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Field data collection of miscellaneous electrical loads in Northern California: Initial results

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Abstract

This report describes efforts to measure energy use of miscellaneous electrical loads (MELs) in 880 San Francisco Bay Area homes during the summer of 2012. Ten regions were selected for metering: Antioch, Berkeley, Fremont, Livermore, Marin County (San Rafael, Novato, Fairfax, and Mill Valley), Oakland/Emeryville, Pleasanton, Richmond, San Leandro, and Union City. The project focused on three major categories of devices: entertainment (game consoles, set-top boxes, televisions and video players), home office (computers, monitors and network equipment), and kitchen plug-loads (coffee/espresso makers, microwave ovens/toaster ovens/toasters, rice/slow cookers and wine chillers). These categories were important to meter because they either dominated the estimated overall energy use of MELs, are rapidly changing, or there are very little energy consumption data published. A total of 1,176 energy meters and 143 other sensors were deployed, and 90% of these meters and sensors were retrieved. After data cleaning, we obtained 711 valid device energy use measurements, which were used to estimate, for a number of device subcategories, the average time spent in high power, low power and "off" modes, the average energy use in each mode, and the average overall energy use. Consistent with observations made in previous studies, we find on average that information technology (IT) devices (home entertainment and home office equipment)

consume more energy (15.0 and 13.0 W, respectively) than non-IT devices (kitchen plug-loads; 4.9 W). Opportunities for energy savings were identified in almost every device category, based on the time spent in various modes and/or the power levels consumed in those modes. Future reports will analyze the collected data in detail by device category and compare results to those obtained from prior studies.

Introduction

Consumer electronics and non-appliance plug loads (collectively referred to as miscellaneous electrical loads or "MELs") constitute an important and increasing share of U.S. residential building electricity consumption. The number of individual devices used in a typical household is increasing. Moreover, consumer electronics rapidly evolve to include a wide array of new features and functions, which often impact power consumption (both increasing and decreasing). As a result, the energy use of MELs has received increased attention in recent years. Unfortunately, due to rapid product evolution, studies often become outdated very quickly. Up-to-date information on the energy use of MELs is therefore limited in the literature, as compared to traditional end-uses such as white goods (*e.g.*, refrigerators, clothes washers) and HVAC equipment (heating, ventilation, and air conditioning).

To address this data gap, Lawrence Berkeley National Laboratory (LBNL), in collaboration with Rising Sun Energy Center[1] (hereafter referred to as Rising Sun) in Berkeley, CA, launched a new field-metering project in conjunction with Rising Sun's free energy audit program known as the Green House Call. The project's goal was to collect in-field data on residential electricity consumption of various MELs commonly found in homes, which would result in the provision of state-of-the-art information on the actual usage pattern and energy efficiency of various consumer electronics and MELs currently available in the market.

Ten regions—all located in the San Francisco Bay Area—were selected for this study. A team of Energy Specialists from Rising Sun visited and surveyed homes within each region. Upon receiving a written consent from an adult occupant, the specialists installed one or more energy meters on selected devices. For some types of devices occupancy sensors or temperature sensors were installed in addition to the meters. Meters and sensors were installed between July 2nd and August 4th, 2012. The equipment was left in the field for a length of time between three and ten (or more) weeks, and all equipment was retrieved no later than November 4, 2012.[2] A total of 880 homes were metered with at least one device, and a total of 1,176 energy meters and 143 other sensors were installed.

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[1] http://www.risingsunenergy.org

[2] The exception to this is 138 meters and sensors that were either lost during the metering period, or were never recovered despite repeated attempts to contact the occupants.

This report describes in detail the project's planning, deployment, data collection, and preliminary data analysis phases. Subsequent reports will be published analyzing, in detail, the energy consumption and usage patterns of individual devices or device categories.

Background

Residential building energy use has been historically dominated by a few end-use categories. These include space conditioning, water heating, lighting, and major domestic appliances. Other plug-load devices, or MELs, have until recently constituted a relatively small share of total energy use. However, with the proliferation of consumer electronic devices, as well as the increased functionality and capacity of these devices, MELs now consume a significant and increasing share of residential electricity (EIA 2012, IEA 2009). The latest full release of the *Annual Energy Outlook* estimates that MELs constitute nearly 30% of residential electricity consumption, with computers, televisions, and set-top boxes alone consuming 10% of residential electricity (EIA 2012). This is confirmed with some recent field-metering studies that suggest total MELs consume 15-30% of residential electricity, with half coming from consumer electronic devices (*e.g.*, Bensch 2010). However, this share is rapidly changing as consumer electronic devices continue to evolve.

For national energy analysts and building energy researchers, MELs are difficult to quantify given that the baseline electricity use keeps changing. The literature contains some studies of total electricity consumption of MELs both in the residential and commercial sectors (see references below), but these studies are often limited in scope and become outdated very quickly. The diversity of MELs continues to hamper a thorough systematic study of total MEL electricity usage. One consistent general theme of these studies, however, is that information technology (IT) devices disproportionately consume more electricity than other MELs. The studies also tend to identify more energy savings opportunities in IT devices than in other types of MELs, such as better power management settings, improved power supplies, and in some cases more efficient components (*e.g.*, the backlight in monitors and televisions).

Several techniques have been utilized to estimate total MELs electricity usage, both in residential and commercial spaces:

1. Individual device metering (*e.g.*, Cheung et al. 2012, Mercier & Moorefield 2011, Moorefield & Calwell 2011, Bensch et al. 2010, Meier et al. 2008, Porter et al. 2006, Nordman & McMahon 2004, McWhinney et al. 2004),
2. Representative surveys (*e.g.*, Strack 2012, EIA 2009),
3. Bottom-up stock estimation (*e.g.*, Lanzisera et al. 2012, Desroches & Garbesi 2011, Sanchez et al. 2007), or
4. Combinations of approaches (*e.g.*, Urban et al. 2011, Roth & McKenney 2007, Roth et al. 2006, Rosen et al. 2000).

Other techniques such as branch-circuit monitoring and non-intrusive load monitoring are a poor fit for studying MELs, given the variety of devices and electronic signatures (Cheung et al. 2012). In general, device metering is the most accurate method for gathering electricity consumption data, but it can be very costly, logistically challenging, and time-consuming to deploy. As a result, only some of the existing studies on MELs use field-metered data.

The field metering activity described in this report was a result of collaboration between LBNL and Rising Sun, a local non-profit organization who contracted with LBNL. Rising Sun provides green workforce development training and employment, offers low-to-no cost residential retrofits and services that lower energy and water usage, and provides education on sustainable behaviors and technologies. Contracting with an energy services organization such as Rising Sun addressed many of the logistical challenges normally associated with a large field metering activity. Given that Energy Specialists had already identified homes to target for performing energy audits, the incremental effort needed to deploy a few meters per home was small. Rising Sun staff members were already interested in energy issues, and the existing network and management structure allowed the project to collect a large amount of data relatively quickly. In addition, Rising Sun's service area in northern California is large, enabling the inclusion of a wide range of demographics in the study.

The project focused on three major categories of devices: entertainment (*e.g.,* televisions, video players), home office (*e.g.*, computers, network equipment), and kitchen plug-loads (*e.g.*, microwave ovens, coffeemakers). These categories either dominate the estimated overall energy use of MELs, are rapidly changing, or there are very little data published on their energy consumption. A preliminary analysis of data collected in each device category is presented in the Results and Discussion sections.

Methodology

Framework of the field study effort

A flowchart of the field data collection process is presented below in Figure 1.

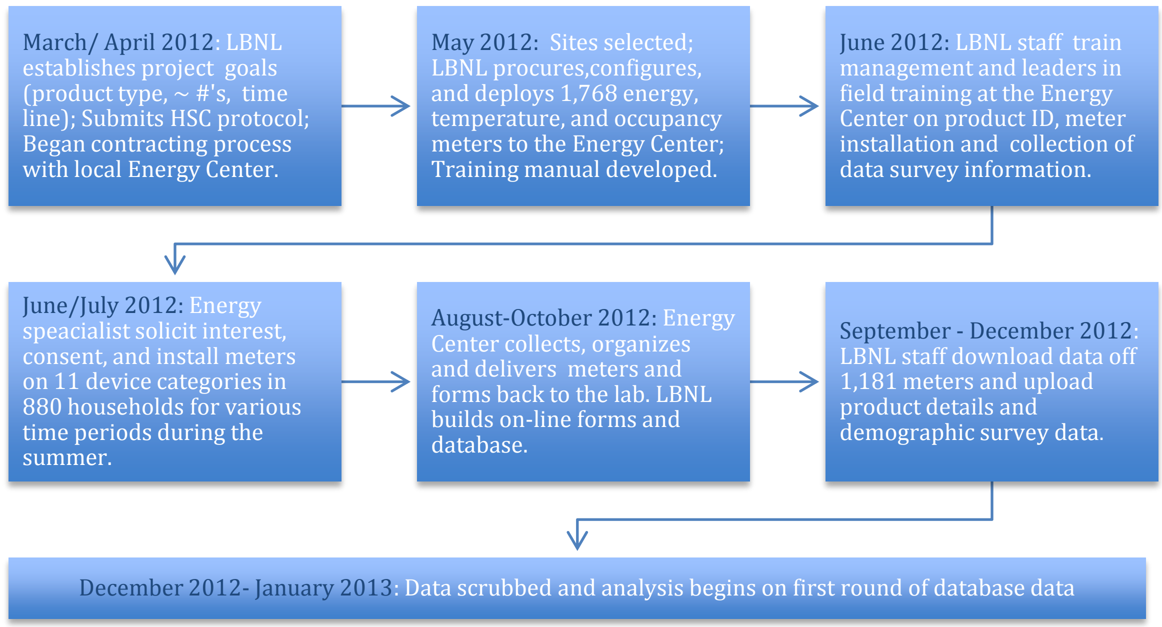

Figure 1. Flow chart of field data collection process

Device Descriptions

Eleven different categories of devices were metered for this study. A description of each device category is found below.

<u>Coffeemakers/Espresso Machines:</u> Devices include drip (brewed) coffeemakers and espresso machines (with and without additional features such as steam, drip coffee or all-in-one/automatic coffee beverage machines). Standalone coffee grinders were not included unless they were part of an automatic coffee beverage machine. A typical drip coffeemaker contains a reservoir that holds water at the start of the cycle. The water is heated up by elements at the base and carried to the top of the drip area via a tube. The water is sprayed over the coffee grounds, and picks up their oil essence on the way down into the coffee pot. A simple espresso machine forces water through the coffee grounds, using pressure that comes from heating water inside a sealed container. The coffee is packed into a funnel-shaped piece of metal that has a tube extending to the bottom of the reservoir. The pressure forces the hot water up through the tube and into a serving cup.

<u>Computers:</u> Computers consist of both laptop (portable) and desktop machines, which commonly run one of three operating systems: Microsoft Windows (Vista, etc.), Apple Macintosh (OS X Lion, etc.) or Linux. All were considered for energy metering. Laptop computers were metered so long as the meter remained plugged into a dedicated outlet and the majority of the time the computer was charged at this location. Devices similar to computers that were not metered included: tablet computers (Apple iPad, Samsung Galaxy Note), eBook readers (Amazon Kindle, Barnes and Noble Nook), smart phones (Android,

iPhone, Blackberry), music players (iPod, MP3 players) or other similar portable electronic devices.

Game Consoles: These devices process interactive video images from cartridges, optical media, and data storage systems that can be displayed on a connected TV or monitor. The latest generation of game consoles have built-in capabilities to connect to the internet which allows players to download and play online games and connect with other players on the internet, as well as stream audio/video materials online. They also include support of new disc formats such as DVD and Blu-Ray. Due to its expanded use, a game console is sometimes considered to be a home entertainment network device. Nintendo and the Sony Playstation are some examples of gaming consoles commonly found in homes. Only game consoles that were connected to a TV were metered.

Microwaves Ovens/Toaster Ovens/Toasters: A microwave oven uses microwaves (electromagnetic energy at a frequency of roughly 2.5 gigahertz) to heat food. A variant of the microwave oven is the convection microwave oven. This type is a combination of a standard microwave oven and a convection oven that allows pre-heating like a typical convection oven (so for instance would allow for baking). Toaster ovens have fast warm-up infrared heating elements at the top and bottom of the oven cavity and have one or two racks. Models are available with convection heat or radiant heat. With convection heat, a fan continually forces the heated air to move around, promoting more even toasting. Radiant heat relies on natural air currents to heat the food. A toaster is a small electric kitchen appliance designed to toast bread products.

Monitors: Monitors are display devices similar to TVs (see below) that are connected to computers (both desktop and laptop). They differ from TVs in that they do not contain tuners. However, any display device (including TVs) that was normally connected to a computer was considered a monitor for our purposes, and was metered.

Network Equipment: These devices comprise the elements of a home data network, which is an electronic communications system linking all devices to the Internet and to each other. A home data network can utilize both wired and wireless technologies, connecting devices to a central point called a hub or switch. In this way, the devices can communicate with each other. Some of these devices could also function as an entertainment hub (see set-top box). Examples include a DSL modem and a wireless router.

Rice Cookers/Slow Cookers: These devices consist of an enclosed volume (typically several quarts) with a lid, electric heating element, and usually a timer. Some are dedicated to cooking rice, while others are versatile electric cooking devices. The main component of an electric rice cooker is the heating element at the base. When in use, a thermostat controls the temperature of this element. The thermostat is placed on top of a spring that is pushed down when the aluminum rice container is placed inside the cooker. During cooking, the rice and water mixture is heated to a temperature of 212°F (boiling point). At the end of the cooking cycle, all the water has been absorbed by the rice. Most rice cookers then switch to low-power mode, keeping the rice warm at a temperature of 150°F. Slow cookers use a similar heating principal; the main differences are in the cooking pot material, typically made of ceramic or porcelain; and the cooking temperature, usually in the range of 160-200°F. A slow cooker can take up to 4-8 hours to cook depending on the type of food.

Set-Top Boxes (STBs): These are devices that connect to a TV and their main function is to allow one to receive video content from a television service provider (e.g., Comcast, DirecTV, AT&T U-Verse) and/or the internet (e.g., Netflix, Hulu, iTunes). STBs associated with television service providers are called pay-TV STBs, and include cable STBs (e.g., from Comcast), satellite STBs (e.g., from DirecTV), and Internet-based pay-TV STBs (e.g., from AT&T U-Verse). Internet-based pay-TV is known as IPTV. A standalone DVR (digital video recorder), such as a TiVo, is also considered a cable STB. In addition, there are STBs that do not require a television subscription, but merely access content available online (e.g., from Netflix, Hulu, iTunes). These STBs are known as streaming STBs (e.g., Boxee, Roku, Vudu, AppleTV). All of these STB were considered for energy metering so long as they were connected to the TV and easily accessible for connection. Other devices that can perform some of the above functions, but are not primarily designed for that purpose (e.g. Blu-Ray players, game consoles, Smart TVs), were not considered STBs.

Televisions (TVs): TVs are display devices that contain a tuner. TVs were only metered if they were attached to a game console, set-top box or DVD/Blu-Ray player, or part of the latest generation of TVs that have an integrated DVD or Blu-Ray player built-in. As noted above under Monitors, TVs connected to computers were considered to be Monitors, and metered as such.

Video Players: These are devices that play compatible discs that store high quality video and audio information. These disc players are connected to a TV to display the output signals. Both DVD and Blu-Ray format players were included, as well as DVD/VCR combination devices; however, standalone VCRs were excluded due to the outdated nature of the technology. It is easy to confuse video players with digital video recorders (DVRs), which function as a set-top box. Some manufacturers have produced portable disc players, which come with small screens for viewing; these players can also be operated on battery power. We did not meter portable disc players, but only devices connected to a TV.

Wine Chillers: Also known as wine coolers, beverage coolers or beverage centers, these are special types of refrigeration devices designed to cool non-perishable goods, mainly liquids (such as wine), at 39° to 65°F. They are not designed like normal refrigerators to safely store perishable foods. This study did not include refrigerators or freezers that have a special wine/beverage cooler compartment, only dedicated wine chiller devices.

Equipment/Instrumentation

Meter Selection

Figure 2 shows the variety of equipment used in the metering effort.

Figure 2. Equipment used in metering effort. From L to R: WattsUp energy meter, Kill-a-Watt energy meter, HOBO occupancy sensor, Thermochron iButton temperature sensor

A description of each meter follows.

WattsUp?.NET meters : We chose to use Think Tank Energy Products WattsUp?.NET meters (hereafter "WattsUp")[3] to measure electric power consumption of all of the above types of MELs. As soon as the WattsUp meters are connected to a power supply, they are able to log the energy data continuously with resolution of up to 1 second, however, for this project a 2-minute time interval was used. Although these meters were not used for their .NET capabilities (ethernet port for downloading data in real time) in this study, they were selected for the following reasons:

- Commonly-used meter for field measurement of plug-in device energy consumption (used by other organizations such as ECOVA and Energy Center of Wisconsin)
- Improvements in meter design, particularly in overcoming calibration corruption problems experienced with earlier versions of the meter (WattsUp Pro and WattsUp Pro ES).
- The only portable handheld meter able to record and produce the amount and quality of data we needed at an affordable price (~$200 per meter).
- We had used earlier versions of WattsUp meters for small-scale projects and were generally satisfied with the results.

Kill-a-Watt meters: We also used inexpensive (~$20 per meter) P3 International Kill-a-Watt meters[4] to measure cumulative energy consumption on certain types of devices when the WattsUp meters were in short supply at particular sites. Unlike the WattsUp meters, the Kill-a-Watt meters were only capable of recording a single pair of data points (total cumulative energy use in kilowatt-hours and total elapsed time) over the entire period of monitoring. Hence, the Kill-a-Watt meters were only deployed for devices whose energy consumption was expected to be relatively constant, such as game consoles, network equipment, set-top boxes and wine chillers.

Hobo data-loggers/sensors: Onset Hobo data-loggers/sensors[5] were selected to meter occupancy movement corresponding to television and computer use. The sensor is a pyro-

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[3] https://www.wattsupmeters.com/secure/products.php?pn=0
[4] http://www.p3international.com/products/p4460.html
[5] http://www.onsetcomp.com/products/data-loggers/ux90-005

electric infrared sensor that detects movements by an object that has a different temperature than the surrounding area. This sensor monitored room occupancy up to 15 ft. from the meter. The recorded time interval was 2 minutes, matching that of the WattsUp meters. Hobo occupancy sensors were about as expensive as WattsUp meters (~$200 each).

iButton Thermochron temperature sensors: To measure temperature inside and outside of the wine chillers, Maxim iButton Thermochron temperature sensors[6] were selected due to their small size and affordable price (less than $20 each). The iButton is a computer chip enclosed in a 16mm thick stainless steel enclosure. An additional thermal wire probe is embedded in the iButton to measure and record the surrounding temperature. Due to limited memory capacity in the iButton, a 1-hour time interval was chosen for metering.

