Advanced Power Strips: Evaluating Energy Savings for Efficiency Programs

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ABSTRACT

Much of the energy consumption of residential consumer electronic and PC devices occurs when these devices are not in use, resulting in active or passive standby energy use. An Australian program is awarding energy saving certificates to qualifying 'smart' power control technologies, called standby power controllers (SPC) or advanced power strips (APS). These products are installed in households to reduce the standby energy losses of existing electronic devices and are typically used to control the energy use of televisions, audio/visual products and personal computer peripherals.

This paper describes the measurement and assessment process developed by the Essential Services Commission (ESC) of Victoria, Australia, in order to calculate comparative energy savings for these power control technologies. The process involves a laboratory test and a small intrusive household survey that logs audio visual and PC equipment energy usage and other important variables. The survey methodology involved a combination of a pre/post comparison of residential energy usage, plus disabling the power controller to record when and how much the power controller would have reduced energy consumption. This enabled accurate estimates of the existing standby energy consumption and potential savings. The ESC then applied a normalization methodology to the data to standardize the energy savings.

The survey and standardization methodology may be applicable to other energy efficiency programs as the normalization approach can utilize energy end-use characteristics specific to a country or region. The potential to extend this approach as the basis for international labeling of APS is explored.

Introduction

The Victorian Energy Efficiency Target (VEET) is a Victorian Government initiative promoted as the Energy Saver Incentive. It was established under the Victorian Energy Efficiency Target Act 2007 (the Act) and commenced on 1 January 2009. It is legislated to continue in three-year phases until 1 January 2030. The purpose of the scheme is to reduce greenhouse gas emissions, encourage the efficient use of electricity and gas, and to encourage investment, employment and technology development in industries that supply goods and services to reduce the consumption of electricity and gas.

The scheme operates by placing a liability on large energy retailers in Victoria to surrender a specified number of energy efficiency certificates every year. Each certificate represents one tonne of greenhouse gas abated and is known as a Victorian energy efficiency certificate (VEEC). The Act and the Victorian Energy Efficiency Regulations 2008 (the Regulations) allow for accredited entities to create VEECs when they help consumers introduce selected energy efficiency improvements to their homes. Revenue generated through the sale of VEECs enables accredited entities to offer consumers special offers that reduce the cost of undertaking these improvements. The Act and Regulations are maintained by the Department of

Primary Industries (DPI). The Essential Services Commission (ESC) is responsible for administering the scheme in accordance with the legislation.

Approximately 30 Prescribed Activities are included in the scheme, ranging from the installation of high-efficiency hot water systems, air heater/coolers, lighting, draught proofing and window treatments through to the purchase of high efficiency appliances such as refrigerators and televisions. The installation of Standby Power Controllers (SPC), also called advanced power strips (APS) is awarded between one and six VEECs. A full list of the eligible activities can be found on the VEET website (www.veet.vic.gov.au).

The purpose of this paper is to describe the process used to calculate the energy savings from the installation of APS under the VEET program. It discusses the eligibility criteria, laboratory tests, field trial methodology, how data is normalized and potential improvements. We also describe the broad types of APS and their functionality, and the definitions of standby power, which are important for classifying the potential energy saving opportunities. Standby power modes are defined according to the International Standby Power Project (EnergyConsult 2010) as:

- Passive Standby - When a product or appliance is not performing its main function (sleeping) but it is ready to be switched on (in most cases with a remote control) or is performing some secondary function (e.g. has a display or clock which is active in this mode)..
- Active standby – this is also called idle mode in many markets, and occurs when the appliance is on but not performing its main function. For example, a DVD may be on but is not playing or recording. This mode is usually only present in devices (a) where there is a mechanical function which is not active (e.g. DVD drive or motor) but where power circuits are on, or (b) where a device has a battery and the device is charging, or (c) the user has unintentionally left the device in use (e.g., an amplifier is left turned on, but no devices are providing input signals).

