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Energy Use of Home Audio Products in the U.S.

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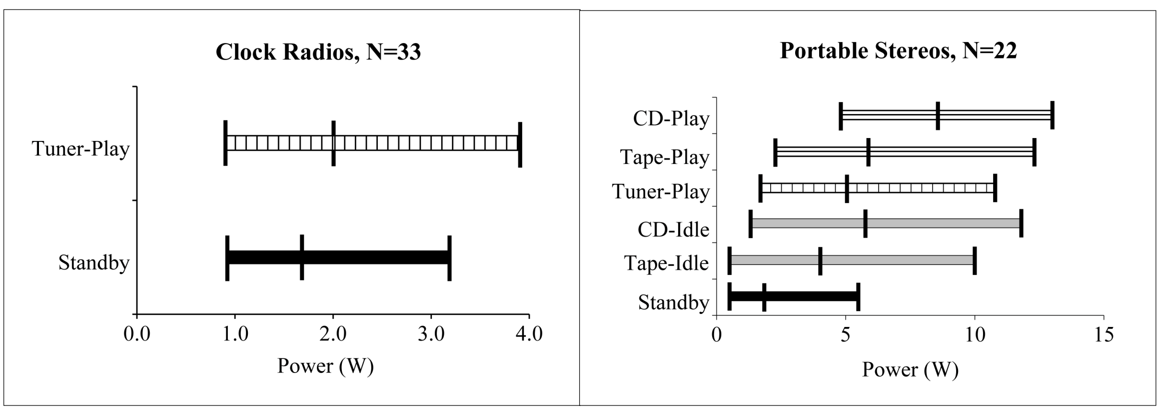
EXECUTIVE SUMMARY

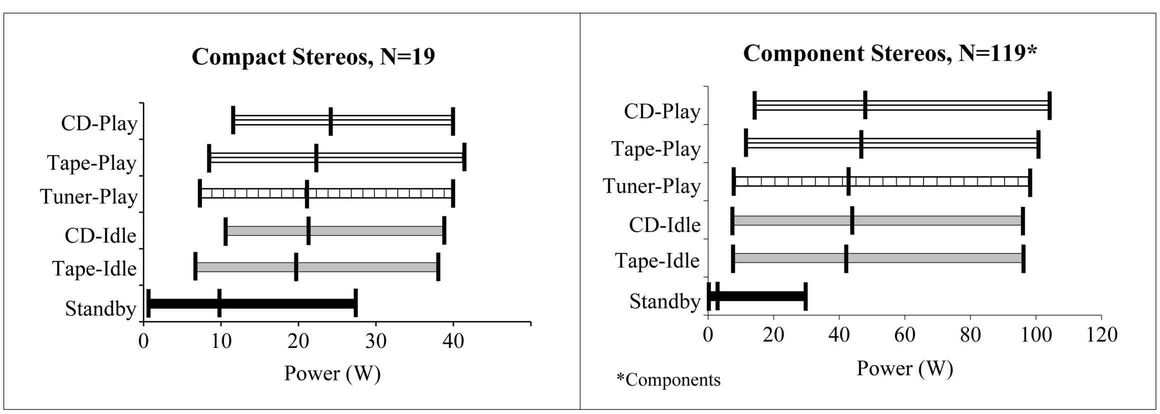
The U.S. Department of Energy (DOE) seeks to maintain an accurate accounting of how the nation consumes energy. They and others use this information in forecasts of energy use and in the development of energy policies. The DOE recently commissioned studies to determine nationwide energy consumption of several appliances that they had not previously studied in detail. The goal of this investigation was to estimate the energy consumption of home audio equipment in the U.S. residential sector in 1998.

We conducted a bottom-up analysis using stock and usage estimates from secondary sources, and our own power measurements. We measured power levels of the most common audio products in their most commonly used operating modes. Power measurements of these products are summarized in **Figure ES-1**.

Figure ES-1. Minimum, Mean, and Maximum Power Draw Values of Clock Radios, Portable Stereos, Compact Stereos, and Component Stereos Measured for This Study



(a) (b)

