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LOW-POWER MODE ENERGY CONSUMPTION IN CALIFORNIA HOMES

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Preface

The California Energy Commission's 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 conducts public interest research, development, and demonstration (RD&D) projects to benefit California.

The PIER Program strives to conduct the most promising public interest energy research by partnering with RD&D entities, including individuals, businesses, utilities, and public or private research institutions.

- PIER funding efforts are focused on the following RD&D program areas:
- Buildings End-Use Energy Efficiency
- Energy Innovations Small Grants
- Energy-Related Environmental Research
- Energy Systems Integration
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- Industrial/Agricultural/Water End-Use Energy Efficiency
- Renewable Energy Technologies
- Transportation

Low-power mode Energy Consumption in California Homes is the final report for the Standby Power Consumption Phase 3: Research Into Low-power modes project (Contract Number 500–99–013, Task Order 20–5, Amendment 2), conducted by Lawrence Berkeley National Laboratory. The information from this project contributes to PIER's Buildings End–Use Energy Efficiency Program.

For more information about the PIER Program, please visit the Energy Commission's website at www.energy.ca.gov/research/ or contact the Energy Commission at 916-654-4878.

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Abstract

Many electrical devices in homes continue to draw power when switched off or not actively performing their primary function. These devices include familiar appliances, such as televisions, microwave ovens, computers, set–top boxes, mobile phone chargers, and video and audio components and less familiar devices, but also less obvious devices like dishwashers, gas water heaters and smoke detectors. The energy use of these devices while in their low-power modes is now about 980 kilowatt hours per year (or 112 watts) per home in California, corresponding to about 13 percent of total residential electricity use in 2006. If treated as a separate end use, low-power mode energy use is the fourth largest residential end use. The low-power mode electricity use of these devices is likely to grow as consumers purchase more products with low-power modes and will soon exceed 132 watts as a consequence of firm trends and building codes.

Many of these products fall into a new category of devices whose primary function is related to information processing, storage, and transmission. About half of the electricity in this electronics end use is consumed in the low-power modes.

Keywords: Appliances, behavior, building codes, computers, efficiency, electricity, electronics, energy, idle, low-power modes, networks, new homes, ready, set-top boxes, sleep, standby power, televisions, white goods

Executive Summary

This project estimated low-power mode energy use in California homes. Nearly all new electricity-consuming products—TVs, computers, set-top boxes, audio components, coffee makers, garage door openers, and dishwashers—have one or more low-power modes. Earlier estimates suggested that these low-power modes were a significant and rapidly growing use of energy. However, most of the studies were limited to narrow groups of products or relied on instantaneous measurements and could not give a definitive estimate of the total energy consumed. This study estimates that the average California home uses 112 watts, or about 13 percent of its average electricity use, for products in their low-power modes.

Approach

To accurately estimate low-power mode energy use, researchers collected data on more than 170 types of electricity-consuming products. Some products were familiar, such as VCRs, microwave ovens, and computers, but others were not previously carefully investigated, such as tankless water heaters, controls for heating systems, toaster ovens, modems, and compact audio systems. Each product had one or more low-power modes and, for each mode, researchers estimated:

- The functionality associated with the mode.
- The average power use (in watts, W) of that mode.
- The fraction of time the product resided in that mode, as well as the average time which consumers unplugged (or otherwise disconnected) the product.

Researchers also estimated the saturation of each product in California homes, considering that for some product types, only some models have low-power modes.

The identification of modes and their power use mostly relied on measurements of products in 75 homes. Even though about 2000 products were measured, researchers still needed to draw on other sources, such as a large monitoring study in Australia, independent studies of specific products, earlier work for the California Energy Commission, and technical literature. Usage patterns were based on a telephone survey of 306 homes, detailed analyses of long–term measurements, data and technical literature about specific products. For saturations of products, the study again relied on the telephone survey, utility surveys, and estimates by trade associations. Researchers considered nearly 200 different types of products and undertook a complete analysis for 170. The sources were sometimes contradictory, were based on limited data, or used different definitions. Researchers were usually able to reconcile the differences and estimate reasonable values for California. Finally, the study explored the sensitivity of the results to the most likely kinds of errors.

Key Results

For 2006, the average low-power mode use in California was estimated to be 112 watts per home (or about 980 kilowatt-hours per year). This is roughly 13 percent of residential electricity use. If low-power mode energy use were treated as a unique end use, it would rank fourth

above air conditioning, miscellaneous, and pools and spas. The results are summarized in Table 1.

Table 1. Summary of key results

	Power (W)*	Products/home
2006 low-power mode energy use per home	112	44
With products in lowest power mode ("standby")	54	44
New, *unoccupied*, homes low-power mode	117	38
Future, including only most certain trends	132	59

* To convert power, W, into kWh/year, multiply power by 8.76

Source: Lawrence Berkeley National Laboratory

The average California home has about 44 products with one or more low-power modes. Four categories are responsible for about half of the total energy: set-top, audio, video, and display. The electronics end use—products whose principal function is processing information—accounts for about 85 percent of low-power mode consumption. Figure 1 shows the breakdown by category.

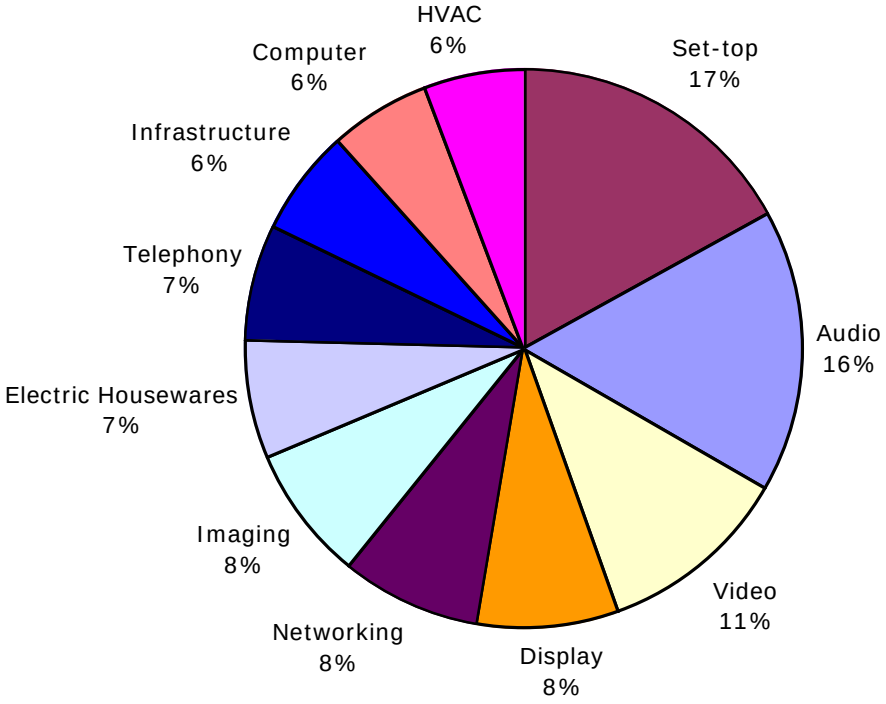

Figure 1. 2006 Low Power Mode Energy Use by Category

Source: Lawrence Berkeley National Laboratory

The ten largest contributors to low-power mode energy use are shown in

Table 2. Together, they are responsible for 40 percent of total low-power mode energy use, while the remaining 160 product types examined are responsible for 60 percent. Note that eight of these 10 are electronic product types.

Table 2. Top 10 Low-Power Mode Product Types

Product type	Average low-power mode energy per home*		Fraction of total low-power mode Use
	Energy (kWh/year)	Power (W)	
Set-top box, satellite	58	7	6%
Set-top box, digital cable	50	6	5%
Television, CRT	47	5	5%
Video, DVR	38	4	4%
Audio minisystem	38	4	4%
Computer, desktop	37	4	4%
Receiver (audio)	33	4	3%
Phone, cordless	33	4	3%
Air conditioning, central	27	3	3%
Oven, microwave	26	3	3%
Total of top 10	**387**	**44**	**40.00%**

* Displayed values reflect saturations of the products in the homes (for example, a single satellite set-top box uses far more energy than displayed but only a small fraction of homes have this device).

Source: Lawrence Berkeley National Laboratory

A common definition of standby power is the lowest power use of a device while still connected to the power source. In California homes, this mode equals about 54 watts. The other low-power modes typically have somewhat greater functionality (but still less than fully active) and account for 58 watts. Thus, low-power mode energy consumption is evenly split between the lowest and the higher modes.

Low-power mode energy use will increase in the future. Researchers did not create a full scenario but instead explored the energy effects of several trends that are almost certain to continue. The researchers did not assign a specific period for this exploration of future energy use, but it represents what will most likely occur in 1015 years. Overall, these trends reflect a greater fraction of products having low-power modes and, to a lesser extent, new product types with low-power modes. Researchers found that the average home's low-power mode energy use would climb, at a minimum, 18 percent to 132 watts (or 1,160 kilowatt-hours per year). The number of products with low-power modes would increase 34 to 59 percent.

The researchers also intensively examined eight new, unoccupied homes. They found that equipment installed by the builder—garage door openers, security systems, smoke detectors, built-in communications components, remote–controlled gas fireplaces, fans, and so forth—led to an average low-power mode consumption of 117 watts (1,020 kilowatt-hours per year), which is more than the estimate for current *occupied* California homes.

Recommendations

The recommendations are divided into three categories: research, market and technology surveillance, and regulation.

Research recommendations include:

- Develop networks, protocols, and network interface devices that minimize low-power mode energy use.
- Develop technologies to reduce low-power mode energy use in set-top boxes, tankless water heaters, and HVAC controls.
- Develop technologies to reduce low-power mode energy use in smoke detectors, ground fault interrupt breakers and other "hard-wired" applications.
- Investigate the potential low-power mode impacts of electric vehicles.
- Investigate the ways in which behavior can affect low-power-mode energy use.
- Establish a research center to investigate technologies to reduce energy use in electronics.

Market and technology surveillance recommendations include:

- Undertake regular surveillance of new products and meter their power use in all modes. Periodically measure low-power mode (and active mode) electricity use in a sample group of California homes.
- Establish a website to display measurements from this study and future measurements.
- Revise residential appliance surveys to capture more information about presence of products with low-power mode energy use.

California may wish to explore regulations when other policies to reduce low-power mode energy use are not effective. Three examples are:

- Accelerate modification of energy test procedures for white goods[1] and HVAC equipment to capture low-power mode energy use.
- Consider requiring the installation of the auto power–down feature in products beyond set-top boxes
- Regulate the efficiency of electricity consuming devices that are required by building codes or typically installed by builders in new homes.

1. White goods comprise major household appliances and may include air conditioners, dishwashers, clothes dryers, freezers, refrigerators, water heaters, washing machines, and microwaves.

Benefits to California

Listed below are the short-term direct benefits to California from this research:

- The residential low-power-mode field measurement research focuses on the growing proliferation of plug loads in California and the associated energy use of these plug loads.
- It allows policy makers and utilities to determine policy and program priorities for low-power-mode plug loads.
- Disseminating project findings at a variety of industry meetings, utility forums, and via the project websites enables stakeholders to learn more about the research. This outreach benefits the Energy Commission, particularly when it makes policies.

1.0 Background to This Report

1.1. Technical Origins of Low-Power Mode Energy Use

In the mid 1990s, several researchers noticed the rising amount of electricity consumed by appliances that were either switched off or not performing their primary function (Meier 1993; Sandberg 1993). "Standby power" is the best-known term used to describe this phenomenon but many other terms were used, phantom loads, leaking electricity, and off–mode power consumption. This electricity consumption was often needed to power internal clocks, infrared receivers (for remote controls), digital displays, or other electronic components. In other cases, the standby power use simply energized power supplies, low voltage switch power switches, and circuits that were expected to do nothing.

These researchers estimated that standby power use was responsible for as much as 11% of residential electricity use in Australia, 10% in Japan, 5% in the United States, and over 5% in some European countries. Energy Star soon developed specifications to reduce standby power use in televisions and VCRs, European manufacturers voluntarily agreed to cut standby in those products, and Japan established an aggressive program to reduce standby in all products (IEA 2001). Considerable progress has been made in reducing the standby power use in some products, especially in televisions, computers, and external power supplies. Notable power–saving innovations include the switch–mode power supply and improved techniques for power management. However, the number of products with standby power use began to grow rapidly; manufacturers wanted every product to have memory, keep track of the time, display information, or be able to act upon receiving a signal from a handheld remote control, a computer, or from a service provider. The savings achieved in some product types were offset by the increased volume of new products with standby; as a result, the total electricity consumed by products while not being used continued to climb.

As the products became more sophisticated and performed more services while "off," the problem of standby power use expanded to cover a range of low-power modes that were nevertheless clearly different in function from "active." There now exists a wide range of services performed while the products are not actively switched *on* ranging from *nothing* (beyond contributing waste heat to the space) to maintaining sophisticated communications to ensure security and continuity of communications links. The common feature of all these modes, however, is that they are not in an *active* mode, that is, performing a primary function (the television showing an image, the PC computing, the coffee maker brewing coffee, or the subwoofer pumping out music). These modes beyond standby have many names—sleep, active standby, hibernate, ready, etc.—but no other term effectively describes all the *non–active* modes as does "low-power mode." In this report we use the term "lopomo" to describe all of the non–active modes. Lopomo is a contraction of "Low-power mode."

The immediate goal of this project is to understand the scale of low-power mode energy consumption and, in future phases, to devise strategies to reduce it. There will also be circumstances where overall energy use is reduced while lopomo energy use is increased; this is the case when time in lopomos is increased because of a reduction of time in high–power, *active*

modes. The potential savings in the active mode (and the much smaller increase in lopomo energy use) are illustrated in Figure 2 for a personal computer. It shows that power management will reduce total PC energy use but lopomo energy use will increase slightly.

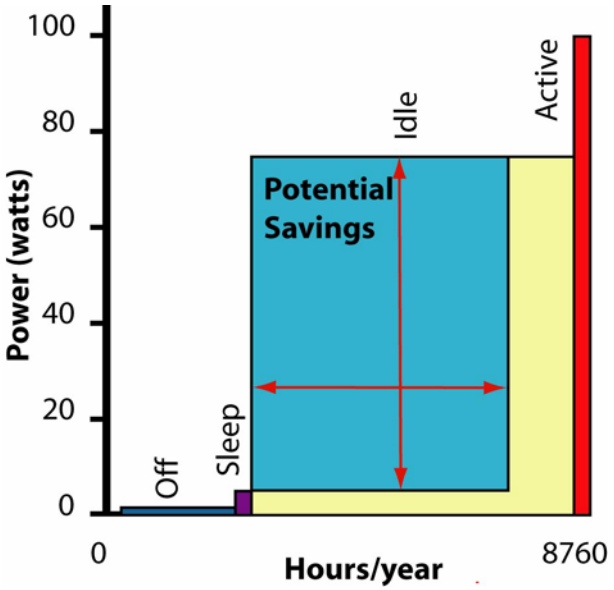

Figure 2. Potential Energy Savings by Shifting a Product's Mode from the Active Mode to a Low-power Mode (idle).

1.2. California Background to This Project

California has a tradition of actively promoting energy efficiency. Many different institutions have participated in these efforts, including governments (both state and local), utilities, and non-profit organizations. The programs have included voluntary efforts, financial incentives, and regulations. There has been an equally strong tradition to ensure that the programs undertake measures that reliably save energy and are cost-effective. These efforts have contributed to the stable consumption (on a per-person basis) of California's electricity use during the last thirty years.

In the residential sector, electricity devoted to some of the major traditional end uses has declined. Clearly new end uses, especially those related to consumer electronics, have risen dramatically. The phenomenon is particularly strong in California because average residential electricity use is already considerably lower than in most other regions of the United States. The percentage of electricity devoted to electronics and lopomo energy use is likely to be higher in California, both because of the smaller denominator and because higher personal incomes are likely to inflate purchases of these products. The 2001 electricity crises also caused a greater appreciation of the contribution of these new products to electricity demand.

But before establishing major new programs, it is important to understand where that electricity is being used today. This knowledge will assist in designing more effective efficiency programs and tracking their success.

1.3. Goals of This Project

1.3.1. Current Energy Use of Equipment in Their Low-Power Modes

The principal goal of this project was to estimate current lopomo energy use in California homes. The estimate applies to "circa 2006" because, while most of the data was gathered in 2006, we also relied on data from 2007, 2005, and earlier years.

1.3.2. Future Energy Use of Equipment in Their Low-Power Modes

A second goal of this project was to estimate future energy use. This goal was a lower–priority because it was recognized that substantial change is occurring within the low power modes. It was beyond the scope of this project to predict the changes that might take place in over one hundred different product types. Future refers to roughly ten years in the future, that is, about 2016.

1.3.3. Other Information That Will Aid Effective Policymaking

In the process of making these estimates, considerable data was collected and experience gained that will be useful to future research and policies. The data will also help forecasters and analysts understand energy consumption characteristics for specific products. For example, how many products in a typical California home have lopomo energy use? The *methodology* employed to estimate lopomo energy use is also important because its advantages and shortcomings (in terms of data sources and analyses) may help design more economical and accurate estimates of residential energy use. For example, how many products need to be metered and what are the key characteristics needed about each product? Information about how people use the products can give clues as to the potential energy savings from efficiency improvements and changes in behavior.

1.4. Earlier Phases in This Project

1.4.1. Phase 1: Workshop and Recommended Research on Low-Power Modes in California

This project had its origins in a workshop in August 2002 sponsored by the California Energy Commission and CIEE. The "California Energy Commission Standby Power Workshop" assembled researchers, industry experts, and policymakers. Through a series of presentations and discussions, the participants recognized the need for better technical grasp of the energy use of equipment in their standby and other low-power modes. This segment of electricity use appeared to be responsible for at least 10% of residential electricity use and growing rapidly. At the same time, the participants realized that effective policies would be impossible without better estimates of the amount of energy consumed by these products in California. The workshop recommended that the California Energy Commission undertake the necessary research to accurately estimate the energy use of both standby and other low-power modes in California (Meier 2002). This has been the goal of this project.

The term *lopomo energy use* also emerged from this workshop to more easily describe "low-power mode energy use".

Recommendations for further research based on the workshop and additional research were prepared. These recommendations included undertaking a major measurement program to better understand the size of lopomo energy use and the characteristics of low-power modes. However, the larger monitoring program was to be preceded by the development of measurement protocols and preliminary measurements to test those protocols.

1.4.2. Phase 2: Measurement Protocols

We identified key parameters (stocks, power levels, and usage patterns) which were required to make reliable estimates of lopomo energy use (Nordman and McMahon 2004). Based on these criteria, two test protocols for measuring low-power modes—in individual products and for whole houses—were developed. These protocols took into consideration broader, statewide data requirements as well as practical considerations of visiting homes and metering. Some of this information could be best collected through in–home measurements while other aspects were best collected through other means, such as a telephone survey, sales data, or utility appliance saturation surveys.

