Arnold Schwarzenegger
Governor

Developing and Testing Low Power Mode Measurement Methods

PIER FINAL PROJECT REPORT

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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)

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.

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 II: TEST AND MEASUREMENT PROCEDURES FOR LOW POWER MODES

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

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

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

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