Arnold Schwarzenegger
Governor

Developing and Testing Low Power Mode Measurement Methods

PIER FINAL PROJECT REPORT

Prepared For:
California Energy Commission
Public Interest Energy Research Program

Prepared By:
Lawrence Berkeley National Laboratory

SEPTEMBER 2004
P500-04-057

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Berkeley, CA
Contract No. 500-99-013-TA20-5

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ACKNOWLEDGEMENTS

LBNL greatly appreciates and wishes to acknowledge the invaluable assistance of those who helped make this project possible and a success.

Nancy Jenkins, California Energy Commission

Don Aumann, California Energy Commission

Tommy Bangthamai, Lawrence Berkeley National Laboratory

Jeff Warner, Lawrence Berkeley National Laboratory

Rich Brown, Lawrence Berkeley National Laboratory

Marcy Beck, Lawrence Berkeley National Laboratory

The eight anonymous homeowners who donated their time and houses for days of intrusive measurement

PREFACE

The Public Interest Energy Research (PIER) Program supports public interest energy research and development that will help improve the quality of life in California by bringing environmentally safe, affordable, and reliable energy services and products to the marketplace.

The PIER Program, managed by the California Energy Commission (Commission), annually awards up to $62 million to conduct the most promising public interest energy research by partnering with Research, Development, and Demonstration (RD&D) organizations, including individuals, businesses, utilities, and public or private research institutions.

PIER funding efforts are focused on the following six RD&D program areas:

- Buildings End-Use Energy Efficiency
- Industrial/Agricultural/Water End-Use Energy Efficiency
- Renewable Energy
- Environmentally-Preferred Advanced Generation
- Energy-Related Environmental Research
- Strategic Energy Research.

What follows is the final report for the project Standby Power Consumption Phase 2: Research Into Low Power Modes (contract #500-99-013, Task Order 20-5, Amendment 2), conducted by Lawrence Berkeley National Laboratory. This project contributes to the PIER Buildings End-Use Energy Efficiency program.

For more information on the PIER Program, please visit the Commission's Web site at: http://www.energy.ca.gov/pier/index.html or contact the Commission's Publications Unit at 916-654-5200.

ABSTRACT

The amount of "standby power" used by products has been an increasing concern, and a workshop sponsored by the California Energy Commission (Commission) in August, 2002 extended this scope of interest to all low-power modes. The goal of this project was to advance the state of knowledge about low power mode electricity consumption to enable a subsequent survey to provide a reliable estimate of California statewide low power mode consumption to serve as a basis for policy and to guide further research efforts. This report summarizes the steps taken towards this goal. The key results of the project are:

1. Confirmed with industry stakeholders six elements the Commission research agenda should include.
2. Developed two test procedures (individual products and whole house) to measure power of residential equipment operating in low power mode.
3. Collected field power measurements for 280 products at eight houses and used the results to plan a state-wide survey.

We also combined the power levels with usage patterns to estimate annual energy consumption, and combined this and other data to estimate annual consumption for the entire state. We then used assessments of uncertainty to identify key parameters for which we need more reliable estimates. In summary, we found that statewide "standby" consumption averages 108 W per house, or roughly 1,000 kWh/year — about 15% of household electricity use.

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EXECUTIVE SUMMARY

The amount of "standby power" used by products has been an increasing concern, and a workshop sponsored by the California Energy Commission (Commission) - in August, 2002 extended this scope of interest to all low-power modes. The goal of this project was to develop a field test protocol to measure low power mode electricity consumption. This report summarizes the steps taken towards this goal — outreach to stakeholders, development of test procedures, measurements, and analysis.

Objectives

The key objectives of the project were to:

1. Confirm the Commission research agenda with stakeholders.
2. Develop test procedures to measure power levels of residential equipment operating in low power modes.
3. Test the protocol by collecting field measurements
4. Apply the results to guide planning for a state-wide survey.

Outcomes

The major accomplishments of the project were:

Produced a refined low power mode research agenda that includes six elements:

> Understand how much energy is actually consumed in the low power modes.
>
> Develop energy test procedures for low power modes and protocols to measure their contribution to whole-building electricity use.
>
> Understand human behavior and preferences as they relate to low power modes.
>
> Investigate feasible technologies offering energy savings opportunities and their economic costs and savings.
>
> Engage in short-term research to address anticipated critical problems related to low power modes.
>
> Engage in long-term research to increase the efficiency of low power modes.

Developed two test procedures for low power modes: individual products and whole houses.

Applied the two procedures at eight homes, measuring 280 products and producing averages for 108 product types.

Identified key parameters (stocks, power levels, and usage patterns) for which we need more reliable estimates.

These results set a solid foundation for the next phase of research to collect power, stock, and usage data from non-survey sources, then conduct phone and on-site surveys to collect information they can best provide. It also confirms or indicates the importance of some research topics for which work can begin in advance of the statewide survey results.

Conclusions

Based on limited survey data residential LPM consumption is estimated to be about 108 W per house average. This totals nearly 1,000 kWh/year, or over 15 % of statewide residential electricity consumption. Over two-thirds of low power mode consumption is from electronic devices (audiovisual, information technology, and telephony).

However, because of the limited data a larger survey is needed to more accurately characterize statewide losses and confirm opportunities to reduce these losses. From the test procedures developed in this research a more in-depth investigation of statewide losses is now possible.

Benefits to California

California is at the forefront of research on low power modes in the U.S. certainly, and one of the leading regions globally. With low power mode consumption rising, and poised to increase significantly in the coming years, this is an important area to make and keep a priority. Our future estimate increases low power mode consumption by 13 %.

Recommendations

Recommended actions for the Commission to take in the future include:

Building on this work to conduct a state-wide survey of home to better characterize low power mode usage and energy saving opportunities.

Research opportunities to reduce low power mode loads in high priority topics that merit immediate attention, including:

Set-top boxes and other networked devices.

Hard-wired products.

- Other electronic products
- Other products that the upcoming state-wide survey shows to have large or increasing aggregate consumption.

1.0 Introduction

1.1. Background and Overview

The amount of "standby power" used by products has been an increasing concern, and a workshop sponsored by the California Energy Commission (Commission) in August, 2002 extended this scope of interest to all low-power modes. The goal of this project was to advance the state of knowledge about low power mode electricity consumption as the foundation for a subsequent survey to provide a reliable estimate of California statewide low power mode consumption which will serve as a basis for assisting policymakers and as a guide further research efforts. This report summarizes the steps taken towards this goal — outreach to stakeholders, development of test procedures, measurements, and analysis.

1.2. Project Objectives

The stated objectives at the outset of the project were to:

1. Confirm the Commission research agenda with stakeholders.
2. Develop test procedures to measure power of residential equipment operating in low power mode.
3. Collect field measurements and use the results to guide survey planning.

Each of these objectives was successfully completed. A more comprehensive discussion of objectives and accomplishments is contained in the Project Outcomes section below.

The project was designed to support the PIER program objective of improving the energy cost/value of California's electricity. This goal was to be accomplished by a mixture of consulting with those highly interested in the topic, reviewing literature, conducting lab and field measurements, and analyzing and summarizing the results.

1.3. Report Organization

This report is organized as follows:

Section 1.0	Introduction
Section 2.0	Project Approach
Section 3.0	Project Outcomes
Section 4.0	Conclusions and Recommendations

The remainder of this report describes the highlights of the project approach and results. Attachment 1 is packaged separately from the report to ease its use. The appendices are included with this report:

1. Appendix I summarizes the results of confirming the Commission's research agenda on low power modes.
2. Appendix II is a survey of existing test procedures relevant to low power mode research.

3. Appendix III presents results of measurements at individual houses in the form of power levels for each mode.
4. Appendix IV combines this with reported usage patterns to arrive at annual average consumptions by products in their low power modes.
5. Appendix V presents an initial estimate for statewide low power mode consumption, and identifies the parameters most critical for refining this estimate.

Attachment I includes the test procedure for individual products, and the procedure for an entire house.

2.0 Project Approach

The first task of the project was to confirm with low power mode stakeholders the content of the Commission's research agenda that resulted from the August, 2002 workshop. LBNL circulated the research recommendations to over 200 interested parties, and 40 stakeholders provided their opinions about the priority that the Commission should give to the six recommendations.

Next we surveyed the literature for products reported to have low power modes and for test procedures that were relevant to the topic. We gathered, evaluated and compared existing methods, to find aspects that are common and that were worth considering or using directly in the protocols that we developed. These set the stage for developing a test procedure specifically designed for low power modes. A second test procedure was created for whole houses.

To test the test procedure, we measured products in actual houses, for subsequent analysis. Finally, we combined the results of these measurements with other data and assessments of uncertainty to identify the most critical parameters necessary to obtain better estimates of statewide low power mode consumption.

3.0 Project Outcomes

The major outcomes of the low power mode research project are described below, organized according to the project objectives to which they pertain. Detailed results are found in the appendices; this report focuses on the process and summary results.

3.1. Confirm the Commission's Research Agenda With Stakeholders

The purpose of the first phase of the project was to confirm that the Commission was pursuing the appropriate research topics in the realm of low power modes. This allowed those people who participated in the August, 2002 workshop eight months previous to further reflect on the topic and to evaluate how LBNL summarized the proceedings, and provided opportunity for input by many people who were not able to attend the workshop.

LBNL circulated research recommendations that arose from the August 2002 Standby Power Workshop to over 200 interested parties. Forty stakeholders provided their opinions about the priority that the Commission should give to the following six recommendations that resulted from the workshop:

A. Understand how much energy is actually consumed in the low power modes.

B. Develop energy test procedures for low power modes and protocols to measure their contribution to whole-building electricity use.

C. Understand human behavior and preferences as they relate to low power modes.

D. Investigate feasible technologies offering energy savings opportunities and their economic costs and savings.

E. Engage in short-term research to address anticipated critical problems related to low power modes.

F. Engage in long-term research to increase the efficiency of low power modes.

Understanding how much energy is consumed by low power mode devices was the clear priority for respondents. Engaging in *long-term* research to increase the efficiency of low power modes was seen as the lowest priority. Some of the respondents suggested research topics the Commission should consider in addition to the six from the workshop. Two that were mentioned by several respondents were (1) the need for a better understanding of market forces affecting the adoption of current technologies to reduce low power mode energy consumption, and (2) the need for Commission coordination with national and international low power mode research, test procedures, and regulatory activities.

Respondents also mentioned specific technologies that they felt deserved priority attention. Among these were power supplies and communications technologies like cable or satellite set-top boxes, personal video recorders, and home network equipment. Understanding the interaction of the end user and the device with regard to usage patterns and enabling behavior was also mentioned.

From all of the detailed comments from stakeholders, we revised the report from the August, 2002 workshop. The revised report including summaries of the detailed comments is in Appendix I.

3.2. Develop Test Procedures for Low Power Modes

We reviewed existing test procedures and measurement protocols for standby power, other low-power modes, and usage patterns. The information gleaned from these procedures helped shape the individual product and whole-house measurement procedures that we developed and that are shown in Attachments I and II. Further details on the existing procedures and how they apply to this project can be found in Appendix II. Table 1 shows the types of issues that are addressed by existing procedures that were potentially relevant to our new procedures.

The procedure we developed for individual products has three parts:

1. A "general framework" that lays out general terms, requirements, and principles;
2. A set of "empirical data" that will be fleshed out over time to indicate what modes or special conditions different types of products have;
3. A discussion of the rationales for the choices made in crafting the procedure.

The procedure was designed with its primary goal to measure products as actually used, though it can be adapted and used for new products or laboratory measurements. As much as possible, the protocol is consistent with IEC 62301, on "Measurement of Standby Power." The primary results of the procedure are average power levels by each mode, characteristics of the product, its use context, and reported usage patterns.

Table 1 Topics Addressed by Test and Measurement Procedures

Topic	Comments
Purpose / Scope	Reason for creating the procedure
Basic Power Characteristics	Voltage, frequency
Power Quality	Total harmonic distortion, current, crest factor
Other Conditions	Air speed, temperature, humidity
Accuracy	Accuracy and resolution of metering equipment
Configuration	Settings, attached hardware, information environment
Usage Patterns	Percent of time in each operating mode
Mode Definitions	What to name modes, what characteristics they have
Mode Derivation	How to determine what modes a product has
Controls	Controls (e.g. switches, automatic) within the device or attached to it
Procedure Steps / Timing	Over what time interval to integrate power use
Sampling	How many units to measure
Reporting	What to record / report
Whole-house Measurements	Entire house and all devices within it

3.3. Collect Field Measurements and Use the Results to Guide Survey Planning

We measured 269 products with low power modes in eight houses which we placed into 108 product types, and grouped the types into ten categories (the 269 does not include products measured but subsequently found not to have any low power modes).

We established a criterion of metering five examples of a product type after which it would be considered "known" and able to be measured with a streamlined test procedure. We reached the criterion of five examples for 16 product types: audio mini-system, audio receiver, CD player, cassette deck, cellular telephone charger, computer, computer speakers, DVD player, night light, microwave oven, power strip (surge), clock radio, cordless telephone, television, timer, and VCR. We decided that it was appropriate to relax the criterion to three for products with known and simple modes which adds 12 additional types: answering machine, aquarium pump (water), battery charger, power tool charger, toothbrush charger, CRT computer display, carbon monoxide detector, garage door opener, hair dryer, DSL modem, inkjet printer, and irrigation timer.

Therefore, 28 of the 108 product types are "known" when assuming that measurements from three products gives confidence to use this data for future analysis.

3.4. Selected Quantitative Results

The full set of results is lengthy, so we only present here aggregate results and a few results for individual products. The 56 external power supplies that we measured ranged from 0.10 W to nearly 5 W unloaded (disconnected from the product), averaging 1.10 W. We found more lights with low power mode consumption than expected; as lighting becomes increasingly electronic, we should expect to see an increasing portion of lights with low power mode consumption.1 The two GFCI outlets we measured averaged 0.73 W in their normal position, and when tripped, neither changed consumption. By contrast, the three hair dryers averaged only 0.10 W, and one cut all of its own consumption when tripped.

3.5. Average Low Power Mode Consumption

The low power mode data collected at our eight houses resulted in average power levels for each low power mode for each product, as well as user-reported usage data for each product. The usage data (including disconnected time) were converted into a "percent of year" value for each mode. The total of all active mode time is the residual from summing the low power mode times and the disconnect time.

Table 2, Table 3, and Table 4 show brief excerpts of the measured data that we gathered for all products — the complete data for one of the 108 product types. Table 2 lists each individual product; Table 3 has the average for each mode across all examples of the product type; and Table 4 incorporates usage pattern data to arrive at the usage-weighted annual average low power level. Active modes ("Play" in this case) are marked with an asterisk and not included in the average power level reported in Table 4. For some products, the mix of modes present and readily measurable varies among units measured resulting in a different "n" for different low power modes. Active mode energy use could be calculated from these figures, but we only use the active power levels to compare to the low power levels for indications, not for robust estimates of active mode energy consumption for these products generally. The complete data tables can be found in Appendices III and IV.

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1 Lighting can have low power mode consumption due to "soft" controls (powered circuits that switch a relay that controls the power to the lamp), dimmers with non-zero "off" positions, transformers for halogen lights downstream of the switch, or electronic controls such as timers or more complex controls.

Table 2 Measured Power for Individual Products [Example: DVD Players]

Product Type	Mode 1	Watts	Mode 2	Watts	Mode 3	Watts
DVD Player	Off	6.50	Ready	27.74	*Play	32.47
DVD Player	Off	0.00	Ready	9.91	*Play	13.55
DVD Player	Off	0.73	Ready	7.33	*Play	10.08
DVD Player	Off	0.40	Ready	12.71		
DVD Player	Off	0.39	Ready	6.05	*Play	7.71
DVD Player	Off	1.43	Ready	6.87		

Table 3 Average Low Power Mode Power Levels (W) by Product Type and Count (n)

Product Type	Mode	*W*	n	Mode	*W*	n	Mode	*W*	n
DVD Player	Off	1.57	6	Ready	11.77	6	*Play	15.95	4

Table 4 Usage-Weighted Average Power Levels by Product Type [Example: DVD Player]

Product Type	Average *(W)*	As-used low power mode power for each product *(W)*
Audiovisual		
DVD Player	1.32	0.01, 0.01, 0.4, 0.43, 0.73, 6.37

Multiplying the usage percent and power level for each mode and then summing over all low power modes for a product results in a usage-weighted annual average power level consumed by the device in low power modes. This can be considered to be a constant power consumption, or multiplied by any convenient time period (e.g. a year) to get energy consumption. For example, 1 W is 8.76 kWh/year. Note that while this is an average over all hours of the year (including that time when the product is in an active mode), it does not reflect any of the active mode energy. All further power levels reported here are an average over all low power modes and *not* the measured power levels for a single mode.

From Table 4, at least one of the DVD players was on a power strip or otherwise disconnected for most of the off time, as its usage-weighted average is much smaller than the off power level (the only other possibility is that it is active the vast majority of the time which is unlikely). The 1.32 W for average as-used low-power power is 11.6 kWh/year.

We calculated the as-used low power mode power levels for each product, as well as the average for each product type. For product types with many examples measured, there is often a wide range in the average power. This can be due to wide variations in power levels of the products, the usage patterns, or both. Products with zero as-used power levels are rarely or never in low power modes because they are always in an active mode, mostly disconnected, or mostly in a zero off mode. Forty products in 33 product types had zero power in the as-used low-power state.

Table 5 presents the usage-weighted average power for each category, by site. Only products that we measured are included in the category totals. The data show that electronic products are the most common types with low power mode consumption, with audiovisual, information technology, and telephony the only categories that appear at all eight sites.

We did a limited amount of "imputing" unmeasured products from the power levels observed at other houses or from the literature. This amounted to about 10% of the total low power mode consumption we report. Most of the imputed power is due to (often hardwired) infrastructure products (GFCI outlets and breakers, furnaces, and a security system), and the average for infrastructure is over 12 W when these are included.

Table 5 Usage-weighted Average Power by Category and House (W)

House / Category	11	12	13	14	15	16	17	18	Average	Standard Deviation
Audiovisual	15.8	21.5	28.8	55.3	24.8	33.2	25.2	34.3	**29.9**	11.9
Food / Beverage	6.0	3.6	1.4	6.1	2.3	0.8	–	1.9	**2.8**	2.2
HVAC	7.8	–	0.0	12.3	–	4.6	–	–	**3.1**	5.2
Health / Hygiene	2.2	–	1.2	1.9	0.1	2.9	2.1	–	**1.3**	1.0
Infrastructure	1.4	9.9	0.8	22.9	19.1	4.3	0.8	2.5	**7.7**	8.8
Information Technology	8.0	41.9	14.0	17.8	12.9	8.0	16.1	24.9	**17.9**	11.1
Lighting	–	1.3	0.7	2.3	12.0	2.3	0.6	0.2	**2.4**	4.1
Garden, Workshop	2.5	–	–	3.7	9.6	–	–	2.0	**2.2**	3.5
Other	0.0	10.7	–	14.2	–	0.7	–	–	**3.2**	7.1
Telephony	7.5	7.2	5.5	11.6	6.6	3.9	4.4	6.2	**6.6**	2.4
TOTAL – Measured	51.1	96.2	52.4	148.1	87.3	60.7	49.2	71.9	**77.1**	33.5
Imputed Products	1.4	4.9	9.5	25.4	23.6	9.1	0.7	8.1	**10.3**	9.4
TOTAL – Measured and Imputed	52.5	101.1	61.9	173.5	110.8	70.0	49.9	80.0	**87.4**	41.0

Note: The power levels shown are the usage-weighted annual average power.

3.6. Analysis by Mode Type

Most products had only one low power mode with reported usage. In total, 299 low power modes were reported to be used for the 280 products measured. The distribution of power among modes and types of devices is easiest to assess when all eight houses are grouped together for a "composite" house. Table 6 summarizes the average power level by category and mode type for the composite house. Most audiovisual low power mode use is in off modes, but for information technology and telephony, most use is ready modes.

Energy use for external power supplies only (plugged into 120V power but disconnected from their device) are included in “off” in Table 6 but are only 0.08 W for audiovisual and 0.06 W for telephony, thus totaling less than 1% of the total off power. For ready modes, those with no function being performed were over 90% of the total. For products with integral batteries, those modes that have some charging (usually a maintenance charge) are mostly found in ready modes. These totaled about 6.5 W, mostly cordless phones.

“Partial low power product types” have some examples with low power modes, and some without. For these, we only measured examples with them, but it is necessary to assess what fraction of the entire stock has low power modes to properly estimate statewide consumption. We found few products with a zero power off mode that also had other low power modes. The great majority either had a non-zero off, or no off mode at all. Some product types had off as the only low power mode.

Table 6 Composite Average Power by Product Type Category and Mode Type (W)

Mode / Category	Off	Ready	Ready some function	Single mode	Power products	Sleep	Single mode, active	Total
Audiovisual	23.5	3.6	2.7	–	–	–	–	29.8
Food / Beverage	1.0	1.8	0.0	–	–	–	–	2.8
HVAC	–	2.5	–	0.6	–	–	–	3.1
Health / Hygiene	0.6	0.8	–	0.2	–	–	–	1.6
Infrastructure	0.4	3.2	0.1	3.3	0.8	–	–	7.7
Information Technology	4.6	11.7	–	–	–	1.6	–	17.9
Lighting	0.2	0.7	0.3	1.1	–	–	–	2.1
Garden, Workshop	0.1	2.1	–	–	–	–	–	2.2
Other	–	–	–	0.1	–	–	3.1	3.2
Telephony	0.1	6.5	–	–	–	–	–	6.6
TOTAL	30.4	32.8	3.1	5.3	0.8	1.6	3.1	77.1

Note: The power levels shown are the as-used annual average power. “Ready some function” means that some function is being performed, such as night lights or the clock part of a clock radio . “Single mode, active” includes aquarium pumps and an indoor fountain.

We found many different modes, which we grouped into the following types: "external power supply only," "off," "ready," and "sleep." We also measured some active modes that we categorized as "on" or "play." Some products have only one power mode such as a GFCI outlet or timer. While different from more conventional low-power modes such as consumer electronics "off" modes, it makes sense to include these in the rubric of low power modes and they are included in this project's testing and procedures.

3.7. Whole house reconciliation

The whole house measurement procedure involves putting all low-power mode devices into a known low-power mode, turning all other products off, then observing the utility meter for eight minutes and recording the number of revolutions of the disk (including fractional revolutions). The utility meter reading is then converted to power and compared to the sum of all of the low power mode products.

The attempt to reconcile measurements of individual products with the power shown by the utility meter was not successful. While we would have expected to find modestly more power on the utility meter at all houses, in three cases the sum of products was greater than the utility meter showed, by 20-29% (this including some imputed products; even without those the discrepancies were from 11-21% in the "wrong" direction). The utility meter reading at one house was just 5 W (6%) above the sum of the products, which is about what we expected. At another house it was 78% over the sum of products, which seems likely to indicate a large missed product. At the remaining three, the discrepancy was in the "right" direction, but varied from 18-35%, larger than seems accountable by small, unmeasured loads.

The original purpose of the whole house procedure was to quickly assess the standby consumption for an entire house, and to serve as a check that all products had been found and measured. For the first purpose, the existence of several low power modes for many products and the incorporation of usage patterns make a single measurement of limited use, and lacking any explanatory power. For the second purpose, the utility meter reading appears to be too coarse. Any further work on this should probably include more direct measurements of the current and power flowing through the main electrical panel rather than relying solely on the utility meter itself.

Another aspect of whole house reconciliation is to compare the total household low power mode energy usage estimate with the metered whole house energy use. Table 7 shows this comparison for the eight test houses.

Table 7 House Meter Data and Comparison to Derived Data

Site	House Meter	Sum of Products	Difference		Imputed Products	Adjusted Sum	Adjusted Difference	
	(W)	(W)	(W)	%	W	W	W	%
11	50.8	59.6	-8.8	-17%	1.4	61.0	-10.2	-20%
12	299.4	362.8	-63.4	-21%	4.9	367.7	-68.3	-23%
13	78.0	46.1	31.9	41%	9.5	55.6	22.4	29%
14	143.6	159.4	-15.8	-11%	21.2	180.6	-37.0	-26%
15	121.0	91.0	30.0	25%	23.7	114.7	6.3	5%
16	76.7	56.9	19.8	26%	5.9	62.8	13.9	18%
17	305.9	65.1	240.8	79%	0.7	65.8	240.1	78%
18	133.9	78.7	55.2	41%	8.1	86.8	47.1	35%

Note: A negative number in the Difference columns means that the sum of measured products exceeds the power level observed from the whole house meter. A positive number means that the meter reading exceeds the sum of the products. A positive number can be offset by unmeasured products that were consuming power during the whole house reading.

3.8. Statewide Results

For each product type we measured, and a few others, we estimated the current statewide stock of the product, the average power levels in low-power modes, and the typical usage pattern. From this we calculated "usage- and stock- weighted annual average power level consumed in low power modes," which we henceforth refer to as the "aggregate average power level" or "aggregate power." This combines all of these factors to show the amount of continuous energy usage per household for each product type to match the statewide total. The sum of this figure for all product types is 108 W. This is similar to average power levels reported for standby power except that it includes more modes and accounts for usage patterns. Product types that are mostly hardwired constitute about 14 W. Table 8 shows these results for our ten categories of product types.

From Table 8 we can see that three categories are mostly or entirely electronic — audiovisual, information technology, and telephony — comprising about 70% of the total. Other categories such as infrastructure also have many electronic products, and the low-power consumption of non-electronic products such as major appliances are often mostly electronics loads. We also assessed the uncertainty of each parameter for each product type to determine which parameters could affect the statewide total the most. Finally, for a number of product types we estimated a near-term future change. Complete details are shown in Appendix V.

Table 8 Aggregate Average Power Totaled by Category

Category	Power (W)	% of Total
Audiovisual	46	43%
Information Technology	21	19%
Infrastructure	11	9.9%
Telephony	8.4	7.8%
HVAC	6.6	6.1%
Food and Beverage	4.4	4.1%
Other	4.2	3.9%
Lighting	3.5	3.3%
Health and Hygiene	1.9	1.7%
Garden and Workshop	1.8	1.6%
Total	**108**	**100%**

3.9. Statewide Survey

The next phase of the low power mode research project is to conduct a statewide survey to provide a more robust estimate that can serve as a benchmark and planning basis for future Commission activities in this area. The first step is to develop a clear taxonomy of products and modes so that boundaries between and groupings of product types are crafted to balance the amount of detail the analysis reflects with the actual needs of energy analysis and the realities of data availability. The second step is to gather data from "non-survey" sources to collect those data items that are more readily available or accurate from non-survey sources than they would be from collection within a survey. Because the statewide estimate is based on many hundreds of data points, most of these will be from non-survey sources. This would result in a revised statewide estimate. The third step would be to collect the survey data itself, using phone and on-site data collection. The fourth step would integrate the results of the survey data collection with all of the other data to produce the final statewide low power mode estimate. Appendix V identifies the parameters that have the most effect on the statewide result (given the size of each product's consumption and the uncertainty of the parameter) and makes an initial assignment of these to the phone survey, the on-site survey, and other sources.

3.10. Hardwired Products

Our statewide estimate for hardwired products is 14 W per aggregate household, or 13% of the 108 W average. Since we generally did not measure hardwired products in our site visits for this project, we do not have an equivalent measure for them. The importance of hardwired products is magnified by several factors: they are often very long-lived in houses so that decisions made in the next few years will determine energy consumption for these for many decades in some cases. There are a variety of hardwired products that are increasing in number, from parts of some security systems to central vacuums to powered smoke detectors to more energy intensive circuit breakers (e.g. arc-fault interrupters). Some of these products are required by building codes but none have any energy labeling that can help consumers identify more efficient products.

4.0 Conclusions and Recommendations

The major conclusions and recommendations of the Power Management Controls project are presented below.

4.1. Major Conclusions

This project made significant progress towards establishing a standard method for measuring and reporting low power mode power levels and creating a credible statewide estimate of low power mode consumption.

We confirmed and updated the research agenda on low power modes for the Commission as first established by the August, 2002 workshop. We developed test procedures for low power modes of individual products and whole house measurements. We measured individual products in eight houses and did whole house measurements for those same eight houses. The most important result of this process is a table of average power levels for dozens of product types in a variety of operating modes. Finally, we made an estimate for the statewide residential low power mode total consumption and identified those parameters most critical to obtain better data to refine this estimate.

Our test procedure fills a needed gap. The data collection process clarified what is important to collect and what can be ignored. The data collection results show significant low power mode energy use, consistent with previous studies of standby power. Over two-thirds of low power mode consumption is from electronic devices (audiovisual, information technology, and telephony). The data needed in the next phase of the survey process is a mixure of those best gathered from surveys and from other sources (e.g. manufacturers, trade associations, and other research).

4.2. Commercialization Potential

The test methods developed in this project are not viable for commercialization, but they can be applied by anybody interested in expanding our database of information. For this reason the test methods are packaged to be distributed independently of the report. The test methods could be adopted by an organization such as the International Energy Code, but that is a lengthy process outside the scope of this project. .

4.3. Benefits To California

Applying the project results will help researchers and California policy makers pursue projects and strategies to reduce low power mode energy use. If 25% of present low power mode energy consumption could be avoided, the savings would be approximately 2.7 TWh/year and an average of 310 MW (assuming 11.5 million households). The percent of low power mode consumption that is readily saveable and what specifically California should do to accomplish these savings are topics for future research, but these figures provide a context to decide how much the topic area should be of interest to the Commission. In addition, there is the potential for significant increases in consumption by some low-power mode devices, particularly networked electronics, and so even more potential future savings.

4.4. Recommendations

Recommendations for future action are organized below.

- Recommended LBNL Actions:
    - Pursue other sources of funding to supplement Commission/PIER resources in assessing low power mode energy use and efficiency options.
- Recommended Commission Actions
    - Build on this work to conduct a state-wide survey of home to better characterize low power mode usage and energy saving opportunities. Fund the next phase of work on the survey.
    - Fund research opportunities to reduce low power mode loads in high priority topics that merit immediate attention, including:
        - Hard-wired products.
        - Set-top boxes and other networked devices.
        - Other electronic products
        - Other products that the survey shows to have large aggregate consumption or are increasing.

GLOSSARY

CEC	California Energy Commission — A state of California agency.
Low Power Mode	A product in a low-power mode is not performing any of its principal functions. Some products have more than one principal function. When feasible, low-power modes shall be categorized into sleep and off modes. (from Test Procedure, Attachment 1)
Product	A piece of equipment that can be powered directly from mains power. (from Test Procedure, Attachment 1)
Product Type	A product type is a general category of product within which there is a sufficient amount of common functionality, modes, and behavior. (from Test Procedure, Attachment 1)
Standby	The minimum power mode of a product, or more formally, "the lowest power consumption mode which cannot be switched off (influenced) by the user and that may persist for an indefinite time when an appliance is connected to the main electricity supply and used in accordance with the manufacturer's instructions." (IEC 62301)

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International Electrotechnical Commission, IEC 62301 Ed 1: Measurement of Standby Power, IEC TC 59, TC59, Working Group 9 59/297/CD Household Electrical Appliances.

Meier, Alan, "Final Report Research Recommendations to Achieve Energy Savings for Electronic Equipment Operating in Low Power Modes: A Summary of Previous Project Work and Identification of Future Opportunities", prepared for the California Energy Commission, Public Interest Energy Research Program, Lawrence Berkeley National Laboratory, LBNL-51546.

APPENDIX I: RESEARCH RECOMMENDATIONS TO ACHIEVE ENERGY SAVINGS FOR ELECTRONIC EQUIPMENT OPERATING IN LOW POWER MODES

Appendix I — Research Recommendations To Achieve Energy Savings For Electronic Equipment Operating In Low Power Modes

1.0 Executive Summary

An increasing amount of electricity is used by equipment neither fully "on" nor fully "off;" we call these low power modes. "Standby" and "sleep" are the most familiar low power modes, but some new products already have many low power modes. Low power modes are now becoming common in household appliances, safety equipment, and miscellaneous products.

Low power mode energy use is responsible for about 10% of total electricity use in California homes — roughly 70 W per home, or 900 MW of connected load. It is likely to continue growing rapidly as products with high low power mode energy use penetrate the market. For example, the TV digital converter (set-top) box — which can draw as much as 20 W when not in use — is likely to appear in every California home in the next five years. New homes are required to install hard-wired smoke detectors and safety outlets, both of which draw small amounts of power all the time. Other sectors such as commercial buildings and industry also have low power mode energy use, perhaps totaling more in aggregate than that of households, but no comprehensive measurements have been made.

A workshop was held August 26, 2002 to discuss the current state of knowledge related to low power mode energy use and to suggest research areas for California and other research sponsors to pursue in reducing low power mode energy use. Six research areas were identified:

A. Understand how much energy is actually consumed in the low power modes.

B. Develop energy test procedures for low power modes and protocols to measure their contribution to whole-building electricity use.

C. Understand human behavior and preferences as they relate to low power modes.

D. Investigate feasible technologies offering energy savings opportunities and their economic costs and savings.

E. Engage in short-term research to address anticipated critical problems related to low power modes.

F. Engage in long-term research to increase the efficiency of low power modes.

After the workshop, the six research areas identified were circulated to over 200 interested parties. 40 stakeholders provided their opinions on the priority that the CEC should give to these topics. The resulting priorities generally followed the order in which the topics are listed above, although they were aggregated into three priority groups: understanding how much energy is consumed in low power modes was a strong first priority; the next four topics were essentially equivalent in perceived importance; and long-term research was distinctly lower in priority than the other five areas.

Overall, there is consensus that low power mode energy consumption is an important area for CEC-funded research. Low power mode energy use is not well-understood in California, but the available data suggests that it could be a significant component of California's total energy consumption in the future. Many see this as a critical time for addressing low power mode issues. As equipment designs move from the binary "on/off" paradigm to one that encompasses multiple power modes, there is a unique opportunity to address the issue of low power mode energy consumption while technology development paths are still flexible.

2.0 Introduction

An increasing amount of electricity is used by equipment neither fully "on" nor fully "off." This category of electricity use will soon have a large impact on energy demand. Millions of devices already have this characteristic, and billions more will have it in the future. The California Energy Commission's Public Interest Energy Research (PIER) Program established a project to develop an agenda for an R&D initiative on reducing this emerging use of electricity. The results of that effort are summarized in this report.

The original focus of this project was "standby power"; however, it soon became clear that a broader perspective was needed, both for research and policy. As a result, this project addresses all "low power modes."

2.1 Terminology — Low Power Modes

In the electromechanical era, appliances had two operating modes: "on" (or "active") and "off" — with "off" meaning zero power consumption. With the advent of electronics, devices could be "off" and yet still draw power. These third set of modes are often called "standby," but have many other names depending on the device (or even the manufacturer of the device.) An increasing number of devices have multiple modes — such as "sleep" and "deep sleep" — between standby and active. Future devices are likely to have many different operational modes between "unplugged" and "active," each with a different level of electricity use and functionality. Figure 1 below depicts operational modes and power levels.

It is important to distinguish between *operational* modes — such as on, sleep, and off — and *power* levels, such as the definitions of standby recently adopted by the Department of Energy (DOE) and the International Electrotechnical Commission (IEC).[1] The DOE and IEC definitions of standby refer simply to the device's lowest power level while connected to the mains, irrespective of functionality.

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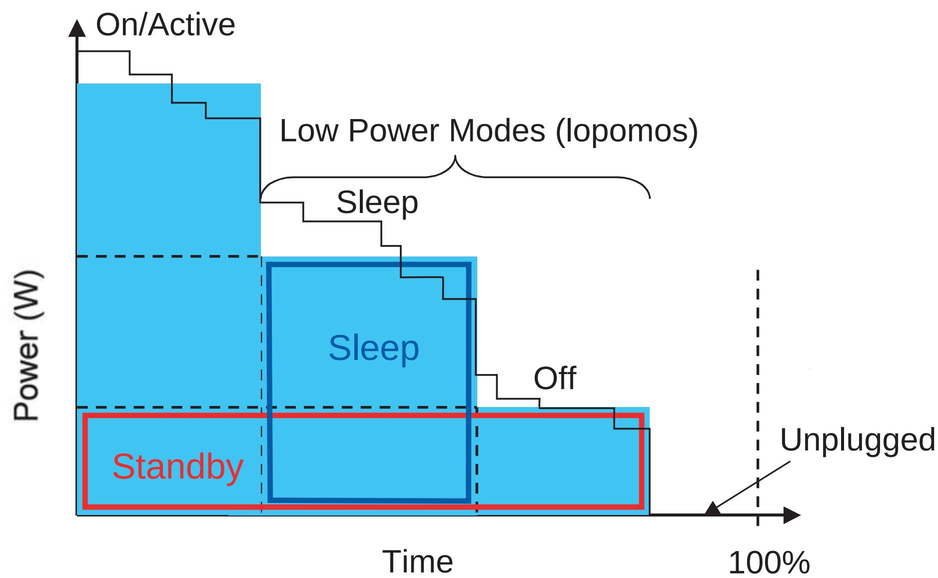
[1] A product may consume its standby power level in any of the three basic operating modes: on, sleep, or off. For example, a telephone answering machine is fully on at its standby level; some printers lack a power button so are asleep in their minimum power mode; and many devices consume standby power when off. Thus, "standby" is a power level, not a operational mode. While it is sometimes more convenient to talk about a product's "standby mode", that really refers to the mode at which the device consumes its standby level, since there is no mode consistent across all devices that is *the* standby mode.

This project focuses on all of the modes between unplugged and active, which we call the "low power modes." One possible term to use as a short-hand is "lopomos" (for LOw POwer MOdes). We used this term often in the course of assessing stakeholder opinions.

Figure 1. A graphical depiction of device power modes. Most products still have only one or two low power modes: a "sleep" mode and an "off" mode.



2.2 Project Summary

This project began with a literature review. We collected and analyzed measurements of low power mode energy consumption, programs and policies addressing low power mode energy use, and research and development activities regarding low power mode devices. We then convened a workshop on August 26, 2002 in Berkeley, California to discuss the results of the literature review and make recommendations for research. Finally, we conducted a survey of interested parties to verify their support for research in this area and to record their opinions of the research priorities the CEC should pursue. This Report summarizes the results of those activities. Detailed documents — such as those prepared as background for the workshop — are available at the website we have established for this project.[2]

[2] The Low Power Mode web page summarizing this research is available at http://standby.lbl.gov/Lopomo/

3.0 Review of Literature Related to Low Power Modes

3.1 Energy Test Procedures

Consistent definitions and test procedures are essential for reliable and comparable measurements. Unfortunately, responsibility for definitions and test procedures of low power modes are spread among many international groups, with no overall organization or coordination. Many actually conflict with each other, either in definition or procedures. The Energy Star program has established *ad hoc* product-specific definitions for most of the products that it covers, but even these tests are inconsistent in both large and small aspects.