Meter and Sensor Preparation

A total of 1,111 WattsUp energy meters, 201 Kill-A-Watt energy meters, 296 occupancy sensors, and 160 temperature sensors were labeled, scanned, configured with the specified time-interval provided in previous section, and packed by a dedicated team of LBNL staff for deployment to Rising Sun.

The WattsUp meters were new and factory-calibrated. Each meter was prepared for field data collection by connecting it to a computer via USB cable. A utility driver for com port detection and WattsUp meter configuration software was installed on multiple computers. To expedite and standardize the configuration process, we developed a script to allow research personnel to configure more than one meter simultaneously.

The Hoboware Pro software was used to configure the occupancy sensors.[7] Another software (1-Wire Driver) was used to set up the iButtons.[8] No preparation of the Kill-a-Watt meters was required prior to field deployment. Except for the iButtons, all instruments were set to start logging when used at the sites. According to the pre-set logging duration, and until they were collected from the field, all data was stored within each device for later downloading at LBNL.

Experience with previous field metering studies suggests that for non-seasonal loads, a sampling time of approximately 2 months is the right balance between accuracy and intrusiveness of the meters. Additionally, a 1-min. sampling resolution is appropriate for the majority of MELs (Cheung et al. 2012). Our logistical and meter memory constraints limited deployment to an average of six weeks[9] with a 2-minute sampling resolution, which was reasonably close to the above recommendations suggested for high-quality data collection.

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[6] http://datasheets.maximintegrated.com/en/ds/DS1921G.pdf
[7] http://www.onsetcomp.com/node/5387/done?sid=21011
[8] http://www.maximic.com/products/ibutton/software/tmex/index.cfm
[9] The memory capacity of the meters actually enabled up to 10.4 weeks of data collection with a 2-minute sample interval.

We labeled every energy meter and occupancy sensor with a unique Quick Response two-dimensional bar code (QR code). We also attached some labels on the energy meters containing LBNL logo, contact information, and a section for writing start and stop times in the event of power outages. Once all the meters and sensors were fully prepared for deployment, they were inventoried and packaged for deployment to their designated sites. More details on deployment can be found in the next section.

Deployment and Monitoring

Contractor: Rising Sun Green House Calls

We contracted with Rising Sun to implement the field data collection. This process was carried out in conjunction with their California Youth Energy Services (CYES) program, which is a seven-week summer program that provides green jobs and green job training to adults and youth (ages 15-22) in the energy efficiency field. Through community marketing and outreach techniques, as well as partnerships with local utility, water district and management companies, the CYES "Energy Specialists"—a term used for the youths under training—offer and perform "Green House Calls" to homes throughout the San Francisco Bay Area. Each home undergoes an efficiency audit, and then, if applicable, is offered free water and energy savings equipment installations along with further guidance on other savings. While conducting the audit, the Energy Specialists solicit further interest from the home occupant(s) in measuring power usage of a select number of MELs during the summer months.

Deployment Site

The selection of deployment regions was limited to areas where the CYES program was conducted. Ten Bay Area sites participated in the program during the summer of 2012: Antioch, Berkeley, Fremont, Livermore, Marin County (San Rafael, Novato, Fairfax, and Mill Valley), Oakland/Emeryville, Pleasanton, Richmond, San Leandro, and Union City. See map below.

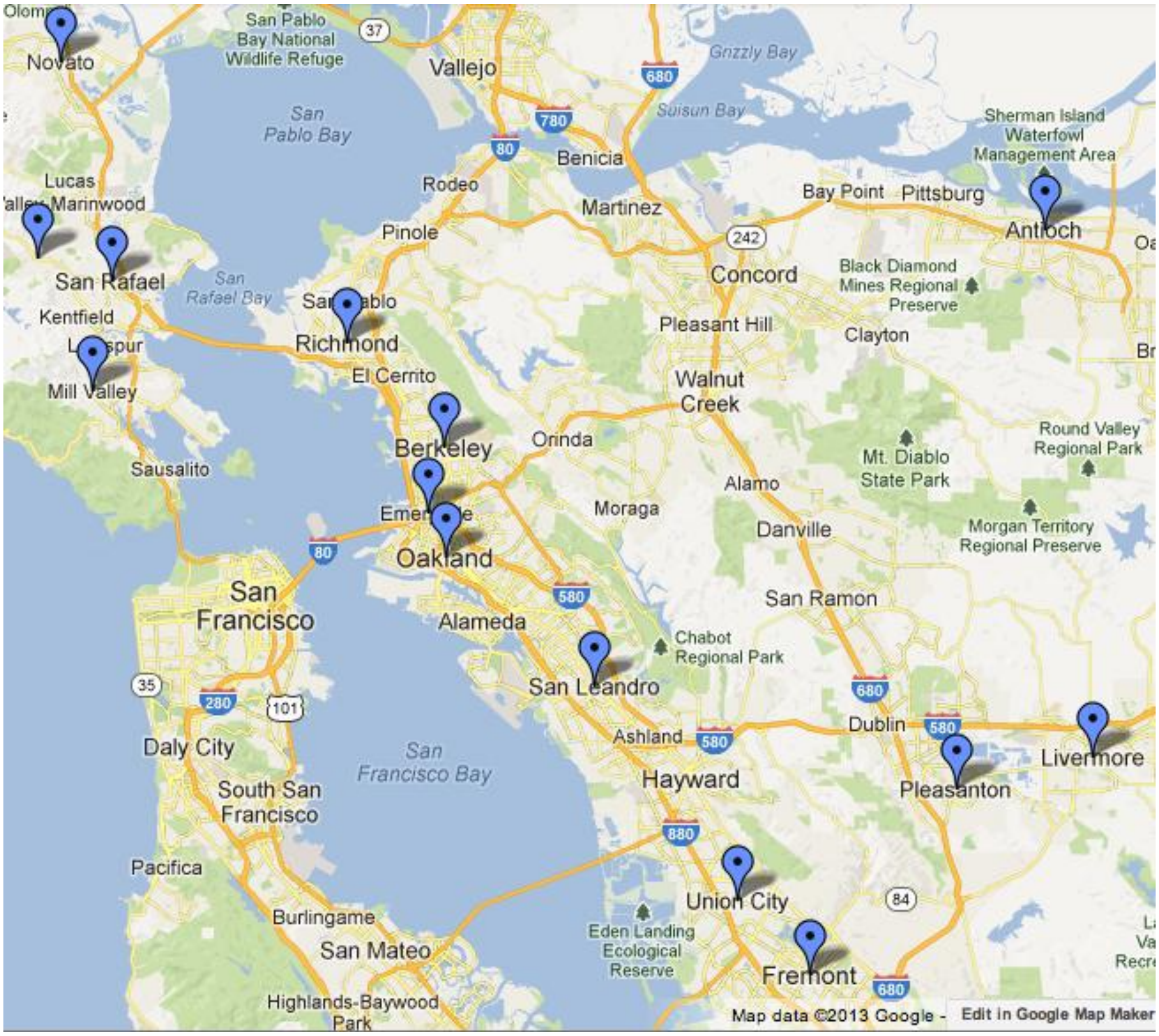

Figure 3. Locations of cities participating in metering study

Cities/municipalities were selected through a request for quotation process administered through the CYES program, which makes its final decisions based on matches to target populations (hard-to-reach residents), in-kind and financial support, and past successful partnerships. Each participating site then established a satellite office where selected Site Managers (2-3), youth Leaders in Field Training ("LIFTs") (1-2), and Energy Specialists (8-12) were assigned. The metering efforts were mostly coordinated by the Site Managers, who also kept track of the daily progress and submitted a weekly report to the main office. The Energy Specialists and LIFTs visited the homes in each site using client lists, which were generated before the start of the summer program. The appointment dates and times were prescheduled for the energy audits.

Training Process

We met and coordinated the training effort with Rising Sun's Program Director and Coordinator. We then scheduled a group training session with the Director's on-site

(Berkeley) team and the LIFTs, who in turn trained the Site Managers and Energy Specialists at the site offices. The training focused on the use and installation of the meters and on the identification and selection of devices for metering. To facilitate this training, LBNL researchers prepared a manual describing the devices, meters, and installation process in detail, along with a sample of the datasheets (Appendices A and B) and the consent form, as well as a one-page checklist for on-site use (Appendix C).

Table 1 summarizes the field metering plan for distribution of devices based on two groups (A and B) of the selected sites. Group A consisted of five sites (Fremont, Livermore, Pleasanton, San Leandro and Union City) whose Energy Specialists and LIFTs were trained to meter roughly one-half of the types of devices, while Group B consisted of the other five sites (Antioch, Berkeley, Marin County, Oakland and Richmond) whose Energy Specialists and LIFTs were trained to meter the other half of the device types. Note that wine chillers, due to their relative scarcity in homes, were monitored by both groups; see Table 1. By dividing the metered devices this way, the amount of information that the field teams had to remember was minimized, allowing for more efficient operation. The CYES program targeted over 3,000 homes in the 10 designated areas (approximately 300 homes per site).[10] Through a combination of funding and staffing limitations and an expectation that less than 30% of homes would participate in the LBNL program, LBNL set a goal of installing meters in 960 homes, or 96 homes per site.

[10] In total, Rising Sun visited 3,239 homes during the summer 2012 effort.

Table 1. Number of meters and sensors prepared for deployment by meter/sensor type, Group (A and B) and device type

	METER/SENSOR TYPE											
	WattsUp Meter			Kill-A-Watt Meter			Occupancy Sensor			Temperature Sensor		
DEVICE	**Group A**	**Group B**	**Total**	**Group A**	**Group B**	**Total**	**Group A**	**Group B**	**Total**	**Group A**	**Group B**	**Total**
Wine Chillers	40	40	80	20	-	20	-	-	-	80	80	160
Game Consoles	190	-	190	60	-	60	-	-	-	-	-	-
Set-top Boxes	50	-	50	50	-	50	-	-	-	-	-	-
Video Players	90	-	90	-	-	-	-	-	-	-	-	-
Televisions	180	-	180	-	-	-	100	-	100	-	-	-
Network Equipment	50	-	50	50	20	70	-	-	-	-	-	-
Computers	-	190	190	-	-	-	-	100	100	-	-	-
Monitors	-	95	95	-	-	-	-	100	100	-	-	-
Microwave Ovens, Toaster Ovens, Toasters	-	100	100	-	-	-	-	-	-	-	-	-
Coffee/Espresso Makers	-	50	50	-	-	-	-	-	-	-	-	-
Rice/Slow Cookers	-	50	50	-	-	-	-	-	-	-	-	-
TOTAL	**600**	**525**	**1,125**	**180**	**20**	**200**	**100**	**200**	**300**	**80**	**80**	**160**
PER SITE	**120**	**105**	**-**	**36**	**4**	**-**	**20**	**40**	**-**	**15**	**15**	**15**

Note: The numbers of meters/sensors shown in this table do not match precisely with the total numbers presented earlier (Meter and Sensor Preparation section), due to slight changes in availability during preparation.

Beginning on July 2nd, 2012, Energy Specialists/LIFTs from both Group A and Group B visited homes that had been pre-selected for energy audits. During this visit occupants were presented with an LBNL program flyer and asked if they were interested in participating in the field metering effort. If the occupants agreed and gave consent to the metering effort[11], the Energy Specialists/LIFTs performed a walkthrough and identified devices based on the priority order shown in Figure 4 for Group A and Figure 5 for Group B until the target number of devices was reached. It should be reiterated that, in both groups, wine chillers were the first device type that the Energy Specialists/LIFTs were looking for. A maximum of three devices were targeted for each home.

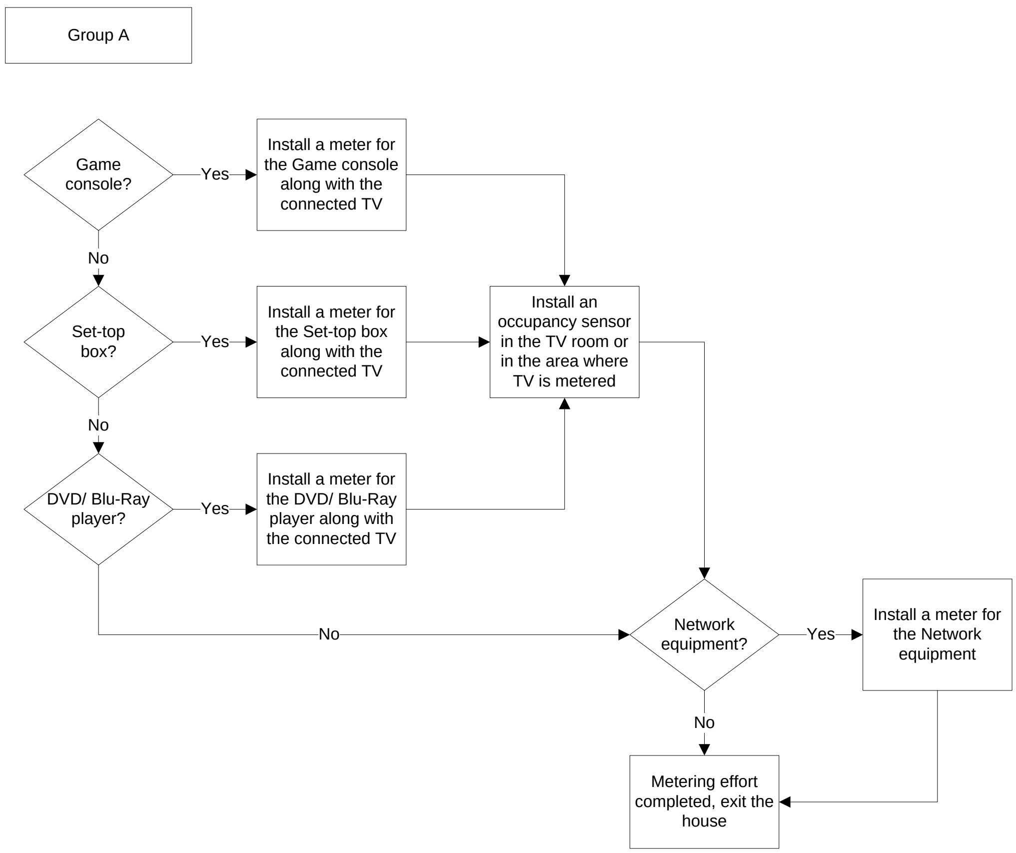

Figure 4. Logic diagram for Group A meter deployment

[11] The occupant was provided with a consent form approved by the LBNL Human Subjects Institutional Review Board (IRB). The Energy Specialist/LIFT was required to obtain a signed consent form before conducting any metering activities.

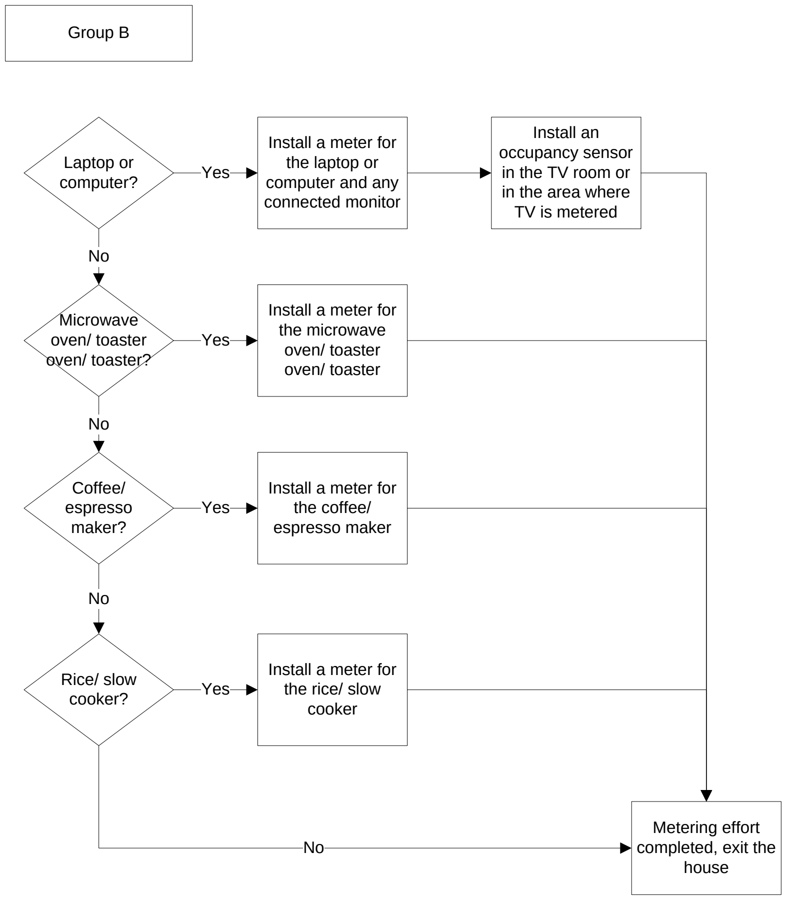

Figure 5. Logic diagram for Group B meter deployment.

After conducting their walk-through, the Energy Specialists/LIFTs discussed the identified devices for metering with the occupant. The Energy Specialists/LIFTs also reviewed with the occupants a checklist of "do's and dont's," the anticipated schedule for meter retrieval, where to record power outages, and whom to contact if they had questions (an email address and telephone number were provided on the meters). During and after installation, information concerning the devices, meter IDs, and household demographics was recorded on a data sheet. All devices were metered for a minimum of three weeks,[12] though some meters were left in the field for ten weeks or more, due to difficulties in contacting occupants for meter retrieval.

On a daily basis, the Energy Specialists/LIFTs reported back to the Site Managers with the data and consent forms. The Site Managers, in turn, reported back to the Coordinator who kept tract of the project device quotas. Both the Coordinator and Program Director at Rising Sun met with the LBNL management team on a weekly basis to report the results and discuss any issues. The dedicated email address and

[12] Although all meters were left in the field a minimum of three weeks, in some cases less than three weeks of valid data were obtained. As described in the Results section, all meters with more than one week of valid data were used in the analysis.

telephone number were checked at least weekly for messages; all inquiries were dealt with promptly.

As an incentive for the Energy Specialists/LIFTs to meet their quotas as quickly and accurately as possible, the sites competed for a dinner party offered by Rising Sun. To incentivize the home owners/renters, energy savings store certificates were provided by Rising Sun when the meters were recovered.

Meter Installation Procedures

The following section describes the specific installation procedures for each type of meter or sensor used in this study.

Energy meters (WattsUp and Kill-a-Watt): Once devices were identified and determined to be accessible and safe for metering, they were plugged into the WattsUp meters, which were in turn plugged into a wall outlet or surge protector where it would remain plugged in throughout the metering process. Once plugged in, the WattsUp meter began recording power consumption immediately. For the Kill-a-Watt meters, the process was nearly identical except that the "start" button needed to be activated to begin recording cumulative energy use.

