Accelerating Adoption of Advanced Plug Load Management Devices

Stephen E. Bickel and Emily Phan-Gruber, D&R International, Ltd.

ABSTRACT

How do we cut plug load? Standards are an effective long-term solution, provided the growth in the number of devices does not outstrip savings from efficiency. However, standards take considerable time to develop and implement, while the number of connected devices in homes and offices grows and inefficient older products remain in the installed base for many years. One promising interim strategy to cut plug load energy consumption and peak demand is rapid deployment of advanced plug load management devices (APMDs), which include communicating smart plugs and Tier 2 advanced power strips (APS). Tier 2 APS are distinct from first-generation (Tier 1) APS because they reduce both active- and passive-mode energy use. Communicating smart plugs confer programmability, remote control, and continuous monitoring of devices that are plugged in to them, making the connected device accessible for demand response programs. Four types of plug load are most suited to consumption or peak reduction through APMDs: audio visual systems, computers and peripherals, and room air conditioners. These savings will materialize only if energy efficiency programs incentivize their sale and distribution, which requires accurate deemed savings numbers, which in turn requires robust field data. The U.S. Department of Energy is well positioned to coordinate generation and capture of such data, but it will need to extend the duration and scope of its existing APS initiative to do so.

Introduction

Televisions, computers, and related equipment accounted for 9% of residential delivered electricity use in 2011, and office equipment (computers and other) represented another 9% (EIA 2013). EIA predicts that by 2030, the share of residential delivered electricity use for televisions, computers, and related equipment and the share for office equipment (PC and non-PC) will both hold steady at 9% (EIA 2013).

Enhanced voluntary and mandatory efficiency standards may help reduce energy consumption of new devices, but they will not address energy use of devices already in consumers' homes. Some devices have relatively long lifetimes, and it could be many years before the inefficient units are retired or replaced. California projects that plug load devices will represent 30% of the total energy savings potential by 2020 (Navigant Consulting 2011).

One promising strategy to curb the growth in plug load energy consumption is rapid deployment of communicating smart plugs and Tier 2 APS, which, unlike earlier (Tier 1) APS, can reduce active mode energy use of electric devices and/or enable remote control and scheduling of these devices. For example, a load-sensing Tier 1 APS will shut off a device and peripherals only when it detects the master control device, such as a TV, is in sleep mode (i.e., not displaying content, but able to respond to a signal from a remote control). The Tier 2 APS, on the other hand, is specifically designed for AV systems. It will shut off power to the TV and peripherals even when the TV is on, provided there have been no infrared communication signals (to change channels, volume, etc.) for at least 60 minutes. Tier 2 APS have dedicated always-on sockets so that devices that need to be kept on all the time (such as set-top boxes, which are slow to start up), stay on.

Tier 2 APS offer the opportunity to reduce unnecessary passive and active energy consumption associated with home audio/visual (AV) equipment, home desktop computers and peripherals, and office computer workstations inexpensively, while communicating smart plugs create the possibility of transforming the liability of peak room air conditioner loads into large demand-response assets.

The theoretical aggregate energy savings potential for home AV and computer equipment is approximately 37,000,000 MWh/yr. Installing APMDs on room air conditioners has the potential to provide approximately 12,956 MW of electricity demand savings (D&R 2014). Although many energy efficiency program sponsors have expressed interest in APMD technologies, they need accurate deemed savings numbers for each device type to incorporate these products into their program portfolios.

Efforts are underway to provide such data for use in commercial buildings. The Northeast Energy Efficiency Partnerships (NEEP), the American Council for an Energy-Efficient Economy (ACEEE), the U.S. General Services Administration (GSA), and the U.S. Department of Energy (DOE) have organized an Advanced Power Strips Campaign. This initiative is focused on generating and disseminating the critical data required by program sponsors to promote use of Tier 1 and Tier 2 devices in commercial buildings.

High-volume deployment of APMDs needed to capture significant energy savings will also require effective communication of the savings potential of these devices, robust field data to validate the savings potential estimates, and identification of devices and program delivery models that enable dependable realization of savings with high levels of customer satisfaction. DOE is probably best positioned to coordinate the necessary data gathering and dissemination.

