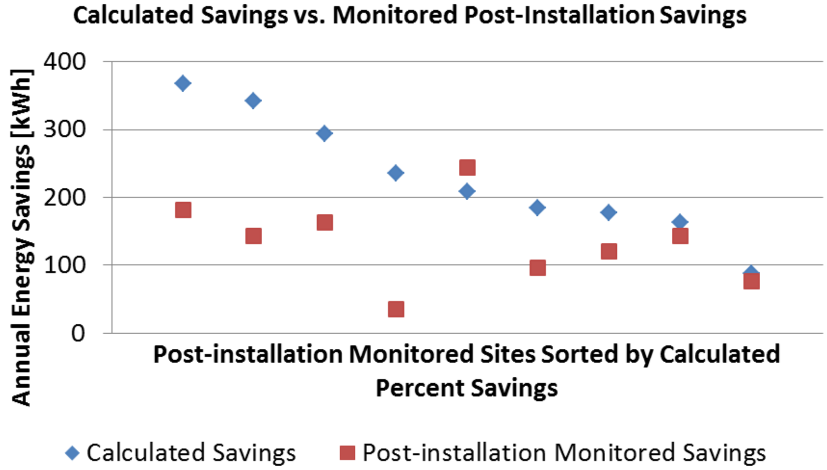

FIGURE 25 - COMPARISON BETWEEN SIMULATED M&V APPROACH SAVINGS AND POST-INSTALLATION MONITORED SAVINGS

While the sample size of the post-installation monitoring was small and the usage patterns were not controlled between the baseline and post-installation monitoring period, there is an obvious reduced savings pattern observable in Figure 25. Since it has been shown that home A/V usage normalizes to a consistent pattern within about a week, the average of 21 days of post-installation monitoring suggests that these findings should be considered when using the results of the CalPlug approach.

Table 11 compares the findings of the CalPlug approach and the small sample of pre-post monitoring. From the comparison, it is seen that the post-monitored savings are about 64% of the simulated savings using the CalPlug method.

TABLE 11 - AVERAGES OF CORRECTED, SIMULATED SAVINGS, POST-INSTALLATION SAVINGS, AND DERATED SAVINGS

METHOD	# OF SITES	BASELINE ANNUAL USAGE [KWH]	STD DEV [KWH]	ANNUAL SAVINGS [KWH]	STANDARD DEVIATION [KWH]	% SAVINGS	STANDARD DEVIATION
CalPlug	42	463	317	234	183	50%	14%
Pre-post	9	461	160	134	57	32%	14%
Total set derated by pre-post findings	42	463	317	149	117	32%	9%

The 90% confidence interval of the post-installation set is 108 to 141 kWh saved per year. This 90% confidence interval of the post-installation group does not overlap with the interval for the total corrected set. This likely implies that the difference between the means could be significant and may not be attributed to random error. It should be kept in mind that both the CalPlug and pre-post approaches have advantages and deficiencies as discussed in the M&V approach section. The difference in findings should be only considered in light of the differences between the two approaches.

PC Results

The field trial of the PC APS device was conducted using the instrumentation described in the M&V plan above. The PC trial was conducted in two phases, office workstations first and computer lab workstations second, using two installations of the same instrumentation. Since some of the workstations were observed to be vacant and an actual installation may or may not encounter this, results are presented for both the total population and after excluding the vacant workstations. Hourly demand, demand reduction, and energy savings were calculated for each PC setup. These were used to calculate typical savings values for computer labs, office workstations, and both settings combined. It can be reasonably assumed that the combined findings are representative of a PC workstation that is actively used about 31 hours per week (evocative of a typical 40 hour work week).

The PC findings with the vacant workstations excluded are presented in Table 12 and Table 13. The active, combined population is comprised of 38 workstations at the host site and is further separated into groups of 19 office workstations and 19 computer lab stations. Refer to the Appendix for similar results specific to the vacant workstations. Baseline demand and demand reduction is also presented on an hourly basis.

Table 12 – Average energy savings results for the PC trial with vacant workstations removed

Dataset	Monitored Time [days]	Avg Weekly Active Usetime [hours]	Avg Baseline Usage [kWh/yr]	Avg Energy Savings [kWh/yr]	Avg % Savings
Office Settings	12.4	24.9	613.4	450.7	65%
Computer Lab Settings	12.6	37.5	339.2	221.4	65%
Combined	12.5	31.2	476.3	336.1	65%

Table 13 - Average PC APS demand Reduction with vacant workstations removed

Dataset	Baseline Demand [W]	Demand Reduction [W]	Base on-peak demand[7] [W]	On-Peak Demand Reduction [W]	DEER on-peak Base demand[8] [W]	DEER On-Peak Demand Reduction [W]
Office Settings	104.1	72.1	124.9	56.5	124.4	54.5
Computer Lab Settings	54.3	32.7	56.9	24.0	57.1	26.0
Combined	80.6	54.0	90.9	40.2	90.7	40.3

[7] On-peak defined by the timeframe of 11 AM to 6 PM.

[8] DEER on-peak defined as 2 PM to 5 PM (CPUC, 2013).

The PC findings including the vacant workstations are presented in Table 14 and Table 15. There were 7 vacant lab workstations and 6 vacant office workstations.

TABLE 14 – AVERAGE ENERGY SAVINGS RESULTS FOR THE PC TRIAL WITH VACANT WORKSTATIONS INCLUDED

DATASET	MONITORED TIME [DAYS]	AVG WEEKLY ACTIVE USETIME [HOURS]	AVG BASELINE USAGE [KWH/YR]	AVG ENERGY SAVINGS [KWH/YR]	AVG % SAVINGS
Office Settings	12.5	19.6	621.4	494.1	73%
Computer Lab Settings	13.0	28.3	342.9	253.5	74%
Combined	12.7	24.0	476.5	371.4	73%

TABLE 15 - AVERAGE PC APS DEMAND REDUCTION WITH VACANT WORKSTATIONS INCLUDED

DATASET	BASELINE DEMAND [W]	DEMAND REDUCTION [W]	BASE ON-PEAK DEMAND[9] [W]	ON-PEAK DEMAND REDUCTION [W]	DEER ON-PEAK BASE DEMAND[10] [W]	DEER ON-PEAK DEMAND REDUCTION [W]
Office Settings	104.1	72.1	124.9	56.5	124.4	54.5
Computer Lab Settings	50.7	34.9	52.7	27.9	53.1	27.4
Combined	75.3	55.0	84.3	45.3	84.0	45.3

The results are similar to the findings of a report on university computers that found that desktop computers were on but inactive about 60% of the time (California Plug Load Research Center, 2014).

Due to the complicated nature of the university's IT protocols and software, the host site required custom software solutions currently being developed by the vendor. Due to this, no post-installation data collection was available as was done with the A/V test. All results are from the simulation M&V approach. Ease of setup is similar to the A/V system, with a little bit of added complexity due to the software installation. If done at a commercial location where the IT department has protocols, security, or daily computer update routines, installation may be more complex. This complication is being managed by the vendor for device applicability to be ensured.

[9] On-peak defined by the timeframe of 11 AM to 6 PM.

[10] DEER on-peak defined as 2 PM to 5 PM (CPUC, 2013).

RAW PC DATA AND PROCESSING

Similar to the A/V analysis, all raw data was compressed from 1 second intervals to 90 second intervals. Each workstation's instrumentation produced data that took the following form, shown in Figure 26 with five of the relevant data series plotted.

The purple series is the baseline cumulative energy consumed, the black and blue lines are the AESC-calculated and vendor backend-calculated cumulative energy savings, and the orange line is the post-installation cumulative energy as calculated by subtracting the energy saved.

