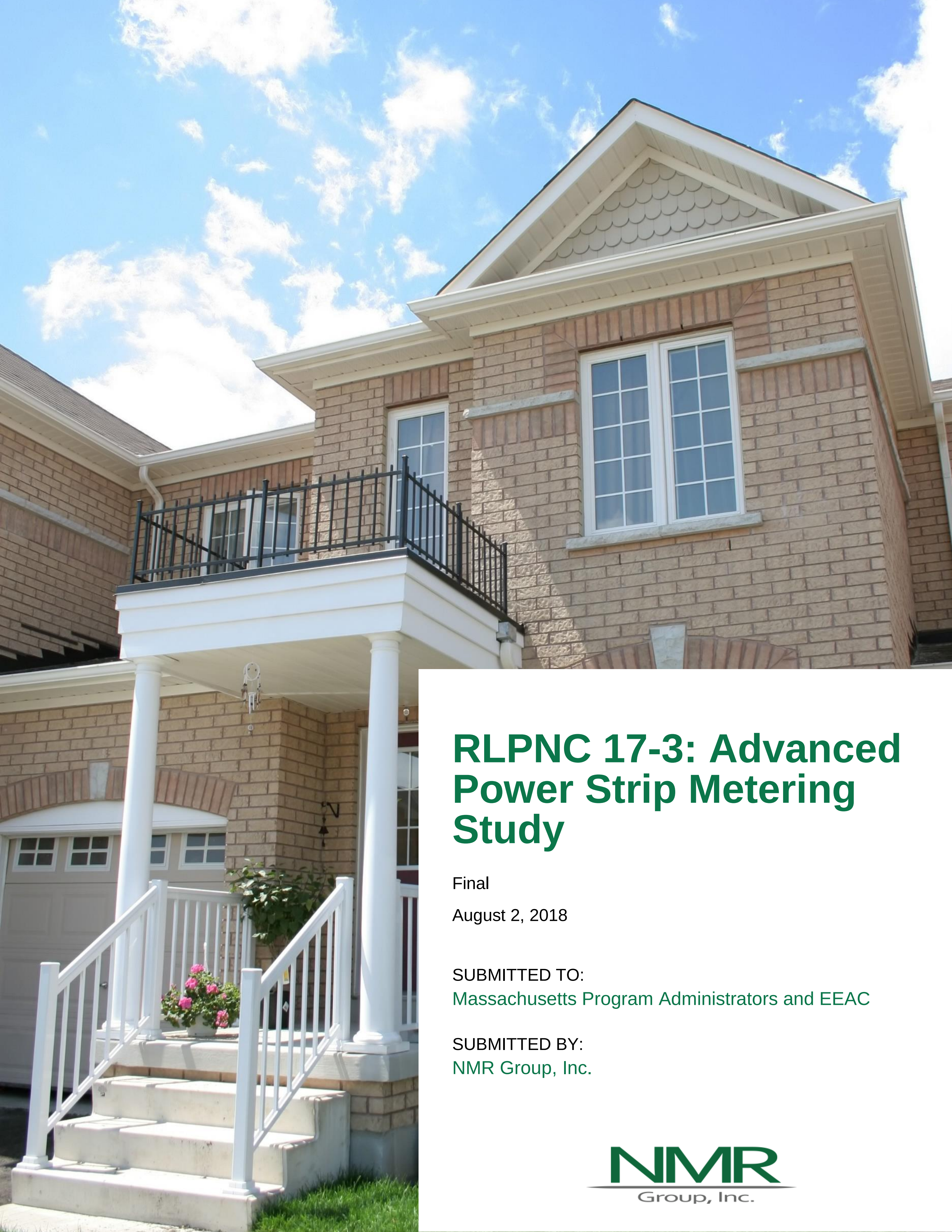


RLPNC 17-3: Advanced Power Strip Metering Study

Final

August 2, 2018

SUBMITTED TO:
Massachusetts Program Administrators and EEAC

SUBMITTED BY:
NMR Group, Inc.

NMR Group, Inc.

Baseline Usage and Advanced Power Strip Energy Reduction Potential

Measuring the baseline energy usage for home entertainment centers and computers, and the energy reduction potential using advanced power strips

We conducted a comprehensive metering study of 133 computer and home entertainment center (HEC) connected strips across Massachusetts to measure baseline usages and the energy reduction potential (ERP) of Tier 1 and Tier 2 advanced power strips (APS). The study found baseline usage values that are lower than those published in the previous Technical Resource Manual (TRM), possibly due to decreased usage times. We found the ERP values to be substantial and in line with the TRM and other APS metering studies. **These results will help to create more accurate TRM usage and energy savings values, and will help inform the PAs on the value of supporting APS units in future program activities.**

Baseline usages for HECs and Computers were lower than the previous TRM values, but in line with other recent metering studies. Usage and hours of use (HOU) varied widely across sites.

HEC Usage	Computer Usage	HEC Peripherals	Computer Peripherals	Seasonality
Annual Usage: 471 kWh **Daily HOU:** 4 hours 45 minutes *Findings support reported decreases in TV viewing habits*	**Annual Usage:** 399 kWh **Desktop Usage:** 468 kWh **Lapop Usage:** 186 kWh	**Average Number:** 3.1 **Highest Energy Users:** Gaming consoles, Routers, Set-top boxes	**Average Number:** 3.2 **Highest Energy Users:** Monitors, Lamps, Printers	**HEC Winter Usage Change (from summer):** 9% **Computer Winter Usage Change (from summer):** 8%

APS Energy Reduction Potential and Savings

Tier 2 Infrared Strips generated the highest ERP, kWh and peak demand savings. Tier 2 Infrared/Occupancy Sensing strips were the next highest performers. Tier 1 APS also demonstrated substantial savings across these metrics.

		ERP	kWh Savings	Demand Savings (Delta-Watts)
Tier 2 (*HEC Only*)	Infrared	48%	225	31
	Infrared/Occupancy Sensing	28%	132	12
Tier 1 (*HEC and Computers, weighted to program initiative end-uses*)	Home Energy Services	26%	114	9
	Online/Upstream	25%	111	6

Table of Contents

Executive Summary

This report presents the results of the RLPNC 17-3 Advanced Power Strip (APS) Metering Study conducted by NMR Group, Inc., and Navigant Consulting, on behalf of the Massachusetts Program Administrators (PAs). The study was designed to update impact factors associated with APS units, namely, baseline energy use and Energy Reduction Potential (ERP). It is important to note that this study was designed as a metering study and not as an impact evaluation. Since customers were not asked to setup or install the APS units on their own, it is possible that saving results are upwardly biased. To capture the full scope of ERP and potential biases, this report also separately considers the set-up, in-service, and persistence rates of APS units (Section 2.3).

The study relied on in-home metering of end-use energy consumption. In total, the study metered 133 sites, including 65 control sites and 68 treatment sites. Metering occurred over approximately nine months for both control and treatment sites, with treatment sites switching midway from having no APS unit installed (pre-period) to having an APS unit installed (post-period).

Through our analysis of the energy usage at these treated sites, along with a control group that did not receive APS units, we produced estimates for baseline usage, ERP, and estimated annual energy savings (i.e., delta kilowatt hours, kWh). In this report, we compare these values to those in the Massachusetts Technical Resource Manual (TRM) and to other existing literature. Additional methodological detail is available in Appendix A.

Program Design. The PAs offer Tier 1 APS as a give-away measure in the Home Energy Serves (HES) program. In the Residential Consumer Products Core Initiative (RCP), they offer Tier 1 and Tier 2 APS for purchase online or through retailers at a reduced shelf price. In both designs, customers install the APS, decide how to set it up, and decide which devices to connect to it. At the time of the study, the PAs offered RCP incentives for one brand of Tier 1 APS and two Brands of Tier 2 APS (referred to in this report as infrared [IR] and infrared-occupancy sensing [IR-OS]). Tier 1 APS use a controlling device, most often a TV or PC, to control outlets with attached peripherals (e.g. gaming consoles, printers, etc.). Controlled outlets are shut off when the main device is not in use, which curbs vampire-usage/plug-load consumption. Tier 2 devices work similarly, but monitor if an idle device is still in use, and shut the device off if there is a lack of user engagement after a set period. Although Tier 2 APS for PCs do exist, they are configured differently from HEC strips and are not offered as a measure by the PAs. For more on these technological differences, see Section 3.4.

Baseline Energy Use. This study suggests decreasing baseline energy use compared to the current TRM values. The evaluation measured baseline usage for two residential end uses: Home Entertainment Centers (HECs) and Personal Computers (PCs). Since current program designs require customers to self-install APS units and select the end-use, this study also looked at combined average baseline usage, weighted by HEC and PC installations. Table 1 compares baseline energy use estimates from this study to current TRM values. The 2016-18 TRM had separate baseline usage values for Tier 1 and Tier 2. This study provides one value for each baseline HEC usage and baseline Computer usage, since Tier 1 APS can be used for both HEC and Computers. We suggest a combined baseline (based on observed proportions of HECs and

PCs). Since the PAs do not support Tier 2 APS designed for computers, we suggest using the baseline usage for HECs for all Tier 2 APS.[1]

Energy Reduction Potential. This study suggests increasing ERP for Tier 1 APS and adopting separate Tier 2 values for Infrared Tier 2 APS (IR) and Infrared and Occupancy Sensing Tier 2 APS (IR-OS). The PAs limit support of Tier 2 APS to units designed to be used with HECs (predominantly connected to TVs), while Tier 1 APS could be used with either HECs or PCs. Table 1 presents Tier 1 ERP separately for HECs and PC; Tier 1 ERP is weighted by the distribution of the two end-uses.

Table 1: Updated Impact Factors

Factor	Prior Value	Updated Value	Updated Value CI*
Baseline Usage			
HEC	603 kWh (Tier 1) 678 kWh (Tier 2)	**471 kWh**	**371-571 kWh**
PC	603 kWh (Tier 1)	**399 kWh**	**254-544 kWh**
Combined	641 (Tier 1 and Tier 2 Average)	**435 kWh**	**353-517 kWh**
Energy Reduction Potential (ERP)			
Tier 1 – HEC	12%	**26%**	**24%-28%**
Tier 1 – PC	12%	**24%**	**21%-27%**
Tier 1 – Combined	12%	**25%**	**23%-28%**
Tier 2 – IR	51%	**48%**	**45-50%**
Tier 2 – IR-OS	51%	**28%**	**26-30%**
Demand Savings			
Tier 1 – HEC	10 W (SF) / 20 W (MF)	**11W**	**10-12W**
Tier 1 – PC	10 W (SF) / 20 W (MF)	**6W**	**5-7W**
Tier 1 – Combined	10 W (SF) / 20 W (MF)	**9W**	**8-10W**
Tier 2 – IR	70 W	**31W**	**29-34W**
Tier 2 – IR-OS	70 W	**12W**	**11-14W**

* The kWh ranges for baseline usage represent a 90% Confidence Interval using absolute precision, while the percentage values in parenthesis represent the relative precision at 90% confidence.

It is important to note that after this evaluation, the Tier 2 IR-OS manufacturer made a change to their product which will likely increase Tier 2 IR-OS ERP. Specifically, the manufacturer decreased the default timer setting from 75-minutes to 60 minutes. This change should have a positive impact on ERP, increasing it from the 28% observed as part of this study. Based on the data collected as part of this study, NMR was unable to determine the magnitude of the impact, however, lab testing by CalPlug found that changing the sensor timer from 75-minutes to 60, increased savings by about 7% a year.[2] Applying this same 7% increase to the Tier 2 IR-OS APS

[1] Note that there are several factors that have prevented Tier 2 PC strips from becoming a program supported measure, including; lack of PC-specific savings estimates, lower baseline usage for PCs, and the higher level of customer engagement required to setup T2 APS for PCs (devices require installation of software on PCs), which could lead to low in-service rates.

[2] Michael Klopfer, Linyi Xia, Joy Pixley, Crystal Rapier and G.P. Li, “Tier 2 Advanced Power Strips – Revisiting behavior based models for estimation of savings in laboratory and field trial evaluations,” *California Plug Load Research Center (CalPlug), University of California, Irvine (UC Irvine),* (May, 2018), p. 47.

in this study would increase ERP to 30%. Note: lab testing does not fully account for customer behavior, including manually increasing the timer setting. For more details please see Section 3.1.3.1.

APS Realization Rate. While identifying sites to participate in this study, Navigant technicians observed 26 pre-existing Tier 1 APS units that had been previously self-installed by customers participating in the RES 1 Baseline Study. While we did not include these sites in the baseline energy use analysis, the existing APS units provided an opportunity to observe whether customers were correctly configuring APS devices. This is important because improperly setup devices are likely to lead to lower than expected energy savings. Based on this sample of 26 Tier 1 APS units, we calculated a realization rate to correct for lost savings due to non-optimal set-ups. We calculated this realization rate as 92%. This is further discussed in Section 2.3.[3]

KEY FINDINGS

This executive summary features key findings related to baseline energy usage and ERP, and presents considerations for the PAs. The remaining body of the report presents more detailed findings. Each section of the report is accompanied by a corresponding appendix with additional details.

Baseline Energy Usage

HECs consumed an average *of 471 kWh per year, and households actively used them an average of four hours and 45 minutes daily.* The daily use is nearly identical to the average Boston TV viewing time reported by Nielsen.[4] This value was 21% lower than the TRM value of 603 kWh for Tier 1 and 31% lower than the TRM value of 678 for Tier 2. We recommend dropping the Tier 1/Tier 2 distinction in the future. These values aligned with those observed in other recent power strip metering studies (see Section 3.3). ***The decreased usage compared to the TRM value may be a result of customers shifting away from traditional TV viewing in favor of streaming on other devices***.[5] Usage varied widely from site to site: while 63% of HEC strips consumed less than 500 kWh per year, 7% drew over 1,000 kWh annually. Strips typically had about three peripherals in addition to the TV; gaming consoles, routers, and set-top boxes were most closely associated with high energy use.[6]

Customers used their TVs for an average of 4.75 hours daily, accounting for 471 kWh/year of total HEC

[3] While this realization rate was fairly high, we found the realization rate to be lower in the RLPNC 17-4/5 APS Survey (see Section 2.3), and additionally there were some persistence issues with customers included our metering (see Appendix E). Both findings suggest that it may be beneficial for the PAs and EEAC to expand their efforts to educate customers across all delivery methods (upstream, online, and leave behind) regarding the optimal set-up and functions of APS.

[4] http://www.nielsen.com/content/dam/corporate/us/en/reports-downloads/2018-reports/local-watch-report-q4-2017.pdf

[5] For decreased use trends see: see: https://www.adweek.com/tv-video/tv-viewers-are-demanding-more-options-and-streaming-services-are-happy-to-oblige/"

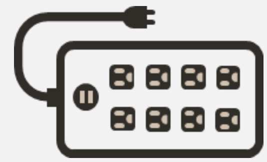
[6] Note that routers and set-top boxes are always left on, and are therefore neither controlled devices in an APS setting, nor candidates to achieve energy savings through the measure.

Computers drew an average 399 kWh per year, with desktops consuming significantly more energy than laptops (468 kWh vs. 186 kWh). This was 34% lower than the previous TRM value for computers receiving Tier 1 strips (603 kWh). Computer usage varied widely across sites; this likely reflects wide variation in their daily hours of use. While most computers drew less than 400 kWh annually, the usage peaked at over 1,000 kWh. Similarly, the average computer was active for six and a half hours daily, but some households rarely used their computers, while other computers remained active most of the day. Desktops saw over eight hours of use per day compared to one hour and 22 minutes for laptops. Computers had an average of three connected peripherals. Strips with monitors, printers, and miscellaneous peripherals (e.g., lamps or heating pads), tended to draw more energy.

Computer usage accounted for 399 kWh/year; usage varied widely across sites

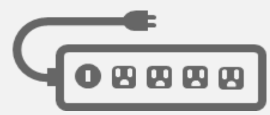
Energy Reduction Potential (ERP)

Tier 2 IR strips demonstrated the highest ERP (48%), similar to the TRM value of 51%. This translates to 225 kWh annual savings when applied to the baseline usage for HEC, lower than the TRM value of 346 kWh per year, primarily due to lower baseline usage. These numbers are also in line with other advanced power strip field studies (see Section 3.3). ***Tier 2 IR-OS strips demonstrated savings with an ERP of 28%, equal to an energy reduction of 132 kWh per year.*** Although IR strips performed better, attrition was higher, and although the sample size was small, persistence may be a threat to their long-term savings outlook.



Tier 2 strips had an ERP of 28%-48%, with one technology outperforming the other

Using weighted averages for HECs and PCs derived from the proportion of end-uses in each program initiative, ***Tier 1 strips achieved an ERP of 26% or 114 kWh savings through the HES initiative, and 25% (111 kWh) through RCP channels.***[7] Despite the higher baseline usage specified in the TRM, both these ERPs and annual kWh savings are higher than the Tier 1 TRM value (12% ERP).



Tier 1 strips achieved an ERP of 26% for HES and 25% for online/upstream

Seasonal and Daily Use Patterns

Winter computer energy use increased by 8% and HES use increased by 9% compared to summer use. Weekly use was highest on the weekends, while PC use was highest during weekday business hours. While largely steady, ERP declined slightly at peak hours, leading to minor peak demand reductions of about 0.03 kW from Tier 2 IR-OS strips and 0.01 kW from all other APS types.

Both computer and HEC usage increased significantly during the winter months

CONSIDERATIONS

Consideration 1: The PAs should adopt baseline usage estimates for HECs, PCs, and combined end-uses as part of updates to the TRM for the 2019–2021 program cycle. The estimates should be independent of APS technology or brand.

Rationale: The 2016–18 TRM includes separate baseline usage estimates for Tier 1 and Tier 2 APS units and does not distinguish between end uses. While the performance characteristics of APS units likely varies by Tier or brand, baseline usage for a given end use should not. In addition, having end-use specific baseline values will allow the PAs to account for savings by type of installation, should the PAs track this via program records or conduct periodic evaluation studies to update the initial estimates provided in this study.

[7] For more details on these weights see Section 3.1.4.

Consideration 2: The PAs should adopt performance bands for Tier 2 APS products as part of the next program cycle (2019–2021). Performance bands should be based on technology differences between Tier 2 APS products.

Rationale: Evidence from this study, as well as other recent APS metering studies, shows that Tier 2 APS units of varying technologies perform differently in terms of ERP; Tier 2 IR strips demonstrated substantially higher ERP values compared to Tier 2 IR-OS strips.

Consideration 3: As discussed in Section 2.3 and Appendix E, the PAs should explore benchmarks outside ERP, including persistence and satisfaction, when considering performance bands.

Rationale: The lower satisfaction and persistence reported by Tier 2 IR customers, as well as their more frequent changes to strip sensitivity, may hurt the potential real-world savings that can be achieved across the population. The PAs should consider whether the significantly higher ERP is enough to overcome these potential limitations.

Consideration 4: The PAs should consider using future program tracking efforts or surveys to update the percentage of HEC versus PC end-uses.

Rationale: The potential energy savings that can be achieved using APS are dictated by their end-uses and the amount of time each are used. A lack of information regarding the HEC versus computer end-use distribution from RCP channels, and regarding laptop versus desktop end uses in general, limited our estimates of ERP and energy savings. Furthermore, as energy use varied widely between laptops and desktops, having more information available on the prevalence of each computer type could help other future program efforts.

Consideration 5: The PAs should continue to monitor and consider the decreases in television viewing time when planning for future program activities and evaluations.

Rationale: In this study, we observed television usage times in line with Nielsen estimates, which have shown continual decreases over the past few years, especially in younger age groups. This likely explains why usage was lower for HEC than the values specified in the previous TRM. If usage continues to decline, it will limit future program opportunities pertaining to HEC and APS. This is a situation that should continue to be monitored however, as increased streaming can continue to drive television usage, even as traditional viewing decreases, and the diminishing time of use trend may not continue.

Section 1 Introduction

The Program Administrators (PAs) and Energy Efficiency Advisory Council Consultants (EEAC) identified Advanced Power Strips (APS), sometimes referred to as smart power strips, as a key product of interest for additional study. APS come in two basic categories: Tier 1 and Tier 2. The PAs currently offer incentives for one brand of Tier 1 and two Brands of Tier 2 APS (referred to in this report as infrared [IR] and infrared-occupancy sensing [IR-OS]). Regardless of tier, APS generate savings by targeting passive standby or vampire energy loads in electronic devices. [8]

The PAs offer Tier 1 APS as a leave-behind measure as part of the Home Energy Serves (HES) initiative. Vendors do not install the APS. The Residential Consumer Products Core initiative (RCP) offers Tier 1 and Tier 2 APS for purchase online or through retailers at a reduced shelf price. As with HES, APS purchasers must choose whether and how to set them up. For more on these technological differences, see Section 3.4.

To increase the understanding of APS savings opportunities, the PAs and EEAC worked with NMR Group, Inc., (NMR) to design and conduct an evaluation that would provide data to update baseload energy usage for devices that can be controlled by smart power strips and the Energy Reduction Potential (ERP) of both Tier 1 and Tier 2 strips. This study leveraged existing field work being conducted by Navigant Consulting as part of the Massachusetts RES 1 Residential Baseline Study. During site visits for the Baseline Study, Navigant technicians collected energy usage information from power strips attached to Home Entertainment Centers (HEC) and Personal Computers (PCs) (both laptops and desktops). This report presents the findings from this field study.

The report is laid out as follows:

Section 2: **Baseline Usage** presents findings on average baseline HEC and computer usage and addresses evidence of seasonal usage behavior patterns.

Section 3: **Energy Reduction Potential** (ERP) provides the energy reduction achieved by tier 1 and tier 2 (separated by technology) smart power strips, as well as a comparison to other APS metering studies and a discussion of the differences between technologies in tier 2 strips.

Appendix A: **Additional Sampling and Methodology Details** provides additional information on how sites were selected and the methods for calculating baseline usage and ERP.

Appendix B: **Demographics** shows the demographic breakdown of the sample and our weighting approach.

Appendix C: **Additional Baseline Usage Information** expands on Section 2, with additional tables and figures.

---

[8] In the Massachusetts Technical Resource Manual (TRM), Tier 1 power strips are referred to as "Smart Power Strips" and Tier 2 power strips are referred to as "Advanced Power Strips." This report uses those terms interchangeably and distinguishes between the two by using the Tier categorizations. See pages 162-165 of the TRM: http://ma-eeac.org/wordpress/wp-content/uploads/2016-2018-Plan-1.pdf

Appendix D: **Additional Energy Reduction Potential Information** expands on Section 3, with additional tables and figures, as well as measured energy savings using different analytic techniques.