Past research has found that more than 10% of the residential energy consumption of consumer electronic and office equipment occurs when these devices are not in use, resulting in active or passive standby energy use (DCCEE 2011). Government actions introducing mandatory energy efficiency requirements will reduce the passive standby power losses of future electronic devices. However, the introduction of these requirements will not affect the energy consumption of the existing stock, nor will it greatly affect active standby power losses. A duel approach is required to reduce current and future standby power use. A recent field study has shown that while active standby or idle mode can be the major contributor to standby consumption, 'smart' power control technologies exist which can significantly reduce the standby energy losses of the existing stock of electronic devices (Ryan & Pavia 2011).

APS Descriptions

There are several types of APS being offered in the market or under development in Australia and internationally. They can be defined as follows:

- Single switched or remote switched power boards – where the user is required to turn off a central switch, that in turn disconnects the power to several devices

- Master/slave – where a master device is detected to off (usually by current sensing) and the APS disconnects power to other devices
- Infrared signal detected – similar to the switched power boards, however the infrared signal of the master device (such as a TV) is detected and when powered off, the APS disconnects power to other devices
- Power and signal sensing – these APS typically use a combination of methods to dynamically control the connected devices.

Requirements for Accreditation of the APS

The regulations specify the minimum requirements that an APS must meet to be eligible for VEECs under the scheme (ESC 2012). These requirements vary depending if an APS is installed in a residential or business premises. An APS installed in the residential sector that controls audio visual (AV) equipment must demonstrate that:

- when tested by an accredited laboratory it was determined suitable for an AV environment
- it can control the power of at least 4 appliances
- it has a mains power switching device rated to a minimum of 50,000 switching cycles
- the device has an average power consumption of one Watt or less when controlled devices are in “off mode”
- it disconnects and reconnects mains power from controlled appliances as appropriate
- the device is not controlled by being paired with an appliance remote control
- it is connected to at least 2 controlled appliances at the time of installation
- it does not require manual setting of a current or power threshold.

The requirements for an information technology (IT) APS that is installed to control IT equipment in the residential sector are slightly different. The IT APS must demonstrate that when tested by an accredited laboratory it was determined to be suitable for an IT environment and as well as with desktop and notebook computers less than two years old. The IT APS is not permitted to rely solely on a USB connection to sense power levels.

These are the basic requirements for an APS to qualify for the Victorian certificates. For APS installed in residential premises that meet the minimum eligibility criteria, they are awarded 1.0 VEEC. For APS that have additional functionality, the number of VEEC awarded depends on the energy savings demonstrated through an ESC approved field trial. The price of a VEEC on the market can vary, however the maximum price is typically AUD$40. This is the penalty price that the obligated parties must pay if they do not surrender the required number of certificates. The penalty price cannot be claimed as a tax deduction, and so the ceiling price that a VEEC could generate may be as high as $50. In the last quarter of 2011, the price reached $40 but in the current market (8 March 2012), VEECs are trading at around $22.

Accreditation and Measurement Process for APS

The accreditation and measurement of the energy savings and subsequent allocation of certificates is managed by the ESC. The APS approval process is split into two distinct phases:

- Phase 1 – The laboratory test phase, where if successful, the APS will be awarded one VEEC.
- Phase 2 – The field trial phase, where the APS will potentially be awarded more than one VEEC on the basis of performance and normalization of the results.

Following Phase 2, the initial data is verified, which includes a high level check that data is internally consistent. The data is also assessed for unusually high or low values (and an explanation sought if observed), to confirm that average savings from the trial are within expected range. A detailed verification of field trial data is then undertaken to check post-analysis results as reported in the spreadsheet from the applicant, by confirming calculations for sample of readings. Finally the VEECs to be awarded for the APS are calculated using average Victorian household energy usage and behavior patterns. These steps are elaborated below:

Phase 1 Laboratory Test

APS are relatively new energy efficient devices in the Australian market. These products come in different designs and operating regimes, and can be connected to many combinations of appliances. The testing and approval of APS for energy efficiency programs is a new discipline and formulating a robust and repeatable test methodology, suited to all possible APS designs and operating environments, is challenging. The ESC developed the test procedure (ESC 2011a) for APS that control the AV or IT equipment. The test method separately addressed those AV APS that control equipment using a master/slave strategy and those that sense the infra-red (IR) signals from existing AV remote controls. There are three categories of devices that are able to be tested:

- IT APS – Master/Slave type. The master is the computer and the slave is the connected peripherals and office equipment.
- AV APS – Master/Slave type. The master is the television and the slaves are the connected AV equipment, such as DVD players, Set-top-boxes (STB) and audio amplifiers
- AV APS – IR Type. The APS relies (solely or additionally) on sensing of infra-red signals from existing AV remote controls (without pairing to an existing remote control button), in order to sense user requirements for the AV installation to be turned on or off

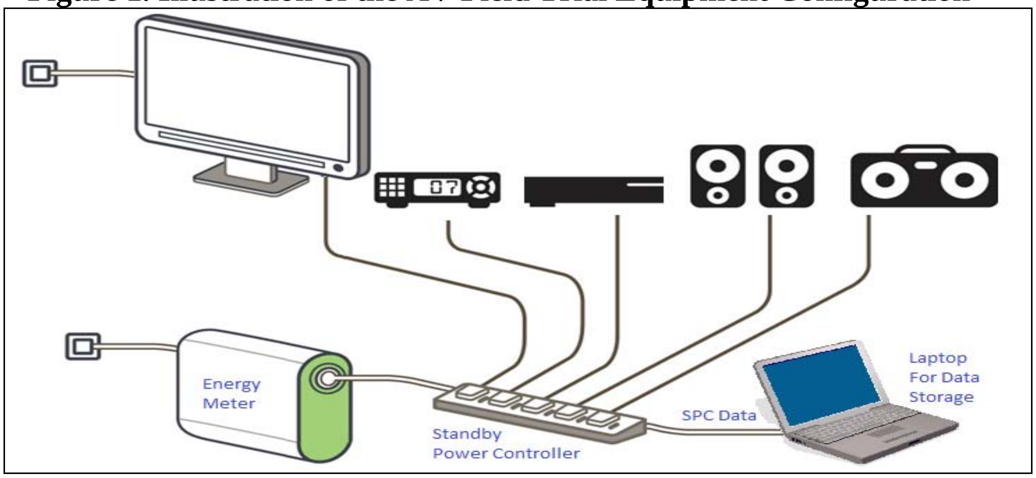
Laboratory tests aim to confirm the operation of the APS is within the performance guidelines that are specified by the regulations for eligible products. The test method allows for the measurement of the power consumption of the various items (the APS, the controlled slave loads and the uncontrolled master or principle loads) as well as examining the operation of the APS. The APS is set up as described by the manufacturer and power meters/loggers are installed. The APS is connected to different Televisions (LCD, plasma) and PCs (desktops, laptops) and controlled loads (DVD, games console, STB, etc., or printers, speakers, scanner, display, etc.) as appropriate. The APS is then put through a number of test cycles including while operating equipment in On-mode, Off-mode and when the master (computer or TV) is put into sleep or standby mode. Measurements of the time to disconnect and reconnect the mains power to the loads are taken. The test report specifies the measurement information to be provided including pass/fail results of various cycle tests, such as APC disconnecting mains power from the peripherals within 2 minutes of the master computer entering off mode.

Phase 2 Field Trial

The approach adopted in the field trial is to develop a process which required no change in householder's interaction with their devices whilst providing a detailed understanding of equipment usage patterns in the home (ESC 2011b). This approach aimed to achieve significant clarity on residential device usage trends in AV and IT. Data on the energy usage is then acquired during the trial, allowing for detailed analysis of household power usage in AV and IT environments. An example of the energy meter and control events that are logged in a field trial is shown in Figure 1. The field trial monitoring is carried out in a minimum of 20 Australian households, with the following specifications:

- The power consumption of all appliances to be attached to the APS is measured, in various modes of operation. This is a short test performed within a matter of minutes.
- Data logging of the power consumption of the principal and controlled appliances (separately) is undertaken over 14 consecutive days.
- The principal and controlled appliances must remain connected to mains power at all times (i.e. the APS shall not interrupt the power supply), in order to allow for accurate calculation of energy consumption of appliances (analogous to the pre-installation period).
- The theoretical ON and OFF events of the APS are logged. This allows for accurate calculation of the energy that would have been saved if the APS had been functioning as intended.
- In order to independently confirm that the APS is functioning as intended, the parameters used by the APS to undertake switching events are also logged.
- Optional Third Week – In order to verify that user behavior is not affected by the APS over a longer period, the field trial may be extended by one further week with the APS operating as intended. The aim of this optional week is to collect information on the APS control strategy and its effect on user behavior.