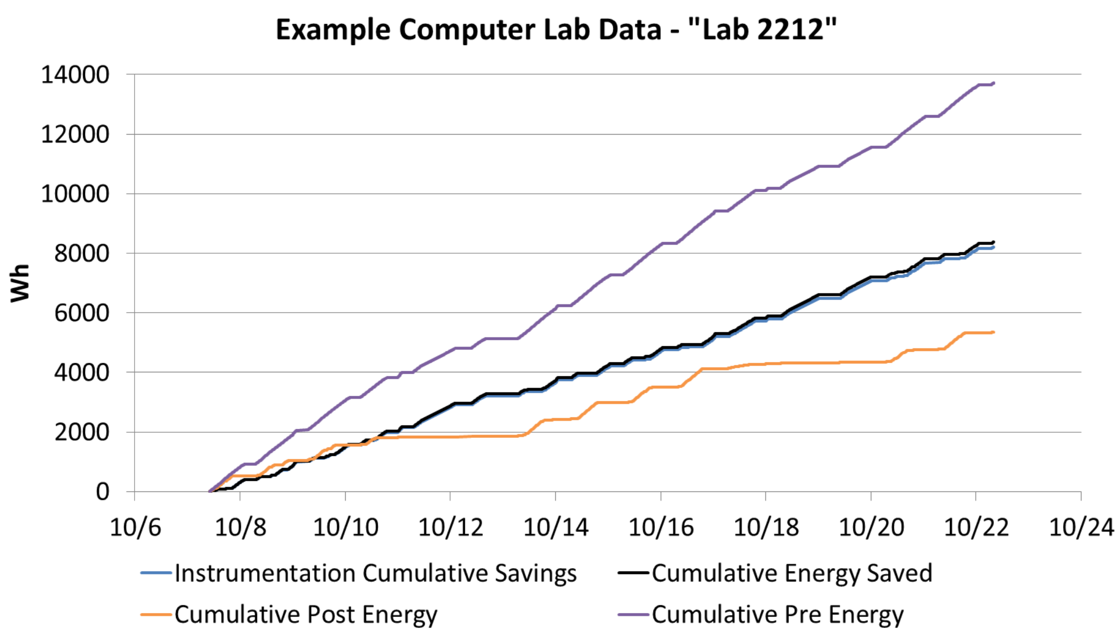

FIGURE 26 - EXAMPLE COMPUTER LAB STATION DATA

Similar to the A/V approach, baseline consumption and energy savings are monitored and calculated simultaneously. The energy savings are calculated using the simulated controlled state of the baseline consumption. The simulation models the actual control strategy by monitoring the user activity, computer activity, and power levels. Savings are calculated by assuming a low-power, sleep state when user activity is non-existent for a certain amount of time, simulating the actual APS control strategy. When these conditions are met, the simulation accumulates energy savings. The savings calculated by the simulation were verified by performing independent calculations based on the system power and simulated APS relay state.

Thirteen of the selected workstations were vacant or nearly vacant during the measurement period. Figure 27 shows the results for a workstation that was largely vacant. The simulated relay state indicated that it was in use only 4% of the time (about 7 hours per week).

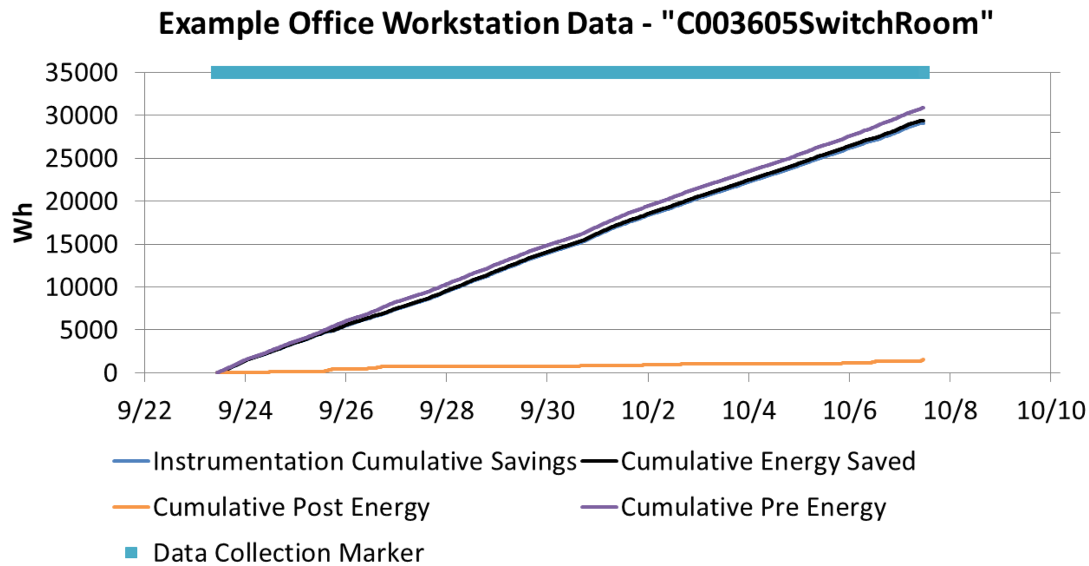

FIGURE 27 - EXAMPLE OFFICE WORKSTATION DATA OF VACANT WORKSTATION.

PC ENERGY SAVINGS AND DEMAND REDUCTION

The averages of weekly active usetime, baseline annual consumption, annual savings, and percent savings are shown in Table 16, separated by active and vacant workstations. The results for the combined, total dataset are shown at the beginning of the PC Results section. Note that the average percent savings was the same for each setting.

TABLE 16 - CORRECTED PC DATASET CHARACTERISTICS, BASELINE ANNUAL USAGE, AND SAVINGS (ACTIVE AND VACANT WORKSTATIONS SEPARATED)

DATASET	MONITORED TIME [DAYS]	WEEKLY ACTIVE USETIME [HOURS]	BASELINE ANNUAL USAGE [KWH]	ANNUAL ENERGY SAVINGS [KWH]	% SAVINGS
Office Settings	12	24.9	613.4	450.7	65%
Computer Lab Settings	13	37.5	339.2	221.4	65%
Combined	13	31.2	476.3	336.1	65%
Unused Lab Workstations	14	3.4	353.0	340.5	96%
Unused Office Workstations	13	2.8	647.3	631.2	97%

The 90% confidence intervals for each set (active PC workstations, only) are shown in Table 17.

TABLE 17 - PC USAGE AND SAVINGS 90% CONFIDENCE INTERVALS

Dataset	Baseline Usage Lower Bound [kWh]	Baseline Usage Upper Bound [kWh]	Savings Lower Bound [kWh]	Savings Upper Bound [kWh]
Office Settings	478.4	748.3	239.1	572.4
Computer Lab Settings	324.2	354.1	198.3	244.5
Combined	367.2	585.3	238.4	433.7

The baseline consumption and energy savings for the 38 active workstations are plotted in Figure 28. The usage and savings for the office settings are significantly higher since there was generally more equipment and inactive time at the university office workstations than computer lab stations.

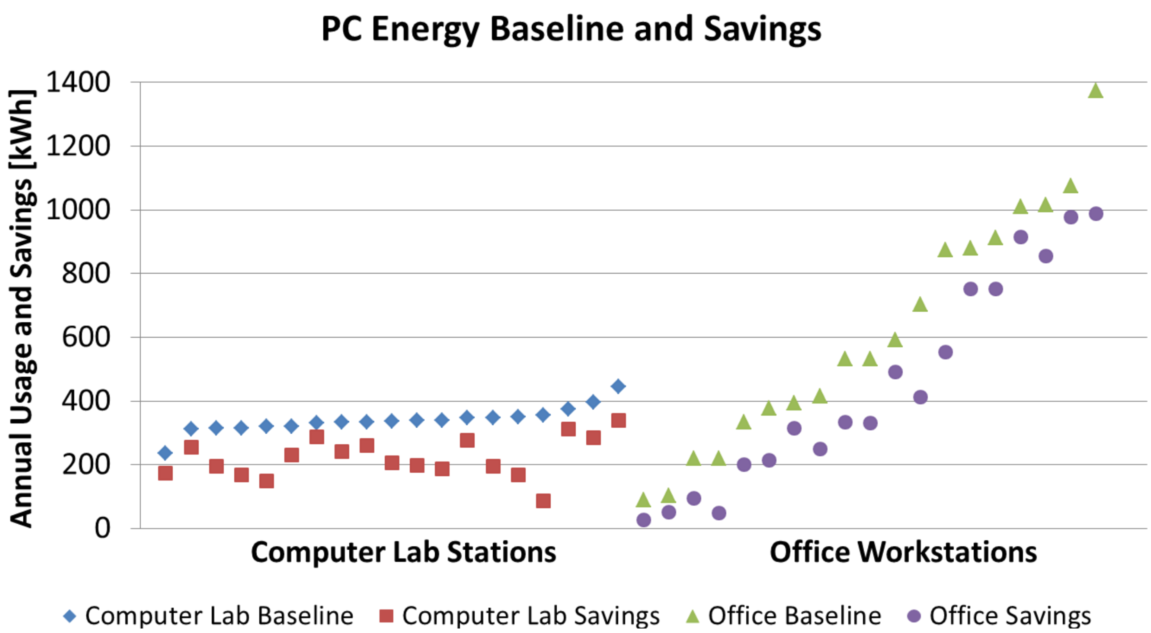

FIGURE 28 - PC BASELINE CONSUMPTION AND SAVINGS, SORTED BY BASELINE CONSUMPTION AND SETTING

Just as in the A/V analysis, it could be valuable to identify correlations between baseline consumption or savings and various demographics or system characteristics. Since demographic information was unavailable for the PC trial, the only available route was to identify relationships between savings and various measured values. Ideally, any identified correlations could potentially be used to develop or evaluate a direct install program, rebate program, or individual host workstations.