Occupancy sensors: In the case of the televisions and computers, if in agreement with the occupants, an occupancy sensor was also placed in an appropriate location (within 15 ft. of occupants with an unobstructed view, and 4-5 ft. above floor level) and set to start recording once the LIFT/Energy Specialist activated the sensor by pressing the start button. Because the sensor detects movements by temperature change within its viewing angle, the LIFTs/Energy Specialists were also instructed not to place the sensor near or facing moving/changing heat sources other than the occupants (e.g. walls/windows exposed to solar radiation, as well as pets who might frequently occupy the space when occupants are not present).

Temperature sensors: After installing an energy meter on a wine chiller, two iButton temperature sensors were installed. To measure the internal temperature of the wine chiller, one iButton was attached on the surface inside the wine chiller unit. To measure the room temperature, a nearby wall, located away from vents of the wine chiller, was utilized. Temperature sensors were not used with any devices other than wine chillers.

For all meters, the start time, along with the meter ID was recorded immediately following installation and the start of data recording. The same applied to the stop time when the meters were collected by the Energy Specialists/LIFTs.

Retrieval and Processing

Retrieval

Beginning the week of August 6, 2012, the Site Managers, LIFTs, and Energy Specialists jointly returned to as many homes as possible to unplug and record stop times for all of the installed meters. At this point the following tasks were completed to finalize the field work process:

- Survey data forms and meter IDs were double-checked to insure accuracy;
- Occupants were queried about any issues such as power outages, and pertinent information was recorded;
- Copies of consent forms were provided to the occupants; and
- Rising Sun-supplied monetary incentives were provided to the occupants

As of September 12, 544 meters and sensors were retrieved from a total of 368 homes. The Rising Sun Coordinator and an assistant continued to contact home occupants, retrieve meters, and organize and package meters for transfer to LBNL through November 1, 2012, after which all formal Rising Sun efforts ceased.

All retrieved meters/sensors, survey data and consent forms were delivered to LBNL on a weekly basis throughout this period. LBNL employees took over the role of managing the return of any straggling meters through the use of prepaid mailers sent to responsive homes. To date, 1,181 out of 1,319 meters and sensors, or 90%, have been recovered from the metering effort. The remaining 138 meters and sensors (10%) were either lost during the metering period or have not been recovered despite multiple efforts to contact occupants. These meters and sensors have been deemed "unrecoverable," and no further attempts are being made to retrieve them, unless occupants contact LBNL directly.

Table 2 summarizes the total numbers of meters and sensors deployed in the field.

Table 2. Total meters and sensors deployed in field

	Energy meters			Sensors		Grand Total
Device	**WattsUp**	**Kill-a-Watt**	**Sub-total**	**Occupancy**	**Temperature**	
Coffee makers	59	-	59	-	-	59
Computers	90	-	90	-	-	90
Game consoles	94	81	175	-	-	175
Microwave ovens, toaster ovens & toasters	287	-	287	-	-	287
Network equipment	12	58	70	-	-	70
Rice & slow	15	-	15	-	-	15

cookers						
Set-top boxes	121	2	123	-	-	123
TVs/Monitors	212	-	212	119	-	331
Video players	127	6	133	-	-	133
Wine chillers	10	2	12	-	24	36
Totals	**1,027**	**149**	**1,176**	**119**	**24**	**1,319**

Meter Downloading and Survey Data Entry

We used the WattsUp meter software to download the data off the meters. All raw data files were saved in Microsoft Excel (.xlsx) format. To standardize the downloading process, we wrote a program to repeat the steps on a computer without operator control. To retrieve the data from the Kill-a-Watt meters, the meters were briefly plugged into a power outlet and the total energy used (kWh) and the time elapsed (hours) were read from the display and recorded on the survey data sheets. The onset software was used to download occupancy data from the HOBO sensors and loggers. The data from iButton sensors was downloaded using iButton software from Thermochron. Both HOBO and iButton files were saved in .csv format.

The datasheets were converted into online survey forms using the Adobe survey program. A team of researchers subsequently entered the responses from the datasheets. After the data entry process was completed, responses were exported into .xlsx format for checking.

Database Development

In the following description, we summarize the database created as an effort to combine the various data files into a single data source. Several scripts were written to pull the data files from several folders in the data server into the database, which was developed using MySQL. The database included information from the data sheets as well as metered data from WattsUp meters, occupancy sensors, and iButton temperature sensors. Four large data tables were created, as follows:

- *SurveyForm*: This table contains all the data entered from the survey forms for Group A and B products.[13]
- *WattsUpMeter*: This is a very large table that compiles all the power consumption data from downloaded WattsUp meters (as of October 22, 2012). This file contains the WattUp IDs (unique QR codes), wattage data, the time stamp, and the power cycle information. We have used this table as the

[13] Group A had data collected from wine chillers, game consoles, set-top boxes, video players, televisions, and network equipment. Group B had data from wine chillers, computers, monitors, microwave ovens/toaster ovens/toasters, coffee/espresso makers, and rice/slow cookers.

parent table of the database. In other words, the WattsUp IDs present in *SurveyForm* have to be present in the *WattsUpMeter* table.

- *OccupancySensor*: This has all the data from the HOBO occupancy sensors.
- *iButton*: This consists of data from iButton temperature sensors.

Several steps were taken before the database was finalized and the data was made available for analysis. We needed to link the WattsUp meter IDs and the corresponding data sheet information so that we could re-populate the time stamps of power consumption data. We also screened the WattsUp data files for outliers and power cycles that were greater than 3.[14] Because of difficulties associated with the lack of a real time clock in the meter and the irregular time taken for the meter to re-start data logging, we excluded any data associated power cycles of 3 or higher. Despite efforts to manually record the start and stop times of power outages, the current limitations of the meter prevented us from validating the time stamps. Several Python (.py) scripts were written to complete these steps.

Table 3 summarizes the number of energy meters included in the database as of November 15, 2012 and the target number of meters for each device.[15] Of note, there are some data files that were collected after the cutoff date, which were not included because of time constraints. In total there were 752 WattsUp files included in the *WattsUpMeter* table. However, there were only 717 matching WattsUp IDs in the *SurveyForm* table. The time stamps were only re-populated for these matching WattsUp IDs. See Table 3. Note that although data were retrieved from meters attached to rice and slow cookers, none of that data was available for analysis before the cutoff date. Therefore, in the Results and Discussion sections below, there is no discussion of rice and slow cooker data analysis.

Table 3. Number of energy meter records by device category in the database (used in the analysis)

Device category	Number of WattsUp meters	Number of Kill-a-Watt meters	Number of total energy meters	Targeted number of meters
Coffee/Espresso Maker	**37**	**0**	37	50
Computer	**69**	**0**	69	190
Game Console	**66**	**67**	133	250

[14] The WattsUp meter records a new "power cycle" each time power to the meter is interrupted. It is normal for meters to record up to three power cycles: the first cycle is recorded during the initial meter configuration, the second cycle is recorded during in-field metering, and the third cycle is recorded during data downloading. Additional power cycles are due to unexpected power loss from *e.g.,* service interruption or accidental disconnection by occupants.

[15] Kill-A-Watt data is included in Table 3. The information was taken from the *SurveyForm* table in the database.

Microwave Oven, Toaster Oven and Toaster	**228**	**0**	228	100
Monitor	**31**	**0**	31	95
Network Equipment	**6**	**53**	59	120
Rice/Slow Cookers*	**0**	**0**	0	50
Set-Top Box	**78**	**2**	80	100
Television	**112**	**0**	112	180
Video Player	**87**	**0**	87	90
Wine Chiller	**3**	**2**	5	100
TOTAL	**717**	**124**	841	1,325

* Although meters were retrieved from these devices, none of the data records made it into the database by the cutoff date (November 15, 2012).

Data Analysis

For this report, the main data analysis objectives were as follows:

- Report total number of valid energy consumption measurements (both WattsUp- and Kill-a-Watt-based) by device category and subcategory:
  - "Category" is defined as major device type (television, video player, etc.) and "subcategory" is defined as distinguishing characteristics among devices within a category (*e.g.,* video players device subcategories would be: Blu-Ray, DVD and DVD/VCR combination).
  - Any data record that was linked to more than one household survey form or contained less than one week of valid data was omitted from further analysis.
- For WattsUp data:
  - Categorize energy use into three modes based on power: off (0 W), low power (less than a device-specific threshold that was less than 10 W in all cases), and high power. Identify and remove any high-power outliers (described below).
  - Calculate the fraction of total time spent in each mode, and the average power level in each mode, by device category and subcategory.
- For both WattsUp and Kill-A-Watt data:
  - Calculate average energy use for each device, and aggregate by device category and subcategory.

Analysis of occupancy and temperature sensor data, as well as any more in-depth analysis of energy use data, will be dealt with in future device-specific reports.

Results

Overview

Over seven weeks, the Rising Sun team was able to serve 3,239 homes, as planned, with free energy services. Simultaneously, they successfully installed at least one meter in 880 of these homes, totaling 1,151 energy meters and 143 other sensors. 90% of these have been delivered to LBNL and processed. At a minimum the meters recorded energy consumption for the designated devices for three weeks.[16] In some cases, data were recorded for ten or more weeks (for WattsUp meters, recording was cut off after memory limits were reached at 10.4 weeks). Table 2 (shown earlier) summarizes the successful metering installations for this effort.

Numbers of devices metered

Out of the total data records recovered from the meter, 717 WattsUp and 124 Kill-a-Watt energy measurements were entered into the database and available for analysis at the time this report was written; see Table 3. Of these available records, 107 WattsUp and 23 Kill-a-Watt records were excluded either because their meter IDs appeared in more than one household survey form (making it impossible to determine which household the meter was actually installed in), contained less than one week of valid data, contained a large number of high-power "outlier" measurements, or did not contain a specified device subcategory.

In sum, we obtained clean WattsUp data records with a metering duration of at least 1 week from 610 devices, and 101 Kill-a-Watt data records from selected devices (game consoles, network equipment, STBs and wine chillers), bringing the total number of devices with energy use measurements to 711. The largest number of measurements within a device category was microwave ovens, toaster ovens & toasters (194), followed by game consoles (111), TVs (95), video players (78) and computers (57). The largest number of measurements within a device subcategory was microwave ovens (122). See Table 4.

Table 4. Count of metered devices by device category, device subcategory and meter type

Device category	Device subcategory	WattsUp	Kill-A-Watt	Total
Coffee/espresso makers	All	31	0	31
	Drip	17	0	17
	Other	7	0	7
	Unidentified	7	0	7

[16] Subsequent data processing reduced the useful portion of data from some meters, in some cases to one week or less. Records with less than one week of data were excluded from further analysis.

Computers	All	57	0	57
	Desktop	39	0	39
	Laptop	11	0	11
	Unidentified	7	0	7
Game consoles	All	57	54	111
	PS2	5	1	6
	PS3	11	19	30
	Wii	20	22	42
	Xbox360	17	12	29
	Unidentified	4	0	4
Microwave ovens, toaster ovens & toasters	All	194	0	194
	Microwave ovens	122	0	122
	Toaster ovens	20	0	20
	Toasters	40	0	40
	Unidentified	12	0	12
Monitors	All	23	0	23
Network equipment	All	5	43	48
	Modem	N/A	16	N/A
	Router	N/A	27	N/A
STBs	All	68	2	70
	Cable	44	N/A	N/A
	Satellite	11	N/A	N/A
	Other	4	N/A	N/A
	Unidentified	9	N/A	N/A
TVs	All	95	0	95
	<30"	17	0	17
	30-39"	28	0	28
	40-49"	31	0	31
	50+"	12	0	12
	Unidentified	7	0	7
Video players	All	78	0	78
	BluRay	23	0	23
	DVD	35	0	35
	DVD/VCR	17	0	17
	Unidentified	3	0	3
Wine chillers	All	2	2	4
Total		**610**	**101**	**711**

The average WattsUp metering duration across all devices was 6.0 weeks, with a minimum duration of 1.0 weeks and a maximum duration of 10.4 weeks (at which point the memory card became full). While the intended goal was to meter each device for a minimum of three weeks, a total of 68 devices, or 11%, contained less than 3 weeks' worth of clean data. With a metering interval of 2 minutes, the average number of data points recorded was 30,468, and the total number of data points recorded across all 610 WattsUp devices was 18,585,363.

Energy consumption of devices

Average hours per mode

We performed a simple mode analysis, based on the assumption that most devices spend a large portion of their time either off (e.g., 0 W power consumption), or in one or more low-power modes, with the balance of time spent in much higher-power modes.[17] With this in mind, we set an adjustable low-power mode threshold that varied between 2 and 10 W by device category based on visual inspection of the data. We found that in many cases setting this threshold was quite straightforward, with high-power modes occurring at much higher power levels than 10 W. We also identified periods of time when the device drew no power ("off").

We found that a small number of data points (0.02% of total) registered very high power levels, clustering around a common value of 3,277 W and occasionally exceeding this value (up to 4,544 W). Note that the vast majority of such "outlier" measurements came from microwave ovens (3,663 out of 3,737 total excluded data points, representing 0.1% of microwave oven measurements). As these power levels were well in excess of the expected maximum rated power of a 15 A, 125 V standard house circuit (1,875 W), we interpreted them as measurement errors and excluded them from analysis.

See Table 5 and Figure 6 for a breakdown of modes by device category and subcategory.

Table 5. Fraction of time spent in each power mode by device category and subcategory (WattsUp data only)

Device category	Device subcategory	Low-power cutoff (W)	Fraction of total time in mode			
			Off	Low	High	Outlier
Coffee/espresso makers	All	10	47.9%	50.0%	2.1%	0.0%
	Drip	10	39.7%	59.9%	0.4%	0.0%
	Other	10	65.8%	26.4%	7.8%	0.0%
	Unidentified	10	49.9%	49.7%	0.4%	0.0%

[17] While we binned data into only a single low-power and high-power mode, for many devices such as game consoles, computers and other electronic devices, each of these "modes" are in fact collections of multiple modes at slightly different power levels.

Computers	All	10	25.3%	42.8%	31.9%	0.0%
	Desktop	10	19.8%	48.1%	32.1%	0.0%
	Laptop	10	42.3%	42.1%	15.6%	0.0%
	Unidentified	10	29.4%	14.3%	56.3%	0.0%
Game consoles	All	8	34.3%	45.8%	19.9%	0.0%
	PS2	8	42.4%	55.6%	1.9%	0.0%
	PS3	8	75.6%	18.2%	6.2%	0.0%
	Wii	8	10.9%	51.5%	37.6%	0.0%
	Xbox360	8	32.0%	51.2%	16.8%	0.0%
	Unidentified	8	37.0%	58.0%	5.0%	0.0%
Microwave ovens, toaster ovens & toasters	All	Varies	40.4%	59.0%	0.5%	0.1%
	Microwave ovens	10	17.9%	81.4%	0.6%	0.1%
	Toaster ovens	10	76.0%	23.6%	0.4%	0.0%
	Toasters	10	90.8%	9.1%	0.2%	0.0%
	Unidentified	3.5	42.6%	56.9%	0.5%	0.0%
Monitors	All	6	20.9%	51.7%	27.4%	0.0%
Network equipment	All	4	0.0%	0.0%	100.0%	0.0%
STBs	All	4.5	5.2%	8.2%	86.6%	0.0%
	Cable	4.5	1.4%	9.3%	89.3%	0.0%
	Satellite	4.5	24.2%	0.0%	75.7%	0.0%
	Other	4.5	0.0%	0.0%	99.9%	0.0%
	Unidentified	4.5	2.9%	16.4%	80.7%	0.0%
TVs	All	5	52.3%	19.3%	28.4%	0.0%
	<30"	5	40.7%	32.8%	26.5%	0.0%
	30-39"	5	53.0%	19.7%	27.3%	0.0%
	40-49"	5	61.9%	8.5%	29.6%	0.0%
	50+"	5	53.8%	12.5%	33.7%	0.0%
	Unidentified	5	33.2%	44.1%	22.7%	0.0%
Video players	All	2	52.8%	15.0%	32.2%	0.0%
	BluRay	2	72.4%	13.6%	14.0%	0.0%
	DVD	2	55.4%	21.1%	23.5%	0.0%
	DVD/VCR	2	20.1%	7.0%	72.9%	0.0%
	Unidentified	2	58.7%	0.0%	41.3%	0.0%
Wine chillers	All	8	10.0%	77.6%	12.4%	0.0%

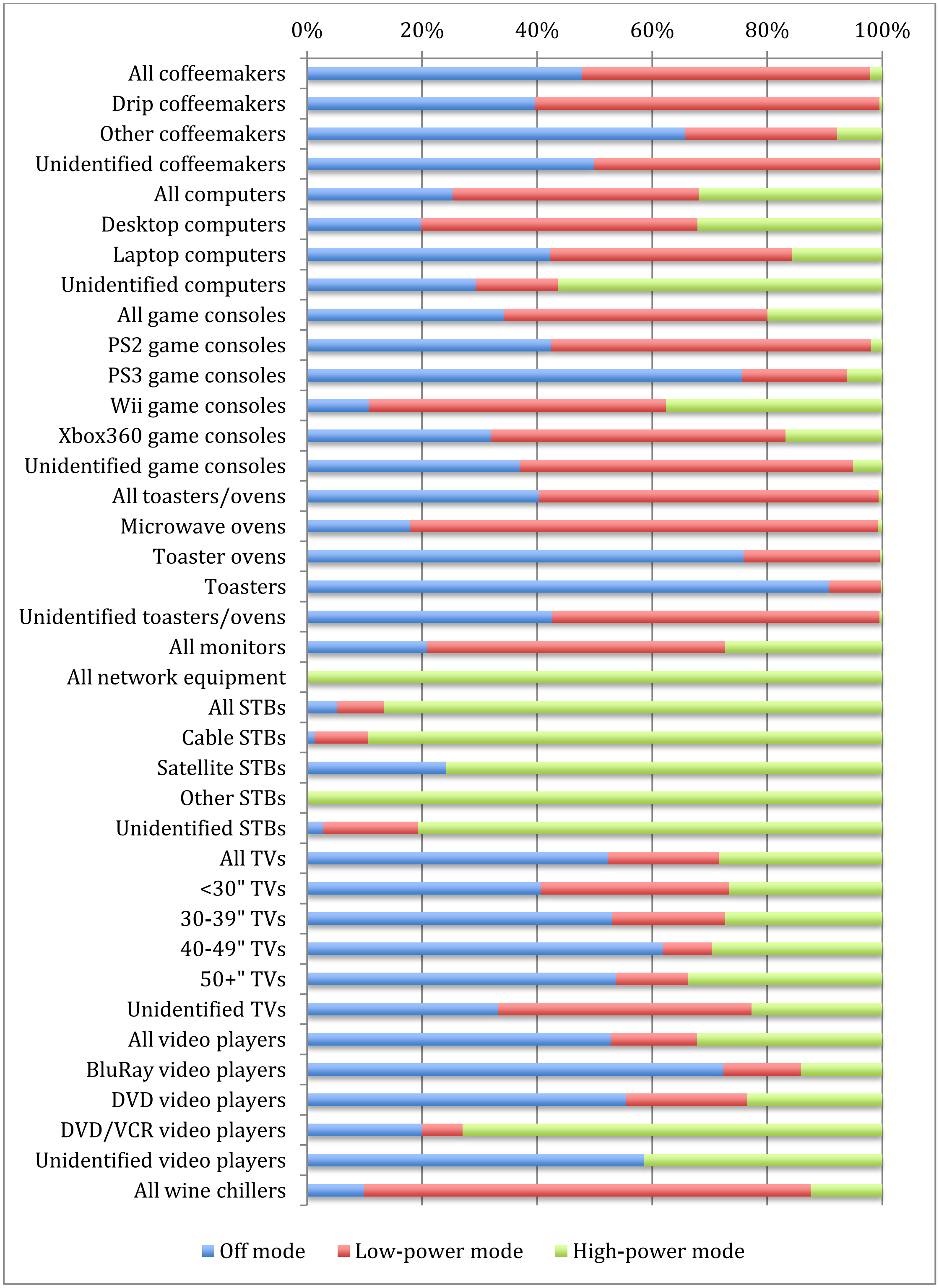

Figure 6. Fraction of time spent in each power mode by device category and subcategory (WattsUp data only)

Average power by mode

Table 6 provides a summary of the average power consumed by mode (WattsUp data only), and the average overall power (WattsUp and Kill-a-Watt data), by device category and subcategory. This data is also depicted in Figure 7 through Figure 9.