1.4.3. Lopomo Energy Measurements in Eight Homes

The two measurement protocols were field–tested in eight homes (Nordman and McMahon 2004). Over 280 products were intensively measured, yielding lopomo energy consumption data for 108 product types. Based on these measurements (and some external data on saturations of various product types) residential lopomo energy consumption was estimated to be about 108 W per home. This corresponds to over 900 kWh/year, or about 15% of statewide residential electricity consumption in 2004. Over two–thirds of low-power mode consumption was from electronic devices (audio video, information technology, and telephony). However, the results were tentative because of large uncertainties surrounding power measurements, usage periods, and statewide saturations of many products. This uncertainty supported further attempts to improve the accuracy and confidence of the estimate.

The sum of the measurements of the individual products was also compared to the whole–house measurement. This approach is much simpler; however, whole–house measurements did not correlate with the sum of measurements of individual products in the homes. Thus, only measurements of the lopomo energy use of each product would lead to an accurate estimate of the total.

2.0 Taxonomy of Products and Modes

In this phase of the project, the authors created a taxonomy of products and explored "builder–installed" miscellaneous electricity use in new homes. These were both preparatory steps to estimating statewide lopomo energy use.

2.1. Taxonomy of Products

Prior studies of "Other" energy use have usually been anecdotal, unsystematic, and *de novo*. Good policy and analysis has been hampered by incomparable and confusing data about products and modes. In the phase 2 study researchers laid out a scheme for terms about modes and other concepts; in this study the authors proposed a standard "taxonomy" of miscellaneous and electronic product types.

A "taxonomy" is defined (The American Heritage Dictionary of the English Language Fourth Edition 2004) as:

- The classification of organisms in an ordered system that indicates natural relationships.
- The science, laws, or principles of classification; systematics.
- Division into ordered groups or categories.

Energy analysis already has a taxonomy of major end uses. Researchers built on that to define two new end uses as well as categories within those. The overall structure is shown in Table 3, with the full taxonomy listed in Appendix B, page 1.

Table 3. Proposed Taxonomy Including Electronics and Miscellaneous End Uses

End use	Categories
Electronics	Audio, Computer, Display, Imaging, Networking, Peripherals, Security, Set–top, Telephony, Video
Miscellaneous	Business equipment, HVAC, Electric Housewares, Hobby/leisure, Infrastructure, Lighting, Major Appliances, Other, Outdoor Appliances, Personal Care, Power, Transportation, Utility, Water heating
Traditional	HVAC, Lighting, Major Appliance, Water heating

The new Electronics end use is defined as "Devices whose primary function is Information (obtaining, storing, managing, or presenting)." This combines Consumer Electronics and Information Technology (Office Equipment), as the distinction is increasingly difficult to make and less worth doing. The end use does not include electronic components in non–electronic products.

The Miscellaneous end use remains as everything not explicitly in one of the other Major end uses, but it also includes categories for overlooked product types which are those performing a function associated with a traditional end use but generally not included in analyses of those end uses. An example is the HVAC category in the Miscellaneous end use, which includes

devices like dehumidifiers, plug-in electric room heaters, etc. The Miscellaneous end use no longer includes Electronics.

In this report the authors distinguish between "product" and "product type":

> **Product.** A piece of equipment that can be powered directly from mains power. This covers a specific instance or model number.
>
> **Product Type.**[2] A general category of product within which there is a sufficient amount of common functionality, modes, and behavior.

The term "product type" is admittedly clumsy, so the authors use it only when the distinction is necessary.

In addition to the overall structure, researchers also developed "product naming principles" to impose some order on names for individual product types, as well as a list of names for products common in California residences.

Such a taxonomy is critically needed for researchers and policymakers involved in the Miscellaneous / Electronics area, and should save considerable time and reduce confusion. It is not intended for use by ordinary people or presentations where ordinary terms do not lead to confusion or ambiguity.[3] The taxonomy needs extension to the commercial sector with new categories such as medical equipment, retail display equipment, and cash exchange. The taxonomy needs to be a living document and be maintained and evolve over time (though who might do this is as yet unclear).

Other researchers (Nissen 2007; Roth and McKenney 2007) have already drawn upon this Taxonomy for classifying products under investigation.

For more detailed discussion of the taxonomy, its development, and related concepts, see the paper by Nordman and Sanchez (Nordman and Sanchez 2006).

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2. This is the core term of interest to energy professionals, e.g. "dishwasher" or "TV, CRT". Product types are differentiated by performance-related features that provide utility to the consumer and affect efficiency.

3. We have adopted the same approach here, that is, use "product type" where confusion or ambiguity may occur.

3.0 Builder-Installed Miscellaneous Electricity Use in New Homes

The purpose of this task was to investigate energy consumption of builder installed devices in new homes. This exploration served two purposes: it improved our understanding of the "Other" electricity use in new homes and the information gathered helped us estimate future lopomo energy use in California. This investigation addressed the following research questions:

- How large a part does builder-installed equipment play in electricity consumption in new homes?
- What types of devices are the highest users?

The following sections summarize the results. A detailed description is available elsewhere (Brown, Rittelman et al. 2006).

3.1. Selection and Methodology for Builder–Installed Products

Researchers gained access to eight models homes and five "inventory" new homes. Inventory homes include only the equipment and devices that would normally be in the home when sold to a homebuyer, whereas model homes include additional or optional devices (e.g., appliances, video and audio equipment) used to decorate the sales model for prospective homebuyers. In some cases models were elaborately "staged" and were equipped with premium grade appliances. The sample includes seven distinct floor plans from four different housing developments. Developments were selected to include a range of climate conditions even though so modest a sample could not be representative. The homes include a range of efficiency levels, from typical new construction in California to low-energy homes with photovoltaic (PV) systems.

In each home, researchers inventoried all of the electrical equipment they contained, plug-in or hardwired, and performed "spot" metering of plug-in devices to measure their power consumption. This covered devices in low-power modes in all cases and in active mode where possible. The inventory included recording manufacturer and model information where this was available so that for devices that could not be metered, manufacturer specifications could be looked up.

To estimate annual energy use for the inventoried devices, researchers used their measurements for power levels (supplemented by manufacturers specifications) and assumptions about time spent in other power modes using data collected in earlier studies. Energy use for lighting was not included in the consumption estimates, although lighting fixtures were inventoried. Excluding lighting from the consumption estimates was necessary because of the high degree of uncertainty in lighting usage estimate, and because most lights have no low power consumption. If lighting were included the active mode power consumption would be significantly increased.

3.2. Results

Not surprisingly, these new homes had fewer devices than found in occupied homes, and this leads to lower electricity consumption than they will eventually have. Figure 3 shows that consumption by these builder-installed devices is about 800 kWh/year (about 90 W) on average, with a range from 308–2460 kWh/year. The model homes had generally higher consumption than the inventory homes, and a much larger range. The average consumption for Models was 881 kWh/yr, and the range was from 390 to 2460 kWh/year. For inventory homes the average was 503 kWh/year and the range from 308 to 834 kWh/year. The two highest consuming homes both among the models and among the inventory homes were in a San Francisco Bay Area development. The high consumption is probably explained the developers targeting a higher income market segment. Home Model 1, in particular, was equipment with premium devices.

One of the main purposes of this study was to determine how much electricity is consumed in low-power vs. active modes. In these new homes, lopomo energy use accounted for about half of the electricity (54% on average) consumed by these devices (see Figure 3). The mean lopomo energy consumption of approximately 440 kWh/year translates to a continuous power draw of about 50 watts.

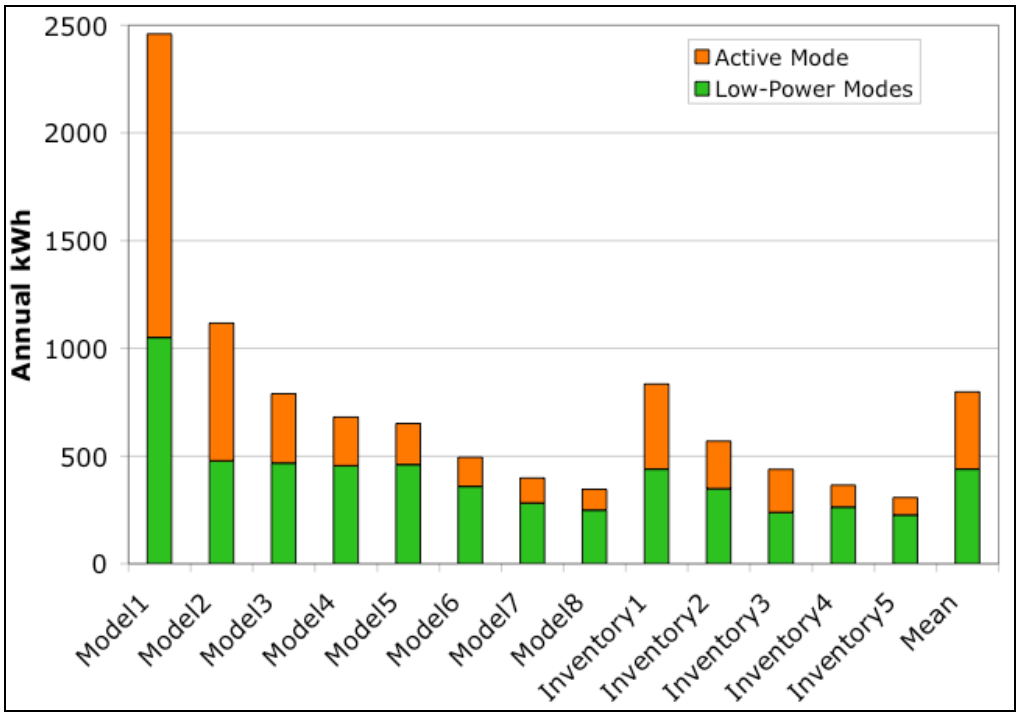

Figure 3. Annual Electricity Use by Builder-Installed Equipment in New California Homes, by Operating Mode
Source: Lawrence Berkeley National Laboratory

Figure 3 distinguishes "model" from "inventory" homes. Model homes have higher consumption than inventory homes (particularly house Model 1). To better understand the types of devices that account for the variation among homes, Figure 4 shows annual electricity consumption disaggregated by product type. Product types that figure prominently in Model

1's high electricity consumption include video (two large-screen televisions), networking (a structured wiring panel that draws 20 watts continuously to power three video security cameras and an internet router), infrastructure (a larger floor area leads to more GFCI outlets, smoke alarms, garage-door openers, bathroom fans, etc.), and appliances (a washer/dryer and very large refrigerator). Model 2 differs from the other homes mainly in that it includes video (a television) and water heating (standby power for an instantaneous gas water heater).

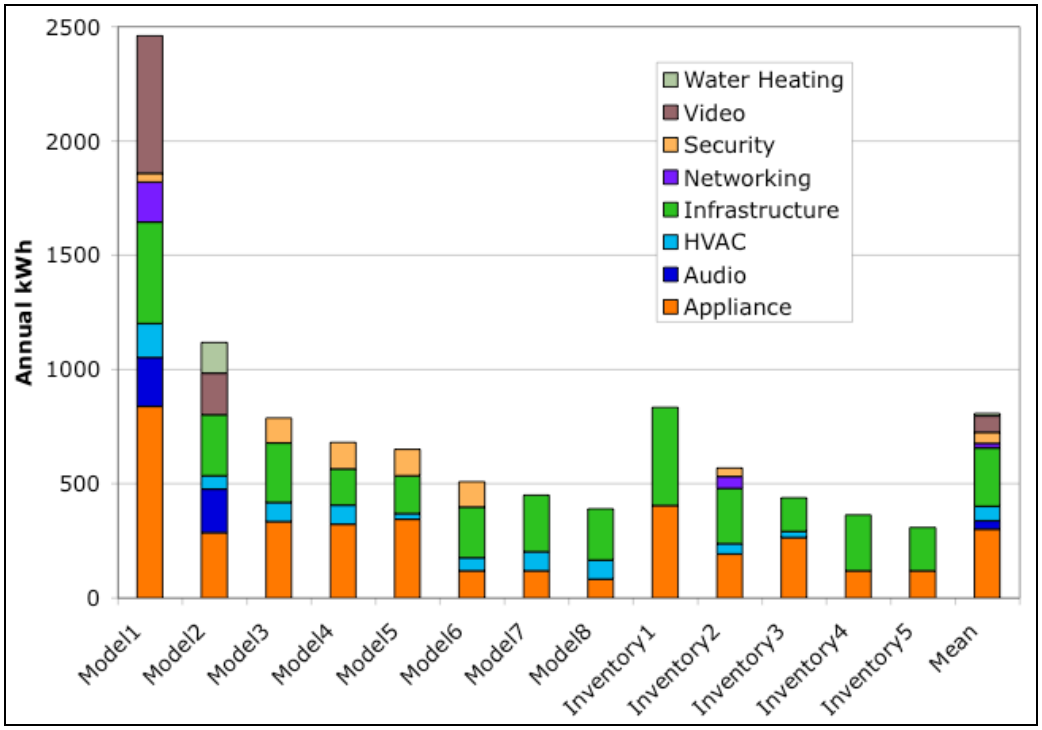

Figure 4. Annual Electricity Use by Builder-Installed Equipment in New California Homes, by Equipment Type
Source: Lawrence Berkeley National Laboratory

Figure 4 provides a more detailed breakdown of the specific types of devices that are found in a typical new home. The categories most frequently appearing were "appliance" and "infrastructure." All but three of the sample homes had some apparent electricity consumption by HVAC equipment. The least common category was water heating, with only one home represented (which is to be expected because the primary water heating fuel was natural gas).

Table 4 shows the detailed device listing for a single model home, showing the number of each kind of product and the low power consumption. These data are for Model 3, which is "typical" in that its annual consumption is closest to the sample mean. It has the following characteristics: floor area of 2,236 square feet, 4 bedrooms, and 2.5 baths. Modes shaded green were measured in this home, the others were imputed using average power levels from earlier measurements. The consumption figure is the first low-power mode, which is generally the mode most closely corresponding to "off" (note that the low power consumptions in Figure 3 are the sum of all low-power modes). The estimate of the annual consumption for devices in Mode 1 in this house is 117 kWh/year. Several devices show higher than expected standby power, such as gas

fireplaces, the structured wiring panel, and the garage door opener. Because this is a model home it contains a few devices, such as a television, that would not normally be present in an unoccupied new home. Nevertheless, it is clear that the electricity use of builder-installed devices will represent a significant fraction of this home's electricity consumption after occupation.

Table 4. "Typical" Model Home Devices and Low-Power Consumption

Product type	Number of units	Total low–power draw (W)	Mode
Intercom (remote)	4	22.0	Off
Sub-woofer (in wall)	1	11.1	Off
Fireplace (natural gas)	2	10.4	Off
Structured Wiring Panel Power Supply	1	9.2	On
Transformer (Lighting)—Address sign	1	6.0	Ready
Structured Wiring Panel	1	5.9	On
Garage Door Opener	1	5.4	Ready
GFCI outlet	7	5.1	Ready
Refrigerator	1	5.0	Standby
Alarm System Panel (system)	1	4.3	Ready
Smoke Detector	7	4.2	On
Irrigation timer	1	4.1	Ready
Clothes Washer	1	3.3	Off
AV Receiver	1	3.0	Ready
Ceiling Fan	1	3.0	Ready
Television	1	2.8	Off
Oven/Microwave combination	1	2.5	Ready, door closed
Intercom (Master)	1	2.5	Off
Garbage Disposal	1	2.3	Standby
Door Bell Chime	1	2.0	NA
Dryer (natural gas)	1	1.6	Off
Dishwasher	1	1.6	Ready, open
Total	38	117	

Source: Lawrence Berkeley National Laboratory

3.3. Conclusion

Builder-installed "other" equipment is a non-trivial component in "other" electricity use. This suggests that devices not traditionally addressed in energy efficiency programs (such as garage door openers, structured wiring systems, smoke alarms, ventilation fans, and even GFCI outlets) might be worth upgrading through residential new construction programs. These

findings also suggest that electricity consumption by “other” end uses is still too large to allow cost-effective zero-energy homes (when residual electricity use must be offset with expensive PV power).

4.0 Data Gathered for Estimation of Lopomo Energy Use

4.1. Overview of Data Sources

Calculating average lopomo energy use requires combining data on power, usage, and saturations from diverse sources. The major sources are summarized in Table 5.

Table 5. Major Sources of Data

Power	Usage	Saturation
Spot measurements in 75 homes with analyses from RLW and Ecos	RLW telephone survey of 306 homes	RLW telephone survey of 306 homes
LBNL preliminary measurements of lopomo energy use in eight houses (from an earlier part of this project)	Ecos and RLW analyses of time series measurements in 50 homes	RLW/Ecos in–home survey of 75 homes
LBNL measurements of builder–installed miscellaneous energy	Surveys (e.g., Nielsen)	California Residential Appliance Saturation Survey (RASS)
Other LBNL measurements	Earlier phases of this project	California Lighting and Appliance Saturation (CLASS)
Australia (*in situ* and in–store measurements)	Magazine articles	Trade journals
Product technical specifications	Australian case studies	Trade associations
Measurements from other countries (principally Denmark, UK, Germany, New Zealand)	Journal articles, typically dealing with specific product types	Australian case studies
Journal articles	Other technical reports	U.S. DOE Residential Energy Consumption Survey (RECS)
Personal communications		Earlier phases of this project

The major sources of new data are described in more detail in the following sections.

4.2. Telephone Survey

A telephone survey was undertaken for this project by RLW Analytics. The RLW study covered 306 homes and captured ownership information on over 60 product types and usage information about a smaller set of product types. This approach is valuable because usage data on many products can be collected quickly and inexpensively. In addition, data on appliance ownership can be obtained. The principal drawback is that consumer responses to these kinds of questions are notoriously unreliable because the respondent may not be the principal user of the product and, even if he or she is, cannot accurately estimate operating hours.

A survey instrument was developed in consultation with experts in survey research and energy use. The taxonomy was tied to common names of some products to aid surveyors in communicating with the respondents. An initial list of questions was created with the goal of obtaining information to reduce the largest contributors to uncertainty in statewide lopomo energy use. However, a survey is by necessity a compromise between what the energy

researchers want to know and what the survey researchers feel a consumer will be able to answer.

The survey obtained responses from 306 homes covering over 8000 products. About 77% of the homes were owner–occupied and about 52% were single–family houses. There were about 2.7 occupants per home. All survey results went into our dataset for informing final estimates of saturation and usage. The authors summarize below some of the key results that were used to develop more accurate usage profiles.

Desktop computers. The survey was intended to help researchers more accurately estimate the number of computers and the hours computers were switched on. The total saturation of all types of computers was 140%. About 75% (239) of the respondents reported having desktop computers. About 16% of the computers were on all the time. The average desktop computer was on 6.7 hours per day. Among the computers not operated continuously, the average on–time was about 3 hours per day. At the other end of spectrum, almost one quarter of the units (23%) were switched on for one hour or less per day.