As shown in Figure 29 several relatively strong correlations within the PC results were observed. The computer lab workstation baseline and savings were correlated to weekly usetime while the office workstation baseline and savings were correlated to average active PC system power. These correlations were not observed, however, when the datasets were switched. This is shown in a more complete set of figures in the Appendix.

This suggests two things. The first is that in environments with very consistent workstation active power (as in a uniform computer lab), the weekly usetime could potentially be used to estimate savings. The second is that in settings with high variation in system components and overall workstation power, savings could be forecasted using spot measurements of overall PC system load. It could be that these two correlations could be combined into a surface map that could be used to calculate savings as a function of both these parameters. Unfortunately, the amount of data collected in this study was insufficient to perform such an analysis.

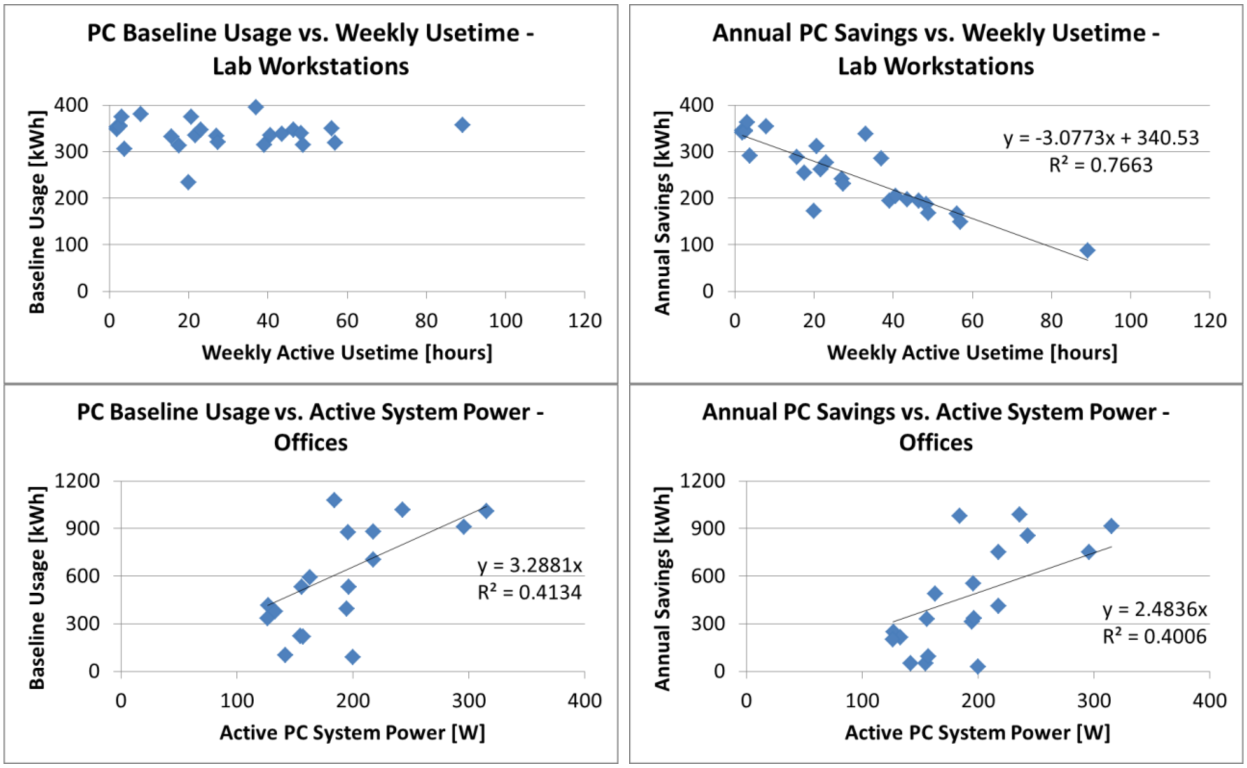

FIGURE 29 - ANNUAL PC BASELINE AND SAVINGS CORRELATIONS TO WEEKLY USETIME AND PC SYSTEM POWER

As is apparent from the figures, computer lab workstations have constant baseline usage across weekly active usetime, suggesting that the computers are of consistent equipment and on the same, controlled schedule. Starting at 340 kWh, annual savings decreases about 3.1 kWh for every hour of weekly usetime. Similarly in office workstations, annual baseline usage and savings increases about 3.3 and 2.5 kWh for every additional watt of active, peak PC system power.

Demand Reduction

In addition to energy savings, the PC APS devices also achieve some demand reduction. However, since workstations are typically occupied during on-peak demand hours, the on-peak demand reduction could be less assured than with A/V usage patterns.

Although the average demand reduction for any given workstation will be relatively small, the collective demand reduction for many installed workstations could provide significant value. This would be especially apparent in a large commercial office or institutional setting where many PC workstation APS devices could be installed on a single service account.

Figure 30 plots the weekday baseline demand profile and demand reduction as averaged across all host sites over the measurement period. The highest demand is during normal working hours while the highest demand savings are outside of working hours. This is most likely due to computers and peripherals being left on after work and high user activity during normal working hours.

Pre demand, post demand, and demand savings are presented on an hourly basis in the Appendix.

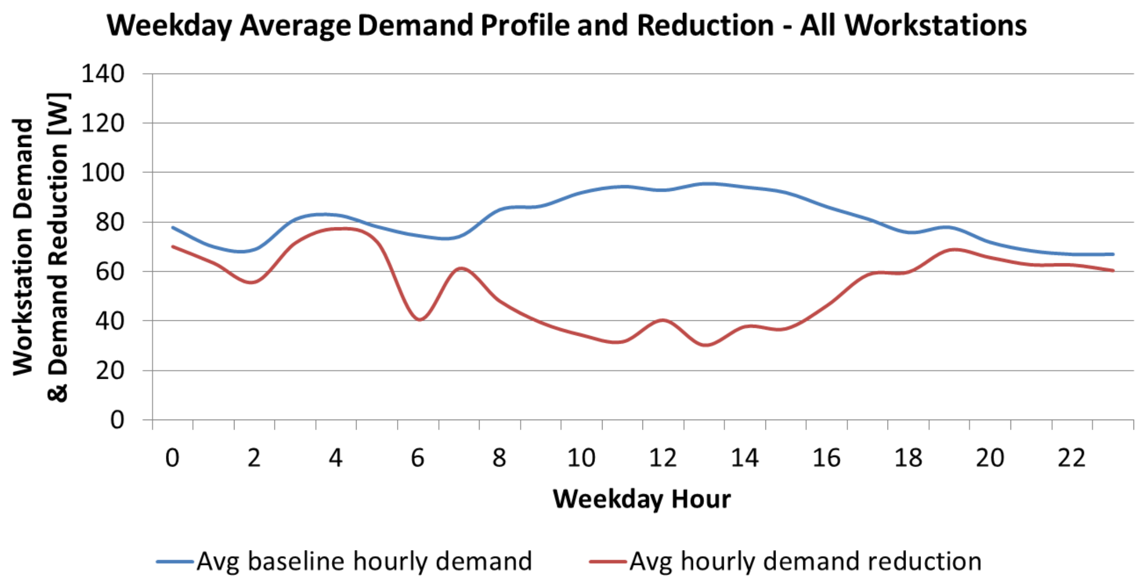

FIGURE 30 - AVERAGE WORKSTATION PC SYSTEM LOAD PROFILE AND DEMAND SAVINGS ON WEEKDAYS

Figure 31 and Figure 32 below show similar demand profiles and savings for the two different PC settings. The patterns are similar, except for an interesting fluctuation in user activity in computer labs around 6-7 AM.