Table 6. Average high-mode power (WattsUp data only) and average overall power (WattsUp and Kill-a-Watt data) by device category and subcategory

Device category	Device subcategory	Average power in mode (W)		Average overall power (W)		
		Low-power	High-power	WattsUp	Kill-a-Watt	Combined
Coffee/espresso makers	All	1.70	729.7	7.59		
	Drip	0.98	858.1	4.40		
	Other	4.14	232.1	19.17		
	Unidentified	1.00	915.4	3.73		
Computers	All	1.99	60.5	20.66		
	Desktop	2.40	67.2	22.73		
	Laptop	1.05	40.1	6.70		
	Unidentified	1.21	54.9	31.08		
Game consoles	All	1.57	54.6	7.59	8.95	8.25
	PS2	0.65	19.6	0.74	33.45	6.19
	PS3	1.67	100.9	6.52	10.79	9.22
	Wii	2.00	18.0	7.79	4.69	6.17
	Xbox360	1.39	54.7	9.88	7.66	8.96
	Unidentified	0.99	154.4	8.34		
Microwave ovens, toaster ovens & toasters	All	1.59	1021.4	4.23		
	Microwave ovens	1.86	1094.3	4.60		
	Toaster ovens	1.21	788.4	6.34		
	Toasters	1.02	968.9	1.87		
	Unidentified	1.34	842.8	4.82		
Monitors	All	1.00	26.0	7.63		
Network equipment	All	2.67	6.7	6.71	6.36	6.40
	Modem				5.80	
	Router				6.69	
STBs	All	3.14	22.2	20.25	38.77	20.78
	Cable	3.31	23.1	20.97		
	Satellite	2.93	*26.5*	*26.50*		
	Other	4.44	*12.0*	*9.07*		
	Unidentified	1.96	*17.0*	*14.06*		

TVs	All	0.94	93.5	27.13		
	<30"	1.85	47.4	13.18		
	30-39"	0.77	94.6	25.95		
	40-49"	0.80	105.5	31.33		
	50+"	0.57	123.2	41.57		
	Unidentified	0.65	97.1	22.32		
Video players	All	0.57	17.3	4.48		
	BluRay	0.47	31.8	4.54		
	DVD	0.56	10.4	2.57		
	DVD/VCR	0.70	9.3	6.83		
	Unidentified	0.80	31.7	13.12		
Wine chillers	All	1.09	83.5	11.22	21.84	16.53

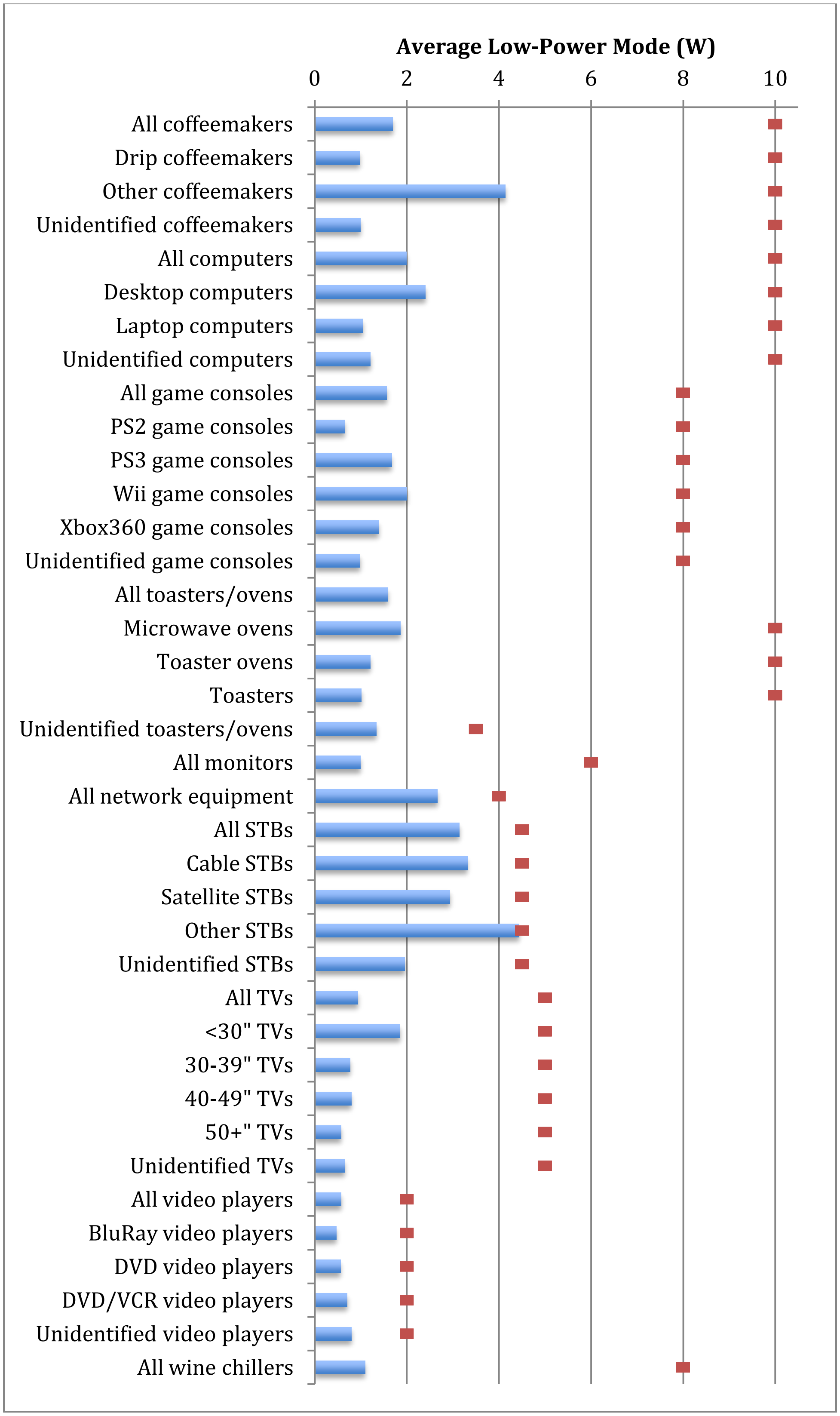

Figure 7. Average low-mode power by device category and subcategory (WattsUp data only). Red squares indicate low-mode power cutoff values assumed.

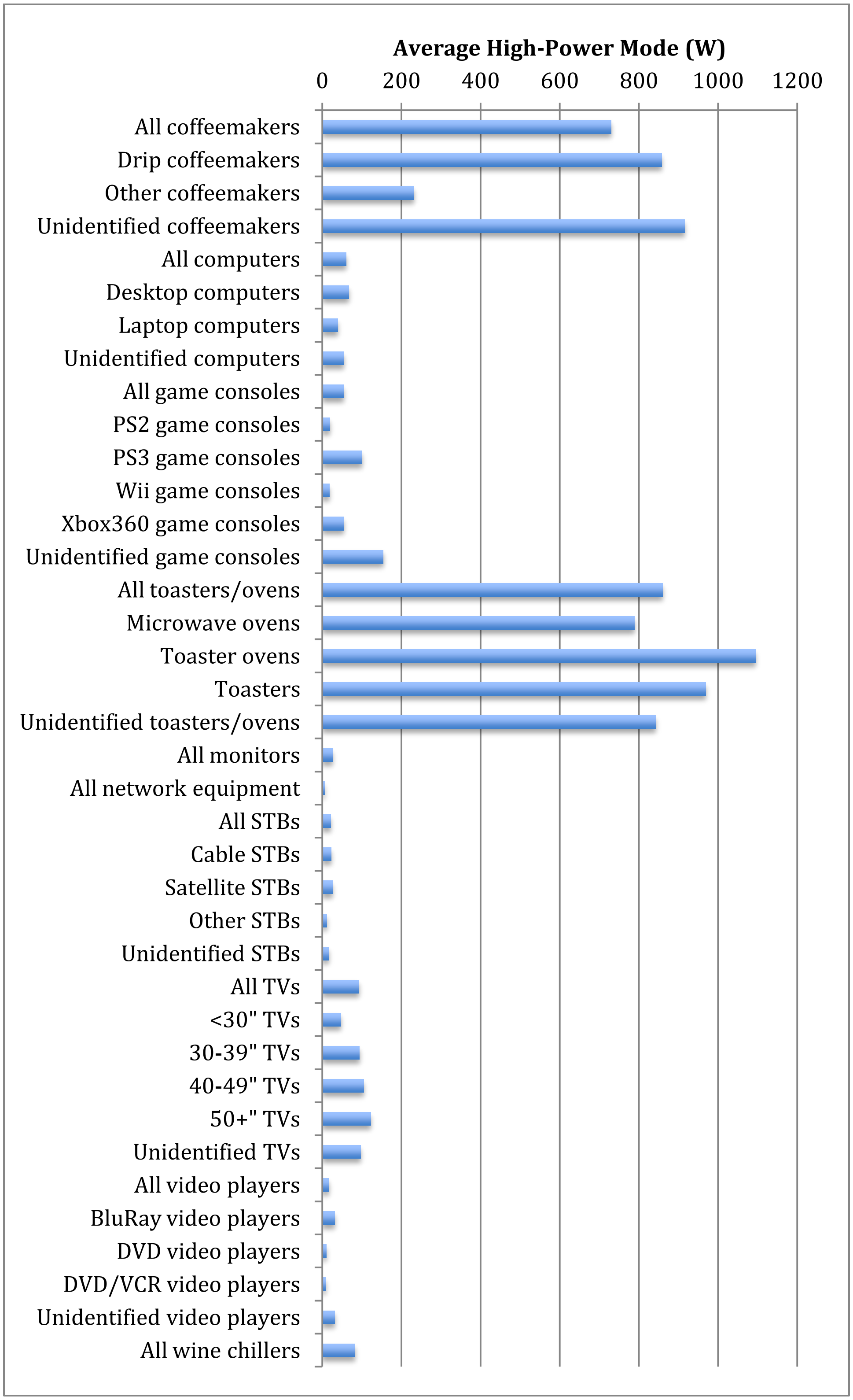

Figure 8. Average high-mode power by device category and subcategory (WattsUp data only)

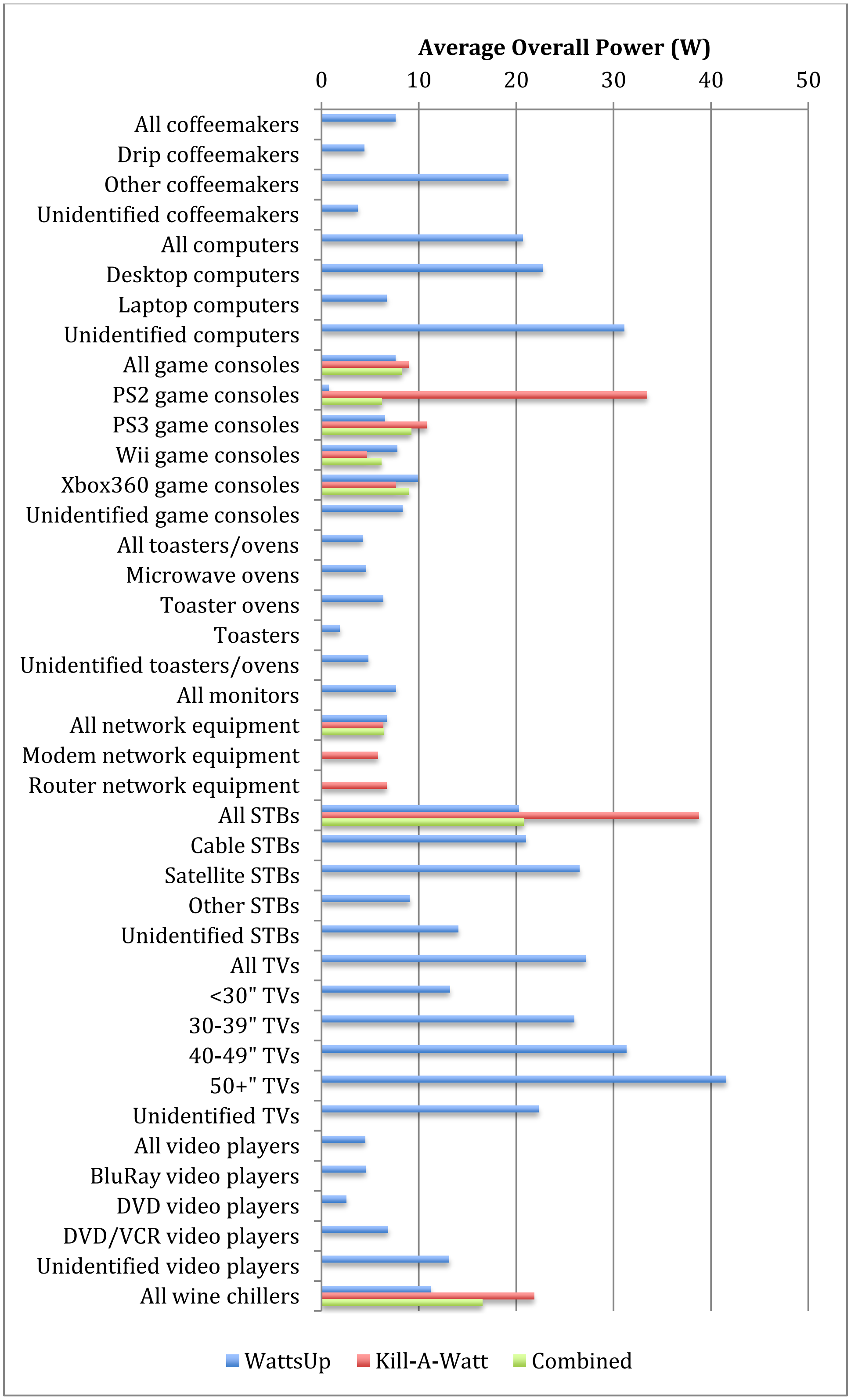

Figure 9. Average overall power by device category and subcategory (WattsUp and Kill-a-Watt data)

Figure 10 shows a sample power use time series obtained from a PS2 game console unit. The result shows that the occupant used the gaming device substantially almost every day of the week and that the unit was left on (in a low-power mode) when the device was not being used. Sample time series for other devices can be found in Appendix D. Further analysis will be performed independently for each major device category, and will be published in future reports.

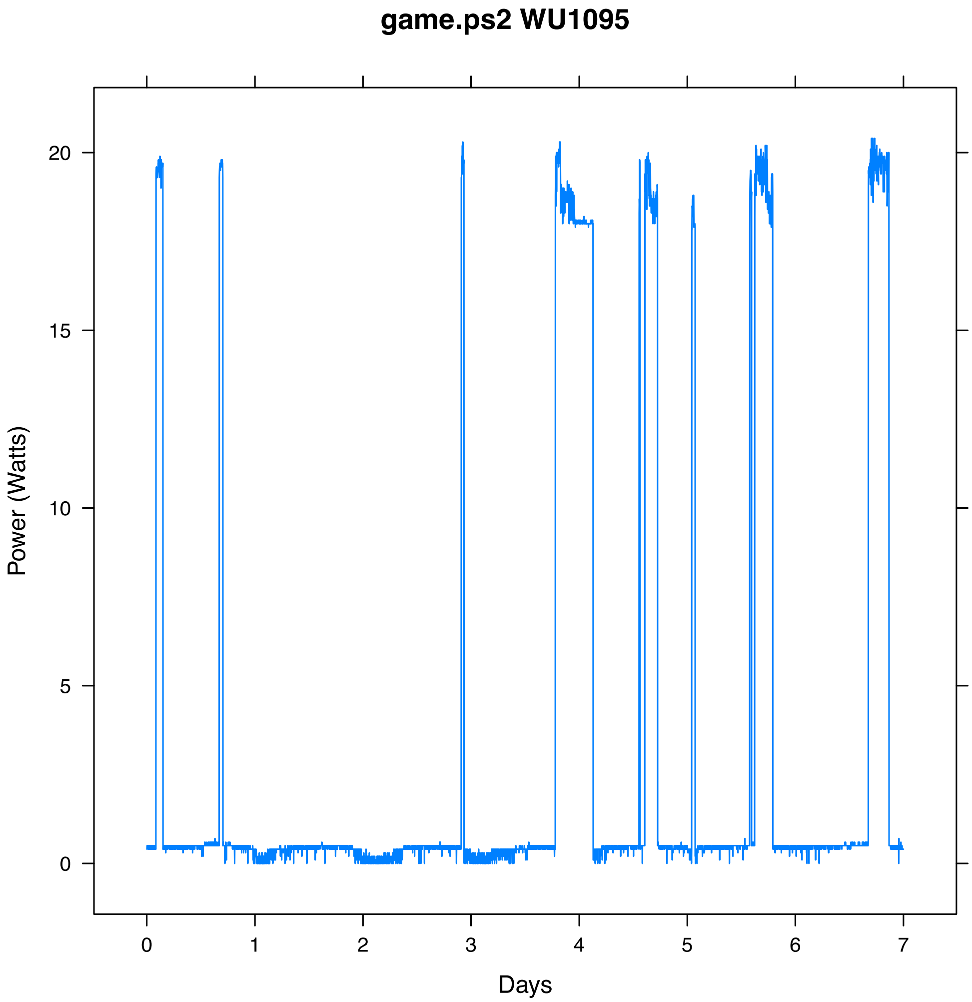

Figure 10. PS2 game console sample power use time series

Demographics

A total of 559 unique households were sampled (474 with WattsUp data and 85 with Kill-a-Watt data). Demographics of sampled households are presented below in Table 7 through Table 12. A wide range of demographics was sampled in this effort, representing a variety of household sizes, occupant ages, household income levels, racial backgrounds and education levels. Moreover, participation was strong in all locations deployed, but with the highest participation levels in Fremont (13%), Pleasanton (12%), Richmond (15%) and Union City (12%).