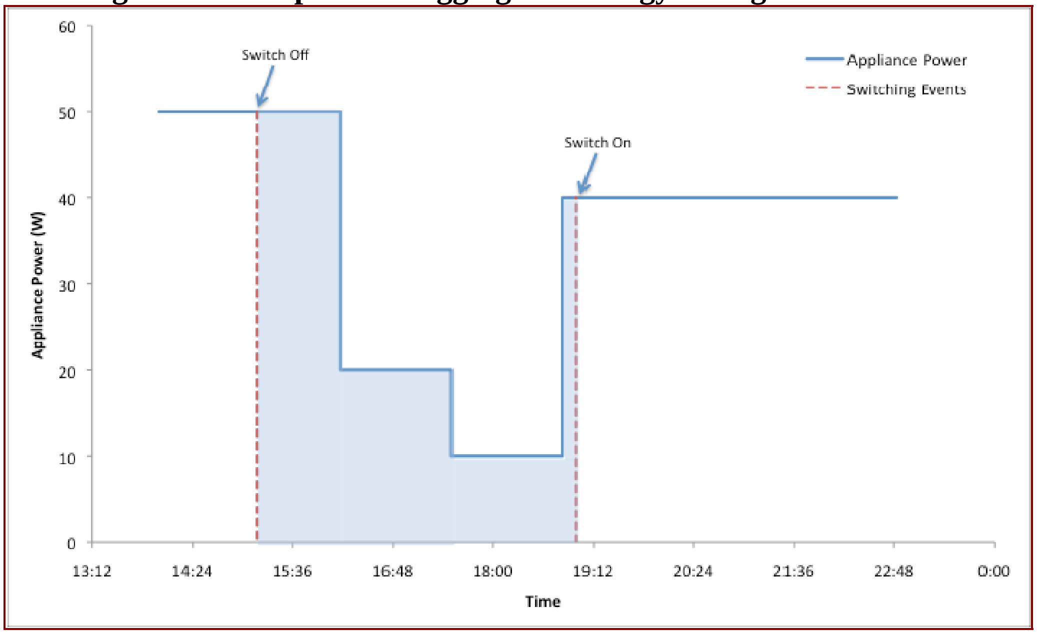
Figure 1. Illustration of the AV Field Trial Equipment Configuration



Source: Ryan and Pavia 2011

Figure 2 shows an example of data logging and a calculation of energy savings. The blue area is the calculated energy savings from the APS automatically switching off the mains power to the device. The area above the blue shaded area in Figure 2 may be misinterpreted as energy savings in a pre and post installation trial leading to false readings and overstated savings.