A technical committee of the IEC (TC 59 WG 9)[3] issued a draft definition and test procedure for standby power in July 2002. The committee's responsibility is white goods, but the test procedure was designed to apply to virtually all electric devices that can be plugged in. No similar, generally applicable test procedure exists for the other low power modes.

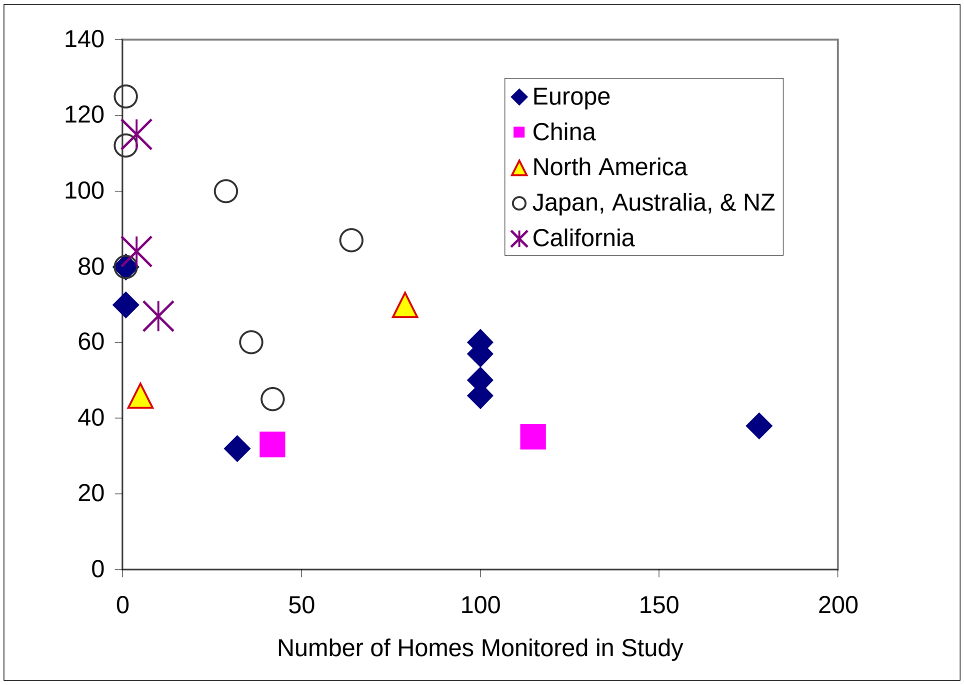
3.2 Field Measurements

Virtually all relevant low power mode measurements to date have been conducted on standby power use in homes. Over one thousand homes around the world have been measured, including some in Europe, Japan, Australia, and China. Only one formal study in the United States has been conducted — 10 homes in California — so we have a poor understanding of both the California and U.S. standby situation. Less information is available for other low power modes. Worldwide, residential standby power measurements range from about 30 to 125 W per home, as shown in Figure 2.

Data are even scarcer for the commercial sector. For one class of devices — office equipment — we have rough estimates of energy use, but for the rest we know almost nothing. No commercial buildings have been monitored, so we have essentially no idea how large low power mode energy consumption is, let alone a comprehensive list of devices with low power modes.

Figure 2 3. Field measurements of residential standby power use in different countries. Less than 15 homes have been measured in California.

[3] The Committee Draft is available at the Low power mode Web site.



3.3 Energy Use of Low Power Modes in California

There is not enough information to estimate confidently energy consumption of low power modes. Based on the existing data, a "best guess" of residential standby is 70 W per home, which is roughly 600 kWh/year (more than most new refrigerators), or about 10% of California residential electricity use. The more modest additional energy use of sleep modes must still be added to this number, so 70 W represents a conservative estimate. This implies a California-wide load of about 900 MW (8,000 GWh/year).

With the available information, we cannot even determine if standby or total low power mode energy use is increasing or decreasing. Energy Star programs may be reducing standby in common consumer electronics, but the rapid appearance of new digital appliances and the dramatic increase in the number of appliances with standby may be offsetting those gains. Some of the key growth areas for residential standby include set top boxes, white goods, and home networks. Another problem is "hard-wired" standby caused by smoke detectors, security systems, GFCIs, and HVAC control systems. A unique problem is digital converter boxes for TVs, which may be required for as many as 200 million TVs in the United States — over 20 million in California alone — in the next 5 years, each drawing as much as 20 W. Anecdotal evidence therefore suggests that residential low power mode energy use will probably rise significantly in the coming years.

Data for the commercial sector are even sketchier. Based on rough assumptions, office equipment alone may be responsible for 1,100 GWh/year. The energy use of other products with low power mode energy use, from emergency lighting and exit lights to communications equipment, still needs to be included (but no data are available). There is reason to believe that the energy use of equipment in their low power modes is the fastest growing component of California electricity use.

3.4 Energy Efficiency Programs

Voluntary and mandatory programs dealing with low power modes exist in North America, Europe, Japan, Australia, China, and several other countries. Most of the voluntary programs, such as Energy Star, target the standby mode for consumer electronics and the sleep mode for office equipment. In contrast, the mandatory efficiency programs, such as efficiency standards for white goods in the U.S., Europe, Australia and Japan, generally target active modes and ignore the low power modes.

Energy Star operates the world's largest program for consumer electronics and office equipment. Energy Star specifications are arguably the *de facto* world standard for these products.

3.5 Research Strategies

There is only limited technical research focused solely on improving the efficiency of low power modes. The wide diversity of products partly explains the lack of specific research on the topic. Nevertheless, research that will impact low power modes is underway. Technologies borrowed from other situations (e.g., battery-powered devices, where power consumption is critical) can often be constructively applied to low power modes. Some corporate research directed to other goals has also led to low-power solutions. For example, the need to reduce heat output and weight of power supplies has resulted in greatly improved efficiencies for some products. Manufacturers have successfully cut irritating fan noise by switching off the fan altogether while in a low power mode. This could only be accomplished by reducing component heat generation while the device is in standby or sleep modes.

There are three principal research strategies to reducing low power mode energy consumption:

1. Improve the efficiency of the components
2. Improve equipment design to help device components better match functional needs
3. Improve (or modify) technologies outside the device or change user behavior

An example of *component improvement* is increasing the efficiency of power supplies in their no-load and part-load performance. Other examples include de-energizing components when not needed and designing ultra-low power circuits.

Design improvements help the device better match operational components with functional needs. These improvements enable the device to shift operating time from active to sleep and from sleep to off. These changes may actually increase energy use while in the low power modes (by shifting operating time from active) but result in lower overall energy use.

External changes can also reduce energy use in low power modes. Important examples are the communications protocols between service providers (such as cable TV providers) and set top boxes, or between a server in a home network and the appliances on the network. Protocols need to be designed to enable devices to enter the lowest possible operational state. This requires coordination between the service providers and the box manufacturers. Other external changes include construction of a low-power DC supply network in buildings (to eliminate the need for separate power supplies) and improved user interfaces that make low power modes easier for consumers to identify and use. Research is also needed on consumer behavior, as well as effective interfaces between consumers and these products.

4.0 Summary of comments from stakeholders

4.1 Summary

LBNL circulated research recommendations that arose from the August 2002 Standby Power Workshop to over 200 interested parties. 40 stakeholders provided their opinions about the priority that the CEC should give to the six recommendations that resulted from the workshop. Understanding how much energy is consumed by low power mode devices was the clear priority for respondents – 38% ranked it the highest priority, and 2/3 ranked it either the first or second priority the CEC should pursue. Conversely, engaging in *long-term* research to increase the efficiency of low power modes was seen as the lowest priority. No respondent ranked it the first priority for CEC research, and the majority of respondents ranked it either fifth or last.

Some of the respondents suggested research topics the CEC should consider in addition to the six from the workshop. Two that were mentioned by several respondents were (1) the need for a better understanding of market forces affecting the adoption of current technologies to reduce low power mode energy consumption, and (2) the need for CEC coordination with national and international low power mode research, test procedures, and regulatory activities.

Respondents also mentioned specific technologies that they felt deserved priority attention. Among these were power supplies and communications technologies like cable or satellite set-top boxes, personal video recorders, and home network equipment. Understanding the interaction of the end user and the device with regard to usage patterns and enabling behavior was also mentioned.

4.2 Introduction

The CEC sponsored a workshop in August, 2002 to assess research needs and opportunities in the area of standby power. The workshop was well-attended, with attendees representing a variety of stakeholders. The recommendations that emerged from the workshop fell into six research areas, and the focus shifted from solely standby power (the single minimum power level) to all **lo**w-**po**wer **mo**des — "lopomos" (encompassing various sleep and off modes.) As a result of that workshop, the CEC commissioned LBNL to more widely circulate the recommendations, receive and consider comments, and prepare a final list of recommendations. This memo describes the methods used to circulate the recommendations and collect the feedback, as well as an analysis of the results. The final deliverable for this task will be a revised list of recommendations.

4.3 Methods

The CEC requested feedback from a variety of actors: government agencies, including the US Department of Energy and Environmental Protection Agency; industry; non-governmental organizations; California investor-owned utilities; and other interested parties, including international respondents. To meet this goal, we compiled a list of potential survey respondents. The list included participants in the August workshop, participants in other workshops about standby power consumption, and people known to be interested in low- power research issues. The final list of contacts included 203 people.

We organized our data collection from these contacts by developing an interview protocol that covered three major topics: a prioritization of the six research areas that came out of the workshop, refinement of the research activities to reflect more specifically the respondent's interest (as necessary), and any additional research topics the respondent felt important but not covered by the original six (again as necessary.) If an additional topic was provided, the respondent was asked where to include the new priority in the ranking of research areas

We recognized that, given the timeframe of this study, all 203 potential respondents could not be interviewed individually. We therefore prioritized the contacts to enhance the likelihood that the variety of respondents sought by the CEC would be surveyed. 37 contacts representing the range of stakeholders were identified as high priority and personally contacted by a member of the survey team. Another 62 were also contacted via personal communication, with the remaining 102 contacted through a more general mass e-mail message. In some cases, our request for comment was passed through one of our identified contacts to a group. This enlarged our pool of potential respondents. For example, the Silicon Valley Manufacturers Association sent out an e-mail notice of our effort to about 200 member contacts interested in energy issues, asking that anyone interested in commenting contact us.

For those respondents we contacted personally, we typically e-mailed a copy of the six research priorities to the respondent before conducting the interview by phone. We also included a web reference to the full report summarizing the August workshop. We then called the respondent to go through the interview protocol questions. For those respondents we contacted solely by e-mail, we provided the same six research priorities and references to the full report and then included the interview protocol questions in the message. We used a standard template for the e-mail text.

We began contacting our priority respondents in mid-April 2003 and collected data through May. We received comments from 46 respondents. 18 respondents were from industry, 10 from government, 8 from NGOs, 3 from utilities, 5 from consulting firms, and 2 "other." Of the 46 respondents, 40 provided specific recommendations about the priorities they gave to each of the research recommendations proposed from the August workshop. The other 6 either expressed no preference for one research area over another (e.g., "They're all important") or provided commentary about the research goals, specific research method suggestions, or other general comments without providing ranking of priorities.

4.4 Priority Results

In Table 1 below, we summarize the results of the prioritization part of the interviews. The columns show the prioritization expressed by the respondent, from highest priority 1st to lowest priority 6th. The rows show each research topic as identified by the August workshop. (The topics are also summarized below the table.) The highest percentage response in each priority column is presented in bold text. Rows do not sum to 100% due to respondents not ranking every research topic.

How much energy is actually consumed in low power modes was ranked the highest priority research topic by a plurality of respondents. A stronger indication comes if one considers both 1st and 2nd priority rankings: 2/3 of the respondents ranked understanding how much energy is consumed as either the highest or second-highest priority for CEC research. Many people commented that understanding the present energy consumption of low power modes was a precondition to much of the follow-on work. Some who did not rank this topic as a high priority expressed the point of view that we already know how much energy is consumed by low power modes, though a careful reading of the material prepared for the workshop says otherwise (and the level of documentation of low-power mode energy consumption other than standby is low).

In contrast to topic 1, topic 5 – "Engage in long-term research to increase the efficiency of low power modes" – was never mentioned as a first priority. It was often mentioned as the last choice of priorities. As can be seen from the table, over half of the respondents rated it last or second to last as a research priority.

Beyond these two ends of the spectrum, the research priorities are muddled. As a general trend, topics 1, 2, and 3 were more often mentioned as higher priorities than topics 4, 5, and 6. However, respondents often grouped their research priorities by identifying one or two primary research topics and then "the rest." In many cases, the research topics ranked as lower priorities were considered to be similar in importance. As a result, little weight should be given to the distinction between, for example, the 3rd and 4th ranking. It is clear from both the numerical results and the comments of the respondents that the lower-ranked research topics should be considered more or less equivalent.

Table 1: Respondents' Prioritization of Research Topics by Percentage Response

Research topics	Priority					
	1st	2nd	3rd	4th	5th	6th
1: How Much Energy	38%	28%	10%	8%	5%	8%
2: Test Procedures	20%	25%	20%	13%	5%	10%
3: Behavior	10%	13%	23%	13%	15%	18%
4: Feasible Technologies	10%	15%	10%	25%	18%	10%
5: Long-term Research	0%	5%	15%	10%	25%	28%
6: Short-term Research	15%	10%	8%	18%	15%	10%
Other	8%	0%	5%	0%	0%	0%

No response	0%	5%	10%	15%	18%	18%

Topic 1: Understand **how much** energy is actually consumed in low power modes.

Topic 2: Develop energy **test procedures** for low power modes and protocols to measure their contribution to whole-building electricity use.

Topic 3: Understand human **behavior** and preferences as they relate to low power modes.

Topic 4: Investigate **feasible technologies** offering energy savings opportunities and their economic costs and savings.

Topic 5: Engage in **long-term research** to increase the efficiency of low power modes.

Topic 6: Engage in **short-term research** to address anticipated critical problems related to low power modes.

Using a pair-wise comparison process to determine which research topics were mentioned before the others, we were able to collapse the rankings to a prioritized list. From most important to least important, the general result was:

1st priority Understand how much energy is actually consumed in low power modes.

2nd priority Develop energy test procedures for low power modes and protocols to measure their contribution to whole-building electricity use.

3rd priority Understand human behavior and preferences as they relate to low power modes.

4th priority Investigate feasible technologies offering energy savings opportunities and their economic costs and savings.

5th priority Engage in short-term research to address anticipated critical problems related to low power modes.

6th priority Engage in long-term research to increase the efficiency of low power modes.

As mentioned above, though, the ordering of the middle four topics is somewhat arbitrary. No significant distinction existed among these options.

4.5 Other Results

Two major additional topics came up in several interviews. The first was the need to understand market forces affecting the adoption of efficient low power mode technologies. Examples of this are cost and other drivers of manufacturers' choices, market research, what functions need to be maintained in low power modes to retain market acceptance, non-energy benefits, and the whole "value proposition" of the needed technology. At least five people mentioned costs.

The second additional major topic was the need for the CEC to coordinate its research priorities with other research and regulatory activities, both nationally and internationally. While industry can be expected to call for this to avoid having multiple targets or standards emerge, it is notable that as many non-industry people mentioned this as industry representatives.

In our interview protocol, we did not use the phrase "technology item," but we culled ideas from the respondents' comments that seemed to qualify. The ones mentioned by more than one person were power supplies, set top boxes, networks, and usage/enabling. In general, it was thought that the California Energy Commission did not need to invent new technologies, but rather understand why some promising existing technologies are not used (at all or as much as they should be) and determine what could be done to remove some of these barriers.

The task order asked us to "Confirm their support for low power mode research (including such products as set top and digital converter boxes, power supplies and battery chargers, etc.)." At least five respondents specifically brought up power supplies as a priority, and at least eight specifically brought up set top boxes (with some mentioning all access boxes, such as also cable modems, and also PVRs — personal video recorders such as TiVo). Both power supplies and set top boxes were widely discussed at the workshop and mentioned in the report and so people may not have felt it necessary to reiterate their importance. Battery chargers were not brought up explicitly. Overall, support for the general idea of low power mode research was high.

Four people mentioned the general problem of networked devices – that being on networks can keep devices in a higher power state than otherwise would need to be. This was seen as a "huge opportunity," as IT, CE, and "internet-aware" devices of all sorts converge in this functionality. Understanding and possibly changing the network protocols was mentioned by several people.

About a dozen people mentioned the issue of usage patterns and enabling of power management. This included better understanding usage patterns, understanding how to change them (four people), and software problems that interfere with enabling (four people). One respondent found that when he turned off his cable modem, the cable company called to ask what was wrong, and that one of his printers lacked any power switch at all.

Other topics mentioned were micro fuel cells, "whole building systems approaches" and devices with a second, small power supply that handles all standby power needs.

For the "how much energy" topic, several people mentioned the importance of making forecasts of future energy consumption, such as five and ten years out, to better understand how it is changing and what technologies may be present or needed. These estimates could be with and without a low power mode policy effort, and any estimate could include a savings potential. One respondent thought we would see differences between old and new homes. Several respondents thought that the results of the "how much energy" investigation would point the way to additional research needs and priorities.

Three people explicitly mentioned that research data should be collected in a way that could be used for future standards in this area. One said that policy research should be explicitly part of the research agenda.

Finally, a number of other comments seemed worth repeating but do not fall into obvious categories. These are: Clarify terminology/definitions; Assess the impact of low power modes on system peak; Look at baseline consumption as indicator of low power mode; Look at the commercial sector; Recognize energy-driven uses of standby (e.g. timers to delay consumption to off-peak); Estimate the effect of over-sizing of power supplies; Quantify the no-load subset of standby power; Assess the energy consumption of battery-only devices that have AC-powered counterparts; and whether concern over standby power could drive some manufacturers to shift to battery power, with uncertain energy consumption implications.

Finally, one suggestion that was emailed to us by a respondent seemed worth quoting directly:

> I would really like to see us collaborate to develop a competition on "lowest stand-by power" for consumer electronics. I would like to see recognition awarded to the "winner" who provides the "lowest stand-by power" and/or "on mode efficiency" performance for a selected "consumer" application, at your or the CEC's or Energy Star's choosing. Overall, the idea would be to award "points" for the various categories (efficiency during normal mode, lowest stand-by power, efficiency during stand-by mode, power supply footprint, and last but not least, system cost vs. traditional solution in the selected electronic). I would relish the chance to prove what is possible by using our ICs to show how committed we are to this effort.

4.6 Related Activities

For related industry activities since the August 2002 Workshop, several respondents mentioned the European Code of Conduct activities on power supplies & set-tops, and several component manufacturers mentioned recent product introductions that facilitate reducing energy consumption in low power modes. Also, while it began operation before the workshop, the Federal Energy Management Program (FEMP) continues to collect voluntarily submitted data from manufacturers. This collection presently covers over 4,000 different electronic devices in 19 product categories.

We also would like to note several developments since the workshop. There will be a set-top workshop at IEA (see standby.lbl.gov/set-top to get to the IEA web page on this.) The Energy Star program is working on new specification levels for imaging equipment and for monitors. Also, the IEC test procedure for standby continues its slow march to being finalized. Finally, interesting reports on standby power continue to come out of Australia (we will reference those in other reports).

4.7 Conclusions

LBNL circulated research recommendations that arose from the August 2002 Standby Power Workshop to over 200 interested parties. 40 stakeholders provided their opinions about the priority that the CEC should give to the six recommendations that resulted from the workshop. Understanding how much energy low power mode devices consume was the clear priority for respondents – 38% ranked it the highest priority, and 2/3 ranked it either the first or second priority the CEC should pursue. Conversely, engaging in *long-term* research to increase the efficiency of low power modes was seen as the lowest priority. No respondent ranked it the first priority for CEC research, and the majority of respondents ranked it either fifth or last.

Some of the respondents suggested research topics the CEC should consider in addition to the six from the workshop. Two that were mentioned by several respondents were (1) the need for a better understanding of market forces affecting the adoption of current technologies to reduce low power mode energy consumption, and (2) the need for CEC coordination with national and international low power mode research and regulatory activities.

Respondents also mentioned specific technologies that they felt deserved priority attention. Among these were power supplies and communications technologies like cable or satellite set-top boxes, personal video recorders, and home network equipment. Understanding the interaction of the end user and the device with regard to usage patterns and enabling behavior was also mentioned.

Overall, there were no significant distinctions in research prioritization based on the respondents' organizational affiliation in the responses we received. In other words, there seemed to be general agreement across the various interest groups.

The workplan as a whole was well-received and seen as substantially in good shape already. Thus, any changes to it ought to be more minor adjustment and integration of the prioritization rather than any major change to its structure or content. For this next deliverable we propose to adapt the content of the Workshop recommendations document, dropping some sections, revising based on the results of this work, and taking into account the work envisioned for the remainder of this Task Order.

5.0 Recommendations for Research

The following recommendations are based on the input gathered in the August 26, 2002 Workshop, through discussions with other knowledgeable persons in the field who were unable to attend the workshop, and the results of the survey of interested parties. Documents providing more detail on each of these topics are available from the Low Power Mode web page.

Both workshop participants and survey respondents strongly endorsed the need for research into the general topic of low power modes. Many from the private sector saw how this problem would impact their own businesses and felt that early action was advisable. The participants were also comfortable with California funding the research, either alone or in collaboration with the federal government. Several survey respondents emphasized that California should collaborate with other government agencies, both nationally and internationally, to establish uniformity in low power mode energy analysis and voluntary or mandatory standards.

5.1 Scope of Recommendations

Many of the recommendations that we received from workshop attendees dealt with overall directions for research. Using these recommendations to create a framework of major research areas the CEC could undertake, we identified six major directions for low power mode research:

A. Understand how much energy is actually consumed in the low power modes.

B. Develop energy test procedures for low power modes and protocols to measure their contribution to whole-building electricity use.

C. Understand human behavior and preferences as they relate to low power modes.

D. Investigate feasible technologies offering energy savings opportunities and their economic costs and savings.

E. Engage in short-term research to address anticipated critical problems related to low power modes.

F. Engage in long-term research to increase the efficiency of low power modes.

Detailed research topics were also identified, including improvements to power supplies, low-power circuitry, and clearer user interfaces for the devices. Potential savings in some cases are as large as 90%.

We then distributed these research directions through our survey process and asked people how they would prioritize these directions. We also asked if there were additional research topics they would suggest.

Below we combine the results of the workshop and the survey in a discussion of each of these research areas.

5.2 How much energy is actually consumed in the low power modes?

Workshop participants were struck by the absence of low power mode energy use measurements in U.S. buildings, especially compared to the data available from other countries. There was nearly unanimous agreement that better understanding of the dimensions of low power mode energy use should be a key research goal. Survey respondents confirmed this view — 2/3 of the respondents ranked developing this understanding as the first or second priority the CEC should pursue. Many remarked that this understanding is a necessary precondition to developing priorities for comprehensive actions to affect low power mode energy use. Research is needed to answer such questions as:

- How large is low power mode energy use?
- How is low power mode energy use distributed across the residential, commercial, industrial, and other sectors?
- Is low power mode energy use growing?
- Are certain products or components responsible for a large part of low power mode energy use?

The answers to these questions will help the Commission and other research agencies select the areas deserving further research or programs. The general approach involves three steps:

1. Assemble lists of product types with low power modes.

2. Measure low power modes of products *in situ* and in the laboratory, including the fraction of time in each mode and other key information.

3. Periodically measure low power modes of new products.

In situ measurements should involve measuring the electricity use of the whole building (in addition to the contribution of each low power mode product) so that the fraction of electricity devoted to low power modes can be determined and no devices are overlooked.

The residential sector is better understood than other sectors. Most of the products with low power modes have already been identified (though new products are introduced every day). Step one is essentially compete, so work could begin immediately on the measurement phase. Less is known about the commercial sector, where a list of products with low power modes does not even exist.

Specific projects that would fall inside this general category include:

- gathering low power mode energy data in a representative sample of residential buildings by means of large-scale measurement campaigns,
- surveying and compiling lists of products with low power mode energy use in residential, commercial, and industrial buildings,
- gathering low power mode energy data in a representative sample of commercial buildings by means of large-scale measurement campaigns,
- measuring the hard-wired low power mode energy use in new, unoccupied homes (and possibly commercial buildings), and
- identifying the contributions of low power mode use to system peak.

5.3 Develop definitions and energy test procedures for low power modes and protocols to measure their contribution to whole-building electricity use

Standby power use is now fairly well defined, and an internationally recognized test procedure is nearly complete. For some Energy Star products, the sleep mode is defined and test procedures exist. Beyond that, however, there are few similar definitions and test procedures for low power modes.

International standards organizations (IEC, ISO, etc.) have begun to address this omission, but the pace has been slow and uncoordinated. In fact, some of the groups are heading in divergent, contradictory directions. Consistent definitions and test procedures are an essential precursor to monitoring projects. The lack of common definitions and terms was often cited as an important problem that the CEC could help overcome. California can have a major influence on the direction and speed of these standards committees by first investigating the technical options and then participating in the deliberations.

The definitions and test procedures determine how to test the low power modes for a single device. A protocol for measuring the low power modes of all the products inside a building must then be used to collect the data for representative samples (discussed earlier). Again, California can lead by developing procedures and field-testing them.

5.4 Understand human behavior and preferences as they relate to low power modes

Small differences in operational settings (such as enabling power management features) can easily lead to ten-fold differences in annual energy consumption of many electronic products. For this reason, the human dimensions of energy consumption must be carefully included in all low power mode research. Three areas deserve special attention:

1. Can additional consumer education change the way consumers operate a device?
2. Can improved product design (e.g., "user interface") encourage users to exploit the low power modes?
3. How much do consumers value the low power modes? For example, in what cases would a hard "off" switch be tolerated? Desirable? What maximum delay times are acceptable when switching modes?

The impact of consumer education and training should not be underestimated. Media campaigns in Japan, Germany, and, to a lesser extent California during the electricity crisis, probably caused many users to more frequently enable the low power modes (or simply unplug devices).

Any program aimed at educating and mobilizing people to use products more efficiently will be more successful if the energy-related controls in these products present a logical, clear, and consistent appearance. Thus, the research necessary to develop and promote design guidelines for controls related to power management is likely to pay off handsomely. The Commission has already initiated research in this area and it appears to be headed towards a successful outcome.

A similar area of analysis mentioned by several survey respondents involves understanding the market behavior of both end-use consumers and product manufacturers. Questions included:

- Would consumers change their purchasing behavior to favor products with reduced low power mode energy consumption?
- How are efficient low power mode technologies adopted by product manufacturers and included in their products? For example, why do some manufacturers choose to implement efficient power supplies?
- Are there "non-energy benefits" inherent to efficient low power mode devices that consumers would find attractive?
- How can we change usage patterns to shift time from active to low power modes?

5.5 Investigate energy savings opportunities and economic feasibilities of technologies to reduce energy use of equipment while in low power modes

Greater understanding of the technical potential for energy savings is integral to informing the adoption of state programs that address low power mode energy consumption. Knowledge of the economic costs and benefits of various low power mode options can determine which programs will save the greatest amount of energy for the lowest total cost. The following questions should be addressed:

- Which products or components use the most low power mode energy?
- What are the technical options to reduce low power mode energy use and how much will they save?
- How much do those technologies cost?

The results of this research are often depicted as "technology-cost curves" for single devices or "supply curves of conserved energy" for an entire end-use category. Developing these curves for low power mode energy use is unusually difficult because so little data exist on energy use, stocks, and patterns of usage. Furthermore, some devices are penetrating the market very rapidly, so energy savings are sensitive to sales rates.

Some products and components are so clearly important that they deserve immediate attention. Set top boxes and digital converter boxes are good examples of products deserving immediate investigation. Power supplies and battery charging systems are good examples of components that deserve immediate investigation.

Survey respondents generally saw this as a research topic that could occur only after a better understanding of low power mode energy consumption had been developed. Those who ranked it as a first priority usually felt that enough is already known about low power mode energy consumption to move forward to this step. This is undoubtedly true for certain products, as mentioned above; however, more research is likely needed on low power mode energy use in general before comprehensive research on this topic can occur.

5.6 Engage in short-term research to address anticipated critical problems related to low power modes

Short-term research can provide valuable support to program development. Some of the results can be used to as inputs to the technology cost curves and other policy tools. Short-term research can also demonstrate proof of a concept to justify additional research or the technical feasibility of a mandatory standard.

Television set top and digital converter boxes are obvious targets for short-term research. This research could investigate technologies to reduce power consumption through improved components and communications protocols. By demonstrating that boxes with lower power use are technically feasible (and economic), the Commission can develop programs to address the anticipated flood of these boxes.

Hard-wired standby in new homes was already identified as an important measurement target. Another example of short-term research would be the development of prototype smoke detectors, built-in LED lighting systems, and other products that would offer the same functionality at lower power levels.

Finally, issues of enabling rates and user interface controls were mentioned as potential critical problems that might be able to be addressed through short-term, focused research.

Many survey respondents rated this research topic overall as a lower priority for CEC research, though higher in value than long-term research (see below). On the other hand, specific technologies (or technology families) were mentioned as important components on which to focus, either because their low power mode energy consumption was perceived to be high or because the prevalence of those particular technologies was expected to increase rapidly in the near future. Examples included the digital set top boxes mentioned above, as well as home networking systems. Many survey respondents mentioned the problem of devices connected to networks being kept awake by the network or by the need to maintain connectivity, with the possibility of large increases in consumption due to this, and large savings if the problems can be solved. The increased penetration of broadband technologies into the home may be a driver for new product growth and corresponding low power mode use.

5.7 Engage in long-term research to increase the efficiency of low power modes

Most efficiency improvements in the low power modes result in savings of only a few watts per product. But the potential savings are large because the improvements apply to so many products and because the products operate in the low power modes so many hours each year. Some savings will also occur when better designed low power modes allow a product to shift time from an active mode to the low power modes.

There are three principal research strategies to reducing the energy consumed in the low power modes:

1. Improve the efficiency of the components
2. Improve software to help equipment operation better match functional needs
3. Improve external aspects to facilitate energy savings

Several components appear ripe for additional efficiency improvements. Power supplies deserve the greatest attention because they exist in all of the products. In many cases, efficiency improvements to power supplies will also save power while the products are in active mode.

Rechargeable products represent an increasing fraction of products with low power modes. Batteries, and the circuitry to charge them, draw upon increasingly sophisticated technologies. Improving the efficiency and overall performance of battery-charger system will yield both energy savings and environmental benefits (by increasing battery longevity). Long-term research could lead to a "California battery" system, with performance characteristics tailored to maximize energy efficiency and minimize disposal costs. Alternatively, adding a battery to a device may allow better power management or reducing standby use to zero.

Manufacturers are striving to add increasing functionality to products while in the low power modes. More efficient circuitry could provide both increased functionality and energy efficiency. This should be another research area. The California-supported CITRIS[4] program is an example: CITRIS researchers developed circuitry with power requirements 1/100 of current levels. Stray air currents, ambient light, and local temperature differences may be able to supply enough power to operate these circuits.

Many California companies, universities, and research institutions are already tangentially involved in these topics and, through collaboration, will be better positioned to market the fruits of the research profitably.

Although these research areas are undoubtedly of value, the majority of survey respondents considered long-term research to be a low priority for the CEC. Some felt that the technologies necessary to reduce low power mode energy consumption already exist — therefore, there was no reason for the CEC to invest in new technology development. Others felt that the need for new products did exist, but that the CEC was not the best actor to implement research in this area. Respondents believed that the private sector was better positioned to develop the means to increase the efficiency of low power modes.

6.0 Overall Conclusions and Recommendations

Even with the limited information available, it seems clear that the electricity consumed by devices while in low power modes already represents a significant fraction of California's total consumption. In California's homes, standby power consumption alone probably accounts for nearly 10% of total residential electricity use. There is also evidence that low power mode energy use will rise sharply. These trends suggest that California is justified in undertaking a range of programs to reduce low power mode energy use.

We have outlined a framework for research, plus many specific projects. The research covers a broad spectrum of activities, from field measurements to understanding consumer behavior to exploration of entirely new technologies. Some of these projects — such as development of energy test procedures — need to begin almost immediately. Other aspects — such as investigations of new technologies — can wait. But, together, this research agenda will ensure that programs to reduce the energy use of low power modes will be effective for both the short and long term.

There was clear guidance from survey respondents that the first priority for CEC research is to understand how much energy is consumed by low power mode devices. The results of the survey also showed a fairly emphatic rejection of long-term research to improve the efficiency of low power mode devices, at least as a high priority for funding

[4] Center for Information Technology Research in the Interest of Society, http://citris.berkeley.edu

by the CEC. The relative priority of the other four topics of research were analytically indistinguishable in our survey results.

APPENDIX II: TEST AND MEASUREMENT PROCEDURES FOR LOW POWER MODES

Appendix II — Test and Measurement Procedures for Low Power Modes

1.0 Introduction

This appendix reviews existing test procedures and measurement protocols for standby power, other low-power modes, and usage patterns. This information helped shape the individual product and whole-house measurement procedures described in Attachment 1.

1.1 Background

Determining *how* to measure low power mode energy consumption was the primary goal of this project, with the actual measured data a necessary bonus.

There are two related ideas reviewed here: a "**test procedure**" is usually designed to measure a new device in a laboratory setting, often for safety or regulatory purposes. The test conditions, such as temperature, supply voltage, etc are well-specified. The device's configuration is constant, or to be as shipped by the manufacturer, and any usage patterns applied during the test are fixed, or dependent on obvious characteristics of the device (e.g. its size or speed).

A "**measurement protocol**" covers a much larger set of methods, including test procedures. In this case, most of our measurements will be made in the field, in actual homes, in which the conditions are not well-controlled (such as temperature, voltage), the provenance of the device is not well-known (e.g. the customer could have modified it or it could have changed with age), and it may have been customized for the consumers' use as by adding to it (e.g. a PC expansion card), the configuration changed, or by it being connected to other devices in ways that change its energy consumption patterns, through data or power flows along wired or wireless connections[1]. Usage patterns are often those of the customer, and so while they might be measurable, they are not fixed or replicable. Measurement protocols may be created for a variety of purposes.

In this project, while we drew primarily on test procedures, we are ultimately used and developed measurement protocols. We conducted some laboratory measurements, but some metrics, such as whole-house low power mode use, are inherently field measurements, and we found and measured many more devices in the field than we could readily bring into our laboratory.

Our approach in this task was to gather, evaluate and compare existing methods, to find aspects that are common and that are worth considering or using directly in the protocols that we ultimately develop for this project. The range of protocols also brings up the many detailed issues which will arise. Table 1 lists the test procedures that we

[1] At present, data and power can be transmitted over wires, and data over wireless connections, but power is not routinely transmitted wirelessly in homes.

evaluated and some of their important characteristics; Table 2 lists the measurement protocols.

Table 1. Attributes of each Test Procedure

Name	Device Types	Intended Use	Measures	Comments
IEC 62301	Appliances => All	Neutral	Power	Standby power only; 2003
IEC 62018	IT equip.	Neutral	Power	All low-power modes; 2002
IEC 62087[2]	Audio / video	Neutral	Power	All modes (orig. EN 50301 - GEEA); 20003
ASTM (imaging)	Copier, laser printer, fax	Energy Analysis	Energy	All modes; 1990s
FEMP	All	Energy Analysis	Power	Standby power only; 2001
DOE-dish	Dishwasher	Mandatory Standard / Label	Energy, Power	All modes (new procedure); 2003
DOE-TV	TV	Mandatory Standard / Label	Energy, Power	No standard implemented using this test
Energy Star	Selected IT, CE, other	Voluntary. Standard	Power	Low-power modes only; 1990s to present
Japan	Selected IT, CE	Mandatory Standard	Power	Law Concerning the Rational Use of Energy; 1990s to present

Notes: "Energy" means some usage assumptions applied. "All" excludes hard-wired. "Neutral" means that no specific uses were targeted. "CE" means consumer electronics, and "IT" is information technology.

Table 2. Attributes of each Measurement Protocol

Name	Device Types	Measures	Comments
Ross/Meier (LBNL)	All	Power, House	A whole-house energy study
Nordman (LBNL)	Copiers	Power, Usage, Energy	Included time-series monitoring, night status surveys; all modes
Roberson (LBNL)	PC / Display	Power	All modes
Webber (LBNL)	Office equip.	Usage	Based on night status surveys
Standby.lbl.gov	Whole house	House power	
Canada	All	Power	Field (in homes and in-stores); sleep and standby
Huber	All	Power	Standby only

Notes: All of these methods used for energy analysis. "Energy" means some usage assumptions or measured data applied. "All" excludes hard-wired.

The procedures we reviewed touched on a wide variety of issues. We grouped these into topic areas as listed in Table 3. No procedure covered all topics.

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2 Our citations of this standard are actually drawn from the EN 50301, the European standard on which it is based.

Table 3. Topics addressed by test and measurement procedures

Topic	Comments
Purpose / Scope	Reason for creating the procedure
Basic Power Characteristics	Voltage, frequency
Power Quality	Total harmonic distortion, current (?) crest factor
Other Conditions	Air speed, temperature, humidity
Accuracy	Accuracy and resolution of metering equipment
Configuration	Settings, attached hardware, information environment
Usage Patterns	% of time in each operating mode
Mode Definitions	What to name modes, what characteristics they have
Mode Derivation	How to determine what modes a product has
Controls	Controls (e.g. switches, automatic) within the device or attached to it
Procedure Steps / Timing	How long to integrate power use over
Sampling	How many units to measure
Reporting	What to record / report
Whole-house Measurements	Entire house and all devices within it

We have not been exhaustive — almost every study measuring the energy consumption of electronic (and increasingly other) devices implicitly addresses low-power modes and so has some procedure. We have reported on those that seemed most important due to their wide usage, or ability to help us cover the full range of types of procedures.

An important point in all of this is that we are avoiding dealing with active ("on") power consumption since that introduces large complexities and is beyond the scope of this project. However, since part of the savings from attention to low power modes involves shifting products from full-on to low-power modes, the energy consumption in full-on needs to be incorporated into later analyses. However, data on that should be transferred from other studies as much as possible and not developed in the context of low-power mode research.

There are three major International Electrotechnical Commission (IEC) standards discussed here. Table 4 lists these for reference since we refer to them by the standard number only which does not indicate its content.

Table 4. Key IEC standards for low-power mode energy consumption

Number	TC	Name / Status
62301	59	"Measurement of **standby power** - Household electrical appliances" / exists as a nearly final draft.
62018	100	"Power consumption of **information technology** equipment - Measurement methods" / exists as a draft – possibly close to final
62087	108	"Methods of measurement for the power consumption of **audio, video and related** equipment" / Finalized March of 2003. Adapted from European Standard EN 50301 of the same name.