Table 7. Number of people in the household

Response	Number of households	Fraction of all responses	Fraction of known responses
1	51	9%	17%
2	69	12%	23%
3	47	8%	15%
4	89	16%	29%
5	28	5%	9%
6	11	2%	4%
7+	9	2%	3%
Unknown	255	46%	N/A
Total	559	100%	100%

Table 8. Ages of occupants in household. Note that the total is larger than the number of sampled households because more than one age group may be present in a household.

Response	Number of households	Fraction of all responses
0-19	167	28%
20-29	65	11%
30-39	90	15%
40-49	98	16%
50-59	85	14%
60-69	50	8%
70+	48	8%
Total	603	100%

Table 9. Annual household income

Response	Number of households	Fraction of all responses	Fraction of known responses
$0-$19,999	61	11%	19%
$20,000-$39,999	68	12%	21%
$40,000-$59,999	47	8%	14%
$60,000-$79,999	25	4%	8%
$80,000-$99,999	35	6%	11%
$100,000-$119,999	34	6%	10%
$120,000-$149,999	32	6%	10%
$150,000-$199,999	11	2%	3%
$200,000+	15	3%	5%
Unknown	231	41%	N/A

Total	559	100%	100%

Table 10. Race/ethnicity of respondent

Response	Number of households	Fraction of all responses	Fraction of known responses
Caucasian	125	22%	31%
African or African American	58	10%	14%
Hispanic/Latino	80	14%	20%
Asian	95	17%	23%
Other	50	9%	12%
Unknown	151	27%	N/A
Total	559	100%	100%

Table 11. Education level of respondent

Response	Number of households	Fraction of all responses	Fraction of known responses
No schooling completed	4	1%	1%
Grades K-12 (no diploma)	14	3%	4%
High school diploma or GED	41	7%	11%
Some college, no degree	68	12%	19%
Associate's degree (AA, AS)	24	4%	7%
Bachelor's degree (BA, BS)	97	17%	27%
Master's degree (MA, MS, MBA)	77	14%	21%
Professional degree (MD, JD)	11	2%	3%
Doctoral degree (PhD, EdD)	28	5%	8%
Unknown	195	35%	N/A
Total	559	100%	100%

Table 12. Geographic location of household

City	Number of households	Fraction of all responses
Antioch	29	5%
Berkeley	57	10%
Fremont	73	13%
Livermore	51	9%
Marin County	36	6%
Oakland	58	10%
Pleasanton	65	12%
Richmond	86	15%
San Leandro	37	7%
Union City	67	12%
Total	559	100%

Discussion

Consistent with observations made in previous studies, we find on average that IT devices (home entertainment and home office equipment) consume more energy (15.0 and 13.0 W, respectively) than non-IT devices (kitchen plug-loads; 4.9 W), as summarized in Table 13.

Table 13. Average power by device grouping and category

Device grouping	Device category	Number of devices	Average power (W)
Home entertainment	Game consoles	111	8.25
	STBs	70	20.78
	TVs	95	27.13
	Video players	78	4.48
	Subtotal	354	14.96
Home office	Computers	57	20.66
	Monitors	23	7.63
	Network equipment	48	6.40
	Subtotal	128	12.97
Kitchen equipment	Coffee/espresso makers	31	7.59
	Microwave ovens, toaster ovens & toasters	194	4.23
	Wine chillers	4	16.53
	Subtotal	229	4.90
Total		711	N/A

Computers and video players are both observed to spend an average of 32% of their time in a high-power mode, whereas it appears unreasonable to expect that occupants actually use these devices this much (7.7 hours per day), especially given that the TVs which video players are connected to are found in a high-power mode an average of only 28%, corresponding to 6.7 hours per day. For comparison, U.S.-wide data from the Nielsen Company (DOE, 2012) indicates that primary (most-used) TV usage is 6.5 hours per day, which is very consistent with our measurement.[18] (The average number of hours that all TVs are used is 4.5 hours per day). Game consoles were observed to spend 20% of their time in a high-power mode, or 4.8 hours per day. It is possible that some of these devices are used this frequently, but in general, better power management could result in less time spent in a high-power mode for all of these types of devices.

[18] The majority of TVs metered in our sample were primary TVs.

Devices that must maintain a connection to a service provider (network equipment and STBs) were found in a high-power mode much more frequently: 100% for network equipment, and 87% for STBs. Although these devices have a constant connection to a service provider, the consumer utilization of these devices is likely to be far lower than 100%. There is therefore an energy savings opportunity via power scaling depending on utilization.

By comparison, kitchen devices are used much less frequently, with the fraction of time spent in a high-power mode being 2.1% for coffeemakers, 0.5% for microwave ovens, toaster ovens & toasters, and 12% for wine chillers (which were somewhat different in that they must operate more or less continuously to maintain a cool interior temperature).

While the measured low-power mode levels were generally very small compared to the high-power mode, there is still potentially room for improvement. For instance, microwave ovens spend an average of 81% of their time in a low-power mode with an average energy consumption of 1.9 W. However, the average overall energy consumption of these devices is 4.6 W, indicating that 41% of total energy is consumed while in a low-power mode. Thus, reducing the energy consumption of this mode by 50% (to ~1.0 W) could result in a 20% reduction in overall energy use. Fewer opportunities may exist for coffeemakers, computers and game consoles; while they respectively spend 50%, 43% and 46% of their time in a low-power mode with average energy consumption levels of 1.7 W, 2.0 W and 1.6 W, the majority of energy use comes from larger proportions of high-power mode consumption, so that reducing the low-power mode by 50% would result in substantially less savings.

Perhaps the other device categories with the greatest potential for savings is in “always on” devices such as network equipment and STBs, which spend virtually all of their time in a high-power mode consuming, respectively, 6.7 W and 22 W. Even small reductions in this level of power consumption could have large energy-saving implications.

Future analyses planned

As indicated earlier, future reports will analyze the collected data in detail by device category and compare results to those obtained from prior studies on MELs. In particular, we plan to utilize the diversity of measurements to elucidate variability in usage patterns, examine the simultaneous usage of connected devices (such as TVs and game consoles or video players) and recorded occupancy data, and compare the distributions of brand/model numbers to publicly available market data in order to normalize data to national distributions.

Limitations of current approach

Despite the high-quality data we obtained, there were a number of areas for improvement, discussed below.

WattsUp energy meters

Although these portable energy meters are capable of collecting relatively long-duration, high resolution data in the field, a combination of outdated software and lack of some key technological features caused an unexpected level of extra effort in preparing meters for the field and processing data upon their return.

The Utility Driver necessary for recognizing the WattsUp meters was not as user-friendly as we had anticipated. For some computers, we also faced issues preventing the use of the same USB serial (com) port during configuration of the meters. Sometimes this was overcome by reinstalling the driver, but sometimes this was insufficient.

Perhaps the most serious limitation was the lack of an internal clock on the meter. To overcome this deficiency required careful recordkeeping on the part of the Energy Specialists/LIFTs and, in some cases, occupants (when they disconnected meters on our behalf). Even with accurate records of the time when meters were installed and disconnected, power outages and inadvertent disconnection of meters during field deployment meant that gaps existed in many records that were not always possible to correct, resulting in loss of valuable data.

During the data downloading process, it was discovered that the WattsUp meters required a "warm up" time that was directly proportional to the amount of data recorded on the meter. The computer would not recognize the meter until this process, ranging from 2-15 minutes, was completed, which in turn added additional recorded time onto the meters while they were plugged in. Only the WattsUp.NET meters exhibited this problem; we did not encounter it with the WattsUp Pro ES meters we had used in a previous project. Because the problem appeared to be "new," we requested that the company (ThinkTank) test a few of our meters with data. They have since confirmed this was an issue without a full explanation. We believe it is not only linked to the lack of an internal clock, but also to their quality of chip technology. We have also confirmed that when there is a power interruption (power outage or if meter is unplugged), the same process occurs.

In conclusion, if another meter became available with similar features to the WattsUp meter and had an internal clock, we would likely choose it over re-using the WattsUp meters, despite the high cost of replacement (~$200 per meter).

Training

We met with the Rising Sun management team in December 2012 to review our processes. Overall, we concluded both the LBNL and Rising Sun learned quite a bit from this effort and agreed that, in general, more time was necessary for planning and training the Rising Sun staff. In summary, we concluded:

- LBNL training materials and delivery requires improvement, and more time must be provided for youth (Energy Specialist and LIFT) training. This includes, but is not limited to, device selection, meter installation, demographic and device data collection, household training, and meter retrieval.
- LBNL should train Site Managers directly, not just Energy Specialists/LIFTs.
- An improved method for data survey collection is needed to avoid data quality loss during information transfer from paper to database. Possibly a direct (computer) interface for field use should be developed.
- A full-time employee at Rising Sun will be required for future efforts, due to the amount of time required.
- A more realistic and organized retrieval plan is necessary for more effective meter/sensor retrieval (see next section).

Training of LBNL staff, on the other hand, was deemed sufficient, barring the unexpected issues and delays we faced as summarized above.

Meter/sensor retrieval

Retrieval of meters and sensors from 880 homes proved to be a larger logistical challenge than anyone at LBNL or Rising Sun had anticipated. The problems stemmed both from lack of sufficient staff time and also the difficulty of re-connecting with many occupants after the initial visit. While 554 meters and sensors were retrieved during the first five weeks of the retrieval period, obtaining the remaining equipment required hiring a new, dedicated person to cover all ten sites over two additional months. Additionally, the two-week time constraint on the Energy Specialists/LIFTs in the field during initial retrieval period caused a rush that in turn required both the Rising Sun Coordinator and the LBNL team to expend tremendous effort, time, and resources to gather and manage the flood of data. Further training as stated above, additional staff resources, and strategic planning for such a large effort would be extremely helpful in any future study.

Summary

The field metering activity described in this report was a result of collaboration between Lawrence Berkeley National Laboratory and Rising Sun Energy Center in Berkeley, CA. A total of 1,176 energy meters and 143 other sensors were deployed in 880 San Francisco Bay Area homes during July and August 2012, and 90% of these meters and sensors were retrieved between August and November 2012; the remaining 10% were deemed "unrecoverable" through loss or inability to contact occupants. Ten regions were selected for this study: Antioch, Berkeley, Fremont, Livermore, Marin County (San Rafael, Novato, Fairfax, and Mill Valley), Oakland/Emeryville, Pleasanton, Richmond, San Leandro, and Union City. The project focused on three major categories of devices: entertainment (game consoles, set-top boxes, televisions and video players), home office (computers, monitors and network equipment), and kitchen plug-loads (coffee/espresso makers, microwave ovens/toaster ovens/toasters, rice/slow cookers and wine chillers). These categories were important to meter because they either dominated the estimated overall energy use of MELs, are rapidly changing, or there are very little energy consumption data published.

For this report, we obtained 711 valid device energy use measurements, and from this data, we have estimated, for a number of device subcategories, the average time spent in high power, low power and "off" modes, the average energy use in each mode, and the average overall energy use. Consistent with observations made in previous studies, we find on average that information technology (IT) devices (home entertainment and home office equipment) consume more energy (15.0 and 13.0 W, respectively) than non-IT devices (kitchen plug-loads; 4.9 W). Opportunities for energy savings were identified in almost every device category, based on the time spent in various modes and/or the power levels consumed in those modes. Future reports will analyze the collected data in detail by device category and compare results to those obtained from prior studies.

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Appendices

Appendix A
Data Sheet for GROUP A

Household Information	
Address:	**Apt. No.:**
City:	**Zipcode:**

Demographic Information			
Number of Occupants in Household:		**IN TOTAL:**	
Age 0-19: Age 20-29:	Age 30-39: Age 40-49:	Age 50-59: Age 60-69:	Age 70+: Age Unknown:
Total Gross Annual Household Income:		☐ $80,000-$99,999	☐ $150,000-$199,999
☐ $ 0-$19,999	☐ $40,000-$59,999	☐ $100,000-$119,999	☐ $200,000+
☐ $20,000-$39,999	☐ $60,000-$79,999	☐ $120,000-$149,999	☐ Decline to state

Races (check all that apply):		
☐ Hispanic/Latino	☐ South Asian	☐ Native American
☐ Caucasian	☐ African or African American	☐ Some other race
☐ East Asian	☐ Southeast Asian or Pacific Islander	☐ Decline to state

Education level (check highest that applies):		
		☐ Master's degree (MA, MS, MBA)
☐ No schooling completed	☐ Some college, no degree	☐ Professional degree (MD, JD)
☐ Grades K-12 (no diploma)	☐ Associate's degree (AA, AS)	☐ Doctoral degree (PhD, EdD)
☐ High school diploma or GED	☐ Bachelor's degree (BA, BS)	☐ Decline to state

Kitchen Equipment

☐ **Wine Chiller (check if metered)**			**Code: WC**
Location (check one):	Family Room/Den: ☐	Bedroom: ☐	Laundry/Utility: ☐
Living Room: ☐	Kitchen: ☐	Bathroom: ☐	Garage/Outside: ☐
Dining Room: ☐	Office/Study: ☐	Hallway: ☐	Other: ☐

Brand/Make:	**Model Name (optional):**	
Model Number:	**Year Manufactured (if known):**	
Capacity (number of wine bottles):	**Thermoelectric?** ☐ Yes ☐ No ☐ Don't Know	
WattsUp Pro Meter ID (WU): ***OR*** **Kill-A-Watt Meter ID (KAW):**	**Start date:** **Stop date:**	**Start time:** **Stop time:**
Interior Temperature Meter ID (TEMP):	**Location in device:**	
Exterior Temperature Meter ID (TEMP):	**Location in room:**	

Home Electronics

☐ **Game Console (check if metered)**			**Code: GC**
Location (check one):	Family Room/Den: ☐	Bedroom: ☐	Laundry/Utility: ☐
Living Room: ☐	Kitchen: ☐	Bathroom: ☐	Garage/Outside: ☐
Dining Room: ☐	Office/Study: ☐	Hallway: ☐	Other: ☐
Make/Model:	☐ Microsoft Xbox		
☐ Nintendo GameCube	☐ Microsoft Xbox 360	☐ Sony PlayStation 2	☐ Other (specify):
☐ Nintendo Wii	☐ Microsoft Xbox 360 + Kinect	☐ Sony PlayStation 3	☐ Don't know
Model number:		**Year manufactured:**	
WattsUp Pro Meter ID (WU):		**Start date:**	**Start time:**
		Stop date:	**Stop time:**

☐ **Set-Top Box (check if metered)**			**Code: STB**
Location (check one):	Family Room/Den: ☐	Bedroom: ☐	Laundry/Utility: ☐
Living Room: ☐	Kitchen: ☐	Bathroom: ☐	Garage/Outside: ☐
Dining Room: ☐	Office/Study: ☐	Hallway: ☐	Other: ☐
Brand/Make:		**STB Base Type (check one):**	☐ Don't Know
Model Number:		☐Cable ☐Satellite ☐IPTV	☐ Streaming
Model Name (optional):		**High Definition?** ☐ Yes ☐ No	☐ Don't Know
Year Manufactured (optional):		**DVR?** ☐ Yes ☐ No	☐ Don't Know
Pay-TV Service Provider (if applicable):			
WattsUp Pro Meter ID (WU):		**Start date:**	**Start time:**
OR **Kill-A-Watt Meter ID (KAW):**		**Stop date:**	**Stop time:**

☐ **Video Player (check if metered)** ***NOTE: DO NOT METER VCRs!!!***			**Code: VP**
Location (check one):	Family Room/Den: ☐	Bedroom: ☐	Laundry/Utility: ☐
Living Room: ☐	Kitchen: ☐	Bathroom: ☐	Garage/Outside: ☐
Dining Room: ☐	Office/Study: ☐	Hallway: ☐	Other: ☐
Brand/Make:		**Model Name (optional):**	
Model Number:		**Year Manufactured (optional):**	
Player type (check one):	☐ Blu-Ray ☐ DVD	☐ DVD/VCR combo	☐ Other ☐ Don't know
WattsUp Pro Meter ID (WU):		**Start date:**	**Start time:**
		Stop date:	**Stop time:**

☐ **Television (check if metered)**			**Code: TV**
Location (check one): Living Room: ☐ Dining Room: ☐	Family Room/Den: ☐ Kitchen: ☐ Office/Study: ☐	Bedroom: ☐ Bathroom: ☐ Hallway: ☐	Laundry/Utility: ☐ Garage/Outside: ☐ Other: ☐
Brand/Make:		**Model Name (optional):**	
Model Number:		**Year Manufactured (optional):**	
Type (check ☐ LCD ☐ LED LCD ☐ Plasma ☐ CRT ☐ Other ☐ Don't Know			
Screen size (diagonal inches): ☐ 0-15" ☐ 16-19" ☐ 20-29" ☐ 30-39" ☐ 40-49" ☐ 50-59" ☐ 60+" ☐ Don't know			
Attached to (check one): ☐ Game console ☐ Set-top box ☐ Video player ☐ Other ☐ Don't know			
WattsUp Pro Meter ID (WU):		**Start date:** **Stop date:**	**Start time:** **Stop time:**
Occupancy Sensor ID (OCC):		**Location in room:**	

Home Office

☐ **Network Equipment (check if metered)**			**Code: NET**
Location (check one): Living Room: ☐ Dining Room: ☐	Family Room/Den: ☐ Kitchen: ☐ Office/Study: ☐	Bedroom: ☐ Bathroom: ☐ Hallway: ☐	Laundry/Utility: ☐ Garage/Outside: ☐ Other: ☐
Brand/Make:		**Device type (check one):**	
Model Number:		☐ Modem	☐ Integrated device
Model Name (optional):		☐ Router	☐ Other type
Year Manufactured (optional):		☐ Wi-fi extender	☐ Don't know
Type of internet service (check one): ☐ DSL	☐ Cable	☐ Fiber optic ☐ Satellite	☐ Dial-up ☐ Don't know
WattsUp Pro Meter ID (WU): ***OR*** **Kill-A-Watt Meter ID (KAW):**		**Start date:** **Stop date:**	**Start time:** **Stop time:**