Televisions. There were approximately 1.33 standard televisions, 0.16 large–screen televisions, 0.13 LCD or Plasma televisions, and 0.22 televisions with built–in VCRs per household. Together, this equals 1.84 televisions per household. Note that this is significantly lower than the 2006 national value found by Nielsen of about 2.3 televisions per household (Nielsen Media Research 2006).

Uninterruptible Power Supplies (UPS). About 3% of the homes had uninterruptible power supplies that were operating continuously. One more person switched it on only while operating the computer (2 hours/day).

Mobile telephones. Nearly 90% (275) of the homes reported having one or more mobile telephones. Table 6 summarizes the results. Unfortunately, these responses address charging habits rather than the status of the charger itself. For example, the responses cannot tell if the persons charging their phones daily remove the chargers from the outlets when finished or (more likely) leave them in the outlets.

Table 6. Charging Patterns for Mobile Telephones

Frequency of charging	Fraction of respondents*
Always plugged into charger	3%
Daily	30%
Several times per week	31%
Less than once per week to bi–weekly	28%
Monthly	9%
Don't know	<1%

* Total exceeds 100% due to rounding

Source: Lawrence Berkeley National Laboratory

Video games. Respondents claimed that their families used video games about 2.7 hours/day (though researchers wonder how many parents can accurately estimate their children's usage.)

4.3. In–Home Measurements

The largest and most important source of power data were in-home measurements of instantaneous (or spot) power use. These measurements were performed for this project by RLW. Data collectors utilized a tablet PC with a custom-developed application, which the collectors used to verify telephone survey product quantities, perform an in-situ sampling of products for measurement, and to enter power measurements. These values were obtained through on–site metering with highly-accurate watt-meters. A watt-meter is inserted into the circuit and the power consumption noted. The spot power measurements were taken to improve our assessments of power levels for low-power mode consuming devices.

The in-home measurements provided power consumption data for 62 product types. A total of 1925 products were measured. The number ("Count") of each product type metered ranged from one to over forty. Over six thousand independent measurements were made since each product had up to five power modes. The results of the metering are summarized in

Table 7. The each product type, the mean, minimum, and maximum values are listed. The "Count" refers to the number of products metered. Note that even this intensive metering exercise was unable to capture measurements for over 100 product types with lopomo energy use that were included in the overall statewide measurement. Researchers relied on other sources for power data when no in-home measurements were available or the number of products was so small as to be not representative.

The voltage was measured once per house. The average for 75 houses for which data were available was 119.95 V.

Table 7. Measurements of Instantaneous Power of Products in 75 Homes

Product/Mode	Mean (W)	Min (W)	Max (W)	Count
Air Conditioner, room/wall				
Off	0.9	0.9	0.9	1
On	134.8	134.8	134.8	1
Car, Wheelchair or Golf Cart				
Active	136.7	136.7	136.7	1
Charger, mobile phone				
On, charged	2.24	0.75	4.11	4
On, charging	3.68	0.27	7.5	23
Power supply only	0.26	0.02	1	32
Clock, radio				
On	2.01	0.97	7.6	23
Off	1.44	1.44	1.44	1
Computer Display, CRT				
Off	0.8	0	2.99	21
On	65.1	34.54	124.78	21
Sleep	12.14	1.6	74.5	14
Computer Display, LCD				
Off	1.13	0.31	3.5	32
On	27.61	1.9	55.48	31
Sleep	1.38	0.37	7.8	30
Computer, desktop				
On, idle	73.97	27.5	180.83	63

Product/Mode	Mean (W)	Min (W)	Max (W)	Count
Off	2.84	0	9.21	64
Sleep	21.13	1.1	83.3	52
Computer, notebook				
Fully on, charged	29.48	14.95	73.1	13
Fully on, charging	44.28	27.38	66.9	8
Off	8.9	0.47	50	19
Power supply only	4.42	0.15	26.4	19
Sleep	15.77	0.82	54.8	16
Fax, inkjet				
Off	5.31	0	8.72	3
On	6.22	2.89	14	8
Fax, laser				
Off	0	0	0	1
On	6.1	6.1	6.1	1
Ready	6.42	6.42	6.42	1
Heating, furnace central				
Off	4.21	0	9.8	16
On	339.71	70.5	796	14
Purge	329	329	329	1
Hub, USB				
Off	1.44	0.95	1.81	5
On	2.06	1.06	3.55	7
Modem, DSL				
Off	1.37	0.33	2.02	16
On	5.37	3.38	8.22	20
Modem, cable				
Off	3.84	1.57	6.62	8
On	6.25	3.64	8.62	16
Standby	3.85	3.59	4.11	2
Multi-function Device, inkjet				
Off	5.26	0	10.03	23
On	9.16	3.9	17.7	24
Multi-function Device, laser				
Off	3.12	0	4.7	3
On	49.68	5	175	4
Night Light, interior				
Off	0.05	0	0.34	10
On	4.47	0	27.97	19

Product/Mode	Mean (W)	Min (W)	Max (W)	Count
Ready	0.22	0	1.2	8
Phone, cordless				
Ready, handset	2.81	1.05	4.89	35
Ready, no handset	1.58	0.59	3.09	35
Active (talking)	1.9	0.59	3.38	33
Off	0.98	0.54	1.8	10
Phone, corded				
Active	1.37	1.37	1.37	1
Ready	0.89	0.89	0.89	1
Phone, cordless with answering machine				
Ready, handset	4	2.15	7.4	20
Ready, no handset	2.82	1.72	4.7	20
Active (talking)	3.53	2.2	6.5	21
Off	2.92	0.9	7.4	11
Message recording	5.23	5.23	5.23	1
Power Tool, cordless				
Ready, charged	8.34	1.82	14	5
Active	29.53	1.39	66	16
Ready	1.74	0	4.7	23
Printer, inkjet				
Off	1.26	0	4	25
On	4.93	1.81	22	25
Printer, laser				
Off	1.58	0	4.5	7
On	131.07	1.7	481.9	5
Peak warmup	251	251	251	1
Range, gas				
Ready	1.13	0.7	1.7	4
Scanner, flatbed				
Off	2.48	0.27	8.2	6
On	9.6	1.71	15.6	10
Security Systems, home				
Ready	2.7	2.7	2.7	1
Set-top Box, DVR				
On, no recording	37.64	25.95	49.2	4
On, recording	29.29	27.27	31.3	2
Off	36.68	23.3	48.6	4

Product/Mode	Mean (W)	Min (W)	Max (W)	Count
Set-top Box, analog cable				
On, TV off	11.5	11.5	11.5	1
On, TV on	11.3	11.3	11.3	1
Off by remote	10.3	10.3	10.3	1
Off by switch	10.5	10.5	10.5	1
Set-top Box, digital cable with DVR				
Not recording, TV off	44.63	44.38	44.87	2
Not recording, TV on	44.4	44.2	44.6	2
Recording, TV on	46.6	46.6	46.6	1
Off by remote	43.46	43.3	43.61	2
Set-top Box, digital cable				
On, TV off	24.65	14.2	74.74	18
On, TV on	29.64	14.1	102.23	18
Off by remote	17.83	13.24	30.6	14
Off by switch	17.5	13.7	26.3	16
Set-top Box, satellite				
with DVR				
Not recording, TV off	28.35	25.8	30.9	2
Not recording, TV on	31.37	24.2	36.3	3
Recording, TV off	24.3	24.3	24.3	1
Recording, TV on	24.3	24.3	24.3	1
Off by remote	27.8	22	33.6	2
Set-top Box, satellite				
On, TV off	15.95	7.69	33.2	33
On, TV on	16.15	7.69	33.2	33
Off by remote	15.66	6.58	33.05	25
Off by switch	15.47	6.58	32.7	31
Speakers, computer				
On, no sound	4.12	0.69	9.84	21
Off	1.79	0	5.6	19
Stereo, portable				
CD, not playing	4.11	1.29	6.83	15
Cassette, not playing	2.42	1.16	5.92	13
CD playing	6.8	3.96	9.2	15
Off	1.66	0.7	5.44	19
Radio playing	3.3	1.36	8.25	20
Television, CRT				
Off by remote	3.06	0.3	10.34	38
Off by switch	2.88	0	16.1	58

Product/Mode	Mean (W)	Min (W)	Max (W)	Count
Television, rear projection				
On	186.09	186.09	186.09	1
Off by remote	6.97	0.2	48.5	16
Off by switch	6.6	0.2	48.5	15
Timer, irrigation				
Off	2.75	1.5	5.9	14
Ready	2.84	1.5	5.9	16
Tuner, AM/FM				
On, not playing	9.48	5.08	16.4	3
On, playing	9.92	5.07	17.7	3
Off	1.12	0	3.37	3
Water Dispenser, bottled				
Ready	0	0	0	1
Amplifier				
On, not playing	33.99	21.4	70.93	6
On, playing	39.16	21.11	69.3	6
Off	0.27	0	1.8	7
Audio Minisystem				
CD, not playing	13.99	1.67	36.95	28
Cassette, not playing	13.85	1.67	33.14	24
CD playing	19.09	5.2	41.2	24
Off	8.32	0.3	24.58	27
Radio playing	14.41	2.98	38	28
Cassette, playing	4.44	4.44	4.44	1
CD Player				
On, not playing	8.62	4	25.7	7
On, playing	9.91	5.8	25.6	7
Off	5.04	2	18.4	7
Caller ID Unit				
Ready	1.27	1.27	1.27	1
Cassette Deck				
On, not playing	4.53	4.36	4.7	2
On, playing	5.72	5.2	6.25	2
Off	0.54	0	1.08	2
Clock				
On	1.74	0.99	3.61	21
Radio playing	2.95	1.7	4.2	2
Coffee Maker				
Off	1.14	0	2.7	12
On and brewing	869.57	644	1034.3	10

Product/Mode	Mean (W)	Min (W)	Max (W)	Count
On and warming	463.07	0.09	983	12
Ready	99.55	0.7	983	10
Copier				
Off	1.49	0	2.97	2
On	9.63	3.6	14	3
Peak warm up	757	757	757	1
DVD Recorder				
Ready	8.6	8.6	8.6	1
Off	0.75	0	1.5	2
On not playing	18.3	18.3	18.3	1
DVD Player				
On, not playing	7.54	0.24	12.7	33
On, playing	9.91	5.28	17.17	33
Off	1.55	0	10.58	33
DVD/VCR				
On, not playing	13.51	8.48	20.5	21
On, playing	15.33	9.43	22.37	19
Off	5.04	0.09	12.7	21
Game Console				
Active	26.98	5.4	67.68	24
Off	1.01	0	2.13	26
Ready	23.34	2.12	63.74	24
Garage Door Opener				
Ready, light	76.9	6	188.5	28
Ready	4.48	1.8	7.3	34
Low-voltage Landscape				
Off	1.17	1.17	1.17	1
On	49.75	49.75	49.75	1
Ready	1.13	1.1	1.17	2
Microwave Ovens				
Ready, door closed	3.08	1.4	4.9	18
Ready, door open	25.79	1.6	39	17

Product/Mode	Mean (W)	Min (W)	Max (W)	Count
Cooking	1433.	966.2	1723.	18
Musical Instruments				
Off	2.82	1.2	4.2	9
Ready	6.5	5.3	7.7	2
Playing	6.5	6.5	6.5	1
Receiver (audio)				
On, not playing	37.61	17.1	65.2	18
On, playing	40.06	22.95	65.2	17
Off	2.92	0	19.7	18
Subwoofer				
On, not playing	10.7	5.8	20.6	7
On, playing	12.42	5.9	20.6	6
Surge Protector				
Off	1.05	0	6.3	6
On	0.8	0	6.92	43
Telephone Answering Device				
Off	2.01	1.31	2.55	7
Ready	2.25	1.42	2.83	7
Television / VCR				
Off by remote	5.15	2.15	13.3	6
Off by switch	5.99	2.15	13.11	7
Turntable (audio)				
On, not playing	6.01	1.72	12.8	3
On, playing	4.8	4.8	4.8	1
Off	0.2	0	0.6	3
VCR				
On, not playing	7.77	3.8	11.62	14
On, playing	11.26	7.36	15.11	12
Off	4.68071	1.2	9.9	14

Source: Lawrence Berkeley National Laboratory

Sample Data for DVD Players

To give a flavor of the detailed data, Table 8 below shows the spot measurements for DVD players.

Table 8. Spot Measurements of DVD Player Power Consumption in Different Modes

DVD mode	Power measurements (W)
Off Average: 1.55 W Count: 33	0 0 0 0 0 0 0.02 0.07 0.17 0.17 0.2 0.27 0.4 0.49 0.5 0.5 **0.58** 0.6 0.64 0.76 0.9 1.43 1.66 1.79 2.24 2.47 2.65 2.95 3.14 3.38 4.4 8.1 10.58
Ready Average: 7.54 W Count: 33	0.24 1.6 3.99 4.1 4.21 4.27 4.5 4.81 5.2 5.2 5.2 5.6 5.7 7.15 7.81 7.99 **8.09** 8.2 8.6 9.26 9.5 9.67 9.7 9.83 9.86 9.9 10.3 10.4 10.67 10.88 11.2 12.56 12.7
Active Average: 9.91 W Count: 33	5.28 5.85 5.95 6.1 6.15 6.28 6.5 6.5 6.5 6.74 7.6 8.52 8.72 9.1 9.4 9.5 **9.75** 10.22 10.3 10.4 10.84 11.07 11.1 11.24 11.75 12 12.59 12.86 13.7 15.4 15.52 16.5 17.17

Note: The median value for each mode is **underlined in bold face**.

Source: Lawrence Berkeley National Laboratory

Some observations about the DVD Player data:

- One product used more when off than most did when they were on (Ready or Active), even while playing.
- A fourth of the products used 0.1 W or less while off, with almost a fifth using no power (these of course can't then be switched on with a remote control).
- The range of power when Ready (which corresponds to on but not playing) was enormous—a factor of more than fifty different.
- The range of power when Active (on, playing) was about as large in absolute terms as with Ready (about 12 W), though just over a factor of 3 in relative terms.

Figure 5 shows the distribution of the power values graphically.

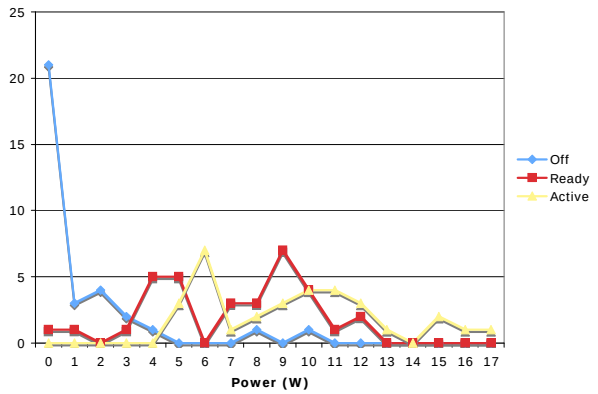

Figure 5. Distribution of Power Use by Mode for 33 DVD Players (Note that bins include listed number and 1 above)
Source: Lawrence Berkeley National Laboratory

For many products, not all modes applied to all products, or there was some reason why some modes could not be or were not measured, so that the counts are not always the same across all modes.

The spot measurements were considered with measurements from other sources to select the final power values. Table 9 is an example of what was created for every product type to summarize the data we collected and helped researchers arrive at the final values.

Table 9. Extract of Database Illustrating DVD Player Power Measurements

Ecos power (W)	Ecos mode	Australia (Aust) power (W)	Aust. mode	Spot power (W)	Phase 2 power (W)	Mode
1	standby	0	off	1.55	1.57	off
5	lowpower	2.6	pas.sby	7.54	11.77	ready
		9	act.sby			NA
3.3	indet.					NA
10.8	active		active	9.91	14	active
32	units					

Source: Lawrence Berkeley National Laboratory

The final values used in this report for DVD Players were 1.2, 6, and 10 W respectively for *Off, Ready,* and *Active*.

4.3.1. Saturations of Products Determined Through In–Home Survey

RLW also undertook an inventory of all electricity-using appliances in the 75 homes that its staff visited. (These 75 homes were a subset of the 306 homes surveyed by telephone.) The results of the inventory are summarized in Table 10. RLW identified 123 different product types. Note that 123 is still much less than the 170+ product types evaluated in this project so some information on saturations still needed to come from other sources.

The group of 75 of homes did not match the mix of California homes overall so the results should be taken as indicative rather than conclusive. RLW also noted products that occupants reported as having but did not (and vice-versa) as well as many other explanations (See Appendix A, page 1). These comments as a whole give a unique insight into the uncertainties surrounding occupant-reported ownership of electrical devices.