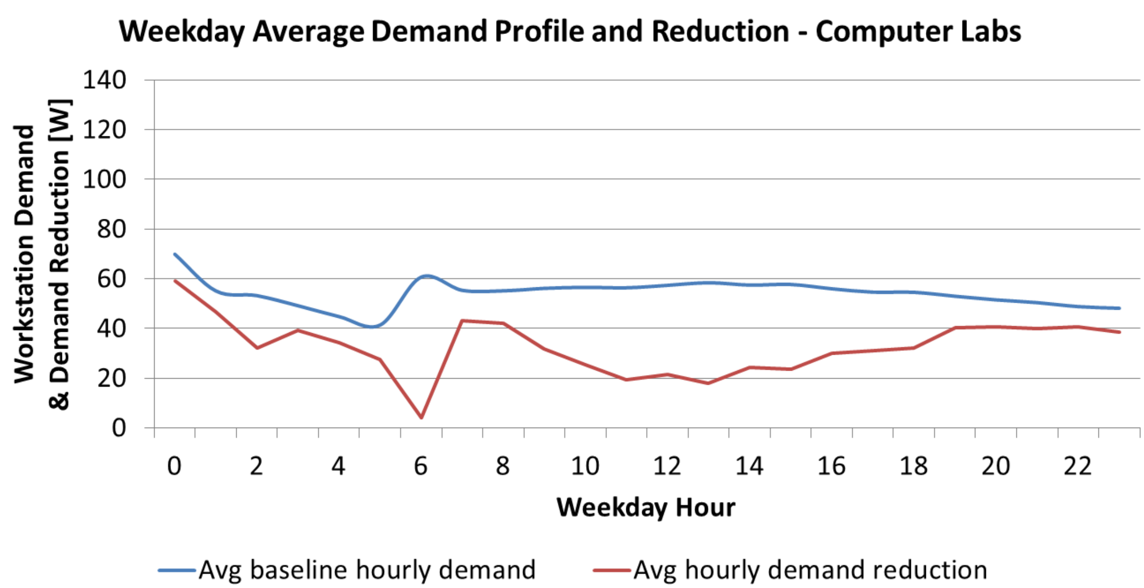

FIGURE 31 - AVERAGE COMPUTER LAB STATION PC SYSTEM LOAD PROFILE AND DEMAND SAVINGS ON WEEKDAYS

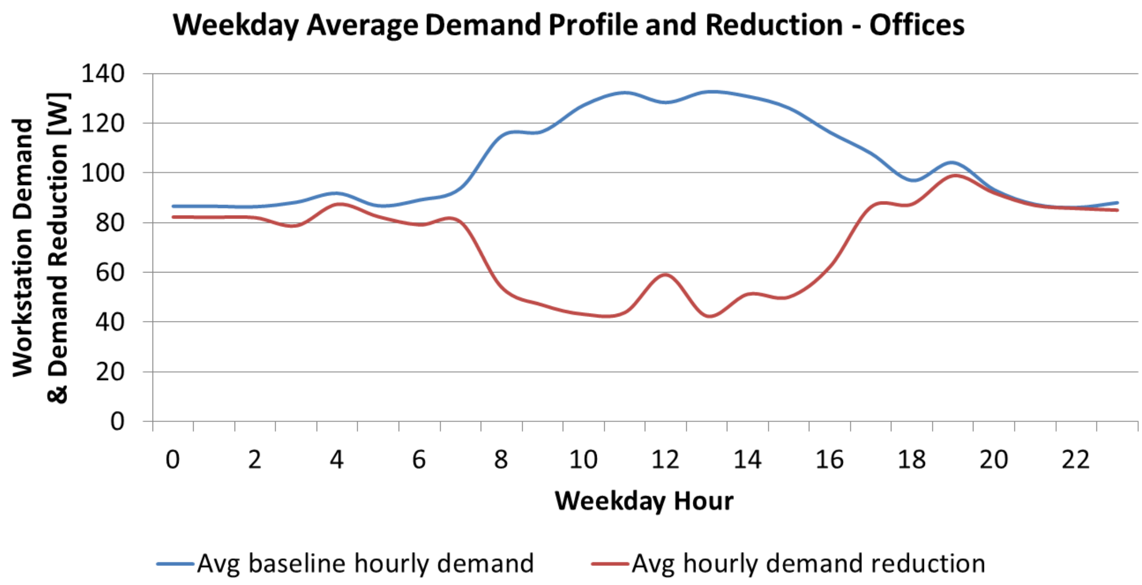

FIGURE 32 - AVERAGE OFFICE WORKSTATION SYSTEM LOAD PROFILE AND DEMAND SAVINGS ON WEEKDAYS

Average demand savings for different on-peak periods of the day are presented in Table 18. Hourly values are shown in the Appendix.

TABLE 18 – WEEKDAY PC DEMAND SAVINGS (VACANT WORKSTATIONS EXCLUDED)

DATASET	BASELINE DEMAND [W]	DEMAND REDUCTION [W]	BASE ON-PEAK DEMAND[11] [W]	ON-PEAK DEMAND REDUCTION [W]	DEER ON-PEAK BASE DEMAND[12] [W]	DEER ON-PEAK DEMAND REDUCTION [W]
Office Settings	104.1	72.1	124.9	56.5	124.4	54.5
Computer Lab Settings	54.3	32.7	56.9	24.0	57.1	26.0
Combined	80.6	54.0	90.9	40.2	90.7	40.3

[11] On-peak defined by the timeframe of 11 AM to 6 PM.

[12] DEER on-peak defined as 2 PM to 5 PM (CPUC, 2013).

Discussion and Conclusions

The Tier 2 APS devices for PC and A/V environments are matured technologies and have been installed in markets across the world. However, their market penetration remains small and the emerging technology has room to grow and become more widespread and accepted. Both APS models (PC and A/V) proved that they could be successful in achieving energy savings and a lower average demand profile. The energy savings and demand reduction of any one instance are relatively small, but when many devices are implemented across many homes or workstations, the savings can accumulate to significant levels.

Implementation of the A/V APS is feasible for the average homeowner as long as the A/V devices are not too complex or installed in inaccessible configurations. Certain installations required significant effort to install and may have been prohibitive outside of a concerted M&V study. For instance, if the TV is mounted on the wall or if the DVD player is not located directly next to the TV, installation can become difficult or unattractive. This was one of the primary reasons that some customers chose not to keep the APS at the end of the study. However, in most cases installation is easy, quick, and hidden from view. Use of the A/V technology is very simple and requires almost no thought by the user. This is of paramount importance when attempting to achieve energy savings at a residential A/V environment with a power strip. Users are likely to reject any device that requires more effort than an extra push or two of a button. The A/V APS excels in this manner.

Acceptance of the A/V APS remains an issue and will impact the design and savings of a large scale installation effort or utility program. Users may not appreciate the control strategy if they have conflicting uses such as using their stereo all day, turning on the TV for pets, passively watching long programs such as sports events, or if they dislike the LED light. Acceptance of the APS devices over the course of the field test was about 78%, although it should be noted that this was not a targeted study. Targeting certain customers may increase the acceptance and persistence rate. Additionally, no concerted effort to survey long-term customer acceptance and reaction was performed since this is being done in the parallel scaled field placement pilot program.

Implementation of the PC model is more complex since it requires a software installation that ties the APS and computer together. The PC APS was not tested in a residential setting, but in a commercial office setting the installation has both advantages and disadvantages. Installation of many workstations at one location is efficient and can impact overall facility demand more than a single workstation, multiplying the effects of implementation. However, as was the case in the commercial host site, IT protocols may interfere or complicate the implementation. Initially the host site thought that this would not be an issue, but now the vendor is working on a custom solution for the host site's IT needs.