Miscellaneous Electric Loads

Miscellaneous electric loads (MELs) represent a growing portion of U.S. electricity loads (Kwatra et al 2013; Navigant and SAIC 2013; EIA 2013). How large and how quickly they are growing depends on the definitions, which are numerous (Kwatra et al. 2013). The broadest definition treats all loads other than heating, ventilating, air conditioning, lighting, and water heating as miscellaneous (Rauch and Baechler 2012). Under this definition, MELs include everything from computers and televisions to distribution transformers, video displays and security systems and represent 35% of electricity demand (EIA 2013). A less expansive definition excludes refrigeration, cooking, and cleaning loads, in which case MELs represent 20% of building electric consumption. Audio visual equipment (TV, DVD players, set-top boxes, audio equipment, and office equipment) account for approximately half of these loads (EIA 2013), making them attractive targets for energy efficiency programs.

Table 1. Electricity consumption of high-energy consuming residential MELs

	TWh/yr
Televisions	70
Pool heaters and pumps	26
Desktop PCs	22
Set-top boxes	22
Ceiling fans	20
Audio equipment	16
Monitors	13
Dehumidifiers	11
Laptop PCs	10
Portable electric spas	9
Modems and routers	7
External power supplies	7
DVD players	6
Non-PC rechargeable electronics	4
Home security systems	1

Source: (Navigant and SAIC 2013)

What Are APMDs?

APMDs are smart plugs and power strips with functionality that enables them to cut active mode electricity use and, in the case of communicating smart plugs, deliver efficiency or demand reduction. They look similar to Tier 1 APS and the plug-in parts of aftermarket remote control switches, but they are a distinct class of products with sophisticated sensing, design, software, and/or communication capabilities.

Tier 2 APS devices allow control of passive and active energy consumption through IR or motion sensing. Connected devices are turned off if no IR signal or motion is detected for a specified period of time (typically 60 minutes). Communicating smart plugs are plugged into existing outlets and offer replacement slots to plug controlled devices. Communicating smart plugs wirelessly report data about the plugged-in device and respond to a remote signal to enable or disable flow of power to the controlled device, thereby turning it on or off.

Figures 1, 2, and 3 show a few examples of APMDs in the market. Table 2 summarizes the array of available products, including descriptions of their use.

Tier 1 APSs were designed to help eliminate electricity being wasted in standby modes by computers, peripherals, televisions, gaming stations, and other TV-connected AV equipment without having to replace the equipment.

Table 2. Tier 1 devices and descriptions

Type	Description
Current sensing	Disconnects any device that has entered sleep mode.
USB sensing	Disconnects any device that has entered sleep mode.
Remote switch	Uses single remote (RF) switch to shut off power to all (controlled) devices on the strip.
Timer based	Wind-up timer, programmable strip, simple 24-hour timer with standard power strip.
Current sensing master/peripheral	Disconnects peripherals when master enters sleep mode.

Source: Northwest Power and Conservation Council Regional Technical Forum 2013

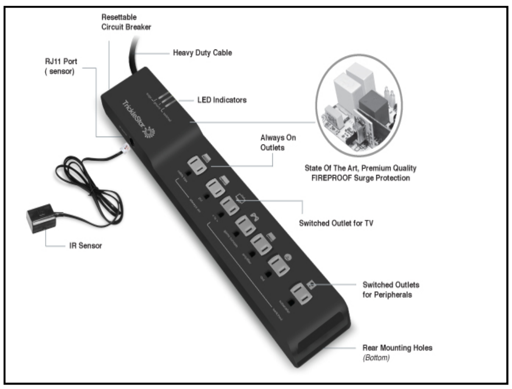

Figure 1. Tricklestar Advanced PowerStrip+ with Infrared (IR) Sensor

Image courtsey of TrickleStar: http://www.tricklestar.com/us/index.php/products-1/advanced-powerstrips-plus/7-outlet-advanced-powerstrip-plus-ir-sensor.html.

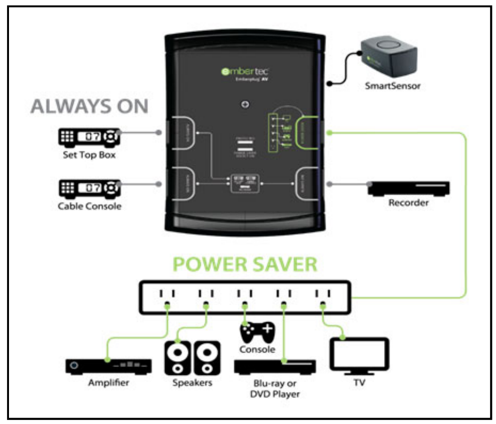

Figure 2. Embertec Emberplug™ AV Device

Image courtsey of Embetec: http://embertec.com/products/emberplug/

Figure 3. ThinkEco Modlet, Modlet BN, USB and ethernet gateway.