Table 10. Saturations of Product Types in 75 California Homes

Appliance	Saturation	Appliance	Saturation
Adding machine	14.7%	Automatic griddles	0.0%
Air cleaner, mounted	2.7%	Bicycle light	5.3%
Air cleaner, portable	22.7%	Blanket	16.0%
Air-conditioning, evaporative cooler	4.0%	Blender	76.0%
Air freshener	13.3%	Breaker, AFI	5.3%
Aquarium	14.7%	Breaker, GFCI	12.0%
Auto engine heater	0.0%	Broiler	10.7%

Appliance	Saturation
Charger, hedge trimmer	4.0%
Charger, weed trimmer	8.0%
Coffee grinder	40.0%
Coil, snow melting	1.3%
Computer display, plasma screen	20.0%
Corn popper, air	16.0%
Corn popper, hot oil	0.0%
Curling iron	74.7%
Deep fryer, residential	10.7%
Dehumidifier	1.3%
Detector, carbon monoxide	9.3%
Detector, smoke	50.7%
Dimming switch	9.3%
Dock, notebook	2.7%
Doorbell	46.7%
Emergency light, interior (commercial)	0.0%
Equalizer (audio)	0.0%
Exhaust fan	77.3%
External drive	8.0%
External power supply	0.0%
Fan, portable	141.3%
Fan, rangehood	70.7%
Fan, whole house	6.7%
Fan, window	5.3%
Fax, laser	0.0%
Fax, thermal	20.0%
Floor polisher	2.7%
Food processor	41.3%
Food slicer	6.7%
Fountain, indoor	6.7%
Frying pan	16.0%
Furnace fans	5.3%
Garbage disposal	62.7%
GFCI outlet	112.0%
Grill, outdoor	0.0%
Grow lamps	0.0%
Hair dryer	92.0%
Hand mixer	69.3%
Heat lamp	4.0%

Appliance	Saturation
Heating pad	45.3%
Heating, fireplace electric	1.3%
Home medical equipment	9.3%
Home theatre system	0.0%
Hot plate (kitchen)	4.0%
Hub, ethernet	8.0%
Humidifier	9.3%
Infant monitor, receiver	8.0%
Infant monitor, transmitter	8.0%
Iron	84.0%
Juicer	24.0%
Karaoke machine	4.0%
Kettle	9.3%
Kiln	1.3%
Knife	17.3%
Lamp, decorative	4.0%
Lawn mower	6.7%
Lights, holiday	102.7%
Massager	29.3%
Modem, POTS	17.3%
Motion sensor, exterior	56.0%
Motion sensor, interior	4.0%
Mug warmer	6.7%
Pasta maker	1.3%
Pencil sharpener	24.0%
Pet fence	1.3%
Phone, conference	5.3%
Photosensors, exterior	21.3%
Pool	0.0%
Power supply	0.0%
Power tool	172.0%
Printer, photo	18.7%
Projector, slide	4.0%
Projector, video	1.3%
Pump, sump	4.0%
Pump, well	1.3%
Refrigerator, wine cooler	0.0%
Rice maker	21.3%
Router, ethernet	22.7%

Appliance	Saturation
Sauna, electric	0.0%
Set–top box, analog cable	0.0%
Set–top box, game console	26.7%
Set–top box, game console with internet connectivity	4.0%
Sewing machine	42.7%
Shredder	58.7%
Slow cooker	54.7%
Spa/hot tub	0.0%
Space heater, portable (electric)	0.0%
Space heater, portable (non–electric)	0.0%
Speakers, powered	0.0%
Speakers, wireless (base station)	0.0%
Speakers, wireless (speakers)	2.7%
Stand mixer	21.3%
Stapler	1.3%
Timer, exterior	22.7%

Appliance	Saturation
Timer, interior	12.0%
Toaster	70.7%
Toaster oven	41.3%
Trash compactor	4.0%
Typewriter	14.7%
Utility meter	5.3%
Vacuum, standard	109.3%
Videocassette rewinder	13.3%
Waffle iron	29.3%
Water heating, instantaneous single point of use	0.0%
Water heating, point of use tank	0.0%
Water softener	2.7%
Waterbed	0.0%
Wire losses	0.0%
Wireless access point	12.0%

Source: Lawrence Berkeley National Laboratory

5.0 Technical Approach to Estimating Low-Power Mode Energy Use in Appliances in California

5.1. Calculating Lopomo Energy Use

The lopomo energy use of a single product is simply the sum of the product's energy use in each low-power mode. This can be written as:

$$\text{Annual lopomo energy use (in kWh/year)} = 8.76 \cdot \sum_{\text{all low power modes, i}} P_i \cdot U_i$$

where Pi is the Power (in watts) and Ui is the Usage (in terms of a fraction of time), both for mode i.[4] The term 8.76 converts the watts into kWh/year.[5]

One product type's California-wide lopomo energy consumption is calculated by multiplying the single unit's energy consumption by the number of homes in California and the product type's saturation:

$$\text{Lopomo energy use in California} = N \cdot S \cdot 8.76 \cdot \sum_{\text{all low power modes, i}} P_i \cdot U_i$$

where N is the number of homes in California and S is the saturation of that product type. The saturation typically ranges from zero to one though can exceed one for products like televisions, ceiling fans, and mobile phones. Some designs of the product may have three modes while others may have only two modes. In a perfect world, these would be defined as different product types but, in practice, they are not differentiated in stock data, and so the researchers combined them with appropriate modes, power levels and usage times. As a result, the power and usage data represent an aggregate of the products with diverse modes. This calculation is repeated for each product type studied.

The saturation must also take into account the fact that some designs within a product type may not have any low-power modes while others do. For example, some washing machines rely on electromechanical controls (and have no lopomo use) while many modern machines rely on electronic controls (which do have low-power mode use).

The California average for each product type will rarely match that of any specific model. Thus, the challenge is to represent a product type with credible average values for power, usage, and saturation based on measurements, surveys, and professional judgment.

The actual final values for saturation, power, and usage are given for each product type are listed in Appendix B, page 1. The sources of information and methodology used to develop these values are described below.

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4. Some product usage patterns include time while disconnected or unplugged; this operating condition must be taken into consideration even though it adds no energy use

5. If the *active* mode is included, then the formula predicts a product's total energy use. A special case of lopomo is "disconnected" by unplugging or external switch or timer.

5.2. Inputs to Calculations

5.2.1. Definitions of Products

Consumer electronics are constantly evolving by adding features, combining with other devices, and splitting to form new products. The VCR, for example, appears as a standalone product but it is also sometimes built into televisions or combined with DVD players. Audio components, such as tuners, amplifiers, speakers, equalizers, CD players, cassette players, and MP3 players, appear individually and combined into single products. Coffee makers have added clocks and even weather forecasts. Researchers developed a taxonomy to consistently define and categorize products (which is described reporting Section 2). Even then researchers encountered numerous situations where they were unsure how to classify a product (in some cases because they had never personally encountered one and the literature describing them was inadequate to form a judgment). Researchers also drew upon other data sources that combined several product classifications into one or otherwise prevented a simple mapping of results to the database.

An effective taxonomy is a compromise. If the universe of products is divided into too many different product types, then it will be impossible to obtain reliable information about the number of them in California's homes. On the other hand, if the classification is too coarse, then the average power and usage numbers will not capture the technical diversity within the products. For example, many sources give accurate estimates of the number of set-top boxes in California, but there exists much less detail about the types of set-top boxes (e.g., satellite, cable, high definition, recording) even though considerable variation in energy use exists within this category.

5.2.2. Number of Homes

The number of homes in California was assumed to be 11.5 million. This includes single-family homes, multifamily homes, and vacation homes.[6]

5.2.3. Saturations of Products in California Homes

The stock of products with lopomo energy use differs in each home; for this reason it is important to have good estimates of saturations for each of the product types. Unfortunately, this information is not collected in any comprehensive or consistent manner for all of the product types under consideration. The saturations of major appliances and some consumer electronics in California have been regularly collected by California utilities, the U.S. DOE's Residential Energy Consumption Survey, and the U.S. Census. National sales of smaller electricity-consuming products and computer–related equipment are available from trade publications like *Appliance Magazine* but much less information is available concerning the number of products in homes today. Furthermore, it is hazardous to extrapolate saturations of

6. There were 12.37 million homes in California in 2006 (California Department of Finance)(2006). California Statistical Abstract, State of California. but this includes some categories to which the estimates do not apply such as "vacant" and "group quarters".

consumer electronics from sales data because these products often experience explosive growth and have uncertain lifetimes in use (as many are discarded as obsolete while still fully functional).

Researchers used the telephone survey to help fill the gaps in saturations of products with lopomo energy use. They could not address every product type in the survey because the survey participants would lose interest or drop out if the survey was too long. In addition, some questions required detailed understanding of the products to answer accurately. For these reasons, they treated the survey results as indicative but not always an authoritative source for saturations. Other major sources included the inventory lists from the audits of 75 homes and investigations made in earlier phases of this project.

Researchers relied on still other sources to fill in when these sources had no information or appeared to be inadequate. For example, an Australian study (Energy Efficient Strategies 2004) gave us saturations and usage rates of breadmakers. They were unable to find information on rice cookers, which are relatively common in California. In these cases they relied on their judgment.

As indicated above, some models of products with the same primary function have lopomo energy use while others do not. Most microwave ovens, for example, have digital clocks but a small percentage have mechanical timers (and no clocks). Many large appliances, such as room air conditioners, stoves, dishwashers, and clothes washers, also fall into this category. Some product types, such as ceiling fans, only have lopomos when shipped with remote controls. Researchers estimated (or drew from other information sources) the fractions of these products having no low-power modes.

Another group of components are permanently wired into the household electrical circuits and are sometimes called "hardwired." Many of these are installed by builders in new homes (which is why researchers undertook a separate project to investigate energy use of builder–installed miscellaneous energy described earlier.) They cannot be easily measured *in situ* because the wires need to be disconnected and then reattached. The most important hardwired components are:

- Smoke detectors
- Ground-fault circuit interrupt (GFCI) outlets and breakers
- Security systems
- Ceiling fans
- Door bells
- Garage door openers (sometimes)
- Lighting controls

Saturations of "hardwired" electrical components are particularly difficult to determine and we used a different procedure for estimation for each product type. Smoke detectors illustrate the

approach used to estimate saturations. Building codes have required installation of mains-powered smoke detectors in new homes for some time but older houses mostly rely on battery-powered detectors. In addition, some older houses were back-fitted with hardwired smoke detectors during renovations (this is required when renovations are extensive). It is usually not apparent from simple observation if a smoke detector is battery-powered or hardwired. The research team concluded that about 15% of California's homes have mains-powered smoke detectors with lopomo energy use, with an average of four detectors per home.

New homes can easily have eight GFCI receptacles and many older homes have been retrofitted with them during kitchen and bathroom remodels although some may be stringed together and controlled by a single GFCI circuit. Researchers believe that about four GFCI circuits are present in the average California home.

5.2.4. Power Levels

Each product type has a set of low-power modes. Each power mode corresponds to a level of functionality. The most common low-power modes are:

- Off
- Ready
- Power supply only
- Battery fully charged
- Battery removed
- Sleep

Many products have only one low-power mode. A notebook computer, however, could easily have four or more modes, after taking into account the status of its external power supply, battery, and display.

Our primary source of power data was the measurements in 75 homes undertaken by RLW described earlier.

Researchers also drew upon measurements made in other countries. The most important source was a large survey conducted in Australia (Energy Efficient Strategies 2006). Australia supplies 220 V electricity to domestic customers, but the power consumption of most products is similar. One problem with the Australian data—and many other sources—were slightly different definitions of modes. In most cases it was possible to map the Australian measurements into the mode definitions. They also consulted measurements conducted in Denmark, Finland, Korea, Japan, New Zealand, and Sweden.

Some consumer electronics can switch themselves to a lower power mode after a period of inactivity. Such devices are difficult to quickly meter during a household survey because it will be necessary to plug in the meter and then wait some time (e.g., half an hour) until the device switches to a lower state. The measurement protocols in this project (and other projects from

which researchers drew data) did not allow for a long period of stable activity, so it is possible that some low-power modes were not observed.

Measurements of hard–wired components were difficult to perform on site. An important component is the smoke detector. Measurements made in Australia (Energy Efficient Strategies 2004) found that mains–powered smoke alarms draw 0.25–0.5 W, with the majority closer to 0.4W. Many of these products were built for the U.S. market and can be expected to draw the same amount of power. If a new home has 5 units, each drawing 0.4 W, then the average standby contributed by smoke alarms in those homes will be 2 W.

5.2.5. Usage

A period of usage corresponding to each power level in a product must be determined. (expressed in percentage of time.) For some product types, these values remain among the most uncertain even though we used several approaches to obtain more accurate data. The telephone survey provided data for some usage parameters related to computers, televisions, and other devices. For example, the research team learned the fraction of computers that were never switched off.

Ecos Consulting (Porter, Moorefield et al. 2006) investigated usage periods in a subset of the RLW data (containing fewer product types). It applied an algorithm to the time series data to identify the different modes, the power levels, and the time the product was in each mode. Researchers drew upon the Ecos results where possible.

Usage information can sometimes be inferred from other measurements. For this reason, researchers consulted various surveys on viewing patterns of television (e.g., Nielsen), computer usage, and children's behavior. Academic studies of topics totally unrelated to energy use, such as World of Warcraft and other "Massive Multiple Online Role Playing Games" (Chen and Duh) provide clues to usage. Most of these studies focused on *active* uses of computers and other electronics, but sometimes other periods could be inferred.

Some products are completely disconnected for various periods of time because they are portable (and the charger is taken with them, such a mobile phone or a notebook computer) while others are controlled by a power strip (such as computer or audio equipment), timer or switch. The fractions of time that these products are disconnected are inputs to the calculation of lopomo energy use; unfortunately they are difficult to obtain through surveys or monitoring. Disconnecting an appliance (or switching off through a power strip) is a behavioral decision and can change over time. There is some evidence that consumers made conscious efforts to disconnect electrical appliances during the California electricity crisis in 2001 (KEMA–XENERGY 2004). Consumer awareness programs, such as that undertaken by Flex Your Power (FYP 2007), can also affect the extent to which consumers disconnect devices.

6.0 California Low-Power Mode Energy Use

6.1. 2006 California Lopomo Energy Use

Based on the data collected and considered in this report, California's lopomo energy use is 112 W per home (or 982 kWh/year). This corresponds to roughly 13% of 2005 residential electricity use.[7] This estimate includes contributions from 170 product types, although many others were considered and some were consolidated where appropriate. The key results are summarized in Table 11. The entire database is listed in Appendix B, page 1.

Table 11. Estimated Lopomo Energy and Power Use in 2006

	Per home		California	
	Power	**Energy/year**	**Power**	**Energy/year**
Lopomo energy	112 W	982 kWh	1.29 GW	11,300 GWh
Standby energy (mode 1)	54 W	470 kWh	0.617 GW	5,410 GWh
Total residential electricity use	840 W	7,350 kWh	9.6 GW	84,500 GWh
Number of lopomo products	44		506 million	

Source: Lawrence Berkeley National Laboratory

The 10 product types responsible for the largest lopomo energy use are listed in Table 12. Together, these product types account for roughly 40% of total lopomo energy use. Two forms of set-top boxes dominate the list. Other product types within the video category, televisions and DVRs, also rank among the highest users of lopomo energy.

Table 12. Top 10 Lopomo Product Types

	Average lopomo electricity use per home		
Product type	**(kWh/year)**	**(W)**	**Fraction of total lopomo energy use**
Set-top box, satellite	58	7	6%
Set-top box, digital cable	50	6	5%
Television, CRT	47	5	5%
Video, DVR	38	4	4%
Audio minisystem	38	4	4%
Computer, desktop	37	4	4%
Receiver (audio)	33	4	3%
Phone, cordless	33	4	3%
Air- conditioning, central	27	3	3%
Oven, microwave	26	3	3%
Total of top 10	**387**	**44**	**40.00%**

Source: Lawrence Berkeley National Laboratory

7. This based on 7,350 kWh per home and is derived from 84,527 million kWh sold to 11.5 million residential customers. California Energy Commission. "California Electricity Consumption by Sector," September 11, 2006. http://www.energy.ca.gov/electricity/consumption_by_sector.html.

Each product type has a slightly different explanation for ranking among the highest. The set-top boxes rank high because individual boxes have high lopomo power use and are present in a relatively large fraction of homes. Televisions (CRT models) and cordless telephones have lower standby but very high saturations. Digital video recorders (DVRs) are present in less than 20% of homes but have extremely high lopomo energy use. Audio minisystems and microwave ovens have relatively high lopomo energy use and are present in nearly all homes.

Desktop computers use less lopomo energy than several other products because survey data indicated that they spend about 40% of the time in active mode. (A program to encourage better power management would save considerable electricity but have the perverse effect of increasing lopomo energy use.) The lopomo energy use of the whole computer set-up, that is including monitors, printers, scanners, speakers, and modems, is much higher.

Central air conditioning appears on the list because of the power needed to operate its controls. Over a third of California homes have central air-conditioning. Researchers were unable to measure these devices because they are hardwired, but other evidence suggests that the controls for these units draw around 9 W when not operating. The moderate saturation, combined with high standby power use, led to high lopomo energy use.

This ranking should be interpreted with caution because some other product types might have ranked higher if similar product types had been combined. For this reason it is more useful to examine the fractions from the different categories (see following section).

If lopomo energy use could be counted separately, then it would rank as the fourth largest residential electricity end use in California (see Table 13).

Table 13. Major Residential Electrical End Uses in California*

End use	Fraction of electricity use (%)
Lighting	22%
Refrigerators & Freezers	19%
TV, PC, and Office Equipment	15%
Lopomo Energy Use	***13%***
Miscellaneous	11%
Air Conditioning	10%
Pools & Spas	6%

* Based on 2003 RASS estimates plus 2005 use (KEMA–XENERGY 2004).

Source: Lawrence Berkeley National Laboratory

This comparison can be misleading, however, because some of the lopomo energy is already captured in other end uses (especially "TV, PC, and Office Equipment" and "Miscellaneous"). Nevertheless, lopomo energy use represents a significant component of residential electricity use.

Many state and federal regulations (2007) and programs focus on the lowest power mode of the product (Power Integrations 2007). This corresponds to "mode 1" in this study.[8] The *functional* interpretation of the mode varies with the product, from *off* to *ready*. Reseachers estimate that about 470 kWh/year—55 W—is consumed by products while in their lowest power mode. This corresponds to about 48% of total lopomo energy use. The remaining 52% of the electricity use occurs in other modes with higher functionality, principally *idle, ready,* and *charging*.

6.1.1. Lopomo Energy Use by Categories

The highly detailed disaggregation makes it difficult to identify broader product areas with high lopomo energy use. Lopomo energy use is concentrated in the electronics categories but, as Figure 6 shows, lopomo energy use is widely dispersed among many categories. Electronics are responsible for about 80% of total lopomo energy use.

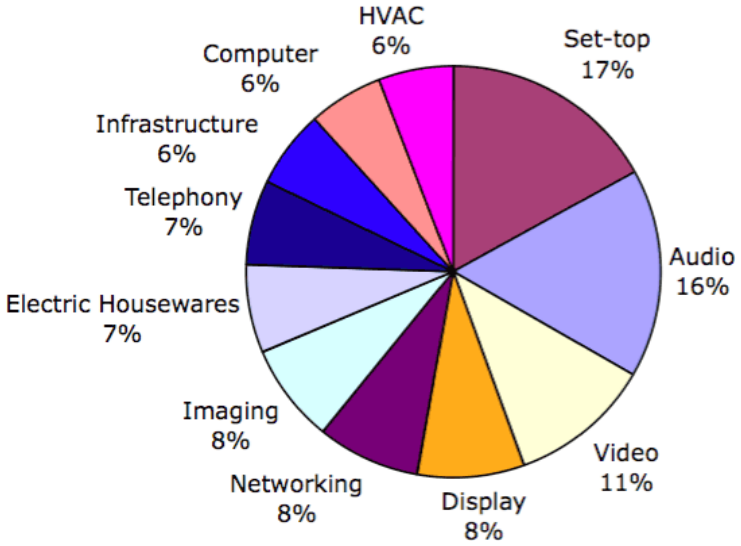

Figure 6. 2006 Lopomo Energy Use by Category

Source: Lawrence Berkeley National Laboratory

6.1.2. Number of Lopomo Products in an Average California Home

The average California home contains about 44 products with lopomo energy use. This estimate includes the visible products like televisions, VCRs, and computers but also often overlooked devices such as doorbell transformers, GFCI outlets, and smoke detectors. The saturation of these less-visible devices are certainly expanding as a result of code requirements for new homes and through remodeling of existing homes. As a result, the number of products with lopomo energy use will climb.

8. In a very few cases of rechargeable products, such as cordless phones, mode 1 corresponds to a higher power mode but with a lower functionality, that is, with the handset on the base station, charging.

6.2. Future Lopomo Energy Use in California

6.2.1. Methodology for Estimating Future Lopomo Use

The stock of products with lopomo energy use is diverse and many product types have relatively short lifetimes. As a result, its energy use could change relatively quickly compared to the traditional end uses. It is difficult to predict the directions it will take; instead, researchers explored the energy impacts of several trends that are almost certain to continue. They have not assigned a specific time period for this exploration of future energy use but it represents what will most likely occur in 10 to 15 years. Overall, these trends reflect a greater fraction of products having low-power modes and, to a lesser extent, new products in the homes with lopomo energy use.