Energy savings for the A/V model were calculated in two ways. The first way used an M&V approach that simultaneously collected baseline data and simulated the controlled state to calculate energy savings at 42 host sites. The second way was follow-up post-installation monitoring at 9 of the 42 residential host sites. The average annual energy savings for these two methods were 234 kWh and 134 kWh, respectively. However, the post-installation monitoring sample size was relatively small and performed as an amendment to the primary M&V method. Nonetheless, applying a derating factor determined by the pre-post method to the 42 host sites yielded an average annual energy savings of 149 kWh. The average demand savings and DEER on-peak demand savings between 2 PM and 5 PM were 28 and 35 Watts, respectively. Surprisingly, no robust correlations between savings and the recorded demographics were observed.

Using the CalPlug methodology, an average energy savings of 50% were observed across all baseline usage. Similarly, the pre-post approach yielded a savings of about 32% (albeit with a smaller sample size). This could be combined with the observation that annual A/V baseline usage has a robust correlation with active A/V system power, as defined by the demand of the controlled A/V devices when in normal use. For ever watt of controlled A/V equipment power, annual baseline consumption went up about 2.44 kWh/year. This could potentially be used to simplify the development or evaluation of a Tier 2 A/V program. A similar correlation was observed in the PC settings.

Energy savings for the PC model were calculated using an M&V approach that simultaneously collected baseline data and simulated the controlled state to calculate energy savings at 51 workstations. Of these 51 stations, 13 were mostly vacant or unused. Including these vacant workstations, the average annual energy savings at office workstations, computer lab stations, and combined were about 494 kWh, 254 kWh, and 371 kWh, respectively. No post-installation monitoring was performed. The average DEER on-peak demand savings between the hours of 2 PM and 5 PM for the office workstations, computer lab stations, and combined were about 55, 27, and 45 watts, respectively.

Based on the market size of residential A/V and commercial PC systems in SDG&E territory and California-wide, the impact of each 1% market penetration is estimated in Table 19.

TABLE 19 - ESTIMATED MARKET PENETRATION POTENTIAL USING CALPLUG METHOD RESULTS[13]

Energy Savings

Territory and Type	Total # A/V or PC Systems[14]	Unit Energy Savings Range[15] [kWh/Yr]	Total Market Potential Savings[MWh/yr]	1% Penetration Savings [MWh/yr]
California Res A/V	31,360,000	234	7,340	73.4
California Com PC	14,990,000	254 to 494	3,810 to 7,410	38.1 to 74.1
SDG&E Res A/V	2,690,000	234	630	6.3
SDG&E Com PC	1,340,000	254 to 494	340 to 660	3.4 to 6.6

DEER On-Peak Demand Reduction

Territory and Type	Total # A/V or PC Systems	Unit DEER On-Peak Demand Reduction [W]	Total Market Potential Demand Reduction[MW]	1% Penetration Savings [MW]
California Res A/V	31,360,000	35	1100	11.0
California Com PC	14,990,000	27 to 55	405 to 824	4.05 to 8.24
SDG&E Res A/V	2,690,000	35	90	0.9
SDG&E Com PC	1,340,000	27 to 55	36 to 74	0.36 to 0.74

[13] Uses PC results that include the vacant workstations.

[14] The A/V market size was estimated using (United States Census Bureau, 2013), (KEMA, 2009), and (The Nielsen Company, 2011). Market size = # households x TV saturation x # TVs per home. The PC market size was estimated using (United States Census Bureau, 2012) and (U.S. Energy Information Administration, 2012). Market size = # business establishments x avg PCs per business establishment.

[15] Based on the field results of this study. Residential A/V values used only the CalPlug method results and did not utilize the pre-post method due to small sample size. Commercial PC kWh and kW variation is from computer lab to office workstation settings.

Using the CalPlug method energy savings results, the system cost, and an assumed blended electricity rate, the payback for the device was estimated to be between 0.9 and 1.9 years, depending on the application. This payback is well below the EUL of the product.

TABLE 20 - ESTIMATED RANGE OF PAYBACK TIMEFRAMES

APS MODEL	COST [$]	BLENDED RATE [$/KWH]	ENERGY SAVINGS RANGE [KWH/YR]	ESTIMATED PAYBACK RANGE [YR]
A/V Residential	$65	0.15	234	1.9
PC Commercial	$65	0.15	253 to 494	0.9 to 1.7

Based on these findings, the PC and A/V APS devices are promising plug load management technologies that may be attractive to many customers. Excess plug load consumption in nearly all commercial and residential buildings is a ubiquitous problem and consumers are likely eager for easy, intuitive solutions. Standby, vampire loads of these electronics are a target for energy efficiency measures that will not negatively affect customers' use of their devices. The Tier 2 APS technology succeeds at addressing this energy efficiency need.

RECOMMENDATIONS

The most appropriate Tier 2 APS program designs are likely giveaways, rebates, or direct installs based on deemed energy savings values. Since the available market for these devices includes virtually all commercial and residential customers, the potential for success, energy savings, and demand reduction is apparent. Past giveaways have been met with challenges, particularly with the actual implementation by the customer. Since customers are likely not eager to spend time on configuring and learning a relatively complex power strip, a direct install program may be most appropriate. The pilot, direct install program performed in parallel with this study will address this idea further. A targeted program may provide added benefits based on these results.

Total Resource Cost (TRC) is a measurement of the net cost-effectiveness of a program by accounting for total societal benefits and costs. For residential customers with only one or two potential APS applications, a free direct install program is likely the best option. Although a small buydown from the residential customer could improve TRC, the cumulative impact of requesting a buydown from residential customers is likely to be negative due to reduced participation. However, medium and large commercial customers with many potential PC workstations can achieve a greater gross reward from participation. Since the potential for total savings is so much larger for a customer with many applications at a single site, a direct install program with buydown may be viable. A direct install program with buydown could be attractive to commercial customers with large savings potential while improving the overall TRC metric of the program for the utilities and ratepayers. Light commercial customers with few PC workstations could be a borderline case applicable to direct install with or without buydown. Further programs development and analysis would be needed to determine which customers would be best suited to each type of direct install program.

In order to support the implementation and penetration of this plug load management technology, several things could be done:

- Follow-up study using a pre- and post-installation approach to compare results with the findings here.
- Follow-up study to determine energy savings using timer settings other than 1 hour.
- If the host sites of this report are not deemed representative, average California A/V and PC consumption could be used with the average percent energy savings to calculate deemed savings values.
- Customer acceptance and installation persistence is an uncertainty not addressed here. Further study and the pilot direct install program should shed light on the long-term customer use and reaction to the APS devices, informing future programs and program evaluations.
- All utility programs should make recommendations on how to best use the device based on industry or customer concerns. For instance, it may be that acceptance and results will be better if A/V APS devices are installed without controlling stereos or game consoles.
- The A/V technology, if economical, should have more timer settings other than 1, 2 and 8 hours in order to improve acceptance.
- As is the case with the commercial host site in this trial, manufacturers and vendors should continue to address the IT concerns of large commercial and institutional customers and develop a PC APS business model around this issue.

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APPENDIX

MEASUREMENT TIMELINE JUSTIFICATION

The relatively short measurement timelines were determined to be satisfactory for the CalPlug approach by examining the transient nature of the calculated energy savings and baseline consumption. Using a continuously updating annualization during the test, it can be shown that annualized consumption and savings level out fairly quickly. The annualization used the following ratio of annual hours to monitored hours:

$$Annual\ Energy = \frac{8760\ hours}{Monitored\ Hours} * Measured\ Energy$$

The short monitoring timeframes can be justified by the effects of time on the calculated energy savings. Figure 33 through Figure 35 show the transient nature of calculated annual savings and baseline usage for three example host sites. The annualizations develop towards steady state fairly quickly as the test progresses. The three sites develop a steady state after about 12, 9, and 5 days, respectively. This is representative of the typical behavior for all the host sites. As such, it is reasonable to state that the measurement timelines were long enough to capture representative user usage patterns. The day-to-day variation tended to become insignificant between 7 and 14 days.

The timeframe was not long enough to claim that seasonal effects are captured in the data and analysis. However, it may be reasonable to assume that host site A/V usage patterns are fairly consistent throughout the year and could be represented by the collected data since it was a shoulder season and did not include any national work holidays.