Image courtsey of ThinkEco: http://www.thinkecoinc.com/products/the-modlet/,
http://www.thinkecoinc.com/products/the-modlet-bn/thinecoinc.com/products/the-modlet-bn/

Table 3. APMDs currently on the market

Manufacturer/ brand	Type	Functionality	Primary target
Embertec Emberplug™ AV	Power strip	Turns off device after user-specified interval if does not receive IR signal	Audio visual equipment
ThinkEco Modlet	Plug	Connected using WiFi. User can turn device on and off or set schedule for device to turn on and off.	Electronics, lights
Tricklestar Advanced Powerstrip+ with InfraRed (IR) Sensor	Power strip	Turns off device if a specified duration passes without an IR signal produced by an AV remote controller.	Electronics
Tricklestar Motion Sensor Powerstrip	Power strip	Shuts off device if it does not detect motion for 30 minutes.	Electronics
Belkin WeMo Switch	Plug	Connects device using Wi-Fi. Users can control device remotely. Some versions come with occupancy sensor that can detect motion from up to 10' away and turn products on and off if motion is detected.	Electronics, appliances, and lights
WattStopper®	Power strip	Shuts off devices after occupancy is not detected for a duration specified by the user.	Lighting, computer monitors, space heaters, fans
Ecobee Smart Thermostat	Plug	Thermostat that can be controlled using WiFi and communicating smart plugs can be included in the system to control lights and entertainment.	Audiovisual equipment, lights
Digi XBee Smart Plug	Plug	Uses ZigBee technology to mMeasures energy use and controls plugged-in devices.	Appliances, lighting, sump pump
Wiser Smart Plug	Plug	Measures energy use and controls plugged-in devices. Can use a Wiser application to set a schedule.	Lamps, small appliances
Ube	Plug	Measures electricity usage. Can be used to monitor, dim, and control lights.	Lights, electronics, appliances
Iris Communicating Smart Plug	Plug	Part of the "Iris Home" energy management system. Has smart plug to control lights.	Lights

APMDs Offer Big Savings Opportunities in Four Areas

Over the long term, the best way to address inefficiency for MELs is by replacing inefficient legacy products with new ones that meet higher efficiency standards. Given product lifetimes, this process will likely take at least a decade. However, significant efficiency and demand-response savings can be captured from AV, computers and peripherals, and room air conditioners through widespread installation of APMDs.

The use of IR-sensing Tier 2 APS with AV systems—televisions, DVD players, amplifiers, speakers, subwoofers, receivers, amplifiers, and gaming consoles—represent the largest savings opportunity (Table 4). The IR-sensing Tier 2 APS monitors for infrared signal. If an hour (or longer duration specified by the user) elapses without a channel, volume, or other adjustment being made, the APS shuts off the television and other non-essential peripherals. The Tier 2 APS also includes the function of a Tier 1 product and will turn off all AV products dependent on the TV when the TV is turned off by the user. Set-top boxes are plugged into always-on sockets and are unaffected.

Other Tier 2 APS are equipped with motion sensors and designed for computers. They turn off the computer when no motion has been detected for an hour or other duration selected by the user. These devices also have always-on sockets to enable users to keep modems and routers on. As with the IR-sensing APS, the motion-sensing APS turns off peripherals in sockets controlled by the computer when the computer is turned off.

Savings numbers are rough estimates as there is only limited data from field trials. Energy efficiency programs beginning to incorporate these devices are being conservative about deemed savings. For example, the Northwest Power and Planning Council's Regional Technical Forum (RTF 2013) provisionally deemed savings of 300 kWh per year.

Table 4. Energy savings potential of Tier 2 APS with home AV and computers

Device	Savings per device (kWh/yr)	Total potential savings (MWh/yr)
AV (IR sensing)	321	36,987,803
Computers (motion sensing)	67	7,720,195

Sources: Unpublished field trials conducted on behalf of Embertec, reported to the Northwest Power and Conservation Council Regional Technical Forum 2013 (RTF 2013); U.S. Census Bureau, 2008-2012 American Community Survey.