The research team incorporated following the trends in an estimate of future lopomo energy use. The actual assumptions used in estimating energy impacts are given afterwards.

- The fraction of products with low-power modes will increase for many product types because they are a high fraction of new sales. For example, about 25% of dishwashers today have a low-power mode, but this is almost certain to increase to near 100% in fifteen years. The same situation exists for other white goods, toaster ovens, coffee makers, rice cookers, and many other products. Researchers assumed 95% for most product types.
- VCRs (and rewinders) and audio cassette decks will disappear as their functions are replaced by superior digital technologies. DVD players are expected to be present in nearly all homes by 2010.
- New buildings will include more GFCI outlets and arc–fault interrupt breakers and existing buildings will be gradually upgraded. Researchers assumed 8 GFCI outlets per home and 15% of homes with AFI breakers.
- Battery–powered smoke detectors will be gradually replaced by hardwired detectors. The research team assumed that the fraction would rise from today's 15% to 75%.
- Set-top box technologies (cable, satellite, internet) will converge such that most homes will have a central box and two remote boxes to serve other televisions. Researchers assumed a penetration of 100% and that the three boxes are represented by a single unit with the characteristics described in Table 14.

Table 14. Assumed Characteristics of Future Set–Top Boxes

Mode	Power	Fraction of time
Active	49 W	20%
Idle	34 W	20%
Sleep	11 W	60%

Source: Lawrence Berkeley National Laboratory

- CRT televisions and CRT displays will have been totally replaced by LCD (2 per home), plasma, and other technologies (about 0.5 per home). Researchers also assumed that the

transitional Digital Television Adaptor came and disappeared as new, digital televisions replaced the analog equipment.

- Wireless access devices will become standard and present in essentially all homes (a few will have more than one and a few will have none).
- The saturation of computers will continue to rise. The research team increased the saturation of computers and displays by 100%, half as desktops and half as notebooks.
- Game consoles will be used more (increasing time outside of the lowest power mode). Researchers assumed the units will reside in a low-power mode above standby for 25% of the time.
- New devices will appear that will have significant lopomo energy use. The digital picture frame, for example, will almost certainly rapidly saturate the market. In any event, one can expect at least one new display per household. Other new products include some sort of home media storage box, medical and health aids, and more lights with remote controls. Surprise products could appear and experience rapid uptake by consumers. The "shower toilet" (which is already present in most Japanese homes with elderly occupants) falls into this category. The authors assumed that three new products with 2 W of annual average low power consumption would appear. This is almost certainly an underestimate of current trends.

The *distribution of time* spent in modes is also likely to change. However, the direction of the shifts is difficult to predict. Greater reliance on power management should cut the fraction of time products spend in active modes and increase the time spent in low-power modes. On the other hand, more products will need to maintain a network presence, leading to a shift from a minimum-power mode to a higher-power, network-active modes or possibly require other products on the network to remain fully on. Other products, such as game consoles, may be used differently.

6.2.2. Estimate of Future Lopomo Energy Use

Based on the assumptions described above, the number of lopomo products would climb to almost 60 products per home (see Table 15). Future lopomo energy use would climb 18% to 132 W per home.

Table 15. Lopomo Energy Use in Future Homes

	Future	2006
Number of products per home	59.3 products	43.9 products
Average lopomo electricity use	1160 kWh	983 kWh
Power	132 W	112 W

Source: Lawrence Berkeley National Laboratory

The number of products rises but mostly because more homes have GFCI outlets, hardwired smoke detectors, and the hypothesized new products. Consolidation of products—such as TVs with DVD players and set-top boxes—could reduce this projection.

The list of the major contributors to lopomo energy use will change significantly if current trends continue (see Figure 7 and Table 16). The top 25 contributors represent 88 W (or about

2/3 of the total). Overall, the distribution is similarly diffuse (compare Figure 7 and compare it with the 2006 distribution in Figure 6).

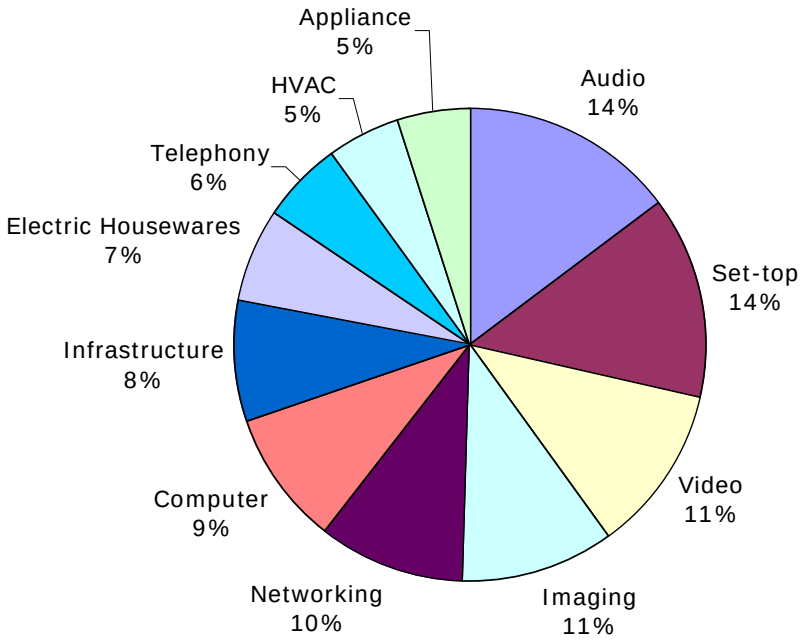

Figure 7. Future Lopomo Energy Use by Category

Source: Lawrence Berkeley National Laboratory

The single largest product—set-top boxes—is responsible for 12% of lopomo energy use. Set-top boxes and computer–linked products continue to dominate the energy consumption but products "hardwired" into homes will represent an increasing fraction. These products include controls for heating and cooling equipment, smoke detectors, GFCIs, and garage door openers. Gas-fired demand (or "tankless") water heaters each draw about 5 W of electricity. The statewide lopomo energy use ranked 47th on the list because researchers assumed that only 15% of future homes will have these products. However, these units appear to be rapidly rising in popularity and could easily contribute a much larger fraction of lopomo energy use.

Table 16. The 25 Largest Contributors to Future California Lopomo Energy Use

Product type	Contribution to average lopomo energy (kWh/year)	Power (W)
Future set–box	117	13.4
Computer, desktop	59	6.7
Wireless access point	41	4.7
GFCI outlet	39	4.5
DVD player	38	4.4
Video, DVR	38	4.3
Audio minisystem	38	4.3
Computer, notebook	35	4.0
Receiver (audio)	33	3.7
Phone, cordless	33	3.7
Air-conditioning, central	27	3.1
Television, LCD	27	3.1
Oven, microwave	26	3.0
Multi-function device, inkjet	24	2.8
CD player	22	2.5
Clock, radio	22	2.5
Printer, inkjet	20	2.3
Garage door opener	19	2.1
Modem, cable	18	2.1
Heating, furnace central	18	2.0
Subwoofer	17	1.9
Game console	16	1.9
Future medical product	16	1.8
Future media product	16	1.8
Future display product	16	1.8
Total for top 25	**775**	**88.4**
Total for all product types	**1162**	**112**

Source: Lawrence Berkeley National Laboratory

These estimates are subject to large uncertainties and should not be treated as a forecast. Societal and demographic changes are often first reflected in the miscellaneous end use, so the energy consumption trends presented here have great uncertainty.

6.3. Sensitivity and Uncertainty

6.3.1. Methodology for Estimating Uncertainty

In the process of estimating California lopomo energy use, this project estimated as many as 13 values for each product type. These values included:

- Two kinds of saturations (overall and fraction with a low-power modes).
- Five power modes.
- Six usage values.

The actual number of values depended upon the complexity of the product type but never fell below six. Thus, for the 170 different product types examined, over *two thousand* values needed estimation (or at least consideration). Each of these values has an uncertainty that will be reflected in the overall estimate of lopomo energy use. It is also possible that some product types with lopomo energy use were overlooked and not captured in the calculations, further adding to the overall uncertainty The purpose of this section is to describe the uncertainty in this estimate.

The *composition* of the uncertainty in this project is complex. The research team drew upon a wide variety of sources to estimate each value. For example, power measurements from as many as five different sources might be considered when estimating power levels for each mode. The major sources were measurements conducted as part of this project, but researchers also drew upon measurements from Australia or values inferred from research not directly related to energy consumption (such as Nielsen ratings for the number of hours people watched television). They used professional judgment to derive a single value from all the measurements, weighting more heavily the sources appearing to be most reliable or relevant.[9] They explored the uncertainty by examining the sensitivity of the results to changes in values that might have arisen through various kinds of errors. These errors were:

- A product type was overlooked (how large would it have to be to cause a 1% error?).
- Saturations were consistently underestimated.
- Power consumptions were consistently underestimated.
- Periods of time spent in low-power modes were incorrectly underestimated.

The results of these sensitivity explorations are discussed below.

6.3.2. Results of Uncertainty Study

Overlooked Product Type

Over 170 product types were considered in this project; however, it is always possible that a significant product was missed. If this occurred, what kind of energy consumption and saturation characteristics must it have in order to equal 1% of lopomo energy use? Table 17 lists three possibilities.

9. In an ideal project, all of the data would be collected from a single set of representative homes. The uncertainties could be estimated in a straightforward manner. However, such a project would need to monitor hundreds of homes (in order to capture products with low saturations) and would be prohibitively expensive to undertake. For example, a survey of only one hundred homes would need long-term measurements from over 4400 devices (assuming 44 lopomo products per home).

Table 17. Impact of Overlooked Product Type

Saturation of overlooked product	5%	20%	100%
Implied power level (W) needed to cause 1% change in statewide lopomo energy use	22.4	5.6	1.1

Source: Lawrence Berkeley National Laboratory

If the product were present in 20% of the homes, for example, then the lopomo power use of that overlooked product must average 5.6 W in order to cause a 1% increase in the statewide estimate. Alternatively, the product need only draw 1.1 W if it is present in all homes to result in the same 1% increase in lopomo energy use.

All of these scenarios are possible for one, or possibly two, products, but it is difficult to imagine overlooking many more than that. Certainly a product drawing 22 W, even if present in only 5% of the homes, would appear in one of the studies. (This is comparable to a set-top box.) Thus, it is unlikely that overlooked product types could lead to an increase in more than a few percentage points in overall lopomo energy use. This error exists almost certainly only in one direction; that is, it is unlikely that a product type was included that actually did not exist.

There are many obscure product types with low saturations but modest lopomo power per product, so that their contribution to the statewide total was insignificant. It seems unlikely that there is more than one of these per house on average, and that the average one of these consumes more than 1 W of low power consumption each, so that the authors expect the total of these to be less than 1% of the total estimate.

6.3.3. Underestimated Saturations

Errors in saturations arise at two levels. First, survey data may be inaccurate. In telephone surveys and in-house surveys, some uncertainty existed in the identification of products. An amplifier might, for example, be mistakenly identified as an equalizer or a plasma TV as an LCD technology. A description of the kinds of uncertainties in estimating saturations is shown in Appendix A, page 1. Researchers also drew upon outside sources for saturations; this leads to other kinds of errors. For example, the saturations of bread makers were taken from an Australian study and may not apply to California.

The fraction of products with low-power modes also may be inaccurate. Many white goods, such as dishwashers and clothes washers, exist in configurations with low-power modes while older units have electro-mechanical controls that switch off entirely. (The surveys did not examine white goods.) This problem extends to a diverse array of other goods, too, including toaster ovens, toasters, and rice cookers.

The authors tested the impact of underestimated saturations on statewide lopomo energy use by increasing all saturations by 20%. In this case, lopomo energy use also increased 20% to about 135 W (which follows directly from the formula for calculating it).

Larger errors in estimates of saturations are more likely in products with low initial saturations (because it is still only a small increase in absolute saturation). This could be a problem if the products also had high lopomo energy use. If many products met these criteria, then errors in

saturation are likely to be more important. Researchers therefore examined products that were present in less than 20% of the homes and whose lopomo energy use exceeded 100 kWh/year (11 W). A scatterplot of saturation vs. lopomo energy use for the 170 products is shown in Figure 8.

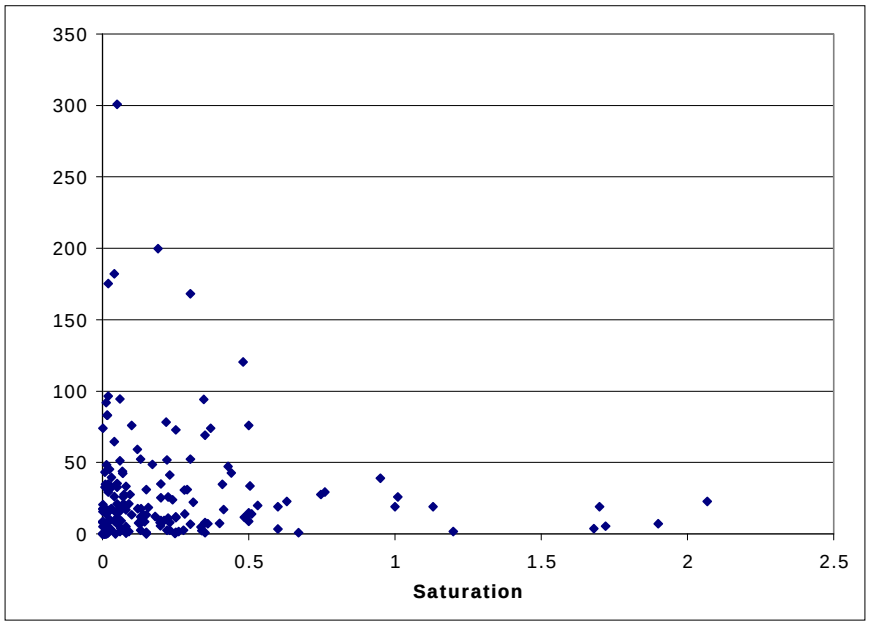

Figure 8. Saturation vs. Lopomo Energy Use

Source: Lawrence Berkeley National Laboratory

Four products met the criteria of saturations less than 0.2 and energy use above 100 kWh/year:

- Set-top box, digital cable with DVR
- Set-top box, satellite with DVR
- Structured wiring
- Video, DVR

An uncertainty in these products' saturations translates into a significant uncertainty in the overall estimate. Furthermore, these products are rapidly penetrating the market. Digital cable set-top boxes could have easily *expanded* 20% in 2006. As a result, the authors believe that errors in estimating the saturations of these products could have translated into significant—easily 10 W—errors in overall lopomo energy use.

The opposite error can just as easily occur, that is, saturations could be *over*estimated. As the notes in Appendix A demonstrate, mistaken identity occurred in both directions. Errors in saturation are probably close to randomly distributed (except for products where consumers are increasing their ownership).

6.3.4. Underestimated Power Values for Low-Power Modes

Power measurements came from a wide variety of sources made up of populations ranging from one to over fifty. Researchers used professional judgment to derive a single value from all the measurements, weighting more heavily the sources appearing to be most reliable or relevant. The accuracy of the measurements themselves is not a problem since most researchers relied on highly accurate watt-meters. A more serious uncertainty arises from failure to measure a representative sample of products. Researchers explored the impact of higher power values in two ways.

First, they increased all lopomo power values by 20%. In this case, lopomo energy use also increased 20% to about 135 W (which follows directly from the formula for calculating it). This scenario implies that, initially, they consistently compiled measurements that were lower than the true average or their judgment favored measurements with lower values. There is no obvious reason to have collected unrepresentative samples with a bias consistently in one direction; it is more likely that some derived values were higher and others lower than actual values. It is, however, conceivable that their professional judgment favored measurements in one direction over another though it would be difficult to sustain this bias for 170 product types.

In a second approach, researchers estimated the impact of raising our estimates of power consumption 1 W in every mode. An absolute adjustment like this does not correspond to any obvious kind of error (though some meters have absolute errors when measuring low values) but is consistent with a tendency to "add a watt just to be on the safe side." The result is a 32% increase in overall lopomo energy consumption. This is a significantly higher value. Here too it is difficult to imagine sustaining this attitude for 170 product types and four power modes. A more likely scenario is making some values higher and some lower, but this "thought experiment" conveys the impact of a bias in the estimates.

6.3.5. Incorrectly Estimated Usage

Each measurement of power use requires a matching estimate of the fraction of time the product resides in that mode. There are two boundary values: the user can either maintain the product in a permanently *active* state or simply disconnect it from the mains. In both cases there will be zero lopomo energy use. A more likely situation, however, is a combination of *active, disconnected*, and one or more low-power modes. These fractions depend on both the behavior of the user and the product itself (because many products automatically shift themselves to lower power modes after preset times).

The research team drew upon field measurements, survey data, and other sources to develop the fractions of time a product resided in each mode. Earlier stages in this project sought to collect data to reduce uncertainties associated usage periods, especially with respect to computers and other products with large differences in low-power modes. Nevertheless, the data are limited and difficult to confirm.

Researchers explored the sensitivity of the results to changes in usage periods through calculations that establish practical limits on lopomo energy use. They estimated overall lopomo power use if all products spent the entire time in their lowest power modes and repeated the calculation for the highest modes. If all products operated constantly in their lowest power mode, then the overall lopomo power use would be 101 W, that is, about 15% less than our estimate. They then repeated the calculation, assuming all products constantly resided in their highest low-power mode. In this case the overall lopomo power use would be much higher, about 302 W.

Is the high estimate of 302 W very likely? The authors explored this question by identifying the highest ten products responsible for the increase from the 112 W (see Table 18).

Table 18. Impact of 100% Usage at Highest Non-Active Power Level

Product type	Increase in lopomo power use* (W)
Computer, desktop	53
Garage door opener	33
Oven, microwave	22
Receiver (audio)	9
Power tool, cordless	6
Computer, notebook	6
Game console	6
Charger, mobile phone	5
DVD player	4
CD player	4

* After adjusting for saturation and fraction with lopomo

Source: Lawrence Berkeley National Laboratory

Three products alone contribute 100 W (about half) to the increase: desktop computers, garage door openers, and microwave ovens. Garage door openers and microwave ovens are present because their highest recorded, non-active mode includes the power consumption of a light that switches on while the door is open. It is highly unlikely that people leave garage and microwave doors open all the time (or even a large amount of the time).

The desktop computer could reasonably operate at higher levels for long periods of time. This mode is idle, not sleep. Many people may maintain their computers at idle in order to use features like voice over internet (VOIP), instant messaging, etc. The research team derived usage profiles from phone surveys and time series measurements, but some uncertainty exists because computers remain a difficult product type to reliably monitor. It is easy to imagine that the correct lopomo value is 10 W higher than our estimate but difficult to imagine much above 20 W. Further research, relying on long–term measurements of many computers, would be needed to further reduce this uncertainty.