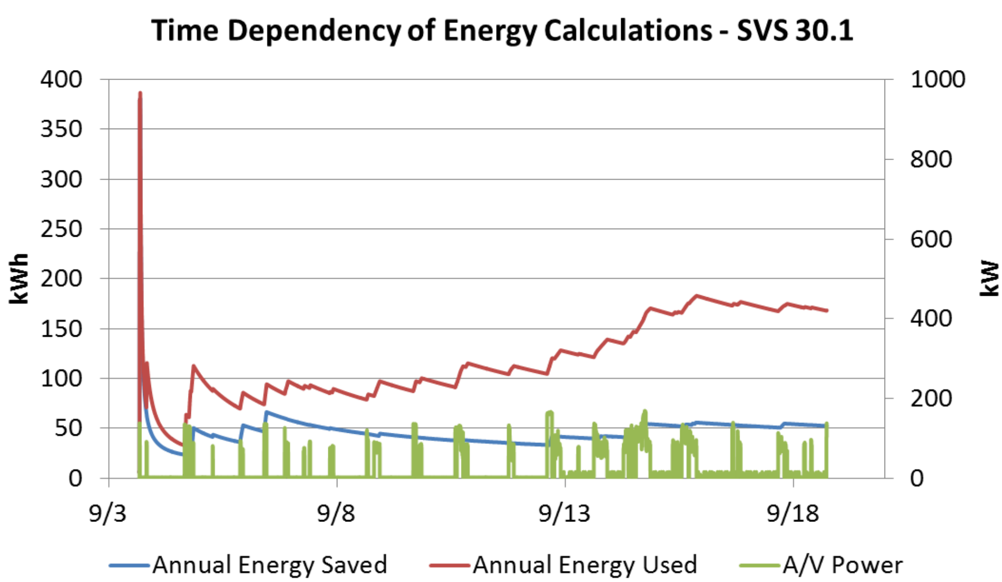

FIGURE 33 - TRANSIENT NATURE OF A/V ANNUALIZED USAGE AND SAVINGS FOR SITE WITH INSTRUMENTATION ID 30.1

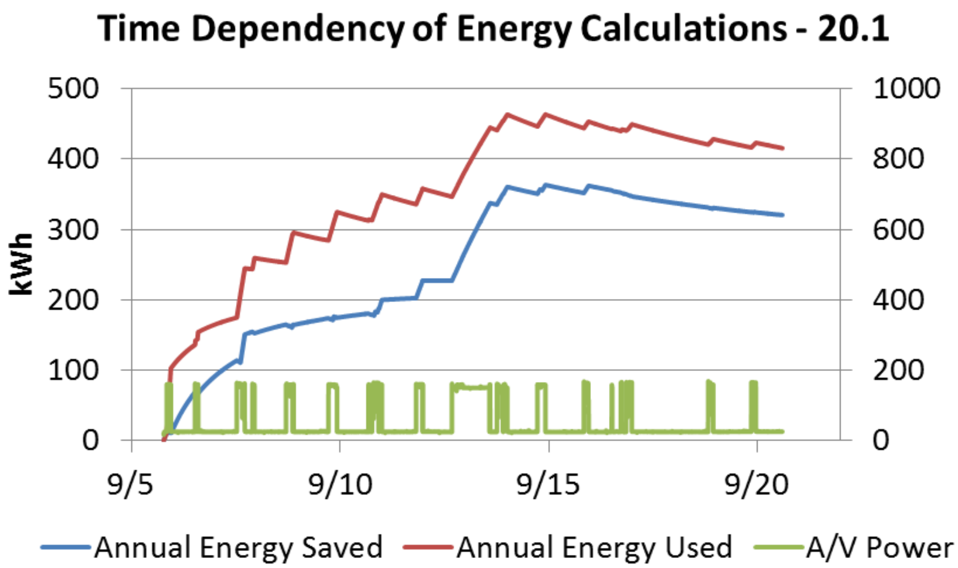

FIGURE 34 - TRANSIENT NATURE OF A/V ANNUALIZED USAGE AND SAVINGS FOR SITE WITH INSTRUMENTATION ID 20.1

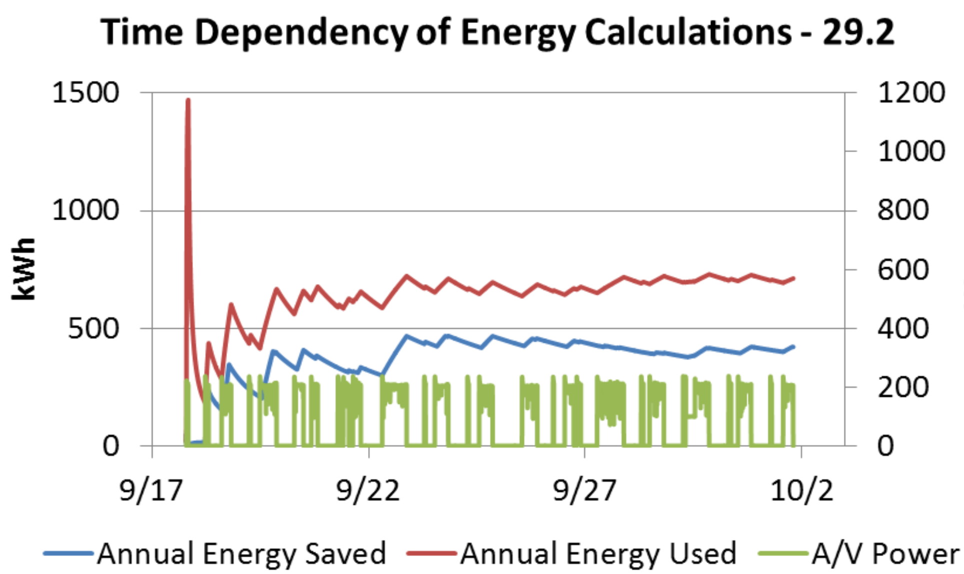

FIGURE 35 - TRANSIENT NATURE OF A/V ANNUALIZED USAGE AND SAVINGS FOR SITE WITH INSTRUMENTATION ID 29.2

Note that this transition to steady state may take longer in a typical pre-post measurement approach as more time is needed to average out the variation in user behavior from one time period to another.

Raw and Corrected A/V Results

As discussed in the A/V Results section, some correction to the data was required due to instrumentation collection error and data omission. Figure 36 and Figure 37 show the raw and corrected baseline usage and savings for all the host sites, sorted by raw baseline usage.

The average baseline consumption and savings decreased 0.8 kWh (0.2% reduction) and 19.2 kWh (7.7% reduction).