Figure 2. Example data logging and energy saving calculation



Source: ESC 2011b

Example of Field Trial Results

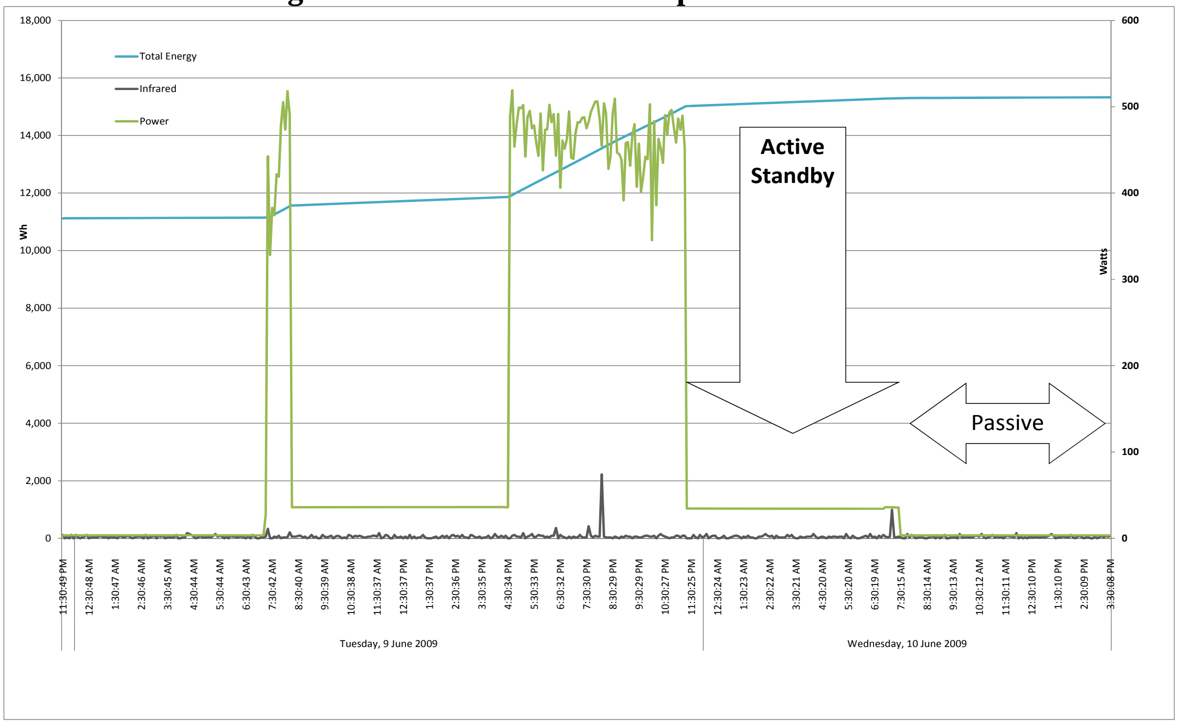
In 2009, EnergyConsult undertook a field study of an APS to determine the potential energy savings and typical use of AV and IT environments in the household. A trial involving 20 South Australian households over a period of 3 months provided sufficient information to determine the functionality of the APS and the potential energy savings. The APS evaluated in this study utilized a power and signal sensing approach to control the connected loads.

The analytical approach applied to this study required the detailed assessment of power use over time, combined with data on the power use of the individual equipment. The actual measured time of use of the equipment was compared and correlated with the stated use of the equipment, as derived from the householder surveys. This enabled a detailed analysis of the typical power use for each electronic AV or PC device for each minute, for the duration of the field trial. The analysis applied standard definitions of power modes. In addition, the active standby mode (also known as idle mode) was further defined as present when:

- For AV Equipment, after no user activity (IR) was detected for a period of 1.5 hours
- For PC equipment, after the power use of the PC was stable for a period of 30 minutes.

Power usage in the active standby mode typically occurs when the user has moved away from the device or has inadvertently left the device on. An example of the potential energy savings in the AV environment is shown in Figure 3, where passive standby mode and active standby mode is shown by the arrows. The width of the arrow indicates the time in the mode.

Figure 3. AV Power Use Example from Field Trial



Source: Ryan and Pavia 2011

The total average energy savings achieved by the APS during the field trial in the AV environment are shown in Table 1. The APS was found to save 54% of the total AV environment energy use and the vast majority of these savings were attributed to the active standby or idle mode. Most devices were controlled by the APS, except for some cases where the consumer had a personal video recording (PVR) STB. All other equipment performed as normally while controlled by the APS.

Table 1. APS Energy Savings by Mode for the AV Environment

	Total AV Energy (kWh pa)	**Average In-use Energy (kWh pa)**	**Average Active Standby mode Energy (kWh pa)**	**Average Passive Standby Energy (kWh pa)**
Energy Use by Mode	1,370	767	548	55
APS Savings	736	164	525	48
Percent savings: Total and by mode	54%	21%	96%	87%

Source: Ryan and Pavia 2011

Table 2 presents a summary of the total energy use by mode and the energy savings achieved by the APS. Overall 41% of total PC environment energy usage was saved or 79% of the total PC peripheral equipment energy used.