Two of the products in the top 10 (power tool, phone charger) are in their “charging” mode (which is higher than the “fully charged”) mode. Many other product types in their charging

mode rank just below the top 10. The duration of the charging mode is short because it is limited by the battery reaching its fully charged state or (in the case of mobile telephones) because sophisticated controls protect the battery from overcharging. Errors in estimation in usage are unlikely to be very significant for these product types.

Consumers adopted significantly different behaviors toward some appliances during the 2001 California electricity crisis. These behaviors included unplugging unused consumer electronics, shutting down computers and peripherals, and wider use of switchable power strips. The result was a roughly 15% reduction in total electricity use. These energy-conserving habits gradually disappeared in the years after the crisis (though some remain). From the perspective of the calculations, these evolving habits translate into changing usage periods. The authors were not able to predict the impact of evolving energy-conserving actions because some decrease lopomo energy use (such as unplugging equipment) while others increase it (such as enabling power management on PCs). Uncertainty can be reduced through periodic *in situ* monitoring studies. On the other hand, large scale changes in behavior will probably be signaled by changes in total residential electricity use.

6.3.6. Confidence in Telephone Survey Data

The incremental nature of this study made it possible to verify the reliability of information supplied by the occupants during telephone surveys. Seventy-five of the homes that took part in the telephone survey were also visited and audited. Many utilities and energy agencies rely on telephone survey data to obtain appliance saturations. However, the authors were unable to find any on-site verifications similar to the one described here.

The respondents claimed that they had 2749 products, corresponding to about 37 per home. The on-site auditors found that 591 products were not present, corresponding to 8 per home.

During the on-site visits, the auditors identified 481 products that the respondents failed to report, which corresponds to about 6 per home.

The errors arise from several sources. The respondents may have misunderstood the definitions (e.g., reporting a TV instead of a TV/VCR), incorrectly recalled the appliances present, or miscounted the number of a specific appliance (such as a television). The auditor may also have failed to find an appliance or was unable to access it. The survey further limited the study to appliances that were in operable condition and/or had been used in the previous year; these criteria could easily be interpreted differently by the occupants and auditors. Finally, a few months passed between the phone survey and the on-site inspection. A characteristic of these appliances is rapid turnover, so it is possible that a few products were discarded and others were purchased. Researchers compiled comments from the auditors (see Appendix B, page 1) which illustrate these problems.

These data show that the average home had roughly 35 products (37 –8 +6) being surveyed. These results also suggest that the telephone survey had a gross error rate of roughly 40% (8+6/35). The net error is much smaller because the errors sometimes refer to the same product, that is the occupants inaccurately report the presence of a product while the auditor reports that

it does not exist and that another (actually the same) product is present. The authors conclude that telephone surveys are reasonably accurate means of determining the number of products present but less reliable in determining the kind of products.

6.3.7. Summary of Uncertainty Analysis

The presentation of confidence intervals and other conventional measures of uncertainty is not appropriate for this kind of project. Instead the authors explored different kinds of errors and their impact on the estimated lopomo energy use. A summary of those explorations is presented below in Table 19.

Table 19. Impact on Lopomo Energy Use from Different Kinds of Potential Errors

Type of Error	Impact
Overlooked product type	Missing product type's lopomo energy use must exceed 5.6 W with a saturation of 20% in order to change overall value 1%
Underestimated saturations	A 20% increase in saturations leads to 20% increase in lopomo energy use
Underestimated power values (by a percentage)	A 20% increase in all power modes leads to 20% increase in lopomo energy use
Underestimated power values (by 1 W in every mode)	A 32% increase in lopomo energy use
Incorrect estimates of the amounts of time that products remain in different modes	If products reside in lowest mode all the time, then lopomo energy use falls to about 100 W If products reside in highest mode all the time, then lopomo energy use rises to about 300 W

Source: Lawrence Berkeley National Laboratory

It is possible to devise scenarios where lopomo energy use is much higher than the researchers' estimate, but their explorations demonstrate that such scenarios are highly unlikely for a variety of reasons. These explorations confirm that their estimate is robust.

6.4. Energy Use of Products While in Their Active Mode

How does the lopomo energy use of a product compare to its active energy use? Measuring electricity use of products while in their active mode was not a goal of this project. Measuring active energy use often requires different meters and monitoring approaches, especially for the "traditional" end uses, such as heating, cooling, water heating and lighting. Gas-fired appliances need gas meters.

However, the authors were able to compare lopomo to active energy use for most product types within the electronics and miscellaneous categories. The energy consumed in active mode is simply the product of the time while in the active mode(s) and the average power level during that time. The DVD player, for example (see Appendix B, page 2), plays 2% of the time, drawing 10 W. This amounts to 1.8 kWh/year, which contrasts to the 19 kWh/year in low-power modes.

Table 20 lists the average lopomo and active power values for most of the electronics and miscellaneous categories. The entries at the bottom of the table are categories for which no active energy use was calculated. Product types shown in bold face are electronics, product types in normal font are miscellaneous, and underlined entries are "traditional" end-use product types.

Overall, active consumption is only 16% greater than lopomo consumption. Thus, these electronics and miscellaneous products—as a group—consume slightly more energy while "on" than as they do when "off." However, there are significant differences among categories. Figure 9 is a scatterplot, showing the relationship between lopomo power and the active/lopomo ratio. Figure 9 reveals a "gulf" of ratio values between 0.5 and 2—that is, every category is either dominated by active or overwhelmingly lopomo. In other words, there are no categories where lopomo and active are similar (such as indicated by the overall ratio).

Table 20. Average Active and Lopomo Power Use by Category

Category	Active (W)	Lopomo (W)	Active/ lopomo ratio
Active > Lopomo			
Display	42.8	8.41	5.09
Computer	29.8	5.99	4.97
Electric Housewares	18.3*	6.88	2.66*
Transportation	5.65	0.50	11.3
Active < Lopomo			
Video	5.52	11.1	0.50
Audio	5.34	16.2	0.33
Set-top	4.58	16.7	0.27
Imaging	0.77	7.79	0.10
Infrastructure	0.54	6.01	0.00
Outdoor Appliances	0.28	0.95	0.29
Security	0.14	0.85	0.16
Telephony	0.08	6.47	0.01
Peripherals	0.04	1.89	0.02
Networking	0.00	7.98	0.00
Total for electronics and most miscellaneous	**114.**	**97.8**	**1.16**
No estimate for Active			
Appliance	—	2.74	—
Power	—	2.37	—
Utility	—	1.10	—
Lighting	—	1.23	—
Personal Care	—	0.95	—
Hobby/leisure	—	0.32	—

Water Heating	—	0.07	—
HVAC	—	5.68	—
TOTAL	**114.**	**112.**	

* Electric Housewares active incomplete

Bold is Electronics. Underline is Traditional.

Source: Lawrence Berkeley National Laboratory

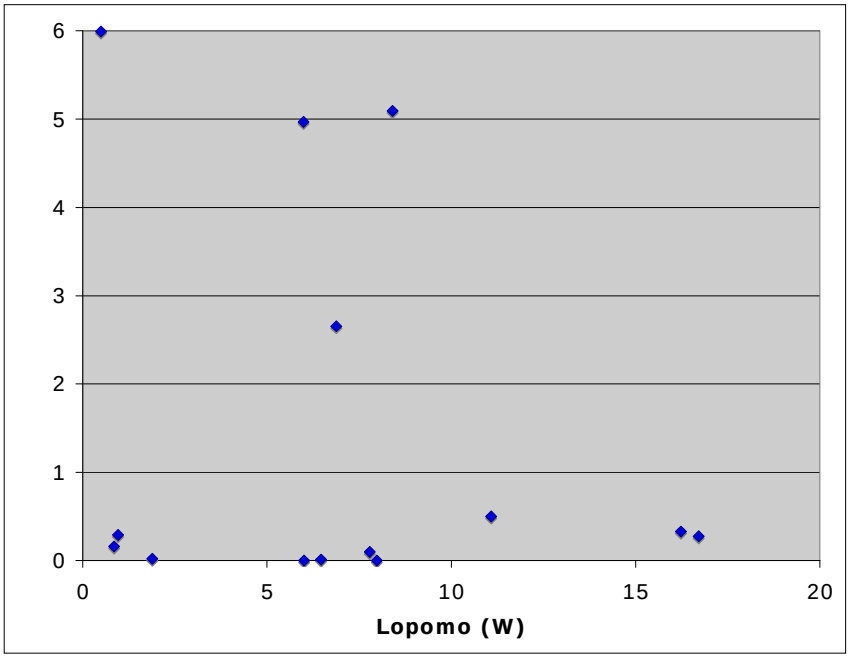

Figure 9. Average Active/Lopomo Ratio vs. Average Lopomo Power Use for by Category.

Note: the value for Transportation was reduced from 11 to 6 to facilitate display.

Source: Lawrence Berkeley National Laboratory

7.0 Discussion

7.1. Comparisons with Other Studies

Measurements of standby power and other low-power modes have been undertaken around the world. The major studies are summarized in Table 21. Few studies are directly comparable to this one because they either focused on a particular mode (such as standby) or group of products (such as electronics). Nevertheless, they help place this study within a global (and historical) context.

An Australian metering study in 120 homes (Energy Efficient Strategies 2006) measured low-power modes in all products. The number of products with low-power modes in Australian homes (27) was lower than our results. The reported result is based on the modes encountered by the auditors when they measured the products' power use. The result is thus consistent with the Australian per home standby power level being higher than the mode 1 level but lower than the total lopomo power. The study did not measure the usage period in each mode, so it was impossible to convert power levels into energy consumption. Power levels for some products metered in the Australian study were used to inform our estimates of power levels.

A New Zealand study (Isaacs, Camilleri et al. 2006) metered selected products in 400 homes. They found an average of only 50 W/home from standby. This included heated towel racks and a few other products not considered in this study. These homes appeared to be stocked with fewer products than California homes. Researchers drew upon some of the New Zealand usage data to form their estimates.

A metering campaign in 297 homes in Italy, Greece, Portugal, and Denmark was the largest study in the world. (Sidler 2002) This study included both long–term and spot measurements, so it was possible to estimate lopomo energy use for many products. After subtraction of refrigerator standby, lopomo energy use averaged around 30–45 W/home, that is, about one third of the values found in this study. However, these measurements took place in 2002 (and earlier) mostly in poorer countries and before the explosive growth of appliance ownership. Furthermore, the study did not capture many of the smaller products such as rechargeable products. An even more detailed examination of energy use relying on the same kind of equipment and methodology is presently underway in Sweden, but results are not yet available.

A Danish metering study (Gudbjerg and Gram–Hanssen 2006) limited to mostly electronics reported a standby level of about 67 W. The estimate may have included some constant ventilation and lighting. The result probably reflects a mixture of modes. This study took place several years after the EURECO multicountry study and increased level reflects a rapid increase in lopomo energy use in Denmark.

The investigation of energy use by builder-installed equipment in new, California homes was part of this project and reported earlier (Brown, Rittelman et al. 2006). These homes were unoccupied yet had lopomo power levels equal to researchers' statewide estimate of existing, occupied California homes. The lopomo energy use would certainly rise when people moved into these homes, bringing their set-top boxes, computers, and other products. The lopomo

energy use observed in these new, unoccupied homes suggests that future energy use in California homes will continue to rise.

A recent investigation of Japanese homes (Ohkuni 2006) found an average standby of only 35 W. Little information is available about this study, but it appears to be based on spot metering and survey data. The study also concluded that standby power use is falling in Japanese homes as a result of lower standby levels in individual products, consolidation of products, and greater efforts by consumers to unplug equipment not being used. This is the first study suggesting that lopomo energy use is falling. The report—available in Japanese only—deserves careful scrutiny because it illustrates the potential impact of two trends not normally credited for reductions: consolidation of products and greater occupant attention to switching off and unplugging equipment.

In 2002, Ross and Meier (Ross and Meier 2002) measured standby power use in 10 California homes. Some products were not measured because they were not easily accessible, and the modes measured were generally in the state encountered during the audit (similar to the Australian procedure) Less than half as many lopomo products per home were observed (19 vs. 44), but the standby power consumption was also about half.

TIAX (Roth and McKenney 2007) recently completed an estimate of electricity consumed by consumer electronics in the United States. This estimate drew upon spot measurements, survey data, and other studies. The authors used some of TIAX's power measurements and usage information to develop their estimates. TIAX estimated that the average home uses about 45 W in all low-power modes. This estimate excludes digital TVs and all products outside the consumer electronics category so, not surprisingly, the estimate is lower than those of the authors. A category–by–category comparison was outside the scope of this project.

Overall, researchers estimate of lopomo energy use appears to be higher than that either reported or implied in other studies. Some of the studies are older or are restricted to fewer categories of products, so growth may be partly responsible. The authors estimate of Mode 1 power use is similar to reported estimates for standby power. On the other hand, their estimates of lopomo energy use appear to be higher than other studies. The most likely explanation for the differences are assumptions regarding other low-power modes and the time the products reside in them. Recall that this was responsible for about half of total lopomo energy use.

These studies employed different methodologies. Nevertheless, all of the studies found it infeasible to meter low-power modes in all of the products in the homes. The most comprehensive studies resorted to long-term measurements of the major appliances and spot measurements of the smaller devices. In this way, they accurately measured lopomo energy use in major appliances but estimated the energy consumption of smaller devices. An important methodological conclusion is that it will be impossible to measure lopomo energy in all of the devices in a home; instead, it will always be necessary to rely on a combination of approaches, that is, long–term measurements for major products and spot measurements for smaller devices. In the case of the smaller devices, usage intervals will need to be obtained through separate procedures, such as from occupant questionnaires.

Table 21. Recent Estimates of Lopomo Energy Use or Closely Related Results

Location, year, and number of homes*	What was reported?	Results (per home)**
This report, California, 2007, all California homes	Combination of spot and long-term measurements, and estimates	44 lopomo products; 112 W lopomo; 54 W mode 1 power
Australia, 2005, 120 homes	Spot measurements of appliances in mode found by auditors	27 lopomo products; 83 W
New Zealand, 2006, 400 homes	Energy use of appliances for several weeks	50 W (after subtracting refrigerator)
Denmark, 2005	Spot measurements of mostly electronic products in various low-power modes	67 W lopomo
Portugal, Greece, Italy, Denmark, 2002, 297 homes	Spot and long-term measurements	46–60 W lopomo (but appears to include ~16 W for refrigerators and excluded very small products)
California, 2006, 14 homes	Spot measurements of builder-installed products in new, unoccupied homes	112 W lopomo (after subtracting refrigerator)
California, 2002, 10 California homes	Spot measurements of all accessible devices in various power modes	19 lopomo products; 67 W
Japan, 2005, unknown number of homes	Spot measurements and survey data	35 W
TIAX, 2007, all U.S. homes (assumed 120 million)	Measurements and estimates for electronics only, all modes, excludes digital TVs	45 W for sleep and off modes (based on their conclusion that 32% of 147 TWh of total is consumed while in off and sleep modes)

* See accompanying text for references.

** The authors adjusted reported results to make them as comparable as possible including conversion of energy to average power and regional consumption to per home.

Source: Lawrence Berkeley National Laboratory

8.0 Conclusions and Recommendations

8.1. Conclusions

The primary goal of this project was to estimate low-power mode energy use in California homes. For 2006, the average lopomo power use in California was estimated to be 112 W per home. This is roughly 13% of residential electricity use. An average California home has about 44 products with one or more low-power modes.

The authors considered nearly 200 different product types and undertook a complete analysis for 170 product types. The ten largest contributors to lopomo energy use are shown in Table 22 below. Together, they are responsible for 40% of total lopomo energy use, while the remaining 160 product types examined are responsible for 60%.

Table 22. Top 10 Lopomo Products

Product type	Average lopomo per home		Fraction of total lopomo energy use
	Energy (kWh/year)	Power (W)	
Set–top Box, satellite	58	7	6%
Set–top Box, digital cable	50	6	5%
Television, CRT	47	5	5%
Video, DVR	38	4	4%
Audio Minisystem	38	4	4%
Computer, desktop	37	4	4%
Receiver (audio)	33	4	3%
Phone, cordless	33	4	3%
Air Conditioning, central	27	3	3%
Oven, microwave	26	3	3%
Total of top 10	**387**	**44**	**40.00%**

Source: Lawrence Berkeley National Laboratory

A common definition of standby power is the lowest power use of a device while still connected to the mains. In California homes, this mode equals about 54 W. The other low-power modes typically have somewhat greater functionality (but still less than fully active) and account for 58 W. Thus, at present, lopomo energy consumption is evenly split between the lowest and the higher modes.

The diverse sources of data prevented a traditional uncertainty analysis but researchers demonstrated that the impact of various kinds of errors—failing to include a product type, underestimating power levels or usage intervals, etc.—rarely led to changes greater than 15% in the results.

Lopomo energy use will unquestionably grow in the near future, although the source of the increased energy use is complex. Consumers will discard obsolete products—such as VCR—or replace existing products with models having lower standby power use. The benefits from products with lower standby power use will be offset by a higher number of products with

lopomo energy use and longer periods spent in modes higher than standby. For example, new digital TVs equipped with CableCARD readers never enter the lowest power mode when a CableCARD is inserted. Simply taking into account existing trends led to an 18% in lopomo energy use (to 132 W). The authors investigation of new, unoccupied homes demonstrated that builder-installed products alone resulted in lopomo power levels of 117 W, which is more than today's California average for an *occupied* home. Products responsible for this 117 W include hardwired smoke detectors, ground-fault interrupt circuits, communications-related equipment, and tankless water heaters. (Tankless water heaters may save natural gas, but their controls also draw 5 W electricity). After people move into these homes and fill them with a typical stock of products, these homes' lopomo energy use will certainly increase.

The authors have partly taken into account two trends observed in a recent Japanese (Ohkuni 2006) study. Researchers there claim that consolidation of appliances (combining for example a TV, PC, computer display, and DVD player) combined with increased occupant attention to disconnecting products, were partly responsible for a fall in electricity consumption. A separate study in Denmark (Gudbjerg and Gram-Hanssen 2006), for example, observed an almost 50% reduction in standby use in home entertainment and computers after an intensive, personalized campaign. This campaign included visits by an energy advisor and distribution of meters and switched extension cords. Even with these extraordinary efforts, the researchers observed a gradual diminution of savings in only a few months. Nevertheless, these trends deserve further investigation and confirmation.

Several side-investigations were also conducted to establish a workable methodology and enhance the confidence in our estimate. A *taxonomy* was established to describe the stock of lopomo products. This is important because it permitted us to track, in a reasonably consistent fashion, the nearly 200 product types encountered in this project.

A side effect of the taxonomy was the recognition of a new end use, the electronics end use, which consists of products whose primary purpose is processing information. Separately identifying the electronics end use may assist in more accurately disaggregating residential (and perhaps commercial) energy consumption and forecasting future energy use. Maintaining an up-to-date taxonomy requires constant effort; this task might be a suitable responsibility for the trade associations dealing in these products or the Energy Information Administration within the U.S. Department of Energy.