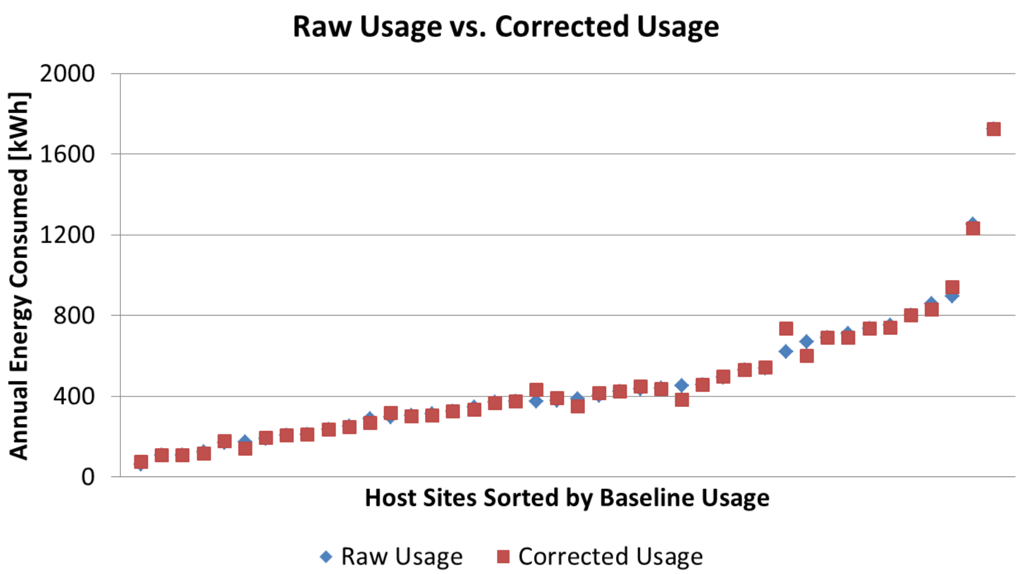

Figure 36 - Raw data annual usage compared to corrected annual usage

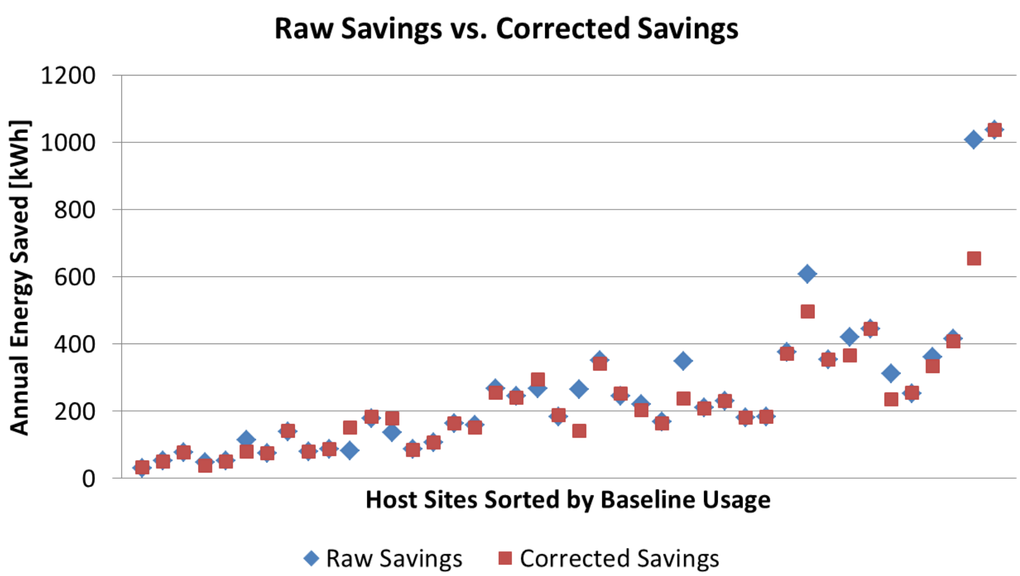

Figure 37 - Raw data annual savings compared to corrected annual savings

SDG&E A/V Host Site Selection Effects

Due to the timeline and host site solicitation restrictions of the project, it was necessary to use the SDG&E employee network to obtain residential participants. It has been suggested that using residential participants that were households of SDG&E employees could skew baseline consumption and savings benefits. This is based on the hypothesis that SDG&E employees would likely use less energy than non-utility employees by being more energy conscious. This hypothesis was tested by comparing the results of SDG&E employee households to others.

There were 28 SDG&E employee household participants and 14 non-SDG&E employee household participants. The average annual baseline consumption, savings, and statistical parameters for each group are shown in Table 21.

Table 21 - Statistics of SDG&E vs. non-SDG&E employee households

Statistic	SDG&E Employees	Non-SDG&E Employees
Average annual baseline consumption [kWh]	442.7	502.1
Standard deviation [kWh]	232.6	437.1
90% confidence interval [kWh]	(370.4,515.0)	(309.9,694.2)
p-value for hypothesis of significant difference between means of the two populations	0.32	
Average annual savings [kWh]	217.4	265.8
Standard deviation [kWh]	127.6	256.7
90% confidence interval [kWh]	(177.7,257.0)	(152.9,378.7)
p-value for hypothesis of significant difference between means of the two populations	0.26	

The p-value was calculated using a Welch's t-test for the populations of SDG&E and non-SDG&E employee households. Although the difference in mean of the baseline consumption and savings suggests that SDG&E employees are more energy conscious in their A/V energy consumption, the t-test suggests that the level of significance in this difference is fairly low. It is reasonable to reject the hypothesis that there is a significant difference in the mean baseline consumption and savings of the SDG&E and non-SDG&E populations.

Still, it may be reasonable to assume that the general California population may have slightly higher baseline than the host site population in this study; this would in turn increase savings slightly, as well.

A/V Demographic Correlations

Although no robust relationships between and demographic data and energy savings were found, the attempts at correlation are presented below in order to inform future studies or programs that may intend on considering such demographic factors.

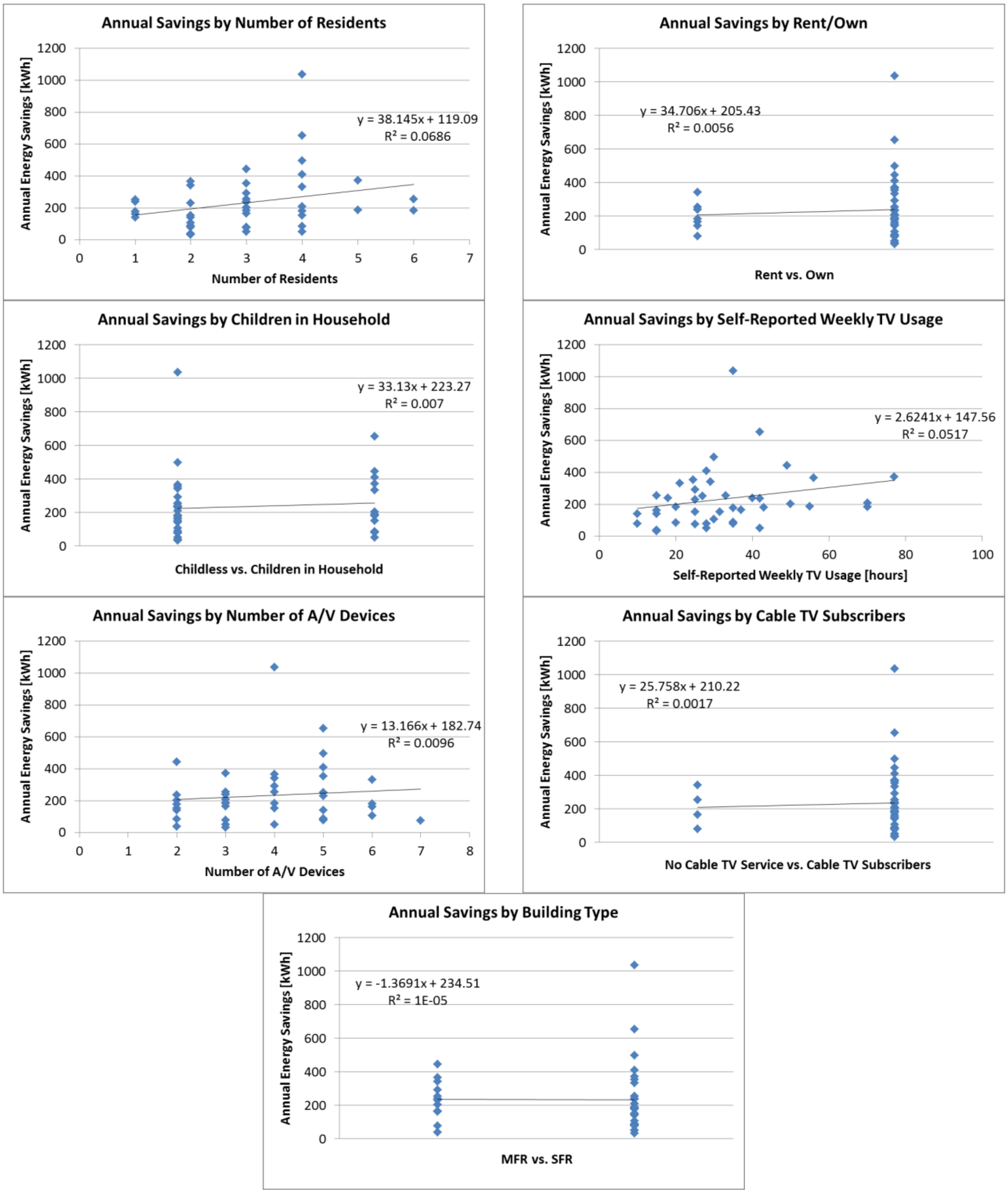

Figure 38 - Attempted correlations between A/V savings and demographic data

A/V AVERAGE HOURLY DEMAND AND DEMAND REDUCTION

As previously shown in Figure 24, the hourly weekday baseline demand, simulated post-demand, and demand savings are shown in the following table. Values are averaged across all the A/V host sites.