Communicating smart plugs can be used to aggregate room air conditioners for peak load reduction. ConEd's coolNYC program uses the Modlet communicating smart plug to aggregate some of the city's 6 million room air conditioners into a demand response resource. The program links the WiFi-enabled Modlet to a handheld remote customer-controlled thermostat. Customers can use the smart phone app to set a cooling schedule and turn off the device remotely. The program delivered 24% reduction in room air conditioner demand across thousands of households during nighttime peaking events (ConEd 2012).

The wireless communication capabilities of communicating smart plugs offer additional benefits including continuously gathering data on the patterns of energy consumption of a large population of controlled devices and be seamlessly integrated into a home or building energy management system, The data gathering may pose privacy concerns,.

Table 5. Energy saving potential of communicating smart plugs with room air conditioners

Product Type	Savings per event per device (kW)	Number of households	Total potential savings (MW)
Room AC	0.40	32,230,000	12,956

Sources: EIAa 2011; Smart 2012; EIAb 2011.

Barriers to Widespread Adoption of APMDs by Electric Utilities

Despite the energy- and demand-savings potential of APMDs, they have not yet been widely adopted by electric utilities. The obstacles impeding the rapid adoption of APMD devices include lack of awareness of product diversity, lack of understanding of savings potential, and lack of robust and uniform field test protocols and data. All of these obstacles can be overcome through a combined effort on the part of the federal government, regional efficiency organizations, utilities, and manufacturers.

Product Diversity

Many people still conflate APMDs with Tier 1 APS. The efficiency community needs greater awareness about the differences between APS and APMDs, especially the differences in their potential. One challenge of APMDs is that the technology is evolving quickly and there are a wide variety of devices. This diversity makes it more difficult to determine the performance of individual APMDs and classify them in a standardized way. It would be best if the products could be assessed individually (like motor vehicles) to encourage innovation and greater efficiency.

Uncertainties in Device-Level Savings

Utilities have been hesitant to add APMDs to their energy efficiency programs because there are limited data on factors that affect energy savings and cost-effectiveness calculations, such as device-level savings and persistence. Several recent independent field trials could serve utilities as a first step in analyzing APMD performance. APMDs would further benefit from a uniform field test method; CalPlug is developing one and will release it in the coming months. This will enable utilities to know the real savings per unit and overall savings potential.

Program design is likely to have a large impact on savings. Direct install programs ensure high rates of installation and installation that is done correctly, and are therefore less likely to result in user dissatisfaction and deinstallation. Mass market programs, in which devices are distributed at retail or mailed for self-installation, risk improper installation, which can erode savings and undermine cost-effectiveness. Yet mass market programs are the most likely mechanism for high-volume distribution, so a program design that minimizes or eliminates these issues could unlock the largest savings from these devices.

Utilities interested in direct install programs need to know the proportion of homes in which APMDs can be easily installed, the average savings of properly installed devices in typical homes and offices, the persistence of those savings, and the cost-effectiveness of direct installation to confidently launch programs. Utilities interested in mass market programs also need to know the proportion of distributed devices that get installed and stay installed, the proportion of devices that are installed correctly, and, for air conditioners, the fraction of households with correctly installed devices that agree to curtailment during a demand response event.

The necessary data can be reliably generated only via field tests and pilot projects. Several pilot programs and field tests are underway, and their results will provide the required data for products from several manufacturers.

Consistency of Performance

Some utilities and regulators also want to be sure that incentivized APMDs of similar type from different manufacturers offer similar savings, durability, and customer satisfaction. At present, there are insufficient data to make such assessments. Program managers will need to decide whether they will approve incentives only for models for which field test data are available or if they will assume that products with similar designs and control mechanisms operate the same way. The former option can be problematic for public entities due to the expense of field testing, while the latter risks poor performance from devices that have not been field tested.