Appendix E: **Customer Satisfaction and Persistence** presents the results from questions asked by technicians upon the removal of the meters at sites that received APS units.

1.1 Objectives

The main goal of this study was to investigate two impact factors for APS:

- Baseline Energy Use
- Energy Reduction Potential (ERP)

Ultimately, these factors are used to calculate energy and demand savings included in the Massachusetts TRM (the TRM). We have reviewed the existing TRM and its underlying methodology and compared our findings for these impact factors throughout the report. The TRM also provides values for demand savings created by APS, which we measured as well. Finally, we compared the results and methodology of this study to other recent APS metering studies conducted nationally to help assess validity.

This study has been designed as a metering study and not as an impact evaluation. While the program designs require customers to setup the APS on their own, this study installed the APS, and was only able to fully measure strips that were left installed throughout the entire metering period – thus eliminating customers who removed their APS and experienced reduced or no savings. Therefore, it is possible that saving estimates are upwardly biased. Accounting for in-service and retention rate, and setup practices should align the savings estimates with actual installation practices (see Section 2.3 and Appendix E).

1.2 Methodology

NMR partnered with the Navigant-led Massachusetts RES 1 Residential Baseline Study to collect the data.[9] Navigant technicians installed meters on 191 power strips connected to televisions and entertainment peripherals. The homes participating in the baseline study were randomly selected, and technicians installed the meters on pre-existing power strips found in these homes. The team successfully scheduled the necessary follow-up visits (three in total) with 170 homes, and assigned each strip as treatment (replaced by an APS) or control (left unchanged). Table 2 shows the number of strips that the technicians visited at each stage, along with the final counts of strip types and end-uses included in the analysis throughout this report.

Initial visits – May and June 2017. During the initial visit, technicians installed plug-load meters to track energy usage from power strips connected to 114 HECs and 36 PCs. During the initial visits, technicians also noted the type of devices and peripherals plugged in.

[9] http://ma-eeac.org/wordpress/wp-content/uploads/RES-1-Baseline-Load-Shape-Study-Heating-Season-Report-Final.pdf

Although most of these were ordinary power strips (i.e., not advanced or smart power strips), there were 26 pre-existing Tier 1 APS units included. These pre-existing Tier 1 APS units were kept in the sample, but excluded from any analysis of baseline energy usage.

Treatment visits – August through October 2017. During the treatment visits, technicians installed a total of 100 Tier 1 and 2 APS at randomly selected sites,[10] and downloaded the metered data available from the pre-period (June–August). During these visits, the techs set up the APS units to their default settings attaching the same devices to the APS that were plugged in to the original strip. They provided customers with a brief overview and information on how to change the timer, and provided them with the packaging material for the APS itself. Customers were instructed to call Navigant if they experienced problems with the APS units, who would in turn coach the customers over the phone on how to resolve any issues (e.g., how to change the timer settings). Technicians carefully marked and noted the configuration of APS units upon installation, and noted which peripherals were plugged into the APS and into which slot.

Technicians also revisited the control sites (i.e., those not receiving a Tier 1 or Tier 2 strip) and downloaded their usage data at that point.

Final visits – January through March 2018. During the final visits, technicians returned to each site for a third time and downloaded the final metered data. While on-site, technicians recorded the configuration of each APS unit and verified the devices connected. For sites where connected devices changed, technicians noted the differences.

Data Cleaning. We were forced to remove some sites from the final analysis for reasons including sites withdrawing from the study, bad data (e.g., a meter malfunctioning or logger data appearing to be inaccurate), customers plugging additional peripherals into the strips during the post-period and receiving no-response when attempting to schedule a second or third visit. After removing these sites, we were left with 164 sites in the pre-period and 133 sites in the post-period to use in the final analysis. This consisted of sixty-eight sites with smart power strips (thirty-six Tier 1 and thirty-two Tier 2) and sixty-five control sites. For more details on the sample breakdown, see Appendix A.

[10] Although we did use a random sample to determine sites receiving advanced power strips, we only installed the units at homes that agreed to both have their energy usage metered and having a smart power strip installed. See Appendix A for more details.

Table 2: Sample Counts at Each Visit and in Final Analysis

APS Details	Count at Initial Visits	Count at Treatment Visits	Final Count Used in Analysis
HEC			
Tier 1	*123*	26	18
Tier 2 IR		26	13
Tier 2 IR-OS		26	19
Control		56	49
PC - All			
Tier 1	*41*	20	18
Control		16	16
Desktop			
Tier 1	*30*	14	13
Control		12	12
Laptop			
Tier 1	*11*	6	5
Control		4	4

1.3 Threats to Validity and Future Considerations

As noted in a recent white paper on APS evaluation, prepared by Johnson Consulting Group and Mesa Point Energy, there have been concerns raised with current methodologies used to quantify APS savings. The white paper quotes an APS researcher as saying that quantifying APS savings "*is difficult because there are a lot of different configurations. It is challenging because of the complications there [for APS]*."[11]

Although NMR feels that the data presented throughout this report portray accurate representations of baseline energy usage and energy reduction potential from Tier 1 and Tier 2 APS for customers across Massachusetts, we faced several limitations that may have impacted results. The following list identifies these potential threats to validity, and lists possible solutions to remedy these obstacles, including current analysis techniques and considerations for future evaluation efforts.

***Threat – small sample sizes*:** This study started with a large pool of 191 homes. We also made efforts to keep the sites similar in terms of connected peripherals and demographic factors. Yet, due to sample attrition issues (see below for more), customers refusing a smart power strip or changing what was plugged into a metered strip, and meter failure, the final analysis only includes 36 Tier 1 and 32 Tier 2 sites. This was substantially smaller than the 40 Tier 1 and 70 Tier 2 sites we had initially targeted. These sample sizes were even smaller for PCs (34), and shrunk further when comparing smaller groups, like laptops and desktops, or IR versus IR-OS Tier 2 strips. The

[11] http://www.johnsonconsults.com/presentations/White%20Paper-Tier%202%20Advanced%20Power%20Strips%209-21-2017.pdf, p. 6.

smaller sample sizes resulted in increased variance and widened the confidence intervals surrounding savings estimates.

> ***Solution*****:** Additional efforts to help customers understand Tier 2 strips prior to planned installations, or selecting from a pool of customers already planning to install this technology could help reduce attrition from the study during any future evaluations, although these solutions could further bias savings results as the additional information and coaching would not reflect the real-world conditions that Tier 2 self-installers would experience. One other solution could be a shorter metering period, which would create more uncertainty about the savings, but would likely reduce the amount of changes customers would make to the devices attached to the APS.

Threat – different baseline usage between strip types**:** HEC customers who received Tier 2 IR-OS power strips used less energy on average in the pre-period (422 kWh) than those who received Tier 2 IR (569 kWh) or Tier 1 (510 kWh). NMR attempted to control for this by allocating samples based on the number of peripheral devices – such that both brands had an average of roughly three peripherals, which is the baseline average for all power strips. However, given the limited sample sizes, this was not sufficient to ensure comparable pre-period energy usage. This may have diminished their potential energy reductions in the post-period (see Appendix D.2).

> ***Solution*****:** NMR accounted for baseline usage in the modeling approach, and although Tier 2 IR average usage was increased by two high-energy use sites, these sites accounted for only a middling ERP compared to the sample (29% and 3% ERP, respectively). A larger sample pool likely would have reduced this variability across groups. An analysis of energy usage data prior to assigning the strip types could have evened out energy consumption; however, this would have removed the randomness of the design and may have required a fourth visit to homes, which in turn may have increased attrition. Despite these differences in usage, we did not observe substantial variation in the number of peripheral devices attached to each strip type (see Section 3). Future studies could also revisit sampled customers to replace APS units with alternative brands, thereby having pre- and post-usage data for both brands of APS units. Again, this approach would add additional visits to the study and further increase attrition.

Threat – Persistence Issue**s:** Fourteen Tier 2 customers (8 IR, 6 IR-OS) removed their APS unit during metering. This decreased the sample sizes for the metering study. Fortunately, this does not affect the way PAs claim savings, as persistence and in-service rate were measured for APS devices through a separate study (MA RLPNC 17-4).[12,13]

> ***Solution*****:** We did not include sites that removed strips, in an effort to derive ERP values achievable by strips that were actively installed. Despite low persistence and satisfaction ratings, the RLPNC 17-4 and 17-5 Products Impact Evaluation of In-service and Short-Term Retention Rates Study suggested that customers who purchased and installed APS units willingly (i.e., not as part of a study) were much more satisfied and likely to retain the product. These Tier 2 APS customers had an 81% ISR and 93% retention rate, and are a

[12] http://ma-eeac.org/wordpress/wp-content/uploads/MA-Leave-Behind-APS-Memo_12APR2018.pdf
[13] http://ma-eeac.org/wordpress/wp-content/uploads/RLPNC_1745_APSProductsSurveys_27MAR2018_-final-1.pdf

more representative sample, as actual program participants, than those observed in this study. Three-quarters (78%) of customers indicated that they were likely to recommend the strips.[14] These ratings were all higher than the persistence and likelihood to recommend ratings found in this study (see Appendix E). Additional efforts to educate metering study participants about APS devices may have helped increase persistence among metering study participants.[15]

***Threat – Seasonality and a shortened metering period*:** The metering period for this study lasted from the summer of 2017 through early 2018; however, due to persistence issues, NMR chose to use July 15, 2017 to December 15, 2017 as the evaluation period. Smart power strips were typically installed on a rolling basis throughout September and October, leaving July and August as months entirely in the pre-period, and November and December entirely in the post. Although this was a longer metering period than some previous APS metering studies, it did not encompass a full year. Therefore, we were unable to fully capture usage patterns across all four seasons.

***Solution*:** After observing higher usage from the control group in the winter than the summer, NMR did account for seasonal changes when calculating baseline energy usages with seasonal adjustment factors for both HEC and computers (see Appendix A). If future evaluations spanned an entire year, this adjustment would not have been necessary, although it is likely that various constraints will often limit the metering period.

***Threat – Various potential approaches for calculating ERP*:** NMR reviewed several APS metering studies with a variety of different approaches for calculating ERP and energy savings generated by smart power strips. Other techniques included using simple pre- versus post-period analysis to observe savings, using some modeling techniques, and creating simulated savings results based on the technical capabilities of the strips and observed consumer behavior.

Solution: We selected a log-linear difference-in-difference model to measure ERP. We felt that this model most accurately accounted for the initial usage differences between the groups receiving each strip type, the non-linear shapes of both usage and energy savings distributions, and the seasonal effects present in the data. For more on the model, see Section 3; for pre-post savings, see Appendix D.2.

Threat – APS units were installed by technicians and not customers: This could bias savings upward as the units were all setup correctly, which does not reflect real-world conditions.

Solution: One solution would be to send customers a non-APS strip connected to a meter and ask them to install it. An evaluator could then send them an APS plugged into a meter and ask them to install it – as if they had purchased it. This would allow for customer behavior to be gauged/recorded, but would potentially increase attrition. However, this may remove the need to visit homes in-person though – assuming the evaluator could walk the customers through the process via phone or email.

---

[14] http://ma-eeac.org/wordpress/wp-content/uploads/RLPNC_1745_APSProductsSurveys_27MAR2018_-final-1.pdf, pp. 12, 18.

[15] Technicians provided limited coaching to APS metering study participants but EEAC consultants specifically requested that NMR not include any additional education materials in along with the APS devices.

Threat – Changes to APS technology settings: As stated in a recent study of Tier 2 APS savings potential, *"It is known that as countdown timer values increase, the savings potential decreases. As timer values increase, there is an increasing likelihood of manual shutoff being the primary source of control and the APS only providing effective control in situations where the TV was left on for extended periods (i.e. the home occupants left while the TV was on). Additionally, even without manual control, the period of time where savings can occur between the next usage period is decreased. Depending on the frequency of use, this may be significant or insignificant."*[16] We tested two Tier 2 devices as part of this study, Tier 2 IR strips had a default timer set at 60 minutes, while Tier 2 IR-OS strips had a 75-minute default timer. The manufacturer of the Tier 2 IR-OS strips has since changed their default settings on new Tier 2 IR-OS strip to a 60-minute timer. Based on the logic above, this change will increase the ERP for Tier 2 IR-OS strips, *when left at the default setting,* but we were unable to measure the exact magnitude of that effect. Since more Tier 2 IR customers adjusted the timer settings (i.e. increased the timer), it is also possible that with the shorter default timer on the IR-OS strips, more customers would have increased this timer setting.

> ***Solution:*** Future evaluations should use the new default settings with a 60-minute timer setting for both IR and IR-OS Tier 2 APS. Although the change cannot be measured retroactively in field studies, it would be possible to adjust savings estimates from laboratory studies that have previously been completed to see the difference between strip types when using the same timer settings. Evaluators and program administrators should continue to monitor APS technologies for updates to technology and/or default settings that may influence future energy savings.

[16] Klopfer *et. al.* "Tier 2 Advanced Power Strips," p. 8.

Section 2 Baseline Usage

This section details the measured baseline usage at the 133 sites in the final analysis. The analysis sample comprises sites at which (1) a follow-up visit was completed, (2) we had complete data from July 15th to December 15th (the final metering period used in analysis), and (3) there were no changes to the major devices plugged in to the strip in the middle of metering (e.g., we removed two sites that replaced their televisions). Results are split by end-use and show the annual energy usage for HEC and PC setups. This section also provides information on daily hours of use (HOU) and the energy impacts caused by additional peripherals. These results are drawn from the pre-period usages of both control and treated sites. Since control group usage increased in the post-period (fall and winter months), we adjusted these results for seasonality to account for the lower summer usage. Results are weighted to the population based on income and building type, unless otherwise noted. Table 3 shows a summary of the findings. For more on this methodology, see Appendix A.

Key findings include the following:

- ***Home Entertainment Centers consumed an average of 471 kWh/year and operated for about four hours and 45 minutes daily.*** Average usage varied widely across sites, and typically increased with additional peripherals.
- ***The average PC setup drew 399 kWh annually and was active for six and a half hours per day, although usage patterns varied widely.*** Computer usage was substantially higher for desktops compared to laptops. There was only a small correlation between increased peripherals and increased usage. Many computers were used primarily for work and operated primarily during business days and hours.
- ***HEC and PC usage were both subject to seasonal effects, and their energy consumption increased in the winter months.*** HEC usage was higher in both the fall and winter compared to the summer months, peaking with an average winter usage of about 9% higher than the summer consumption. Computer usage was similar in the summer and fall, but rose by about 8% during the winter months.

Table 3: Energy Usage and Number of Peripherals by End-Use

End Use	N	Average Number of Peripherals	Average Annual Usage
HEC	99	3.1	471
PC - All	34	3.2	399
Desktop	*25*	*3.0*	*468*
Laptop	*9*	*3.9*	*186*

2.1 AVERAGE HEC USAGE

This subsection details baseline energy use patterns for power strips with HEC (i.e., televisions and associated peripherals) attached.

2.1.1 Overall Usage (kWh and HOU)

Table 4 shows the annual average energy consumption for HEC. The average HEC *not* attached to a smart power strip consumed 471 kWh/year. We have used that number (excluding sites with pre-existing APS) as the baseline in ERP calculations throughout this report (see Section 3). Figure 1 displays the average annual usage at each metered HEC site. While most systems (63%) consumed less than 500 kWh/year, there were some very high-use sites, including four whose annual usage exceeded 1200 kWh annually.

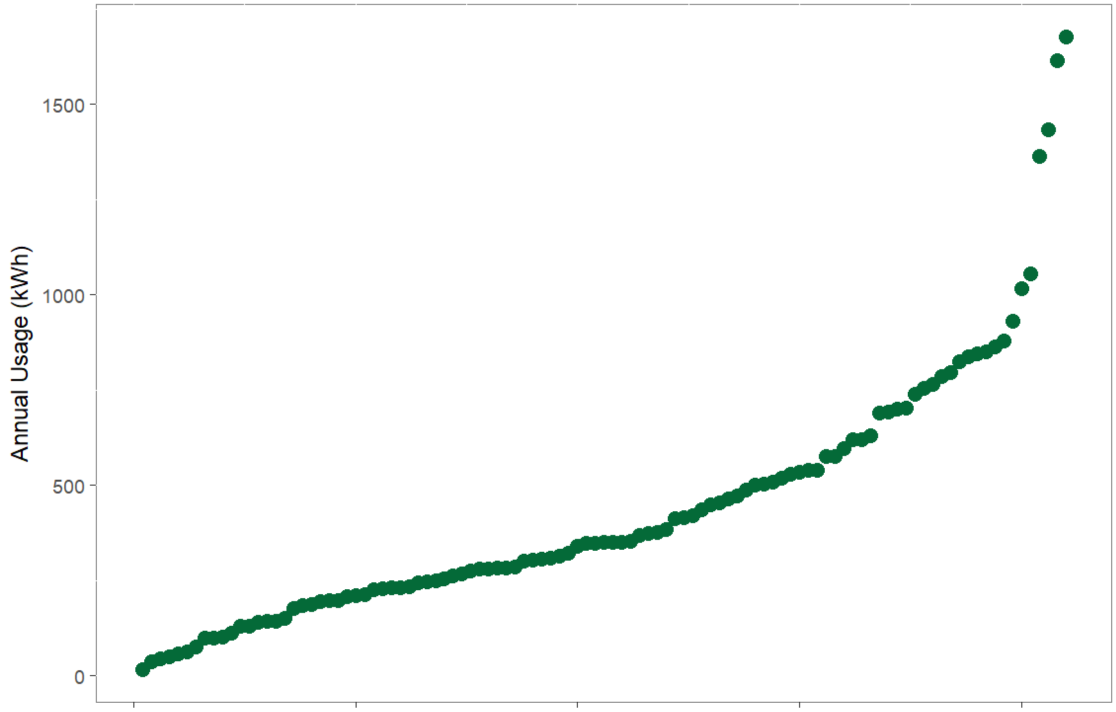
Table 4: HEC Annual Energy Consumption

(Base: All HEC sites, excluding those with pre-existing APS)

Strip Type	N	Adjusted Annual (kWh)	90% Confidence Interval (kWh)	Relative Precision (90% Confidence)	MA TRM (kWh)[17]
Total	83	471	371-571	+/- 21%	603 (Tier 1) 678 (Tier 2)

[17] http://ma-eeac.org/wordpress/wp-content/uploads/2016-2018-Plan-1.pdf, 164.

Figure 1: Average Annual Usage of Metered HEC Sites*



n=99
*Unweighted

The resulting average consumption values are substantially lower than the values included in the TRM, which are defined as 603 kWh/year for Tier 1 HEC smart power strips, and 678 kWh/year for Tier 2 – an overall average of 641 kWh/year. The difference may reflect the broader trend of reduced TV watching; many consumers now stream programs on a tablet or computer.[18] To get a sense of this, we looked at the average HOU for HEC across the metered period. HEC systems were active (i.e., turned on) for an average of four hours and 45 minutes per day (Table 5). This result was nearly identical to the number reported in the fourth quarter 2017 Nielsen Report, which reported that the average adult in Boston consumed four hours and 46 minutes of TV use daily across all mediums (i.e., Live TV, time-shifted TV, DVD/Blue-Ray, Gaming, and Streaming).[19] Nielsen also reported that time spent watching both live and time-shifted TV has decreased by about five hours per-month in the past year.[20] This may explain decreases in HEC energy consumption.

There was also substantial variance across the average daily HEC activity from site to site. While most HEC units were active for 200 minutes (3:20) or less daily, several were kept on for over half the day. The roughly 10% of customers who had active HEC systems for 800 minutes (13:20)

[18] For example, see: https://www.adweek.com/tv-video/tv-viewers-are-demanding-more-options-and-streaming-services-are-happy-to-oblige/
[19] http://www.nielsen.com/content/dam/corporate/us/en/reports-downloads/2018-reports/local-watch-report-q4-2017.pdf
[20] http://fortune.com/2017/04/03/nielsen-news-report/

or more daily represent a subset of the population that would likely see substantial savings from Tier 2 APS with their automatic shut-off capabilities.

Table 5: Average Daily HEC HOU

Classification	N[21]	Time On (Hours)	Std. Dev. (Hours)
MA TV Daily Usage (Adjusted)	*60*	4:45	4:40
Nielsen Q4 2017 Boston TV Daily Usage	*N/A*	4:46	N/A

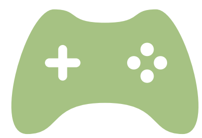
2.1.2 Effects of Peripherals

Sites had an average of 3.1 peripherals alongside their televisions. The most common were as follows:

Set top-boxes (67% of strips)

DVD/Blue-ray players (56%)

Streaming devices (36%)

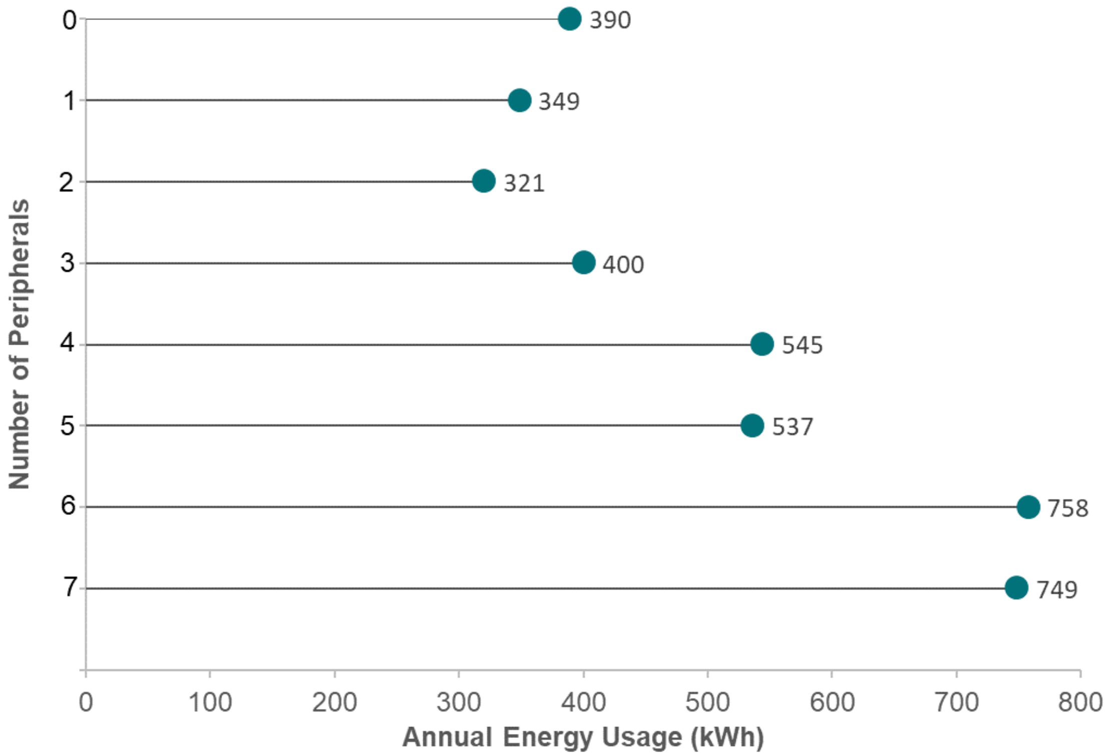


For more on the peripherals, see Appendix C.