Observations/Notes (optional)

Appendix B
Data Sheet for GROUP B

Household Information	
Address:	**Apt. No.:**
City:	**Zipcode:**

Demographic Information			
Number of Occupants in Household:		**IN TOTAL:**	
Age 0-19: Age 20-29:	Age 30-39: Age 40-49:	Age 50-59: Age 60-69:	Age 70+: Age Unknown:
Total Gross Annual Household Income:		☐ $80,000-$99,999	☐ $150,000-$199,999
☐ $ 0-$19,999	☐ $40,000-$59,999	☐ $100,000-$119,999	☐ $200,000+
☐ $20,000-$39,999	☐ $60,000-$79,999	☐ $120,000-$149,999	☐ Decline to state
Races (check all that apply):			
☐ Hispanic/Latino	☐ South Asian		☐ Native American
☐ Caucasian	☐ African or African American		☐ Some other race
☐ East Asian	☐ Southeast Asian or Pacific Islander		☐ Decline to state
Education level (check highest that applies):		☐ Master's degree (MA, MS, MBA)	
☐ No schooling completed	☐ Some college, no degree	☐ Professional degree (MD, JD)	
☐ Grades K-12 (no diploma)	☐ Associate's degree (AA, AS)	☐ Doctoral degree (PhD, EdD)	
☐ High school diploma or GED	☐ Bachelor's degree (BA, BS)	☐ Decline to state	

Kitchen Equipment

☐ **Wine Chiller (check if metered)**			**Code: WC**
Location (check one):	Family Room/Den: ☐	Bedroom: ☐	Laundry/Utility: ☐
Living Room: ☐	Kitchen: ☐	Bathroom: ☐	Garage/Outside: ☐
Dining Room: ☐	Office/Study: ☐	Hallway: ☐	Other: ☐
Brand/Make:		**Model Name (optional):**	
Model Number:		**Year Manufactured (if known):**	
Capacity (number of wine bottles):		**Thermoelectric?** ☐ Yes ☐ No ☐ Don't Know	
WattsUp Pro Meter ID (WU): ***OR*** **Kill-A-Watt Meter ID (KAW):**		**Start date:** **Stop date:**	**Start time:** **Stop time:**
Interior Temperature Meter ID (TEMP):		**Location in device:**	
Exterior Temperature Meter ID (TEMP):		**Location in room:**	

☐ **Microwave Oven, Toaster Oven or Toaster (check if metered)**			**Code: OVEN**
Location (check one): Living Room: ☐ Dining Room: ☐	Family Room/Den: ☐ Kitchen: ☐ Office/Study: ☐	Bedroom: ☐ Bathroom: ☐ Hallway: ☐	Laundry/Utility: ☐ Garage/Outside: ☐ Other: ☐
Brand/Make:		**Model Name (optional):**	
Model Number:		**Year Manufactured (if known):**	
Type (choose one): ☐ Convection (Toaster) Oven	☐ Microwave Oven ☐ Toaster	☐ Combination Microwave/Convection Oven ☐ Other	☐ Don't Know
WattsUp Pro Meter ID (WU):		**Start date:** **Stop date:**	**Start time:** **Stop time:**

☐ **Coffee Maker (check if metered)**			**Code: COF**
Location (check one): Living Room: ☐ Dining Room: ☐	Family Room/Den: ☐ Kitchen: ☐ Office/Study: ☐	Bedroom: ☐ Bathroom: ☐ Hallway: ☐	Laundry/Utility: ☐ Garage/Outside: ☐ Other: ☐
Brand/Make:		**Model Name (optional):**	
Model no.:	**Capacity:** cup/oz	**Year Manufactured (if known):**	
Type (choose one): ☐ Drip coffee	☐ Espresso	☐ Both ☐ All-in-One	☐ Kettle ☐ Don't Know
WattsUp Pro Meter ID (WU):		**Start date:** **Stop date:**	**Start time:** **Stop time:**

☐ **Rice/Slow Cooker (check if metered)**			**Code: COOK**
Location (check one): Living Room: ☐ Dining Room: ☐	Family Room/Den: ☐ Kitchen: ☐ Office/Study: ☐	Bedroom: ☐ Bathroom: ☐ Hallway: ☐	Laundry/Utility: ☐ Garage/Outside: ☐ Other: ☐
Brand/Make:		**Model Name (optional):**	
Model no.:	**Capacity:** cup/quart	**Year Manufactured (if known):**	
Type (choose one):	☐ Rice Cooker	☐ Slow Cooker ☐ Other	☐ Don't Know
WattsUp Pro Meter ID (WU):		**Start date:** **Stop date:**	**Start time:** **Stop time:**

Home Office

☐ **Computer (check if metered)**			**Code: COMP**
Location (check one): Living Room: ☐ Dining Room: ☐	Family Room/Den: ☐ Kitchen: ☐ Office/Study: ☐	Bedroom: ☐ Bathroom: ☐ Hallway: ☐	Laundry/Utility: ☐ Garage/Outside: ☐ Other: ☐
Brand/Make:		**Model Name (optional):**	
Model Number:		**Year Manufactured (optional):**	
Type (please check one): ☐ Desktop	☐ Laptop	☐ Other	☐ Don't know
Operating system: ☐ Windows ☐ Macintosh	☐ Linux	☐ Other	☐ Don't know
WattsUp Pro Meter ID (WU):		**Start date:** **Stop date:**	**Start time:** **Stop time:**
Occupancy Sensor ID (OCC):		**Location in room:**	

☐ **Monitor (check if metered)**			**Code: MON**
Location (check one): Living Room: ☐ Dining Room: ☐	Family Room/Den: ☐ Kitchen: ☐ Office/Study: ☐	Bedroom: ☐ Bathroom: ☐ Hallway: ☐	Laundry/Utility: ☐ Garage/Outside: ☐ Other: ☐
Brand/Make:		**Model Name (optional):**	
Model Number:		**Year Manufactured (optional):**	
Type (check one): ☐ LCD ☐ LED LCD	☐ Plasma ☐ CRT	☐ Other	☐ Don't Know
Screen size (diagonal inches): ☐ 0-15" ☐ 16-19" ☐ 20-29" ☐ 30-39"	☐ 40-49" ☐ 50-59"	☐ 60+"	☐ Don't know
WattsUp Pro Meter ID (WU):		**Start date:** **Stop date:**	**Start time:** **Stop time:**
Occupancy Sensor ID (OCC):		**Location in room:**	

Observations/Notes (optional)

IMPORTANT: Please read the manual fully before using this check list in the homes

- ❑ Check with your Site Manager for quota updates before entering field every day.
- ❑ Collect /print/ pack appropriate number of copies of:
    - consent forms, flyers, check list, datasheets, WattsUp?, Occupancy, iButton meters, tape, plug adapters, surge protectors

When you open discussions with homeowner or tenant:

- ❑ Provide the flyer in appropriate language
    - perhaps before you begin your audit to give the homeowner time to read it
- ❑ Give a brief summary of the metering effort project: *E.g. Rising Sun is collaborating with Lawrence Berkeley National Laboratory in a home electronics and appliance energy-use metering effort for the summer. The goal is to measure power usage and collect data for specific high energy use devises in order to aid the government in setting manufacturing energy-saving standards. The devises we are collecting data on has been split up between 10 sites in the bay area.*
- ❑ Provide a list of devises (refer to A or B):

Product	**Group A teams**	**Group B teams**
Wine chillers	✓	✓
Game consoles	✓	-
Set-top boxes	✓	-
DVD/ Blu-Ray players	✓	-
TVs	✓	-
Network equipment	✓	-
Computers	-	✓
Monitors	-	✓
Microwave ovens, toaster ovens, and toasters	-	✓
Coffee makers	-	✓
Rice cookers and slow cookers	-	✓

- ❑ Discuss Incentive(s)
- ❑ Show the meter(s)
    - WattsUp? power meter – for everything (kill-a-watt are just a back up if run out)
    - Occupancy meters – for TV and computers monitoring only (placed on ceiling or other)
    - iButton – for Wine chillers only (inside and out for temperature)
- ❑ Are they interested in participating?
- ❑ Answer any questions

In order to participate please ask and confirm the following:

- ❑ Are they over 18?
- ❑ Are they currently living at this location and planning to remain here throughout the summer?
    - Vacation is fine
- ❑ Are they willing to keep the power meters plugged in at all times?
    - Although it may be contradictive to the energy saving rules they are being given, note they only need to do this for the devices(s) your are monitoring
- ❑ Are they willing to continue to use the same devise (not replace) during this metering effort?

If still yes, before installing meters:

- ❑ Get TWO consent forms signed
    - leave one copy and file the other safely for LBNL

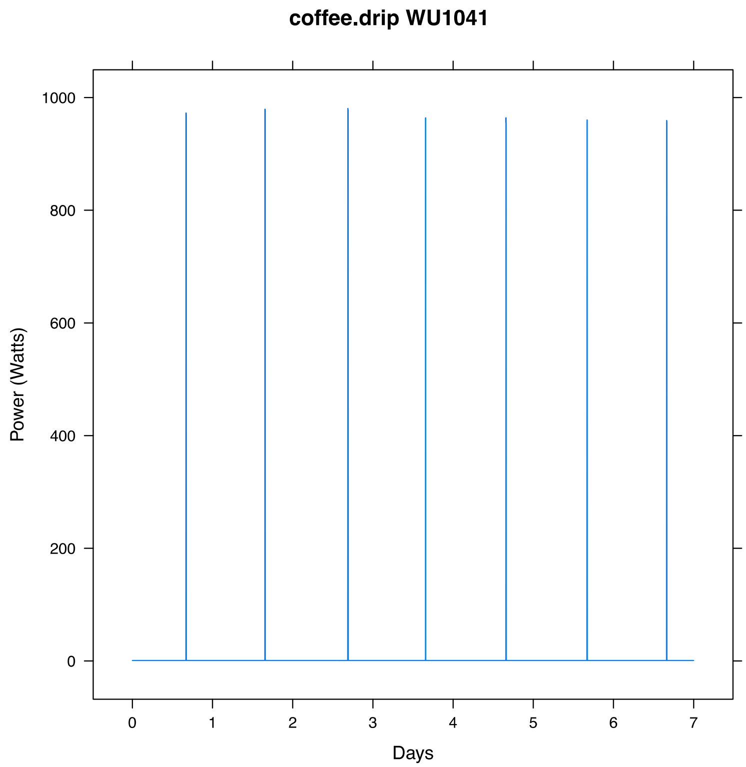
- ❑ Determine what appliance(s) would be the best candidate(s):
  - Utilize Site A or B flow chart as needed while simultaneously randomizing
  - Remember:
    - Site A&B: No cats, dogs or other pets that would roam the room with the occupancy meters if humans are not present
    - Site A&B: Wine Chiller – must be in use FT and ONLY a WC
    - Site A: STB – Confirm with owner if it will be OK to unplug the STB
    - Site A: All electronic equipment must be connected to TV
    - Site A: No portable DVD players or VCR; combined DVD and VCR OK
    - Site B: Laptop charger must be used in same location all the time (non-mobile)
    - Site B: PC must be connected to a monitor
    - Site B: No tablet computers
- ❑ Review final location of meters with homeowner before installing
  - Remember:
    - Avoid water areas; keep meter cords out of walkways, away from pets and children and untangled
    - Occupancy meters would be best on ceiling; never facing windows directly
    - iButtons need to be installed outside and inside wine chillers
- ❑ Fill out the correct Data sheet completely

  Important: Check your QR code identifier(s) are written correctly and match the home address
  - Keep the data sheets in a safe location until you can turn them into your Site manager
- ❑ **INSTAL METER(S)!**
  - Remember:
    - TURN OFF the devise before plugging it into the power meters
    - Utilize three prong adapter and surge protector as needed
    - You must start set the occupancy meters
    - Once plugged in or started, all meters begin to record (except ibuttons are set to begin July 1)

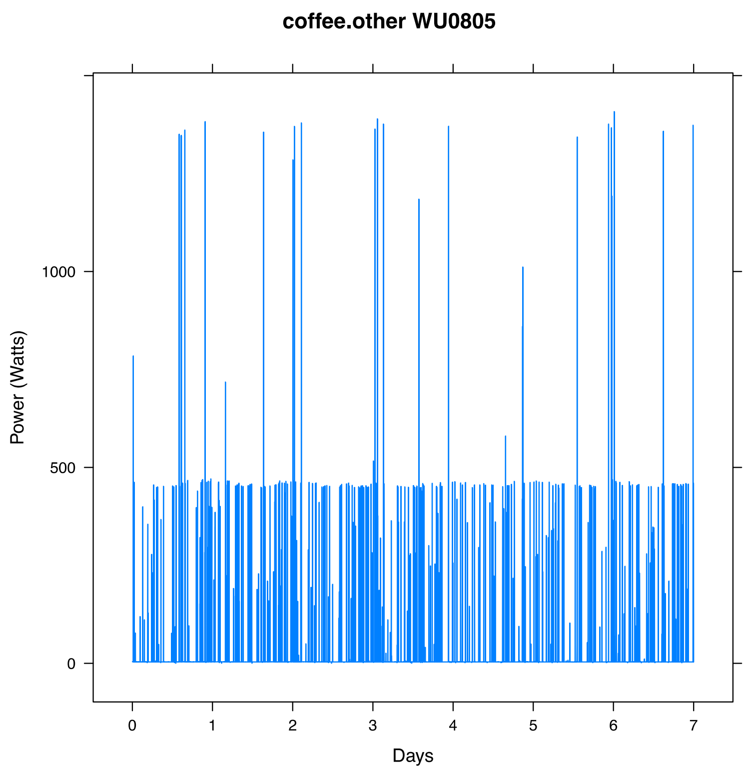
<u>After installation, review with homeowner or tenant:</u>

- ❑ Do not touch any buttons on any meters
- ❑ Minimal handling of the meters if at all; avoid water; do not unplug
- ❑ Record when power outage or accidentally unplug on back of power meter (start and end)
- ❑ Note technical contact information on back of meters if any issues
- ❑ If plugging electronics into meter, be sure the devise if OFF before doing so
- ❑ If using the surge protector it is fine to plug others into that, but not to plug anything into the power meter except the dedicated devise
- ❑ Meters, adapters, recorders are all the property of LBNL and must be returned
- ❑ Give them an approximate date for collecting the meters
  - Alternative for sending them in – pre-paid if they will be out of town?
- ❑ Resume life as usual!

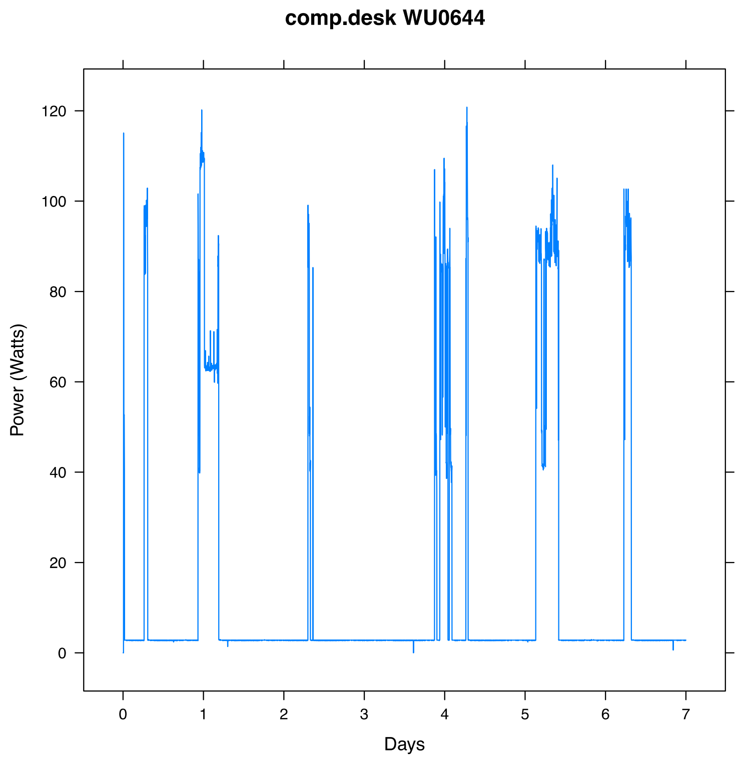
Appendix D: Sample energy use time series