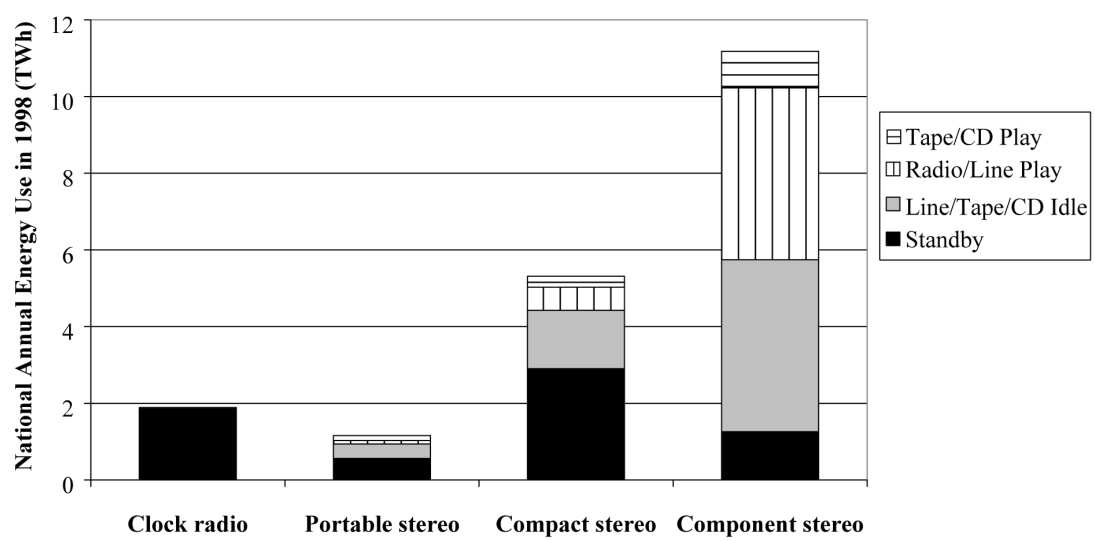


(c) (d)

We found that the combined energy consumption of standby, idle, and play modes of clock radios, portable stereos, compact stereos, and component stereos was 20 TWh/yr, representing about 1.8% of the 1998 national residential electricity consumption. Compact and component stereo systems combined accounted for 84% of this electricity use. This high percentage is due in part to the large fraction of these stereo systems that are used to enhance TV sound. Such systems are used several times as much as audio systems that are not used for TV sound.

We found that U.S. audio energy use was nearly equally divided among the standby, idle, and play modes. Standby power requirement accounted for 34% (6.6 TWh/yr) of audio electricity use, while idle modes accounted for 33% (6.4 TWh/yr), and play modes 34% (6.6 TWh/yr). **Figure ES-2** shows the annual energy use of each mode of each type of audio product included in this study.

Figure ES-2. 1998 Electricity Consumption of Audio Products in the U.S.



We performed sensitivity analyses for our major assumptions, including past efficiency improvements, idle mode usage, and inclusion of non-residential uses of home audio products. Low and high estimates for 1998 audio energy consumption were 14 and 33 TWh, respectively.

Energy savings could be achieved by reducing standby power requirements and idle mode usage in low-power audio products, and by implementing more efficient amplifier technology in high-power audio products. These improvements could reduce audio energy use by as much as 50%.

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1 BACKGROUND AND INTRODUCTION

The U.S. Department of Energy (DOE) seeks to maintain an accurate accounting of how the nation consumes energy. They and others use this information in forecasts of energy use and in the development of energy policies. The DOE periodically updates estimates as the U.S. energy demand structure evolves, or as new information becomes available.

In the residential buildings sector, the "miscellaneous" or “all other” end use has attracted special attention in the past few years. This end use covers the energy consumed by appliances that do not fall into the major end-use categories of space heating and cooling, water heating, refrigeration, and lighting. Some of the most important appliances in the miscellaneous end use are televisions, videocassette recorders, audio equipment, telephony, microwave ovens, fans, and pumps.

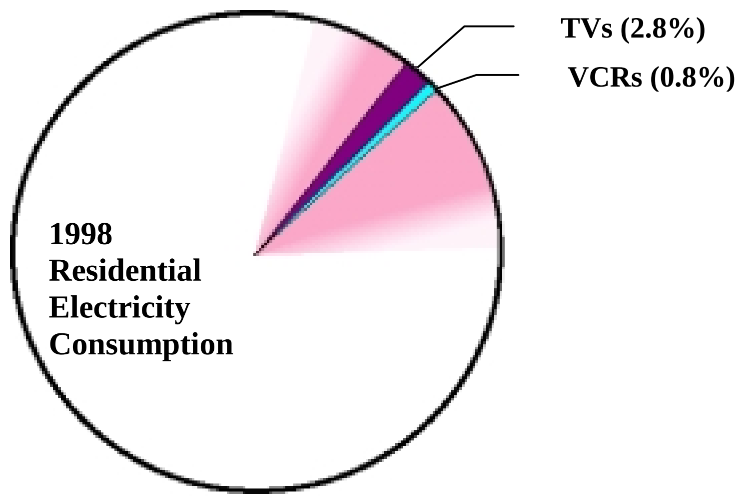
Recent information suggests that the miscellaneous end use is larger than once thought and may be experiencing unusually high growth. In the *Annual Energy Outlook 2000*, the U.S. Energy Information Administration estimated that this end use is currently responsible for 30% of residential primary energy use, and is expected to account for 40% by 2020 due to the proliferation of small electronic products [1].

There is, however, considerable uncertainty about the size of miscellaneous energy use. Some of the uncertainty is simply a consequence of differing definitions of which appliances should be treated as "miscellaneous." There are also uncertainties regarding the amount of energy consumed by appliances in the miscellaneous end-use category. Regardless of these ambiguities, the miscellaneous end use is an important feature of residential energy demand.

The DOE recently decided to improve its understanding of the miscellaneous end use. To this end, the Office of Building Technology and State Programs (BTS) has commissioned studies of its major components. The principal aim is to accurately determine unit and nationwide energy consumption values for the most significant appliances. They will use this information to improve energy demand forecasts and to explore the feasibility of new efficiency programs directed at appliances within the miscellaneous end-use category. The first investigation, which focused on televisions and videocassette recorders, found that these two devices were responsible for about 3.6% of residential electricity use in the U.S. [2].