Table 2. APS Energy Savings by Mode for the PC Environment

	Total PC Energy (kWh pa)	**PC Peripheral Energy (kWh pa)**	**PC Peripheral Average Active Standby mode Energy (kWh pa)**	**PC Peripheral Average Passive Standby Energy (kWh pa)**
Energy Use by Mode	859	448	290	77
APS Savings	352	352	290	62
Percent savings: Total and by mode	41%	79%	100%	87%

Source: Ryan and Pavia 2011

Normalization Approach

Following the completion of the field trial the ESC applied a normalization process to ensure that the savings allocated to the APS reflected the average savings which were likely to be achieved from the products when deployed in Victorian homes and not biased by field trial design. The process used to normalize the data involved the following steps:

- Enter the field trial results and check ranges of savings
- Adjust the field trial results if necessary to account for abnormal field trial results
- Calculate and apply average savings to the standardized Victorian household and calculate the average savings per APS
- Adjust the average 10 year savings for changes in appliance stock and the impact of Minimum Energy Performance Standards (MEPS) or other government regulations.

The benefit of this approach was that the field trial results were used to primarily determine the proportion of energy savings compared to the total energy use of the equipment being controlled. This savings percentage was independent of the absolute size of the energy consumption of the connected equipment. The absolute energy savings that are used to calculate the VEET certificates are calculated by multiplying the percentage savings of the APS and the estimated energy consumption of the controlled equipment of an average Victorian house. The percentage saving is however highly dependent on the control strategy of the APS and the amount of time equipment is used and/or left in idle or high power modes. To ensure that these parameters are within the boundary of normal behavior, the field trial results are checked and compared with the maximum savings possible under a range of behaviors. The four steps used to normalize the field trial results are described below.