Strengthening the Case for Utility APMD Incentives

To meet utility requirements for both direct install and retail distribution, APMDs must demonstrate that they can consistently generate savings when properly installed and that a large proportion of them will be properly installed and remain installed. Given the product diversity, lack of data about device-level savings, and questions about consistency of performance, wide adoption of APMDs by program sponsors depends on the following:

- Coordination among utilities to fund field tests or evaluate existing field test data using a uniform method
- Field tests of statistically significant levels with respect to the approved field testing process to generate data for both direct install and mass market programs
- Coordinated analysis and dissemination of field test results

Efforts and resources could be coordinated through the DOE, NEEP's EM&V Forum, the Consortium for Energy Efficiency, or a dedicated program similar to the DesignLights Consortium®. DOE may be the best candidate for this role, as it is already working on an advanced power strip campaign (DOE 2013; DOE 2014) focused on developing a technical specification for commercial applications of first-generation APS and APMDs. The campaign is scheduled to end in September 2014, but DOE could consider expanding or extending it to focus on residential applications. The commercial technical specification will likely make it easier to develop a residential technical specification and help build utility confidence. The campaign has already created a core working group of stakeholders, but it would need to generate broad utility incorporation of APMDs into their residential energy efficiency and demand response programs. DOE would need to review and endorse pilot and field test data and communicate the value of APMDs and field trial analysis to the broader energy efficiency and demand response communities. DOE and its working group could review, refine, and ultimately support the field test methodology being developed by CalPlug to give utilities a uniform method to follow. DOE could also function as a clearinghouse for utility-run and -supplied field trial data and analysis, which would give the energy efficiency community a central location for the most up-to-date findings and analysis of APMDs.

The continued growth of consumer and business electronics, along with shrinking savings from other energy efficiency measures, means APMDs represent one of the few new single-measure savings opportunities for utilities. Evolution by DOE of its current APS campaign into a longer-running APMD campaign is a promising route to encouraging wider adoption of APMDs and capturing the energy savings and demand-response capacity that they can provide.

References

Consolidated Edison Company Of New York, Inc. 2012. Evaluation of Program Performance and Cost Effectiveness of Demand Response Programs.

D&R International, Ltd. 2014. *Assessing the Potential Energy Savings for Advanced Plug-load Management Devices. DRAFT*.

DOE. 2014. Discussion of APS Campaign Technical Specifications. Presentation for APS Tech Spec Working Group. February 6, 2014.

DOE. 2013. *Better Buildings Alliance 2013 Annual Report.* http://www4.eere.energy.gov/alliance/sites/default/files/uploaded-files/better-buildings-alliance-annual-report-2013.pdf

EIA. 2013. Annual Energy Outlook 2013. Washington, D.C.: U.S. Energy Information Administration. http://www.eia.gov/forecasts/aeo/pdf/0383%282013%29.pdf.

EIAa. 2011. *Air conditioning in nearly 100 million U.S. homes.* . Washington, D.C.: U.S. Energy Information Administration. http://www.eia.gov/consumption/residential/reports/2009/air-conditioning.cfm. Accessed 2/27/2014.

EIAb. 2011. *Table HC9.7 Household Demographics of U.S. Homes, by Census Region, 2009.* Residential Energy Consumption Survey 2009. Washington, D.C.: U.S. Energy Information Administration. http://www.eia.gov/consumption/residential/reports/2009/air-conditioning.cfm. Accessed 2/27/2014.

Kwatra, S., Amann. J., and Sachs, H. 2013. *Miscellaneous Energy Loads in Buildings.* American Council for an Energy-Efficient Economy. http://www.aceee.org/sites/default/files/publications/researchreports/a133.pdf

Navigant Consulting, Inc. and SAIC (now Leidos). 2013. *Analysis and Representation of Miscellaneous Electric Loads in NEMS.* Prepared for the U.S. Energy Information Administration.

Navigant Consulting. 2011. *Analysis to Update Energy Efficiency Potential, Goals and Targets for 2013 and Beyond: Track 1 Statewide Investor Owned Utility Energy Efficiency Potential Study*. Prepared for the California Public Utilities Commission.

Northwest Power and Conservation Council Regional Technical Forum. 2013. *Planning Workbook.* http://rtf.nwcouncil.org/measures/measure.asp?id=150. Accessed 11/26/2013.

Rauch, E. and Baechler M. 2012. *Assessing and Reducing Miscellaneous Electric Loads (MELs) in Banks.* http://www.pnnl.gov/main/publications/external/technical_reports/PNNL-20973.pdf

Smart, C. 2012. *Evaluation of Program Performance and Cost Effectiveness of Demand Response Programs.* Prepared by Consolidated Edison Company of New York, Inc. Prepared for the State of New York Public Service Commission.

U.S. Census Bureau. *American Fact Finder.* 2008-2012 American Community Survey. http://factfinder2.census.gov/faces/tableservices/jsf/pages/productview.xhtml?pid=ACS_12_5YR_DP04&prodType=table. Accessed 2/27/2014.