TABLE 22 - HOURLY A/V DEMAND AND DEMAND SAVINGS

Weekday Hour	Pre Power [W]	Post Power [W]	Demand Savings [W]
0	30.2	11.2	19.0
1	27.1	7.8	19.4
2	22.9	4.0	18.9
3	21.2	4.6	16.6
4	26.4	7.7	18.7
5	26.2	5.6	20.6
6	29.4	10.5	18.9
7	37.3	18.1	19.2
8	39.4	20.3	19.1
9	40.0	14.9	25.1
10	42.7	17.2	25.6
11	45.7	21.4	24.3
12	52.0	23.1	28.9
13	54.3	24.6	29.7
14	59.7	24.5	35.2
15	62.9	29.5	33.4
16	71.9	36.9	35.1
17	84.6	50.0	34.6
18	91.8	52.4	39.4
19	104.6	63.5	41.2
20	109.9	63.7	46.2
21	92.7	49.4	43.3
22	59.2	30.5	28.7
23	39.4	19.1	20.3

PC Workstation Baseline and Savings Correlations

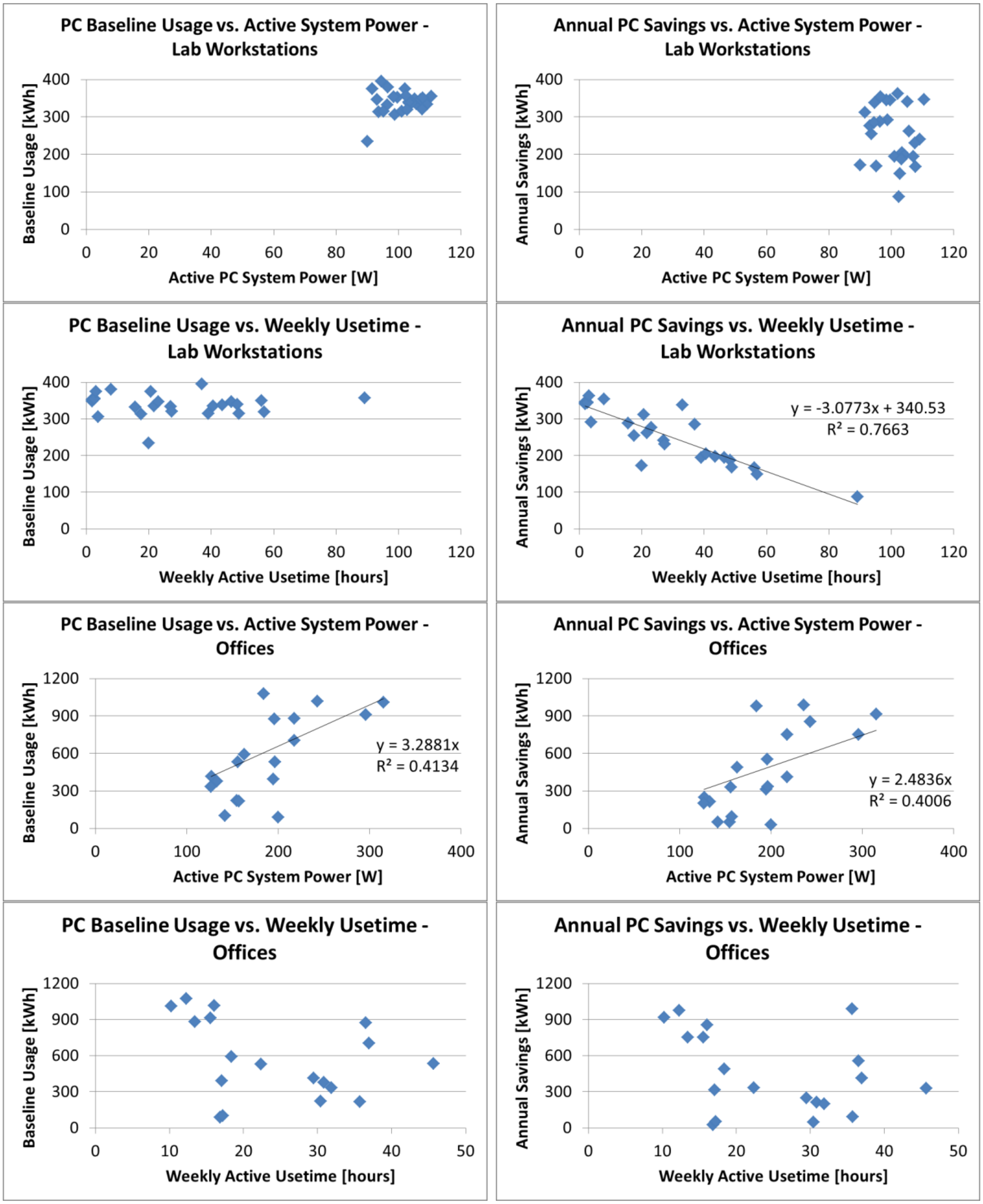

Figure 39 - Annual PC baseline and savings correlations to weekly usetime and PC system power

PC Average Hourly Demand and Demand Reduction

As previously shown in Figure 30 through Figure 32, the hourly weekday baseline demand and simulated demand savings are shown in the following table. Values are averaged across all the PC host workstations.

Table 23 - Hourly PC demand and demand savings

	Computer Lab Workstations		Office Workstations		Combined Lab and Office Workstations	
Hour	Pre Power [W]	Demand Savings [W]	Pre Power [W]	Demand Savings [W]	Pre Power [W]	Demand Savings [W]
0	70.1	58.9	75.4	66.2	77.8	70.1
1	55.3	46.3	75.5	66.1	70.0	63.4
2	53.2	33.4	75.2	65.9	68.9	55.7
3	49.2	39.2	79.2	68.2	81.1	71.6
4	44.8	34.4	79.4	70.1	82.9	77.3
5	41.4	27.4	75.4	66.0	78.1	71.9
6	60.5	4.4	77.8	68.8	74.5	40.6
7	55.1	43.0	87.9	66.6	74.1	61.2
8	55.1	41.4	125.7	35.9	85.0	48.0
9	56.1	31.5	133.8	37.4	86.4	39.4
10	56.5	25.0	118.1	39.2	91.9	34.3
11	56.4	18.4	129.6	21.1	94.4	31.6
12	57.6	21.4	150.1	37.5	92.9	40.3
13	58.4	17.6	131.8	26.2	95.5	30.2
14	57.5	23.9	144.0	24.8	94.1	37.7
15	57.8	23.1	143.2	30.2	91.9	36.9
16	55.9	29.7	121.9	44.7	86.2	46.2
17	54.6	30.3	105.3	80.8	81.3	58.7
18	54.5	31.5	96.0	78.6	75.8	59.8
19	53.0	40.3	98.2	86.2	77.9	68.7
20	51.7	40.5	89.1	86.3	71.8	65.6
21	50.7	39.5	80.5	79.5	68.4	62.7
22	48.8	40.5	77.5	76.7	67.0	62.7
23	48.1	37.8	76.2	69.8	67.0	60.4

PC Energy Savings and Demand Reduction of Vacant Workstations

The following tables present the energy and demand savings for the isolated vacant workstations in both the office and computer lab PC settings. Note that nearly all energy and demand is predicted to be eliminated by the CalPlug APS methodology.

Table 24 – Average energy savings results for the vacant PC workstations

Dataset	Monitored Time [days]	Avg Weekly Active Usetime [hours]	Avg Baseline Usage [kWh/yr]	Avg Energy Savings [kWh/yr]	Avg % Savings
Office Settings	12.9	2.8	647.3	631.2	97%
Computer Lab Settings	13.9	3.4	353.0	340.5	96%

Table 25 - Average PC APS demand Reduction for the vacant workstations

Dataset	Baseline Demand [W]	Demand Reduction [W]	Base On-peak demand[16] [W]	On-Peak Demand Reduction [W]	DEER on-peak Base demand[17] [W]	DEER On-Peak Demand Reduction [W]
Office Settings	84.1	81.4	92.1	88.0	89.7	85.8
Computer Lab Settings	42.2	40.2	41.4	38.3	42.5	37.6

16 On-peak defined by the timeframe of 11 AM to 6 PM.

17 DEER on-peak defined as 2 PM to 5 PM (CPUC, 2013).