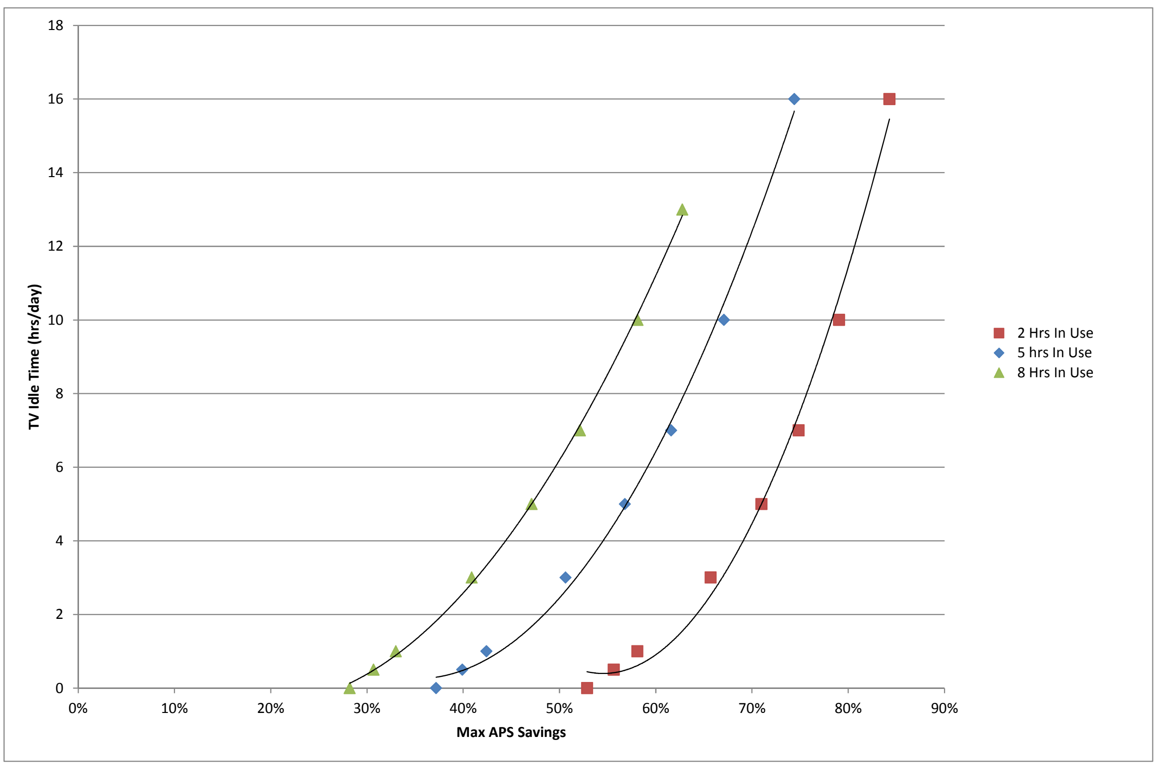
Checking of Savings Ranges

To validate field trial results for each site, data was entered in the spreadsheet to check the range of savings and average savings for the whole field trial. Each site was entered individually; spreadsheet calculations then sum and average the inputs to calculate the average savings. To check if the savings were within the boundary of maximum savings, the spreadsheet plotted the savings percentage of the APS device in terms of the hours of idle (AV) or in use time (IT).

The checking of the savings ranges compared the field trial results with the relationship between the maximum possible energy savings and the assumed usage of the controlled equipment. A simple master/slave APS will save energy of the controlled appliances when the master device (typically the TV) is switched off (or Passive mode). The controlled equipment is most likely to be in passive or idle mode and the savings will be determined by the number of controlled appliances and the magnitude of power use in passive and idle mode for the controlled equipment. The likely total load controlled will be in the range of 20 to 70 Watts. A more advanced APS will control the TV and is likely to be addressing the potential savings of TV idle mode, which will then provide the majority of the savings (TV power consumption is in the range of 100 to 300 Watts). Therefore the key variable to check in a field trial is the representativeness of the idle mode savings of the TV or the savings that have resulted from the APS turning off all controlled equipment (including the TV) when the TV is not in-use.

To illustrate the relationship, Figure 4 shows the maximum savings possible from an APS when it has controlled a TV and additional devices, compared to the amount of idle time of the TV. The maximum savings also vary depending on the amount of time the TV is in use, with each curved line representing either 8, 5 or 2 hours of TV use per day. The actual savings of the APS will depend on the control strategy and the equipment usage characteristics of the field trial participants.

Figure 4. Relationship between Max Savings and TV Idle Time over a Range of In-use times



Source: Calculated from the appliances typically used in the average Victorian household (ESC 2011, unpublished)

Adjusting Field Trial Results

If results of a field trial have provided average values of savings that are above the maximum possible savings or shown the vast majority of household behavior is outside the expected normal range, the ESC may need to adjust the results or request further field trial data.

Adjustment of the results may be undertaken however, this requires careful analysis of the field trial sites to determine if above or below average behavior has caused the abnormal result. Alternatively, the APS control strategy can affect the savings and also produce abnormal results. If the control strategy of the APS is very aggressive, in terms of rapidly turning off controlled devices when end users are not present in the room (either by sensing occupancy or remote control signals), the field trial may produce results that are not deliverable in practice. Analysis of the additional week of monitoring data that is currently optional in the field trial may establish if the APS controller is being used as intended by the end users or if the end users have adjusted their behavior due to the APS operating. This may show that end users have either: (1) removed controlled loads that were not suitable for connection to the APS; or (2) signaled to the APS that they require the controlled devices to be on when the APS was attempting to turn them off.

Calculate and Apply Average Savings of APS to Standardized Household

The average savings of the APS are calculated by summing the total energy savings and dividing this figure by the sum of the baseline energy savings for all the valid field trial sites. This value is then multiplied by the average energy consumption of the controlled loads for the AV and IT Standardized house. For the AV environment, the average controlled load for the standardized house is 1060 kWh pa. The other key variable for input to the normalization process is the approximate number of APSs that will be installed per house. This calculation of this figure for Victorian houses can be based on the following constraints:

- the maximum number of APSs per house allowed under the regulations (4 per house)
- the minimum number of controlled loads per APS (2 controlled devices per APS)
- the types of devices recommended for connection to the APS
- the presence of these devices in the one location for each APS.