HEC energy use increased with additional peripherals (Figure 2). There were substantial increases from two to three, three to four, and five to six peripherals. The average HEC site with zero to two peripherals consumed 325 kWh/year, while those with three or more averaged 520 kWh/year. Based on this, it seems that homes with three or more peripherals attached to their HEC have the greatest opportunities to achieve substantial savings when switching to APS.

[21] Due to the sensitivity of the meters, we were unable to accurately assess whether some units were being turned on or off, and therefore did not include all sites in this analysis.

Figure 2: Average HEC Usage by Number of Peripherals*



*Unweighted

See the Data ▶

While metering the entire power strips prevented us from measuring the exact energy consumption of specific peripherals, we performed a simple linear regression to analyze which end-uses typically used more electricity (see full details in Appendix C). We found that the presences of **gaming consoles** most commonly led to increased energy usage. **Routers**, **set-top boxes**, **audio equipment** (including surround sound), and **modems** also all had significant, positive correlations with increased energy use.

2.2 Average Computer Usage

This subsection discusses baseline energy use patterns for power strips with computers attached.

2.2.1 Overall Usage (kWh and HOU)

Strips with computers as the primary end-use consumed an average of 399 kWh annually when excluding sites with pre-existing smart power strips (Table 6). As with HEC, usage varied widely from site to site. Desktops consumed 467 kWh, substantially higher than the average usage of 186 kWh that laptops consumed. These values were substantially lower than those outlined in the TRM. The TRM provides the same baseline values (608 kWh/year for Tier 1 units and 678 kWh/year for Tier 2) for PCs as it does for HEC. Based on the TRM methodology, it appears that these values were derived primarily from television baseline usages in other APS metering studies, and therefore NMR feels that the estimates resulting from the current research effort better reflect actual computer energy usage.

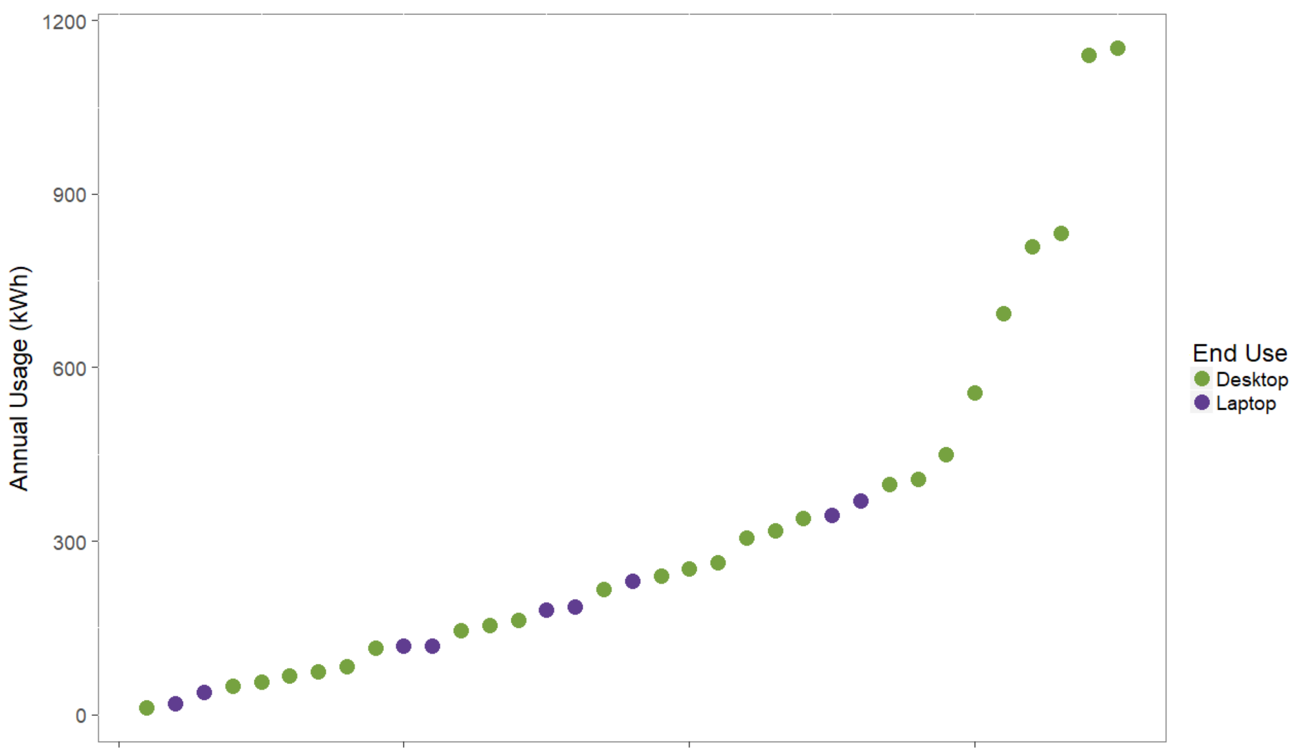
Table 6: Average Computer System Usage

(Base: All PC sites, excluding those with pre-existing APS)

Strip Type	N	Adjusted Annual kWh	90% Confidence Interval (kWh)	Relative Precision (90% Confidence)	TRM
Total	28	399	254-544	+/-36%	
Desktop	20	467	295-639	+/-37%	603 (Tier 1)
Laptop	8	186	78-294	+/-25%	678 (Tier 2)

Figure 3 displays the average annual consumption at each PC site. Most computers consumed less than 400 kWh per year, although there were a few high-usage sites, including two that drew over 1,000 kWh annually. The top nine highest consuming computers were all desktops, while laptops accounted for two out of the three lowest draws.

Figure 3: Average Annual Usage of Metered Computer Sites



Computers were active for an average of six hours and 33 minutes per day, although the usage varied widely across households (Table 7). Desktop computers had an average daily HOU of approximately seven times that of laptops. Computers in the sample were most commonly active Monday through Friday (see Appendix C), so it is likely that many of these computers were used for work in a home office environment, which may also explain the substantial difference from laptop usage time.

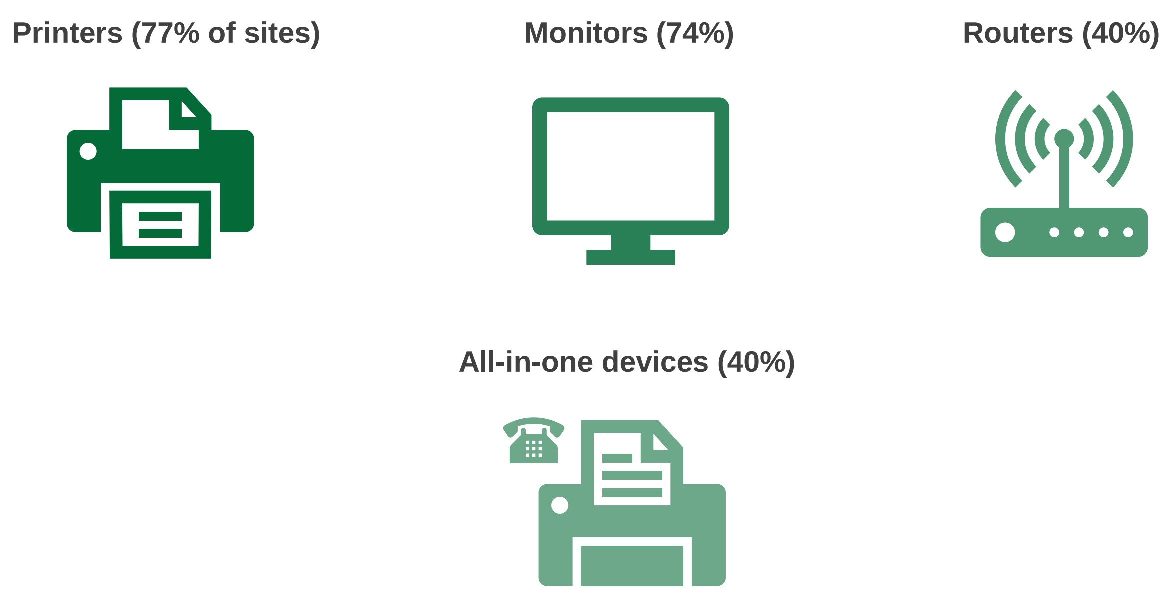
There was wide variance in HOU; several computers were essentially unused most days, while others were nearly always active. Desktops accounted for each of the 41% of computers that were used for 400 minutes (6:40) or more per day (see Appendix C for more).

Table 7: Daily HOU for Computers

End-Use	N	Average Daily Hours of Use	Standard Deviation (Hours)
Computer (All)	22	6:33	8:18
Desktop	17	8:10	8:56
Laptop	5	1:22	3:28

2.2.2 Effects of Peripherals

Computers had an average of 3.2 peripherals plugged in alongside them on the power strip. The most common devices plugged in with a computer were as follows:

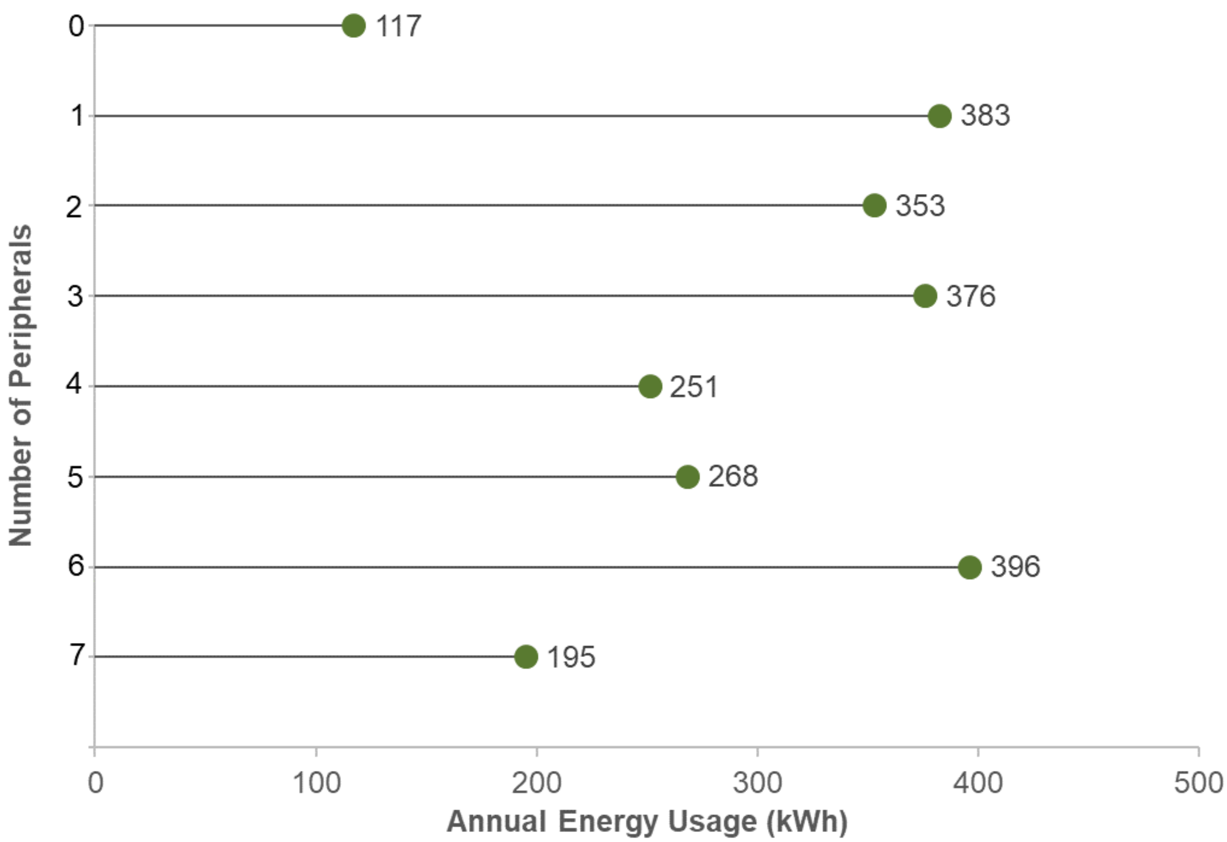


Appendix C contains a more detailed breakdown of connected peripherals.

While there were some corresponding increases in usage with a greater number of peripherals, additional peripherals did not correlate with increased usage to the extent that it did for HEC end-uses. Figure 4 shows that computers with six peripherals drew the greatest amount of energy (396 kWh/year), but those with just one peripheral consumed the second most (383 kWh/year). These results are likely affected by small sample sizes for some of these peripheral groups, along with the high variation in average daily HOU. There is some evidence of a relationship between increased peripherals and increased usage when the sites are divided into larger groups.

Computers with zero or one peripheral averaged 289 kWh/year in total usage, while those with two or more averaged an annualized draw of 320 kWh.

Figure 4: Average Computer Usage by Number of Peripherals



n=34

See the Data ►

We examined the peripherals associated with increased energy usage in computer systems using the same model as we did for HEC, outlined in Section 2.1.2. **Monitors** were the greatest driver of increased energy**. External hard-drives**, **printers**, and **lamps** were also all closely associated with increased energy use. These results are outlined further in Appendix C.

2.3 Pre-Existing APS Set-Up and Realization Rate

We also analyzed the peripherals associated with the 26-metered pre-existing Tier 1 APS (20 HEC and six desktops). While we did not include these sites in the baseline energy use analysis, the existing set-ups that we encountered should help to inform the PAs on the potential energy savings that are being lost due to improper set-ups. To estimate this, we calculated a realization rate based on the proportion of correct and incorrect set-ups. In addition to analyzing pre-existing

Tier 1 APS set-ups found in this study (RLPNC 17-3), we evaluated the Tier 1 APS set-ups that HES participants reported having during the RLPNC 17-4/5 APS survey.[22]

Based on the pre-existing set-ups that the technicians found, and the reported set-ups from RLPNC 17-4/5, we assigned strips into the following three unique categories:

- *No savings:* Strips with no peripherals in the controlled (i.e. switched) outlets, and/or with no device in the controlling outlet
- *Reduced savings:* Strips with at least one peripheral plugged into the controlled outlets, a device in the controlling outlet, but with the primary end-use (i.e. the TV or PC) plugged in to an always-on outlet.[23]
- *Full savings:* Strips with at least one controlled peripheral and the primary end-use device (i.e. the TV or PC) plugged in to the controlling outlet.

We used these designations to calculate realization rates using the following formula, which assumes that no-savings sites accounted for no savings, reduced savings sites achieved 50% savings, and full savings sites needed no adjustment:

*Realization_Rate = 1-(%No Savings + (50% * %Reduced Savings))*

Table 8 shows the no- and reduced-savings sites from each study, along with the suggested realization rate for each initiative. The technicians found that pre-existing strips in this metering study were installed correctly to a much greater extent than what respondents reported in the RLPNC 17-4/5 survey. While over one-third (38%) of strips in RLPNC 17-4/5 achieved no savings due to improper set ups, only 4% of pre-existing strips in this metering study were set up in no savings configurations. There was a similar percentage of sites with reduced savings in each study, but survey respondents had slightly more occurrences of reduced savings (13%), than those observed from pre-existing strips (8%). Combining these rates using the formula above yields a suggested realization rate of 56% based on RLPNC 17-4/5 survey responses, and 92% based on RLPNC 17-3 pre-existing strip set-ups. Note that the RLPNC 17-4 survey did not ask RCP (i.e. online) APS purchasers (Tier 1 or Tier 2) what was plugged into their APS units and therefore we were unable to calculate a realization rate for that initiative. However, since these customers actively sought out and purchased these strips, as opposed to HES customers who received them as a leave behind measure from another service, we speculate that these strips would be set-up correctly to a greater extent than Tier 1 HES strips.

---

[22] For Tier 1 HES Initiative findings, see: http://ma-eeac.org/wordpress/wp-content/uploads/MA-Leave-Behind-APS-Memo_12APR2018.pdf,
For Tier 1 and 2 Online Purchaser findings, see: http://ma-eeac.org/wordpress/wp-content/uploads/RLPNC_1745_APSProductsSurveys_27MAR2018_-final-1.pdf.

[23] The always-on outlet targets devices that need to communicate with a network; cable set-top boxes and modems were the most common examples. The control outlet contains the device that, when turned off, also turns off the switched – or controlled – devices. Optimal control devices include TVs and computers, while optimal controlled devices include game consoles, surround-sound systems, monitors, and similar peripherals. If a user has a less optimal device installed in the control outlet, it should still save some energy. For example, if the monitor turns off the printer, the user will still achieve savings.

Table 8: APS Set-up Status and ISR Reductions

Study	Methodology and Technology	% Sites with No Savings (a)	% Sites with Reduced Savings (b)	Suggested Realization Rate [1-(a+(50%*b)]
RLPNC 17-3	Observed by Technicians; Pre-Existing Tier 1 APS	4%	8%	92%
RLPNC 17-4/5	Survey of HES participants; Tier 1 APS	38%*	13%*	56%

We believe that the set-ups observed by technicians in this study provide a more accurate portrayal of APS set-ups than survey responses, as it is possible that survey participants did not fully understand the distinctions between outlet types (i.e. always-on, control, and switched), or misremembered what was plugged into their strips, leading to inaccurate responses. Therefore, we suggest using the RLPNC 17-3 set-ups for guidance when applying a realization rate for APS.

For more detailed findings on the pre-existing Tier 1 set-ups that technicians encountered, see Appendix C.

Section 3 Energy Reduction Potential

This section outlines the ERP that we observed from the advanced power strips. The final results are reported based on technology (i.e., Tier 1, Tier 2 IR, and Tier 2 IR-OS). Tier 1 ERPs are further separated out by initiative (HES and RCP), using a weighted average of HEC and PC end-uses in each initiative.

Key findings include the following:

- ***Tier 2 APS achieved an ERP of 28% (IR-OS) and 48% (IR), which yields annual energy savings of 132 and 225 kWh, respectively, when applied to the baseline HEC usage.*** These values are similar to the TRM and other APS studies in terms of percent ERP, but fall slightly short of the TRM's values in terms of kWh savings due mainly to a smaller measured baseline energy usage in this study. Note that Tier 2 IR units did use significantly more energy during the pre-period than Tier 2 IR-OS.
- ***Tier 1 strips had an ERP of 26% across HEC and PCs for the HES initiative, and 25% for RCP channels, equal to annual savings of 114 kWh and 111 kWh, when applied to the baseline.*** Tier 1 units created an ERP of 26% (123 kWh/year) for HEC and 24% (96 kWh/year) for computers. These are slightly higher values than both the 12% ERP and 75.1 kWh/year currently written in the TRM.
- ***Savings were fairly similar throughout the day, leading to small power reductions during peak hours.*** Tier 2 strips had an average ERP of 42% (IR) and 24% (IR-OS) during peak hours, while Tier 1 strips experienced a 22% ERP at peak hours. This equates to peak demand reductions of 0.03 kW (Tier 2 IR) and 0.01 kW (all others).
- ***After this evaluation was completed, the manufacturer of Tier 2 IR-OS APS devices changed the default timer setting from 75 minutes to 60 minutes.*** This should have a positive impact of ERP for new Tier 2 IR-OS APS devices moving forward. The magnitude of this increase will be dictated by the frequency of earlier shut-downs compared to the old settings, and customer interactions with the new default (e.g. how many customers will increase the timer setting to the previous value).

3.1 ERP Calculation Methodology and Limitations

We calculated the energy reduction potential using the same 133 sites included in baseline analysis. There were some differences in energy usage in the pre-period. Most notably, Tier 2 IR-OS strips consumed an average of 422 kWh, far less than those of Tier 1 HEC strips (510 kWh) and Tier 2 IR (569 kWh). Despite these differences in usage, there were not substantial differences in the number of peripherals attached to each strip type. Tier 1 computers had an average of 2.9 additional connected devices, compared to 3.6 for computers in the control group. Otherwise, the average number of peripherals fell between 3.0 and 3.3 for all strip types. The 3.3 additional peripherals attached to Tier 1 HEC strips, and 3.2 connected to Tier 2 IR strips, may explain some of the additional energy usage over Tier 2 IR-OS strips (3.0 peripherals), although these differences in peripherals are small (Table 9).

Table 9: Baseline Usage and Number of Peripherals for Strips used in ERP Analysis

Measure	n	Average # of Peripherals	Pre-Period Energy Usage (kWh)
Control			
Computer	16	3.6	275
HEC	49	3.1	440
Tier 1			
Computer	18	2.9	312
HEC	18	3.3	510
Tier 2 IR			
HEC	13	3.2	569
Tier 2 IR-OS			
HEC	19	3.0	422

3.1.1 ERP Model Methodology

To estimate the ERP, we used a log-linear difference-in-difference model approach. The difference-in-difference framework allowed us to account for seasonal usage patterns (i.e., increased energy usage across the whole sample in the fall and winter would not diminish the measured savings). We also used this approach because we did not expect the savings to follow a linear pattern (e.g., customers with higher energy use would likely save more energy). Simple unadjusted pre- vs. post-usage averages are available in Appendix D.2. We used the following model to measure the savings:

$$\ln(Y_{it}) = \beta_0 + \beta_1 Treat_i + \beta_2 Post_t + \beta_3 \, Treat_i * Post_t + \alpha_m Month_t + \varepsilon_{it}$$

Where:

$\ln(Y_{it})$ = The log of kWh usage at location *i* and hour *t*

β_0 = The model intercept

$Treat_i$= A binary variable that takes the value of 1 if the site received an APS unit and 0 if they did not, which is multiplied by model coefficient β_1

$Post_t$ = A binary variable that takes a value of 1 if an observation is in the post-period (after the strip was installed) and 0 if it is in the per-period (prior to the strip being installed), which is multiplied by model coefficient β_2

$Treat_i * Post_t$ = The interaction between the treatment and post variables, yielding the results for a site that received a smart power strip *after* the installation occurred (i.e., the effects of having a strip installed in the post-period), which is multiplied by the primary coefficient of interest for this model, β_3

$Month$ = A vector of fixed-effects for each month, *m*, in the metered period used in the regression (July 2017 through December 2017) with associated coefficients, α

This approach yielded usage values for the treatment (APS) sites in the post-period as percentages of the baseline usage. We present the ERPs below, along with annual kWh savings projections created by multiplying the percent ERP from the models by the baseline energy usage observed in the study. For additional information on the modeling approach and a full range of outputs, see Appendix D.