Notes. "TC" is IEC Technical Committee. Emphases added.

2.0 Topics

Our intention is to base protocols that we develop on IEC 62301, so that is used to begin the discussion of most topic areas. Reporting all details of all procedures here would be voluminous, so we selected items that show the range of definitions and specifications and raise important points. We also include some discussion of how each topic affects the protocols we develop and our measurements.

2.1 Purpose / Scope

IEC 62301 was nominally created for appliances but was specifically designed to be generic and therefore applicable to nearly any household or normal office device. While "on" power is covered by many IEC standards each specific to a different product type, this standard was created so that the standby level could be measured consistently across many products (this also had the advantage of avoiding the need to amend the many other standards and to keep the standby portion consistent over time). It is noted that it is not designed to cover "normal operation ('on mode')," but that it could be used for other low-power modes.

Other procedures are for specific products (e.g. DOE, Energy Star, Japan), categories of products (e.g. IT or CE), or generic (e.g. standby, whole-house). Several procedures (Ross, FEMP, IEC 62301, Fung) explicitly exclude hard-wired devices, but other than the issue of making safe and proper electrical connections, it isn't clear that they need to be treated any differently from those powered through ordinary outlets and plugs for making low-power measurements.

Discussion

Our scope will be any device found in a residence potentially powered from the mains. This excludes those powered from non-115 VAC sources such as directly from on-site DC generation (photovoltaic, wind, or fossil), or exclusively from battery power.

2.2 Basic Power Characteristics

In IEC 62301, voltage and frequency are as specified by the manufacturer, though nominal combinations are provided for Europe (230 V, 50 Hz), North America (115 V, 60 Hz), Japan (100 V, 50/60 Hz), and Australia/New Zealand (230 V, 50 Hz). The provided power is to be within 1% of the value intended for both voltage and frequency. Reference is made to power being supplied at twice the nominal voltage (e.g. 230 V for North America) and to three phase power so that there is apparently no barrier to using this procedure on devices powered that way.

Other standards specify different ranges possible for these two factors, with the voltage allowed to range up to 5% from nominal (none are more strict than IEC 62301), and the voltage and frequency variation ranging from 0.1 Hz to 3%. Some (e.g. the Japanese VCR standard) specify no range.

Some standards specify that the nominal voltage and frequency should be used unless it is outside the product's stated range. Others state that the voltage and frequency listed on the product should be used.

Discussion

The frequency of delivered power is quite stable and reliable and so while any standard should reference it, it is not particularly of concern. Many devices do change their efficiency modestly with changes in the voltage supplied, and voltage does vary by location. Thus, attention to this factor is warranted, though measurements taken outside the specified range are still quite useful.

2.3 Power Quality

Two primary metrics of power quality are noted in the different procedures: Total Harmonic Distortion (THD) and crest factor. IEC 62301 specifies that the waveform is to be close to normal, with total harmonic distortion to be under 2%. Other procedures allow 3% or as much as 5% THD. The specification of THD varies, usually by specifying how many harmonics need to be accounted for. Note that this is the characteristic of the supplied power, not the power factor of the device itself.

The other measure of power quality most frequently mentioned is peak voltage (usually measured as the "crest factor"). For IEC 62301, the crest factor is to be within 5% of normal (between 1.34 and 1.49, as normal is the square root of 2 – 1.414). Note that a crest factor rating also applies to the capability of the measuring equipment. The Energy Star copier and MFD procedures requires a "true sine wave."

Discussion

We may want to assure that our laboratory equipment meets the IEC 62301 specification. For field measurements, we simply need to report these values.

2.4 Other Conditions

IEC 62301 specifies that air speed is to be ≤ 0.5 m/s and temperature to be 20 ± 5 °C (68 ± 9 °F), preferably 20. This is the most common temperature measurement specified, though others include 22 ± 4 °C (Energy Star consumer electronics), 21 ±3 (Energy Star copiers), and 23 ± 5 °C (IEC 62018 and the old Energy Star monitor and computer specifications). The FEMP procedure specifies that the air speed shall be 0.5 m/s — not that that is a maximum — we suspect that this was a typographic error and unintended.

The ASTM copier test requires attention to relative humidity (40-60%), the distance from the closest wall (2′), and "preconditioning" the device and supplies (paper chiefly) for 12 hours. These are repeated in the Energy Star copier and MFD procedures and they also require that line impedance be less than 0.25 ohm.

The Japanese TV procedure notes that for active power, some units change their brightness in response to the ambient light levels.

Discussion

It seems likely that most devices will be little affected by air speed and temperature (at least within ordinary ranges). For field measurements however, we should report these, particularly for devices outdoors.

2.5 Accuracy

Power measurement accuracy can be specified in absolute terms or as a percentage of the reading. For measurement of power, IEC 62301 refers to IEC 60050[3]. It further states that:

> Measurements of active power of 0.5 Watt or greater shall be made with an uncertainty of less than or equal to 2% at the 95% confidence level. Measurements of active power of less than 0.5 Watt shall be made with an uncertainty of less than or equal to 0.01 Watt at the 95% confidence level. The power measurement instrument shall have a resolution of 0.01 W or better for active power.[4]

IEC 62301 recommends that measuring equipment have a resolution of 1 mW or better, be able to handle a crest factor of at least 3, and a minimum current of 10 mA (80 mW at 120V). Accumulated energy should be reported to at least 0.1 mWh. Note that at 1 W, 1 mWh is accumulated in 3.6 seconds.

IEC 62301 notes that one should be alert for asymmetric currents (not equal in positive and negative), which are DC loads supplied by AC. None of the other test procedures mention this issue. IEC 62301 also includes a discussion of the 95% confidence level and uncertainty.

Among other procedures that specify absolute accuracy, the Energy Star TV/VCR specification states that the watt meter should be accurate to 0.1 W. The ASTM copier test requires a 0.1 Wh resolution on accumulation. The meter used in the Canadian study (Fung, 2003) had a resolution of 0.1 W and accuracy at low levels of ±0.4W. IEC 62087 sets a "maximum permitted error [of] 5%" for measurements.

The DOE test procedure specifies that the power meter should be accurate to 1% of full scale, and that readings should always be done in the upper half of that scale, implying a

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[3] IEC 60050 is a general review of terminology covering many topic areas. This reference is probably to 60050-300: International Electrotechnical Vocabulary - Electrical and electronic measurements and measuring instruments - Part 311: General terms relating to measurements - Part 312: General terms relating to electrical measurements - Part 313: Types of electrical measuring instruments - Part 314: Specific terms according to the type of instrument.

[4] Note that this reference to "active power" does *not* refer to the active power mode, but to ordinary power consumption in the standby mode. Specifically, it refers to "The mean value, taken over one period, of the instantaneous power" with a period being an AC cycle, but multi-cycle measurements are also acceptable.

maximum error of 2%. There is no separate discussion of metering for low-power levels, so one interpretation is that the same meter is to be used as is used for the active mode readings; another is that a lower range is required on the same or different meter to maintain the upper-half criterion.

Most of the test procedures state that the measured values should be reported (in the context of their guarantees about maximum error). An exception is Energy Star consumer electronics specifications which states that the reported figures should be accurate to +10% - 0%; this is to assure that the product in question absolutely falls under the power limit(s) specified and so the reported results will be the raw readings plus the known uncertainty of the measuring equipment. For Energy Star copiers, the accuracy doesn't matter though to assure that the measured value insists that the specification level is a hard limit, the accuracy parameter should be added to the reading so that a higher reading will not occur.

The existing Energy Star display (monitor) specification states that the calibration should be traceable to the National Bureau of Standards.

Discussion

We need to assess whether the equipment that we already own meets these conditions. If not, we may want to purchase a meter for lab use that meets the IEC 62301 standards. For field work, our existing equipment is probably fine. Whether we need to be able to detect asymmetric currents is unclear – that may be a rare event.

2.6 Configuration

For how to configure the device being tested, IEC 62301 is typical. The device is to be configured per the manufacturer's instructions, or in the absence of those, at the default settings, or if all else fails, as found. The only other possibilities mentioned in the test procedures is are when specific settings (e.g. maxima) or output criteria (e.g. display luminance) are specified. For battery-operated devices, it is expected that the device will be removed from the charger, presumably on the assumption that the removed state will occur frequently enough to be significant. The Energy Star TV/VCR specification (and others) says that configuration is to be "as shipped to the customer" (which could be different from the manufacturer recommended or default values. Some devices have a "reset to default settings" function. The DOE TV procedure requires removing any batteries present (for TVs that can be powered from batteries or the mains), and that any "automatic controls affecting brightness" (presumably those responding to ambient light sensors) should be disabled, and any sensor that can't be disabled should be illuminated to maximize screen brightness.

IEC 62087 provides an example of the most detailed configuration specifications, partly because it includes measurement of the devices in their active modes. Many of these specifications will usually not affect low-power mode energy consumption, but as we cannot be sure (for all products now and in future) what may influence low-power mode consumption, we will need to at least consider specifying these types of details, and reporting on them for field measurements. IEC 62087 specifies the content of input signals (audio and video), output signal electrical characteristics (e.g. speaker power), output content characteristics (e.g. display light intensity), and functional configuration (e.g. that a wide screen TV should be tested in its wide screen mode). These types of configuration settings are necessarily specific to certain classes or types of devices.

The ASTM fax procedure includes a "PBX line simulator" to mimic two phone lines, and the phone cords are to be "exactly 6 ft" long. The ASTM printer specification requires using a computer or a computer simulator[5]. The DOE TV test procedure calls for a signal generator capable of generating standard TV test patterns. While in some of these cases only the active power measurements may be affected, the test procedures don't provide for leaving them out when active is not being measured.

The Energy Star telephony specification includes a reference to an IEC standard and its identification of speaker termination characteristics; the same test also requires that the device be connected to an active phone line. The Energy Star copier specification notes that consumption (active mode) depends on the page size used so that that must be included and reported. The existing Energy Star monitor specification notes that when a USB hub is present, no USB cables should be plugged-in upstream or downstream.

The Japanese VCR standard observes that some VCRs have the ability to pass-through power to other devices (PCs in the U.S. used to commonly have this feature, generally to be used for the display). No consumption like this is allowed during the test.

In several studies (Huber, Fung), computers were measured as-configured. Fung assured consistency in playback devices in stores by using a constant media object, including cassette tapes, video tapes, CDs, and DVDs.

Discussion

For field measurements, changing configuration can be problematic as the owner may not want the configuration to be tampered with and there is the risk of not being able to get it back to the proper configuration. It is best for field measurements to conduct evaluations "as-is" as much as possible, but record all configuration parameters that are be known to (potentially) affect the power levels of interest. Exceptions to this may be necessary, such as when the ability to go into some states is disabled by the configuration, since one of the uses of data is to know what the savings would be if the product *was* enabled to power manage more.

What conditions affect the power consumption of devices in different low-power modes, and what standards to use for these is an empirical question that can best be discovered through testing of products or conversations with manufacturers.

2.7 Usage Patterns

Usage patterns are generally recorded only for field studies, though some lab measurements use a standard usage pattern to extrapolate the measured data to monthly or annual consumption. Some studies note the difficulty of assessing usage patterns. The ASTM copier test provides that applied usage patterns may be default or "actual" (but doesn't say how to arrive at the actual figures).

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[5] Yes, apparently at one time such a device was sold.

Usage Measurements

Webber et al., 2001 outlines a procedure for gathering "night status" data about office equipment. Data collection is to commence after 6pm on a weeknight, and record information about the power status (on, sleep, off) of each device found. When an office is found occupied, it is to be revisited later in the hope that the person there will have left. Weekend audits are also acceptable. When docking stations are found, they are checked to see whether a notebook is present in it or not. Any information about company practices that would affect night status are to be noted, such as night backups or company power management policies. In Nordman, 1998, night audits are to begin after9 prm.

The Japanese procedure for televisions includes standby power in its estimate of annual consumption assuming that that mode is operative 81% of the time. The VCR procedure assumes that the clock display is enabled 80% of the time in calculating annual energy consumption. The Energy Star TV/VCR specification allows for an extra watt for an illuminated or backlit display, when warranted.

Discussion

Usage is a combination of product characteristics, the usage environment, and the user. Some products, like smoke detectors, have a clear profile of use regardless of the user (presuming they are connected to the mains at all). Others, such as computers, vary widely with the particular user.

2.8 Mode Definitions

Standby

IEC 62301 defines:

> **Standby mode**
>
> the lowest power consumption mode which cannot be switched off (influenced) by the user and that may persist for an indefinite time when an appliance is connected to the main electricity supply and used in accordance with the manufacturer's instructions.
>
> Note: The standby mode is usually a non-operational mode when compared to the intended use of the appliance's primary function.

Most definitions of standby-like modes take being connected to the mains as a given. Some are consistent with IEC 62301 in specifying that it is the smallest such mode that is of interest, but many are written on the assumption that there is only one such mode (some products have more).

Many definitions specify that the standby mode is non-operational, at least for the primary function of the device (e.g. Ross/Meier, Energy Star consumer electronics and ceiling fans, and Fung). Some specify some minimum capability, such as being able to respond to commands from a remote control[6]. These open up the possibility of equipment having either no standby mode or several, depending on the device. It is

[6] IEC 62018 specifically mentions the possibility of a device dropping automatically from its "standby" mode to a lower power mode after a period of time so that the standby level is not necessarily the minimum power mode. The Energy Star TV/VCR specification is unclear as to whether the remote turn-on is *mandatory* or just *allowed* for the standby level.

important to distinguish between having no standby level and having a standby level of zero (as when you have a hard off switch; the FEMP procedure and Energy Star set-top box procedures allow for this). An advantage of the IEC 62301 definition is that all devices have a standby mode, though for some simple devices (e.g. a nightlight or plug-in air freshener) it may also be the *only* power mode.

The IEC Task Force 1 definition[7] states that "Standby power use depends on the product being analyzed. At a minimum, standby power includes power used while the product is performing no function. For many products, standby power is the lowest power used while performing at least one function." This seems ambiguous. It further states that devices that consume no energy when off "do not have standby power consumption" though whether they have no standby mode or that the consumption in that mode is zero is not clear.

The FEMP definition of standby includes that the product be used "in accordance with the manufacturer's instructions,", which may not apply to devices as-found in homes. The FEMP procedure specifies that the standby mode consumes less than modes that are automatic ("self-initiated"). This distinction is unnecessary and not always true.

The Energy Star TV/VCR specification uses one of the standby definitions from IEC 62087.

In some cases, explicit exceptions are made for certain device types. For example, Ross/Meier takes the most common power mode that the users of the device select as the standby level for office equipment, so that it could be off, sleep, or on, depending on the user's behavior. Other procedures specify that for cordless phones, the handset is to be in the cradle (not charging, but trickle charge OK; the Energy Star telephony specification states this). For other devices, such as a notebook computer, the unit is to be removed from whatever power supply or docking station is provided. The FEMP procedure specifies that fax machines are not to be switched off if such a switch is present so the standby level is sleep or on. The proposed new DOE dishwasher procedure requires that the door lock be unlatched.

In addition, there is also reference to "Standby Energy," which is standby power over time. According to some definitions (e.g. IEC 62087), it does not accumulate when the device is active. No definitions explicitly say that it accumulates in more than one mode; most simply do not address the issue.

The Japanese television procedure specifies that the standby power is the average of two other power levels: that when the main power switch is used to turn it off, and that for when the remote control is used (and the separate main power switch is not touched). When only one of these exists, that single level is used.

Some definitions of Off (e.g. IEC 62087) explicitly state that they only respond to a power switch and not a remote control. This means that some devices (e.g. most U.S. TVs) do not have an Off mode, but only Standby and Disconnected modes. IEC 62087 distinguishes among some modes by whether the device responds to a remote or

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[7] See http://www.standby.lbl.gov/definition/IEATaskForce1.html .

internal signal, to an external signal, or based on whether it is communicating. Many procedures differentiate some modes by whether the device produces functional output or not.

The Energy Star set-top box specification defines a “standby/low-power” mode that has a flexible definition, though if the device is “designed for a network environment” then it must remain connected while it goes to sleep, and be able to be turned on by a remote control.

For the Energy Star telephony and set-top box specifications, if there are multiple “standby modes,” then the measurement which counts is to be the highest power level. For Energy Star copiers, the lowest mode is the “off” mode. The DOE TV test procedure uses the minimum power definition of standby (and also requires that the power switch is to be off). It also defines a “filament keep-warm” mode which is often the standby level, and notes that some TVs have a “vacation switch or master on-off switch” that turns off the filament warmer, and others have a “remote control defeat switch” to turn off the circuitry that listens for a remote signal, allowing standby to potentially be zero.

“Standby” is used to mean different things in different contexts, and while most of these are readily separable from its technical usage for energy consumption, a notable contrary example is water heating or cooling devices. For example, the Energy Star specification for Bottled Water Coolers uses “Standby Energy” to refer to the consumption required to maintain internal temperatures but with no water dispensing. The specification even notes that some devices have timers to reduce their consumption, but it is the daily average consumption that is of interest, not the lower, “off” modes.

Standby energy also refers to the gas or oil energy needed to keep a water heater (or similar appliance) at the proper temperature, and/or for a pilot light. This may apply to hot water dispensers, hot water heaters, and space heating. “Energy consumption during standby” means the energy consumed by a gas or oil space heater when the main burner is not operating, not including energy consumption related to associated cooling equipment, and reported in watts, based on a conversion factor of 3.412 Btu per watt-hour (CEC, 2002. p. 125).

Other Modes

The modes other than Standby that are most commonly defined are On and Disconnected. Other modes defined or referred to in different test procedures are Active, Normal operation, Standby-passive (low), Standby-passive (high), Standby-active, On Mode/Active Power, Sleep Mode/Low Power, Off Mode/Standby Power, Download Acquisition Mode (DAM), On (play), On (record), On-Active, On-idle, Soft-off, and Hard-off. The DAM mode is “typically” more than standby and less than on.

Some modes are explicitly ignored, generally when they are known to be small. For example, in IEC 62087 the dish positioning mode for a satellite TV receiver is specifically not counted.

There are many mode categorizations of electronic products created for non-Energy purposes. Sometimes these have direct or indirect energy implications and sometimes they only change functions and not energy consumption. An important example is the ACPI (Advanced Configuration and Power Interface; Compaq, 2000) specification for processors/PCs. ACPI includes On/Working, various Sleep modes (S1, S2, S3, S4), Soft Off, and Mechanical Off.

The ASTM copier procedure defines five common modes, including "automatic shut-off mode" and "plug-in mode" highlighting that these can be different. "Energy-saver" is the term for sleep modes, though it notes that some manuals use the term "standby" for this mode ("standby" in the ASTM procedure is the name for the ready mode; note that neither of these usages qualifies as standby power!). The ASTM test also includes recovery energy, a warm-up mode, a ready mode, and actual copying mode. The printer and fax procedures are similar but have fewer modes.

Devices that are composites and/or Multi-Function Devices are generally to be considered one device (if marketed under one model number) and one example is Energy Star set-top boxes; another is the copier/printer multi-function devices.

Discussion

Some definitions should be crafted that can apply to all product types. Others will need to be defined with reference to specific product types that they apply to. Most derivation of this will be empirical, discovering what product have what modes and capabilities. There is an issue of what constitutes a mode — as opposed to a part of a cycle, or a transition state between stable modes. There are also actions that by themselves change power levels but don't cause a new mode, such as plugging a USB device into a PC.

Devices may have zero or multiple *off* modes, zero or multiple *sleep* modes, and one or more *on* modes. The standby power level could occur in *on*, *sleep*, or *off*, depending on the device. Low-power modes are all *sleep* and *off* modes; that is, all modes other than *on* modes

2.9 Mode Derivation

IEC 62301 specifies that for making the measurement, it is understood that the device may have many power modes and that it may take some time for it to settle into the "standby mode." It is understood that the person making the test may not have documentation describing all the modes or how they are entered. No specific details are specified for particular types of devices on this account.

Many of the procedures, including IEC 62301, note that some devices have a constant power consumption in their standby mode but others undergo regular cycling. All of these specify that it is the average power over one of these regular cycles is the figure of merit. Several, like IEC 62301, provide that the measurement can either be an instant measure (measured over at least one AC cycle of course) if the reading is reasonably constant, or the average power over a period of time. Since it would seem that these are quantitatively equivalent, presumably the reason for allowing the two methods is that some meters do not accumulate power over time (more than one cycle) and so can only be used on constant-load devices. The FEMP procedure notes that it might be necessary to run the product through different uses and modes to discover all applicable ones.

Discussion

Discovery of what modes a product has will be largely empirical, based chiefly on product manuals and testing.

2.10 Controls

It is useful to describe the types of controls (manual or automatic) that a device has to best understand its modes, capabilities, and behavior. IEC 62301 provides a taxonomy of device types with respect to power switching, the "operating load," "subsidiary load(s)," and external power supplies. Subsidiary function examples are listed: remote controls, auto-off switches, displays, power for memory or clocks, power for controls or switches, "EMC filters," and "cooling fan or auxiliaries." Knowledge of this categorization can help indicate what kinds of modes the device is likely to have.

IEC 62301 also defines power switch types are hard-off switches ("all-off"), auto-off switches ("auto power off"; when function completed), or those that incorporate variable power control ("power control" e.g. dimming). The definition implies that <u>both</u> power poles are disconnected on hard-off switches; this may not matter for energy consumption, but presumably usually doesn't occur (except on some medical devices for which it is required for safety reasons).

Discussion

We should record basic information about type of controls on a product, and in the field, also record the presence of power strips or switched outlets that control devices we are measuring.

2.11 Procedure Steps / Timing

Initial studies of standby power generally used the "plug in and count to five" method of getting power values. This works for many product types, and was sufficient for that early work, but not always for present-day uses, particularly standards.

In IEC 62301, stable power consumption is defined as not varying by more than 1% over a three-minute period. The device is put into its standby mode, then observed for five minutes to assure that it is stable. A reading is taken and a further five minutes of observation done to assure continued stability. The FEMP procedure replicates this timing.

Other procedures specify different timing. For IEC 62087, one is to wait for 15 minutes after entering any mode before making the measurement. For IEC 62018, one is to wait not less than one minute. For Energy Star monitors (the new specification), <u>active</u> power measurements are to be made after a 20 minute wait for "warm-up." For the Energy Star TV/VCR measurement procedure the device is to be allowed to stabilize before taking <u>active</u> power readings, usually about 90 minutes. The DOE TV test procedure says to wait for 5 minutes before measuring active power, and 2 minutes before measuring standby power.

As for how long to monitor the power consumption to assure stability, some procedures are consistent with IEC 62301 in the 1% / three minute criteria (e.g. the new Energy Star display specification). In the Canadian test (Fung, 2003), power is measured over one minute. Rosen et al., 2001 measured power levels for 30 seconds, based on observations that they varied only 0.1 to 0.2 W within that time. Some procedures are not specific about what constitutes a stable mode.

For Energy Star imaging devices, one makes a copy, then waits the default time for a machine to enter the lower-power mode, then take the average of the energy consumption for one hour. The ASTM imaging tests are based on measured periods of one our of different types.

For how to assess cycling, it is implied that the cycling will be regular enough that a single or modest number of cycles will be sufficient for analysis. Some cycling is due to preprogrammed activity, such as periodically checking sensor status. In other cases it is based on thermostat activity, such as the temperature of a copier fuser roll, and this is likely to be different immediately after entering a low-power mode than it is for a longer period of time. How to determine when cycling is regular and stabilized is also a matter for empirical testing.

For Energy Star telephony, the procedure is to measure at least 2 hours and up to 24 hours. The printer/fax and scanner procedures have one-hour-to-capture cycles, but in any case it should be "sufficiently long." If the device doesn't cycle, then several "instantaneous" measures can be used.

For cycling devices, under IEC 62301, the measurement simply needs to capture one or more cycles. For measuring time, the FEMP test says that they need to be accurate to within 2 seconds. The ASTM copier test says that accuracy should one second.

Roberson et al, 2002 provides a metering protocol for PCs and displays. The display protocol requires a PC to put it into low-power states (for many displays, the sleep mode can be engaged by simply unplugging the data cable, but this should not be relied on to be always true). The PC's power management settings are to be recorded, as it may be necessary to enable power management (if it is disabled), and to reduce delay times to shorten the test. Power readings are taken no earlier than 15 seconds after the mode is entered, and must be stable for at least 30 seconds thereafter. Each automatic low-power level is to be measured separately, as is each manual low-power state (e.g. manually selecting sleep from an on-screen menu) even if it corresponds to an automatic state. Notebook PCs are to be measured with the battery fully charged, removed, or disconnected, so that battery charging is not included in any of the measurements.

Some studies are fairly vague about measurement methods, probably because the devices found for the most part exhibited constant loads in their standby mode and because they were field studies for which keeping the data collection time short was often important. For example, (Huber, 1997) measured devices "over short periods of time."

The Japanese VCR standard recognizes that the clock display can be turned off on some units and so the power is to be measured in both cases. Similarly, the DOE TV procedure specifies to measure standby power with any vacation or remote defeat switches on and off.

The ASTM imaging specifications say that when there are too many errors like paper jams, the test should be stopped. One misfeed in 1,000 is stated to be OK.

Discussion

For laboratory measurements, we can utilize the timing procedures of IEC 62301, but for field work, it is too time-consuming. We will need to build up knowledge about what types of devices have what types of behavior and so can abbreviate the test by shortening the times over which the measurement is made when we can reasonably expect this to be stable.

2.12 Sampling

Most procedures do not address sampling. For the Energy Star new monitors specification, five or more random units are to be taken from the production line to account for some amount of variability among otherwise-identical products. The Energy Star computers specification includes a requirement that measurement be done on "a representative sample of the configuration that it ships." The ASTM test says to do the test twice on different units and if the result differs by more than 10%, it should be repeated.

The DOE TV test specifies that the sample size should determine what measured values can be reported. A calculation is done on the confidence intervals around the mean, and a wider range (from a smaller sample generally) will lead to values being reported which imply that the device is less efficient. Thus, manufacturers have an incentive towards larger sample sizes.

Discussion

For our purposes, we will simply report each observation and not apply any sampling methodology. In some cases we may measure multiple instances of the same model, particularly in field measurements.

2.13 Reporting

Unless otherwise specified, the results of measurements are to be expressed as power, in Watts for the average power in a particular mode. Sometimes a usage pattern is applied and an energy consumption is calculated; these are variously reported as kWh/day or kWh/year. Power levels are always to be reported as average Watts.

IEC 62301 neatly categorizes the values to be reported as follows:

Product Data ("Appliance (equipment) details"): Brand, model, type, serial number, description, rated voltage and frequency, and "details of manufacturer."

Test Conditions ("Test parameters"): Temperature, voltage, frequency, total harmonic distortion of supply, test setup.

"Measured Data": For each mode, the "average power in Watts rounded to the second decimal place," or 3 places for loads over ten Watts; the measurement method (stable or over time); raw data (accumulated energy and time, if applicable);

how got to the selected mode; the sequence of events to reach the mode; and other notes on device operation.

<u>Administrative ("Test and laboratory details")</u>: Test number, date, laboratory, "test officer(s)."

For IEC 62087, the input signals used are to be reported.

For the new Energy Star display specification, one is to report all measured results (at all 3+ input voltages and an average). It also includes performance specifications, both recommended and maxima.

The Japanese TV procedure adjusts annual consumption by a factor based on the use of a "power saving switch." This is presumably to disable the remote control or the filament heaters.

According to the Energy Star TV/VCR specification, when a set of boxes is sold as one "model or system," it is considered a single device for standby power level attainment even if there is more than one power cord. Additional allowance is given for backlit displays in some circumstances.

In several cases, multiple standby levels measured are to be averaged. The DOE TV procedure averages the power with and without vacation or remote defeat switches enabled. The Japanese procedure averages the power consumed with the display on and off, weighted to reflect it being on 80% of the standby time.

Discussion

For IEC 62301, it is unclear how the "sequence of events to reach the mode where the equipment automatically changes modes" is different from "description of how the appliance mode was selected or programmed"

2.14 Whole-house Measurements

The only measurement procedure that we have is Ross and Meier (2000) (it refers to only two other extant whole-house studies -- Murakoshi and Sidler/ADEME).

The general procedure was to: survey all "appliances," measure each one's standby power, then measure the whole house with everything switched off. Standby in this case is lowest power while connected to the mains. However, computers were measured in their "most frequently used" mode. For cordless phones, the handset was "removed from the charger." Every device was also photographed.

The whole-house reading was taken for eight minutes from the house meter. If the two measures have a "large discrepancy," further loads are to be searched for. Regardless, the two readings should be an upper and lower bound of the true answer.

Discussion

This is largely new ground. A protocol should specify whether each device is measured at the outlet or at the last extension cord if any are used. Some devices will be present but not presently plugged in (e.g. on a switched off at a power strip — those in the attic collecting dust don't count). In addition to power strips, some devices may be on wall-switch controlled outlets.

A whole-house measurement is partly an audit procedure to identify all the devices of interest in the home.

For some hardwired devices, turning off entire circuits with a circuit breaker (or fuse if the house wiring is old enough) could be used to estimate these by subtraction, but it can be difficult to know with confidence what is on a particular circuit, and this could inadvertently interfere with the operation of some devices.

For assessing the whole house consumption, the method of tracking the spinning disk on the main house meter (assuming they are of that type) is attractive as it avoids opening up the breaker box and getting current transformers on house wires and making a voltage tap (with unknown liability and safety issues). Many customers will also be more comfortable with the less-intrusive procedure.

Harrington, 2002 reports experience with a spinning disk meter in Australia. He found that it was consistently unreliable for measurements of about 5 W and below, and reliable for several measurements taken at 13 to 50 W. This suggests that for a typical house with expected standby levels of 40 W or more (per Ross/Meier), disk meters may be adequate, for the total, and for taking differences as when a circuit with a hard-wired device is turned off. The meter itself was measured to consume 1.16 W. Further details on spinning disk meters can be found at: http://standby.lbl.gov/Measuring/electrometer.html. Some digital meters mimic the spinning of a disk with a set of small indicator lights.

There are other intriguing aspects of whole-house consumption. There are energy losses in the wire resistance within houses, and in extension cords. The house meter itself also consumes some power — another example of hard-wired standby.

3.0 Individual Procedures

In this section, pertinent information about individual test procedures not mentioned above are listed.

3.1 Appliances

No U.S. DOE appliance standard test procedure *explicitly* addresses standby power. Some DOE test procedures include low-power modes *implicitly* by reporting consumption over a period of time including non-active periods; this applies to refrigerators and water heaters. Other test procedures, such as for clothes washers, only record energy consumption during cycles of active processing.

The dishwasher procedure is presently being amended, and all discussion in this paper is of the September, 2002 draft DOE procedure. The proposed new procedure includes standby power in the testing and reporting. For standby, the measurement procedure is as stated to be the FEMP procedure.

3.2 Consumer Electronics

IEC 62087's scope mentions as example devices covered: TVs, VCRs, Set top boxes, audio equipment, and equipment with more than one function. It specifies seven different "operating modes." It was created from the European standard EN 50301, which is used by the GEEA (*define GEEA*) program of appliance (and other device) labeling.

3.3 IT equipment

IEC 62018, "Power consumption of information technology equipment - Measurement methods" is being crafted by IEC TC 108: Safety of electronic equipment within the field of audio/video, information technology and communication technology. The intended purpose of this standard is not clear. It is ostensibly to address power management of office equipment, but does not correspond to actual functioning of these devices enough to be useful for this purpose. The content of the proposed standard has so many problems as to not be particularly useful. "Standby" is not referenced or defined. An "energy saving mode" is one in which "one or more functions are switched off," but this could define most on modes as well for many devices.

The Japanese copier standard does not explicitly measure or specify low-power mode consumption, only active consumption. The computer standard mentions the existence of low-power modes, but again, only addresses active consumption.

3.4 Canada

A study of standby power in Canada was recently conducted (Fung et al. 2002). The intent of this study was to look at standby power in a Canadian context. Power modes defined were active, low, and standby power. Measurements were made in homes and in retail stores. In homes, in addition to characteristics of the product, they recorded the house size, number of occupants, and whether a home office was present. Also, people were asked about usage of the products.

3.5 Energy Star

The Energy Star specification for ventilating fans says that "power used for lights, sensors, heaters, timers, or night lights is not included in the determination of power consumption." Note that this provision is not included in the ceiling fan specification.

There is a new monitor test procedure (undated, but probably 2003) to be finalized in the next few months. It is the most specific test procedure developed specifically for Energy Star purposes. It specifies general test conditions, test room illuminance, display output settings, input signal characteristics, and procedures for measuring both the power and the display content.

3.6 FEMP

The Federal Energy Management Program (FEMP) created measurement "guidelines" to support the Executive Order (13221) on Standby Power. As of June, 2003, the program makes recommendations for standby power levels for ten product categories, both office equipment and consumer electronics ("audio/video products").

3.7 Other field measurements (e.g. in stores)

A general problem with measuring power of devices in the field is that the act of unplugging them to connect them to the power meter disrupts their status. Specifically, it may take some time for the device to return to its minimum power mode (e.g. a set-top box may need to fully reload electronic programming guide information), or some information may be lost (e.g. the time on a microwave).

3.8 Other procedures

In Nordman, 1997, three types of equipment audits are described. A "Level One" audit records only brand and model information; "Level Two" adds relevant configuration settings, particularly power management; "Level Three" involves taking time-series data so that different power modes and the time delays needed to engage them can be observed. The time series data also verify that enabled power management actually occurs.

Nordman, 1998 describes three types of data gathering relevant to low-power modes: "model audits" of the capabilities and ways to configure a specific model; "night audits" of the night status (these are to take place after 9 pm to allow the final state for the night to occur); and "detailed monitoring" which requires time-series monitoring (for 2 weeks usually in this study). This study was about copiers, but the principles are generic (though copiers can have unusually long delay times possible before power management is engaged, such as four hours or more).

Alan Meier proposed a new method for designing energy test procedures in the late 1990s. This was to recognize current and forthcoming development in appliance behavior that had significant energy implications but whose effect was not evaluated correctly by existing test procedures; sometimes with over-estimates, and sometimes under-estimates of real performance. The major problems noted are inability to measure part-load conditions, learning, advanced sensing, and networking. Ultimately, these issues are particular to each specific device and known parameters of its usage context. This type of approach is what is needed to assess multiple power modes of products.

California's appliance standards (CEC, 2002) include standby *energy* for non-packaged boilers, duct furnaces, and unit heaters, but for unit heaters (and probably the others) the figure to be reported is the *total* of electricity and gas standby consumption; the individual components are not to be reported. The referenced procedures are from ANSI, UL, federal procedures, and the Hydronics Institute. The federal procedure does not include standby power (even though an annual consumption figure is calculated) and it is unlikely that the others do at all or in any detail.

For auditing miscellaneous consumption in the commercial sector, Roberson, 2004 proposed a protocol for recording the following information about miscellaneous devices: their presence, power status (on, off, asleep, or unplugged), and whether they were hardwired or plugged in. This was an initial protocol, with the expectation that with experience, additional information might be recorded for selected devices.

3.9 Related Standards

Some procedures are not about energy directly, but are still relevant. For example the ASTM test procedures on "productivity" (essentially speed) of imaging devices are used to determine the usage pattern to apply in the energy test procedure. The "BWS Batterymark" test procedure ("Business Winstone"; Veritest, 2002) puts a notebook computer through a defined set of usage steps to allow battery lifetime to be assessed. When it is used, they recommend to disable the screen power management, but to assess battery lifetime with the main power management in three different settings: as-is, disabled, and with it maximally enabled[8]. Such software that imposes "information conditions" on a device will likely be needed for some types of other energy tests.

Some standards are not test procedures that produce data for low-power modes directly, but are useful references. One example is IEEE 1515 (IEEE, 2000) which defines principles for how to measure power supply characteristics, including efficiency. It provides definitions for crest factor, total harmonic distortion, power factor, and active/real power. The Japanese test procedures use Standard Test Conditions C6101 of the Japanese Industrial Standard.

3.10 Limitations

In principle, any mandatory standard or labeling program in any country for any device could have a corresponding test procedure which covers standby power or other low-power modes. However, many countries refer to procedures outlined in international standards, or to the procedures of other countries and so do not have their own unique ones (sometimes an existing procedure is adapted with only minor modification). If a more comprehensive review was to be done, the procedures used in the following countries or programs should be investigated: Australia, China/SETC, EU Code of Conduct, EU Ecolabel, EU CECED, Japan Eco Mark, Korea Energy Savings, and Swiss Energy 2000, Blue Angel (Germany), TCO (Sweden), and the "Copier of the Future." As more countries adopt Energy Star, the number of different test procedures may drop.

4.0 Implications for This Project

IEC 62301 provides a sound foundation on which to build test procedures for low-power modes more generally, both for measurements made in a laboratory setting, and those taken in a field context. For field work, there will be individual device measurements, and another procedure for measuring the whole house.

For parameters such as voltage, our main concern should be to comprehensively record (and report these), with less concern about assuring that parameters such as 115 V ±1% are followed.

[8] The documentation for BatteryMark notes that on some computers, available battery lifetime is reduced when hibernation is selected to assure that there is always reserve energy to accomplish the hibernate function. Brightness and volume are to be 50% of their maximum (however that is measured—it doesn't say).

A major challenge for this project was to identify what products have what modes and how to get into them easily.

As we developed the lab, field, and whole-house procedures for this project (there is much overlap), we addressed many of the topics listed here, building on the discussion and other content above.

5.0 Conclusions

We reviewed over 15 test procedures and measurement protocols — well over 20 when protocols for different products from the same organization are counted separately. We reviewed each procedure for fourteen topic areas covering the test conditions, testing procedure, and mode issues.

In many respects there is and will be a bifurcation between what is done in a laboratory setting as opposed to in the field. In a laboratory, conditions are specified as much as possible to assure replicability. In the field, many conditions are taken as-is, both to reflect actual consumption, and as is realistic given the limitations of field work.

IEC 62301 provides a good basis for the procedures we developed. Some conditions and methods apply to all products, but many issues apply only to particular types of devices. The area of low-power modes other than the minimum power mode is not well explored, and so we will needed to determine what products (may) have what modes and how to move the product through all the modes. Empirical evidence about the stability of power consumption in different modes can show how to make the field measurements expeditious.

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APPENDIX III: MEASUREMENTS OF LOW POWER MODE ENERGY USE FROM A SMALL SAMPLE OF HOMES

Appendix III — Measurements of Low Power Mode Energy Use from a Small Sample of Homes

1.0 Introduction

During this project, we measured individual products in eight houses and did whole house measurements for those same eight houses. The most important result of this process is a table of average power levels for dozens of product types in a variety of operating modes. Many of these power levels fed into our initial estimate for statewide electricity consumption in low power modes.