No methodology of estimating lopomo energy use is entirely satisfactory. A review of the literature demonstrated that all researchers relied on combinations of long-term and short-term measurements to obtain power levels. They used various techniques to obtain periods of time the products operated in each mode, ranging from surveys to assuming that the as-found mode was the dominant mode. When measurement resources are limited, then one must act strategically to measure where the greatest uncertainty exists. This is complicated when the uncertainty exists at the product level (power levels, usage profile) and the aggregate level (saturation and fraction of products in that product type with lopomo energy use). In retrospect the authors found that the average lopomo energy use obtained through intensive measurements in eight homes provided surprisingly similar results to the aggregate analysis

(108 W vs. 112 W). This could have been a coincidence, but the pilot study helped researchers focus on the important products.

8.2. Recommendations for Research, Market and Technology Surveillance, and Regulation

It is important to keep lopomo energy use in perspective. If treated as a separate end use, its 982 kWh/year would rank as only the fourth-largest residential electrical energy use. On the other hand, this aspect of energy consumption is likely to grow rapidly. An 18% increase will occur simply through unavoidable trends and additional growth is highly probable.

The authors offer the following recommendations based on the results of this project. The recommendations are divided into three categories: research, market and technology surveillance, and regulation.

8.2.1. Research Recommendations

Develop networks, protocols, and network interface devices that minimize lopomo energy use. Networked products will be responsible for an increasing fraction of lopomo energy use. If networks are poorly designed, then the products will spend more time in unnecessarily high power modes. (Digital TVs equipped with CABLECards is a recent example.) This will apply to both electronic products that are already, or will soon be, networked as well as emerging networks for traditional energy end uses such as HVAC and lighting.

Develop technologies to reduce lopomo energy use in set-top boxes, tankless water heaters, and HVAC controls. These three product types are responsible for large amounts of current lopomo energy or will be significant soon.

Develop technologies to reduce lopomo energy use in smoke detectors, ground fault interrupt circuits and other "hardwired" applications. This category of code-required safety and health products is an increasing cause of lopomo energy use, and these products are exceptionally long-lived.

Investigate the potential lopomo impacts of electric vehicles. Many types of electric vehicles are likely to appear soon. The plug-in hybrid may be the most publicized but street-ready golf carts, Segways, wheelchairs, and electric bicycles are likely to be more common. Many of the charging systems are poorly designed.[10] Minimum standards may be appropriate.

Investigate the ways in which behavior can affect lopomo energy use. There appears to be conflicting results from Japan and Denmark regarding the extent to which consumer education can reduce lopomo energy use. Results from this research could influence the design of network interfaces to encourage energy-saving behavior. This research could also develop survey questions that more reliably track usage patterns for key products.

10. A charging system for one common electric vehicle draws 15 W even when not connected to the car. Over a year, this is sufficient energy to propel the vehicle from San Francisco to Los Angeles.

Establish a research center to investigate technologies to reduce energy use in electronics. Energy conservation in electronics requires careful management of information flows, both within a single product and in networks of products, as well as improved components. Today, innovations from one product (such as mobile phones) often fail to get transferred to other products (such as set-top boxes). A dedicated research center could identify these innovations and accelerate the adoption of energy-saving technologies.

8.2.2. Market and Technology Surveillance Recommendations

Undertake regular surveillance of new products and meter their power use in all modes. This task could be coordinated with similar activities in Australia, Canada, Europe, and Japan. California may have unique products or conditions, such as appliances connected to utility real-time price networks that deserve special attention.

Periodically measure lopomo (and active mode) electricity use in a sample group of California homes. The results from this project suggest that intensive measurements in less than 10 homes will still yield useful information.

Revise residential appliance surveys (RASSes) to capture more information about presence of products with lopomo energy use. These revisions would also include questions to track usage patterns associated with these products. The surveys—which are typically done through mail or telephone—should be verified with on-site inspections of smaller samples to verify results.

Maintain the taxonomy of products in the "electronics" end use. Unlike the traditional end uses, the electronics end use often suffers from ambiguous definitions, leading to confusion about what exactly is being manufactured, purchased, used, or surveyed. An association of manufacturers or an independent non-profit organization might take responsibility for maintaining and updating this list.

Establish a website to display measurements from this study and future measurements. Public access to these measurements will allow better understanding of current energy use patterns and potentials for energy savings. The website will also fulfill a useful consumer service.

8.2.3. Regulation Recommendations

California may wish to explore regulations when other policies to reduce lopomo energy are not effective. It is important to understand that all existing energy efficiency standards are not designed to deal with lopomo energy use (with the exception of standards addressing external power supplies). A standard is typically associated with a specific product while lopomo energy use is a *characteristic* that cuts across many products. This distinction may necessitate a new kind of *horizontal* standard (Meier and Siderius 2006). Thus, a regulation might address the behavior of all products connected to networks (including the user interface). Three additional examples are listed below.

- Energy test procedures for most white goods and HVAC equipment ignore lopomo energy use. The test procedures should be modified to capture lopomo energy use. This process has already begun but could be accelerated through regulations.

- Auto power-down has recently been proposed for some set-top boxes. This feature may be appropriate for other lopomo products but would probably require regulations to ensure consistent behavior.
- California may wish to regulate the efficiency of electricity consuming devices that are required by building codes in new homes.

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10.0 Glossary

AFCI	An arc fault circuit interrupter detects electrical arcs and breaks the circuit. It acts to prevent arc faults, which is a major cause of fires.
CableCARD	A card that plugs into certain televisions and set–top boxes which contains customer information.
CLASS	California Statewide Lighting and Appliance Efficiency Saturation Study
Ecos	Ecos Consulting. Collaborating contractor in this project who undertook separate analysis of energy use of certain products. http://ecosconsulting.com/
GFCI	Ground fault circuit interrupt. This circuit is installed in outlets near standing water to protect against electrical shock hazard.
HVAC	Heating ventilation and air conditioning
Lopomo	Low-power mode
PIER	California State Energy Commission Public Interest Energy Research
PV	Photovoltaic
RASS	Residential Appliance Saturation Survey
RLW	RLW Analytics. Collaborating contractor in this project responsible for metering and surveys. http://www.rlw.com/
Saturation	Stock of products divided by number of homes
Spot metering	Measurements of instantaneous power consumption based (performed with a watt–meter)
Standby power	Electricity consumed by an appliance while switched off or not performing its primary function. A more technically precise definition is available in test standards established by IEC 62301.
TIAX	TIAX LLC. A consulting firm. http://www.tiaxllc.com/

Appendix A

Auditors' Notes from Inspections of 75 Homes

The process of taking spot power measurements was driven by knowledge of products present based on the telephone survey supplemented by those found in the on–site inventory. Taking these measurements resulted in a wide variety of insights: almost 2000 products were assessed in 75 houses. These comments also contribute to our understanding of the uncertainty in saturations and usage behavior.

Product identification / type

- <u>Products of a different type than expected</u>
    - Electronics
        - Cable STB in reality just a cable hub.
        - Subwoofers identified as "Speaker, powered".
        - "TV, Plasma" is really "LCD projection".
        - MFD is really only a copier.
        - Cordless phone with ans. machine really is corded (+).
        - Cordless power tool "not rechargeable" (so presumably uses regular batteries?) Also a DVD player "uses batteries only".
        - Amplifier "actually a DVD player".
        - Clock "battery operated".
        - MFD has no fax (could still be an MFD).
        - Amplifier is really a receiver.
        - Equalizer is really an amplifier.
        - Wireless router is really wired ("non–wireless").
        - Cable modem is really DSL.
    - Other
        - Actually measured the furnace fan, not the furnace.
        - Gas range with electric oven really all gas.
        - Interior night light is really a "Pest Repeller" (+).
- <u>Product of a different type and a combo product</u>
    - Electronics
        - "Clock" that actually also has a radio and CD player. Clock that also has a radio. Clock radio that really has a CD player.
        - Receiver (audio) also has integrated DVD and speakers.
        - Desktop PC is really an integrated computer.
        - Portable DVD player really a portable TV. (presumably with a DVD player too).

        - DSL modem includes wireless.
        - Clock “includes lamp”.
        - “radio has a corded phone included”.
        - Clock “is a clock radio” (+).
        - CD player “is a boombox”.
        - Clock radio “has a CD player”.
        - LCD TV has “dvd player on side”.
        - Fax is actually an MFD.
        - TV is really TV/VCR.
        - DSL modem includes a router.
    - Other
        - “Night light, interior” is really an “electrostatic air cleaner with a nightlight”.
        - “Flashlight and radio”.
        - Microwave oven “has built–in coffee maker”.

Product usage

- Products not used (but sometimes plugged in!)—aside from toothbrush, all electronics
    - Not plugged in: Audio minisystem, Clock radio, toothbrush.
    - Security system “no longer used”. STB, satellite “not used”.
    - Phone not charged at home.
    - Computer speaker plugged in but not connected to computer audio output.
    - Plugged into a non–working outlet (irrigation timer).
    - VCR “never used but plugged in”. Cassette deck “not used” (+).
    - Clock “not plugged in”.
- Other—all electronics
    - Unplugged when not in use: CE ensemble.
    - TV/VCR is “part of security system plus on at night”.
    - Charger supports “2 phones”.
    - Desktop computer “for kids games only”.

Characteristics

- Impeded metering
    - Hard–wired: Central furnace, garage door opener.
    - Corded phone that doesn’t require (or use as configured) AC power (several).
    - Scanner is USB powered.

- Broken products—all electronics except power tool and night light
    - Turntable "broken". DVD "not working right". VCR "video not working". Game console "broken".
    - Cordless phone "does not work". Power tool, cordless "won't activate". Night light, interior "not working". PC and monitor "not working".
    - Audio minisystem "off button does not work". DVD/VCR "broken does not play". Laser printer "broken not in use".
- Other—all electronics except microwave and garage door openers
    - No power switch: microwave, fax machine (+), copier, cable modem (+), DSL modem (+), computer speakers, subwoofer, STB (cable).
    - Cordless phone also has Bluetooth.
    - Garage door opener with no or burnt–out bulb (several).
    - Desktop computer is "custom".

How metered

- "Off" is external power supply only. (many). A few unplugged EPS for off.
- On is radio playing (several).
- Mode includes charging of battery (e.g. off and sleep for notebook PC—+).
- Ready = no battery (power tool charger).
- Answering machine "active is with speakerphone on".

Not a separately powered product

- Speaker

Peculiar

- A night light that uses more power in Off than when On.
- "Stereo, portable" "attached to toaster oven".
- STB, satellite, "in outdoors cab[ana], for poolside".
- STB, cable "not connected to a tv".

Peculiar but also reported elsewhere

- Microwave oven "has built–in coffee maker".
- "Radio has a corded phone included".
- Clock "includes lamp".
- "Night light, interior" is really an "electrostatic air cleaner with a nightlight".

Metering difficulties—all but last two and occupant issues are electronics

- Lack of appropriate media e.g. CD or tape to get active power.
- Could not get computer to hibernate (+) or to sleep.

- Could not get display to sleep.
- Can't find external power supply for product. Sometimes a product that can be powered by batteries such as a portable stereo.
- Computer has virus so hard to work with.
- Can't tell when battery if fully charged or not.
- Can't find the remote (for TV) (MANY) so can't check "off by remote" power level.
- Can't tell if asleep or off.
- "Switch broken" on satellite STB.
- Notebook computer "not here".
- "Couldn't get to turn on".
- Game console "unable to activate".
- Irrigation timer "unable to turn on".
- For desktop computer sleep mode "was told it has not been working" (so could not meter).
- Night light shows no consumption (rated at 0.03 W).
- For cordless power tool, "power tool not available".

Occupant issues

- "Homeowner did not give access to bdrm1, didn't allow us to do any thing with computer related stuff".
- "Owner requests not to do anything with TV's & set top boxes".
- "Owner didn't want us in garage".

Appendix B

Low-Power Mode Database

		Final Power Levels (W)					Usage (Fraction of Time)						Lopomo of Products		Saturations			Lopomo per Home	
Category	Product Type	Mode 1	Mode 2	Mode 3	Mode 4	Active	Dis-connected	Mode 1	Mode 2	Mode 3	Mode 4	Active	Power (W)	Energy (kWh/yr)	Prod-ucts /HH	Fract-ion of Stock Having a Lopomo	Final	Power (W)	Energy (kWh/yr)
Audio	Amplifier	0.2	33.0			34.0		0.78	0.20			0.02	6.8	59	0.17	0.70	0.12	0.80	7.0
Audio	Audio minisystem	8.0	13.0	13.0	14.0	15.0	0.02	0.68	0.00	0.00	0.23	0.07	8.7	76	0.50	1.00	0.50	4.33	37.9
Audio	Cassette deck	0.6	4.5			5.7		0.91	0.08			0.01	0.9	8	0.28	0.82	0.23	0.21	1.8
Audio	CD player	2.0	8.0			9.0		0.78	0.20			0.02	3.2	28	0.83	0.90	0.75	2.36	20.7
Audio	CD player, portable	1.2	1.8			3.2	0.20	0.04	0.73			0.03	1.4	12	0.25	1.00	0.25	0.34	3.0
Audio	Charger, digital music player	0.4	1.5			5.0	0.50	0.35	0.08			0.07	0.3	2	0.34	1.00	0.34	0.09	0.8
Audio	Equalizer (audio)	2.0				30.0		0.80				0.20	1.6	14	0.03	0.40	0.01	0.02	0.2
Audio	Home theater system	0.7	34.0			38.0		0.92	0.10			0.08	4.0	35	0.05	1.00	0.05	0.20	1.8
Audio	Karaoke machine	6.0	12.0			13.0	0.80	0.19				0.01	1.1	10	0.03	1.00	0.03	0.03	0.3
Audio	Musical keyboard	2.5	3.0	6.0		6.5	0.05	0.05	0.86	0.03		0.01	2.9	25	0.20	1.00	0.20	0.58	5.1
Audio	Radio, CB	1.0				60.0		0.99				0.01	1.0	9	0.00	0.50	0.00	0.00	0.0
Audio	Radio, table	1.5				11.0	0.10	0.85				0.05	1.3	11	0.75	0.30	0.23	0.29	2.5
Audio	Receiver (audio)	3.0	37.0			40.0		0.50	0.25			0.25	10.8	94	0.36	0.96	0.35	3.72	32.5
Audio	Speakers, powered	5.0	5.5			9.0		0.75	0.00			0.25	3.8	33	0.05	1.00	0.05	0.19	1.6
Audio	Speakers, wireless (base station)	5.0				8.0		0.75				0.25	3.8	33	0.03	1.00	0.03	0.11	1.0
Audio	Speakers, wireless (speakers)	5.0				8.0		0.75				0.25	3.8	33	0.03	1.00	0.03	0.11	1.0
Audio	Stereo, portable	1.6	4.0			7.0	0.30	0.51	0.13			0.06	1.3	12	0.51	0.95	0.48	0.65	5.7
Audio	Subwoofer	7.0	10.0			11.0		0.16	0.78			0.06	8.9	78	0.22	1.00	0.22	1.94	17.0
Audio	Tuner	1.0				9.0		0.97				0.03	1.0	8	0.16	0.90	0.14	0.14	1.2
Audio	Turntable (audio)	1.0				14.0		1.00				0.00	1.0	9	0.15	0.90	0.14	0.13	1.2
Computer	Computer, desktop	3.5	17.0	60.0		70.0	0.07	0.44	0.03	0.04		0.42	4.5	39	0.95	1.00	0.95	4.23	37.0
Computer	Computer, integrated (all)	3.0	30.0	60.0		110.0	0.07	0.62	0.03	0.04		0.24	5.2	45	0.02	1.00	0.02	0.12	1.0
Computer	Computer, notebook	1.0	3.0	2.5	18.0	22.0	0.15	0.15	0.14	0.28	0.15	0.13	4.0	35	0.41	1.00	0.41	1.63	14.3
Computer	Dock, notebook	2.0				12.0	0.20	0.50				0.30	1.0	9	0.02	1.00	0.02	0.02	0.2
Display	Computer display, CRT	1.2	8.0	8.2		65.0	0.07	0.54	0.12	0.08		0.19	2.3	20	0.53	1.00	0.53	1.21	10.6
Display	Computer display, LCD	1.1	1.4			29.0	0.07	0.54	0.19			0.20	0.9	8	0.40	1.00	0.40	0.34	3.0
Display	Projector, video	2.0	20.0			175.0	0.64	0.30	0.05			0.01	1.6	14	0.01	1.00	0.01	0.02	0.2
Display	Television, CRT	3.1				71.0	0.00	0.84				0.16	2.6	23	2.11	0.98	2.07	5.38	47.2
Display	Television, LCD	2.0				70.0	0.00	0.77				0.23	1.5	13	0.14	1.00	0.14	0.22	1.9
Display	Television,plasma	2.5				250.0	0.00	0.75				0.25	1.9	16	0.02	1.00	0.02	0.04	0.3
Display	Television, rear projection	3.2				160.0	0.00	0.75				0.25	2.4	21	0.09	1.00	0.09	0.22	1.9
Display	Television/VCR	4.5				55.0	0.00	0.78				0.22	3.5	31	0.28	1.00	0.28	0.98	8.6
Imaging	Copier	20.0	1.5			50.0	0.12	0.20	0.55			0.13	4.8	42	0.07	1.00	0.07	0.34	2.9
Imaging	Fax, inkjet	6.0	5.3			40.0		1.00				0.01	6.0	52	0.13	1.00	0.13	0.78	6.8
Imaging	Fax, laser	4.0				30.0		1.00				0.01	4.0	35	0.02	1.00	0.02	0.08	0.7
Imaging	Fax, thermal	5.0				80.0		0.99				0.01	5.0	43	0.01	0.85	0.01	0.04	0.4
Imaging	Multi-function device, inkjet	7.8	9.9	11.0		16.0	0.07	0.68	0.04	0.20		0.01	7.9	69	0.35	1.00	0.35	2.77	24.2
Imaging	Multi-function device, laser	5.0	7.8	10.6		36.0	0.07	0.68	0.04	0.20		0.01	5.8	51	0.06	1.00	0.06	0.35	3.1
Imaging	Printer, inkjet	1.4	4.9	7.8		12.0	0.07	0.02	0.57	0.33		0.01	5.4	47	0.43	1.00	0.43	2.32	20.3
Imaging	Printer, laser	10.0	3.5	8.0		110.0	0.07	0.13	0.58	0.21		0.01	5.0	44	0.07	0.95	0.07	0.34	3.0
Imaging	Printer, photo	1.4	3.5	7.2		13.4		0.99				0.01	1.4	12	0.18	1.00	0.18	0.25	2.2
Imaging	Scanner, flatbed	3.0	4.0	9.0		36.0	0.07	0.58	0.25	0.09		0.01	3.5	31	0.15	1.00	0.15	0.53	4.7
Power	Uninteruptible Power Supply (UPS)	5.0				10.0	0.05	0.90				0.10	4.5	39	0.03	1.00	0.03	0.14	1.2
Networking	Hub, ethernet	3.6	3.8			5.0		0.00	1.00				3.8	33	0.08	1.00	0.08	0.30	2.7
Networking	Hub, USB	1.2	1.4	1.4		2.8	0.07	0.00	0.00	0.93			1.3	11	0.25	1.00	0.25	0.32	2.8
Networking	Modem, cable	1.4	8.1	8.3	8.4	9.0		0.00	0.10	0.66	0.24		8.3	73	0.25	1.00	0.25	2.08	18.2
Networking	Modem, DSL	1.0	1.4	6.5	6.5	7.0		0.00	0.10	0.24	0.66		6.0	52	0.30	1.00	0.30	1.80	15.7
Networking	Modem, POTS	1.4	1.7	6.5	6.5	7.0	0.07	0.00	0.10	0.24	0.59		5.6	49	0.17	1.00	0.17	0.95	8.3
Networking	Modem, satellite	5.0	10.0			11.0		0.10	0.90				9.5	83	0.02	1.00	0.02	0.15	1.3
Networking	Router, ethernet	1.3	5.4	5.9		40.0		0.00	0.00	1.00			5.9	52	0.22	1.00	0.22	1.30	11.4
Networking	Wireless access point	1.7	4.7	4.7		6.2		0.00	0.00	1.00			4.7	41	0.23	1.00	0.23	1.08	9.5
Peripherals	Speakers, computer	1.5	1.7	4.1		7.0	0.10	0.00	0.45	0.45			2.6	23	0.63	1.00	0.63	1.64	14.4
Peripherals	Dock, PDA	1.1	2.0			5.0	0.05	0.60	0.35				1.4	12	0.13	1.00	0.13	0.18	1.5
Peripherals	CD recorder	1.0				12.0		0.99				0.01	1.0	9	0.00	1.00	0.00	0.00	0.0
Peripherals	External drive	1.3				12.0	0.15	0.80				0.05	1.0	9	0.08	0.80	0.06	0.07	0.6
Security	Security system	4.0				25.0		1.00					4.0	35	0.20	1.00	0.20	0.80	7.0
Security	Security system	1.2				1.2	0.20	0.50				0.30	0.6	5	0.08	1.00	0.08	0.05	0.4
Security	Infant monitor transmitter	1.1	1.1			1.5	0.05	0.00	0.05			0.90	0.1	0	0.08	1.00	0.08	0.00	0.0