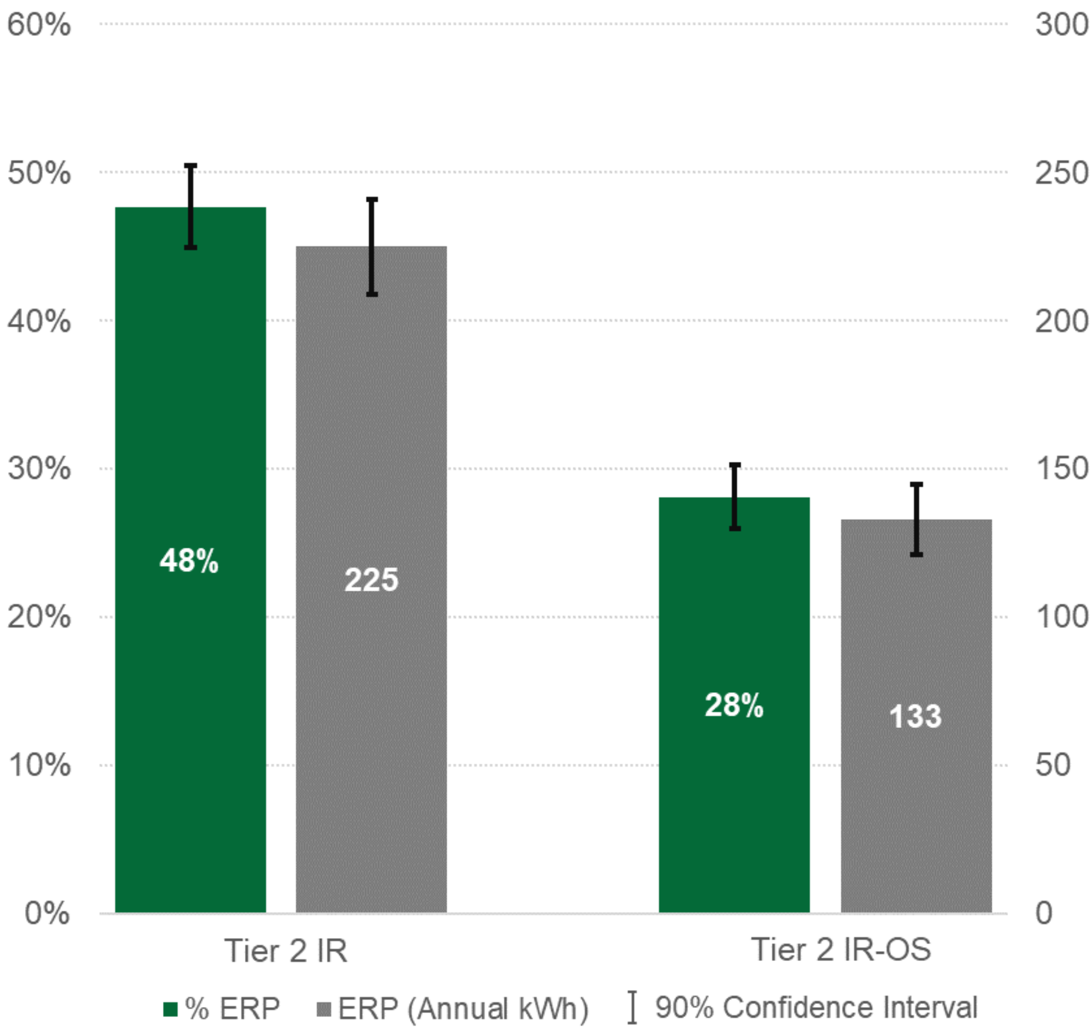
3.1.2 Limitations

It is important to note that the log-linear difference-in-difference model that we employed yielded substantially higher ERP estimates than simple pre- versus post-comparisons between treatment and non-treatment sites (Appendix D). While we feel that this modelling approach was the best method to calculate the savings given the increased usage in the fall and winter months, and the variation in savings from site to site, there are several limitations to the approach that create some threats to validity. The small sample sizes for each technology diminish the reliability of the estimates. Although the confidence intervals were fairly small, our models had low R-squared values, indicating substantial unexplained variation in consumption patterns. Our model form is designed to detect changes in average consumption patterns for the power strips, not to make hour-by-hour predictions of individual behavior, which is the main source of the unexplained model variation. And although these R-squared values were low, they were higher than an alternative model form tested, in which we used a linear model to fit the data.

3.1.3 Tier 2 Home Entertainment Center ERP

As shown above, Tier 2 strips achieved the greatest ERP that we measured in the study. Tier 2 IR had an ERP of 48%, worth 225 kWh/year when applied to the baseline HEC usage of 471 kWh annually (Figure 5). The Tier 2 IR-OS strip produced an ERP of 28%, or an annual 132 kWh reduction from the sample baseline. Despite the fairly small sample sizes, the confidence interval for both strips fell within +/- 3% of the calculated ERP, and both produced an ERP that was significantly different from the control sites at the 99% confidence level.

Figure 5: ERP for Tier 2 HEC Units



See the Data ►

3.1.3.1 Tier 2 IR-OS Default Setting Change

As mentioned above, the timers for the Tier 2 IR-OS strips were set to their default value of 75 when installed, while the Tier 2 IR strips were set to their 60-minute default. The Tier 2 IR-OS brand has since changed their default setting to a 60-minute timer. Since a longer default timer setting has been shown to reduce the energy-savings generated by an APS (and vice versa), it is likely that the shorter default timer setting will generate a higher ERP from IR-OS strips moving forward.[24] It is difficult to retroactively measure the exact increase in ERP that this may have generated during this study without information on customer interactions with the new default settings. A study of Tier 2 IR-OS strips conducted in a simulated, laboratory, setting by CalPlug found that changing the sensor timer from 75-minutes to 60 increased savings from 270 kWh/year

[24] For more on the inverse relationship between increased timer settings and energy savings, see: Klopfer *et. al.* "Tier 2 Advanced Power Strips," p. 8.

to 289 kWh/year, a 7% increase. Applying this same 7% increase to the Tier 2 IR-OS APS in this study would increase ERP to 30% and annual energy savings to 142 kWh.

While the shortened decreased default timer settings would likely generate energy savings, these would be lessened if more customers increased timer settings on their own. When asked, 31% of Tier 2 IR customers reported changing their timers (all reporting that they increased the time-out), compared to just 6% of Tier 2 IR-OS customers (see Appendix E). If both strips had a 60-minute default during the metering period, it is possible that Tier 2 IR-OS customers would have also increased the timer more frequently. However, these increases may also have been a function of technological features. The occupancy sensing capability of the Tier 2 IR-OS strip may still have reduced the need for increased timer settings. For more on the technological differences between the strips, see Section 3.4. To find the true change to ERP resulting from the shorter default study would require additional monitoring to assess customer interactions with the new settings, but there would be some increase to the ERP.

3.1.4 Tier 1 ERP

Tier 1 power strips also demonstrated a statistically significant ERP. We measured Tier 1 savings separately for HEC and computers and created two weighted ERPs for each initiative that the PAs sponsor: HEC and Residential Consumer Products. Although the strips left behind through the HES program are meant to be used for HECs rather than home offices (i.e. PCs), the findings in the RLPC 17-5 APS Products Survey found that customers use the strips in both applications. Based on the findings in that report, that televisions (25%) and computers (11%) were the devices most often plugged into the control outlet, we determined the HES distribution for end-uses to be 69% HEC and 31% computers.[25] We applied these weights to both the ERP values for each measure for Tier 1 strips, and used them to create an average weighted combined usage of 449 kWh/year for any PC or HEC unit connected to a Tier 1 strip.

Lacking data on the end-uses from the RCP initiative, we based the RCP ERP and weighted average combined usage on the breakdown of televisions and computers found in homes during the RES 1 Residential Baseline Study.[26] This showed an average of 2.1 televisions per home, and 1.5 computers, equal to 3.6 total TVs and computers, or 58% televisions and 42% PCs. Using these values, we derived the weighted ERP for Tier 1 strips through the RCP initiatives and a combined usage average of 441 kWh.

Using this methodology, the ERP for Tier 1 strips in the HES initiative was 26%, and a similar 25% through RCP channels. The corresponding kWh savings created from the weighted baseline usages were an annual 114 kWh through HES and 111 through RCP (Figure 6). As with Tier 2 units, the confidence ranges surrounding the Tier 1 unit's ERP values were fairly compact. The 90% intervals for Tier 1 were +/-2% for HEC, +/- 3% for Computers, and +/- 2% across all units. The ERPs and savings in each initiative exceed the TRM values for Tier 1 strips in terms of both

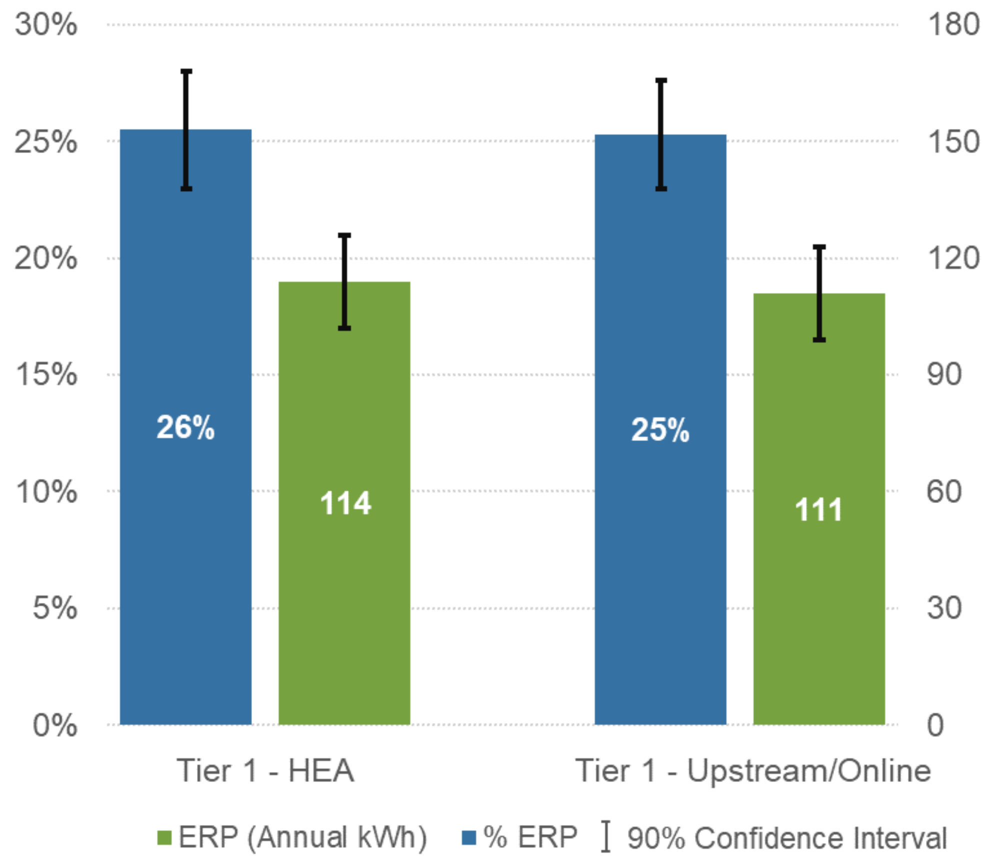
---

[25] We calculated the 69% HEC, 31% computer breakdown by dividing the 25% of televisions and 11% of computers by the 36% television and computer total as reported for end uses found in http://ma-eeac.org/wordpress/wp-content/uploads/RLPNC_1745_APSProductsSurveys_27MAR2018_-final-1.pdf, p. 9

[26] Forthcoming RES 1 Massachusetts 2018 Residential Baseline Study.

percentage reduction and kWh savings. The TRM assigns savings of 75.1 kWh per year for Tier 1 strips, which equates to 12% of the TRM's baseline values.

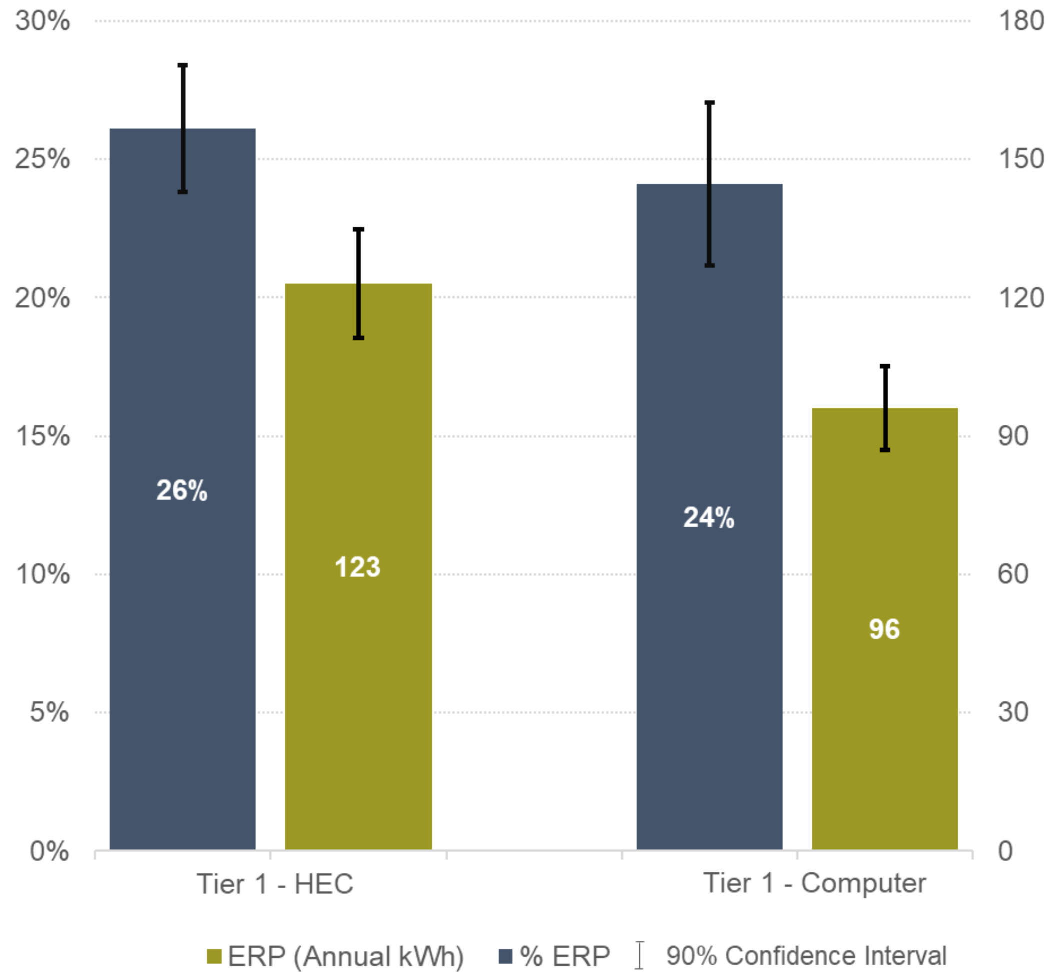
Figure 6: ERP for Tier 1 Units



See the Data ▶

Figure 7 reveals that Tier 1 strips performed similarly in both HEC and PC applications (26% ERP vs. 24% ERP). While HEC annual kWh savings (123 kWh) were a bit higher than those for computers (96 kWh), this was mostly attributable to the higher baseline usage of HEC.

Figure 7: HEC and Computer ERP for Tier 1 Strips



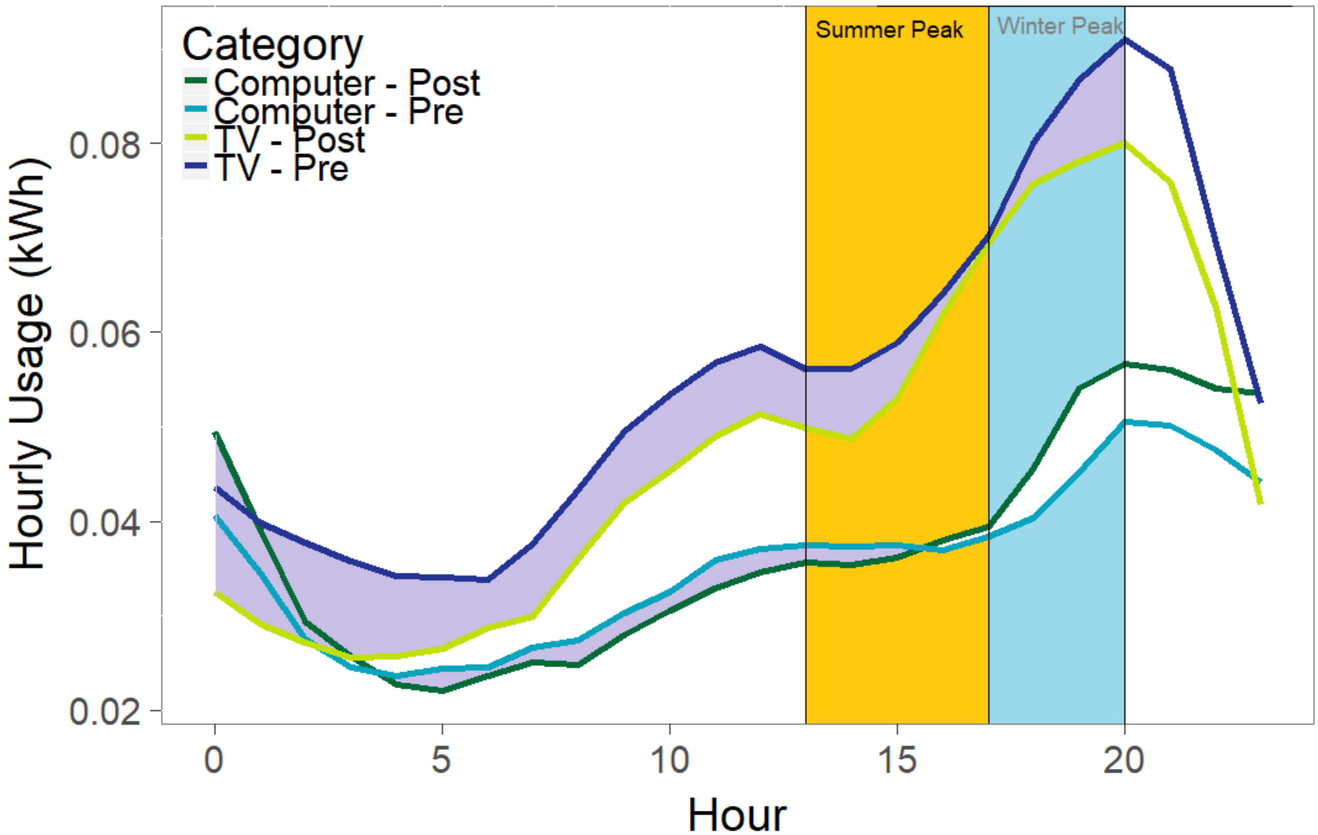
See the Data ►

3.2 Demand Reduction Potential

3.2.1 Load Shapes and Shifts

The Massachusetts TRM assigns Tier 2 power strips a demand reduction value (i.e., delta-kW) of 0.07 kW. Tier 1 power strips through the HES initiative are given 0.02 kW, and Tier 1 strips through LI MF retrofits have a value of 0.01 kW. We examined the potential demand-reductions created by smart power strips and found that the ERP at peak hours is similar to the overall ERP, yielding some potential kW savings. Figure 8 shows the pre- and post-period average hourly usage across a day for all metered APS sites. The decrease in usage throughout the day in the post-treatment period is relatively steady, although it does diminish slightly during the late afternoon peak hours. Note that this does not account for seasonality, so the energy reductions would be more substantial when accounting for higher usage in the post-period.

Figure 8: Load Shifts Created by All Metered Smart Power Strips



3.2.2 Peak/kW ERP

We measured the ERP created by the strips using the same log-linear difference-in-difference model, limited only to peak hours. The Massachusetts TRM defines the summer on-peak period as “1pm–5pm on non-holiday weekdays in June, July, and August” and the winter on-peak period as “5pm–7pm on non-holiday weekdays in December and January.”[27] Unfortunately, much of the summer on-peak period occurred prior to the treatment period, and our analysis period ended in mid-December, so we were unable to measure the impact of the strips during much of these defined peak-periods. Instead, we measured the ERP at 1pm–5pm and 5pm–7pm on non-holiday weekdays, separately, throughout the entire metered period, and averaged the two results. The weighted averages are presented in Table 10. The full outputs for each of these periods are available in Appendix D.

We calculated peak-demand savings by multiplying the average ERP at peak by the average power draw at those peak hours, across each end-use. Tier 2 IR APS had demand reduction potential of 0.03 kW, while Tier 2 IR-OS and Tier 1 strips achieved 0.01 kW peak savings.

[27] TRM, 434.

Table 10: ERP at Peak Hours and Demand (kW) Savings

Strip Type	% ERP (Peak)	90% CI	△ W	90% Confidence (Relative Precision)
Tier 2 IR	42%	+/-8%	31.4 W	28.9-33.9W (8%)
Tier 2 IR-OS	24%	+/-7%	12.4 W	11.2-13.6W (10%)
Tier 1 – HES	22%	+/-7%	9.4 W	8.3-10.5W (12%)
Tier 1 – RCP	22%	+/-8%	8.8 W	7.8-9.8W (11%)
Tier 1 – HEC	*21%*	*+/-7%*	*11.2 W*	*10.1-12.3W (11%)*
Tier 1 - PC	*23%*	*+/-9%*	*5.5 W*	*4.5-6.5W (19%)*

3.2.3 Standby Effects/ERP

We also checked for evidence of changes at standby hours, using 3 AM through 5 AM to measure this period. We specifically wanted to measure these energy savings while end-use measures were likely turned off to see if the energy reduction achieved by APS were successfully targeting vampire usage. These ERP values were nearly identical to overall ERP, signifying that the units are effectively reducing standby draws. Tier 2 IR strips had the greatest reduction of 48%, Tier 2 IR-OS achieved 29%, while Tier 1 strips had ERPs of 26% and 25% for HES and RCP, respectively. For more, see Appendix D.