Other results are found in Appendix IV. This covers the whole house measurements observed from the electricity meters, and how they compared with the sum of the measured products in the mode they were in during the whole-house measurement. It also reports the annual energy consumption due to low power modes from the measured data combined with usage information reported by the house occupants.

2.0 Overview

Throughout this project, we use the term *product type* for a generic type of device, e.g. "television" or "telephone (cordless)" and *product* for a specific model or instance. Products are always in some operating *mode*, such as *off*, *ready*, or *play*; a special mode is *disconnected* if physically unplugged. Modes that are not low power modes (or *disconnected*) are "Active" modes. For clarity, modes are italicized.

The measured results of individual products are shown in three tables at the end of this appendix. Table 4 lists the energy use of external power supplies for selected consumer electronics products with only the power supply connected, not the electronic product. Table 5a shows the *average* power level in each low power mode for each *product type*. Table 5b lists active modes and some low power modes that we metered but see as a distraction to a clear presentation in Table 5a. Table 5c lists products with no low power mode that we metered before discovering this fact. Finally, Table 6 lists each individual *product* and all of the modes.

We first review issues related to mode nomenclature, existence, and definition. We then discuss general categories of product types. Finally, we address results raised by the specific products we measured, including quantitative results.

3.0 Individual Products Measured

We measured 280 products in the eight houses (plus a few measured at LBNL) which we categorized into 108 product types. Table 1 lists the number of each product type measured.

Table 1. Count of Products Measured by Type

Product Type	n	Product Type	n	Product Type	n
Air Freshener	1	Computer Display, LCD	1	Multi-Function Device, Inkjet	2
Answering Machine	3	Computer Speakers	5	Musical Keyboard	2
Aquarium Heater	1	Computer, Integrated	1	Network Device, VPN	1
Aquarium Pump, Air	1	Computer, Notebook	2	Oven, Microwave	6
Aquarium Pump, Water	3	Detector, Carbon Monoxide	4	Power Strip	2
Audio Amplifier	1	Dishwasher	1	Power Strip, Surge	10
Audio Minisystem	13	DVD Player	6	Printer, Inkjet	5
Audio Receiver	7	Ethernet Bridge	1	Printer, Laser	1
Blender	1	Ethernet Router	1	Radio	1
Boiler	1	Extra Remote Sensor, Garage Door	1	Radio, Clock	10
Bread Maker	1	Fax Machine	1	Radio, Clock/Cassette Deck	1
Breast Pump	1	Fax Machine, Inkjet	1	Radio, Clock/CD Player	1
Cassette Deck	6	Fountain, Indoor	1	Security System	1
CD Player	6	Furnace	1	Set-Top Box, Cable	1
CD Player, Portable	1	Furnace/Air Conditioner	1	Space Heater, Portable	2
CD Writer	1	Garage Door Opener	4	Subwoofer	1
Charger, Battery	4	GFCI Outlet	2	Surge Protector	1
Charger, Bicycle Light	2	Hair Dryer	3	Telephone, Corded	2
Charger, Cellular Telephone	7	HVAC Controls	2	Telephone, Cordless	13
Charger, Digital Music Player	1	Image Scanner	2	Television	15
Charger, Men's Shaver	2	Infant Monitor Receiver	1	Television/VCR	3
Charger, Power Tool	3	Infant Monitor Transmitter	1	Timer	5
Charger, Still Camera	1	Iron	2	Timer, Irrigation	3
Charger, Toothbrush	4	Karaoke Machine	1	Toaster	1
Charger, Two-Way Radio	2	Lamp, Dimmable Floor	2	Tuner	1
Charger, Video Camera	1	Light, Decorative	2	Turntable	2
Charger, Weed Trimmer	1	Light, Display	1	USB Hub	1
Clock, Alarm	1	Light, Emergency	2	Vacuum Cleaner, Portable	1
Clothes Washer	1	Light, Incandescent	1	VCR	10
Clothes Washer/Dryer	1	Light, Low-Voltage Outdoor	1	VCR/DVD Player	1
Coffee Maker	2	Light, Night	10	Videocassette Rewinder	1
Computer, Desktop	7	Modem, Cable	2	Wireless Router	1
Computer Display, CRT	4	Modem, DSL	4		

For individual products in the measured houses, we followed the protocol described in Attachment 1. The protocol calls for a detailed recording of product information and usage context (e.g. power switches upstream of it). It also calls for measuring each mode for 5 minutes after a stabilization period. When five separate examples of a product type have been measured and each mode is seen to be stable, the product type is considered to be "known" and the recording period can be shortened to 30 seconds. In the course of the metering we reached the 5-product threshold for the 16 product types shown in Table 2.

Table 2. Product Types with 5 or more Examples Measured

Audio Minisystem	Audio Receiver	CD Player	Cassette Deck
Charger (Cellular Telephone)	Computer (Desktop)	Computer Speakers	DVD Player
Night Light	Oven (Microwave)	Power Strip (Surge)	Radio (Clock)
Telephone (Cordless)	Television	Timer	VCR

In the course of the monitoring, it seemed reasonable to consider reducing the criterion to three. By doing that, 12 additional types that would be "known" are presented in Table 3. It seems reasonable to relax the criterion for products that are relatively simple, meaning that it is clear which modes that are present and no expectation that any of the modes are unstable. Therefore, we will follow this 3-product rule to declare a product "known."

Table 3. Product Types with 3 or 4 Examples Measured

Answering Machine	Aquarium Pump (Water)	Charger (Battery)	Charger (Power Tool)
Charger (Toothbrush)	Computer Display (CRT)	Detector (Carbon Monoxide)	Garage Door Opener
Hair Dryer	Modem (DSL)	Printer (Inkjet)	Timer (Irrigation)

While a few of the products we measured are obscure, the vast majority are ones that can be found in a large number of houses.

To gather the time-series power level data, we recorded the start time for each power mode and the range of power levels seen during that mode. This served to assure that we correctly associated the right set of time series data points within each mode. With up to six modes, this was a necessary part of the process. We also gathered many other characteristics of the product as specified in the protocol. Finally, we reviewed the power data for each product graphically and adjusted the start and stop times as necessary to assure that the average covers only the mode in question.

We also reviewed and reconsidered the names of each mode for consistence within each product type, and between them. For consistency, all averages reflect time periods of 30 or 300 seconds (with a few undersized due to lack of data). In a few cases we removed hardwired products and measured them, but did not do this generally due to time, intrusion, damage risk, and liability concerns.

The averages we report are often for small sample sizes, and often reflect wide variance among the measured products. For estimation purposes, when there are better data (that reflect much larger sample sizes), those should be used instead. For many products though, there may not be better data so that using our results — interpreting them with sufficient caution — is the best option.

In many cases we conducted spot measurements of products to determine whether or not they had any low power modes. In a few cases, we only discovered the lack of a low power mode after collecting time-series data. Products with no low power mode that we collected data for are: portable air filter, aquarium heater, portable fan, graphic equalizer, toy oven, paper shredder, pencil sharpener, research instrumentation, treadmill, and tuner.

4.0 Modes

A critical issue is how to name and categorize modes, what to consider a separate power mode, and what to consider an active (and hence not low power) mode.

4.1 External Power Supply Only

Perhaps the simplest mode is "XPS only" which is when an external power supply is disconnected from the rest of the product. For some products this commonly occurs in normal usage, such as the external power supply for a mobile phone or notebook computer. Some people have several power supplies for the same mobile product in different places, such as at work and at home. For other products, XPS only mainly gives a simple measure of power supply efficiency, and how the common modes (e.g. "*ready*") relate to the no-load condition.

4.2 Off

Many products have an "*off*" mode, most commonly attained with a power button or switch, though sometimes with a control that also specifies a functional mode (e.g. CD or tape for an audio minisystem). *Off* does not necessarily mean zero power or no display or indicator light active, though it can. In most cases the power control must be used before any other control will activate the machine, though there are exceptions.

Some products have auto-off (e.g. turned off by a timer) and regular *off* modes. These can consume different power levels, or can be the same.

4.3 Ready

"Ready" modes are usually those in which the product does not need to be turned on before doing something active, but rather functional controls (e.g. CD vs. tape), external stimuli (e.g. ambient light or a phone call), or timers by themselves will cause the change. When a product had no power control (e.g. a single-mode product), we categorized the basic mode as *on*, but counted it as a low power mode as it often could be controlled to reduce energy consumption. Some products have several *ready* modes, such as a cordless phone handset being on the cradle, or off.

Some low power modes embody some function, but clearly not the primary function of the product. Two examples of this are the lights in some microwave ovens that come on when the door is opened, and the lights in most garage door openers that are turned on when the opener is activated. In the latter case there is usually a delay time after which the light goes back off. Microwaves could benefit from such a timer for times when they are left open for extended periods of time.

Sometimes the existence of a *ready* mode depends on a product's capability. For example, some powered speakers can sense if there is a signal being sent to them and change their power status accordingly, much like a computer display does. Other speakers (and some older displays) do not have this intelligence. Another example of this is network devices (e.g. switches and routers) that could in principle use less energy when not connected to a network at all, or when only some of their network connections are active. Network connections can be unused (no cable attached), with a cable and other product attached but the other product off, with the other product on but without the network connection activated, and finally, with the network connection activated.

4.4 Active Modes

We designated many modes as some form of "active" mode that are clearly outside the scope of low power mode research (with the caveat in the paragraph after next). "*Play*" modes such as audio and video systems are a prime example of this, in addition to modes such as a telephone being used for a call, or an imaging device printing.

There are some modes that are on the edge of what should be considered within low power modes. For a power tool charger that explicitly finishes charging and then enters a different mode (visually and in power consumption), we considered the charging mode an active mode. For products that have a constant trickle charge for a battery, that power could presumably be modulated via a timer or sensor to reduce consumption — this brings it within the low power purview. While *ready* modes are in general *on* modes, they are not active. We used *on*-only for products without a *ready* mode (though in some product types there are some individual examples with a *ready* mode and some without).

One reason to include active power in measurements of low power modes is to estimate savings when a product automatically shifts from an active to a low-power mode, or could do so. Many types of consumer electronics could benefit from this feature.

4.5 General Mode Issues

It is common for different models of the same product type to have different sets of modes. This complicates interpreting averages across a group of products of the same type for their power levels, and combining them with usage information.

Some products, such as audio minisystems, have many active modes, such as record or *play* or fast-forward on a variety of media. Others, such as computers, have many low-power modes, especially integrated computers[1] with separately power-managed displays. Notebook computers have the most modes; we measured seven distinct low-power modes and two active modes (none of which include modes disconnected from AC power), and didn't even include the battery-removed modes that are possible, or variations depending on the status of network connections.

In a few cases we did experiments with different modes to check edge conditions. We measured a few products with and without an internal backup battery. For some clock radios we changed the display brightness, and measured the difference between normal time display and a flashing display reflecting un-set time due to a power outage. The latter might seem rare, but was a fairly common occurrence at the vacation house we measured which had long absences, relatively frequent power outages, and rooms that were only intermittently used.

One set of products we included within the low power universe was single-mode products that were performing a function. One reason for including them is that in theory they may be controllable to be on only part of the time. Others are that their power consumption profile resembles other low power mode products more than they resemble other, more traditional, energy end use categories such as lighting or HVAC. In addition, policy responses also are more similar to those for low power mode products.

5.0 Types of Products We Measured

The products we measured can be categorized in a variety of ways. Some product types fall into more than one of the categories below.

5.1 Single-mode Products

A special category of products can be called "single-mode products." These have only one power mode when plugged in, and of the product types we measured include: air freshener, aquarium pump (air), aquarium pump (water), carbon monoxide detector, extra remote sensor (garage door), emergency light, indoor fountain, GFCI, HVAC controls[2], surge protector, and timer.

For the detectors with alarms (smoke detector, carbon monoxide detector), they are presumably in their alarming mode extremely rarely, and so those modes are not significant for energy consumption and are not considered separate power modes.

Single-mode products are sometimes in product types in which some examples do have multiple modes. Night lights are a good example, with some having no control (and so

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[1] An integrated computer is a computer with an integral display (CRT or LCD) and one power cord for both. While notebook computers meet this definition, we use it only for desktop (non-battery powered) machines. The Apple iMac is the most well known of these, but there are integrated Windows PC models as well. Some Apple displays are powered through the data cable and so integrated by this definition by having only one power cord.

[2] HVAC controls refers to electronics for controlling the HVAC system that have an AC power source separate from the furnace or air conditioner. In most houses, the power for external controls is integral to the furnace or air conditioner.

only a single mode), some having a manual power switch, some a photocell detector for turning off during ambiently lit times, some both, and some with batteries for lighting when the power is off or they are unplugged (though we classify this last type as "emergency light"). Reasons for including single-mode products in low power mode analyses are that sometimes the product could be reasonably controlled via a timer, occupancy sensor, or other control and so reduce its on-time; and often the single mode is a *ready* mode in which the product is waiting for action (e.g. detectors) so that it is not doing much. Also, their energy consumption profiles have more in common with low power modes so they are better evaluated in that context.

5.2 Partial Low Power Product Types

Many product types never have examples with low power modes, and in others, all (or nearly all) do. There is a third set of product types in which many examples have no low power mode and many others have some. This category includes many kitchen small appliances (blenders, toasters, coffee makers, microwave ovens), fans, hair dryers, space heaters, computer speakers, and all major appliances (refrigerators, freezers, dishwashers, washing machines, dryers). Others are portable fans, space heaters (portable and built-in), and ceiling fans, all of which can be bought with remote controls.

For these product types, it is best to measure those with low power modes, and separately arrive at an estimate of the portion of the stock that has no low power modes at all. For most of these, we can expect the portion with low power mode consumption to rise as remote controls and touch controls become more common in them.

5.3 Hard Off Products

The only product types we found that *always* had a zero *off* power were a CD writer (a sample of only one though) and power strips. The rest either sometimes or always had non-zero *off* or had no *off* mode.

Product types that sometimes had a zero-power *off* mode also included some coffee makers, some night lights, some audio equipment, and a few video products. The great majority of products with low power modes have non-zero *off* power.

5.4 Off as only Low Power Mode

Products we saw with an *off* mode as the only low-power mode include audio receiver, men's shaver, clothes washer/dryer, coffee maker, hair dryer, iron, specialty lights (lamp, dimmable floor; light, decorative; light, display; and light, incandescent), oven (microwave), radio, space heater (portable), various audio equipment, and television. The fact that examples of a product type have *off* as the only low power mode does not mean that all do. Most products with a non-zero *off* mode also have other low power modes. If the *off* power is zero and there are no other low power modes, the device is not considered to have any low power modes and so not part of low power mode analysis.

5.5 No Low Power Modes

In a few cases, we measured a product before determining that it actually had no low-power modes. However, a reason to be expansive in what is evaluated include that in some cases individual products have low-power modes when the product type in general does not. For example, most toasters have no low power mode, but an increasing number of models do, including one we measured that even has a *sleep* mode.

6.0 Observations about Our Quantitative Results

Some of the results appear anomalous, such as product types with *ready* power less than *off* power (e.g. answering machines). This is always the result of the set of products in each average not being the same; in fact, all *off* modes are lower power (or the same in a few cases[3]) than *ready* modes on products that have both. For this and other reasons, it is often instructive to check Table 6 when questions arise from Table 5a.

6.1 Mode Differences

Some modes are different but only very slightly so. For example, one alarm clock was measured with the alarm active and not, and the power difference was only 0.02 W. Maintained an entire year this is only 0.18 kWh, or just over a penny at typical prices. Similarly, for clock radios, one used just 0.06 W more when the display was bright rather than dim. Eight clock radios were measured with the time unset and blinking and in the normal constant set mode. Three used about the same power in both modes (within 0.03 W) with the rest using from 0.07 to 0.52 W more when not blinking. Blinking saves energy since the display need not be illuminated during the off periods. For the dishwasher, a power failure causes “PF” to flash on the display until it is reset, increasing consumption by 0.1 W.

There is a category of products that are (at least sometimes) always on, and plug directly into an outlet, without any power cord. These are generally small loads such as air fresheners (1.86 W), detector (carbon monoxide; 1.99 W), light (emergency; 0.25), night light (2.43 W); surge protector (0.33 W), and timer (2.45 W). Some of these have power or other controls and some don’t.

Computer speakers are an example of a product type in which the *off* and *ready* power levels are both more than half of the full active power. Many products have this characteristic, and it suggests inefficiency in the system. On one of the speakers, the *ready* power was over 20 W!

Many consumer media products have high *ready* power levels compared to *off*. As these can easily be left on by mistake or lack of interest, an auto-off feature has great advantage. For DVD players, the *ready* power averaged more than 12 W, while the *off* power was about one eighth of this. For DVD players, there was no clear correlation between *off* power and *ready* power.

Of four chargers for toothbrushes, two used the same amount of power whether the brush part was in the charger or not, one used less when the brush was removed, and one oddly used more power when the brush was removed.

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[3] The subwoofer we measured did show greater *off* power than *ready* power in our monitored data, but the difference is less than 1% and we don’t think it is statistically significant.

One of the houses had a toaster with a *sleep* mode (which turned off a numeric digit display after 30 seconds of non-use). Curiously, there was no power difference measurable between the *ready* and *sleep* modes (we ignore differences of under 1%).

Some products for which we had relatively larger samples showed great variation in low power modes. Audio minisystems are perhaps the best example of this as we had 13 examples measured. The *off* power (measured on eight) averaged 3.01 W but ranged from 0.48 to 15.44 W. *ready* modes varied from less than 1 W to well over 20 W. For televisions, *off* power varied from 0.42 to 11.80 W.

6.2 External Power Supplies

For many product types we measured the consumption of the external power supply (XPS) when not connected to the main product. Occasionally external power supplies cannot be separated without cutting the cord, but usually there is a low voltage plug connection. In a few cases there was an *off* mode on the product identical to the external power supply consumption — breast pump, some computer speakers, infant monitor (transmitter and receiver), and musical keyboard. In other cases, the *off* mode used more than the XPS only — modem (DSL), printer (inkjet), and timer (irrigation). However, most products with external power supplies had no *off* mode at all.

Fifty-six products were measured in the mode with an external power supply unconnected to anything else. Table 1 lists these in order of increasing consumption. Chargers generally use less than other types of products. Note that inkjet printers can be found near both ends of the spectrum.

7.0 Types of Products

Some products are in categories that traditionally never had low power modes, but recently have had them introduced. Examples of these that we measured are kitchen products (blender, coffee maker, toasters), household appliances (dishwasher, clothes washer), and hair dryer.

Several types of lighting were seen to have low power modes, such as a lamp (dimmable), light (decorative), light (display), and one light (incandescent) — the latter presumably had a low-voltage halogen lamp or incorporated a dimmer. However, these all had relatively low *off* levels, with the two lamp (dimmable) products averaging just 0.05 W in their low power mode. Certainly most lights have no low power mode, but as lights include more electronic controls, and as the light sources themselves are poised to become increasingly solid-state, we can expect more and more lights to have low power modes.

Energy uses associated with outdoor products are increasing. We found a weed trimmer charger, outdoor lights (presumably the transformer on the hot side of the switch or timer), and several irrigation timers, all using several W each in their predominant mode.

We measured three major appliances, a washer, a washer/dryer, and a dishwasher. Each used about 2 to 2.5 W in their quiescent non-washing modes.

Many HVAC products are hard-wired. We were able to measure four, a furnace, a furnace/air conditioner, HVAC controls, and a boiler; these used over 4 to more than 9 W in their *ready* modes.

Table 4. External Power Supply Only Consumption (W)

Product	W	Product	W	Product	W
Charger, Cellular Telephone	0.10	Computer Speakers	0.78	Charger, Battery	1.22
Charger, Cellular Telephone	0.14	Telephone, Cordless	0.78	Ethernet Router	1.25
Charger, Men's Shaver	0.14	Telephone, Cordless	0.79	Charger, Two-Way Radio	1.32
Charger, Digital Music Player	0.17	Vacuum Cleaner, Portable	0.80	Modem, Cable	1.38
Charger, Cellular Telephone	0.19	Charger, Bicycle Light	0.91	Telephone, Corded	1.39
Printer, Inkjet	0.27	Computer, Notebook	0.93	Charger, Weed Trimmer	1.41
Computer, Notebook	0.28	Charger, Bicycle Light	0.95	Modem, DSL	1.44
Charger, Cellular Telephone	0.33	Telephone, Cordless	0.98	Timer, Irrigation	1.56
Charger, Cellular Telephone	0.33	Answering Machine	1.00	Modem, DSL	1.62
Wireless Router	0.33	Charger, Battery	1.02	Answering Machine	1.64
Charger, Cellular Telephone	0.35	Telephone, Cordless	1.02	Modem, DSL	1.67
Charger, Cellular Telephone	0.35	Telephone, Cordless	1.05	Computer Speakers	1.87
Network Device, VPN	0.37	Telephone, Cordless	1.10	Musical Keyboard	2.04
Charger, Still Camera	0.57	Infant Monitor Transmitter	1.14	Computer Speakers	2.20
Charger, Video Camera	0.57	Breast Pump	1.15	USB Hub	2.38
Charger, Two-Way Radio	0.70	Computer Speakers	1.18	Printer, Inkjet	2.61
Modem, DSL	0.75	Radio, Clock	1.18	Musical Keyboard	3.29
Telephone, Cordless	0.76	CD Player, Portable	1.20	HVAC Controls	4.95
Telephone, Cordless	0.77	Telephone, Corded	1.20		

7.1 Digital Products

While computers meeting the Energy Star specification are required to use less than 15 W in *sleep* (or some higher amount depending on power supply size), the lowest of the five that we measured used over 39 W in *sleep*. While many desktop computers do use the lower Energy Star amounts, this is an example of where theory and reality can conflict. This is probably a combination of older hardware, older software, and non-optimal settings. Some computers may not have been able to go to *sleep* as configured, e.g. with certain types of internet connections active or software installed.

Most, though not all, network devices showed modest increases in consumption when they were connected as opposed to isolated. However, this is a complicated issue. For example, there are different types of connection: physical / mechanical (simply the cable plugged in, with another device at the other end or not), electrical (at least some of the wires energized), and information (data actually being exchanged across the link). Which type of connection a particular product has while being metered is not always clear.

A printer we measured with a network adapter showed interesting behavior. When the adapter was in, the *off* power level was raised to nearly the *ready* power level (and more than the *ready* power when the adapter was not present). Thus, the presence of the adapter seemed to both add power consumption and affect the consumption of the balance of the system.

A USB hub is most similar to a power strip in that it doesn't accomplish an active result, but mainly provides (low-voltage) power to downstream devices (in addition to providing data connections which can be done without an external power source). The one we measured showed similar consumption with the external power supply only, unconnected, and connected (to other devices).

7.2 Input/Activity Sensing

Computer displays show that non-zero *off* power values can be low (0.01, 0.03, 0.04 and 0.32 W for CRTs). This is probably due to the presence of a small power supply that powers signal-sensing circuitry and the power switch, and has the ability (via a relay) to energize the main power supply which provides for the high-current display electronics. These low *off* power levels show the potential for this approach.

The powered subwoofer that we metered showed behavior much like a computer display, in that it sensed when there was a signal incoming, and when the signal ceased, the subwoofer entered an effective *sleep* mode, with power consumption close to the *off* power, and much less than the active power. Since many people are unlikely to remember to turn a subwoofer off when not in use, this is a practical feature. On the other hand, the *off* power for this unit was over 11 W (and the active power was less than 20 W), among the highest *off* powers we found on any product.

Some products effectively turn themselves off after completing a task or not being used for a time. Examples we observed of this include a charger (men's shaver), charger (power tool), computer (notebook), toaster, and an iron. Other products may have had this feature, unobserved by us due to time constraints or not knowing to look for it.

7.3 Switches

Some products have mechanical switches that change consumption of the controls. For example, on a dishwasher, closing the door adds about 0.4 W and allows a series of soft switches and indicator lights to operate. Many products with tape transport mechanisms use the play and other buttons to energize much of the system. This allows the "ready, cassette" mode on audio minisystems to be much lower (1.79 W) than any of the other *ready* modes (over 4, 10, and 27 W).

Reassuringly, all the power strips we measured did not consume power when *off*. For power strips (regular and surge protecting) with indicator lights, each light added about 0.1 W.

Products we found that can change power mode only by the power switch are audio amplifier, breast pump, lights, and power strips.

The two turntables measured averaged 3.7 W when *ready*. This is an interesting case in that they generally have no power controls (switches or indicators). Also, one of them used ten times the power of the other in *ready*.

7.4 Hard Wired

The two GFCI outlets we measured averaged 0.73 W in their normal position, and when tripped, neither changed consumption. By contrast, the three hair dryers (not hard-wired) averaged only 0.10 W, and one cut all of its own consumption when tripped. This is interesting since they each nominally serve the same purpose — to monitor a circuit of up to 15A of load for a fault and trip a breaker when they do. It may be that the outlets have requirements beyond those that are applied to hair dryers, but the topic does deserve further investigation.

Some products are not hard-wired themselves, but always connect to dedicated wiring. An example of this is the one security system we measured, which consumed over 11 W. These are generally never unplugged (even when not armed), and often incorporate both battery charging and external power supplies. Furnaces can also be in this category, in that the thermostat wire is dedicated, and many garage door openers are as well.

Products we found that were hard wired and not measured included several furnaces, an air conditioner, timer, doorbell transformers, and many GFCI outlets.

7.5 Active Modes

While we did measure some active modes on some products, we did not try to do this universally. The purpose was to give a sense of how active power (and consequently energy) compares with low power modes. One mode we can't explain is the high active power for the set top box, though it seems as if it might include the TV itself.

The fact that the boiler energy in *ready* is over 20% of the active power, and the product is not active for anything like 20% of the year means that this product consumes the great majority of its electricity when not active.

7.6 Other Notes

It may seem surprising to find only one product listed for many common types. There are several factors that exclude products actually present in the houses, such as hardwired examples are not included, those that were determined to have no low power mode were not included. In addition, we often found different modes on different examples of the same product type , often due to the presence or absence of specific switches and/or indicators. In other cases there are differences in product capability that drive different modes. This explains anomalies that show up in Table 5a, such as that the average for the "ready, cassette" mode is less than off for audio minisystems. One of the telephones listed as corded also has a cordless handset as part of the same unit.

Table 3a. Average Power for Products in Low Power Modes[4]

Product Type	Mode	W	n	Mode	W	n
Air Freshener	On	1.86	1			
Answering Machine	Off	4.21	2	Ready	3.83	3
	XPS only	1.32	2			
Aquarium Heater	On	6.89	1			
Aquarium Pump, Air	On	7.53	1			
Aquarium Pump, Water	On	99.74	3			
Audio Amplifier	Off	2.61	1			
Audio Minisystem	Off	3.01	8	Ready	10.36	5
	Ready, CD	4.48	9	Ready, cassette	1.79	7
Audio Receiver	Off	2.29	7	Ready	27.38	2
Blender	Ready	1.48	1			
Boiler	Ready	8.51	1			
Bread Maker	Ready	2.49	1			
Breast Pump	Off	1.15	1	XPS only	1.15	1
CD Player	Off	2.46	6	Ready	7.43	6
CD Player, Portable	Ready	1.76	1	XPS only	1.20	1
CD Writer	Off	0.00	1	Ready	3.53	1
Cassette Deck	Off	1.47	5	Ready	7.90	6
Charger, Battery	Battery out	1.03	1	Ready	1.63	3
	XPS only	1.12	2			
Charger, Bicycle Light	XPS only	0.93	2			
Charger, Cellular Telephone	XPS only	0.26	7			
Charger, Digital Music Player	XPS only	0.17	1			
Charger, Men's Shaver	Fully charged	0.59	1	Off	0.24	1
	XPS only	0.14	1			
Charger, Power Tool	Battery out	1.15	1	Fully charged	35.56	1
	Ready	1.74	2			
Charger, Still Camera	XPS only	0.57	1			
Charger, Toothbrush	Ready	1.95	1	Ready, toothbrush in	1.89	2
	Ready, toothbrush	1.95	3			

[4] W = Watts; n = count

Product Type	Mode	W	n	Mode	W	n
	removed					
Charger, Two-Way Radio	Ready, handset on	3.66	2	Ready, handset removed	1.55	2
	XPS only	1.01	2			
Charger, Video Camera	XPS only	0.57	1			
Charger, Weed Trimmer	Charge/Ready	2.60	1	XPS only	1.41	1
Clock, Alarm	On, alarm off	1.04	1	On, alarm on	1.07	1
Clothes Washer	Off	2.26	1	Ready	2.58	1
Clothes Washer/Dryer	Off	2.54	1			
Coffee Maker	Off	0.83	1	Ready	0.00	1
Computer, Desktop	Off	3.17	7	Sleep	46.97	5
Computer Display, CRT	Off	0.10	4	On, computer off	3.37	3
	Sleep, computer off	1.86	1	Sleep, computer on	5.03	3
Computer Display, LCD	Off	1.25	1	Sleep	1.36	1
Computer Speakers	Off	1.62	3	Ready	20.44	1
	XPS only	1.51	4			
Computer, Integrated	Display sleep	76.84	1	Off	2.90	1
	Sleep	30.19	1			
Computer, Notebook	Display sleep, fully charged	17.88	1	Hibernate, fully charged	0.95	1
	Off, charge	7.21	1	Off, fully charged	2.50	1
	Sleep, charge	24.04	1	Sleep, fully charged	1.93	2
	XPS only	0.61	2			
DVD Player	Off	1.57	6	Ready	11.77	6
Detector, Carbon Monoxide	On	1.99	4	Test	2.15	2
Dishwasher	Power failure, door open	2.05	1	Ready, door closed	1.95	1
	Ready, door open	1.56	1			
Ethernet Bridge	On, connected	3.79	1	On, disconnected	3.62	1
Ethernet Router	On, computer connected	5.93	1	On, disconnected	5.36	1
	XPS only	1.25	1			
Extra Remote Sensor, Garage Door	On	0.73	1			
Fax Machine	Ready	3.32	1			
Fax Machine, Inkjet	Ready	7.60	1			

Product Type	Mode	W	n	Mode	W	n
Fountain, Indoor	On	3.15	1			
Furnace	Ready	4.87	1			
Furnace/Air Conditioner	Ready	9.13	1			
GFCI Outlet	Tripped	0.73	2	Untripped	0.73	2
Garage Door Opener	Light on	78.65	1	Ready	3.11	4
HVAC Controls	On	4.64	1	XPS only	4.95	1
Hair Dryer	Off	0.10	3	Tripped	0.08	2
Image Scanner	Off	0.46	2	Ready	13.90	2
	Ready, low power	4.05	1			
Infant Monitor Receiver	Receiver off, battery out	1.16	1			
Infant Monitor Transmitter	Transmitter off	1.13	1	Transmitter off, battery out	1.16	1
	XPS only	1.14	1			
Iron	Auto off	1.60	1	Off	1.64	2
Karaoke Machine	Ready	12.31	1	Standby	6.50	1
Lamp, Dimmable Floor	Minimum	0.07	1	Off	0.03	1
Light, Decorative	Off	1.17	1	On	38.22	1
Light, Display	Off	0.31	1			
Light, Emergency	Auto	0.25	2	Off	0.24	2
	On	0.25	1			
Light, Incandescent	Off	0.35	1			
Light, Low-Voltage Outdoor	Ready	6.23	1			
Light, Night	Off	0.00	5	On	2.80	7
	Ready, lit	1.55	3	Ready, unlit	0.00	2
Modem, Cable	Off	8.07	1	Ready, computer connected	4.01	1
	Ready, computer disconnected	3.78	1	Ready, computer off	8.29	1
	Ready, computer on	8.40	1	Standby, computer connected	3.92	1
	Standby, computer disconnected	3.70	1	XPS only	1.38	1
Modem, DSL	Off	1.74	2	Ready, computer connected	7.45	2
	Ready, computer disconnected	7.50	1	Ready, computer off	6.49	1
	Ready, computer on	6.46	1	Ready, connected	7.21	1
	Ready, disconnected	7.21	2	XPS only	1.37	4
Multi-Function	Off	7.75	2	On	10.96	1

Product Type	Mode	W	n	Mode	W	n
Device, Inkjet						
	Ready	10.59	2	Sleep	7.85	1
Musical Keyboard	Off	3.31	1	Ready	4.13	2
	XPS only	2.67	2			
Network Device, VPN	XPS only	0.37	1			
Oven, Microwave	Off	6.34	1	Ready, door closed	2.53	5
	Ready, door open	17.31	3	Timer	3.41	1
Power Strip	Off	0.00	1	On	0.09	2
Power Strip, Surge	Master switch on, individual switches off	0.11	1	Master switch on, individual switches on	0.73	1
	Off	0.09	9	On	0.60	9
Printer, Inkjet	Off	3.50	4	Ready	7.18	4
	Off, network adapter in	5.47	1	Off, network adapter removed	0.97	1
	Ready, network adapter in	5.49	1	Ready, network adapter removed	4.23	1
	XPS only	1.44	2			
Printer, Laser	Ready	4.45	1			
Radio	Off	0.62	1			
Radio, Clock	Ready	1.83	8	Ready, blinking	1.68	8
	Ready, display bright	1.05	1	Ready, display dim	0.90	1
	Time set	1.38	1	XPS only	1.18	1
Radio, Clock/CD Player	Ready	3.45	1			
Radio, Clock/Cassette Deck	Ready	1.53	1			
Security System	Ready	11.59	1			
Set-Top Box, Cable	Off	17.97	1	Ready, television disconnected	18.63	1
	Ready, television off	19.77	1			
Space Heater, Portable	Off	0.26	1	Ready	0.44	1
Subwoofer	Off	11.07	1	Play	18.64	1
	Ready	10.99	1			
Surge Protector	On	0.33	1			
Telephone	Ready	4.84	1	Ready, handset on	4.36	1
	XPS only	1.29	2			
Telephone, Cordless	Ready	3.74	3	Ready, handset on	2.84	10
	Ready, handset removed	2.01	13	XPS only	0.91	8

Product Type	Mode	W	n	Mode	W	n
Television	Off	3.54	14	Off, mains off	0.01	1
	Off, mains on	2.15	1			
Television/VCR	Off	4.44	3			
Timer	On	2.45	5			
Timer, Irrigation	Off	2.19	1	Ready	6.68	2
	Ready, battery in	2.20	1	Ready, battery out	2.19	1
	XPS only	1.56	1			
Toaster	Off	0.81	1	Ready	0.80	1
Turntable	Ready	3.74	2			
USB Hub	On, no load	2.44	1	XPS only	2.38	1
VCR	Off	5.02	10	Ready	12.85	10
VCR/DVD Player	Off	2.58	1	Ready	13.96	1
Vacuum Cleaner, Portable	Charge	2.73	1	XPS only	0.80	1
Videocassette Rewinder	Ready	1.09	1			
Wireless Router	On, disconnected	5.85	1	XPS only	0.33	1

Table 3b. Average Power for Products in Active and Extra Low Power Modes

Product Type	Mode	W	n	Mode	W	n
Answering Machine	Call incoming	4.72	1	Call outgoing	4.31	2
	Ready, battery out	4.25	1	Record incoming	4.09	1
	Record outgoing	4.09	1			
Audio Amplifier	On	42.55	1			
Audio Minisystem	Off, time flashing	13.93	1	Play, CD	8.64	8
	Play, cassette	6.51	8	Play, radio	4.71	10
	Ready	23.44	1			
Audio Receiver	Play, CD	22.41	2	Play, radio	24.50	4
	Play, television	42.15	1			
Boiler	On	40.72	1			
CD Player	Play	7.18	3			
CD Player, Portable	Play	5.08	1			
CD Writer	Read	9.81	1			
Cassette Deck	Play	10.13	4			
Charger, Battery	Charge	3.00	3			
Charger, Bicycle Light	Charge	6.63	1			
Charger, Cellular Telephone	Charge	3.14	5			
Charger, Digital Music Player	Charge	2.97	1			

Product Type	Mode	W	n	Mode	W	n
Charger, Men's Shaver	Charge	5.49	1			
Charger, Power Tool	Charge	25.39	2			
Charger, Still Camera	Charge	14.26	1			
Charger, Toothbrush	Charge	1.57	2			
Charger, Video Camera	Charge	4.79	1			
Computer, Desktop	On	67.78	6	On, display sleep	77.92	3
Computer Display, CRT	On, blank screen	70.06	1	On, computer on	84.20	4
Computer Display, LCD	On	14.81	1			
Computer Speakers	On	6.35	5			
Computer, Integrated	On	88.06	1			
Computer, Notebook	On, charge	47.47	1	On, fully charged	24.20	2
DVD Player	Play	15.95	4			
Image Scanner	On	14.05	1			
Infant Monitor Receiver	Receiver on, battery out, high volume	2.28	1	Receiver on, battery out, minimal volume	1.79	1
Infant Monitor Transmitter	Transmitter on	1.40	1	Transmitter on, battery in	1.42	1
Karaoke Machine	Play, cassette	13.09	1	Voice input only	6.47	1
Light, Decorative	On, high intensity and focus	6.85	1			
Light, Night	Auto	0.28	1			
Multi-Function Device, Inkjet	Print	24.40	1			
Musical Keyboard	Play	4.23	2			
Network Device, VPN	On, computer connected	3.43	1	On, computer disconnected	3.42	1
Printer, Inkjet	Print	13.80	2			
Printer, Laser	Test print	249.30	1			
Radio, Clock	Play, radio	1.43	3	Ready, display bright	1.02	1
Radio, Clock/Cassette Deck	Play, cassette	5.04	1	Play, radio	1.90	1
Set-Top Box, Cable	Play, television	139.85	1			
Telephone	Call incoming	5.22	1	Call, remote handset	5.37	1
Telephone,	Call outgoing	3.01	5	Ready, handset on	2.23	1

Product Type	Mode	W	n	Mode	W	n
Cordless				(turned off)		
Television	Play	65.52	10	Play, VCR	89.92	1
	Play, music	113.34	1	Play, television	102.29	1
Television/VCR	Play, VCR	42.35	1	Play, television	48.43	2
Toaster	Off	0.82	1	Turn on	0.81	1
Tuner	Play	13.09	1			
Turntable	Play	5.61	2			
USB Hub	On, load	2.44	1			
VCR	Play	17.12	7			
VCR/DVD Player	Play, DVD	16.30	1	Play, VCR	16.38	1
Wireless Router	On, connected	5.82	1			