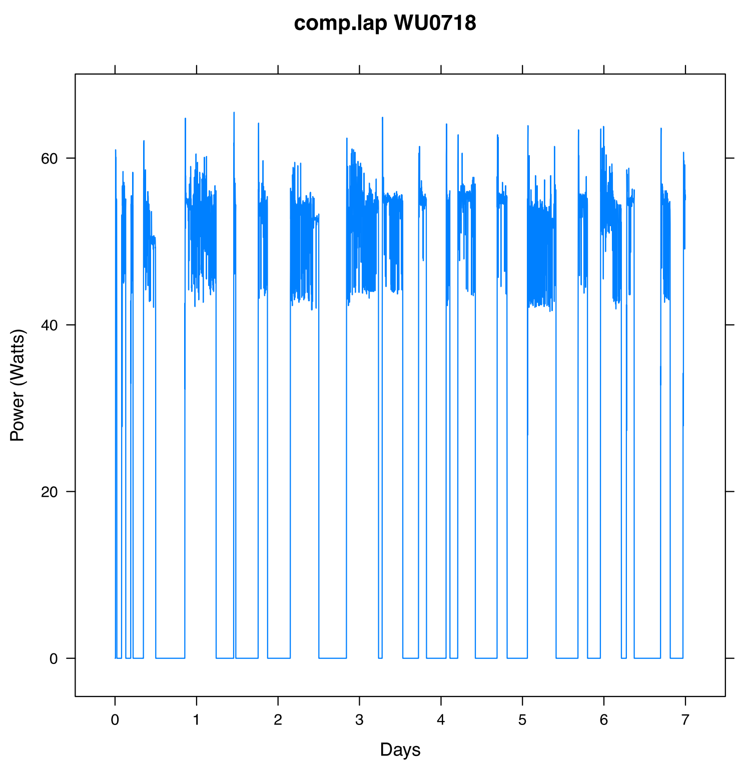
Drip coffeemaker



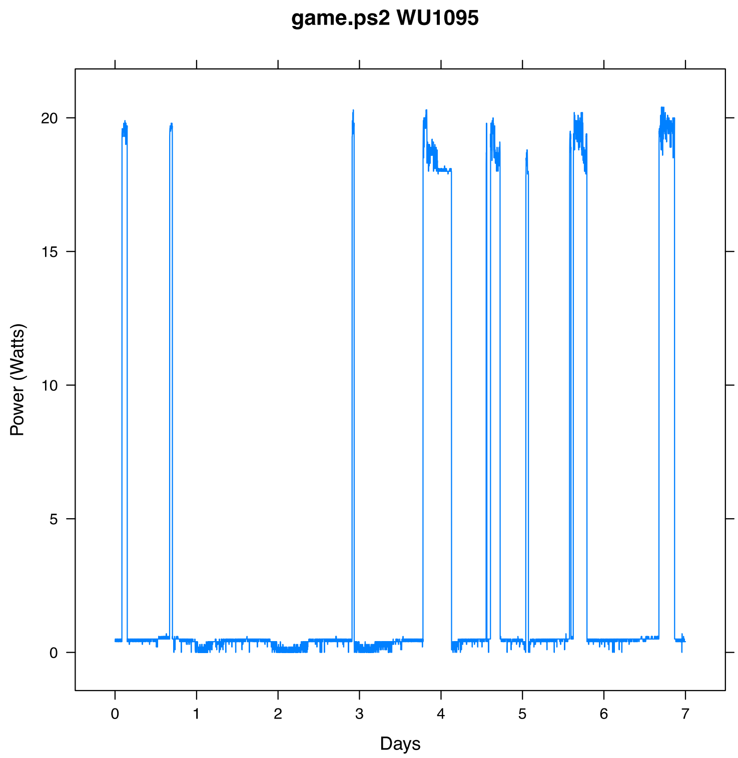
Other coffee/espresso maker



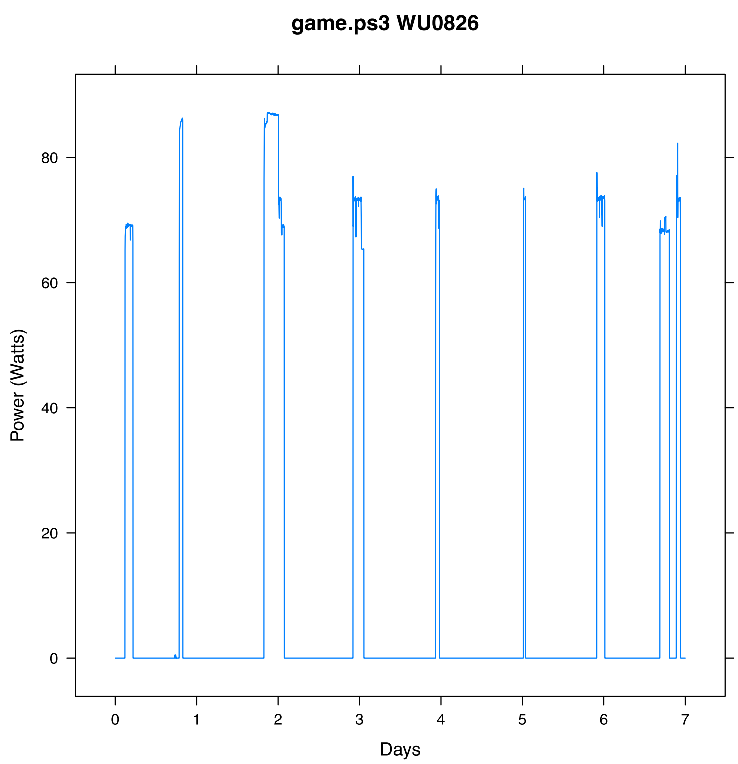
Desktop computer



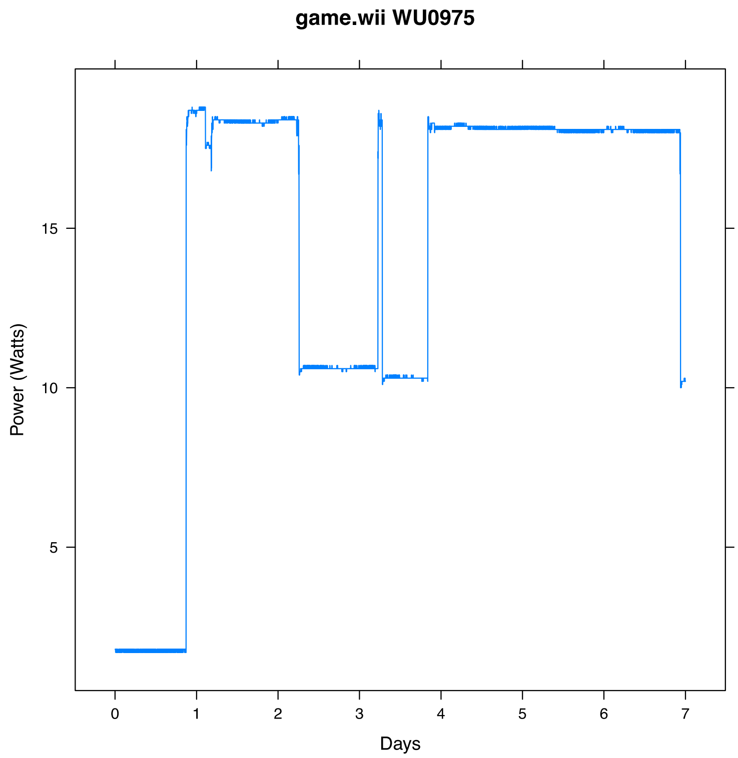
Laptop computer



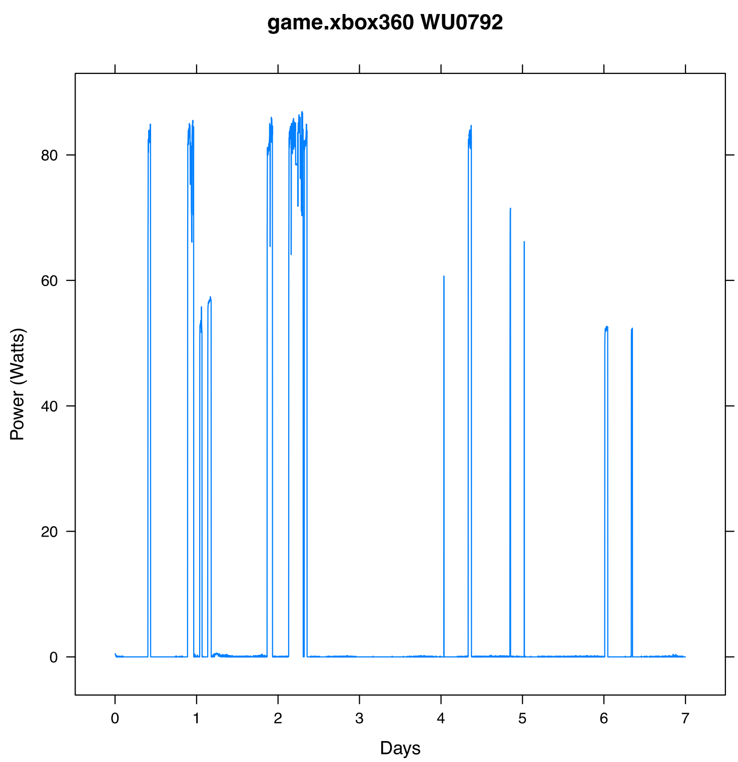
PS2 game console



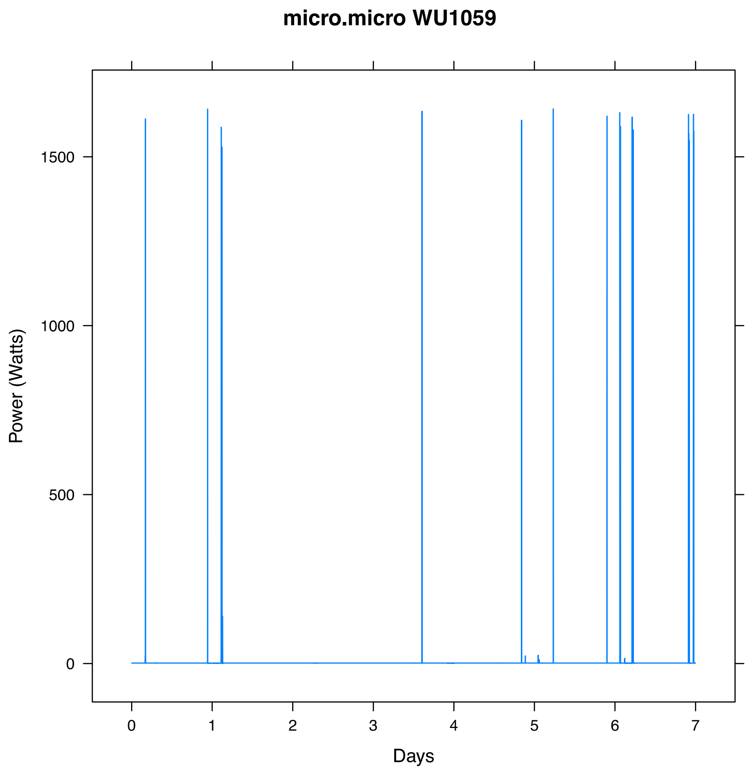
PS3 game console



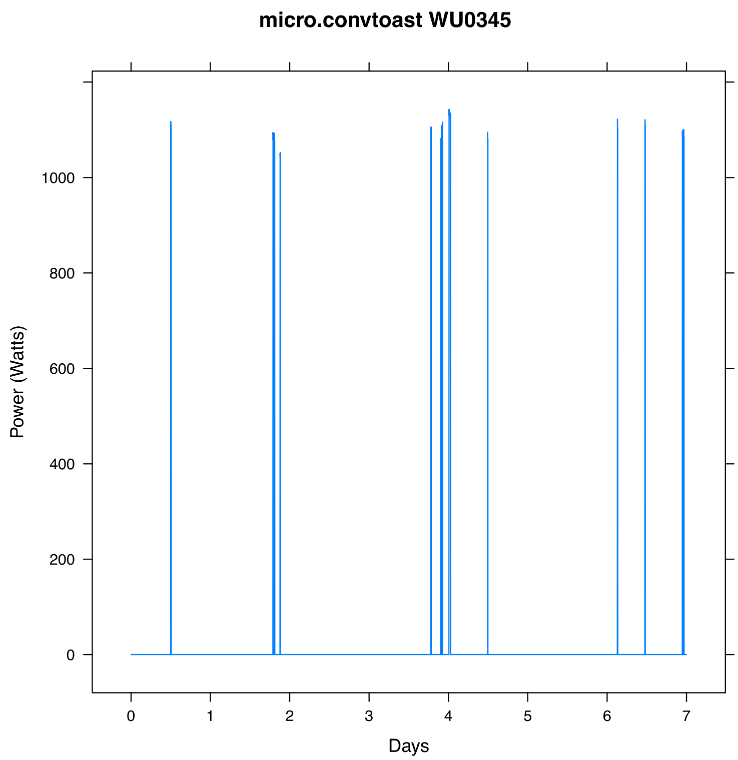
Wii game console



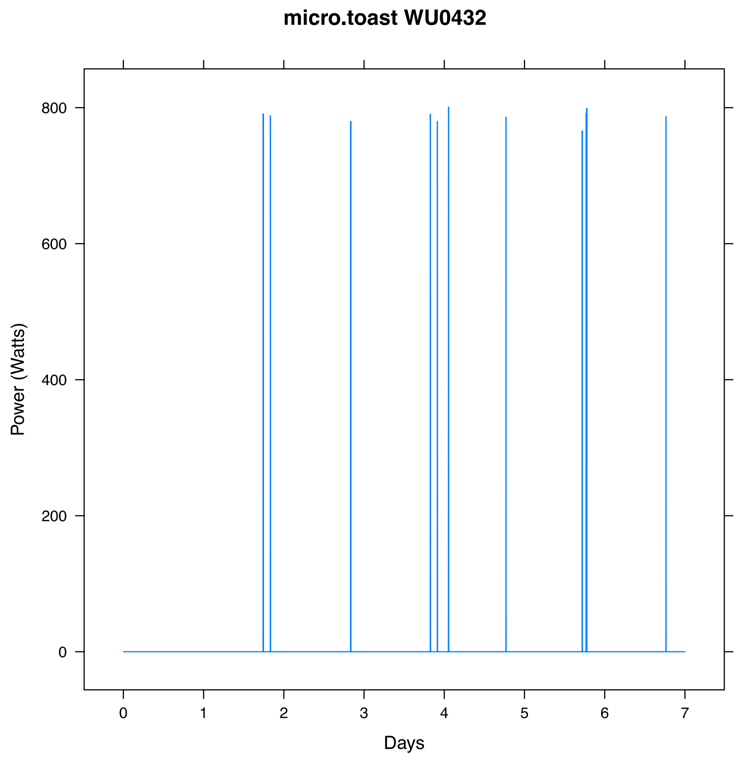
Xbox360 game console



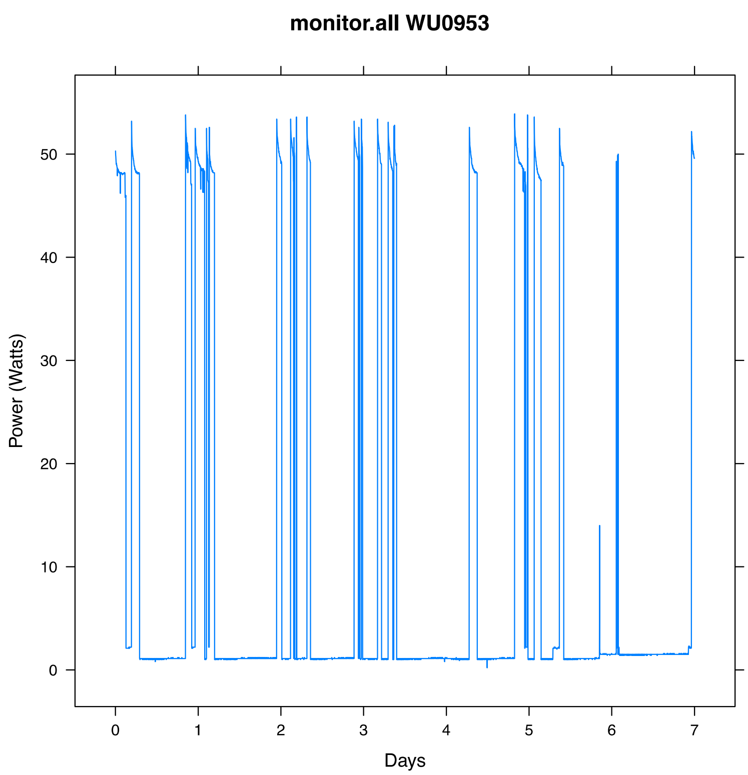
Microwave oven



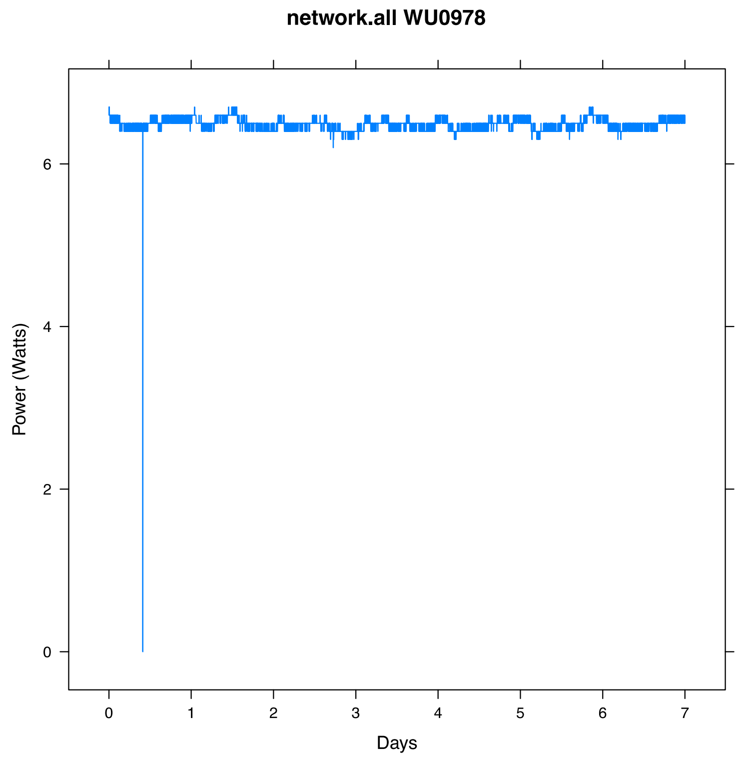
Toaster oven



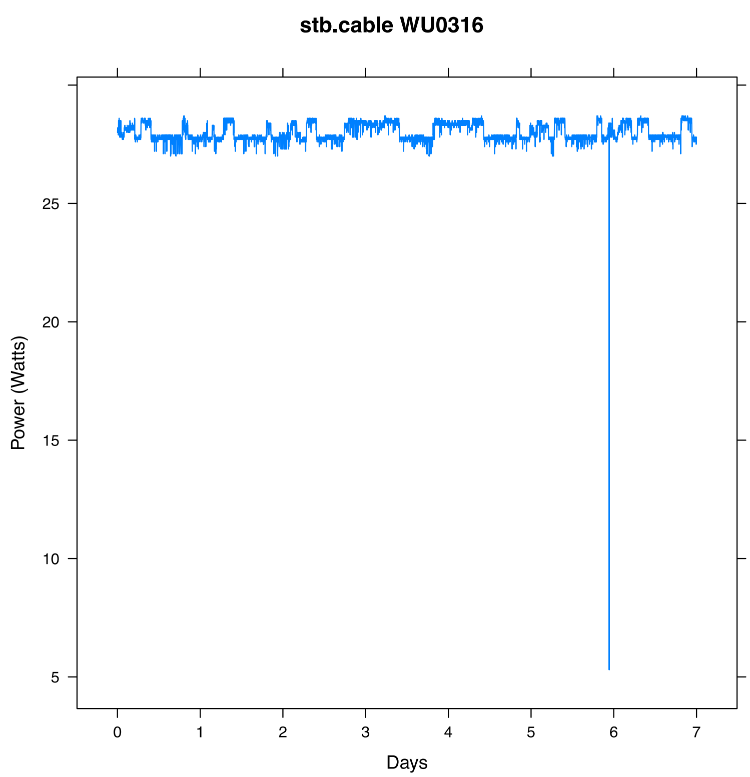
Toaster



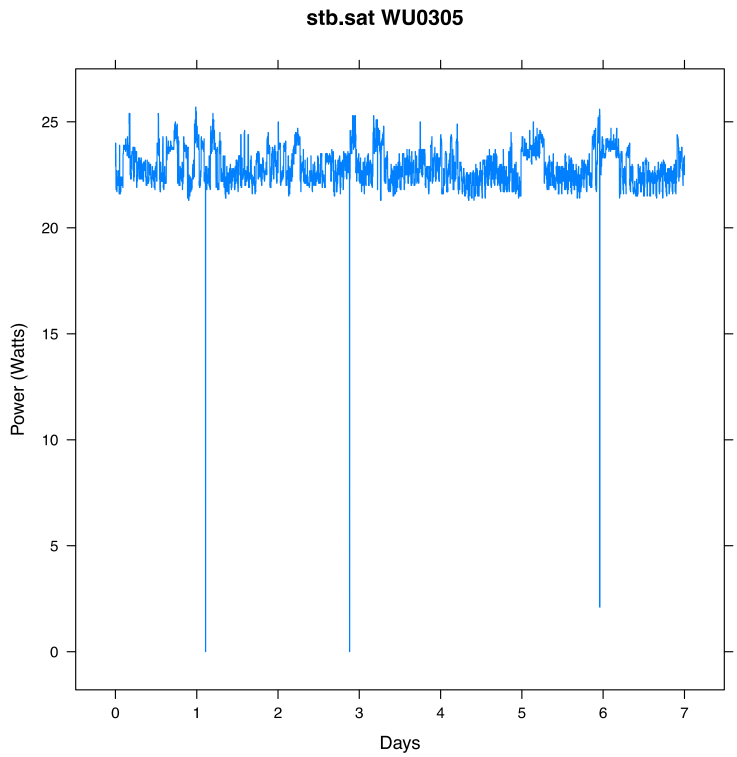
Monitor



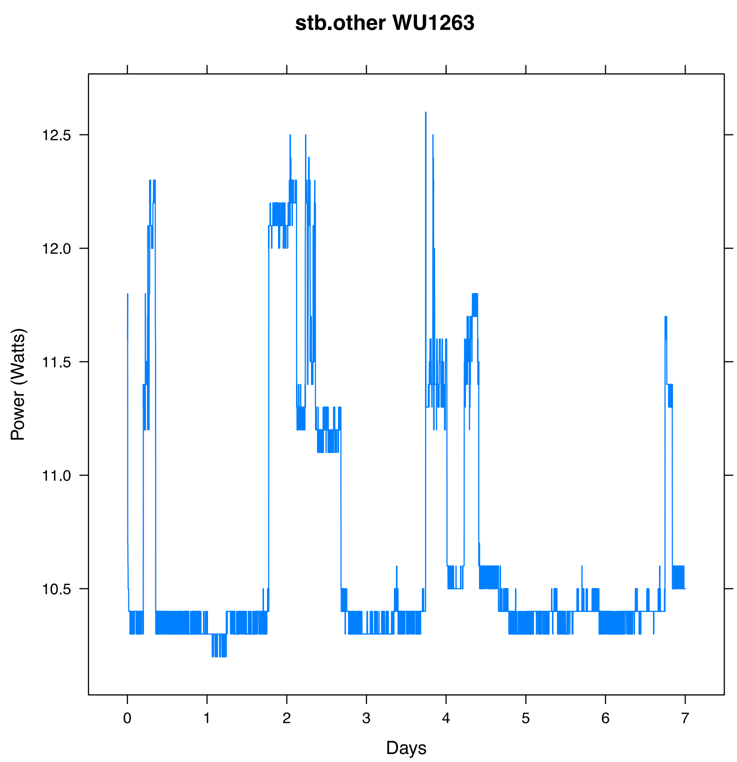
Network equipment