3.3 Comparisons with Other Studies

Table 11 shows how the measured results from RLPNC 17-3 compare with other metered studies involving Tier 2 APS units (we were unable to find recent and reliable Tier 1 field studies). As the table shows, the results that we observed were similar to other studies in terms of measured ERP, kWh savings, and annual baseline usage. These studies relied on diverse methodologies to calculate ERP, and some utilized a blend of simulated results and true field testing. While simulated and laboratory models have been frequently used in the past, NMR feels that these methods do not truly account for real world behavior and human interactions with the smart power strips – key elements in determining their true reduction potentials. Pre- versus post-testing is a stronger method to measure the effectiveness of the strips; however, we feel that this approach does not fully account for seasonality, the pre-existing behavior of the control and treatment groups, and variability in usage and ERP across sites.

While the Tier 2 results from this study fall within the middle range of ERP and kWh savings from other field studies, the 111-114 kWh savings measured in this study outperform most Tier 1 field studies, which have typically reported about 70-100 kWh in annual savings.[28]

[28] http://www.neep.org/sites/default/files/APSTier2CaseStudy.pdf

Table 11: ERP and Baseline Energy Use Comparison with other Tier 2 APS Field Studies

Study	Methodology	% ERP	Savings (kWh)	Baseline Usage (Annual kWh)
RLPNC 17-3	**Regression Model**	**28%-48%**	**133-225**	**471**
UL Environment[1]	Laboratory Testing	22%-47%	79-333	397-702
Calplug[2]	Simulated Savings/Laboratory Testing	48-53%	306-386	602.8[7]
PG&E[3]	Simulated Savings	27%-50%	118-214	432
PG&E	Pre/Post Testing	25%-29%	110-125	432
SCE[4]	Pre/Post Testing	22%-69% (49% average)	240.4[6]	487
Silicon Valley Power[5]	Pre/Post Testing	49.5%	164	331

1 http://www.neep.org/sites/default/files/resources/ULEnvironmentTrickleStarVerification.pdf
2 http://www.efi.org/docs/studies/calplug_tier_2_apsplus.pdf
3 http://www.embertec.com/assets/pdf/ETCC%20Report.pdf
4 "Tier 2 Advanced Smart Connected Power Strips" Prepared by RMS Energy Consulting LLC on behalf of Southern California Edison (SCE), Oct. 12, 2017.
5 http://www.neep.org/sites/default/files/APSTier2CaseStudy.pdf
6 A detailed review of the SCE study oerformed by the CPUC found that this study did not provide "adequate information or analysis to support the savings increase from [the previous value of] 130 kWh." See "Detailed Review: SCE17CS014 Revision 1 Tier 2 Advanced Smart Connected Power Strips," *California Public Utilities Commission (CPUC), Energy Division, Jun. 1, 2018.*
*7 *Total Entertainment Energy Consumption, Annual Consumer Electronics was 800.8 kWh*

3.4 Technological Differences between T2 Strips

Table 12 shows the technological differences between Tier 2 strip types. Note that one significant difference across the two brands is the motion sensing control on IR-OS. This likely leads to less-frequent automatic shutdowns, which may explain the lower ERP, but could also lead to slightly higher customer satisfaction, as unwanted device shutdowns have shown to have significant negative effects on customer satisfaction.[29] Although the sample sizes were small, attrition was higher (i.e., removing the strip during the treatment period) with IR (31% of customers removed their strips during metering) compared to IR-OS (24% removed). Furthermore, only 42% of IR customers indicated that they planned to keep their devices installed after the metering period ended, compared to 65% of IR-OS participants. This may have been influenced by the shut-down protocols of IR devices. IR strips were on a default 60-minute shutdown timer that the user must manually prevent, while IR-OS were on a 75-minute timer, during the metering period, with IR and OS readings to automatically stop the shutdown. Note that changes to the timer settings were *increases* to time-out (i.e., time before automatic shutdown). This adjustment would lower energy savings at these sites compared to the default setting (including as simulated in lab testing), or those set to shorter periods by the consumer. After the metering was completed, the default setting on the Tier 2 IR-OS strips was changed to a 60-minute timer, which likely increases the

---

[29] See: http://www.embertec.com/assets/pdf/ETCC%20Report.pdf p. 58

ERP moving forward, however it may also decrease customer satisfaction and/or persistence. In this study, 31% of IR customers reported changing the timer settings on their strips compared to only 6% of IR-OS customers. For more on satisfaction and persistence, see Appendix E.

Additionally, the APS technologies differ in the number of outlets on each strip, as Tier 2 IR strips offer an additional power saving outlet. While the results in this study suggest that the average number of peripherals is roughly three, this additional outlet could result in higher ERP values from a pre-post comparison between each technology, in which every outlet is occupied, due to the additional power-saving component on the IR strip. However, in most scenarios it is likely that both APS units would sufficiently fit all the devices a customer wishes to control.

Table 12:Technical Differences between Tier 2 APS Technologies

Sensing/Control	IR	IR-OS
Sensing Approach	Infra-Red/Power Sensing of all controlled devices	Infra-Red/Motion Sensing
Outlets	8 (2 always-on, 6 power saving)	7 (2 always-on, 5 power saving)
Default Settings	60-minute countdown timer followed by 10-minute blinking LED warning then shutdown.	75-minute countdown timer[1] looking for Infra-red activity with occupancy sensing beginning after 2/3 of the timer setting has passed (49.5 minutes on the default setting). Three-minute warning with an audible buzzer and flashing light if neither IR or OS detected after 75 minutes, followed by shutdown.

[1]Although the Tier 2 IR-OS strip had a default timer set at 75-minutes when the metering occurred, this has since been changed to a 60-minute timer.
Source: “Energy Savings of Tier 2 Advanced Power Strips in Residential AV Systems” pp. 13-15 (https://www.etcc-ca.com/reports/energy-savings-tier-2-advanced-power-strips-residential-av-systems?dl=1527198593).

Appendix A Additional Sampling and Methodology Details

This appendix provides additional information on the sampling methodology and APS set-up by technicians. It also provides information on weighting both to the population and based on seasonal usage.

A.1 Sampling Methodology

We limited the initial recruitment for sites to homes that agreed to participate in the Massachusetts Residential Baseline Study. Participating households received three visits – initial, treatment, and final – from trained technicians. During the initial visit, technicians installed a meter on the pre-existing power strip to track energy usage. At the same time, technicians recorded details about the types of equipment connected to the selected power strip. During the treatment visit, technicians downloaded the metered data up to that point, replaced the pre-existing power strip with a new Tier 1 or Tier 2 smart power strip and meter, and identified any changes in connected equipment types our outlets used. At the final visit, technicians completed a final data download, recorded changes in connected equipment, and recovered the meters.

An examination of the program data revealed that the PAs offer incentives for one brand of Tier 1 smart power strips and two brands of Tier 2 smart power strips. While both Tier 2 brands offer strips designed to work with PCs, the PAs do not currently offer incentives on Tier 2 PC APS units. Since the program only provides incentives for the HEC-compatible Tier 2 APS units, and does not plan to offer incentives for the PC versions, the team only installed HEC Tier 2 units.

Upon installation of the new smart power strips, techs used the default timer settings[30] and left all the strip's packaging materials with the customer. Techs provided a brief overview of how the strips work and how the customer could change the timer settings, if desired.[31] If the customer

[30] Tier 1 strips have a total of seven outlets (two always-on, one control, and four switched). The switched outlets turn on and off in conjunction with the device plugged into the control outlet. Tier 2 IR strips have a total of eight outlets (two always-on and six power saving) and use only remote-control infrared (IR) signals as user activity input. As a default, Tier 2 IR has a countdown timer set to 60 minutes followed by a ten-minute blinking LED warning of the upcoming shutdown that will result if HEC equipment continues to be on but not in use. A user can prevent the shutdown and reset the timer by pressing any button on the remote control or the button on the strip's sensor. Tier 2 IR-OS strips have a total of seven outlets (two always-on and five switched) and use IR signals and occupancy motion sensing (OS) as user activity input. As a default, Tier 2 IR-OS has a countdown timer set to 75 minutes (since changed to 60 minutes), during which the sensor will look for IR activity. After 2/3 of the timer has passed (49.5 minutes with a default 70 minute timer), the sensor begins to also look for OS activity. If neither OS or IR activity is detected at the end of 75 minutes, for another three minutes an audible chirp and blinking LED will signal to the user that a shutdown will occur if the timer reaches zero. A user can prevent the shutdown and reset the timer by triggering an OS signal with movement or by pressing any button on the remote control or the button on the strip's sensor. The strip additionally has flash memory to remember countdown timer setting in the event of power interruption.

[31] The alternative setting for Tier 2 IR is a countdown timer set to 120 minutes and the alternative setting for Tier 2 IR-OS is a countdown timer set to 135 minutes (with the OS sensor beginning at the 75-minute mark). Both brands also have an eight-hour music/extended viewing mode, which can be activated if devices without the TV are turned on.

experienced any difficulty with the strip during the study, they could call Navigant, who would coach them over the phone about how to troubleshoot the problem.

The study started with 191 strips in the metering as part of the baseline study. To maximize sample sizes and expose any differences in ERP by product, the team targeted a disproportionate division of strips amongst the three group types: Tier 1 (66), Tier 2 (70), and Control (55). Within the Tier 1 Group, there were 26 pre-existing Tier 1 smart power strips. The Tier 2 Group was the largest because this group was further divided into two strip types: IR and IR-OS. We maintained a large control group because controlling for seasonality affecting all households was a key study design consideration to avoid misattributing consumption changes unassociated with the smart strips to their effects. We also maintained a large control group because Massachusetts-specific results may differ from those in other jurisdictions and establishing baseline consumption patterns as part of the energy savings calculation was a priority.

The three groups were created to be as demographically similar as possible and share similar numbers of peripherals. The team proportionally assigned strips to each group by looking at the following household demographics and peripheral information:

- End-use: desktop, laptop, or PC
- Income level: low-income or non-low-income
- Building type: multifamily, single-family attached, or single-family detached
- Peripherals: number of peripherals plugged into the strip

Within the Tier 2 Group, the team looked at additional demographics, including:

- Participant/non-participant status
- Education level: college degree or no college degree
- Home ownership/renter status

As a result of drop-outs and other complications during fielding, households were sometimes reassigned to a different group. Whenever possible, the team made efforts to maintain a proportional distribution of demographic variables and comparable peripheral counts. When a technician was not able to install the intended Tier 1 or Tier 2 strip during a treatment visit, they tried to install another type of smart power strip. When this was not possible, but the homeowner permitted the pre-existing strip to be left in place, these sites were moved into the Control Group. Table 13 shows that targeted distribution and the sites at which strips were successfully installed. Note that the household sites are lower than the installed strip counts because some sites had meters installed on both HECs and PC strips. Fifteen strips left the study and another 33 strips were redistributed into the Control Group. The final distribution is 36 strips in Tier 1, 41 in Tier 2, and 73 in the Control Group. Within Tier 2, we installed IR-OS strips at 24 sites and IR strips at 17 sites.

Table 13: Targeted vs. Actual Distribution

Demographic	Overall		Tier 1		Tier 2		Control	
	Target	Actual	Target	Actual	Target	Actual	Target	Actual
N	*165*	*150*	*40*	*36*	*70*	*41*	*55*	*73*
Income (LI)								
LI	40	35	10	10	17	8	13	17
NLI	125	115	30	26	53	33	42	56
End-Use (EU)								
Desktop	30	26	11	10	0	0	11	16
Laptop	11	10	7	4	0	0	4	6
TV	124	114	28	22	56	41	40	51
Building Type (BT)								
MF	29	21	7	4	12	6	10	11
SFA	47	46	11	11	20	11	16	24
SFD	89	83	22	21	38	24	29	38

Excluding the end use variable, which required all Tier 2 households use their metered strip with a HEC, the proportion of households within each category was similar between groups. The largest difference was 8% for the income variable (Table 14). Distribution of low-income households ranged from 28% in Tier 1 to 20% in Tier 2, which is driven by the fact that we could not install Tier 2 strips with PC systems, and these are less common in low-income households.

Table 14: Sample Distribution

Demographic	Overall		Tier 1		Tier 2		Control	
	Count (n = 150)	%	Count (n = 36)	%	Count (n = 41)	%	Count (n = 73)	%
Income (LI)								
LI	35	23%	10	28%	8	20%	17	23%
NLI	115	77%	26	72%	33	80%	56	77%
End-Use (EU)								
Desktop	26	17%	10	28%	0	0%	16	22%
Laptop	10	7%	4	11%	0	0%	6	8%
TV	114	76%	22	61%	41	100%	51	70%
Building Type (BT)								
MF	21	14%	4	11%	6	15%	11	15%
SFA	46	31%	11	31%	11	27%	24	33%
SFD	83	55%	21	58%	24	59%	38	52%

A.2 Weighting and Seasonal Adjustments

A.2.1 Seasonal Adjustments

To calculate the baseline usage, we first took the average daily usage from the control group for each season that we had data for:

- Summer (June–August 2017)
- Fall (September–November 2017)
- Winter (December 2017–January 2018)

Although we had some data from April 2017, May 2017, and February 2018, these were the months of the install and removal visits, so the data were incomplete and the sample size was insufficient. For HEC, we assigned February to the winter months of data and assigned it the average usage from December 2017 and January 2018 (1.29 kWh/day). Since we had no data from the spring months (March–May), we assigned those months the same usage as the fall months (1.21 kWh/day). This was based on the assumption that the months are similar in terms of weather, are both part of the school year. This was also based on the observation that the summer and winter months were the low and high-usage periods in our period of observation, respectively. We then averaged the four seasons to find an approximate annual daily usage, which we found to be 1.22 kWh/year. Finally, we compared the approximate annual daily average usage to the average daily usage from the pre-period (1.18 kWh/day). This comparison found that the control sites in the pre-period used approximately 97% of the daily annual average usage. Based on this, we used a weight of 1.03 to adjust the pre-period baseline usage to account for seasonal changes in usage (Table 15).

Table 15: HEC Seasonality and Adjustment Factors

Period	HEC Daily Usage (kWh)	PC Daily Usage (kWh)
Summer (Jun–Aug)	1.18	0.69
Fall (Sep–Nov)	1.21	0.66
Winter (Dec–Feb*)	1.29	0.73
Spring (March–May**)	1.21	0.66
All*	1.22	0.69
Pre-Period:	1.18	0.66
Pre-Period Use Compared to Annual Average	97%	96%
Adjustment	1.03	1.05

We calculated computer seasonal adjustment factors using the same methodology; Appendix C shows the seasonal breakdowns and final adjustment for computers.

A.2.2 Weighting

NMR ultimately weighted the baseline data to calculate annual usage using a combination of demographic factors, including income (low-income vs. non-low-income), and building type (Single-Family Detached, Single-Family Attached, and Multifamily). The weights are shown in Table 16 below. Note that the sample size of 121 households is smaller than the 133 strips used in the final analysis due to some sites being metered for both HEC and PC strips.

NMR also experimented with weighting the number of peripherals per strip and the breakdown of computer versus laptop presence. Ultimately, we did not use these methods as we could not find reliable information to use to determine the population breakdown. Within the sample data, the interaction between number of peripheral weights and the inclusion/removal of pre-existing APS led to significant differences on baseline energy usage, which varied substantially from other methods.

Table 16: Baseline Usage Weighting Scheme

Building Type and Income	Households (ACS 5-Year Estimates)	Sample Size	Proportional Weight
Total	*2,508,788*	*121*	*N/A*
Single-Family Attached	137,294	19	
Low-Income	28,496	2	0.69
Non-Low-Income	108,798	17	1.06
Single-Family Detached	1,323,370	74	
Low-Income	154,651	21	1.06
Non-Low-Income	1,168,719	51	0.36
Multifamily	1,047,554	28	
Low-Income	386,620	9	0.69
Non-Low-Income	660,934	19	1.06

Appendix B Demographics

This Appendix provides demographic information from the sites used in the analysis. Table 17 shows the income level, education, tenure of occupancy, age, and home size of participants in the metering. Participants were typically well educated (79% held college degrees) and homeowners (75%). While over three-quarters (77%) of participants were non-low-income, this figure was lower than the overall non-low-income population in Massachusetts.

Demographic factors were similar across all strip types. While the sample was designed for this, it was possible that dropouts, bad-data, and refusals could have skewed this distribution. This table indicates that was largely not the case.

Table 17: Demographics for Metered Households

	Overall	Tier 1	Tier 2	*Tier 2 IR*	*Tier 2 IR-OS*	Control
Income (n=120)						
Low-Income	23%	28%	20%	*12%*	*25%*	23%
Non-Low-Income	77%	72%	80%	*88%*	*75%*	77%
Building Type (n=122)						
MF	14%	11%	15%	*6%*	*21%*	15%
SFA	31%	31%	27%	*29%*	*25%*	33%
SFD	55%	58%	59%	*65%*	*54%*	52%
Education (n=121)						
College degree	79%	79%	80%	*82%*	*79%*	78%
No college degree	21%	21%	20%	*18%*	*21%*	22%
Rent/Own (n=122)						
Rent	25%	31%	24%	*18%*	*29%*	27%
Own	75%	79%	76%	*82%*	*71%*	73%
Age (n=121)						
Under 30	11%	3%	4%	*3%*	*1%*	5%
30-39	22%	5%	7%	*1%*	*3%*	11%
40-49	19%	5%	4%	*1%*	*3%*	11%
50-59	21%	4%	5%	*2%*	*3%*	11%
60-69	17%	5%	4%	*4%*	*2%*	7%
70-79	8%	2%	3%	*1%*	*1%*	4%
80-89	1%	0%	1%	*0%*	*1%*	0%
Home Size (n=121)						
500 Sq. Ft. or Less	6%	1%	2%	*0%*	*2%*	3%
501-1,000 Sq. Ft	22%	5%	4%	*1%*	*3%*	13%
1,001-1,500 Sq. Ft	24%	7%	7%	*3%*	*4%*	11%
1,501-2,000 Sq. Ft.	23%	9%	8%	*5%*	*3%*	9%
2,001-2,500 Sq. Ft	8%	2%	2%	*1%*	*1%*	4%
2,501+ Sq. Ft	17%	3%	4%	*1%*	*3%*	10%

Appendix C Additional Baseline Usage Information

This appendix expands on Section 2. It provides tables and figures detailing usage patterns, split out by end use, day of the week, strip type, and other factors. We also present more in-depth information on the presence of peripherals and how they affect energy usage.

C.1 Additional Baseline Usage Information

Table 18 and Table 19 show the average HEC and computer usage with and without the seasonal adjustment applied.

Table 18: Unweighted Average HEC Energy Usage by Strip Type

Strip Type	N	Adjusted Annual kWh	Unadjusted Annual kWh
Total	122	431.4	417.2
Total (Excluding Tier 1 Smart Power Strips)	101	443.4	428.8
Manual Power Strip (User Shuts Off After Use)	59	454.8	439.8
Always-on Power Strip	40	401.6	388.4
Tier 1 Smart Power Strip	21	424.4	410.4
Other (Battery Backup)	2	1087.3	1051.5

Table 19: Unweighted Average Computer Energy Usage by Strip Type

Strip Type	N	Adjusted Annual kWh	Unadjusted Annual kWh
Total	42	308.0	294.3
Total (Excluding Smart Strips)	35	337.4	322.5
Manual Power Strip (User Shuts Off After Use)	20	373.4	356.9
Always-on Power Strip	15	278.5	266.2
Smart Power Strip	7	151.4	144.7

Figure 9 shows that while most HEC units were active for 200 minutes (3:20) or less daily, several were kept on for over half the day. The roughly 10% of customers who had active HEC systems for 800 (13:20) minutes or more daily signify a subset of the population who would likely see substantial savings from Tier 2 devices with their automatic shut-off capabilities.