Table 3c. Average Power Use for Product Types with no Low Power Mode

Product Type	Mode	W	n	Mode	W	n
Air Filter, Portable	High	123.77	1	Low	42.04	1
	Maximum	189.42	1	Medium	60.19	1
	Minimum	135.20	1	Off	0.00	2
Aquarium Heater	Off	0.00	1	On	282.00	1
Fan, Portable	High, oscillating	36.89	1	Low, oscillating	27.55	1
	Low, stationary	27.44	1	Medium, oscillating	31.48	1
	Off	0.00	1			
Graphic Equalizer	On	9.28	1			
Oven, Toy	On	99.68	1			
Paper Shredder	Ready	0.00	1	Shred	29.13	1
Pencil Sharpener	Ready	0.00	1	Sharpen	72.46	1
Research Instrumentation	On	38.56	1			
Treadmill	Off	0.00	1	On	5.22	1
Tuner	Off	0.00	1	Play	8.28	1

Table 4. Individual Product Data

Product Type	Mode 1 / Mode 4	Avg. W	Mode 2 / Mode 5	Avg. W	Mode 3 / Mode 6	Avg. W
Air Freshener	On	1.86				
Answering Machine	Ready	4.12	Off	3.99	*Call outgoing	4.12
	*Ready, battery out	4.25	*Record outgoing	4.09	*Record incoming	4.09
Answering Machine	XPS only	1.64	Ready	2.65	*Call outgoing	4.50
Answering Machine	XPS only	1.00	Off	4.43	Ready	4.72
	*Call incoming	4.72				
Aquarium Heater	On	6.89				
Aquarium Pump, Air	On	7.53				
Aquarium Pump, Water	On	288.40				
Aquarium Pump, Water	On	3.36				
Aquarium Pump, Water	On	7.45				
Audio Amplifier	Off	2.61	*On	42.55		
Audio Minisystem	*Play, radio	1.29	Ready, cassette	0.63	*Play, cassette	1.71
Audio Minisystem	Off	0.48	Ready	14.68	*Play, radio	15.01
Audio Minisystem	Off	1.73	Ready	3.69	Ready, CD	5.00
	*Play, CD	5.03	*Play, radio	2.99		
Audio Minisystem	Off	0.83	Ready	4.43	Ready, CD	4.43
	*Play, CD	6.35	*Play, cassette	4.00	*Play, radio	3.41
Audio Minisystem	Off	1.19	Ready	4.70	Ready, CD	4.74
	*Play, CD	7.79	*Play, cassette	4.84	*Play, radio	3.96
Audio Minisystem	Ready, cassette	1.42	*Play, cassette	5.42	*Play, radio	4.40
	Ready, CD	5.26	*Play, CD	7.15		
Audio Minisystem	Ready, cassette	1.56	*Play, cassette	3.24	*Play, radio	4.35
	Ready, CD	3.59	*Play, CD	4.75		
Audio Minisystem	Off	2.06	Ready, cassette	5.29	Ready, CD	7.52
	*Play, radio	6.57				
Audio Minisystem	*Off, time flashing	13.93	Ready	24.30	*Play, CD	27.93
	*Play, cassette	26.64	*Ready, CD	23.44	Off	15.44
Audio Minisystem	Ready, cassette	1.14	Ready, CD	2.85	*Play, CD	5.56
	*Play, radio	2.07	*Play, cassette	2.62		
Audio Minisystem	Off	1.46	*Play, cassette	3.61	*Play, radio	3.10
	Ready, CD	3.33	*Play, CD	4.56		
Audio Minisystem	Off	0.91	Ready, cassette	0.91		
Audio Minisystem	Ready, cassette	1.60	Ready, CD	3.57		
Audio Receiver	Off	1.30	*Play, CD	19.62	*Play, radio	21.98
Audio Receiver	Off	0.00	Ready	19.90	*Play, radio	24.98
Audio Receiver	Off	0.38	*Play, radio	26.29	*Play, CD	25.19
Audio Receiver	Off	0.63	*Play, television	42.15		

Product Type	Mode 1 Mode 4	Avg. W	Mode 2 Mode 5	Avg. W	Mode 3 Mode 6	Avg. W
Audio Receiver	Off	0.00	Ready	34.85		
Audio Receiver	Off	1.83	*Play, radio	24.74		
Audio Receiver	Off	11.91				
Blender	Ready	1.48				
Boiler	Ready	8.51	*On	40.72		
Bread Maker	Ready	2.49				
Breast Pump	XPS only	1.15	Off	1.15		
Cassette Deck	Off	3.93	Ready	6.07	*Play	7.32
Cassette Deck	Off	1.11	Ready	8.54	*Play	10.32
Cassette Deck	Off	1.28	Ready	3.41	*Play	6.09
Cassette Deck	Ready	12.85	*Play	16.78		
Cassette Deck	Off	0.00	Ready	8.37		
Cassette Deck	Off	1.04	Ready	8.14		
CD Player	Off	0.00	Ready	7.63	*Play	7.53
CD Player	Off	2.22	Ready	4.91	*Play	6.90
CD Player	Off	2.21	Ready	4.97	*Play	7.11
CD Player	Off	0.00	Ready	5.84		
CD Player	Off	6.19	Ready	13.32		
CD Player	Off	4.17	Ready	7.94		
CD Player, Portable	XPS only	1.20	Ready	1.76	*Play	5.08
CD Writer	Off	0.00	Ready	3.53	*Read	9.81
Charger, Battery	Battery out	1.03	*Charge	1.86		
Charger, Battery	XPS only	1.02	Ready	1.89	*Charge	2.74
Charger, Battery	Ready	1.04	*Charge	4.40		
Charger, Battery	XPS only	1.22	Ready	1.97		
Charger, Bicycle Light	XPS only	0.91	*Charge	6.63		
Charger, Bicycle Light	XPS only	0.95				
Charger, Cellular Telephone	XPS only	0.35				
Charger, Cellular Telephone	XPS only	0.10	*Charge	4.95		
Charger, Cellular Telephone	XPS only	0.33	*Charge	3.97	*Charge	3.86
Charger, Cellular Telephone	XPS only	0.35				
Charger, Cellular Telephone	XPS only	0.14	*Charge	1.79		
Charger, Cellular Telephone	XPS only	0.33				
Charger, Cellular Telephone	XPS only	0.19	*Charge	1.14		
Charger, Digital Music Player	XPS only	0.17	*Charge	2.97		
Charger, Men's Shaver	XPS only	0.14	*Charge	5.49	Fully charged	0.59
Charger, Men's	Off	0.24				

Product Type	Mode 1	Avg.	Mode 2	Avg.	Mode 3	Avg.
	Mode 4	**W**	**Mode 5**	**W**	**Mode 6**	**W**
Shaver						
Charger, Power Tool	Battery out	1.15	*Charge	46.44	Fully charged	35.56
Charger, Power Tool	Ready	0.92	*Charge	4.34		
Charger, Power Tool	Ready	2.57				
Charger, Still Camera	XPS only	0.57	*Charge	14.26		
Charger, Toothbrush	Ready, toothbrush in	2.48	Ready, toothbrush removed	3.49		
Charger, Toothbrush	Ready, toothbrush in	1.30	Ready, toothbrush removed	1.14		
Charger, Toothbrush	*Charge	1.21	Ready, toothbrush removed	1.22		
Charger, Toothbrush	*Charge	1.94	Ready	1.95		
Charger, Two-Way Radio	XPS only	1.32	Ready, handset removed	1.73	Ready, handset on	5.20
Charger, Two-Way Radio	XPS only	0.70	Ready, handset removed	1.37	Ready, handset on	2.11
Charger, Video Camera	XPS only	0.57	*Charge	4.79		
Charger, Weed Trimmer	XPS only	1.41	Charge/Ready	2.60		
Clock, Alarm	On, alarm off	1.04	On, alarm on	1.07		
Clothes Washer	Off	2.26	Ready	2.58		
Clothes Washer/Dryer	Off	2.54				
Coffee Maker	Ready	0.00				
Coffee Maker	Off	0.83				
Computer, Desktop	Off	1.94	*On	46.08	Sleep	40.19
Computer, Desktop	Off	2.79	*On	46.80	Sleep	38.99
Computer, Desktop	Off	3.27	*On	133.66	*On, display sleep	128.56
	Sleep	65.52				
Computer, Desktop	Off	2.64	*On	58.48	*On, display sleep	52.20
Computer, Desktop	Off	3.34	*On	57.40	Sleep	44.61
	*On, display sleep	53.01				
Computer, Desktop	Off	3.23	*On	64.27	Sleep	45.53
Computer, Desktop	Off	4.99				
Computer Display, CRT	Off	0.32	On, computer off	3.42	*On, computer on	71.74
	Sleep, computer on	3.58				
Computer Display,	Off	0.03	On, computer	3.31	*On, computer	95.78

Product Type	Mode 1	Avg.	Mode 2	Avg.	Mode 3	Avg.
	Mode 4	W	Mode 5	W	Mode 6	W
CRT			off		on	
	*On, blank screen	70.06				
Computer Display, CRT	Sleep, computer off	1.86	Off	0.04	*On, computer on	82.93
	Sleep, computer on	8.15				
Computer Display, CRT	Off	0.01	On, computer off	3.38	*On, computer on	86.35
	Sleep, computer on	3.37				
Computer Display, LCD	*On	14.81	Sleep	1.36	Off	1.25
Computer Speakers	*On	3.26	XPS only	1.18		
Computer Speakers	Ready	20.44	*On	20.56		
Computer Speakers	Off	1.87	*On	2.90	XPS only	1.87
Computer Speakers	XPS only	0.78	Off	0.78	*On	0.86
Computer Speakers	XPS only	2.20	Off	2.21	*On	4.19
Computer, Integrated	Off	2.90	*On	88.06	Display sleep	76.84
	Sleep	30.19				
Computer, Notebook	XPS only	0.28	Off, charge	7.21	Hibernate, fully charged	0.95
	*On, fully charged	29.13	Display sleep, fully charged	17.88	Sleep, fully charged	1.22
Computer, Notebook	XPS only	0.93	Off, fully charged	2.50	*On, fully charged	19.28
	Sleep, fully charged	2.64	*On, charge	47.47	Sleep, charge	24.04
Detector, Carbon Monoxide	On	0.75				
Detector, Carbon Monoxide	On	3.94	Test	1.87		
Detector, Carbon Monoxide	On	2.13	Test	2.42		
Detector, Carbon Monoxide	On	1.15				
Dishwasher	Power failure, door open	2.05	Ready, door open	1.56	Ready, door closed	1.95
DVD Player	Off	6.50	Ready	27.74	*Play	32.47
DVD Player	Off	0.00	Ready	9.91	*Play	13.55
DVD Player	Off	0.73	Ready	7.33	*Play	10.08
DVD Player	Off	0.40	Ready	12.71		
DVD Player	Off	0.39	Ready	6.05	*Play	7.71
DVD Player	Off	1.43	Ready	6.87		
Ethernet Bridge	On, disconnected	3.62	On, connected	3.79		
Ethernet Router	XPS only	1.25	On, disconnected	5.36	On, computer connected	5.93

Product Type	Mode 1 Mode 4	Avg. W	Mode 2 Mode 5	Avg. W	Mode 3 Mode 6	Avg. W
Extra Remote Sensor, Garage Door	On	0.73				
Fax Machine	Ready	3.32				
Fax Machine, Inkjet	Ready	7.60				
Fountain, Indoor	On	3.15				
Furnace	Ready	4.87				
Furnace/Air Conditioner	Ready	9.13				
Garage Door Opener	Ready	3.10				
Garage Door Opener	Ready	3.65				
Garage Door Opener	Ready	1.73				
Garage Door Opener	Light on	78.65	Ready	3.97		
GFCI Outlet	Untripped	0.75	Tripped	0.75		
GFCI Outlet	Untripped	0.70	Tripped	0.70		
Hair Dryer	Off	0.05				
Hair Dryer	Off	0.09	Tripped			
Hair Dryer	Off	0.16	Tripped	0.16		
HVAC Controls	XPS only	4.95				
HVAC Controls	On	4.64				
Image Scanner	Off	0.44	Ready	13.49	Ready, low power	4.05
	*On	14.05				
Image Scanner	Off	0.48	Ready	14.30		
Infant Monitor Receiver	Receiver off, battery out	1.16	*Receiver on, battery out, minimal volume	1.79	*Receiver on, battery out, high volume	2.28
Infant Monitor Transmitter	XPS only	1.14	Transmitter off	1.13	*Transmitter on	1.40
	*Transmitter on, battery in	1.42	Transmitter off, battery out	1.16		
Iron	Off	0.44				
Iron	Off	2.83	Auto off	1.60		
Karaoke Machine	Ready	12.31	Standby	6.50	*Play, cassette	13.09
	*Voice input only	6.47				
Lamp, Dimmable Floor	Off	0.03				
Lamp, Dimmable Floor	Minimum	0.07				
Light, Decorative	Off	1.17	*On, high intensity and focus	6.85		
Light, Decorative	On	38.22				
Light, Display	Off	0.31				
Light, Emergency	Off	0.25	On	0.25	Auto	0.26
Light, Emergency	Off	0.22	Auto	0.23		
Light, Incandescent	Off	0.35				

Product Type	Mode 1 / Mode 4	Avg. W	Mode 2 / Mode 5	Avg. W	Mode 3 / Mode 6	Avg. W
Light, Low-Voltage Outdoor	Ready	6.23				
Light, Night	Ready, unlit	0.00	Ready, lit	2.59		
Light, Night	Ready, unlit	0.00	Ready, lit	1.76		
Light, Night	Off	0.00	On	1.26		
Light, Night	Off	0.00	On	2.16		
Light, Night	Ready, lit	0.29	*Auto	0.28		
Light, Night	On	3.53	Off	0.00		
Light, Night	On	7.04	Off	0.00		
Light, Night	On	1.46				
Light, Night	On	4.18	Off	0.00		
Light, Night	On	0.00				
Modem, Cable	XPS only	1.38	Off	8.07	Ready, computer off	8.29
	Ready, computer on	8.40				
Modem, Cable	Ready, computer disconnected	3.78	Standby, computer disconnected	3.70	Standby, computer connected	3.92
	Ready, computer connected	4.01				
Modem, DSL	XPS only	0.75	Ready, computer off	6.49	Ready, computer on	6.46
Modem, DSL	Off	1.60	Ready, disconnected	7.31	Ready, computer connected	7.60
	XPS only	1.62				
Modem, DSL	XPS only	1.44	Ready, computer disconnected	7.50	Ready, computer connected	7.30
Modem, DSL	XPS only	1.67	Off	1.88	Ready, disconnected	7.11
	Ready, connected	7.21				
Multi-Function Device, Inkjet	Off	7.89	Ready	13.38	*Print	24.40
	Sleep	7.85				
Multi-Function Device, Inkjet	Ready	7.80	Off	7.61	*Print	10.96
Musical Keyboard	XPS only	2.04	Ready	2.87	*Play	2.88
Musical Keyboard	XPS only	3.29	Off	3.31	Ready	5.38
	*Play	5.58				
Network Device, VPN	XPS only	0.37	*On, computer disconnected	3.42	*On, computer connected	3.43
Oven, Microwave	Ready, door closed	3.39	Ready, door open	24.02	Timer	3.41
Oven, Microwave	Ready, door	3.71	Ready, door	25.60		

Product Type	Mode 1	Avg.	Mode 2	Avg.	Mode 3	Avg.
	Mode 4	W	Mode 5	W	Mode 6	W
	closed		open			
Oven, Microwave	Ready, door closed	1.37				
Oven, Microwave	Off	6.34				
Oven, Microwave	Ready, door closed	2.31	Ready, door open	2.30		
Oven, Microwave	Ready, door closed	1.89				
Power Strip	On	0.04				
Power Strip	On	0.14	Off	0.00		
Power Strip, Surge	Off	0.00	On	0.08		
Power Strip, Surge	On	0.62	Off	0.00		
Power Strip, Surge	Off	0.00	On	0.43		
Power Strip, Surge	Off	0.00	On	0.78		
Power Strip, Surge	Off	0.00	On	1.07		
Power Strip, Surge	Off	0.00	Master switch on, individual switches off	0.11	Master switch on, individual switches on	0.73
Power Strip, Surge	On	0.29				
Power Strip, Surge	On	0.77	Off	0.78		
Power Strip, Surge	Off	0.00	On	0.59		
Power Strip, Surge	Off	0.00	On	0.73		
Printer, Inkjet	Ready	8.63	*Print	17.21	Off	0.28
Printer, Inkjet	Off	1.19	Ready	5.50	*Print	10.39
Printer, Inkjet	Off	5.36	Ready	6.06		
Printer, Inkjet	XPS only	2.61	Off	7.18	Ready	8.51
Printer, Inkjet	XPS only	0.27	Off, network adapter in	5.47	Off, network adapter removed	0.97
	Ready, network adapter removed	4.23	Ready, network adapter in	5.49		
Printer, Laser	Ready	4.45	*Test print	249.3		
Radio	Off	0.62				
Radio, Clock	Ready, display dim	0.90	Ready, display bright	1.05	*Play, radio	1.26
	*Ready, display bright	1.02				
Radio, Clock	Ready	3.74	Ready, blinking	3.47		
Radio, Clock	Ready, blinking	1.20	Ready	1.23		
Radio, Clock	Ready, blinking	1.54	Ready	1.55		
Radio, Clock	Ready, blinking	1.17	Ready	1.24	*Play, radio	1.24
Radio, Clock	Ready,	1.53	Ready	1.74	*Play, radio	1.78

Product Type	Mode 1 Mode 4	Avg. W	Mode 2 Mode 5	Avg. W	Mode 3 Mode 6	Avg. W
	blinking					
Radio, Clock	XPS only	1.18	Time set	1.38		
Radio, Clock	Ready, blinking	1.21	Ready	1.23		
Radio, Clock	Ready, blinking	1.35	Ready	1.47		
Radio, Clock	Ready, blinking	1.96	Ready	2.48		
Radio, Clock/Cassette Deck	Ready	1.53	*Play, radio	1.90	*Play, cassette	5.04
Radio, Clock/CD Player	Ready	3.45				
Security System	Ready	11.59				
Set-Top Box, Cable	Off	17.97	Ready, television disconnected	18.63	*Play, television	139.85
	Ready, television off	19.77				
Space Heater, Portable	Off	0.26				
Space Heater, Portable	Ready	0.44				
Subwoofer	Ready	10.99	Play	18.64	Off	11.07
Surge Protector	On	0.33				
Telephone	XPS only	1.20	Ready, handset on	4.36	*Call incoming	5.22
	*Call, remote handset	5.37				
Telephone	XPS only	1.39	Ready	4.84		
Telephone, Cordless	XPS only	0.79	Ready, handset removed	1.92	Ready, handset on	3.73
Telephone, Cordless	Ready	3.66	XPS only	0.78	Ready, handset removed	3.21
	*Call outgoing	3.64				
Telephone, Cordless	Ready	3.74	Ready, handset removed	3.02	*Call outgoing	3.77
Telephone, Cordless	XPS only	1.05	Ready	3.82	*Call outgoing	3.11
	Ready, handset removed	2.45				
Telephone, Cordless	XPS only	1.02	Ready, handset on	2.84	Ready, handset removed	1.90
	*Call outgoing	2.54				
Telephone, Cordless	Ready,	0.71	Ready,	2.70		

Product Type	Mode 1	Avg.	Mode 2	Avg.	Mode 3	Avg.
	Mode 4	W	Mode 5	W	Mode 6	W
	handset removed		handset on			
Telephone, Cordless	Ready, handset removed	1.86	Ready, handset on	3.50		
Telephone, Cordless	Ready, handset removed	1.99	Ready, handset on	3.05	XPS only	0.77
Telephone, Cordless	XPS only	1.10	Ready, handset removed	2.28	Ready, handset on	2.94
Telephone, Cordless	Ready, handset on	3.90	Ready, handset removed	3.27		
Telephone, Cordless	XPS only	0.76	*Ready, handset on (turned off)	2.23	Ready, handset removed	1.64
	Ready, handset on	2.49	*Call outgoing	2.01		
Telephone, Cordless	XPS only	0.98	Ready, handset on	1.90	Ready, handset removed	1.36
Telephone, Cordless	Ready, handset on	1.35	Ready, handset removed	0.48		
Television	Off	3.80	*Play	64.74		
Television	Off, mains on	2.15	Off, mains off	0.01	*Play, television	102.29
	*Play, VCR	89.92				
Television	Off	0.83	*Play	72.82		
Television	Off	9.73	*Play	86.36		
Television	Off	1.10	*Play	120.17	*Play, music	113.34
Television	Off	9.37	*Play	67.54		
Television	Off	0.28	*Play	50.45		
Television	Off	0.79				
Television	Off	0.42				
Television	Off	2.08				
Television	Off	5.60	*Play	35.80		
Television	Off	0.65	*Play	37.15		
Television	Off	11.80	*Play	84.32		
Television	Off	1.30				
Television	Off	1.88	*Play	35.81		
Television/VCR	Off	3.54	*Play, television	42.31	*Play, VCR	42.35
Television/VCR	Off	4.67	*Play, television	54.55		
Television/VCR	Off	5.11				
Timer	On	2.24				

Product Type	Mode 1	Avg.	Mode 2	Avg.	Mode 3	Avg.
	Mode 4	W	Mode 5	W	Mode 6	W
Timer	On	3.58				
Timer	On	2.02				
Timer	On	2.28				
Timer	On	2.12				
Timer, Irrigation	Off	2.19	XPS only	1.56	Ready, battery out	2.19
	Ready, battery in	2.20				
Timer, Irrigation	Ready	3.69				
Timer, Irrigation	Ready	9.68				
Toaster	*Turn on	0.81	Off	0.81	Ready	0.80
	*Off	0.82				
Tuner	*Play	13.09				
Turntable	Ready	0.60	*Play	1.15		
Turntable	Ready	6.89	*Play	10.06		
USB Hub	XPS only	2.38	On, no load	2.44	*On, load	2.44
Vacuum Cleaner, Portable	XPS only	0.80	Charge	2.73		
VCR	Off	3.36	Ready	9.33	*Play	14.35
VCR	Off	8.24	Ready	32.80	*Play	40.64
VCR	Off	6.73	Ready	9.27	*Play	13.70
VCR	Off	5.76	Ready	12.04	*Play	16.94
VCR	Off	5.08	Ready	7.11	*Play	11.23
VCR	Off	4.10	Ready	7.11	*Play	11.26
VCR	Off	0.00	Ready	10.18		
VCR	Off	9.68	Ready	23.54		
VCR	Off	5.29	Ready	8.23	*Play	11.73
VCR	Off	1.91	Ready	8.91		
VCR/DVD Player	Off	2.58	Ready	13.96	*Play, VCR	16.38
	*Play, DVD	16.3				
Videocassette Rewinder	Ready	1.09				
Wireless Router	XPS only	0.33	On, disconnected	5.85	*On, connected	5.82
Air Filter, Portable	Off	0.00	High	123.77	Medium	60.19
	Low	42.04				
Air Filter, Portable	Off	0.00	Maximum	189.42	Minimum	135.20
Aquarium Heater	On	282.00	Off	0.00		
Fan, Portable	Off	0.00	*Low, stationary	27.44	*Low, oscillating	27.55
	*Medium, oscillating	31.48	*High, oscillating	36.89		
Graphic Equalizer	*On	9.28				
Oven, Toy	*On	99.68				
Paper Shredder	Ready	0.00	*Shred	29.13		
Pencil Sharpener	Ready	0.00	*Sharpen	72.46		
Research	*On	38.56				

Product Type	**Mode 1**	**Avg.**	**Mode 2**	**Avg.**	**Mode 3**	**Avg.**
	Mode 4	**W**	**Mode 5**	**W**	**Mode 6**	**W**
Instrumentation						
Treadmill	Off	0.00	*On	5.22		
Tuner	Off	0.00	*Play	8.28		

APPENDIX IV: FIELD MEASUREMENTS: AVERAGE ANNUAL POWER CONSUMPTION AND WHOLE HOUSE RECONCILIATION

Appendix 4 — Field Measurements: Average annual power consumption and whole house reconciliation

1.0 Introduction

This appendix reports the power consumption that results from combining the measured average power levels with reported usage patterns, as well as a comparison of whole-house meter readings with the sum of the appropriate power levels of each product.

2.0 Average Low Power Mode Consumption

The low power mode data collected at our eight houses resulted in average power levels for each low power mode for each product, as well as user-reported usage data for each product. The usage data were converted into a "percent of year" value for each mode. In addition, there is a value for the percent of year disconnected, which can be due to the device being unplugged for part of the year, or switched off by a power strip or timer. We did not collect active mode usage information, but the total of all active mode time is the residual from summing the low power mode times and the disconnect time, so could be calculated from our data.

Multiplying the usage percent and power level for each mode and then summing over all low power modes for a product results in a usage-weighted annual average power level consumed by the device in low power modes, or a "as-used low power mode power" for each product. This can be considered to be a constant annual power consumption, or multiplied by any convenient time period (e.g. a year) to get energy consumption. For example, 1 W is 8.76 kWh/year. Note that while this is an average over all hours of the year — including that time when the product is in an active mode — it does not reflect any of the active mode energy.

Table 1 presents the as-used low power mode power levels for each product we measured, as well as the average of all of the examples we measured for each product type[1]. For product types with many examples measured, there is often a wide range in the average power. This can be due to wide variations in power levels of the products, the usage patterns, or both. The zero power levels reported are due to products that rarely or never are in the low power modes, either because they are always in an active mode, or because they are mostly disconnected (or mostly in a zero off mode). While we generally rounded the values to the nearest 10 mW, for devices between one and 10 mW we rounded to the nearest mW. Products are grouped into ten categories.

[1] The only changes we made to Table 1 from the data presented in Appendix III are to exclude the 288 W load of an aquarium pump (water) since it overwhelms the other loads (and is arguably an active mode load), and a decorative light mode of 1.91 W (was determined to be an active mode).

Table 1. Usage-Weighted Average Power Levels by Product Type

Product Type	Average (W)	As-used low power mode power for each product (W)
Audiovisual		
Audio Amplifier	2.59	2.59
Audio Minisystem	1.91	0, 0, 0, 0.001, 0.58, 0.77, 1.14, 1.22, 1.26, 1.44, 1.59, 1.79, 15.00
Audio Receiver	2.17	0, 0.01, 0.35, 0.41, 1.10, 1.68, 11.66
CD Player	2.45	0, 0.01, 2.20, 2.23, 4.10, 6.18
CD Player, Portable	1.65	1.65
Cassette Deck	1.21	0, 0, 1.04, 1.09, 1.28, 3.84
Charger, Digital Music Player	0	0
Charger, Still Camera	0	0
Charger, Two-Way Radio	3.64	2.08, 5.20
Charger, Video Camera	0.57	0.57
Clock, Alarm	1.04	1.04
DVD Player	1.32	0.01, 0.01, 0.40, 0.43, 0.73, 6.37
Karaoke Machine	0	0
Musical Keyboard	1.44	0, 2.87
Radio	0	0
Radio, Clock	1.64	0.90, 1.23, 1.23, 1.24, 1.38, 1.41, 1.55, 1.72, 2.38, 3.37
Radio, Clock/CD Player	3.38	3.38
Radio, Clock/Cassette Deck	0.77	0.77
Set-Top Box, Cable	14.97	14.97
Subwoofer	11.15	11.15
Television, CRT	3.13	0.27, 0.42, 0.53, 0.65, 0.75, 0.92, 1.19, 1.86, 2.04, 2.07, 3.56, 5.54, 8.59, 8.76, 9.83
Television/VCR	2.66	0, 3.50, 4.48
Tuner	0	0
Turntable	0.28	0, 0.57
VCR	4.72	0, 0.001, 3.38, 4.06, 4.55, 5.08, 5.76, 6.66, 8.08, 9.65
VCR/DVD Player	2.53	2.53
Videocassette Rewinder	1.09	1.09
Food / Beverage		
Blender	0	0
Bread Maker	0	0
Coffee Maker	0.41	0, 0.82
Dishwasher	1.58	1.58
Oven, Microwave	3.14	1.36, 1.87, 2.29, 3.57, 3.64, 6.08
Toaster	0.81	0.81
HVAC		
Boiler	7.80	7.80
Furnace, Central	4.59	4.59
Furnace/Air Conditioner	7.67	7.67
HVAC Controls	2.32	0, 4.64
Space Heater, Portable	0.01	0, 0.01
Health / Hygiene		
Air Freshener	1.86	1.86
Breast Pump	0	0.001
Charger, Men's Shaver	0	0, 0
Charger, Toothbrush	0.79	0, 0.01, 1.24, 1.91
Clothes Washer	2.23	2.23
Clothes Washer/Dryer	2.12	2.12

Product Type	Average (W)	As-used low power mode power for each product (W)
Hair Dryer	0.07	0.05, 0.08, 0.09
Iron	0	0, 0
Vacuum Cleaner, Portable	2.73	2.73
Infrastructure		
Detector, Carbon Monoxide	1.99	0.75, 1.15, 2.13, 3.94
GFCI Outlet	0.70	0.70
Garage Door Opener	2.90	1.73, 1.73, 3.07, 3.64, 4.34
Infant Monitor Receiver	0.57	0, 0.58, 1.13
Infant Monitor Transmitter	0.58	0.06, 1.10
Power Strip	0.09	0.04, 0.14
Power Strip, Surge	0.53	0.04, 0.27, 0.29, 0.43, 0.59, 0.62, 0.73, 0.73, 0.77, 0.78
Security System	11.59	11.59
Surge Protector	0.33	0.33
Timer	2.29	2.02, 2.02, 2.02, 2.02, 2.12, 2.24, 2.28, 3.58
Information Technology		
Computer	2.29	0, 0.49, 2.29, 2.56, 2.73, 3.01, 4.93
Computer Display, CRT	0.32	0, 0.14, 0.33, 0.82
Computer Display, LCD	0.51	0.51
Computer Peripheral	0	0
Computer Speakers	4.11	0, 0, 0.74, 1.40, 18.40
Computer, Integrated	5.34	5.34
Computer, Notebook	3.11	0.22, 5.99
Ethernet Bridge	3.79	3.79, 3.79
Fax Machine, Bubblejet	0.31	0.31
Fax Machine, Inkjet	3.32	3.32
Hub, USB	0	0
Image Scanner, Flat-Bed	0.27	0, 0, 0.82
Modem, Cable	5.75	4.01, 7.48
Modem, DSL	6.39	5.17, 6.32, 6.48, 7.60
Multi-Function Device, Inkjet	8.34	7.78, 8.89
Network Device, VPN	0	0
Printer, Inkjet	3.49	0.03, 0.48, 3.07, 5.37, 8.48
Printer, Laser	4.44	4.44
Router, Ethernet	5.93	5.93
Router, Wireless	0	0
Lighting		
Lamp, Dimmable Incandescent	0.01	0, 0.02
Lamp, Incandescent	0.31	0.31, 0.31
Light, Decorative	0	0 (1.91 lamp removed)
Light, Display	0.31	0.31
Light, Emergency	0.25	0.23, 0.26
Light, Low-Voltage Outdoor	5.19	5.19
Light, Night	0.91	0, 0.15, 0.15, 0.15, 0.34, 0.70, 0.73, 1.04, 1.08, 1.26, 1.76, 3.52
Lawn, Garden, Workshop		
Charger, Battery	0.54	0, 0, 0.18, 1.96
Charger, Bicycle Light	0	0, 00
Charger, Power Tool	0.04	0, 0, 0.11
Charger, Weed Trimmer	0	0
Irrigation Timer	5.16	2.19, 3.67, 9.62

Product Type	Average (W)	As-used low power mode power for each product (W)
Other		
Aquarium Pump, Air	7.53	7.53
Aquarium Pump, Water	4.72	3.36, 3.36, 7.45 (288.4 pump removed)
Extra Remote Sensor, Garage Door	0.73	0.73
Fountain, Indoor	3.15	3.15
Telephony		
Answering Machine	3.81	2.65, 4.08, 4.71
Charger, Cellular Telephone	0.07	0, 0, 0.01, 0.02, 0.14, 0.16, 0.18
Telephone, Corded	4.48	4.22, 4.74
Telephone, Cordless	2.45	0, 1.34, 1.86, 2.08, 2.13, 2.35, 2.44, 2.67, 2.81, 3.07, 3.62, 3.68, 3.85

For 40 products in 33 product types, we measured power levels in low power modes, but the reported usage pattern included no use of *those* modes (active modes were used, since products that were not used at all were excluded from our measurements entirely). These products are listed in Table 2. Note that for some of these types, other instances that we measured did have low power mode usage.

Table 2. Products reported to have no low power modes as used

Audio Receiver	Blender	Bread Maker
CD Player	Cassette Deck (2)	Charger, Battery (2)
Charger, Bicycle Light (2)	Charger, Cellular Telephone (2)	Charger, Digital Music Player
Charger, Men's Shaver	Charger, Power Tool (2)	Charger, Still Camera
Charger, Toothbrush	Coffee Maker	Computer
Computer Display, CRT	Computer Peripheral	Computer Speakers (2)
Hub, USB	Image Scanner, Flat-Bed (2)	Iron
Karaoke Machine	Light, Decorative	Light, Night
Musical Keyboard	Network Device, VPN	Radio
Router, Wireless	Space Heater, Portable	Telephone, Cordless
Television/VCR	Tuner	Turntable

Table 3 presents the usage-weighted average power for each category, by site. Only products that we measured are included in the category totals. The data in Table 3 show that electronic products are the most consistent types with low power mode consumption, with audiovisual, information technology, and telephony the only categories that appear at all eight sites. Details on the "Imputed" products are presented later in this report. Most of the imputed power is due to infrastructure products; the average for that category is over 12 W when these are included. Of the imputed products, most are infrastructure, either GFCI outlets or circuit breakers, furnaces, or a security system.

2.1 Analysis by Mode Type

Of the 269 products with a low power mode that we measured, 40 had no usage of any of the low power modes. Of the rest, most had only one low power mode with reported usage. In total, 299 low power modes were reported to be used. The distribution of power among modes and types of devices is easiest to assess when all eight houses are grouped together for a "composite" house. The composite has fractional products; for example, as we found just one set-top box, the composite has one eighth of a set top box which contributes just under 2 W to the composite total (as the actual set top box consumes about 15 W). Table 4 summarizes the average power level by category and mode type for the composite house.

Some patterns are evident in Table 4. Most audiovisual low power mode use is in Off, but for information technology and telephony, most use is ready.

We grouped modes in other ways to explore other issues. For example, some products have secondary functions such as microwave ovens illuminating the inside while the door is open (secondary to the primary function of cooking). All of these modes totaled to only 0.09 W on average, split between food / beverage and infrastructure. External power supply *only* modes are included in "off" in Table 3 but are only 0.08 W for audiovisual and 0.06 for telephony, so less than 1% of the total "off" power. For ready modes, those with no function being performed were over 90% of the total.

Table 3. Usage-weighted Average Power by Category and House

House Category	11	12	13	14	15	16	17	18	Average	Standard Deviation
Audiovisual	15.77	21.53	28.83	55.34	24.80	33.23	25.15	34.32	29.87	11.94
Food / Beverage	5.96	3.64	1.36	6.08	2.29	0.82	–	1.87	2.75	2.15
HVAC	7.80	–	0.01	12.31	–	4.59	–	–	3.09	5.19
Health / Hygiene	2.23	–	1.24	1.86	0.05	2.90	2.13	–	1.30	0.99
Infrastructure	1.38	9.94	0.78	22.94	19.08	4.34	0.77	2.47	7.71	8.79
Information Technology	7.96	41.89	14.03	17.77	12.88	8.00	16.08	24.85	17.93	11.11
Lighting	–	1.30	0.70	2.34	11.98	2.25	0.62	0.23	2.43	4.14
Lawn, Garden, Workshop	2.48	–	–	3.67	9.62	–	–	1.96	2.22	3.53
Other	0	10.68	–	14.17	–	0.73	–	–	3.20	7.11
Telephony	7.48	7.17	5.46	11.60	6.56	3.86	4.44	6.24	6.60	2.38
TOTAL – Measured	51.06	96.15	52.41	148.08	87.26	60.72	49.19	71.94	77.10	33.52
Imputed Products	1.40	4.90	9.49	25.40	23.57	9.07	0.70	8.09	10.33	9.35
TOTAL – Measured and Imputed	52.46	101.05	61.90	173.48	110.83	69.97	49.89	80.03	87.43	41.04

For products with integral batteries, those modes that have some charging (usually a maintenance charge) are mostly found in ready modes. These totaled 6.49 W, mostly cordless phones, but 1.45 W for the one security system. Other charging modes are found in "off/charging" (emergency lights) and the notebook computers have several charging modes each.

Some modes are borderline low-power modes but we chose to be expansive in what was included in our definition as it is easier in future to contract the definition than to expand it and not have the needed data. Single-mode products such as clocks may have efficiency options that are largely the same as those for standby mode generally. A principal reason to include other single mode products such as aquarium pumps (which included the highest-consuming low-power mode we measured) is that they could potentially be controlled by a timer and so shifted to a low-power mode.

Table 4. Average Power by Category and Mode Type

House / Category	Off	Ready	Ready some function	Single mode	Power products	Sleep	Single mode, active	Total
Audiovisual	23.54	3.59	2.70	–	–	–	–	29.83
Food / Beverage	0.96	1.75	0.04	–	–	–	–	2.75
HVAC	–	2.51	–	0.58	–	–	–	3.09
Health / Hygiene	0.57	0.75	–	0.23	–	–	–	1.55
Infrastructure	0.36	3.21	0.05	3.28	0.81	–	–	7.71
Information Technology	4.61	11.69	–	–	–	1.64	–	17.94
Lighting	0.18	0.65	0.27	1.09	–	–	–	2.19
Lawn, Garden, Workshop	0.14	2.07	–	–	–	–	–	2.21
Other	–	–	–	0.09	–	–	3.11	3.20
Telephony	0.06	6.54	–	–	–	–	–	6.60
TOTAL	30.42	32.76	3.06	5.27	0.81	1.64	3.11	77.07

Notes: "Ready some function" means that some function is being performed, such as the clock part of a clock radio and night lights. "Single mode, active" includes aquarium pumps and an indoor fountain.

The eight houses were selected mostly for convenience rather than being representative of the stock of California homes, since the purpose was to test the procedures, not gather statistically significant data. To provide more background about the houses, we provide some basic characteristics in Table 5.

Table 5. Basic Characteristics of the Measured Houses

House	Age (approx.)	Size (ft^2)	Occupants	Location	Comments

11	85	1,500	3	Berkeley	Currently being remodeled
12	50	2,000	2	El Cerrito	
13	75	1,900	5	Albany	Recent extensive remodel
14	30	2,800	4	Concord	
15	15	2,900	3	Martinez	
16	10	1,300	1	Truckee	Vacation house
17	100	1,250		Berkeley	Addition 40 years ago
18	80	1,150	4	Berkeley	Area includes 200 ft^2 garage converted to office

3.0 Whole house measurements

The whole house measurement procedure is described in Attachment II. It involves putting all products in the house into a known low-power mode, measuring the total with the house utility meter, and summing the total of all devices from individual measurements with the power meter. All hardwired products are included as is the refrigerator if it is not readily disconnectable.