		Final Power Levels (W)					Usage (Fraction of Time)						Lopomo of Products		Saturations			Lopomo per Home	
Category	Product Type	Mode 1	Mode 2	Mode 3	Mode 4	Active	Dis-connected	Mode 1	Mode 2	Mode 3	Mode 4	Active	Power (W)	Energy (kWh/yr)	Prod-ucts /HH	Fract-ion of Stock Having a Lopomo	Final	Power (W)	Energy (kWh/yr)
Set-top	Set-top box, analog cable	10.3	11.3			11.5		0.00	0.77			0.23	8.7	76	0.10	1.00	0.10	0.87	7.6
Set-top	Set-top box, digital cable	17.8	25.0			30.0		0.00	0.77			0.23	19.2	168	0.30	1.00	0.30	5.76	50.5
Set-top	Set-top box, digital cable with PVR	43.0	44.6			46.6		0.00	0.77			0.23	34.3	301	0.05	1.00	0.05	1.72	15.0
Set-top	Set-top box, game console with internet connectivity	8.0				50.0		0.92				0.08	7.4	64	0.04	1.00	0.04	0.29	2.6
Set-top	Set-top box, satellite	15.7	15.9			16.0		0.50	0.37			0.13	13.7	120	0.48	1.00	0.48	6.59	57.7
Set-top	Set-top box, satellite with PVR	25.0	27.0			27.6		0.00	0.77			0.23	20.8	182	0.04	1.00	0.04	0.83	7.3
Set-top	Set-top box, internet	12.2	15.4			15.4		0.00	0.70			0.30	10.8	94	0.06	1.00	0.06	0.65	5.7
Telephony	Answering machine	1.3	2.2	2.1		2.9		0.00	0.99	0.00		0.01	2.2	19	0.60	1.00	0.60	1.31	11.4
Telephony	Caller ID unit	1.3				1.3		1.00					1.3	11	0.05	1.00	0.05	0.07	0.6
Telephony	Charger, mobile phone	0.3	2.2	3.6		6.0	0.15	0.75	0.10				0.4	4	1.68	1.00	1.68	0.70	6.1
Telephony	Phone, conference	2.0				3.0	0.00	1.00					2.0	18	0.03	1.00	0.03	0.06	0.5
Telephony	Phone, corded	1.3	0.9			1.4		0.01	0.99				0.9	8	0.98	0.20	0.20	0.18	1.6
Telephony	Phone, cordless	0.9	1.6	2.8		3.4		0.00	0.49	0.50		0.01	2.2	19	1.70	1.00	1.70	3.71	32.5
Telephony	Charger, cordless phone handset	1.3	2.7	3.3		5.0	0.50	0.00	0.10	0.40			1.6	14	0.28	1.00	0.28	0.45	3.9
Video	Charger, still camera	0.6				5.0	0.80	0.15				0.05	0.1	1	0.67	1.00	0.67	0.06	0.5
Video	Charger, video camera	0.6				5.0	0.80	0.15				0.05	0.1	1	0.35	1.00	0.35	0.03	0.3
Video	VCR	2.5	7.5			13.0	0.00	0.71	0.21			0.08	3.4	29	0.76	1.00	0.76	2.55	22.3
Video	VCR/DVD	2.3	5.1			13.0	0.00	0.64	0.21			0.15	2.5	22	0.31	1.00	0.31	0.79	6.9
Video	DVD player	1.2	6.0			10.0	0.00	0.77	0.21			0.02	2.2	19	1.00	1.00	1.00	2.18	19.1
Video	DVD recorder	0.8				18.3		0.73				0.27	0.6	5	0.00	1.00	0.00	0.00	0.0
Video	Game console	1.0	23.0			24.0		0.77	0.12			0.11	3.5	31	0.29	1.00	0.29	1.02	9.0
Video	Video, PVR (no multifunctionality)	37.0	38.0			38.0	0.00	0.00	0.60			0.40	22.8	200	0.19	1.00	0.19	4.33	37.9
Video	Videocassette rewinder	1.1				5.0	0.21	0.78				0.01	0.9	8	0.13	1.00	0.13	0.11	1.0
Electric Housewares	Toaster	1.0				800.0	0.10	0.89				0.01	0.9	8	0.80	0.02	0.02	0.01	0.1
Electric Housewares	Toaster oven	1.0				800.0	0.10	0.89				0.01	0.9	8	0.41	0.30	0.12	0.11	1.0
Electric Housewares	Iron	0.5					0.98	0.01				0.01	0.0	0	0.90	0.05	0.05	0.00	0.0
Electric Housewares	Blender	0.5					0.90	0.24				0.01	0.1	1	0.80	0.01	0.01	0.00	0.0
Electric Housewares	Water dispenser, bottled	1.0					0.05	0.94				0.06	0.9	8	0.04	0.03	0.00	0.00	0.0
Electric Housewares	Coffee maker, residential	1.2				870.0	0.10	0.89				0.01	1.1	9	0.70	0.30	0.21	0.22	2.0
Electric Housewares	Espresso maker, residential	2.0				900.0		0.99				0.01	2.0	17	0.01	0.20	0.00	0.00	0.0
Electric Housewares	Rice cooker	1.0				1000.0	0.50	0.47				0.01	0.5	4	0.21	0.30	0.06	0.03	0.3
Electric Housewares	Oven, microwave	3.0	3.5	25.0		1400.0		0.99	0.00	0.00		0.01	3.0	26	1.02	0.99	1.01	3.00	26.3
Electric Housewares	Clock					1.0		0.00				1.00	0.0		1.00		0.00	0.00	0.0
Electric Housewares	Clock, radio	2.2				4.7		0.99				0.01	2.2	19	1.13	1.00	1.13	2.46	21.6
Electric Housewares	Clock, alarm	1.0				1.3		1.00					1.0	9	0.50	1.00	0.50	0.50	4.4
Electric Housewares	Vacuum, central	3.0				700.0		0.99				0.01	3.0	26	0.07	1.00	0.07	0.21	1.8
Electric Housewares	Vacuum, rechargeable	0.8	2.7			5.0	0.20	0.01	0.78			0.01	2.1	19	0.16	1.00	0.16	0.33	2.9
Hobby/leisure	Aquarium					15.0						1.00	0.0	0	0.14	0.10	0.01	0.00	0.0
Hobby/leisure	Exercise equipment	2.0					0.10	0.88				0.02	1.8	15	0.15	0.30	0.05	0.08	0.7
Hobby/leisure	Ride-on toy car	8.0					0.75	0.24				0.01	1.9	17	0.03	0.50	0.02	0.03	0.3
Hobby/leisure	Sauna, electric	4.0						0.99				0.01	4.0	35	0.01	1.00	0.01	0.04	0.3
Hobby/leisure	Spa/hot tub	3.0	3.0					0.40	0.40			0.20	2.4	21	0.09	0.80	0.07	0.17	1.5
HVAC	Air cleaner, portable	1.0					0.50	0.20				0.30	0.2	2	0.20	0.30	0.06	0.01	0.1
HVAC	Ceiling fan	0.8						0.88				0.12	0.7	6	0.99	0.20	0.20	0.13	1.1
HVAC	Controls, HVAC	3.0						0.80				0.20	2.4	21	0.05	1.00	0.05	0.12	1.1
HVAC	Dehumidifier, portable												0.0	0	0.01	0.70	0.01	0.00	0.0
HVAC	Fan, portable	3.0				45.0	0.75	0.13				0.12	0.4	3	1.41	0.02	0.03	0.01	0.1
HVAC	Fireplace	2.0						1.00				0.01	2.0	17	0.30	0.20	0.06	0.12	1.0
HVAC	Heating, fireplace electric	2.0						1.00					2.0	18	0.01	0.10	0.00	0.00	0.0
HVAC	Heating, fireplace, gas	2.0						1.00					2.0	18	0.10	0.30	0.03	0.06	0.5
HVAC	Humidifier												0.0	0	0.09	0.10	0.01	0.00	0.0
HVAC	Space heater, portable (electric)	0.3	0.4			500.0	0.75	0.22				0.03	0.1	1	0.80	0.02	0.02	0.00	0.0

		Final Power Levels (W)					Usage (Fraction of Time)						Lopomo of Products		Saturations			Lopomo per Home	
Category	Product Type	Mode 1	Mode 2	Mode 3	Mode 4	Active	Dis-connected	Mode 1	Mode 2	Mode 3	Mode 4	Active	Power (W)	Energy (kWh/yr)	Prod-ucts /HH	Fract-ion of Stock Having a Lopomo	Final	Power (W)	Energy (kWh/yr)
Infrastructure	Detector, carbon monoxide	1.5	2.1			10.0		1.00	0.00				1.5	13	0.10	1.00	0.10	0.15	1.3
Infrastructure	Detector, smoke	0.4				1.0		1.00					0.4	4	4.00	0.15	0.60	0.24	2.1
Infrastructure	Dimming switch	0.2						1.00					0.2	2	0.09	1.00	0.09	0.02	0.2
Infrastructure	Doorbell	1.7						1.00					1.7	15	0.50	1.00	0.50	0.85	7.4
Infrastructure	Garage door opener	4.5	80.0			108.0		1.00	0.01				4.9	43	0.44	1.00	0.44	2.15	18.8
Infrastructure	GFCI outlet	0.6						1.00					0.6	5	4.00	1.00	4.00	2.24	19.6
Infrastructure	Breaker, GFCI	2.0						1.00					2.0	18	0.12	1.00	0.12	0.24	2.1
Infrastructure	Breaker, AFI	3.0				10.0		1.00					3.0	26	0.04	1.00	0.04	0.12	1.1
Lighting	Emergency light, interior (residential)	0.8				75.0	0.05	0.94				0.01	0.8	7	0.30	1.00	0.30	0.24	2.1
Lighting	Low-voltage landscape	1.1					0.25	0.50				0.25	0.6	5	0.34	1.00	0.34	0.18	1.6
Lighting	Lamp, decorative	1.0				30.0	0.05	0.92				0.03	0.9	8	0.10	0.02	0.00	0.00	0.0
Lighting	Motion sensor, exterior	0.8						1.00					0.8	7	0.36	1.00	0.36	0.29	2.5
Lighting	Motion sensor, interior	0.8						1.00					0.8	7	0.05	1.00	0.05	0.04	0.4
Lighting	Night light, interior	0.4					0.20	0.50				0.30	0.2	2	1.20	1.00	1.20	0.24	2.1
Lighting	Light, exterior sensors	0.4						0.70				0.30	0.3	2	0.28	1.00	0.28	0.08	0.7
Lighting	Photosensors, exterior	0.4						0.70				0.30	0.3	2	0.22	1.00	0.22	0.06	0.5
Lighting	Timer, exterior	0.4						0.70					0.3	2	0.23	1.00	0.23	0.06	0.6
Lighting	Timer, interior	0.4						0.70					0.3	2	0.13	1.00	0.13	0.04	0.3
Other	Fountain, indoor						0.05					0.95	0.0	0	0.05	0.05	0.00	0.00	0.0
Outdoor Appliances	Charger, hedge trimmer	1.6	2.6			15.0	0.50	0.25	0.24			0.01	1.0	9	0.04	1.00	0.04	0.04	0.4
Outdoor Appliances	Charger, weed trimmer	1.4	2.6			60.0	0.25	0.01	0.73			0.01	1.9	17	0.08	1.00	0.08	0.15	1.3
Outdoor Appliances	Lawn mower	1.4	2.6			60.0	0.25	0.01	0.69			0.05	1.8	16	0.06	1.00	0.06	0.11	1.0
Outdoor Appliances	Timer, irrigation	2.6	2.8			6.0	0.00	0.00	0.97			0.03	2.7	24	0.40	0.60	0.24	0.65	5.7
Personal Care	Air freshener	1.9				1.9						1.00	0.0	0	0.15	1.00	0.15	0.00	0.0
Personal Care	Shaver, men's	0.1	1.2			1.4	0.79	0.10	0.10			0.01	0.1	1	0.25	1.00	0.25	0.03	0.3
Personal Care	Toothbrush	1.6				3.8		0.99				0.01	1.6	14	0.51	1.00	0.51	0.81	7.1
Personal Care	Shaver, women's	0.1	1.2			1.4	0.79	0.10	0.10			0.01	0.1	1	0.15	1.00	0.15	0.02	0.2
Personal Care	Hair dryer	0.0				1000.0	0.50	0.49				0.01	0.0	0	0.80	0.01	0.01	0.00	0.0
Personal Care	Home medical equipment	2.0						0.90				0.10	1.8	16	0.01	0.20	0.00	0.00	0.0
Personal Care	Massager	2.0					0.10	0.85				0.05	1.7	15	0.25	0.20	0.05	0.09	0.7
Power	Surge Protector w/ powerstrip	0.8				0.8		1.00	0.00				0.8	7	1.90	1.00	1.90	1.52	13.3
Power	Timer	1.0					0.10	0.90					0.9	8	0.59	0.60	0.35	0.32	2.8
Power	Structured wiring	20.0				20.0		1.00					20.0	175	0.02	1.00	0.02	0.40	3.5
Transportation	Wheelchair	10.0	15.0			250.0		0.50	0.30			0.20	9.5	83	0.02	1.00	0.02	0.14	1.2
Transportation	Car	15.0	18.0			6000.0	0.30	0.40	0.25			0.05	10.5	92	0.01	1.00	0.01	0.14	1.2
Transportation	Golf cart	15.0	20.0			1000.0	0.30	0.40	0.25			0.05	11.0	96	0.02	1.00	0.02	0.22	1.9
Utility	Bicycle light	0.9	2.0				0.90	0.06	0.02			0.02	0.1	1	0.02	1.00	0.02	0.00	0.0
Utility	Charger, battery	1.0	1.0	1.6		2.9	0.80	0.15	0.00	0.02		0.03	0.2	2	0.26	1.00	0.26	0.05	0.4
Utility	Power tool, cordless	1.9	4.2				0.79	0.10	0.10			0.01	0.6	5	1.72	1.00	1.72	1.05	9.2
HVAC	Air conditioning, central	9.0						0.94				0.06	8.4	74	0.37	1.00	0.37	3.12	27.4
HVAC	Air conditioning, heat pump	9.0						0.94				0.06	8.4	74	0.01	0.20	0.00	0.02	0.1
HVAC	Air conditioner, room/wall	3.0					0.30	0.64				0.06	1.9	17	0.13	0.20	0.03	0.05	0.4
HVAC	Heating, Boiler	4.2						0.89				0.11	3.7	33	0.01	1.00	0.01	0.03	0.3
HVAC	Heating, furnace central	4.2				340.0		0.91				0.09	3.8	33	0.56	0.90	0.50	1.93	16.9
HVAC	Heating, furnace baseboard, floor or wall gas	0.5						0.92				0.08	0.5	4	0.22	0.10	0.02	0.01	0.1
HVAC	Heating, heat pump	4.2						0.80				0.20	3.4	29	0.02	0.95	0.02	0.06	0.6
Appliance	Clothes dryer, electric		3.3						0.95			0.05	3.1	27	0.37	0.20	0.07	0.23	2.0
Appliance	Clothes dryer, gas		3.3						0.95			0.05	3.1	27	0.47	0.20	0.09	0.29	2.6
Appliance	Clothes washer	2.0	5.0					0.96	0.02			0.02	2.0	18	0.73	0.18	0.13	0.26	2.3
Appliance	Clothes washer/dryer	2.5						0.93				0.07	2.3	20	0.01	0.20	0.00	0.00	0.0
Appliance	Range	1.1						0.98				0.02	1.1	9	0.25	0.80	0.20	0.22	1.9
Appliance	Cooktop, electric	1.0						0.98				0.02	1.0	9	0.33	0.05	0.02	0.02	0.1
Appliance	Cooktop, gas	1.0						0.02				0.98	0.0	0	0.62	0.40	0.25	0.00	0.0
Appliance	Oven, electric	3.0						0.98				0.02	2.9	26	0.25	0.90	0.23	0.66	5.8
Appliance	Oven, gas	2.0						0.98				0.02	2.0	17	0.46	0.90	0.41	0.81	7.1
Appliance	Dishwasher	1.5	2.0	2.0				0.76	0.20			0.04	1.5	13	0.60	0.25	0.15	0.23	2.0
Appliance	Freezer	0.0				200.0		0.66				0.34	0.0	0	0.18	0.00	0.00	0.00	0.0
Appliance	Refrigerator	0.0				250.0		0.66				0.34	0.0	0	1.15	0.00	0.00	0.00	0.0
Water Heating	Water heater, electric							0.00				1.00	0.0	0	0.09	0.00	0.00	0.00	0.0
Water Heating	Water heater, gas (instantaneous)	6.0				80.0		0.92				0.08	5.5	48	0.01	0.95	0.01	0.07	0.6