Figure 9: Histogram of Daily Active HEC Use

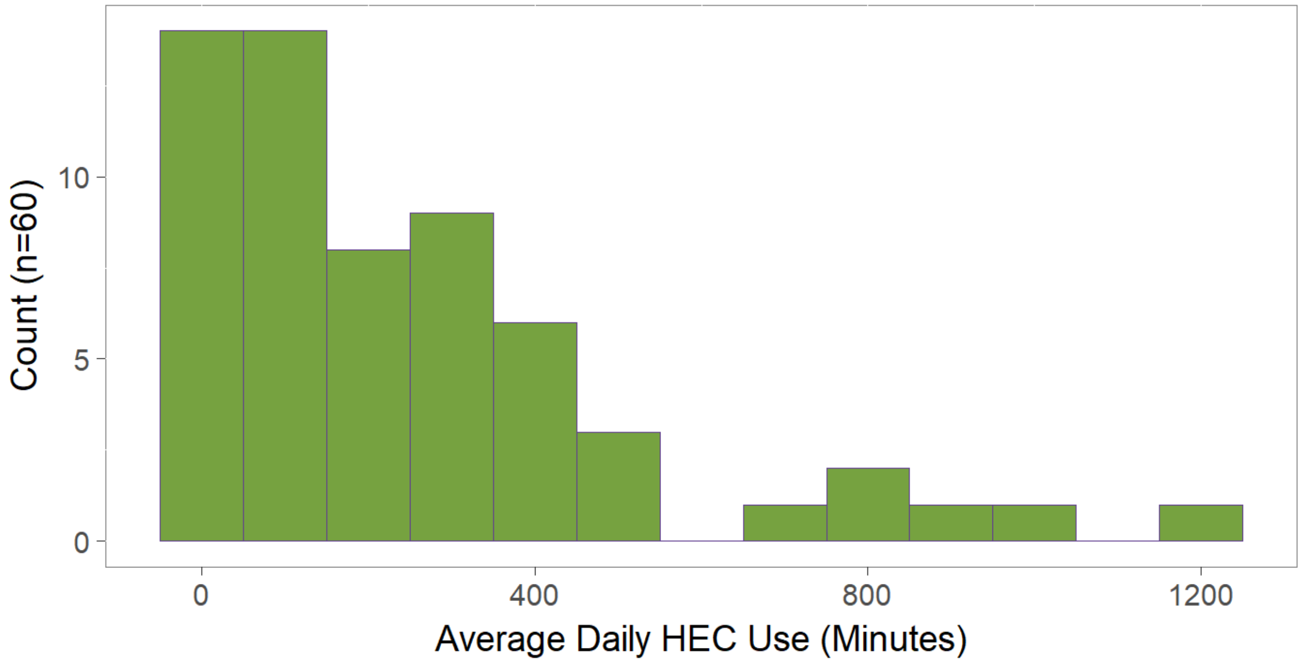
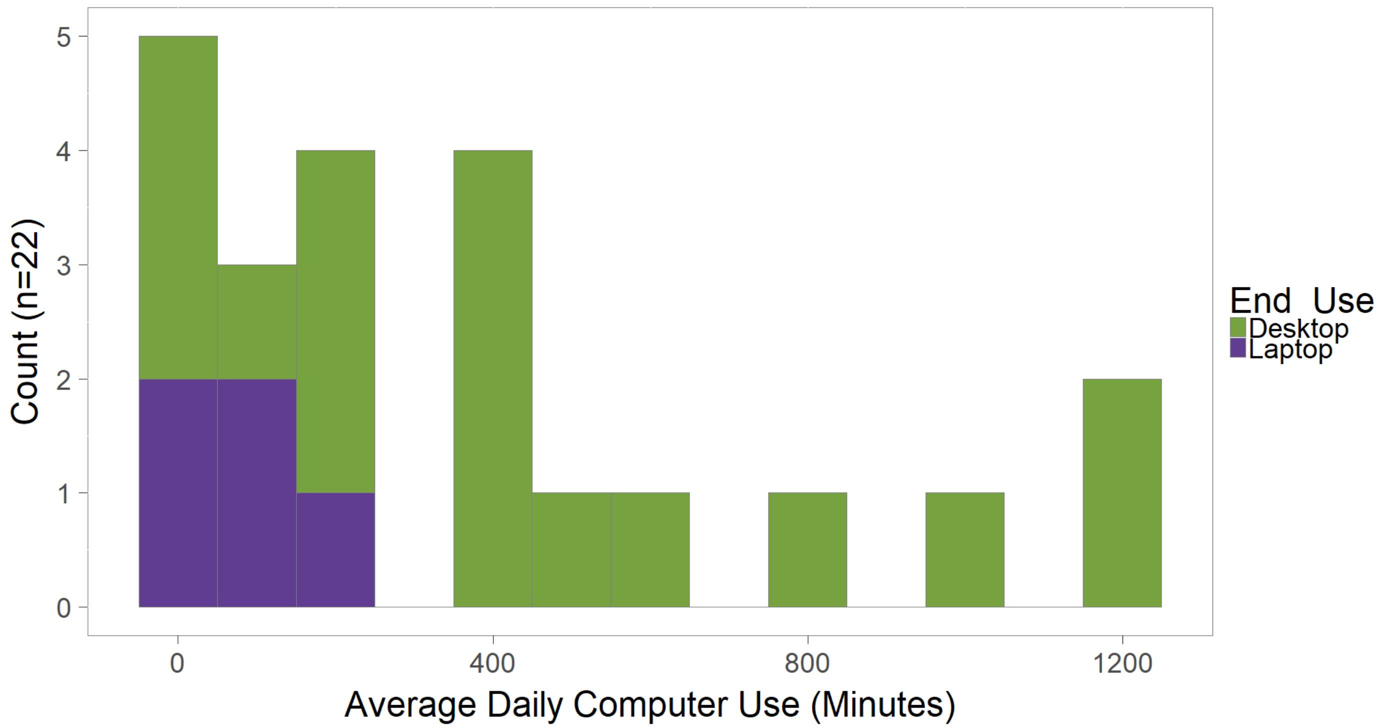


Figure 10 displays the average daily active time for computer systems during the metered period. There was wide variance in usage; several computers were essentially unused most days, while others were nearly always active. Desktops accounted for each of the 41% of computers that were used for 400 minutes (6:40) or more per day.

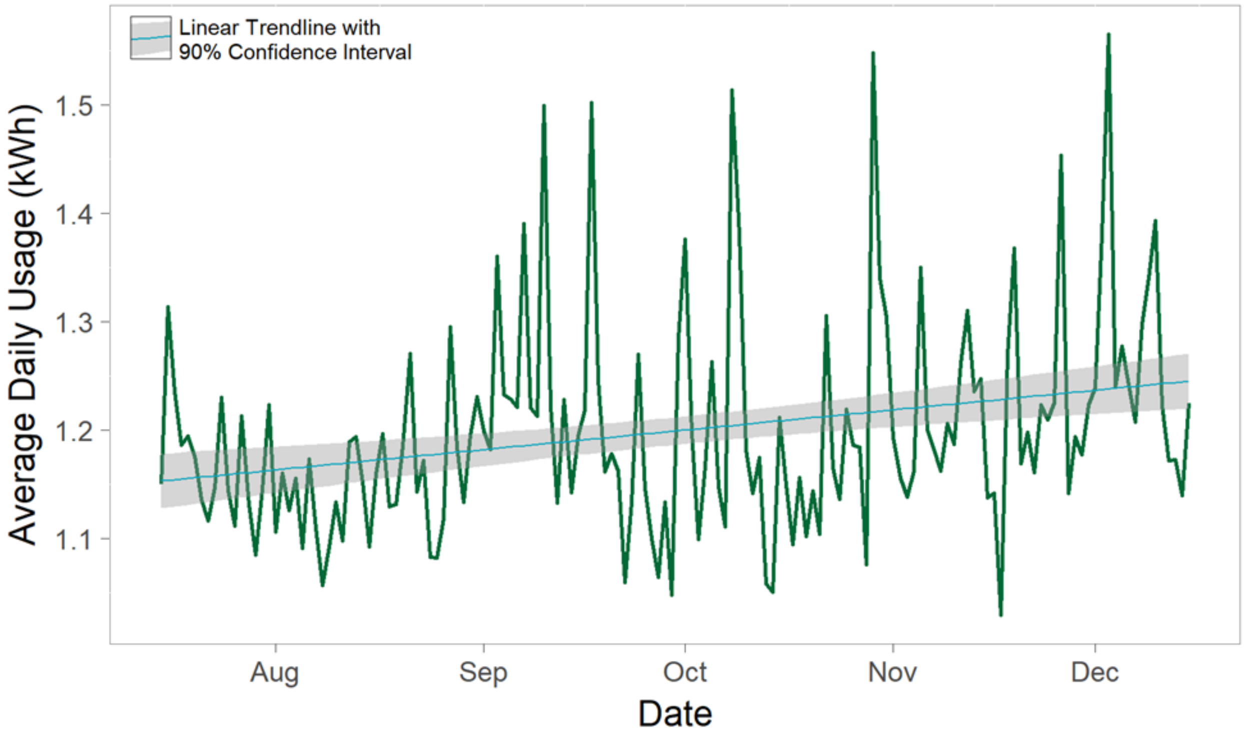
Figure 10: Histogram of Daily Active Computer Use



C.2 DAILY AND SEASONAL BEHAVIOR PATTERNS

We observed seasonal patterns in HEC usage, specifically increased usage in the fall and winter months compared to the summer. Figure 11 depicts this pattern by showing the steady increase of average daily energy use across the control group from July through December. Winter usage (December and January) exceeded average summer usage (June through August) by about 9%. Fall usage (September through November) fell almost exactly between Summer and Winter consumption. Using those data, we calculated the adjustment factor of 1.03 to apply to the pre-period usage when calculating energy consumption on an annual basis.

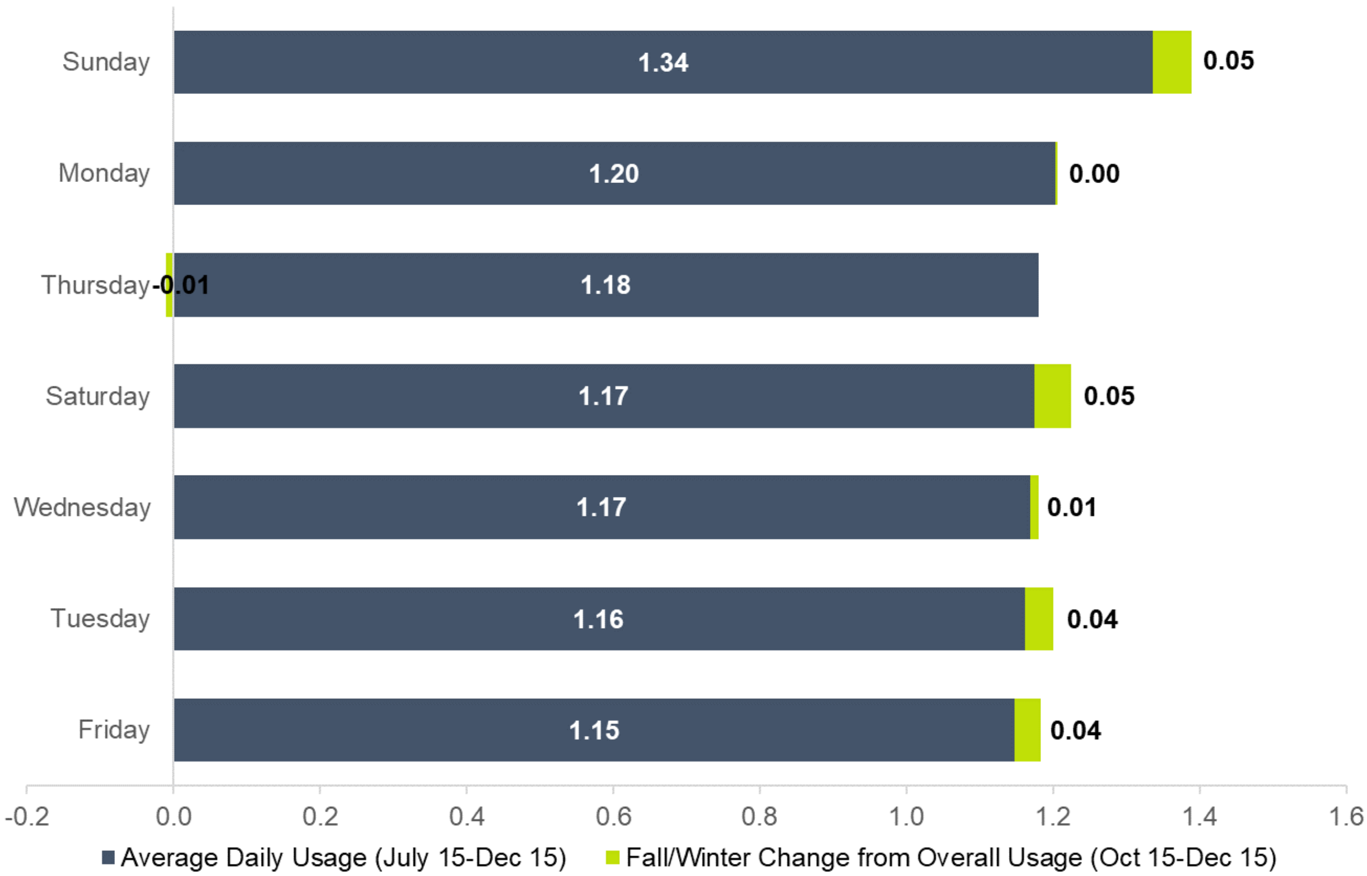
Figure 11: Average Daily Usage of All Control Sites in the Metered Period



n=49

To further measure customer behavior patterns, we looked at average HEC usage for each day of the week. Figure 12 shows the average usage by day of the week for HEC units, along with the usage shift from October 15 and beyond compared to the sample as a whole**.** Unsurprisingly, Sundays had the highest daily average use at 1.34 kWh/day across the entire period. Monday and Thursday were the next highest usage days at 1.20 and 1.18 kWh/day, respectively, even after removing federal holidays. While it was somewhat surprising to see the usage of these days surpassed Saturdays (the fourth highest day at 1.17 kWh/day), when limiting the daily usage to only fall and winter months, Saturday became the second-highest day for HEC usage, at 1.22 kWh/day. This further supports that seasonal behavior changes affect consumption as it seems consumers spend their Saturdays differently during the summer months than they do later in the year.

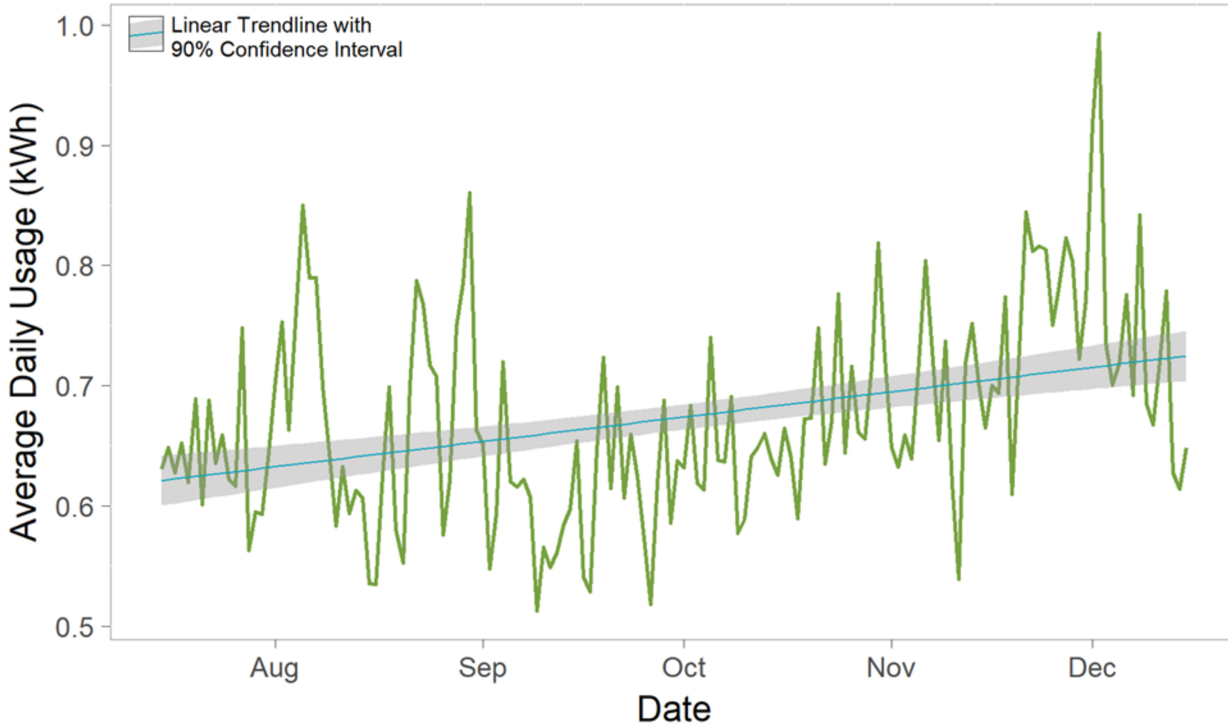
Figure 12: Average HEC Energy Consumption by Day of the Week



Computer usage also increased during the winter months. After falling slightly from summer to fall before rising to a winter peak that was about 8% above the June through November average. Based on these seasonal changes, we calculated an adjustment factor of 1.05 to normalize the pre-period usage to the rest of the year.

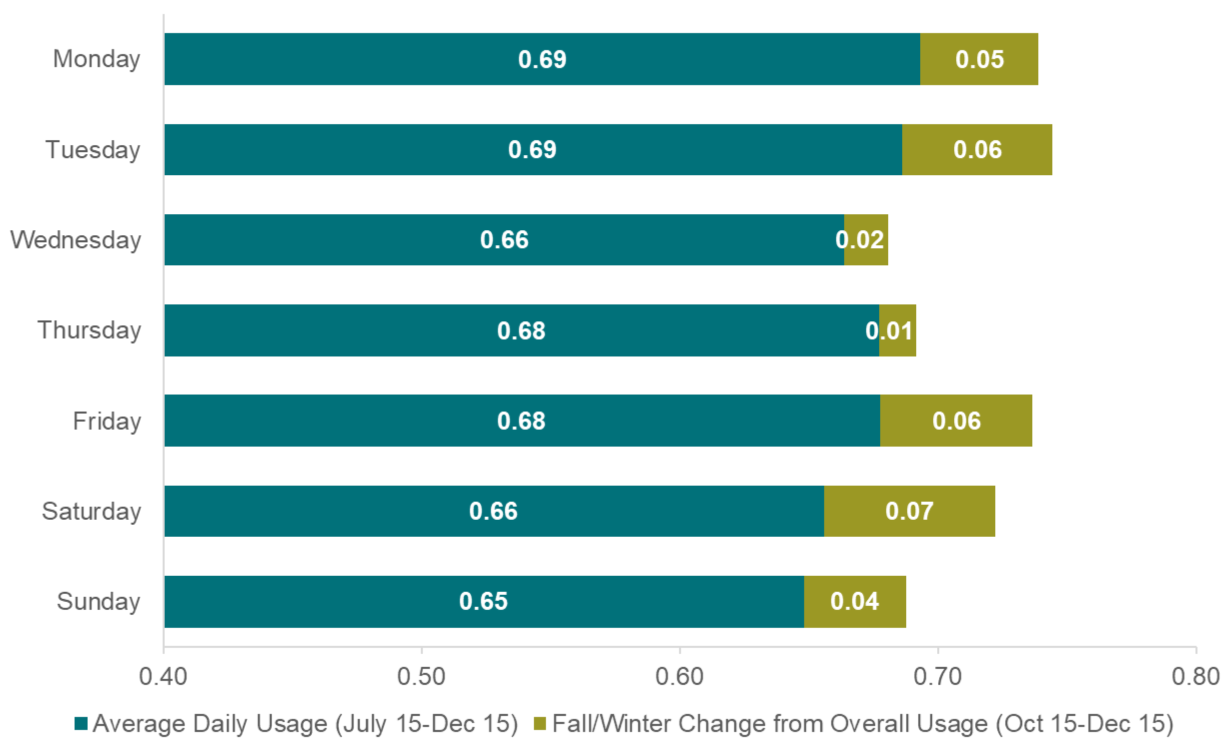
In addition to seasonal changes, customer usage behavior also varied by day of the week. As indicated in Figure 14, weekday use tended to be higher than weekend use, but Wednesday looked more like the weekends. Use on Sunday averaged 0.65 kWh/day, use on Wednesday and Saturday averaged 0.66 kWh/day, and all other days were 0.68 to 0.69 kWh/day. Again, this suggests that many of these units may be used for work. It also means that advanced power strips may have more peak demand reduction potential when used on computers than in an HEC setting. This is discussed further in Section 3.

Figure 13: Average Daily Usage of All Control Sites in the Metered Period



n=16

Figure 14: Average Computer Energy Consumption by Day of the Week



C.3 Presence of Peripherals and Peripheral Usage

Table 20 shows the percentage of sites with select peripherals on the same strip as a TV in an HEC setup. Two-thirds of sites had set-top boxes present (67%), making that the most common peripheral. DVD/Blu-Ray players (56%), streaming devices (36%), gaming consoles (24%), and surround sound (24%) were also frequently present.

Table 20: Percentage of Sites with Peripherals Present

Peripheral	% Sites Present
Total Sites	*106*
Set Top	67%
DVD/Blu-Ray	56%
Streaming	36%
Gaming Console	24%
Surround Sound	24%
Modem	16%
Audio	11%
Router	6%
Antenna	2%

Printers were the most commonly installed peripheral alongside computers (77%), followed closely by monitors (74%). Table 21 shows the percentage of sites with each peripheral present. Routers (40%), all-in-one devices (40%), modems (34%), and phones (34%) were also commonly plugged-in alongside computers.

Table 21: Percentage of Sites with Peripherals Present

Peripheral	% Sites Present
Total Sites	*35*
Printer	77%
Monitor	74%
Router	40%
All-in-One	40%
Modem	34%
Phone	34%
Lamp	23%
Charger	9%
Heating Pad	3%
Gaming Console	3%

Table 22 shows the average annual energy use by number of peripherals for HEC systems. The data include usage from all the sites included in the final analysis during the pre-period.

Table 22: Average HEC Energy Use by Number of Peripherals

Number of Peripherals	N	Avg. Annual Energy (kWh)	Std. Dev. (kWh)
0	6	390	555
1	6	349	520
2	29	321	422
3	31	400	442
4	16	545	742
5	10	537	679
6	6	758	633
7	1	749	588

Back to Report ►

Table 23 shows the average annual energy use by number of peripherals for HEC systems. The data include usage from all the sites included in the final analysis during the pre-period.

Table 23: Average Computer Energy Use by Number of Peripherals

Number of Peripherals	N	Avg. Annual Energy (kWh)	Std. Dev. (kWh)
0	1	117	182
1	3	383	425
2	5	353	510
3	9	376	652
4	12	251	304
5	1	268	203
6	3	396	316
7	1	195	81

Back to Report ►

Table 24: Number of Peripherals Attached to Each Strip Type

Measure	Average # of Peripherals
Control	
Computer	3.6
HEC	3.1
Tier 1	
Computer	2.9
HEC	3.3
Tier 2 IR	
HEC	3.2
Tier 2 IR-OS	
HEC	3.1

Table 25 shows the peripherals that technicians found on HEC strips with pre-existing Tier 1 APS, along with the outlet into which each device was plugged. Televisions most often controlled the strips (14), with gaming systems (2), lights (1), and a soundbar (1) also plugged into the control outlet. Two televisions were incorrectly plugged into the always-on position. Technicians also found three DVD/Blu-Ray players, a surround sound system, streaming device, and gaming system installed in always-on outlets. These measures could all be moved to controlled outlets to help the strips achieve maximum energy savings potential. Note that the technicians did not find any previously installed Tier 2 strips, and did not log the peripherals at two sites.

Table 25: HEC Peripherals at Pre-Existing Tier 1 APS Sites

(Base: Sites with Tier 1 APS installed at initial visit [n=18])

End-Use	*Total*	Always-On	Control	Controlled
TV	*18*	2	14	2
DVD/Blu-Ray	*11*	3	0	8
Gaming System	*7*	1	2	4
Set Top Box	*7*	7	0	0
Stand-Alone Audio System	*5*	2	0	3
Surround Sound	*4*	1	0	3
DVR	*3*	2	0	1
Streaming Device	*3*	1	0	2
Antenna	*3*	0	0	3
Nothing	*2*	2	0	NA
Router	*2*	2	0	0
Lights	*1*	0	1	0
Soundbar	*1*	0	1	0
Phone	*1*	1	0	0
Security Camera	*1*	1	0	0
Subwoofer	*1*	1	0	0
Charger	*1*	0	0	1
Bluetooth Chord	*1*	0	0	1

Table 26 shows the peripherals that technicians found on computer strips with pre-existing Tier 1 APS, along with the outlet into which each device was plugged. All six sites had a desktop as the primary end-use. Five used the desktop to control the strip, while one site had an empty controlling outlet. The monitor that technicians found plugged into an always-on outlet could have benefitted from being plugged into a controlled outlet. The lone laptop attached to a controlled outlet was connected alongside a desktop plugged into the controlling port.