All the utility meters that we encountered were of the type with spinning mechanical disks. The disks all had 100 marks around their circumference. Table 6 shows the "counts" per minute of these marks recorded as the utility meter was observed spinning. In all cases we observed the meter for eight minutes and computed the average counts per minute over that period, and in most cases we recorded the minute-by-minute count data. The conversion from counts to Watts was based on the formula in Ross and Meier (2000):

Watts = Kh (watt-hours) x 3600 (seconds/hour)/ Time (seconds)

The process of watching the meter has the potential for about a 1-2% error over one minute as the observer's eye moves from the disk to the stopwatch and back. However, using the eight minute measurement period renders this effect quite small.

Table 6. House meter raw data and conversion to power

Site	Average *(counts/min)*	Kh factor	Watts *(W/rev)*
11	11.8	7.2	50.8
12	139.6	3.6	299.4
13	18.1	7.2	78.0
14	33.3	7.2	143.6
15	28.0	7.2	121.0
16	17.8	7.2	76.7
17	141.6	3.6	305.9
18	31.0	7.2	133.9

At three of the houses, during the eight minute period the speed of the disk varied significantly by visual observation, and in two of these we have per-minute data to confirm it (and two separate readings for one of these houses). The raw count data are shown in Table 7, with the minimum period(s) bolded and darkly shaded and the maximum period bolded and lightly shaded for each reading. When the location on the meter disk where the maximum and minimum values (which range by more than a factor of two) occur, it becomes clear that the minimum periods occur at the same part of the disk as do the maximum periods. This is strong evidence that the meter disk is not reliable for periods of less than one revolution for these three houses. However, for the two we have detailed data for, the total period is close to one revolution, reducing the effect of this error. For the other readings, the variation was not observed and in any case the meter spun around enough times to make this effect small if it does exist for them.

Table 7. Whole House meter reading raw data for three houses

House 11: Final Data		House 11: Earlier Data			House 18	
Reading	**Change**	**Reading**	**Change**		**Reading**	**Change**
		20			0	
40		38	18		15	15
47	7	47	9		60	45
54	7	53	6		93	33
62	8	60	7		121	28
72	10	70	10		161	40
80	8	77	7		199	38
97	17	93	16		214	15
115	18	110	17		248	34
134	19					
Average	**11.8**	**Average**	**11.3**		**Average**	**31**

3.1 Whole house comparisons

Table 8 shows the power level derived from the house meter observations and the sum of the measured products in the mode they were in while the whole house measurement was taken. The two figures should in principle be similar, with the house meter larger by the consumption of the products not measured. However, with three of the houses showing a discrepancy of the opposite sign, the difference does not seem to be a reliable indicator of the consumption of the non-metered products. Table 8 also includes adjusted data for the imputed products. It reduces the discrepancy for five of the houses, but increases it for three of them. For house 17, the discrepancy is in the direction of an electricity load occurring in the house that the inventory of equipment status did not find or recorded erroneously; it is also the largest discrepancy in absolute and percentage terms. The same might also hold true for house 18.

Table 8. House Meter Data and Comparison to Derived Data

Site	House Meter	Sum of Products	Difference		Imputed Products	Adjusted Sum	Adjusted Difference	
	(W)	(W)	(W)	%	W	W	W	%
11	50.8	59.6	-8.8	-17%	1.4	61.0	-10.2	-20%
12	299.4	362.8	-63.4	-21%	4.9	367.7	-68.3	-23%
13	78.0	46.1	31.9	41%	9.5	55.6	22.4	29%
14	143.6	159.4	-15.8	-11%	21.2	180.6	-37.0	-26%
15	121.0	91.0	30.0	25%	23.7	114.7	6.3	5%
16	76.7	56.9	19.8	26%	5.9	62.8	13.9	18%
17	305.9	65.1	240.8	79%	0.7	65.8	240.1	78%
18	133.9	78.7	55.2	41%	8.1	86.8	47.1	35%

Note: A negative number in the Difference columns means that the sum of measured products exceeds the power level observed from the whole house meter. A positive number means that the meter reading exceeds the sum of the products. A positive number can be offset by unmeasured products that were consuming power during the whole house reading.

This meter variation while the disk was spinning and the discrepancies between the meter and the sum of products raised the question about the absolute accuracy of the meters at these power levels. To delve into this further we consulted the Handbook for Electricity Metering (EEI, 1981) which has a graph of the percent error in a variety of meters as a function of load. The load is expressed in current and presumably is for 220 V, so that a 50 W load would be about a quarter of an Amp and a 100 W load about half an Amp. At half an amp, the error ranges from about 5% to 1% depending on the meter (this for recently calibrated meters), and at a quarter of an Amp, the range is from zero to 10% (with the meter reading higher than actual consumption). Below a quarter, the error increases rapidly for most meters.

To confirm that the disk variation is due to the meter and not changing demand, at house 11 we turned off all circuit breakers except for one which only serviced outlets in the house crawlspace and so had nothing routinely connected to them. A nominal 50 W and 100 W incandescent light bulb were each connected to the outlet separately, and together. The meter was watched for eight minutes under each of the three tests, and for the 50 W test, watched until the meter had completed one full revolution. Immediately after the meter reading tests, the bulbs were measured with the same power line meter we used for the rest of the project measurements. During this process we observed that the voltage varied by up to 2 V, which has about a 2% effect on the power consumed (and accounts for why the sum of the two bulbs is less than the two bulbs measured together). The results are shown in Table 9. The voltage variation could account for the 2% errors at 100 and 150 W, but in no way can account for the 25% variation in the 50 W test. The difference between the two 50W tests is an error introduced by not using an exact revolution of the meter.

Table 9. Test Measurements of Utility Meter

	Exactly 8 minutes measured			One full revolution
nominal W	50	100	150	50

	Exactly 8 minutes measured			One full revolution
Counts in 8 minutes	75	190	287	(11.33 minutes)
Counts/minute	9.4	23.8	35.9	8.8
Measured W from				
House Meter	40.5	102.6	155.0	38.1
Power Meter	51	105	158	51
Difference				
Power (W)	10.5	2.4	3.0	12.9
Percent (%)	21%	2%	2%	25%
Counts per 30 seconds				
Minimum	2	9	15	
Maximum	10	21	21	
Ratio	5	2.3	1.4	

We recorded the meter reading every 30 seconds and so had 16 intervals over each 8 minute period. Table 9 also shows the minimum and maximum number of counts observed during each 30 second period, and the ratio of these. Not surprisingly, the variation is greatest for the 50 W test. Since these data are the result of visual observation of the meter, some error is introduced in the recording process so that the actual variation could be modestly smaller or larger than shown here. Regardless, the effect is clearly real and — for loads in the realm of 50 W at least — dramatic. The electric service at this site is XXX Amps, which matches the more recent meters cited in the metering reference cited above.

Such a test should be repeated with other meters, but it appears that for readings in the realm of 50 W the result may be unreliable, but at 100 W and above it should be more accurate. In addition, future measurements should be made with an integral number of disk rotations rather than a single fixed time.

3.2 Imputed Products

The "Imputed" products are those products that were not measured at the site but whose consumption can be reasonably estimated from other sources, such as examples of the same product type measured at other sites. We used the average of the products we did measure as shown in Table 10. Some products remained outside of the estimate after the imputation process, though in many cases, we believe these had no low power consumption (e.g. washing machines, for which only relatively newer models have low power modes).

Table 10. Imputed Products

House Category	11	12	13	14	15	16	17	18
GFCI Outlets	1.4	4.9	4.9	1.5	2.8	2.8	0.7	3.5

House Category	11	12	13	14	15	16	17	18
Furnace			4.59	4.59	9.18			4.59
Other				15.08	11.59	6.27		
Total	1.4	4.9	9.49	21.17	23.57	9.07	0.7	8.09

Note: The GFCI in house 14 is actually a single GFCI breaker; the 1.5 W value is from a manufacturer. For the "Other" products, house 15 had a security system which we assigned 11.59 W. House 16 had a hard-wired microwave oven which we assigned 3.14 W, and an inadvertently unmetered TV which we assigned 3.13 W. For house 14, several products were spot-measured with our power meter for a total of 14.04 W: three clock radios (2.14 W, 1.51 W, and 1.33 W), a lamp/clock combination (3.31 W with the lamp off), and a cordless telephone (3.33 W with the handset on). In addition, there was one alarm clock which we imputed to be 1.04 W, for a total of 15.08 W. For the annual usage (but not the whole house measurement), there are additional products in use that we did not measure but imputed to be as follows: 4 night lights for a total of 3.64 W; a cell charger with a 0.07 W; and two emergency lights for a total of 0.50 W. These all sum to 4.23 W, and combined with the 21.17 W above results in 25.40 W.

Some products are not covered by what we measured or the imputation. For house 13, the refrigerator was not unplugged, but was set to a low setting to reduce the chances that it came on (and the whole house data don't suggest it did). For house 15 this included a wine refrigerator, 2 outdoor motion lights, a doorbell transformer, and a house number light. For house 14, we did not account for a notebook computer, and for two videotape rewinders (though these are on a power strip when not in active use anyways). For house 16 we did not measure a microwave, doorbell transformer, and an outdoor motion sensor — all hardwired. The average GFCI energy (excluding those on hair dryers) for the eight houses is 2.9 W.

4.0 Lessons Learned

In the course of the metering we learned a variety of lessons useful for future such projects.

- More attention should be paid to the circuit breaker panel, including consideration of turning off some breakers for the whole house measurement (e.g. ones feeding only hardwired equipment such as HVAC), and checking to see if any of the breakers are energy-consuming GFCI or AFI (arc fault interruptor) breakers. The panel should be photographed for later reference. As the labeling on panels is often poor, any turning off of circuits should be done before each product's mode is assessed for the whole house measurement to note if any products are disconnected by this unexpectedly.
- We noted relatively few dishwashers and measured only one. Some are hard-wired, and of those that aren't, the dishwasher often needs to be pulled out which can require removing screws. However, it seems possible that we failed to count some dishwashers that were present, so they should be put on a checklist to explicitly look for.
- Doorbell transformers are often hidden, so won't be noticed except by actually looking for the button at each exterior door. Of course, the button might not be operable because the transformer is disconnected from power, or some other connection is broken, so pressing the doorbell is not a surefire way to determine if a doorbell transformer is not

present and operating, but it will indicate positively if one is present. Future doorbells will be increasingly wireless.

- Many kitchen appliances have low power modes but are in most cases plugged in only very occasionally, so consume little low-power mode energy (e.g. breadmakers and some blenders). It is probably not worth counting these unless they are plugged in at the time the house is assessed, an indication that they are often plugged in.
- Some chargers are used only occasionally and often not in immediate sight (such as shavers, portable vacuums, and power tools). These should be on the checklist for explicitly asking the homeowner.
- Hair dryers commonly have GFCI capability and so consume power whenever plugged in. These are not obvious low power mode consumers so should be specifically asked about.
- Clothes irons often have low power mode consumption, though they are probably unplugged the great majority of the time so may consume little low power mode energy in aggregate.
- More lights than expected had some low power consumption, so that a special effort should be made to identify those that do. In addition, some lighting power controls that are wired into switch boxes consume power. We metered one with a "pilot light" and integral dimmer in the lab (of a model found at one of the houses) and found it consumed only 0.02 W. However, an electronic timer metered in the lab (again of a model found at one of the houses) used 1.20 W when off and 1.09 W when timing (this an example of the rare product that uses more energy when "off" than when active).
- Line-powerable smoke detectors present a difficult case. The two we inspected in the laboratory had no indication on their exterior that they have the capability to be line-powered; one must remove them from the ceiling (or wall) to see if there are cables entering it from the back, requiring a ladder to inspect each unit. Even if it is identified as line-powerable, the circuit may not be energized, and it would require testing each unit's connector individually to determine this.
- In areas with many pieces of information technology or audiovisual equipment, the clutter of power and other cables can be time-consuming to assess.
- Low power modes can appear unexpectedly. For example, while we have seen toasters in the past with continuously-lit darkness indicators that clearly require standby power, one of the houses had one with standby power but no indicator lights showing during its minimum power mode to signal that it uses standby power.
- Some products have modes that are difficult to get to in the course of our metering. For example, we found a battery charger with a 13-hour timer integral to it to determine when the charge was finished. Thus, it would have taken more than 13 hours to determine the power consumption of that mode, which could happen frequently. Other examples of timers are auto-off timers on irons. New major appliances such as dishwashers or clothes washers could have distinct modes that occur after a wash cycle

has finished. Since the wash cycle could be lengthy and might have power spikes that would blow the fuse on our meter, we did not get to these potential modes.

- The number of possible modes for network equipment is large, with cables to other devices connected or not, the other devices connected to those cables or not, the other device (e.g. a computer) turned on or not, and data actively being transmitted or not. We have not yet determined which of these commonly affect the power consumption, though we did note that it does sometimes. This is an example of where the usage pattern of one product affects the energy consumption of a second product.

5.0 References

Handbook for Electricity Metering, Edison Electric Institute. 1981.

Ross, J.P., and Alan Meier, "Whole-House Measurements of Standby Power Consumption," prepared for the Second International Conference on Energy Efficiency in Household Appliances, Naples Italy, September 2000, LBNL-45967.

APPENDIX V: DATA TO BE COLLECTED IN STATE-WIDE SURVEY

Appendix 5 — Data to be Collected in State-wide Survey

1.0 Introduction

This report identifies the parameters most critical for generating a reliable estimate of state-wide low power mode electricity use and the source to use to develop them. The parameters are expected to be obtained from a combination of a phone survey, on-site survey at houses, and other research.

The previous deliverable, "Statewide Low Power Mode Estimate: Analytical Method and Survey Considerations" described the intended method for arriving at these parameters. This document presents the results of that process and further details of the method.

As with earlier deliverables for the project, we present results as the "usage- and stock-weighted annual average power level consumed in low power modes," which we henceforth refer to as the "aggregate average power level" or "aggregate power." This is a power level in Watts for an individual house. It incorporates how widespread the product is, so that a fractional number of products is assumed, e.g. 1.13 VCRs per household, or 0.12 security systems per household. It also incorporates the effect of usage, so that a product that consumes 2 W in its only low power mode and is in that mode half of the time will contribute 1 W to the aggregate level. When products are disconnected they consume no power so don't contribute to aggregate power. In addition, energy consumption in active modes is also not included in our estimate. Product types consume large amounts of aggregate average power due to some combination of their being numerous, consuming high power levels in low power modes, and being in low power modes a large portion of the time.

To put these figures in perspective, 1 W of aggregate power is 8.76 kWh/year for each household, or $1.06 at current estimated California electricity rates[1]. For the 11.5 million households in the state at present, 1 W is 11.5 MW, or 101 GWh/year, or $12 million/year.

Some details of the calculations are presented at the end of this report.

2.0 The Calculation Method

The factors which form the basis of our calculation method are: <u>Stocks</u>, the number of each product type in use in California residences; <u>Power Levels</u>, the modes of operation and corresponding power levels (for low power modes only); and <u>Usage Patterns</u>, the distribution of time among the operating modes. Table 1 shows a simplified version of the source data (in a spreadsheet) used to generate the results presented here. There are further complexities not shown, such as a factor applied to some product types for the percent of the stock that has a low power mode at all.

[1] Year 2004 residential data from http://www.energy.ca.gov/electricity/statewide_weightavg_sector.html.

Table 1. Schematic of Initial Estimate Source Data

	Stock *millions*	Disconn-ected Usage (*%*)	Mode 1			Mode 2			...	Uncertainties		
			Name	Power *W*	Usage *%*	Name	Power *W*	Usage *%*		Stock	Power	Usage
Product Type 1												
Product Type 2												
…..												

Note: Usage is expressed in the percent of the year in each mode.

The data that populate the spreadsheet for stocks, power levels, and usage come from a variety of sources. We used data from the following sources (see References section for full reference):

- 2003 California Residential Appliance Saturation Survey for many stocks and and some usage (Xenergy, 2004).
- Data collected in earlier parts of this project, particularly for power levels and usage.
- The Consumer Electronics Association "eBrain" survey, for stocks (CEA, 2003).
- The 2001 Residential Energy Consumption Survey (RECS) from the U.S. Department of Energy (EIA, 2003).
- The "Home IT" paper (in draft) from Nordman and Meier, prepared for DOE (Nordman and Meier, 2004)
- The Ecos/LBNL spreadsheet estimating savings from more efficient power supplies (Webber, 2003).
- Consumer electronics papers from Rosen and Meier (Rosen et al., 1999, 2000, 2001).
- Our best estimate based on past experience.

2.1 Key Terms

Aggregate Average Power Level

The "usage- and stock-weighted annual average power level consumed in low power modes" is a power level which, if consumed for an entire year in all households, equals the electricity consumption of all the devices in a product type (or group of product types) in that year. A simple example is doorbell transformers which have an aggregate power level of 2W, reflecting our assumptions that there is an average of exactly one per house (some having none and some more than one) and their being on 100% of the time, using 2 W each. The number of units per household, the power levels, and usage patterns all affect the aggregate average power level.

Parameter

One of the three core inputs (stocks, power levels, or usage —each defined in "The Calculation Method" earlier) for an individual product type, e.g. stocks of desktop computers or usage of cordless telephones.

Uncertainty Factor

A number reflecting our level of confidence in a particular parameter.

Base Case

Our central estimate for individual parameters and the aggregate average power level for individual product types, and the total aggregate power for groups of product types.

Effect

The "effect" of the uncertainty of a parameter is the difference in aggregate average power resulting from the low and high estimates of the parameter in question and the base estimate for the other two. The following equations show several ways of expressing the same item, the effect of the uncertainty in usage on the consumption of the product type in question.

$$Effect_{Usage} = (Usage_{max} \cdot Power_{base} \cdot Stock_{base}) - (Usage_{min} \cdot Power_{base} \cdot Stock_{base})$$

$$= (Usage_{max} - Usage_{min}) \cdot Power_{base} \cdot Stock_{base}$$

$$= BaseEstimate \ \ ((Usage_{max} - Usage_{min}) \ / Usage_{base})$$

Minimum and Maximum Cases

The maximum is the extreme high estimate possible from the high estimate for all three parameters simultaneously. For example:

$$Maximum = Usage_{max} \cdot Power_{max} \cdot Stock_{max}$$

The minimum is the extreme low estimate based the low estimate of all three parameters.

3.0 Key Parameters and Sources

Table 2 presents the data to be collected from each major data source in the next phase of the research. It is ordered by and also shows the aggregate "effect" of the parameter — the difference between the minimum and maximum values generated by its uncertainty, using the central estimate for the other parameters.

There are three parameters (stock, power, and usage) for each of the 119 product types for a total of 357 parameters for which we calculated a result. Because most of these are too small to be of concern, Table 2 only includes the 39 most important ones — those that have an effect on the aggregate average power level of 1 W or more due to their uncertainty. Table 3 lists the next 58 parameters, those that have an effect between 0.5 and 1 W. Since there are three parameters for each product types, some product types occur multiple times in the two tables.

Table 2. Key Parameters (Effect ≥ 1 Watt) and Expected Data Sources

Effect (W)	Product Type	Parameter Needed			Recommended Data Source				
					Phone	Onsite	Other		
		Stock	Power	Usage			Stock	Power	Usage
6.2	VCR		Power			X			
5.7	Set-top box, digital		Power					X	
5.2	Computer speakers		Power					X	
3.6	Computer, desktop			Usage	X				
3.5	Audio, subwoofer	Stock			X				
3.5	Audio, subwoofer		Power			X		X	
3.3	Set-top box, digital satellite		Power					X	
3.2	Television, CRT		Power			X			
2.9	Computer speakers	Stock			X				
2.8	Set-top box, analog		Power					X	
2.6	Light, night	Stock			X	X			
2.5	DVR			Usage	X				X
2.5	Set-top box, digital	Stock					X		
2.4	Air conditioner, central		Power					X	
2.2	DVD player		Power			X		X	
2.1	GFCI outlet	Stock				X			
2.1	Furnace, central		Power					X	
2.1	Copier	Stock			X*				
1.9	Timer	Stock			X	X			
1.9	Computer, desktop	Stock			X				
1.9	Computer, desktop		Power			X		X	
1.8	DVR		Power					X	
1.7	Audio, CD player		Power			X			
1.7	Doorbell		Power					X	
1.6	Multi-function device, inkjet		Power		X*				
1.6	Light, low-voltage outdoor		Power			X			
1.6	Computer speakers			Usage	X				
1.5	Scanner	Stock			X				
1.5	Scanner		Power			X			
1.5	Set-top box, digital satellite	Stock					X		
1.4	VCR	Stock			X				
1.4	Detector, carbon monoxide	Stock			X	X			
1.3	Audio minisystem		Power			X			
1.3	Audio, receiver		Power			X			
1.2	Set-top box, analog	Stock					X		
1.2	Audio, turntable		Power			X			
1.2	DVR	Stock			X		X		
1.0	Timer, irrigation	Stock			X	X			
1.0	Timer, irrigation		Power			X		X	
Counts	**39**	**15**	**21**	**3**	**14**	**17**	**4**	**12**	**1**

Note. *For the copier and multi-function device, the phone survey question would be about the number of any type of imaging device — printer, multi-function device, copier, or fax machine — and then what type they are.

Table 3. Second Tier of Key Parameters (Effect ≥ 0.5 and < 1.0 W)

Effect	Product Type	Parameter	Effect	Product Type	Parameter
0.97	Answering machine	Stock	0.71	Telephone, cordless	Power
0.97	Answering machine	Power	0.70	Television/VCR	Power
0.96	DVD player	Stock	0.70	Modem, cable	Stock
0.93	Oven, microwave	Power	0.70	Modem, cable	Power
0.92	Audio minisystem, portable	Usage	0.70	Air freshener	Stock
0.91	VCR	Usage	0.70	Computer, notebook	Usage
0.90	Light, night	Power	0.69	Multi-function device, inkjet	Stock
0.90	Detector, smoke	Stock	0.67	Set-top box, internet	Power
0.89	Printer, inkjet	Stock	0.66	Charger, power tool	Power
0.89	Printer, inkjet	Power	0.65	Modem, cable	Usage
0.89	Audio, cassette deck	Power	0.64	Caller ID unit	Power
0.86	Copier	Power	0.63	Light, outdoor motion	Power
0.84	Furnace, floor or wall gas	Power	0.60	Structured wiring	Stock
0.84	Set-top box, digital	Usage	0.60	CD player, portable	Power
0.78	Caller ID unit	Stock	0.59	Audio minisystem	Stock
0.78	Telephone, corded	Stock	0.56	Modem, satellite	Stock
0.78	Telephone, corded	Power	0.55	Range	Stock
0.77	Audio, subwoofer	Usage	0.55	Range	Power
0.75	Clock, radio	Stock	0.55	Oven, standard electric	Stock
0.75	Clock, radio	Power	0.55	Oven, standard electric	Power
0.75	Audio, CD player	Stock	0.55	Garage door opener	Power
0.74	Audio minisystem, portable	Power	0.55	Audio, receiver	Stock
0.73	Television, CRT	Stock	0.54	Air conditioner, central	Stock
0.73	Hub, USB	Stock	0.53	Audio minisystem	Usage
0.72	Set-top box, game	Stock	0.52	Power strip, surge	Stock
0.72	Set-top box, game	Power	0.52	Modem, DSL	Stock
0.72	Light, low-voltage outdoor	Stock	0.52	Modem, DSL	Power
0.72	Light, low-voltage outdoor	Usage	0.51	Security system	Power
0.71	Telephone, cordless	Stock	0.50	Vacuum cleaner, portable	Stock

The sources of data to be used to gather the data are a phone survey, an on-site survey, and other methods such as laboratory or store measurements, or consultation with industry or other experts. For 9 parameters we assigned two sources when one source was not clearly preferable to the other (these have two "source" columns checked in Table 2).

A striking feature of Tables 2 and 3 is that usage patterns are much fewer in number than are power levels or stocks as shown in Table 4. This is attributable to the fact that most of these devices are in a low power mode most of the time, so that even a relatively high uncertainty factor doesn't change the total that much. For example, something that is in a low power mode 90% of the time with an uncertainty factor of two will vary from 80 to 95%, or only a variation of 17% of the original value. By contrast, a power level uncertainty of 2 causes a variation of 150% of the original value (from half to twice). For products for which the distribution of time *among* low power modes itself is uncertain (e.g. between *sleep* and *off*), the uncertainty estimation method we use may under-estimate the importance of the parameter.

Table 4. Counts of each Parameter Type by Size of Effect.

Effect	Number	Stock	Power	Usage
≥ 1W	39	15	21	3
0.5 to < 1W	58	26	24	8
Total	97	41	45	11

4.0 Intermediate Results by Product Type

The purpose of this process was to identify important parameters — stocks, power levels, or usage patterns for particular product types. A necessary part of getting to this result was producing an estimate of the current statewide low power mode total and uncertainties for each product type and for the total. These results were not part of the plan for this project, but since we have produced them, they are worth reporting. It needs to be strongly emphasized that this is only an initial estimate and so should not be over-interpreted. On the other hand, many of the discrepancies between this estimate and reality will be of opposite sign and so cancel each other out, so that the total of all product types should be considerably more reliable than the figures for individual product types.

The uncertainty estimation in this process is NOT statistically-based, but rather only intended to be sufficiently indicative of the magnitude to sort the parameters by importance. Uncertainty is commonly expressed in terms of a percentage of the central estimate or constant amount, e.g. 80 ±10% or 80 ±8. Because we wanted to be able to express large variations (such as up to 2 or 3 times the central estimate), this approach could yield zero or negative values which have no physical meaning. To accommodate large variations while keeping the scheme simple (that is, just three uncertainty values for each product type), we multiply and divide the base estimate by the uncertainty amount. For example, a value of 80 with an uncertainty of 1.5 yields 80*1.5 = 120 and 80/1.5 = 53, which is an increase of 50% and a decrease of 33%. Most of the uncertainty values we use are 1.5 or less, but there are some 2s and a few 3s, 4s, and 5s.

For audiovisual and some information technology (IT) products, we expressed uncertainty in a different way, with a percent of time (from 5 to 30%) to be subtracted from the base estimate for the minimum case, and then the resulting ratio between base and minimum used inversely to get the maximum (never going beyond 100% of course). For example, a device in all low-power modes 60% of the time with a 20% uncertainty would be reduced to 40% in the minimum case, and increased to 90% for the maximum[2]. The reason to use this second method is to more transparently express these uncertainties.

In this report we have not changed the "taxonomy" of products — their naming and categorization — from earlier reports in this project. The categorization we used is shown in Table 5 (originally presented in the Measurements from a Small Sample of Homes deliverable).

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[2] The maximum is not 80% (60% + 20%) because the maximum is calculated as the inverse ration of the minimum. In this case, the minimum is 2/3 of the base, so the maximum is specified as 3/2 of the base.

Table 5. Category Codes

Abbrev.	Category	Abbrev.	Category	Abbrev.	Category
AV	Audiovisual	HC	HVAC	LI (LT?)	Lighting
IT	Information Technology	FB	Food and Beverage	HH	Health and Hygiene
IS	Infrastructure	OT	Other	GW	Garden and Workshop
TP	Telephony				

Table 6 presents the base estimate and minimum and maximum values for all 119 product types we considered, sorted by the base estimate value. Maximum values reflect the highest stock, power, and usage simultaneously (and the minimum the lowest) and so are extremes and not the values used to evaluate individual parameters, which use only one maximum at a time. In reality, uncertainties are usually not correlated so that generally one of the three will be in a different direction and offset the other two. For example, power and stock could be overestimates with usage an underestimate so that these partially cancel each other out.

In Table 6, values of 2 W or greater are in boldface type and shaded for emphasis, since these contribute the bulk of the consumption. For the base estimate, these twenty product types sum to 64.6 W, or about 60% of the 108 W total in an average house. Note that among the first 20 product types are three types of set-top boxes (four if DVRs — Digital Video Recorders — are included). The ratio of the highest- to lowest-consuming product type in the list is over 20,000. The product types that are generally hardwired together consume 13% of the total.

Table 6. Aggregate average power levels and Maximum and Minimum estimates

Average (W) Base Case	Product Type	Category	Maximum (W)	Minimum (W)
108	**HOUSE TOTAL**		**233**	**54**
14	**Hard-wired TOTAL**		**27**	**7.3**
7.4	VCR	AV	**13**	**4.0**
6.8	Set-top box, digital	AV	**13**	**3.6**
5.2	Computer, desktop	IT	**9.8**	**2.2**
4.0	Set-top box, digital satellite	AV	**7.6**	**2.1**
3.8	Television, CRT	AV	**6.7**	**2.2**
3.5	Computer speakers	IT	**12**	0.78
3.3	Set-top box, analog	AV	**6.4**	1.7
2.8	*Air conditioner, central	HC	**4.8**	1.7
2.7	Answering machine	TP	**3.8**	1.8
2.6	DVD player	AV	**4.8**	1.3
2.6	*Furnace, central	HC	**4.3**	1.5
2.5	Oven, microwave	FB	**3.4**	1.9
2.4	Printer, inkjet	IT	**3.6**	1.6
2.3	Audio, subwoofer	AV	**9.6**	0.41
2.2	*GFCI outlet	IS	**3.9**	1.2
2.2	DVR	AV	**7.0**	0.55
2.1	Telephone, corded	TP	**3.0**	1.5

Average (W) Base Case	Product Type	Category	Maximum (W)	Minimum (W)
2.1	Clock, radio	OT	**3.0**	1.4
2.0	Audio, CD player	AV	**3.7**	1.0
2.0	*Doorbell	IS	**3.3**	1.2
1.9	Telephone, cordless	TP	**2.8**	1.3
1.9	Multi-function device, inkjet	IT	**3.4**	1.0
1.7	Light, night	LT	**4.4**	0.65
1.6	Audio minisystem	AV	**3.2**	0.69
1.5	Garage door opener	IS	**2.0**	1.1
1.5	Clock	OT	1.5	1.5
1.5	Audio, receiver	AV	**2.7**	0.75
1.4	Security system	IS	1.8	1.1
1.3	Modem, cable	IT	**2.4**	0.47
1.3	Timer	IS	**2.9**	0.58
1.2	Timer, irrigation	GW	**2.7**	0.53
1.1	Audio, cassette deck	AV	1.9	0.47
1.1	Light, low-voltage outdoor	LT	3.8	0.22
1.0	Scanner	IT	**4.2**	0.24
0.98	Modem, DSL	IT	1.8	0.34
0.93	Caller ID unit	TP	**2.0**	0.44
0.89	Audio minisystem, portable	AV	**2.5**	0.26
0.86	Set-top box, game	AV	**2.1**	0.36
0.84	Television/VCR	AV	1.5	0.48
0.80	Charger, cellular telephone	TP	1.4	0.39
0.80	Set-top box, internet	AV	1.6	0.30
0.80	Audio, turntable	AV	**2.0**	0.30
0.72	CD player, portable	AV	1.6	0.30
0.66	*Range	FB	1.5	0.29
0.66	*Oven, standard electric	FB	1.5	0.29
0.60	*Detector, smoke	IS	1.4	0.25
0.57	Copier	IT	**6.1**	0.052
0.56	Audio, tuner	AV	1.0	0.28
0.56	Audio, amplifier	AV	1.0	0.28
0.56	*Furnace, floor or wall gas	HC	1.4	0.22
0.52	Clock, alarm	OT	0.87	0.31
0.52	Detector, carbon monoxide	IS	**2.2**	0.12
0.48	Hub, USB	IT	1.5	0.16
0.47	Multi-function device, laser	IT	1.0	0.22
0.47	Air freshener	HH	1.1	0.19
0.43	Fax machine, inkjet	IT	0.78	0.22
0.43	VCR/DVD	AV	0.79	0.21
0.42	*Light, outdoor motion	LT	1.2	0.15
0.40	*Structured wiring	IS	1.2	0.13
0.35	Power strip, surge	IS	0.97	0.12
0.34	Computer display, CRT	IT	0.63	0.17
0.33	Vacuum cleaner, portable	HH	1.1	0.088
0.29	Air conditioner, window	HC	0.82	0.076
0.27	Musical keyboard	AV	1.2	0.060
0.27	Water heater, gas	HH	0.59	0.12
0.25	*Fan, ceiling	HC	1.1	0.052
0.25	Charger, power tool	GW	**2.2**	0.027

Average (W) Base Case	Product Type	Category	Maximum (W)	Minimum (W)
0.24	Clothes washer	HH	0.38	0.16
0.23	Computer display, LCD	IT	0.50	0.10
0.23	Fax machine, laser	IT	0.49	0.098
0.23	*GFCI breaker	IS	0.68	0.075
0.23	Videocassette rewinder	AV	0.85	0.037
0.20	Charger, PDA	IT	0.45	0.072
0.20	Computer, notebook	IT	1.35	0.028
0.19	Bottled water dispenser	FB	0.46	0.079
0.18	Drill/screwdriver	GW	0.83	0.041
0.18	Router, wireless	IT	0.54	0.060
0.18	Router, ethernet	IT	0.43	0.075
0.17	Hub, ethernet	IT	0.49	0.055
0.17	Charger, toothbrush	HH	0.37	0.073
0.16	Modem, POTS[3]	IT	0.51	0.031
0.16	Coffee maker	FB	0.29	0.081
0.15	Fountain, indoor	OT	0.61	0.037
0.15	Modem, satellite	IT	1.19	0.019
0.15	Clothes dryer	HH	0.23	0.096
0.14	Printer, laser	IT	0.25	0.082
0.14	*Dishwasher	FB	0.19	0.11
0.14	Light, exterior sensors	LT	0.45	0.040
0.13	Light, motion sensor, interior	LT	0.36	0.046
0.12	Karaoke machine	AV	0.66	0.0057
0.12	Electric vehicle, wheelchair	HH	0.48	0.025
0.094	Charger, battery	GW	0.56	0.016
0.090	*Vacuum cleaner, central	HH	0.55	0.015
0.089	Fireplace	IS	0.27	0.030
0.073	Radio	AV	0.15	0.035
0.071	Light, emergency	LT	0.13	0.039
0.063	Computer, integrated	IT	0.20	0.016
0.062	*Boiler	HC	0.19	0.020
0.045	Power strip	IS	0.13	0.016
0.044	Charger, video camera	AV	0.32	0.0062
0.035	Infant monitor receiver	IS	0.13	0.0063
0.031	*AFIB breaker	IS	0.094	0.010
0.029	Hair dryer	HH	0.094	0
0.029	Blender	FB	0.11	0
0.029	Toaster	FB	0.053	0.015
0.028	Projector, video	AV	0.26	0.0030
0.027	Charger, still camera	AV	0.19	0.0037
0.020	Lawn mower	GW	0.49	0.00034
0.020	Charger, weed trimmer	GW	0.49	0.00030
0.0070	Iron	HH	0.058	0.00090
0.0063	*Water heater, heat pump	HH	0.025	0.0016
0.0053	Fan, portable	HC	0.095	0.00029
0.0038	Charger, men's shaver	HH	0.012	0.0012
0.0033	Clothes washer/dryer	HH	0.0066	0.0017

[3] POTS is Plain Old Telephone Service.

Average (W) Base Case	Product Type	Category	Maximum (W)	Minimum (W)
0.0026	Charger, bicycle light	GW	0.021	0.00033
0.0025	Infant monitor transmitter	IS	0.010	0.00059
0.0019	Charger, digital music player	AV	0.018	0.00016
0.0013	Charger, women's shaver	HH	0.0080	0.00020
0.00037	Space heater, portable	HC	0.0067	0.00002

Note: "*" denotes a product type that we included in the hardwired category.

4.1 Groups of Product Types

Table 7 aggregates groups of product types, such as all that begin "Set-top box." Note that these groupings are derivative of the nomenclature used, so that "Computer" does not include "Computer Displays," and "Audio" is only component audio products, not everything that produces sound as its primary function.

Table 7. Aggregate average power levels for groups of product types

Power (W)	Product Type Group	Count	Power (W)	Product Type Group	Count
15.	Set-top box	5	1.6	Charger	12
8.1	Audio	7	1.6	Audio minisystem	2
5.3	Computer	3	1.3	Timer	2
3.1	Light	6	0.52	Detector	2
2.8	Air conditioner	2	0.48	Hub	2
2.6	Furnace	2	0.43	Fax machine	2
2.5	Oven	2	0.34	Computer display	2
2.5	Modem	4	0.27	Water heater	2
2.4	Printer	2	0.25	Fan	2
2.1	Telephone	2	0.18	Router	2
2.0	Clock	3	0.090	Vacuum cleaner	2
1.9	Multi-function device	2	0.045	Power strip	2

Table 8 shows the results from Table 3 totaled by category. The categories audiovisual, information technology, and telephony together use almost 70% of the total, making electronic devices the dominant users of low-power mode electricity.

4.2 Future Trends

For each product type we considered whether the stock of low-power devices was likely to change significantly in the near future (5 to 10 years). In a few cases our results reflect insights about usage as well. We simply multiplied the current estimate by an adjustment factor. We developed the factors based on our judgment of current and likely trends.

Table 9 shows the changes in aggregate consumption levels for 39 product types that we applied the "future" factor to. The sum of all of these (including the negative numbers for product types that decline) is 13.7 W, or 12.7% of the current total. The first ten items are all electronic (either audiovisual or IT). Note that the great majority of changes, in number and in total power, are electronics of some form.