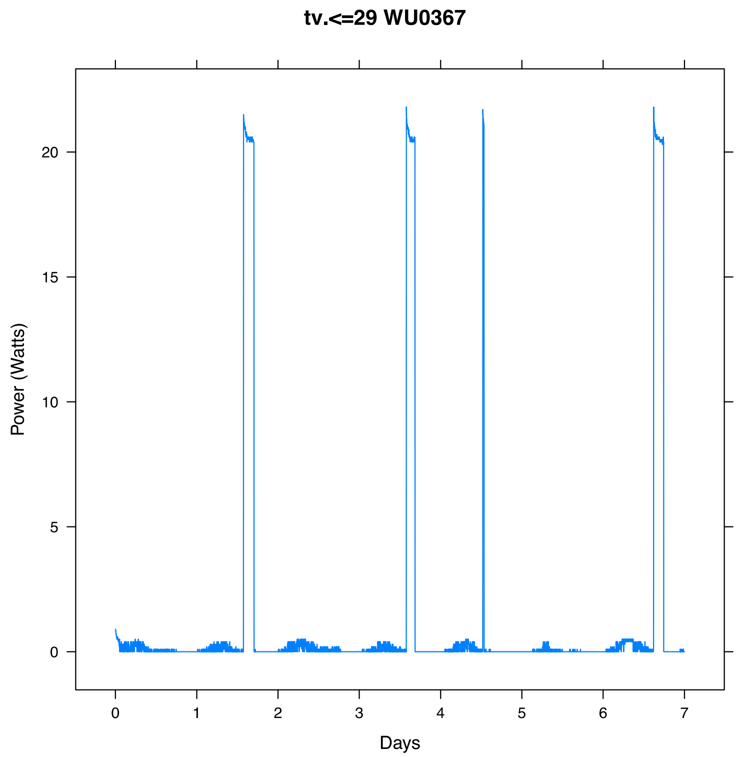
Cable STB



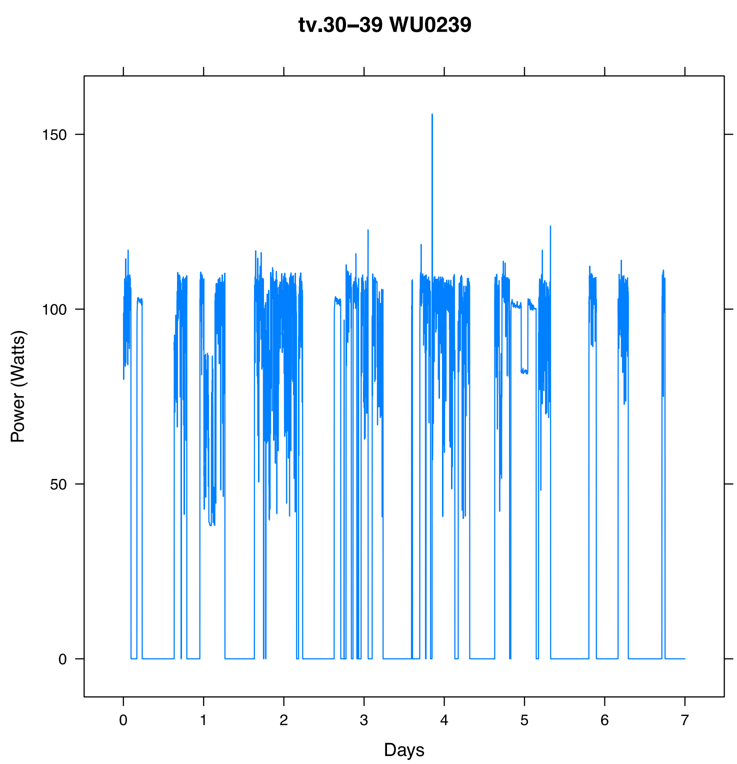
Satellite STB



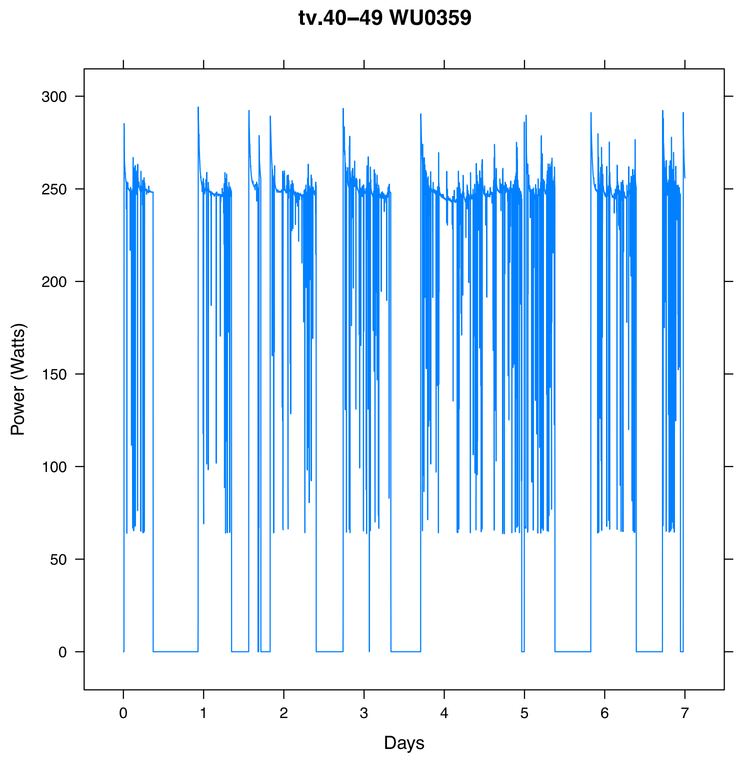
Other STB


tv.<=29 WU0367
Power (Watts)
0
5
10
15
20
Days
0
1
2
3
4
5
6
7

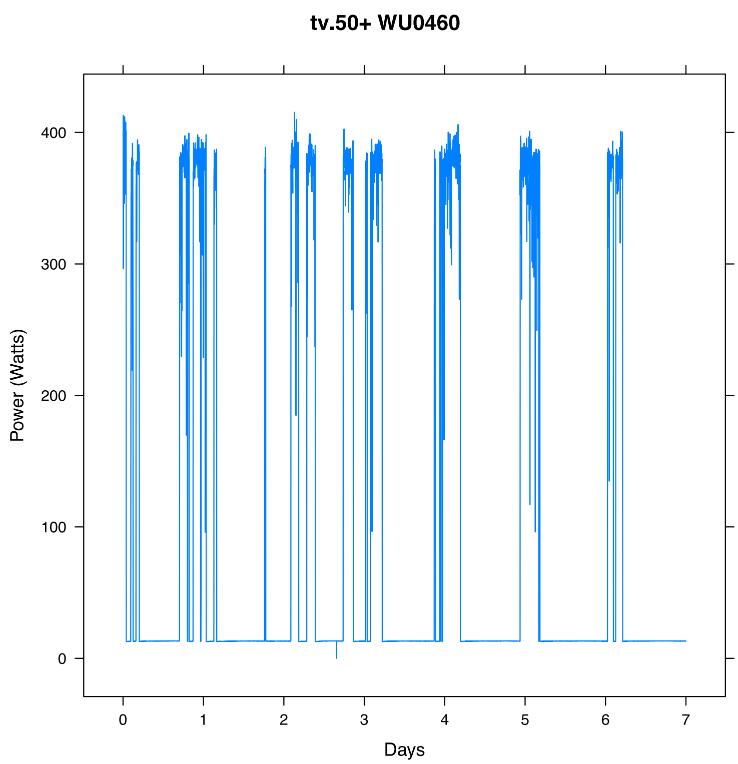
<30" TV


tv.30–39 WU0239
Power (Watts)
0
50
100
150
Days
0
1
2
3
4
5
6
7

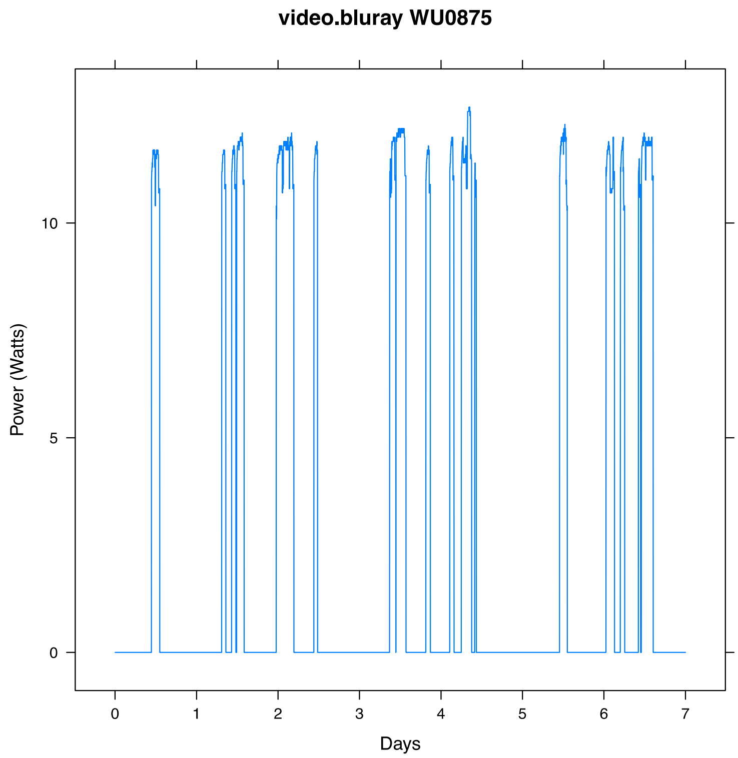
30-39" TV


tv.40–49 WU0359
Power (Watts)
300
250
200
150
100
50
0
Days
0
1
2
3
4
5
6
7

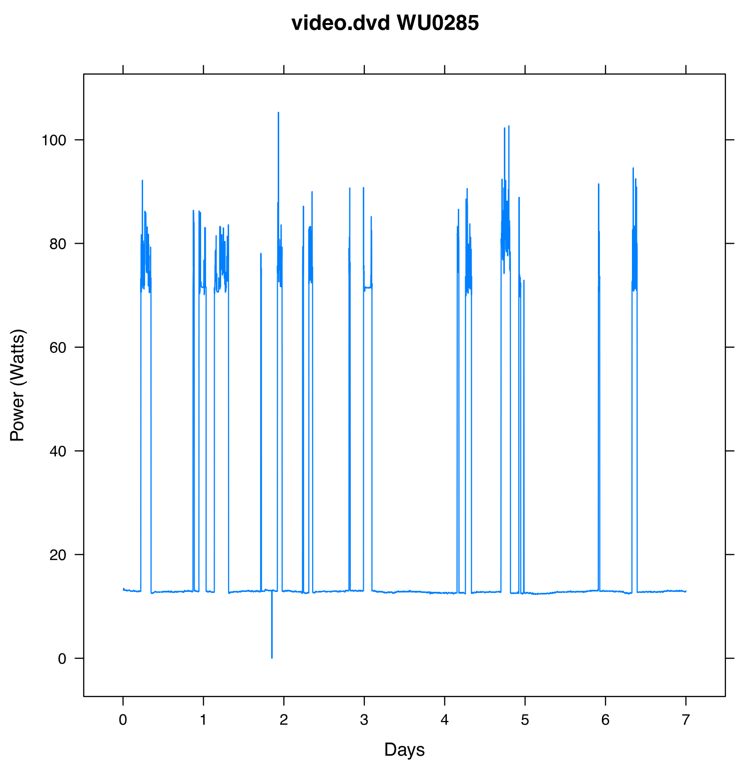
40-49" TV


tv.50+ WU0460
Power (Watts)
400
300
200
100
0
Days
0
1
2
3
4
5
6
7

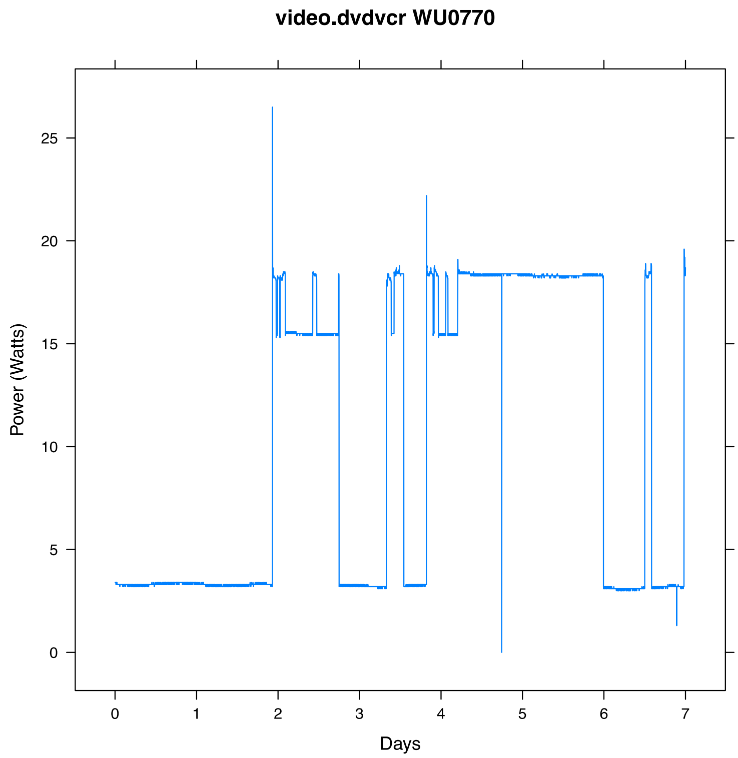
50+" TV



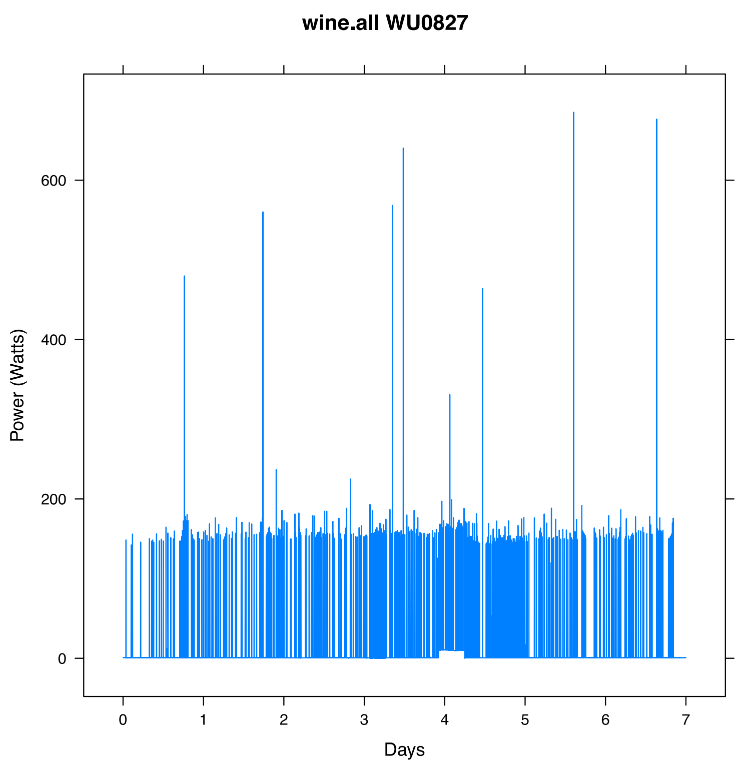
Blu-Ray video player



DVD video player



DVD/VCR video player



Wine chiller