Table 26: Computer Peripherals at Pre-Existing Tier 1 APS Sites
(Base: Sites with Tier 1 APS installed at initial visit [n=6])

End-Use	*Total*	Always-On	Control	Controlled
Desktop	*6*	1	5	0
Printer	*4*	0	0	4
Nothing	*3*	2	1	NA
Monitor	*2*	1	0	1
Speakers	*2*	0	0	2
Router	*1*	1	0	0
Other Power Strip	*1*	1	0	0
Lamp	*1*	1	0	0
All-in-One	*1*	0	0	1
Monitor	*1*	0	0	1
Laptop	*1*	0	0	1

C.3.1 Energy Impacts of Specific Peripherals

While metering the entire strips made it impossible to fully separate out the energy consumption of each peripheral, we used the following model to assess which peripherals were typically associated with higher energy usage at a site:

$$Y_{it} = \beta_0 + \theta_p Peripheral + \alpha_s Strip\_type + \varepsilon_t$$

Where:
Y_{it} = The kWh usage at location *i* and hour *t*
β_0 = The model intercept
$\theta_p Peripheral$ = A vector of binary variables for each peripheral, *p*, encompassing all peripherals attached to an HEC or Computer, with associated coefficients, θ.
$\alpha_s Strip\_type$ = A vector of binary variables representing the pre-existing strip types, *s*, that were included in the metering with associated coefficients, α.

We applied this model to energy usage during the pre-period only (to increase the sample size), and used it separately to assess the usage for HEC and computers. Table 27 shows the results for HEC-associated peripherals, while Table 28 displays the findings for strips associated with computers. While the coefficients do give a numerical estimate towards the effect that the presence of a specific peripheral has on the daily energy usage (e.g., the presence of a gaming console leads to a 0.537 kWh increase in daily consumption), the direction of the coefficient (i.e., a positive sign for increased usage) and high t-Values may give the best indication as to whether a specific peripheral is driving an increased energy use. While the coefficients for some peripherals take a negative sign, indicating that these peripherals lead to *decreased* energy usage, this is not fully the case. These peripherals were typically not present at very many sites, and tended to be at lower energy use sites, leading to this inaccurate result. Antennas, for example, were present at only two sites. The low-usage at these sites can likely be attributed to them not having a set-top box, one of the higher consuming peripherals.

Based on this, it appears gaming consoles, routers, set-top boxes, and surround sound and other audio systems are frequently attached to higher energy usage in HEC. Based on that same methodology, we found monitors, miscellaneous devices (i.e., lamps and heating pads), and printers to be associated with higher energy use alongside computers.

Table 27: Effects of Peripherals on HEC Energy Usage

Peripheral	Coefficient	Std Error	T-Value
Intercept (No Peripherals)	0.739	0.013	56.577
Set Top Box	0.233	0.009	26.242
DVD Blu-Ray	-0.022	0.008	-2.672
Gaming Console	0.537	0.087	61.706
Streaming Device	-0.129	0.080	-16.154
Antenna	-0.357	0.238	-14.994
Surround Sound	0.206	0.009	22.491
Other Audio Equipment	0.283	0.012	22.816
Modem	0.136	0.011	12.789
Router	0.723	0.016	44.718

Table 28: Effects of Peripherals on Computer Energy Usage

Peripherals	Coefficient	Std Error	T-Value
Intercept	0.672	0.018	37.464
All-in-One	-0.480	0.015	-32.412
Speakers	-0.216	0.012	-19.626
Modem	-0.120	0.015	-8.443
Printer	0.096	0.015	6.764
Monitor	0.657	0.012	57.045
Hard Drive	0.069	0.028	2.515
Lamp	0.207	0.016	12.615
Charger	0.082	0.028	2.879
Heating Pad	0.418	0.040	10.388
Gaming Console	-0.392	0.029	-13.587
Phone	-0.411	0.021	-19.465

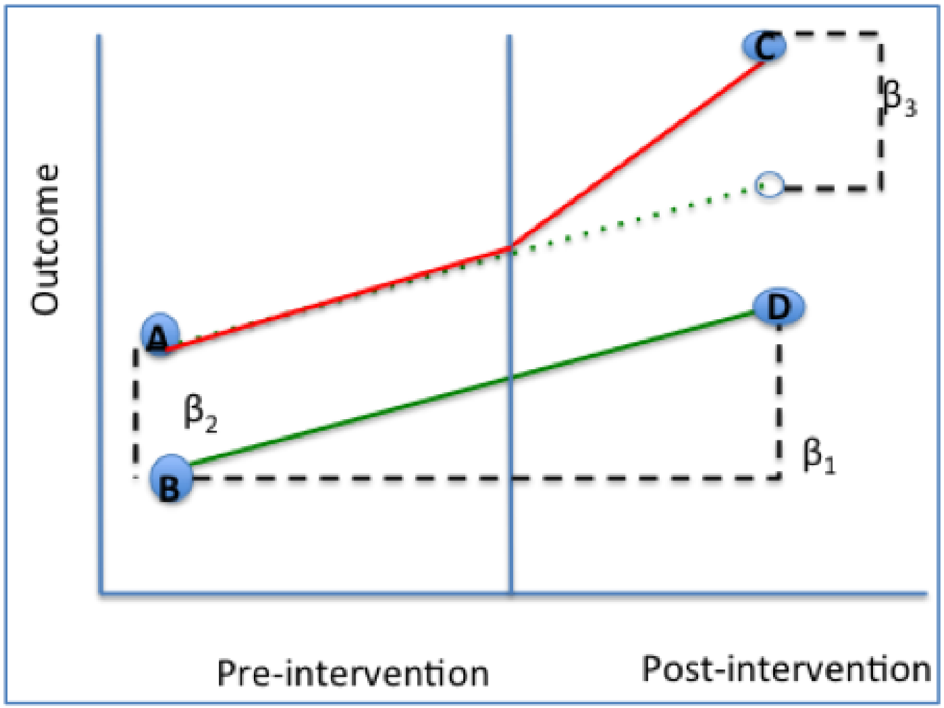
Appendix D Additional ERP Information

This appendix expands on Section 3. It contains the full outputs from the models used to measure ERP; energy usage in the pre- and post-periods; and additional tables and figures relating to ERP, energy savings, and demand savings.

D.1 Additional Model Information

As outlined in Section 3, NMR used a log-linear difference-in-difference modeling approach to calculate ERP values. This technique allowed us to measure changes over time while accounting for the different usage and behavior patterns that existed between the control and treatment groups. Figure 15 provides an example of how difference-in-difference modeling works. β_3 represents that variable of interest, as it accounts for the changes in the treatment group in the post-period. The model accounts for changes, or difference, over time (β_1), as well as the initial differences that exist between the two groups (β_2). In this way, by subtracting β_1 and β_2 from the estimate of the value of β_3, the model is estimating a difference of the differences of the groups to avoid confounding that estimate with pre-existing differences between the groups or differences that unfolded in both groups over time. Unlike the example in Figure 15, the treatment effect in the post-period was negative when looking at ERP values, so β_3 would be a downward shift rather than the positive one depicted here.

Figure 15: Difference-in-Difference Model Framework



Source: https://www.mailman.columbia.edu/research/population-health-methods/difference-difference-estimation

Figure 16 shows the full outputs from the log-linear difference-in-difference models used to calculate the ERP values (see Section 3 for more). The coefficient associated with the *Post*Treat* variable is the primary output of interest, representing the percentage change of energy used by treated sites in the post period (i.e., the change in energy at sites with smart power strips installed, during the time the strips were actually being used). As mentioned above, this variable is statistically significant at the 99% confidence level across all smart power strip types and end uses. We tested the models with several additional independent control variables, but did not find that any had significant impacts on the ERP values or the overall fit of the model.

The results are in the log-form created by the model. To calculate the ERP values, we took the exponents of the coefficients, which yielded the percent energy use for treated sites in the post-period. For example, the exponent of the -0.649 value of the Tier 2 IR Post*Treat coefficient is 0.523. This can be interpreted as Tier 2 IR strips using 52% of their baseline energy in the post-treatment period, or a 48% energy reduction, the value shown throughout this report.

Figure 16: Full ERP Model Outputs

Table 1:

	Dependent variable: ln(kWh/hour)			
	(Tier 2 IR)	(Tier 2 IR-OS)	(Tier 1 HES)	(Tier 1 PC)
Intercept	−3.488***	−3.626***	−3.541***	−4.276***
	(0.016)	(0.015)	(0.015)	(0.023)
Post	−0.074***	−0.002	−0.080***	0.258***
	(0.012)	(0.012)	(0.012)	(0.020)
Treat	0.388***	0.039***	0.045***	−0.166***
	(0.012)	(0.009)	(0.010)	(0.013)
July 2017	−0.191***	−0.032*	−0.160***	0.173***
	(0.019)	(0.017)	(0.018)	(0.026)
August 2017	−0.162***	−0.028*	−0.119***	0.182***
	(0.017)	(0.016)	(0.017)	(0.024)
September 2017	−0.131***	0.004	−0.063***	0.069***
	(0.016)	(0.014)	(0.015)	(0.021)
October 2017	−0.130***	−0.027**	−0.023*	−0.029
	(0.013)	(0.012)	(0.012)	(0.018)
November 2017	−0.067***	−0.024**	−0.026**	0.017
	(0.013)	(0.012)	(0.012)	(0.018)
Post*Treat	**−0.649*****	**−0.329*****	**−0.303*****	**−0.275*****
	(0.017)	(0.013)	(0.014)	(0.018)
Observations	190,415	224,125	222,525	114,090
Number of Households	62	68	67	34
R^2	0.010	0.006	0.005	0.013
Adjusted R^2	0.010	0.006	0.005	0.013
Residual Std. Error	1.388 (df = 190406)	1.393 (df = 224116)	1.447 (df = 222516)	1.483 (df = 114081)
F Statistic	237.213*** (df = 8; 190406)	170.177*** (df = 8; 224116)	134.770*** (df = 8; 222516)	194.729*** (df = 8; 114081)

Note: Standard Errors in Parentheses — *p<0.1; **p<0.05; ***p<0.01

Tables 31-34 split out the ERP values by technology and brand, with 90% confidence intervals applied, and compare these values to the MA TRM. They are an expansion on the figures displayed in Section 3.

Table 29: ERP for Each Technology

APS Technology	Energy Reduction Potential	kWh Savings*	MA TRM
Tier 2 IR	48% (45-50%)	225	51% (346 kWh)
Tier 2 IR-OS	28% (26%-30%)	133	51% (346 kWh)
Tier 1 – HES	26% (23%-28%)	114	12% (75.1 kWh)
Tier 1 – RCP	25% (22-28%)	111	12% (75.1 kWh)
Tier 1 – HEC	26% (24%-28%)	123	12% (75.1 kWh)
Tier 1 – Computer	24% (21-27%)	96	12% (75.1 kWh)

*Calculated by multiplying the ERP by the baseline TV energy estimates for Tier 2 strips, and a weighted average of HEC and Computer for Tier 1 for each initiative.

Table 30: Tier 2 APS ERP by Brand

APS Technology	Energy Reduction Potential (90% CI)	kWh Savings*	MA TRM
Tier 2 IR	48% (45-50%)	225	51% (346 kWh)
Tier 2 IR-OS	28% (26%-30%)	133	51% (346 kWh)

Back to Report ►

Table 31: Tier 1 APS ERP by Initiative

Technology and Initiative	Energy Reduction Potential (90% CI)	kWh Savings*	MA TRM
Tier 1 – HES	26% (23%-28%)	114	12% (75.1 kWh)
Tier 1 – RCP	25% (22-28%)	111	12% (75.1 kWh)

Back to Report ►

Table 32: Tier 1 APS ERP by End Use

Technology and Initiative	Energy Reduction Potential (90% CI)	kWh Savings*	MA TRM
Tier 1 – HEC	26% (24%-28%)	123	12% (75.1 kWh)
Tier 1 – Computer	24% (21-27%)	96	12% (75.1 kWh)

Back to Report ►

D.2 Pre- vs. Post- Savings

Table 33 and Table 34 show the pre- and post-period usage for each strip type and end use. The values are not weighted or adjusted for seasonality, but have been extrapolated to total annual usage. As with the modeling approach, Tier 2 IR strips had the greatest decrease in usage from the pre- to the post-period. Sites with Tier 2 IR strips consumed 20% less energy than they did in the pre-period in the HEC setting. Tier 1 strips had a 12% decrease in usage, while Tier 2 IR-OS strips reduced energy usage by 11%. These reductions occurred while the control groups' usage increased, suggesting that the reductions were diminished by post-period behavior.

Table 33: Pre- vs. Post-Period Energy Usage for HEC Strips

Pre or Post	Annual kWh	Difference from Pre	% Change from Pre
Control (n=49)			
Pre	440	-	-
Post	445	5.0	1%
Tier 1 (n=18)			
Pre	510	-	-
Post	446	-63.6	-12%
Tier 2 IR (n=13)			
Pre	569	-	-
Post	455	-114.1	-20%
Tier 2 IR-OS (n=16)			
Pre	422	-	-
Post	376	-46.1	-11%

Tier 1 strip usage increased by 4% in the post-period when used on computer-led strips. While this increase masks the presence of energy reductions among Tier 1 strips used on computers, the computer control group's usage increased by 22%, indicating that Tier 1 strips did curb consumption (Table 34).

Table 34: Pre- vs. Post-Period Energy Usage for Computer Strips

Pre or Post	Annual kWh	Difference from Pre	% Change from Pre
Control (n=16)			
Pre	275	-	-
Post	337	61.8	22%
Tier 1 (n=18)			
Pre	312	-	-
Post	325.7	13.6	4%

Figure 17 shows the savings (or lack of) that we measured at each metered HEC site in the pre- and post-periods. These results are extrapolated to represent a full year of usage and ordered based on measured usage in the pre-period (least to most). Sites with positive values in the annual savings category (Y-axis) had reduced usage in the pre-period. Those with negative values increased their usage after the post-period began in October, which was the case at 68% of control sites, 48% of Tier 1 sites, and less than 30% of all Tier 2 sites. Although not always the case, this figure presents some evidence that greater savings are typically achieved by sites with higher baseline usages, and that Tier 2 sites (both brands) tend to outperform Tier 1 units. Based on these findings, it seems there may be some value in strategically targeting high-use sites the most effective APS technologies.

Figure 17: Pre-Period Usage and Annual Savings for HEC Customers

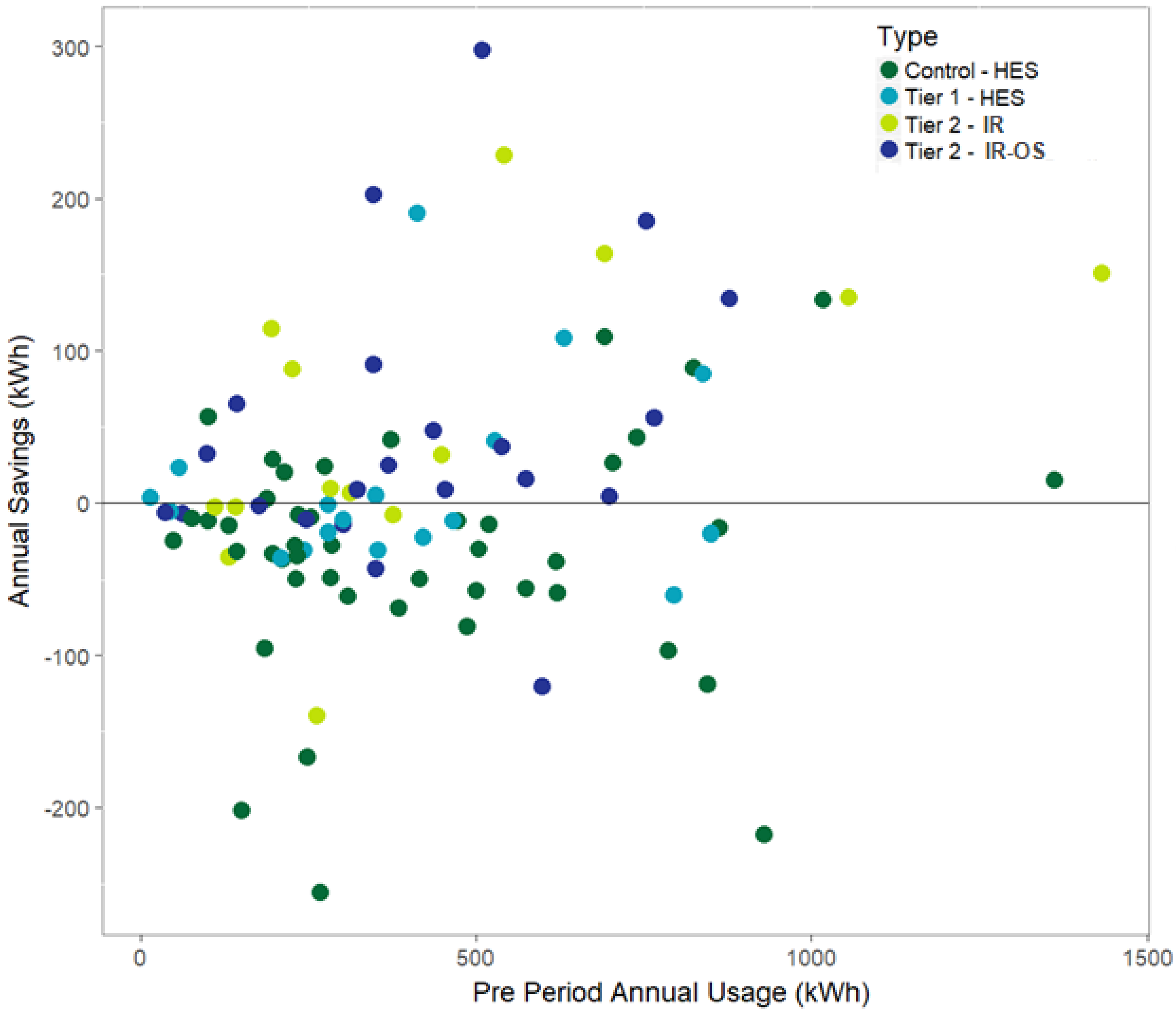
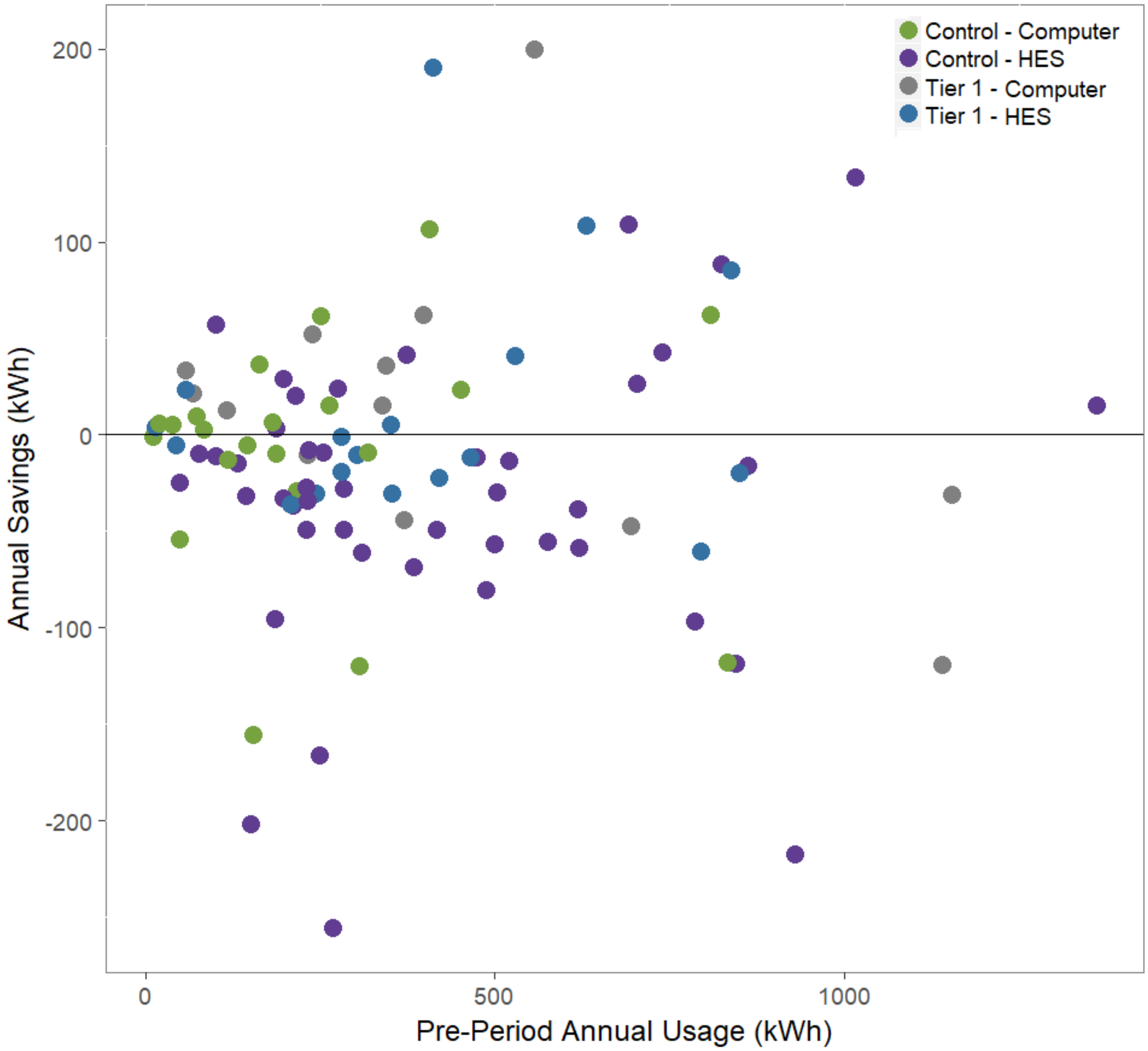


Figure 18 shows the pre-period usage (X-Axis) and Annual savings (Y-Axis) for Tier 1 strips. Positive values on the Y-axis indicate energy savings (i.e., decreased energy usage in the post-period).