Table 8. Aggregate average power totaled by category

Abbrev.	Category	Power (W)	% of Total	Maximum	Minimum
AV	Audiovisual	46	43%	97	22
IT	Information Technology	21	19%	53	8.1
IS	Infrastructure	11	9.9%	21	6.0
TP	Telephony	8.4	7.8%	13	5.5
HC	HVAC	6.6	6.1%	13	3.6
FB	Food and Beverage	4.4	4.1%	7.4	2.8
OT	Other	4.2	3.9%	5.9	3.3
LT	Lighting	3.5	3.3%	10	1.2
HH	Health and Hygiene	1.9	1.7%	5.0	0.78
GW	Garden and Workshop	1.8	1.6%	7.3	0.62

Table 9. Aggregate Power Changes for a "Future" Estimate

Effect (W)	Product Type	Cat.	Effect (W)	Product Type	Cat.
3.4	Set-top box, digital	AV	0.14	Dishwasher	FB
2.6	DVD player	AV	0.13	AFIB breaker	IS
2.2	DVR	AV	0.12	Detector, smoke	IS
2.0	Set-top box, digital satellite	AV	0.094	Charger, battery	GW
1.3	Modem, cable	IT	0.045	GFCI breaker	IS
0.98	Modem, DSL	IT	0.044	Charger, video camera	AV
0.80	Structured wiring	IS	0.029	Toaster	FB
0.72	Router, wireless	IT	0.028	Projector, video	AV
0.48	Hub, USB	IT	0.027	Charger, still camera	AV
0.47	Computer display, LCD	IT	0.020	Lawn mower	GW
0.44	GFCI outlet	IS	0.020	Charger, weed trimmer	GW
0.40	Charger, cellular telephone	TP	0.0033	Clothes washer/dryer	HH
0.26	Detector, carbon monoxide	IS	0.0019	Charger, digital music player	AV
0.24	Clothes washer	HH	-0.17	Computer display, CRT	IT
0.20	Computer, notebook	IT	-0.27	Audio, cassette deck	AV
0.18	Router, ethernet	IT	-0.40	Audio, turntable	AV
0.17	Hub, ethernet	IT	-0.76	Television, CRT	AV
0.17	Charger, toothbrush	HH	-2.5	Set-top box, analog	AV
0.15	Clothes dryer	HH			

5.0 Calculation Method Details

The calculation for each product type includes the statewide stock (millions of units), power levels in each low-power mode (active mode power is excluded), usage time (% of year) in each low power mode, and disconnected time (% of year). Any residual time from adding up all of the usage percents is the active time. Disconnected time by definition uses no energy; disconnection occurs from unplugging the product or the use of a power strip, timer, or other control.

For each mode, the power level is multiplied by the usage time to get its portion of the aggregate power for each instance of a product type. The base estimate for each product type is simply the sum of the average power attributable to each mode. For example, a product with a 10 W *sleep* mode used half the time and a 2 W *off* mode used 25% of the time will have an average low-power power level of 5.5W (5W for the *sleep* and 0.5 W for the *off*).

We estimate three uncertainty factors that are multiplicative: stock, power, and usage. For example, a stock uncertainty value of 2 implies that we think the actual stock could plausibly be from half to twice the value in our base case. For power levels, the uncertainty factor is applied to all low-power modes equally. For usage, it is more complicated since multiplying percents can raise the total of all modes over 100%. The Usage uncertainty calculation is described below.

6.0 Usage Uncertainty Calculation

The calculations for usage differ for those for stocks and power levels. First, consider the disconnected, low-power, and active times as percent of the year. These always add to exactly 100%. Active can be zero, as in the case of a smoke detector for which alarm mode is quite rare, or single-mode products such as timer with no separate active mode. Since disconnected power is zero and active power not considered, the only factor that directly contributes to our result is the change in low-power time. We consider three basic cases, mostly disconnected, mostly active, and mostly low-power.

6.1 Mostly disconnected

For devices that are disconnected more than half the time, the uncertainty factor is applied to the combination of the low-power and active modes. This can reduce the disconnected time to zero in which case the other modes are kept proportional to their base proportion.

For example, consider a cordless power tool product type that is disconnected 85% of the time, charging 10% of the time (an active mode), and in external power supply only mode (a low-power mode) 5% of the time. An uncertainty factor of two will cause the low power mode to range from 2.5% to 10%. An uncertainty factor of 10 would cause it to range from 0.5% to 33%. It would not rise to 50% as simple multiplication would suggest since that would bring the active plus low-power time to 150%. The extreme high case is zero disconnected time which results in two-thirds (67%) active and one third (33%) low power taking the proportions from the base case.

6.2 Mostly Active

For devices that are active more than half the time, the uncertainty is applied to the combination of low power and disconnected. If the uncertainty factor eliminates all active time, then the other modes are kept proportional while adding to 100%.

6.3 Mostly Low Power

All remaining cases are dominated by low-power time. In principle a product could have its usage time roughly evenly divided among active, disconnected, and low power, but our assumptions do not include such a case. In this case the usage factor is applied to the combination of active and disconnected, with the residual low power time adjusted accordingly.

For example, consider a case with 80% low power, 10% active, and 10% disconnected. An uncertainty of two will raise the non-low power to 40% (from 20%) or drop it to 10%, so that the low power total will be 60% or 90%.

6.4 Alternate Usage Method

For audiovisual and some information technology (IT) products, we expressed uncertainty a different way, with an amount of percent of time (from 5 to 30%) to be subtracted from the base estimate for the minimum case, and then the resulting ratio between base and minimum used inversely to get the maximum (never going beyond 100% of course). For example, a device in all low-power modes 60% of the time with a 20% uncertainty would be reduced to 40% in the minimum case, and increased to 90% for the maximum.

6.5 Uncertainty Summary

The power level and stock uncertainty factors have a direct proportional effect on the statewide total, but the usage factor effect can be different from the usage factor uncertainty itself. That is, an uncertainty factor of two on usage does not necessarily double or half the statewide total in the way that a power level uncertainty does.

7.0 Limitations and Next Steps

This estimation procedure was designed to identify the priority parameters for data collection. It was not designed to produce a statewide estimate directly, though it also does this. The procedure is simplified, does not consider shifts of time among low power modes in the uncertainty of usage, and can be misinterpreted as lower low-power time can result from more active time which means more total energy consumption, not less.

A better system of expressing uncertainties would be to identify sets of percentages of low-power mode time that would be substituted for the base case percentages. One each would be needed for the maximum and minimum cases. In addition, it would make sense to the degree possible to incorporate active power consumption so that changes in or uncertainties in the low power figure can also report those changes as well. We did not use this approach due to lack of time and data to justify the additional complication.

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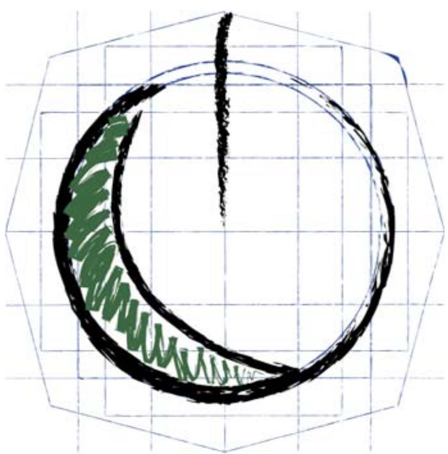
ATTACHMENT I: LOW POWER MODE MEASUREMENT TEST PROCEDURES: INDIVIDUAL PRODUCTS AND WHOLE HOUSES

CALIFORNIA ENERGY COMMISSION

Developing and Testing Low Power Mode Measurement Methods: Attachment 1 — Measurement Protocols



STANDARDS RESOURCES

September 2004
P500-04-057-A1

Arnold Schwarzenegger, *Governor*

CALIFORNIA ENERGY COMMISSION

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Legal Notice

Acknowledgements

LBNL greatly appreciates and wishes to acknowledge the invaluable assistance of those who helped make this project possible and a success.

Nancy Jenkins, California Energy Commission
Don Aumann, California Energy Commission
Tommy Bangthamai, Lawrence Berkeley National Laboratory
Jeff Warner, Lawrence Berkeley National Laboratory
Rich Brown, Lawrence Berkeley National Laboratory
Marcy Beck, Lawrence Berkeley National Laboratory

The eight anonymous homeowners who donated their time and houses for days of intrusive measurement

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Preface

The Public Interest Energy Research (PIER) Program supports public interest energy research and development that will help improve the quality of life in California by bringing environmentally safe, affordable, and reliable energy services and products to the marketplace.

The PIER Program, managed by the California Energy Commission (Commission), annually awards up to $62 million to conduct the most promising public interest energy research by partnering with Research, Development, and Demonstration (RD&D) organizations, including individuals, businesses, utilities, and public or private research institutions.

PIER funding efforts are focused on the following six RD&D program areas:

- Buildings End-Use Energy Efficiency
- Industrial/Agricultural/Water End-Use Energy Efficiency
- Renewable Energy
- Environmentally-Preferred Advanced Generation
- Energy-Related Environmental Research
- Strategic Energy Research.

What follows is the attachment to the final report for the project Standby Power Consumption Phase 2: Research Into Low Power Modes (contract #500-99-013, Task Order 20-5, Amendment 2), conducted by Lawrence Berkeley National Laboratory. This project contributes to the PIER Buildings End-Use Energy Efficiency program.

For more information on the PIER Program, please visit the Commission's Web site at: http://www.energy.ca.gov/pier/index.html or contact the Commission's Publications Unit at 916-654-5200.

Executive Summary

Measurements of product energy consumption are generally based on test procedures for each specific product type. This document was produced as part of a study of residential low power modes that covered in excess of 100 product types, most of which have no established test procedure, and those which do have test procedures do not adequately cover low power modes. This document presents a test procedure for measuring low power mode energy use which fills this gap. It covers terminology, test conditions, measurements, and reporting. An extension of this procedure to whole house measurements is also presented, but has not been shown to be effective in practice.

Abstract

Measurements of product energy consumption are generally based on test procedures for each specific product type. This document was produced as part of a study of residential low power modes that covered in excess of 100 product types, most of which have no established test procedure, and those which do have test procedures do not adequately cover low power modes. This document presents a test procedure for measuring low power mode energy use which fills this gap. It covers terminology, test conditions, measurements, and reporting. An extension of this procedure to whole house measurements is also presented, but has not been shown to be effective in practice.

1.0 Scope

The purpose of this protocol is to measure the power consumption in each low-power mode of *any* electrical product found in residential settings that is connected to ordinary mains power (i.e., 120-volt circuits, in the United States, either from a standard receptacle or by hard-wiring). It is intended principally as a field measurement protocol (in homes or stores) although measurements can also be performed in a laboratory. This protocol is not designed for regulatory purposes, however, future test procedures for regulations should be derived from this protocol and any sound procedures designed for the active mode(s) of the product in question. The protocol can be adapted to commercial, industrial, or other settings.

The primary intended use of this protocol is to collect data about typical electricity consumption of products as actually used in homes, businesses, and elsewhere. This is distinct from procedures designed for regulatory purposes which require measurements to be performed in a laboratory under tightly controlled conditions and detailed specifications of the configuration of the product being measured (which is usually new and unmodified).

As much as possible, this protocol is consistent with IEC 62301, on "Measurement of Standby Power." Excerpts from IEC 62301 included in this protocol are underlined. Notable departures from IEC 62301 are noted.

The protocol is for a single device. It can be used within a separate "whole house" protocol that is used to evaluate all products in a given housing unit or other individually metered space.

This protocol is driven in part by the observed characteristics of products evaluated previously — the sum of these is laid out in the "Empirical Product Data" appendix to this protocol. There is also an appendix of "Rationales and Discussion" that explains the choices made that determine the protocol.

2.0 Terms and Concepts

2.1 Actors

User

The person at the field site who resides there or is otherwise responsible (e.g., a homeowner). For some products at the site, this person's knowledge may be incomplete; it may be another occupant who is really the "user" of the product.

Tester

The person (or people) conducting the measurements and recording the results.

2.2 Hardware

Product

A piece of equipment that can be powered directly from mains power (may be also referred to as the Equipment Under Test, EUT). Some products provide power to additional mains-powered products (e.g., some computers provide power to connected displays); these additional products are *not* to be included in power measurements of the EUT. When power is supplied at low voltages to other hardware (e.g., through a Universal Serial Bus (USB) port), then the other hardware *is* considered part of the EUT and is included in its energy consumption. A description of the attached hardware (products or devices) shall be recorded.

All attached products shall be measured separately, including powered USB hubs (per above, unpowered hubs are included as part of the EUT).

Equipment under test

EUT is used instead of "the product" when there is more than one product under discussion.

Product type

Product types are differentiated "by capacity or other performance-related features that provide utility to the consumer and affect efficiency."[1] In other words, a product type is a general category of products within which there is a sufficient amount of common functionality, modes, and behavior.

Product subtype

Whether and when a product type should be split into multiple types or subtypes is a matter of professional judgment; reasons to split a product type include wide ranges in size / capacity (e.g., the speed of a printer or size of a display), technology (e.g., inkjet vs. laser printer), and functionality (e.g., multi-function devices that add fax capability to printers, or set-top boxes that may be analog or digital, or for cable, satellite, or over-the-air broadcasts). Factors that differentiate product types may significantly affect power levels or operating times, in current or future products.

"Known" product type

A product type is "known" when it has been measured enough times to determine what modes it commonly has and what low-power modes are "stable" and so can be measured with the abbreviated procedure. Known product types are added to the database of empirical product data. A type becomes known when five instances (all different models) have been evaluated and measured. For simple product types with stable modes, the threshold for being known is reduced to three instances.

When a product type is split, tester judgment informed by the empirical product data will determine which new subtypes are known and which are not.

Product model

A specific brand and model of a product.

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[1] U.S. Department of Energy (DOE). 1991. Energy Conservation Program for Consumer Products: Final Rule Regarding Energy Conservation Standards for Three Types of Consumer Products. Code of Federal Regulations, Title 10 Part 430, Vol. 56, No. 93, May 14, 1991. Docket No. CE-RM-88-101.

Device

An item of hardware that is not a product (and so does not have a mains power supply, unless it is a power conditioning, power control, or other upstream device).

External power supply

An external power supply (XPS) is one that is separate from the rest of the product, with a connector feeding the low-voltage output of the supply to the rest of the product. The external power supply can be at the plug or in the middle of a power cable.

Power conditioning device

A device that alters the power delivered, other than simply turning it on or off. The most common examples are surge protectors (usually found on power strips) and uninterruptible power supplies. Power conditioning devices always consume some power themselves, even in a no-load situation.

Power control device

Any external switch that controls the supplied power such as switched outlets (not including circuit breakers in main electrical panels or subpanels), timers, power strips with switches, power-line carrier (PLC) controls, occupancy sensors, and daylight sensors. Power control devices can consume power themselves (e.g., some types of switches and some power strips), but some do not.

2.3 Configuration

The following are all potential aspects of the configuration of a product. The *power supply context* applies to any device. The empirical product data identify which of the other aspects apply to what product types.

Power supply context

The presence and status (on or off) of any power conditioning devices, power control devices, and other upstream devices. An example of an upstream device is a power line carrier data module that passes power through without conditioning or control but provides data communications capability. These are to be measured separately according to the test procedure for power control devices.

Attached devices

Includes those devices that might draw power from the main device (e.g., external cards, USB devices), and those that do not draw power but might affect the power status of the product. A network connection is considered an attached device; other products and devices on the network are not attached.

Attached products

Includes those products that might draw power from the main device (e.g., some computer monitors), and those that do not draw power but might affect the power status of the product.

Connected hardware

Those devices and products known to affect the power status of the EUT. These may be connected over networks (possibly wireless) and so need not be attached, but can be.

Internal added hardware

Extra internal cards, internal disks, and memory in computers, beyond what the model is sold with.

Hardware settings

Settings changed by dedicated mechanical controls (e.g., physical switches) that can affect energy consumption in low-power modes.

Software settings

All settings other than hardware settings, such as those on software menus. For both hardware and software settings, it is only those that can affect energy consumption through power levels or changed operation times that are relevant.

Information environment

Any dynamic information that might affect energy consumption in low-power modes. Examples include information communicated over network connections and broadcast media feeds.

2.4 Characteristics

Characteristics are immutable aspects of a product, such as the ability to be driven by battery power in addition to mains power, the ability to be operated by a remote control, and the power control user interface (switches, indicators, etc.). Other characteristics are related to function, such as the size or capacity of the product or the underlying technology it uses. The only characteristics that need to be recorded are those that may affect power levels or usage patterns.

2.5 Modes

Modes refer to the various functioning states of a product, and often determine or constrain its capacity or behavior.

Many product modes are also power modes, such as *on*, *sleep*, *off*, or variants thereof. Some variants depend on physical states such as a product being disconnected from an external power supply, a battery present or removed, or a product partially open or in a physical error mode (e.g., a paper jam). Some modes may be similar or identical in power consumption but exhibit different power behavior (e.g., a computer display which may have similar power consumption in *sleep* and *off* modes but be able to transition to *on* only from *sleep*). Most modes can be readily initiated by the tester, but some may be difficult or impossible to induce on-demand, such as some types of error modes.

Some low-power modes can be sustained indefinitely; others are of a limited duration such as intermediate low-power states when a device is not actively being used, or those that are defined by a (non-primary) function such as charging a battery.

Modes known to be rare can be ignored, with rare defined as "it is unlikely that an ordinary user would use it for more than 1% of the time" (i.e., about 90 hours per year under continuous use). An example is the dish positioning mode for a satellite TV receiver.

Most transitions between states are short enough and have a similar enough power levels to the adjacent states that they can be ignored for the purposes of energy consumption assessment. During measurement, the test procedure specifies that a short delay should elapse before data are recorded for the new state in order to be sure that the transition has completed. When transitions are sufficiently lengthy or apparent to the user, they shall be identified as a separate state in the empirical product data for a product type. Examples include lamp cool-down on a projector and warm-up on larger copiers. However, transition states may still be rare and so ignored.

Modes in which no part of the product (including its external power supply) is connected to the mains are not included. Thus, battery-only modes are not covered by this protocol.

Low-power modes

A product in a low-power mode is not performing any of its principal functions. There will be some cases in which a mode can be reasonably argued to be either a low-power or on (active) mode. In these cases, that fact of the borderline condition shall be recorded, and the mode shall be measured. Single-mode products that are customarily on most of the time are considered to be in a low power mode (e.g. a night light or GFCI outlet).

Some products have more than one principal function, such as multi-function imaging devices that can send and receive facsimiles, scan documents, and print images. Background operations such as downloading do not inherently mean that the product is in an *on* mode.

When feasible, low-power modes shall be categorized into *sleep* and *off* modes. The empirical product data should contain the general name of the mode, the name used within the product type, and, when needed, that used with specific models.

Battery modes

Devices with rechargeable batteries may be in a *charging* mode (that has a finite duration), a *fully charged* mode (after a charging mode), or a *trickle charge* mode (when no separate *charging* or *fully charged* modes exist), as well as battery *discharge*, battery *not present*, and battery *defective*.

"Standby"

IEC 62301 defines "Standby mode" as:

> the lowest power consumption mode which cannot be switched off (influenced) by the user and that may persist for an indefinite time when an appliance is connected to the main electricity supply and used in accordance with the manufacturer's instructions.

> Note: The standby mode is usually a non-operational mode when compared to the intended use of the appliance's primary function.

As defined in this protocol, "standby" is a power level, *not* a fixed mode, since it may occur in the *off*, *sleep*, or *on* modes, depending on the particular product. It can, but is not encouraged to, refer to the "standby mode" of a specific product, although not of a product type since it can vary within a product type.

When the standby power level occurs in an *on* mode (e.g., some telephones and answering machines), it shall always be measured even though it is not a low-power mode. The standby level can occur in a mode in which the product performs a principal function, including products with only one mode such as some nightlights and air fresheners. When measurements of *on* modes can readily be performed, these may also be measured by this protocol.

Disconnected

Any product can be disconnected from mains power so that the disconnected state is an additional one to the modes that can be attained with the product connected to the mains. The disconnected mode always requires zero power.

2.6 Mode stability

For each type of mode for each known product type, a stability rating is assigned. The possible ratings are listed in Table 1. Modes with the first three ratings (stable, unstable, and cyclical) provide clearly adequate data for assessing energy consumption. Testers must decide on an individual basis how to measure energy use in an unstable mode, considering the aggregate energy consumption in question and difficulty in getting complete data. Stability ratings are assigned in the process of a product type becoming known.

Since a cycle duration could be much longer than 5 minutes, it is possible that there are cyclical modes that this procedure will not identify. When there is an indication from manufacturers, literature, or user manuals that such modes exist, longer metering times shall be used to determine if the cycling can be identified and correctly measured for at least one full cycle, and in all cases, the measurement should be for an integral number of cycles.

2.7 Empirical Product Data

The procedure to employ for a particular product is guided by the empirical data gathered about the same or similar product types in the course of previous measurements, as well as the best judgment of those taking the measurements. The major types of data that are included in the empirical product database are what modes exist (and their stability rating), and what special conditions might exist or characteristics to record. More details on the information to include in the database are described in the Empirical Product Data appendix to the protocol. To the extent possible, these data will be generic for an entire product type, but eventually some brand- and model-specific data will need to be tracked.

The record of empirical product data should include at least the country where the data originate, so that any product types that are determined to sometimes vary across countries can utilize separate empirical product data for each region.

Table 1. Stability Ratings and Measurement Procedures for Power Modes

Mode Type	Procedure	Criteria
Stable	Wait at least ten seconds for any transition to pass, then average the readings over ten seconds.	Five-minute periods show that the maximum reading minus the minimum reading is less than 5% of the average.
Unstable	Wait at least 30 seconds for any transition to pass, then average the readings over 5 minutes.	Does not meet stable criteria, but there are obvious patterns or trends in the 5-minute period such as might be induced by non-primary-function device activity or by battery charging.
Cyclical	Wait at least 30 seconds for any transition to pass, then average the readings over at least two cycles.	The measured data show cycles in power consumption or the product type is known or to have cycles in this mode.
Random	Wait at least 30 seconds for any transition to pass, then average the readings over 5 minutes.	Does not meet stable criteria, and variation in the 5 minute period appears to be random.

3.0 General Conditions

3.1 Basic Power Characteristics

The voltage supplied to the product shall be recorded. This protocol sets no limit on the voltage, but readings outside the normal nominal range (e.g., 110 V to 120 V for the U.S.) should be treated with caution. The frequency need not be recorded. The rated voltage range of the product should be checked to see if the supplied voltage falls within it, and record that fact if it is not.

3.2 Power Quality

This protocol does not include measuring the quality of the supplied power.

3.3 Physical Conditions

Temperature

The expected dry-bulb air temperature range is 20 ± 5 °C (68 ± 9 °F). When the temperature is within that range, it need not be recorded; when it is outside that range, it shall be recorded.

Other Physical Conditions

For any product in a type known to be sensitive to another physical condition, that condition shall be measured and recorded. As these conditions are added to the empirical product data, the measuring instrument and accuracy required shall be determined. Example conditions that could be added are humidity, air speed, ambient light levels, ambient noise or sound level, air pressure, or water temperature.

3.4 Accuracy

This protocol adopts the accuracy criterion from IEC 62301:

> Measurements of active power of 0.5 Watt or greater shall be made with an uncertainty of less than or equal to 2% at the 95% confidence level. Measurements of active power of less than 0.5 Watt shall be made with an uncertainty of less than or equal to 0.01 Watt at the 95% confidence level. The power measurement instrument shall have a resolution of 0.01 W or better for active power.[2]

The meter used shall have a power resolution of at least 0.01 W, with an accuracy of at least 0.5% plus one least significant digit. The meter shall have an accumulated energy resolution of at least 1 mWh and accuracy of at least 0.5% plus one least significant digit.

Measurements of average power shall be reported to 0.01 W. Measurements of accumulated energy shall be reported to the nearest 1 mWh.

3.5 Equipment

The following are the measuring instruments that are needed for conducting the measurements.

- A power meter with a power resolution of 0.01 W (10 mW) and accumulated energy resolution of 1 mWh.
- A thermometer for measuring the ambient dry-bulb temperature.
- A clock for noting the time of day of data collection.
- A stopwatch for monitoring the length of measurements (can be done with the clock)
- A digital camera for photographing each device (not required, but recommended).
- A tape measure for measuring characteristics and as a scale in photographs.
- Other measuring instruments of physical conditions that the empirical product data show are needed.

[2] Note that this reference to "active power" in IEC 62301 does *not* refer to the active power mode, but to ordinary power consumption in the standby mode. Specifically, it refers to "The mean value, taken over one period, of the instantaneous power" with a period being one cycle of alternating current, though multi-cycle measurements are also acceptable.

4.0 Measurements

4.1 Configuration / Controls

Product configuration consists of several parts, as defined in section 2.3: the power supply context, attached devices, attached products, connected hardware, internal added hardware, hardware settings, software settings, and the information environment.

Relevant configuration information about the product shall be recorded. The extent of configuration information to collect for particular products may be described in the Empirical Product Data appendix to this protocol. For example, internal added hardware will generally not be assessed due to the difficulty in describing it and drawing conclusions about energy consumption.

The types of controls (manual and/or automatic) on the product shall be recorded. In many cases, this will consist only of a power switch.

4.2 Unknown Product Types

For products of types not "known," the procedure from the IEC 62301 procedure shall be followed for each mode except that only the first 5 minutes of data need be collected (i.e., not the second 5 minutes specified to be certain of stability). If there is any indication that the mode is in fact not stable, then the second 5 minutes of data shall also be taken (or longer as needed to incorporate cycling, per IEC 62301).

When evaluating products to collect information to add to the empirical product data, the following sources should be considered:

- All manuals for the product, including quick-start guides, user manuals, reference manuals, and service manuals. Some manuals may be found only with the product, some only found via the Internet, and some available through both routes.
- Tester manipulation of the product.
- User-supplied information.
- Past experience and professional judgment of the tester.
- Empirical data from similar product types.

Information to record are (from the empirical product data):

- The modes the product has,
- How they are entered,
- The stability of each mode,
- Whether it can be powered from batteries, and
- Any other special conditions or helpful information.

Transitions between modes shall be evaluated to determine if they are longer than the ten seconds allowed in the measurement procedure (for stable modes in known product types), or if a reasonable operating pattern could lead to their duration being more than 1% of typical on-time. Transitions that exceed the criteria shall be identified as separate modes to be measured.

4.3 Procedures

When a product of a *known type* is encountered it shall be tested using the accumulated knowledge in the empirical data for that product type, such as what modes exist and whether any modes are not stable. The tester shall always be alert for additional low-power modes (beyond those listed in the empirical product data).

When a product is encountered that is in a type that is *not known*, it shall be evaluated in detail, with the results added to the empirical product data. Even when the type is known, if a product appears to have different characteristics from what the type specifies (e.g., a new mode, different basic technology, or size), the product shall be evaluated in detail. The results shall be added to the empirical product data to possibly form the basis for a new subtype.

Preparation

A product shall be measured at its plug, that is, downstream from any power conditioning devices that may be present. It may be necessary to turn power conditioning devices on to perform the test. The no-load loss of *each* power conditioning and power control device shall be measured. The procedure is to connect (and turn on if necessary) the device, wait at least 5 seconds, then measure for at least 10 seconds. Uninterruptible power supplies (which contain batteries) may require a more complicated procedure which will be incorporated into the empirical product data as that type becomes known. For timers, record the settings because they limit the possible usage times. For products that are hard-wired, the tester shall disconnect it from the wiring, then measure it with the meter.

Product configuration shall be recorded as found. For products that can be powered by batteries instead of mains power, record whether or not they are present and leave any batteries as-is. The tester shall record any other information that is deemed to be potentially relevant or informative.

It is recommended, but not required, to photograph each product, and photographs should include a scale.

Measurement

The product is measured in each mode that it can be set to operate in. For each mode, the measurement shall be according to the appropriate procedure listed in Table 1 as indicated by the stability rating in the empirical data. As necessary, the configuration shall then be altered and then the product tested in additional modes. It is acceptable for the user to make changes in the configuration needed for the test rather than the testers.

If a product cannot be manipulated at all or into all modes, that fact shall be recorded. Causes of this type of situation include products for which it would be problematic to change the mode (e.g., medical equipment and security systems), error conditions that may be difficult or problematic to generate, and hard-wired products that are difficult to access.

For cycling products, as per IEC 62301, the measurement simply needs to capture one or more cycles.

Products with a hard-off switch have a standby level of zero W. In some cases, a device will be found that has no non-zero, low-power mode consumption, even though it is in a product type for which products commonly do have low-power mode consumption. Data shall still be recorded for these devices, as it can help in extrapolating to consumption across the entire product type.

When enough examples of anomalous data accumulate (e.g., a mode not reflected in the empirical product data, or different stability ratings) then the empirical data shall be revised.

4.4 Usage

The apparent power status of the product (*on*, *sleep*, or *off*) shall be recorded before any action is taken by the tester. An example of such action includes a proximity detector waking up or turning on a product.

For any product that monitors its own usage, that information shall be recorded (an example is some video projectors that record lamp usage time).

For applicable products, the user shall be asked what percent of the year the product is in each major operating mode. The tester need not ask this question directly; for example the user can be asked how many hours per week the product is in each mode. All results shall be recorded as percent of year for each mode including disconnected, with the residual the active time.

5.0 Reporting

Unless otherwise specified, the results of measurements are to be expressed as power, in Watts for the average power in a particular mode. The data specified by IEC 62301 are underlined. For some parameters, the applicable section of this procedure is noted.

<u>Product Data (“Appliance (equipment) details”)</u>:

<u>Brand</u>

<u>Model</u>

<u>Type</u>

<u>Description, *as appropriate*</u>

Characteristics (2.4), configuration (2.3), and controls (4.1) (per empirical product data); (<u>description of how the appliance mode was selected or programmed</u>)

Product type

Whether it has an external power supply, and if so, rated output voltage and current/power

Whether it can be powered from batteries, and if so, whether they are present (4.3)

Usage data (4.4)

Test Conditions ("Test parameters"):

Temperature (if outside the ordinary range) (3.3)

Voltage (3.1)

Any other physical / general conditions that apply to the particular product.

"Measured Data": For each mode:

Average power in Watts rounded to the second decimal place. For loads greater than or equal to 10 Watts, three significant figures shall be reported. (4.3)

The assumed and actual mode stability rating (2.6)

Raw data (accumulated energy and time, if applicable)

Sequence of events to reach the mode (IEC 62301 continues with "where the equipment automatically changes modes" but the meaning of that is unclear)

Other:

Other notes on product operation

Test number (test report number/reference)

Any differences between the EUT and the empirical data for the product type

Misc: Different power source for hard-wired (4.3); modes not enterable (4.3)

Any other information that seems relevant (4.3)

Information for a series of tests (need be recorded only once):

The test setup

Date and Time (beginning and end of series)

Location (at least city or county, state/province, and country)

Type of location: laboratory, store, or home

Test officer(s)

Unlike IEC 62301, it is not necessary to record the serial number, rated voltage and frequency, actual frequency, total harmonic distortion of supply, or details of manufacturer.

6.0 References

International Electrotechnical Commission, IEC 62301 Ed 1: Measurement of Standby Power, IEC TC 59, TC59, Working Group 9 59/297/CD Household Electrical Appliances.

Appendix I: Empirical Product Data

1.0 Introduction

The procedure to use for a particular product is guided by the empirical data[3] gathered about the same or similar product types in the course of previous measurements, as well as the best judgment of the testers. Some assumptions are made for all products and assumed true until shown otherwise. For example, for products with separable external power supplies, the "no load" condition in which the external supply is disconnected from the main product is assumed to be a distinct mode and power level from any stable mode in which the power supply is connected to the main product. Another example is that products are assumed to be *not* sensitive to physical conditions in their low-power modes until evidence about the product arises that suggests otherwise.

Information that is obvious shall not be included. Examples are that a power indicator that is off indicates that the product is *off*, and that a device is moved from *off* to *on* with the power button or switch.

2.0 Types of information to collect

- What modes exist (and how to allocate among *on*, *sleep*, *off*)
- How to get into each mode
- How to tell/confirm that you are in each mode
- Special characteristics to record (e.g., screen size, power management settings)
- Special conditions to assess (e.g., physical conditions)
- Keeping time (does the device track it, lose it on power-off, and how to reset the time after the measurement is completed)
- Whether or not to ask about usage

To the extent possible the data collected will be generic for an entire product type, but inevitably some brand and model-specific data will need to be tracked. Data collection should also identify key active modes to measure.

2.1 All product types

2.1.1 Generic

Any product with an external power supply (XPS)

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[3] The information listed here is drawn from general knowledge, supplemented by data collected in the process of "knowing" product types, so it will be replaced and augmented by that data as it becomes available. In that process, the stability ratings for each mode will be listed.

It has a stable no-load mode (main product disconnected from XPS) in addition to other named modes.

2.1.2 Usage

Products for which Testers shall ask users about usage

All office equipment (PC, display, inkjet printer, laser printer, scanner), consumer video electronics (TV, PVR, projector, DVD player, VCR, etc.), consumer audio electronics (Audio Minisystem, Audio Receiver, CD Player, Cassette Deck, etc.)

2.1.3 Features that may reduce low-power energy use (by product type)

Products with switches to dim or turn off the clock / display: VCR, clock radio, microwave, some audio products.

Remote defeat switches: TV

Ambient light detector (active mode only): TV

2.1.4 Products that may have remote controls

Consumer electronics: TV, VCR, DVD, audio, PC

Other: Ceiling fan, room air conditioner, garage door opener

2.1.5 Attributes of multiple product types

Portable products with a base station and an integral battery

Examples: cordless phone, cordless vacuum ("dustbuster")

Modes: Product in base station and charging; product in base station and *not* charging; product out of base station

Portable products with a separable battery

Examples: power tool

Modes: Battery absent; battery being charged; battery fully charged; battery defective.

Portable product with whole product connected to XPS

Examples: cell phone, notebook computer

Modes: Product disconnected; product connected and charging; product connected and fully charged; Product trickle-charging.

2.2 Individual Product Types

2.2.1 Consumer Electronics

TV

Modes: off-remote aware, off-remote disabled, off-by-sleep-timer. Active.

Notes: May have a remote defeat switch and/or an ambient light sensor (active only)

Any device with a tape transport (e.g., VCR, audio tape)

Modes: rewind, ready, off-by-remote, off-by-switch. Active: play, record.

2.2.2 Infrastructure

Battery Charger

Modes: no battery present, discharging battery, battery full, defective battery. Active: charging.

2.2.3 Information Technology

Personal computer (PC)

Modes: Off, hibernate, sleep; Active: idle, active.

Record: power management enabling and delay times; attached devices; attached products; connected hardware.

Notes: hibernate should be same as traditional off; sleep power level may be different if manually selected vs. being automatically engaged.

Display (also called computer monitor)

Modes: Off, sleep. Active.

Record: If USB ports are present and powered by the display, record attached devices and products (otherwise include them with the upstream PC).

Notes: Sleep by disconnect should be the same as sleep by PC.

Copier

Modes: Sleep ("energy saver"), manual off, auto off. Active: Ready.

Record: power management enabling and delay times; rated speed, analog vs. digital.

Notes: Manual off and auto-off are same for some machines; large copiers may have multiple sleep states, and/or adjustable power levels for sleep states; possibly temperature / humidity sensitive if has an anti-condensation heater and it is turned on.

Projector

Modes: warm-up, cool-down, off. Active.

Record: Power management enabling and delay times; lamp usage time.

2.2.4 Outside / Landscape

Outdoor lights

Modes: Off. Active.

Physical condition: ambient light

2.2.5 Major Appliances

Dishwasher

Modes: door open, door closed, delay start

Notes: may have multiple doors.

Microwave

Modes: door open, door closed, door closed (display off), delay start

Notes: may have multiple doors. Active power is complex.

2.2.6 Other

Appendix II: Rationales and Discussion

1.0 Background

This Protocol was developed as part of a project whose goal was to determine *how* to measure low-power mode energy consumption, with the actual measured data a necessary bonus. Specifically, this document is to be "A draft measurement protocol for the major categories of products applicable to existing equipment located in homes and for new equipment not yet in use." Results from the protocol will feed into calculations of annual energy consumption for individual products.

The primary purpose of this protocol is to answer the question "how much energy is used in low-power modes" while providing information to address the related question of potential energy savings. This protocol is distinct from procedures used for regulatory purposes such as mandatory standards, or even voluntary labeling programs, which measure new, unused products as configured at the factory in isolation from any particular use context (although some standard context is prescribed by some procedures). While this protocol is not designed for regulatory purposes, regulatory procedures should be derived from this protocol and from sound procedures designed for the active mode(s) of the product in question.

Measurements can be taken in the field (in homes, offices, or in stores) or in a laboratory.

While developing this Protocol, LBNL staff reviewed several power measurement test procedures and assessed two related concepts. The first was a "test procedure" which is usually designed to measure a single new product or mode in a *laboratory* setting, often for safety or regulatory purposes. The test conditions, such as temperature, supply voltage, etc., are well-specified. The product's configuration is constant or as-shipped by the manufacturer, and any usage patterns applied during the test are fixed or dependent on obvious product characteristics (e.g., size or speed).

The second concept was a "measurement protocol" which covers a much larger set of methods, including test procedures. Measurement protocols facilitate data collection in various contexts, including:

- In the field in which the conditions (such as temperature, voltage) are not well controlled
- Situations where the history or condition of the product is not well-known (e.g., the user may have modified it or performance could have changed with age), and
- Circumstances when products have been customized for the user by adding to it (e.g., a PC expansion card), changing the configuration, or by connecting it to other products in ways that change its energy consumption patterns, through data or power flows along wired or wireless connections.[4]

[4] At present, data and power can be transmitted over wires, and data over wireless connections, but power is not routinely transmitted wirelessly in homes.

Usage patterns are often unique to the product owner and so, while they might be measurable, they are not constant and are difficult to replicate. Measurement protocols help build a database of individual usage patterns to inform estimates of what is typical.

While some products behave similarly throughout the world, others may vary depending on the region or country they are found in. In these cases, the empirical data will need to be tailored to the "population of interest."

This protocol is a measurement protocol. While some devices will be measured in a laboratory for convenience, most measurements, and all whole-house measurements, will be conducted in the field.

We use the word "procedure" to refer to a single, well-defined, series of actions. A "protocol" is a larger idea which can include several procedures, to be used or customized depending on the context or product.

From our review of test procedures, it was clear that IEC 62301, "Measurement of standby power - Household electrical appliances" (a nearly final standard) should be the principal foundation upon which to build our new protocol. The review covered the 14 topic areas listed in Table 1.

Table 1. Topics addressed by test and measurement procedures

Topic	Comments
Purpose / Scope	Reason for creating the procedure
Basic Power Characteristics	Voltage, frequency
Power Quality	Total harmonic distortion, crest factor
Other Conditions	Air speed, temperature, humidity
Accuracy	Accuracy and resolution of metering equipment
Configuration	Settings, attached hardware, information environment
Usage Patterns	% of time in each operating mode
Mode Definitions	What to name modes, what characteristics they have
Mode Derivation	How to determine what modes a product has
Controls	Controls (e.g., switches, automatic) within the product or attached to it
Procedure Steps / Timing	How long to integrate power use over time
Sampling	How many units to measure
Reporting	What to record / report
Whole-house Measurements	Entire house and all products within it

The new protocol follows a structure similar to IEC 62301, and covers most of the topics listed in Table 1. The whole-house protocol is described in Appendix III.

1.1 Structure

This new, general protocol has three components:

The **general protocol** — the protocol that contains within it several procedures to utilize in conducting measurements. It covers the issues that can arise for each individual product — but does not cover any specific products. The structure of the protocol is shown in Table 2.

Empirical product data — observed characteristics and behavior of different types of products — and the implications for how the general protocol is implemented for each product (Appendix I).

A discussion of the **rationales** for the particular choices made. Standards rarely include much of this, partly as it reveals compromises that were made to get agreement, but this should help people who implement or revise the protocol (Appendix II).