Calculate 10 year Average Savings and VEET Certificates

After undertaking field trials and standardizing data, the final step is to adjust the average savings according to changes in the appliance stock due to market factors and government regulations. The values of savings are adjusted by the various external market factors. In the AV environment in Victoria, the following factors will affect the projected energy savings over the next decade:

- MEPS for TVs, introduced in 2009 and planned to be increased to 4 stars in 2012, which lowers the available savings
- Standby Power regulations which are planned to be implemented in 2013
- Increased screen size of TVs, which will most likely increase the average power consumption.

These factors were included in the projected energy consumption found in the various Regulatory Impact Statements (RIS) reports for these products. The change in projected energy consumption under the BAU and MEPS case was calculated and applied to the relevant share of total energy savings for the AV controlled devices. Similar calculations were applied in the IT environment.

The final calculation of the number of VEET certifications is the application of the emission factors for Victorian electricity to the calculated 10 year lifetime energy savings. The average Victorian marginal emission factor used for this calculation is 0.963 kg CO2-e /kWh over the forecast 10 year period. The ESC has so far approved 8 APS products for the AV environment, and 6 APS products for the IT environment. The most energy efficient products in the AV environment have been awarded between 3 and 4 VEECs, and just over 2 VEECs in the IT environment.

Discussion

The combination of the field trial and the subsequent normalization of the results to the local or regional characteristics, provide some guidance on the potential savings of APS in a standardized format. The approach is relatively low cost to implement and provides a reasonable estimate of the energy savings that might be achieved without interfering with the householder's behavior. As the analysis uses the proportion of energy savings rather than the absolute savings, some of the variations in savings due to equipment characteristics are reduced. However the energy savings of the APS are highly dependent on the device functionality and the household usage characteristics.

There are legitimate concerns that the sample of 20 households may not be sufficient to represent the range of behaviors in a community. Use of TVs and other appliances varies significantly between households and it would require a sample of 300 households to provide a greater level of confidence. As the ESC collects more field trial data, the average variation in usage can be determined. Current data suggests that variations in TV usage are wide (from 1 to 10 hours per day) with an average of approximately 4.5 hours use per day. The amount of time a TV is idle (or inadvertently left in-use) ranges from 0.5 to 16 hours per day, with an average of approximately 3 hours per day. Other equipment can be left in idle mode for much longer, such as AV receivers, DVDs or STBs. As these modes provide the majority of savings for IR sensing type APS, future surveys of the presence of idle modes will assist with refining methodologies for assessing APS savings.

Another area of potential variation within the field trials is very high standby power, as the proportion APS savings are increased if the controlled devices have unusually high standby power usage. This can be checked and corrected if abnormal levels of standby power are noticed in the field trial.

Further analysis and development is recommended to reduce the reliance on field trial results for calculating the potential energy savings of APS. An ideal methodology would involve the testing of the APS in a laboratory to determine the functional characteristics and control parameters, and to then apply these characteristics to a defined usage and equipment profile(s). The profile would include high and low idle usage of the AV/IT equipment coupled with different power use. The profile could be constructed from surveys of household AV and IT equipment and usage and may vary with regions. For instance, in regions with higher penetration or ownership of AV equipment the equipment power consumption would be higher as would the standby power. In regions with a greater proportion of older householders and young families, the use of TV is likely to higher and similarly, the time a TV and other AV equipment is spent in idle mode.

Once a framework for testing and measuring the functionality of APS is developed, a labeling program or endorsement (such as the ENERGY STAR) program could be applied. The information on the label would provide consumers with comparative information on the potential savings from alternative APS and could be used for defining incentives or certificates in energy efficiency programs. There is still merit in conducting field trials of an APS to confirm savings are actually achievable and to check the usability of a device in households. The current optional third week of the field trial, where the device is operated as installed, could become mandatory and information collected to examine user reactions, operation issues and behavior changes.

Conclusion

The APS is a new energy savings device that can provide savings of up to 50% of AV and IT energy use in households. A laboratory test, field trial and normalization methodology can be applied to determine the potential savings of these devices without significant costs. The approach can be customized for various countries or regions, according to energy end-use equipment characteristics and household behavior. Further analysis and development of a methodology for testing the functionality and control characteristics of APS is recommended to create a more robust and repeatable savings estimate. Once this methodology is established, a labeling or endorsement program could be applied and assist with the inclusion of APS devices in energy efficiency programs.

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