Figure 18: Pre-Period Usage and Annual Savings for Control and Tier 1 Strips



D.3 Peak and Standby

Table 35 shows the ERP achieved by each strip type at mid-day peak hours (1pm to 5pm on non-holiday weekdays). Tier 2 IR strips had the greatest ERP (43%), although this was slightly lower than their overall ERP of 48%. Tier 1 strips attached to computers had slightly higher ERP at peak hours (31%) than they did overall (24%).

Table 35: ERP at Peak Hours (1pm‑5pm; non-holiday weekdays)

Strip Type	% Savings (1 PM-5 PM)	90% CI
Tier 2 IR	43%	8%
Tier 2 IR-OS	26%	6%
Tier 1 – All	23%	5%
Tier 1 – HEC	*21%*	*6%*
Tier 1 – Computer	*31%*	*7%*

Table 36 shows the ERP achieved by each strip type during evening peak hours (5pm to 7pm on non-holiday weekdays). These values were largely identical to those achieved during mid-day peak hours, although the confidence ranges were slightly wider.

Table 36: ERP at Peak Hours (5pm–7pm; non-holiday weekdays)

Strip Type	% Savings (5 PM -7 PM)	90% CI
Tier 2 IR	43%	10%
Tier 2 IR-OS	26%	8%
Tier 1 – All	23%	6%
Tier 1 – HEC	*21%*	*8%*
Tier 1 – Computer	*31%*	*10%*

Table 37 shows the ERP achieved by each strip during standby hours (3am to 5am, all days). The ERP values during standby hours were similar to the overall ERP. Computers had the lowest energy reductions at 23%, but based on HOU data, it seems that computers were sometimes active in these hours, while televisions were essentially always shut down.

Table 37: ERP at Standby Hours (3am–5am)

Strip Type	% ERP (Standby)	90% CI
Tier 2 IR	48%	+/-4%
Tier 2 IR-OS	29%	+/-3%
Tier 1 – HES	26%	+/- 5%
Tier 1 – RCP	25%	+/- 5%
Tier 1 - TV	*27%*	*+/-4%*
Tier 1 - Computer	*23%*	*+/-6%*

Figures 19-22 show the load changes between the pre- and post-periods at sites that received smart power strips. Tier 1 strips are split by measure rather than initiative due to the different load shapes of computer and HEC usage. While these figures do show decreases in usage in the post-period, the actual shift is greater than what is displayed, as the lines do not account for increased usage in the post-period.

Figure 19: Computer Load Shifts Created by Tier 1 Smart Power Strips

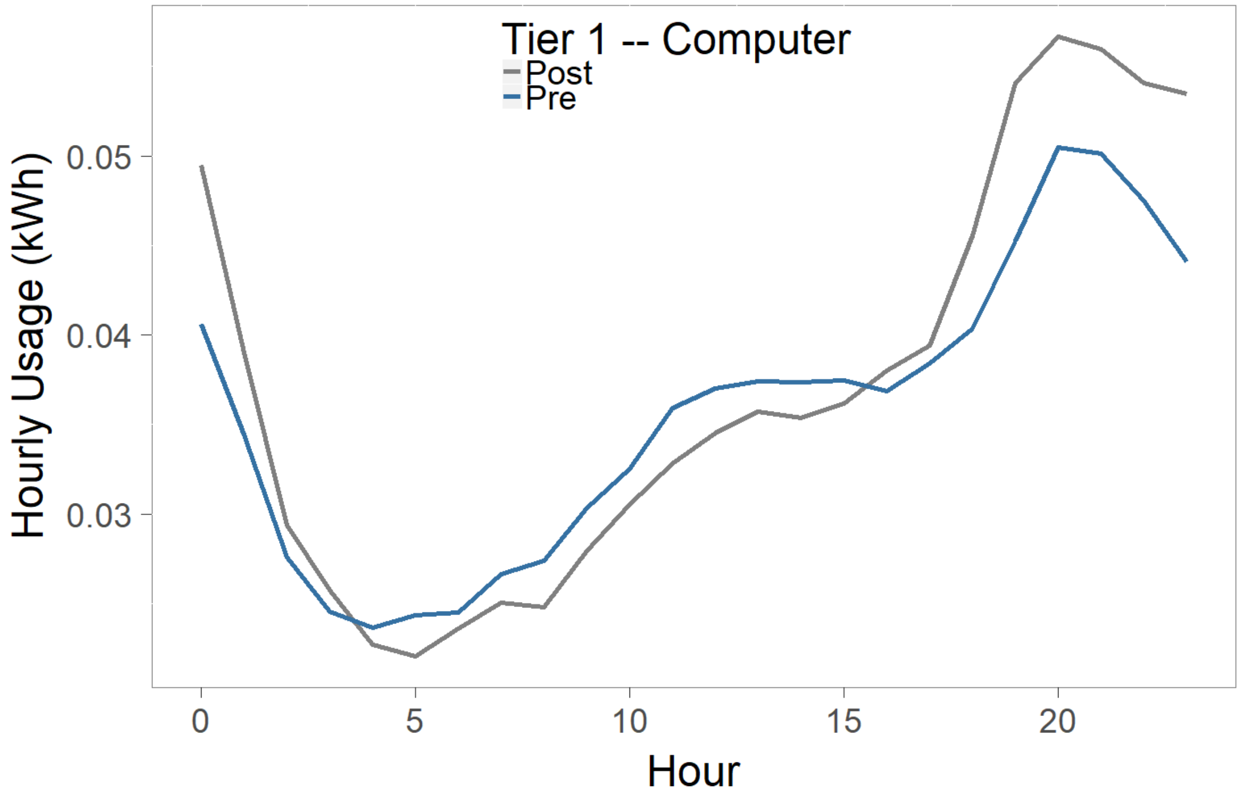


Figure 20: HEC Load Shifts Created by Tier 2 IR-OS Smart Power Strips

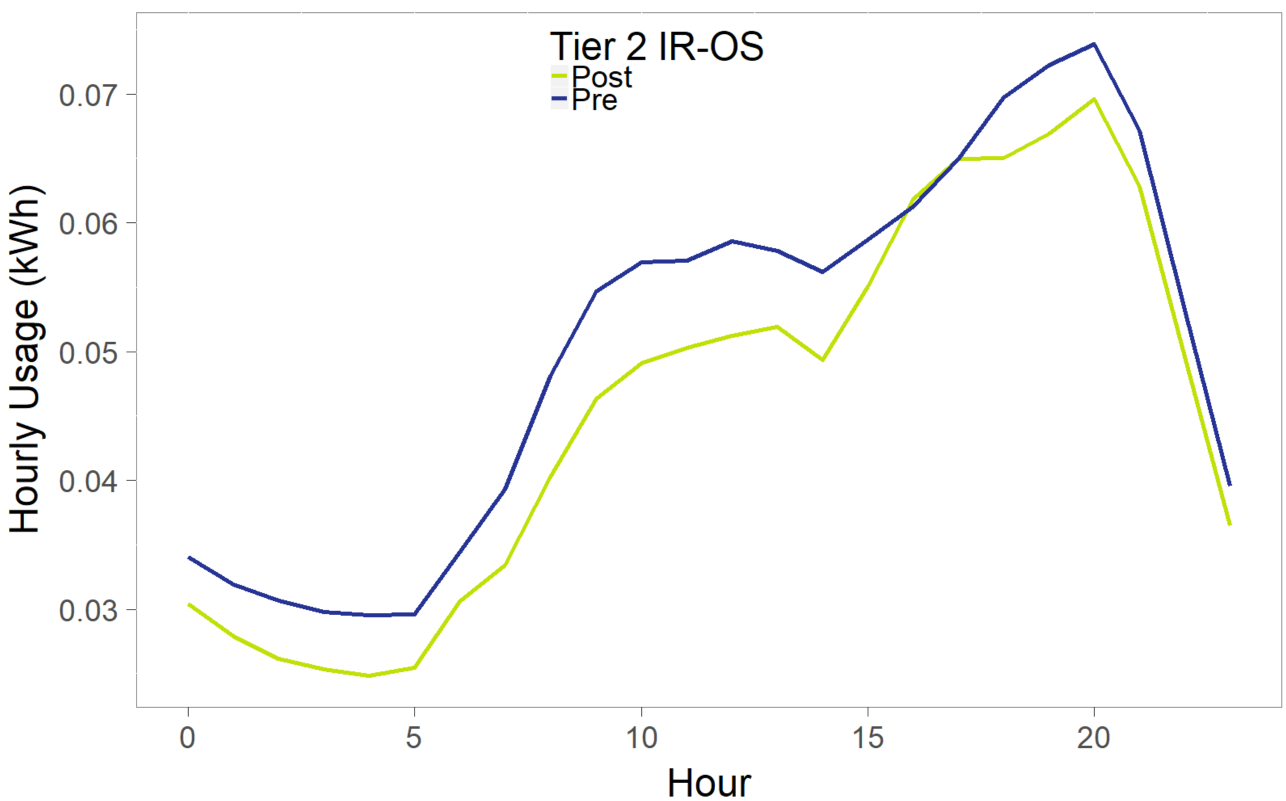


Figure 21: HEC Load Shifts Created by Tier 1 Smart Power Strips

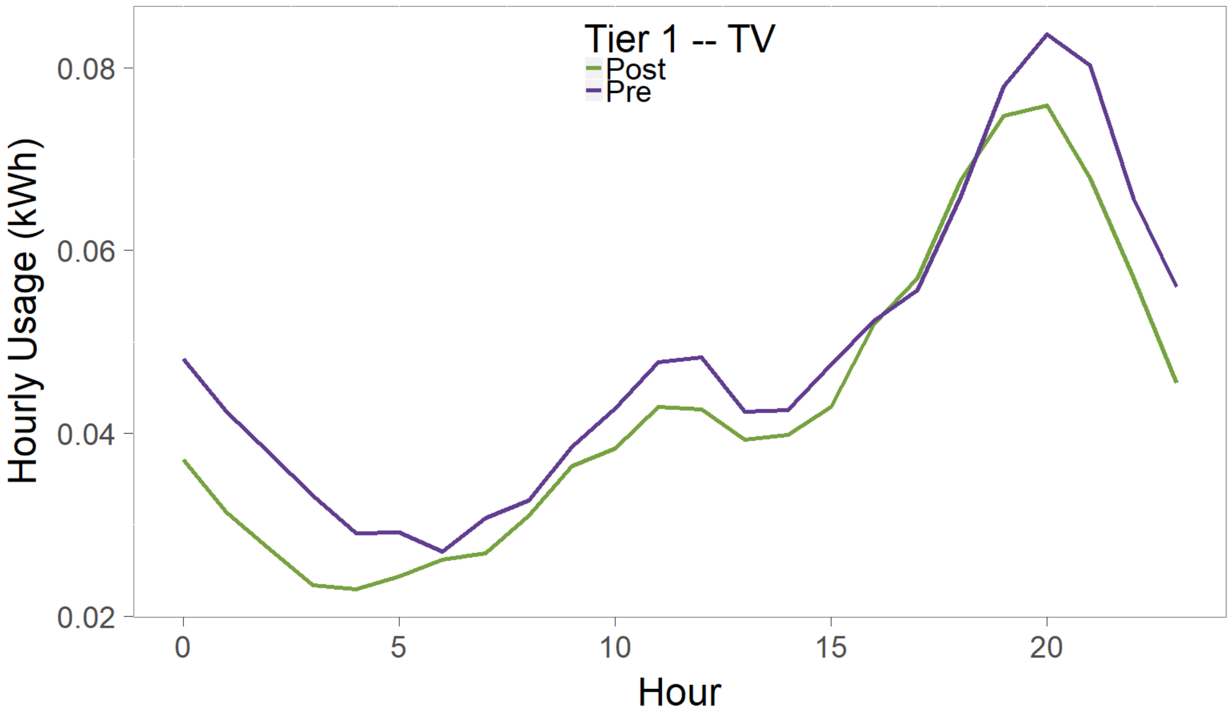
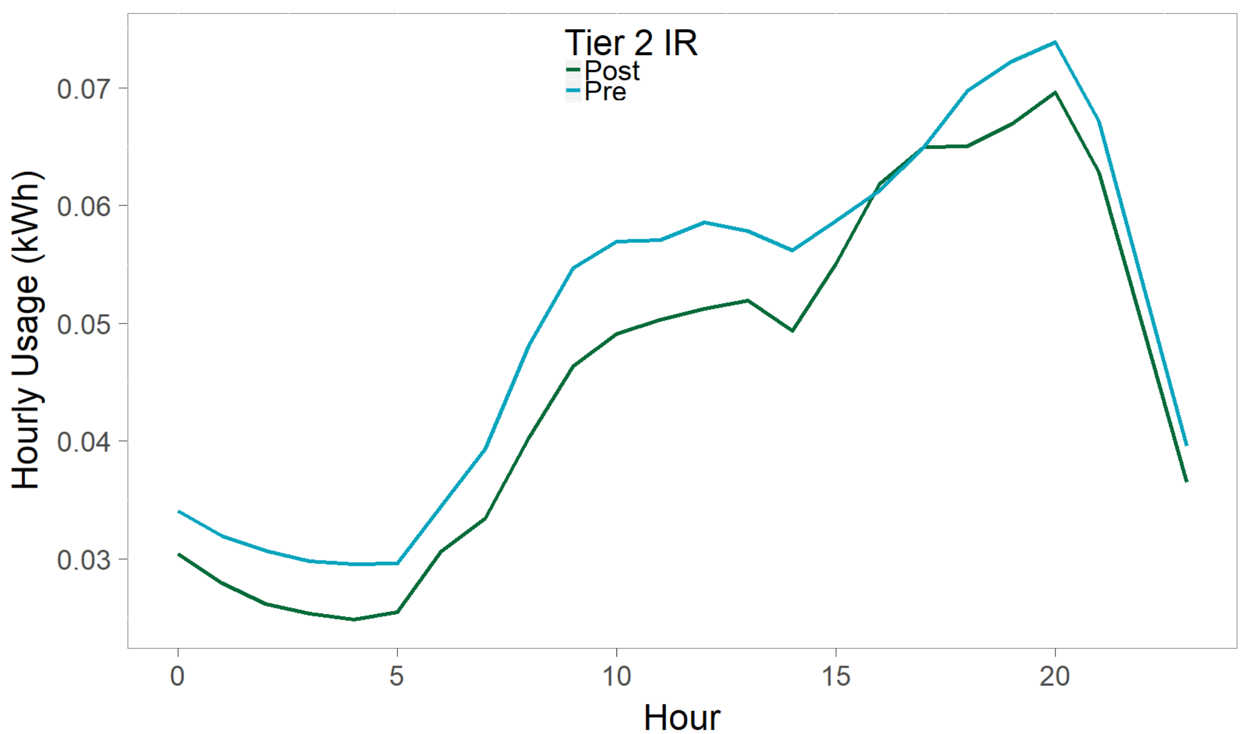


Figure 22: HEC Load Shifts Created by Tier 2 IR Smart Power Strips



Appendix E Customer Satisfaction and Persistence

This appendix presents findings on customer satisfaction with the smart power strips, as well as customer responses to questions pertaining to persistence and other interactions with the strips, asked during the final removal visits. We compare the satisfaction of participants in the metering study to that of the respondents to the HES and RCP surveys conducted as part of the RLPNC 17-4/5 APS Products Survey.[32]

E.1 Customer Satisfaction and Likelihood to Recommend

Table 38 shows reported customer satisfaction with the smart power strips. Tier 1 customers were generally far more satisfied with their strips than Tier 2 recipients. Nearly three-quarters (71%) of HEC participants reported being somewhat or very satisfied with Tier 1 strips, compared to just over half (53%) of Tier 2 IR-OS recipients and just one-third (33%) of Tier 2 IR participants. Tier 1 computer customers were similarly satisfied with the strips, with 78% claiming to be somewhat or very satisfied. Half (56%) of all Tier 2 IR strip users reported being not satisfied with the strips, while one-third (37%) of Tier 2 IR-OS customers gave the strips low satisfaction ratings.

These low satisfaction results reported by Tier 2 recipients may have been a result of the nature in which these customers received the strips. Specifically, these customers did not seek out and receive the strips; instead, the strips were "forced" on them as part of the study. In the RLPNC 17-4 and 17-5 Persistence and ISR study, 71%-78% (based on technology) of Tier 2 APS customers indicated that they were likely or extremely likely to recommend the strips. These customers had purchased the strips online, so their understanding of the technology and desire to use it was likely higher than the participants in this study.

Table 38: Customer Satisfaction with Smart Power Strip

	Tier 1 – PC	Tier 1 – HEC	*Tier 1 – RLPNC 17-4/5*	Tier 2 – IR	Tier 2 – IR-OS	*Tier 2 – RLPNC 17-4/5*
N	*9*	*14*	*342*	*18*	*19*	*306*
Not at all satisfied/Somewhat unsatisfied	22%	14%	-	56%	37%	-
Neither satisfied nor unsatisfied	0%	7%	-	11%	5%	*30%*
Somewhat/Very satisfied	78%	71%	*81%*	33%	53%	-
Don't Know	0%	7%	-	0%	5%	-

[32] http://ma-eeac.org/wordpress/wp-content/uploads/RLPNC_1745_APSProductsSurveys_27MAR2018_-final-1.pdf, p. 17.

Tier 1 recipients were also more likely to recommend the technology than those with Tier 2 strips. Most (71%) Tier 1 HEC respondents rated their likelihood to recommend as a 6 or higher on a 0 (extremely unlikely) to 10 (extremely likely) scale. Tier 1 PC customers also gave relatively high ratings; 66% rated their likelihood to recommend as above a 5. Under half (38%) of Tier 2 IR customers rated their likelihood to recommend as a 5 or higher. Tier 2 IR-OS participants were slightly more likely to recommend the advanced power strips; 42% gave ratings of 6 or higher, (Table 39).

Table 39: Likelihood to Recommend Smart Power Strip

Rating	Tier 1 – PC	Tier 1 – HEC	*Tier 1 – RLPNC 17-4/5 (Leave behind)* [33]	*Tier 1 – RLPNC 17-4/5 (Online)*	Tier 2 – IR	Tier 2 – IR-OS	*Tier 2 – RLPNC 17-4/5 (IR online)*	*Tier 2 – RLPNC 17-4/5 (IR-OS online)*
N	*9*	*14*	*222*	*342*	*16*	*19*	*251*	*55*
0-4	22%	7%	*12%*	*11%*	44%	26%	*18%*	*15%*
5	11%	14%	*9%*	*6%*	13%	26%	*8%*	*7%*
6-10	66%	71%	*75%*	*81%*	38%	42%	*71%*	*78%*
Don't Know	0%	7%	*5%*	*1%*	6%	5%	*4%*	*0%*

E.2 Persistence and Behavior

This subsection shows participant responses to behavioral questions asked during the final removal visits.

Table 40 shows the responses given by Tier 1 HEC recipients. Most (81%) of these customers plan to keep the smart power strip installed. This 81% is the same percentage as was found for the ISR for leave behind Tier 1 customers in the RLPNC 17-4/5 study.[34] Online Tier 1 customers in that study had a slightly higher ISR of 89%, further confirming that strips purchased willingly are used more frequently than those left behind or installed through a metering study. While the majority of metered RLPNC 17-3 customers did not make alterations to the strip during the metering period, over one-quarter of customers reported unplugging the strip (27%), changing what was plugged in (36%), and/or manually turning off the strip (29%) during the period.

---

[33] http://ma-eeac.org/wordpress/wp-content/uploads/RLPNC_1745_APSProductsSurveys_27MAR2018_-final-1.pdf, p. 18.

[34] http://ma-eeac.org/wordpress/wp-content/uploads/RLPNC_1745_APSProductsSurveys_27MAR2018_-final-1.pdf, p. 12.

Table 40: Tier 1 HEC Persistence and Customer Interactions with Strip

	N	Yes	No
Is the customer planning to keep the strip installed?	26	81%	19%
Did the customer unplug the strip at any time during the metering period?	15	27%	73%
Did the customer change what was plugged in at any point during the metering period?	14	36%	64%
Did the customer manually turn off the strip at any time during the metering period?	14	29%	71%

Table 41 shows the responses given by Tier 1 computer recipients. Three-quarter (78%) of these customers plan to keep the smart power strip installed. None of these customers reported turning off the strips during metering; however, nearly half (44%) changed what was plugged in, while roughly one-quarter (22%) unplugged the strip at some point.

Table 41: Tier 1 Computer Persistence and Customer Interactions with Strip

	N	Yes	No
Is the customer planning to keep the strip installed?	9	78%	22%
Did the customer unplug the strip at any time during the metering period?	9	22%	78%
Did the customer change what was plugged in at any point during the metering period?	9	44%	56%
Did the customer manually turn off the strip at any time during the metering period?	9	0%	100%

Over half (58%) of Tier 2 IR customers plan to remove the strips (Table 42). One-third (33%) of customers unplugged the strip during metering, while 31% adjusted the timer at some point. Although persistence was relatively low in this study, the 17-4/5 ISR study findings suggest that customers who sought out APS units and purchased them online were more likely to continue using the strips. The study found Tier 2 power strips to have a short-term retention rate of 93% and an ISR of 81% (across all brands).[35]

Table 42: Tier 2 IR HEC Persistence and Customer Interactions with Strip

	N	Yes	No
Is the customer planning to keep the strip installed?	19	42%	58%
Did the customer unplug the strip at any time during the metering period?	18	33%	67%
Did the customer change what was plugged in at any point during the metering period?	16	25%	75%
Did the customer manually turn off the strip at any time during the metering period?	16	12%	88%
Did the customer adjust the timer at any point did the customer adjust the timer?	16	31%	69%

[35] http://ma-eeac.org/wordpress/wp-content/uploads/RLPNC_1745_APSProductsSurveys_27MAR2018_-final-1.pdf, p. 12.

Most Tier 2 IR customers plan to keep their strips installed (Table 43). There was a fairly high instance (40%) of customers reporting that they unplugged the strip during the metering period; however, very few (6%) changed the timer settings on the device. There may be more instances of customers changing the timer with the new 60-minute default, compared to the 75-minutes that the strips in this study had.

Table 43: Tier 2 IR-OS HEC Persistence and Customer Interactions with Strip

	N	Yes	No
Is the customer planning to keep the strip installed?	21	65%	35%
Did the customer unplug the strip at any time during the metering period?	20	40%	60%
Did the customer change what was plugged in at any point during the metering period?	18	22%	78%
Did the customer manually turn off the strip at any time during the metering period?	16	25%	75%
Did the customer adjust the timer at any point did the customer adjust the timer?	16	6%	94%