In addition, the protocol is built on the idea of a product type being "known" (e.g., microwave ovens). A known product type has been measured enough times to determine what low-power modes are "stable" and so can use the abbreviated measurement procedure. Known product types are added to the database of empirical product information.

This protocol does not address active ("on") power consumption since it would introduce large complexities and is beyond the scope of this project. However, since part of the energy savings from the study of low-power modes involves shifting products from full-on to low-power modes, the energy consumption in full-on needs to be incorporated into later analyses. Energy use and other data should be transferred from other studies as much as possible, although active power should be measured whenever readily possible while making low-power measurements (e.g., when active power consumption patterns are not complicated). Regardless, this protocol is not intended to replace those crafted for individual types of products that are more detailed in specifications for measuring active power. As an example, a display test procedure might specify many attributes of the input signal and displayed content such as contrast, brightness, and illuminance, but a low-power-oriented procedure might measure only the power use of the screen as found.

Table 2. Structure of the protocol

1. Scope	3. General Conditions
2. Terms	3.1. Basic Power Characteristics
2.1. Actors	3.2. Power Quality
2.2. Hardware	3.3. Physical Conditions
2.3. Configuration	3.4. Accuracy
2.4. Characteristics	3.5. Equipment
2.5. Modes	4. Measurements
2.6. Mode Stability	4.1. Configuration / Controls
2.7. Empirical Product Data	4.2. Unknown Product Types
	4.3. Procedures
	4.4. Usage
	5. Reporting
	6. References

2.0 Scope

2.1 Scope

The protocol is designed for mains-powered devices. It is possible that it could be extended to non-mains power, or DC power from on-site generation. It would be more difficult to extend it to low-power distribution as presently accomplished through mechanisms such as USB, Firewire, and Ethernet, since this consumption interacts with the mains consumption of the connected products. It may be possible to apply this to battery-only products or to those powerable from batteries or the mains in their battery-only mode, although battery drain processes introduce complexities not present with mains power and not considered in the development of the protocol. Similarly, there may be issues introduced if the protocol were extended to DC power.

IEC 62301 was designed to be generic and so applicable to nearly any household or ordinary office product. While *on* or active power is covered by many IEC standards (each specific to a different product type). The discussion is oriented to measuring low power modes in residential products, but can be applied without modification to commercial or other contexts. IEC 62301 was created to allow low-power levels to be measured consistently across all product types and provide a procedure for the many product types (principally electronics) for which there is no generally recognized test procedure. IEC 62301 was not designed to cover "normal operation ('on mode')," but it was intended that it could be used for low-power modes other than the one at which the standby level occurs.

Other than ensuring proper and safe electrical connections, hard-wired products should not need to be treated differently than those powered through ordinary plugs and receptacles.

There are four distinct types of measurements possible:

- Field measurements in a home (with a full usage context)
- Field measurements in a store (generally new products, but possibly modified or connected)
- Laboratory measurements of devices from homes (used products, possibly modified)
- Laboratory measurements of new products (provenance known).

Test procedures developed for regulatory purposes use laboratory measurements of new products exclusively. Procedures and products used for research purposes may use any or all of these methods.

2.2 Terms

2.2.1 Actors

2.2.2 Hardware

Product

The term “product” is used here rather than “appliance (equipment)” (IEC 62301) or “equipment under test” (which makes for awkward language), although we do use EUT when helpful for clarity, such as when a second product is connected to the EUT.

There are several reasons not to separate low-voltage devices (e.g., USB) from the mains-powered product they are connected to. These include:

- There may be many of these and it would be time-consuming for relatively small electricity loads. While a USB device is allowed to use up to 2.5W when the bus is active and 0.5 W while it is suspended, many use less than this.
- Many low-voltage devices are integral to the functioning of the attached computer, such as a keyboard or mouse, so measuring them separately offers little value.
- Tracking information on the stock and usage of these devices would be time-consuming.
- It would require a separate monitoring setup.
- The behavior of the system may be altered as the (potentially many) USB devices are plugged in and unplugged.
- Since USB ports are often in the back of computers, the mechanics of doing this are difficult.

Despite all this, powered USB hubs are to be measured as separate products. Among the reasons to do this are that they are separately powered and so may be left on when the PC they are connected to is turned off. A USB hub can provide power to non-data devices (e.g., lights, fans) and so may not actually be connected to any PC.

Product type

There are no rigorous rules for when to make additional product types. Having more product types is burdensome but necessary in some cases.

Known product types

In the definition of “known” product types, we initially chose five as the number of instances of a product type needed in order to make it known. This choice was purely based on judgment; in the course of measuring products, we concluded that three was sufficient with simple modes and consumption patterns. Also, while the term “known” may sound awkward in this context, a better word for this idea is not apparent.

Power conditioning and control devices

These devices have no function independent of other products. It needs to be determined whether power consumption by these devices depends on that of the main product, or if it is a constant no-load loss regardless of how much the main product is using, if anything.

There is some power loss (use) in extension cords, but we concluded that the losses were not large enough to merit tracking their use within this protocol.

A dimmer would rarely be utilized with a device that has low-power modes, perhaps never.

2.2.3 Configuration

Among the reasons to track configuration information are that it may help explain power levels, usage patterns, and inform evaluations of the potential for changes in them. Since specific products may have a large amount of configuration information, it is important to identify which ones merit tracking.

2.2.4 Characteristics

It is useful to describe the types of controls (manual or automatic) that a product has to best understand its modes, capabilities, and behavior. IEC 62301 provides a taxonomy of product types with respect to power switching, the "operating load," "subsidiary load(s)," and external power supplies. Subsidiary function examples include: remote controls, auto-off switches, displays, power for memory or clocks, power for controls or switches, "EMC filters," and "cooling fan or auxiliaries." Knowledge of this categorization can help indicate what kinds of modes the product is likely to have.

IEC 62301 also defines power switch types as hard-off switches ("all-off"), auto-off switches ("auto power off", when function completed), or those that incorporate variable power control ("power control," e.g., dimming). The definition implies that *both* power poles are disconnected on hard-off switches. This may not matter for energy consumption, and presumably is rare (except on some medical devices for which it is required for safety reasons).

2.2.5 Modes

Products may have zero or multiple *off* modes, zero or multiple *sleep* modes, and one or more *on* modes. The standby power level could occur in *on*, *sleep*, or *off*, depending on the product. Low-power modes are all *sleep* and *off* modes; that is, all modes other than *on*.

We chose 1% as the cutoff for a mode being interesting because the ultimate goal of the protocol is to assess annual energy use. A mode used so infrequently is unlikely to consume much energy.

Low-power modes

A low-power mode is any mode in which the product is not performing any of its principal functions. For example, off modes, sleep modes (as on a PC, or even a TV that is off by the remote control), and ready modes in consumer electronics. A PC, on the other hand, may not be running any application software and therefore idle, but still in a fully on mode. A television may be disconnected from a video source and displaying static, a black screen, or an error message, but still be fully on. These are not low-power modes.

Some products have more than one principal function, such as a multi-function imaging device that can send and receive facsimiles, scan documents, and print images.

It is important to not become distracted by whether particular modes are low-power modes or not. It is more critical to identify and measure the modes. Similarly, it is not critical to have a rigid definition of a principal function. An example of potential confusion is whether the mode of a coffee maker to keep coffee warm after being made is an active or low-power mode.

Most definitions of standby-like modes take being connected to the mains as a given. Some are consistent with IEC 62301 in specifying that it is the mode with the lowest power consumption that is of interest, but many are written on the assumption that there is only one such mode (some products have more).

Products that are composites and/or multi-function devices are generally to be considered one product (if marketed under one model number); an example is set-top boxes as defined by Energy Star; another is copier/printer multi-function device products.

Some definitions apply to most or all product types. Others need to be defined with reference to specific product types that they apply to. The latter definitions will evolve empirically, as product are measured and evaluated.

There is an issue of what constitutes a mode — as opposed to a part of a cycle, or a transition state between stable modes. There are also actions that by themselves change power levels but do not cause a new mode, such as plugging a USB device into a PC.

Per IEC 62301, some products have a constant power consumption in their standby mode but others undergo regular cycling. The average power over one of these regular cycles is the figure of merit. IEC 62301 provides that the measurement can either be an instant measure (measured over at least one AC cycle) if the reading is reasonably constant, or the average power over a period of time. Since it would seem that these are quantitatively equivalent, presumably the reason for allowing the two methods is that some meters do not accumulate power over time (more than one cycle) and so can only be used on constant-load products.

"Standby"

Many definitions specify that the standby mode is non-operational, at least for the primary function of the product. An advantage of the IEC 62301 definition is that it states that all products have a standby mode, even though for some simple products (e.g., a nightlight or plug-in air freshener) it may also be the *only* power mode.

The term "standby energy," is sometimes used to mean standby power over time. According to some definitions (e.g., IEC 62301 and IEC 62087), it does not accumulate when the product is active. No definitions explicitly say that it accumulates in more than one mode; most simply do not address the issue.

2.2.6 Mode Stability

The choice of the 3 and 5 minute periods in IEC 62301 was arbitrary (another term for professional judgment). We chose the 5 minute period for consistency with IEC 62301 and to be conservative (since most low-power modes are relatively stable). We initially used a 30-second period for collecting data and the 30-seconds of transition time, but empirical data indicated that ten seconds for each was generally sufficient.

The 5% difference between maximum and minimum readings to qualify as a stable mode was a function of professional judgment. Alternative criteria that were considered and could still be used are a) to compute the standard deviation of the readings and set a percent threshold below which a mode would be considered stable, and b) a scheme in which many 30-

second periods would be excerpted from the 5-minute reading and the range or standard deviation of these would be computed.

We assume that the 1% criteria in IEC 62301 refers to taking the difference between the maximum and minimum readings.

Rosen (Rosen et al. 2001) measured power levels for 30 seconds, based on observations that they varied only 0.1 to 0.2 W within that time. Some procedures are not specific about what constitutes a stable mode.

2.2.7 Empirical Product Data

This protocol is for use with a wide variety of products, and so the details have to be drawn from characteristics of these products. As information is gleaned about products and their annual energy consumption, the protocol should be updated. Most of the updates will be to the known empirical product data, but additional factors may be revealed.

IEC 62301, Section 5.3, implicitly recognizes the need for empirical data. Specifically, in describing what to record, it cites (in part):

- description of how the appliance mode was selected or programmed
- sequence of events to reach the mode where the equipment automatically changes modes
- any notes regarding the operation of the *appliance* (equipment).

In addition, the empirical product data suggest which active modes to measure. Those modes that are at all complex (e.g., imaging on larger products) are not to be included. Additionally, details on how to configure the device for the active mode measurements are not included since measurements obtained from complex (or unstable) active modes are expected to be only generally indicative of values, not conclusive or precise.

2.3 General Conditions

2.3.1 Basic Power Characteristics

Products consume energy at the voltages they experience, not at the level provided in a test procedure, so on average, field voltages are more appropriate for this protocol than nominal voltages. We are not aware of measurements that show how power consumption of the wide range of products found in residences vary with voltage *in low-power modes*. Electronics running at controlled DC levels will not vary in their demand, so the main effect of mains voltage changes will be in how the power supply responds to the voltage changes. A switching supply should be relatively indifferent to the supply voltage. A linear supply should vary in efficiency roughly proportionally to the voltage. Since a difference between the prescribed laboratory voltage and one found in the field will be under 5%, the effect of supply voltage changes should be well under 5%. This could be tested on a variety of products to provide actual data if it proves to be of interest.

In California, and presumably most of the world, the frequency of grid power is well-controlled and so this is not an informative factor for field measurements. The geographic location of measurements should be recorded so that the frequency (50 Hz or 60 Hz) a particular measurement was taken at can always be ascertained.

In IEC 62301, voltage and frequency are as specified by the manufacturer, though nominal combinations are provided for Europe (230 V, 50 Hz), North America (115 V, 60 Hz), Japan (100 V, 50/60 Hz), and Australia/New Zealand (230 V, 50 Hz). The provided power is to be within 1% of the value intended for both voltage and frequency

There are no apparent complications introduced by products that use 230 V or even three-phase power, although it would require different metering equipment.

2.3.2 Power Quality

We do not specify power quality as the devices are to be measured with the quality of power typically found in houses, not in the controlled environment of a laboratory.

IEC 62301 specifies that the waveform is to be close to normal, with total harmonic distortion (THD) to be under 2%, specifying THD as covering up through the 13th harmonic. Note that this is the characteristic of the *supplied* power, not the power factor of the product itself.

For IEC 62301, the crest factor (a function of peak voltage) is to be within 5% of normal (between 1.34 and 1.49, since normal is the square root of 21.414). Note that a crest factor rating also applies to the capability of the measuring equipment. For field measurements, we simply need to report these values.

2.3.3 Physical Conditions

Temperature, Humidity, Air Speed

Most products are not known to be sensitive to air temperature or humidity. Some large copiers may be sensitive, particularly those with anti-condensation heaters that may be turned on (although whether they are actually used in machines in California is doubtful). Measurements made outdoors are the most likely source of values outside the target range, although those in attics or garages may also see more extreme temperatures.

It seems likely that few, if any, products will be affected by air speed and temperature (at least within ordinary ranges) in low-power modes. IEC 62301 specifies that air speed is to be ≤ 0.5 m/s and temperature to be 20 ± 5 °C (68 ± 9 °F), preferably 20 °C.

Ambient light

No products are known to be sensitive to ambient light levels in low-power modes, although those with light sensors (e.g., for outdoor lighting or possibly nightlights) or photovoltaic cells (if any have these in addition to mains power) might be. IEC 62301 refers to possibly recording ambient light, but specifies no limits or measurement procedures.

2.3.4 Accuracy

Power measurement accuracy can be specified in absolute terms or as a percentage of the reading. For measurement of power, IEC 62301 refers to IEC 60050.[5]

IEC 62301 recommends that measuring equipment have a resolution of 1 mW or better, be able to handle a crest factor of at least 3, and a minimum current of 10 mA (80 mW at 120V). Accumulated energy should be reported to at least 0.1 mWh.

Table 3 shows the energy use accumulation for several constant power levels over several time periods. If we assume 20 devices per house and that all have the error in the same direction, the error from an accuracy of 0.01 W is 2 kWh. Out of a likely per-house average low-power consumption of at least 70 W (Meier, 2002), this is an error of about 3%.

Table 3. Annual, 5-minute, and 30-second energy use of several power levels

Power Level	Annual Energy	5-minute Energy	30-second Energy
10 W	88 kWh	830 mWh	83 mWh
1 W	8.8 kWh	83 mWh	8 mWh
0.1 W	0.9 kWh	8 mWh	0.8 mWh
0.01 W	0.1 kWh	0.8 mWh	0.1 mWh

Our choice of accuracy criteria is perhaps colored by the capabilities of our metering equipment, as the new PLM 1-LP does not meet the resolution/reporting for watts or accumulated energy specified in IEC 62301, missing each by a factor of 10. However for our purposes this does not seem to be a problem.

IEC 62301 notes that one should be alert for asymmetric currents (not equal in positive and negative), which are DC loads supplied by AC. None of the other test procedures mention this issue. Asymmetric currents may appear only rarely. Some meters are incapable of measuring them.

2.3.5 Equipment

2.4 Measurements

2.4.1 Configuration / Controls

Power conditioning devices (power strips or UPSs) may alter the voltage and waveform the product sees. Therefore, in principle the meter should be plugged into the power

[5] IEC 60050 is a general review of terminology covering many topic areas. This reference is probably to 60050-300: International Electrotechnical Vocabulary - Electrical and electronic measurements and measuring instruments - Part 311: General terms relating to measurements - Part 312: General terms relating to electrical measurements - Part 313: Types of electrical measuring instruments - Part 314: Specific terms according to the type of instrument.

conditioning device(s), not just any household outlet. However, this complicates the measurement process and in the absence of evidence that this factor is significant, the only requirement is that the product be metered with power from the site.

IEC 62301 is typical for how to configure the product being tested. The product is to be configured per the *manufacturer's instructions*, or in the absence of those, at the *default settings*, or if not ascertainable, *as found*. The only other possibilities mentioned in the test procedures is when specific settings (e.g., maxima) or output criteria (e.g., display luminance) are specified. For battery-operated products, it is expected that the product will be removed from the charger, presumably on the assumption that the removed state will occur frequently enough to be significant.

Connections can be relevant by their existence, the electrical details (e.g., supplied power), and in information transmitted across them.

IEC 62087 provides an example of the most detailed configuration specifications, partly because it includes measurement of the products in their active modes. Many of these specifications will usually not affect low-power mode energy consumption, but as it is not certain what may influence low-power mode consumption (for all products now and in future), the procedure will need to at least consider specifying these types of details, and reporting on them for field measurements. IEC 62087 specifies the *content of input signals* (audio and video), *output signal electrical characteristics* (e.g., speaker power), *output content characteristics* (e.g., display light intensity), and *functional configuration* (e.g., that a wide-screen TV should be tested in its wide screen mode). These types of configuration settings are necessarily specific to certain types or types of products.

The "information environment" that products exist within is an increasingly important factor in energy consumption as products and devices affect each other's behavior and hence energy consumption. Examples are a fax connection to a phone line, a printer to a computer, a computer to a modem or router, and a set-top box to a content source (cable or satellite).

Measures of active power should be done with a "constant media object." For example, the same DVD should be used in all DVD players, or the same image burned onto a CD in CD recorders. There may be more than one instance of the media object, but they should contain identical information. For low power measurements, the media object should not be a factor.

For field measurements, changing configuration can be problematic as the user may not want the configuration to be tampered with and there is the risk of not being able to get it back to the proper configuration. It is best for testers to conduct evaluations "as-is" as much as possible, but record all configuration parameters that are be known to (potentially) affect the power levels of interest. Exceptions to this may be necessary, such as when the ability to go into some states is disabled by the configuration, since one of the uses of the data is to estimate what the savings would be if the product *was* enabled to power manage more.

Products may have long delay times before some low-power modes are entered. In some cases, these delay times may be temporarily reduced by changing the configuration, but in others, it may preclude some modes from being tested at some sites.

What conditions affect the power consumption of products in different low-power modes, and what standards to use for these are empirical questions that we will only be clarified through testing of products or through conversations with manufacturers.

2.4.2 Unknown Product Types

IEC 62301 specifies that for making measurements, it is understood that the product may have many power modes and that it may take some time for it to settle into the "standby mode." It is understood that the person making the test may not have documentation describing all the modes or how they are entered.

2.4.3 Procedures

Initial studies of standby power generally used the "plug in and count to 5" method of getting power values. This works for many product types, and was sufficient for that early work, but not always for present-day uses, particularly standards.

Other procedures stipulate different timing specifications. For IEC 62087, the tester is to wait for 15 minutes after entering any mode before making the measurement. For IEC 62018, one is to wait not less than 1 minute. For Energy Star monitors (the 2003 specification), *active* power measurements are to be made after a 20-minute wait for "warm-up." For Energy Star TV/VCRs, the product is to be allowed to stabilize before taking *active* power readings, usually about 90 minutes. The DOE TV test procedure states that one should wait for 5 minutes before measuring active power, and 2 minutes before measuring standby power.

In IEC 62301, stable power consumption is defined as not varying by more than 1% over a 3-minute period. The product is put into its standby mode, then observed for 5 minutes to assess its stability. A reading is taken and a further 5 minutes of observation is performed to assure continued stability.

In the assessment of cycling, we implicitly assume that the cycling will be regular enough that a single or modest number of cycles will be sufficient for analysis. Some cycling is due to a preprogrammed activity such as periodically checking sensor status. In other cases, it is based on thermostat activity, such as the temperature of a fuser roll, and this is likely to be different immediately after entering a low-power mode than it is for a longer period of time. How to determine when cycling is regular and stabilized is also a matter for empirical testing.

For cycling products, under IEC 62301, the measurement simply needs to capture one or more cycles.

Roberson (Roberson et al., 2002) provides a metering protocol for PCs and displays. The display protocol requires a PC to put the display into low-power states (for many displays, the sleep mode can be engaged by simply unplugging the data cable, but this should not be relied on to be always true). The PC's power management settings are to be recorded, as it may be necessary to enable power management (if it is disabled), and to reduce delay times to shorten the test. Power readings are taken no earlier than 15 seconds after the mode is entered, and must be stable for at least 30 seconds thereafter. Each automatic low-power level is to be measured separately, as is each manual low-power state (e.g., manually selecting sleep from an on-screen menu) even if it corresponds to an automatic state. Notebook PCs are to be measured with the battery either fully charged, removed, or disconnected, so that battery charging is not included in any of the measurements.

IEC 62301 notes that it may take some time for a product to settle into the “standby mode.”

At the conclusion of the test, it is recommended that the product be returned to its initial configuration and setup, unless the user requests otherwise. Power loss while plugging the device into the meter may result in loss of the current time or other settings. These should be restored.

2.4.4 Usage

Usage is a combination of product characteristics, the usage environment, and the user. Some products, like smoke detectors, have a clear profile of use regardless of the user (presuming they are connected to the mains at all). Others, such as computers, vary widely with the user.

2.5 Reporting

2.6 References

International Electrotechnical Commission, IEC 62301 Ed 1: Measurement of Standby Power, IEC TC 59, TC59, Working Group 9 59/297/CD Household Electrical Appliances.

International Electrotechnical Commission, IEC 62018 Ed.1: Power consumption of information technology equipment - Measurement methods, (draft of 3/28/2003),

International Electrotechnical Commission, IEC62087, “Methods of measurement for the power consumption of audio, video and related equipment,” 2002-03.

Rosen, Karen B., Alan K. Meier, and Stephan Zandelin, Energy Use of Set-top Boxes and Telephony Products in the U.S., Lawrence Berkeley National Laboratory, June 2001, LBNL-45305.

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Appendix III: Whole-house Low-power Measurement Protocol[6]

1.0 Scope

The purpose of this procedure is to measure the electricity use and other characteristics of many products in homes. These data inform estimates of the current energy consumption of such products in low-power modes, and potential savings. The protocol provides a snapshot of total house low-power mode consumption, audits of the presence, usage, and characteristics of relevant products and for measured products, power levels consumed in each low-power mode. This protocol is to be used in conjunction with the "General Measurement Protocol For Equipment In Low-power Modes" (the "General Protocol"), which specifies how to measure each individual product.

2.0 Terms

The terms defined below are used throughout this protocol. Some terms are also found in the General Protocol, and such text is underlined to show the linkage.

Site

The housing unit being measured, usually a single-family house (attached or detached), but can also be a condominium, apartment, or mobile home.

User

The person at the field site who resides there or is otherwise responsible (e.g., a homeowner). For some products at the site, this person's knowledge may be incomplete; it may be another occupant who is really the "user" of the product.

Tester

The person (or people) conducting the measurements and recording the results.

Product

A piece of equipment that can be powered directly from mains power and therefore can be measured according to the General Protocol.

Low-power mode

A product in a low-power mode is not performing any of its principal functions.

Power Status

[6] This procedure was developed to be used in conjunction with the individual product procedure but was not shown to be effective in practice.

The power status of a product can often be reduced to forms of *on*, *sleep*, or *off*. However, many products have specialized modes, such as *on-ready*, *on-active*, battery charging, and error modes.

Product Type Classification

Products types are categorized as one of four types for the likelihood of having low-power modes as defined in Table 1.

Table 1. Attributes of Product Types

Product Type Classification	Characteristic	Examples
Always	Always (or nearly always) have low-power modes.	Cordless telephone
Sometimes	Some examples have low-power modes; others do not.	Floor fan, ceiling fan, radio
Never	Never have low-power modes	Corded power tools
Excluded	Not included in this measurement procedure, regardless of whether or not they have low-power mode consumption.	Refrigerator

Imputed Product

A product deemed too difficult to measure at a particular site. The two most common reasons are that they are either hard-wired or problematic to disconnect (e.g. security or medical equipment). Power consumption by mode, and even the modes that exist, are estimated from sources exogenous to the site.

Power conditioning device

A device that alters the power delivered, other than simply turning it on or off. The most common examples are surge protectors (usually found on power strips) and uninterruptible power supplies. Power conditioning devices always consume some power themselves, even in a no-load situation.

Power control device

Any external switch that controls the supplied power such as switched outlets (not including circuit breakers in main electrical panels or subpanels), timers, power strips with switches, power-line carrier (PLC) controls, occupancy sensors, and daylight sensors. Power control devices can consume power themselves (e.g., some types of switches and some power strips), but some do not.

3.0 Conditions

3.1 General Conditions

While the whole house consumption is being measured, neither the user, tester(s), nor anyone else shall actively use any product.

3.2 Equipment

All of the equipment specified in the General Protocol is needed. In addition, the following equipment is often useful in collecting these data: flashlight, extension cords, multi-outlet power adapter, cut extension cord (plug on one end, wires on the other), wire nuts, wire stripper, electrical tape, screwdrivers, 15 A power meter, mirror, recording system for characteristics data, e.g. paper or a notebook computer.

4.0 Measurement Procedure

The procedure includes 6 steps:

1. Review products and record status.
2. Measure each product.
3. Assess remaining products and summarize.
4. Power down products that are *on*.
5. Measure whole house consumption.
6. Restore site conditions.

Throughout the procedure, unless otherwise noted, "products" does not include "excluded products."

4.1 Review products and record status

First, record the information as described in Section 5 (or new section number)

Explain the procedure to the user, so that the user can be of more assistance in locating products.

With the user, assess every room of the site, including basements, attics, garages, and any auxiliary rooms such as mechanical closets that may have relevant equipment. Equipment to look for that may be difficult to find include transformers for doorbells, thermostats, or HVAC controls (the latter two may be powered by the furnace), sprinkler alarms (fire sprinklers), irrigation timers, and garage door openers. Inspect the outside of the house and landscape. Assess all circuit breaker boxes, looking for GFCI circuit breakers, clues to products present at the site, and breakers to turn off products not readily turned off otherwise (e.g., hardwired or difficult to get to the receptacle as with some refrigerators and dishwashers).

Products to include in the measurement are:

- Products that are plugged in, but switched off by a power control device.
- Products that are not plugged in, but have been used in the previous 12 months.
- Products that are on all the time, such as some aquarium pumps, night lights, clocks and clock radios.

Products to **not** include in the measurement are:

- Products that are not plugged in at all and have not been used in the previous 12 months.
- Products that have never been used.
- Products with an "excluded" product type classification. A principal example is refrigerators, since their cyclical activity makes separating out their low power mode consumption difficult.

If a refrigerator cannot be unplugged or turned off at a circuit breaker, then the temperature controls should be set to minimize the likelihood that it will cycle on during the whole house measurement. Before changing the controls, record their setting to allow them to be restored at the conclusion of that measurement.

If not completely clear, record everything that seems potentially relevant to determining the power mode such as switch positions, indicator light status, noise, display contents, etc. The examination in Section 4.4 may clarify the state. Ask the user about usage patterns as indicated by the General Protocol.

Count the number of each type of power conditioning and control devices, such as:

- GFCI outlets (not downstream outlets controlled by a GFCI outlet),
- GFCI circuit breakers,
- Photocell or photocell/motion exterior lights, and
- Clock timers and electronic timers.

Note and count all power control devices that consume power including lighted hard-wired switches and electronic timer switches. Power conditioning and control devices that are readily measurable should be measured as products.

4.2 Power down products that are *on*

For products with a product type classification of "always" or "sometimes" that are *on* (e.g. in a ready or active mode), place them in any low-power mode. Products that are "never" or "excluded" should be turned *off*.

4.3 Measure whole-house consumption

Observe the main house meter and record the time required for one full disk revolution. If less than 8 minutes, wait for additional revolutions to complete until the time exceeds eight minutes and calculate the average time for one revolution. Find the "Kh" value on the meter face. From the eight minutes of observation, calculate the time (in seconds) for a single complete revolution of the disk. Calculate the average power as:

Power (W) = kH x 3600 / Time

See Appendix IV for an explanation of the method.

Photograph the meter. Photograph the entire house from the front.

4.4 Measure each product

Measure each product identified in Section 4.1 according to the General Protocol *unless* the testers determine that it is unnecessary or infeasible. When duplicate products (the same model) are found at the site, identical models can be measured once if there is no reason to believe they function differently.

Some products may be not be practical to measure due to the need to disconnect hard-wired products, which the user or testers may object to, or because it would be too disruptive to unplug, such as a security system or some medical equipment. Products may also be infeasible to measure if the plug is inaccessible.

Products that are not measured are then imputed products for their power consumption levels, but the characteristics data (such as brand and model) shall still be recorded.

For significant products that are otherwise not readily measurable, consider doing an additional whole-house measurement with a specific circuit breaker switched off, or with all breakers but the specific one switched off

4.5 Assess remaining products and summarize

Review the list of found products that were not measured or confirmed to have no low-power mode, and make a final determination as to whether these should be considered imputed or excluded products.

4.6 Restore site conditions

Put power cords (including power strips) back in their original outlet and location. Set the correct time on all devices that keep the current time and might have lost it. Examples include clocks, clock radios, timers, thermostats, and ovens. Turn circuit breakers and products back on that had been turned off earlier.   Restore temperature settings in refrigerators if they were changed.

5.0 Reporting

5.1 Site data

User name and contact information

Address (street, city, zip code)

Original construction date (may be estimated and presented as within a decade, e.g., the 1930s)

Number of full-time occupants

Approximate floor area (to nearest one hundred square feet)

Date(s) of measurement

Comments (e.g. difficulties in measurement, peculiar or notable conditions)

House meter reading

List and count of products measured that have no low-power consumption but are in the "sometimes" product type classification.

5.2 Results for each measured product

Power mode as found

General Protocol results

5.3 Results for each non-measured product

Power mode as found

General Protocol information other than power level measurements

5.4 Interpretation results

Calculated power from house meter reading(s)

Total of each product measured in the as-measured mode

Total of each product measured in the as-measured mode plus the power for imputed products.

Estimated annual low-power consumption of each product based on its measured power levels and the usage patterns as specified by the user.

5.5 Use of data

The user name, contact information, and street address shall generally not be made public.

Appendix IV: Whole-house Low-power Measurement Protocol — Rationales and Discussion[7]

1.0 Scope

Unlike measurements of whole-house standby consumption, the whole-house low power figure is not directly of great interest, but rather a tool to cross-check the data collected. The results that are of most interest are the power measurements for individual products, the inventories of products present, and usage pattern information.

Later modifications of the scope could extend it to multi-family buildings, by also assessing common area consumption, and to commercial buildings.

2.0 Terms

User

For some products at the site, this person's knowledge may be incomplete as it may be others who live there who are really the "user" of the product.

Product Type Classification

A principal reason to exclude refrigerators is that the whole house measurement relies on modes being stable, and the cyclical nature of refrigerator operation makes this infeasible. In addition, the sudden surge in consumption when a refrigerator does cycle on may exceed the capability of many power meters used to measure low power modes accurately.

3.0 Conditions

3.1 General Conditions

3.2 Equipment

For assessing characteristics of devices, a tape measure is needed for measuring some products such as displays. A flashlight is often helpful for reading product characteristics in dark places, and a mirror can be of help in seeing specifications or power cord arrangements on the back of large or heavy products. Also, screwdrivers may be needed for opening product cases.

[7] This procedure was developed to be used in conjunction with the individual product procedure but was not shown to be effective in practice.

As one moves around the site, it is helpful to have several extension cords and multi-outlet power adapters to allow the meter and recording equipment to be moved close to the products being measured.

For disconnecting hard-wired products, screwdrivers are usually needed. For measuring the power used by hoard-wired products, it is simplest to utilize a cut extension cord (plug on one end, wires on the other) along with wire nuts, a wire stripper, and electrical tape.

A 15 A power meter is used to check high-power products for suitability of use of the high-accuracy meter (which may have a much lower maximum current rating).

For a recording system for characteristics data, a notebook computer is highly recommended.

4.0 Measurements

The procedure's six steps are in brief:

1. **Review products and record status.** With the user, inspect the entire house for two types of products: those products that *may* have low-power modes and those of the remaining products that are *on*. Record the power status of each product found. Ask the user about usage.
2. **Measure each product.** Apply the General Protocol to each readily measurable product.
3. **Assess remaining products and summarize.** For imputed products, fill in the estimated mode power levels from other sources.
4. **Power down products that are *on*.** For those that are *on*, place them in the low-power mode with the highest consumption easily obtainable and stable — and consequently for those that lack low-power mode consumption, turn them *off*.
5. **Measure whole house consumption.** Observe the main house meter for 8 minutes, and record the average power shown over this period.
6. **Restore site conditions.** Restore product status and settings to the as-found mode unless instructed otherwise by the user.

There are three other known measurement procedures for whole house standby power: Ross and Meier (2000), Sidler[8], and Murakoshi. We do not know of any publication of the Murakoshi procedure.

For the Ross and Meier study, the general procedure was to: survey all "appliances," measure each one's standby power, then measure the whole house with everything switched off. Standby in this case is lowest power while connected to the mains. However, computers were measured in their "most frequently used" mode. For cordless phones, the handset was "removed from the charger". Every product was also photographed. The whole-house reading

[8] While the Sidler study includes a whole house measurement procedure, we do not have a copy of it.

was taken for eight minutes from the house meter. When the two measures had a "large discrepancy", a search was to be made for further loads. Regardless, the two readings should be an upper and lower bound of the true answer.

4.1 Review products and record status

It may be useful to track single mode "always-on" products (e.g. clocks and nightlights) separately from those products with multiple power modes (some of which are low-power modes).

4.2 Power down products that are *on*

It is not critical which low-power mode is used for the whole house reading so long as it is recorded which mode each product is in, since it is the usage patterns along with all power levels that determine annual consumption.

4.3 Measure whole-house consumption

For some hardwired products, turning off entire circuits with a circuit breaker (or fuse if the house wiring is old enough) could be used to estimate these by subtraction, but it can be difficult to know with confidence what is on a particular circuit, and this could inadvertently interfere with the operation of some products.

If the whole house consumption is so low as to make the utility meter inaccurate, then a known load can be added to the house consumption, then subtracted from the measurement indicated by the meter.

4.4 Measure each product

For assessing the whole house consumption, the method of tracking the spinning disk on the main house meter (assuming they are of that type) is attractive as it avoids opening up the breaker box and getting current transformers on house wires and making a voltage tap (with unknown liability and safety issues). Many users will also be more comfortable with the less-intrusive procedure.

Harrington, 2002 reports experience with a spinning disk meter in Australia. He found that it was consistently unreliable for measurements of about 5 W and below, and reliable for several measurements taken at 13 to 50 W. This suggests that for a typical house with expected standby levels of 40 W or more (per Ross/Meier), disk meters may be adequate, for the total, and for taking differences as when a circuit with a hard-wired product is turned off. The meter itself was measured to consume 1.16 W. Further details on spinning disk meters can be found at: http://standby.lbl.gov/Measuring/electrometer.html (see Figure 1). Some digital meters mimic the spinning of a disk with a set of small indicator lights.

4.5 Assess remaining products and summarize

4.6 Restore site conditions

5.0 Reporting

It is best to put all resulting data in electronic tabular format such as a spreadsheet provides, for later summary and analysis.

5.1 Site data

5.2 Results for each measured product

5.3 Results for each non-measured product

5.4 Interpretation results

Non-metered consumption

This procedure does not capture all electricity use in houses. There are energy losses in the wire resistance within houses, and in extension cords. The house meter itself also consumes some power — another example of hard-wired standby. Excluded products may have low-power mode consumption that is should otherwise be included in the total derived by this procedure. The consumption of imputed products may vary to some degree from the power levels imputed. The consumption of the meter itself may or may not be included in the consumption it reports.

LBNL owns some traditional spinning disk meters (the brown box meters). They do not register at 1 W total power. They measure marginal power over some base load. The "Handbook of Electricity Metering" lends insight. A typical Class 200, 1970-era meters (probably current) register very accurately (less than 1/4% error) down to 1.0 A, then ramp up to over-register about 3% over at about 0.3 A, then decrease to under-registering by 2% at about 0.2 A, where the curve (a straight line at this point) ends with a slope of about 15% error per Amp. The curve is non-linear below that. At some point, that energy is implicitly too cheap to meter! It is not clear if the data are even gathered by the manufacturers beyond a 2% error.

6.0 References

Handbook for Electricity Metering, Edison Electric Institute. 1981

Ross, J.P., and Alan Meier, "Whole-House Measurements of Standby Power Consumption", prepared for the Second International Conference on Energy Efficiency in Household Appliances, Naples Italy, September 2000, LBNL-45967.

Harrington, Lloyd, 'Comparative Energy Comparative Energy Measurements: digital power Measurements: digital power analyser versus electro analyser versus electro-mechanical rotating disk meter mechanical rotating disk meter", Energy Efficient Strategies, Australia, Presentation to Standby Power Forum, Sydney 2002. http://www.energyefficient.com.au/standby/forum.html

Figure 1. The Electromechanical Meter Page from Standby.lbl.gov (adapted)
http://standby.lbl.gov/Measuring/electrometer.html (accessed 9/18/2003)

Using an electromechanical meter to estimate leaking electricity

QuickTime™ and a TIFF (Uncompressed) decompressor are needed to see this picture.

All electromechanical kilowatt-hour meters have a rotating disk in them. The disk's rotational speed is proportional to the amount of electricity consumed. This disk turns even when very small amounts of electricity are being consumed. You can calculate the electricity use by timing the disk revolutions. The calculation requires the "Kh" value, which is the factor used to convert rotations into units of energy called watt-hours (Wh). On most US meters the Kh is 7.2 -- so each full rotation of the disk corresponds to 7.2 watt-hours of electricity. Most kWh-meters list the Kh on the front of the meter.

First, find the Kh value on the front of your meter and write it down. Then measure the amount of time it takes for the disk to make one complete turn. Write down the time in seconds. (Remember, there are 60 seconds in a minute, so multiply the number of minutes by 60 to get seconds.) Do this 3 or 4 times to ensure accurate results. Here's an example of what your measurements might look like. This meter's Kh = 7.2

Measurement	Time (for one rotation)	Power
#1	582 seconds	44.5 watts
#2	600 seconds	43.2 watts
#3	609 seconds	42.6 watts
#4	597 seconds	43.4 watts

Average standby power = (44.5 + 43.2 + 42.6 + 43.4) / 4 = **43.4 W**

Calculate the standby power in Watts for each measurement. The formula is:

Watts = Kh (watt-hours) x 3600 (seconds/hour) / Time (seconds)

For example, if your Kh factor is 7.2 and the disk takes 10 minutes (or 10 x 60 = 600 seconds) to go around once, then the total leaking electricity is:

7.2 Wh times 3600 seconds/hour divided by 600 seconds, or:

7.2 x 3600 / 600 = 43.2 watts

Add all the watts and divide by the number of measurements to get an average value for leaking electricity in your home.