Figure 1-1 shows the approximate electricity consumption of the miscellaneous end use, including the portion of miscellaneous electricity use attributed to televisions (TVs) and videocassette recorders (VCRs). The fuzzy boundaries indicate the uncertainty in the size of this end-use category.

Figure 1-1. Miscellaneous End-Use as an Uncertain Fraction of U.S. Residential Electricity Use, with Portions of Electricity Use Attributed to TVs and VCRs



This report describes our second investigation: home audio products. We chose to focus on audio products because we expected that they would account for a substantial portion of residential electricity use. In addition, we knew that the same basic methods used for TVs and VCRs could be applied to audio products. The main goal of this study, therefore, was to estimate the 1998 energy consumption of home audio products in the U.S. residential sector. In addition, we explored opportunities for reducing the energy consumption of these devices.

2 SCOPE

The term, “audio product” covers many different kinds of devices, each having one or more colloquial names. For this reason, we begin by describing and defining the products covered in this study. Since most audio products operate in several modes, we also describe the modes investigated for this study.

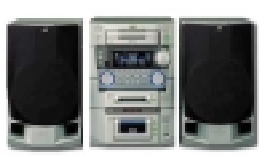
2.1 Audio Products Considered in This Study

All audio systems require an amplifier, speakers, and one of several media devices capable of converting some type of media format to audible sound. Some common media devices include tuners, magnetic tape players, and CD players. These devices can be sold separately, or can be combined with other components and sold as a unit.

Figure 2-1. Audio Products Investigated for this Study

Clock radio

Portable stereo



Compact stereo

Component stereo

For this report, we address the following audio systems: clock radios, portable stereos, compact stereos, and component stereos, as shown in **Figure 2-1**. Following are rudimentary descriptions of each of these categories as we define them for this study.

Clock radios include non-portable audio devices with a clock and a radio. Some models may have a tape or CD player.

Portable stereos (or "boomboxes") can be powered using batteries or a power cord. All models have a handle and attached speakers, which in some cases are removable. Nearly all models are capable of playing the radio and tapes. Most new models are also capable of playing CDs.

Compact stereos, including mini-systems, are non-portable bookshelf stereo systems. They consist of three sections: the center component and two detached speakers. Common models are capable of playing the radio, tapes, and CDs.

Component stereos consist of separate components often made by different manufacturers. A small percentage of component systems, called "rack" audio systems, are sold as a set. The base component of a component system is either a receiver or an amplifier.[1] Other components included in this study are tuners, tape players, and CD players.

[1] We include power amplifiers and integrated amplifiers in this category. Based on availability at retail stores, we expect that the number of power amplifiers in the U.S. is relatively small.

Products that we did not cover in detail for this study include digital versatile disk (DVD) players, radios without clocks, power speakers, and others. For descriptions, available power measurements, and some rough estimates of national energy consumption of these products, see Appendix A.

2.2 Audio Modes Considered in This Study

A mode is an overall appliance state, defined by the activities or "functions" performed. Most audio products have many modes, and power requirements usually differ from one mode to the next. An accurate estimate of national audio energy consumption should include energy use for each appliance mode. This entails defining each mode, and then obtaining estimates of average power requirements and usage for each mode.

Since audio products often have more than a dozen modes, we limited our investigation to the most common audio modes: play, idle, standby, and disconnected. These modes are defined in **Table 2-1**. We did not consider recording for this study because consumers record so infrequently [3]. Likewise, we did not address other modes involving motor functions, such as fast-forward and rewind.

Table 2-1. Audio System Modes Addressed in This Study

Line- Tuner- Tape- CD- **Play**	Amplification of an audio signal from an external audio source (line), a tuner, a tape player, or a CD player.
Line- Tape- CD- **Idle**	The unit is plugged in and the power switch is in the "on" position, but the unit is not producing sound and no motors are active.
Standby	The unit is plugged in and the power switch is in the "off" position.
Disconnected	The unit is unplugged.

This list of modes is not exhaustive. As mentioned above, many audio systems have, in addition to those listed, fast-forward, rewind, pause, and more. Some products even have high- and low-power displays, which nearly doubles the number of possible modes. We chose to address only the modes listed above for two reasons, (1) simplicity, and (2) assumption that these modes account for nearly all electricity use of audio products.

Play and Idle Modes

Play and idle modes for audio products occur when the power switch is in the "on" position. In the play mode, an audio product produces sound originating from a tape, a CD, a radio or television broadcast, or some other audio source. The idle mode can be thought of as the mode in which an audio product remains after the audio source (line, tape, or CD) has stopped playing, but before the user switches the system off.

Table 2-1 indicates that there are several play and idle modes for audio equipment, including line, tuner, tape, and CD. "Line-play" refers to the mode in which an audio product is amplifying sound from an external source, such as a TV or external CD player. “Tuner-play,” “tape-play,” and “CD-play” modes refer to the modes in which an audio system is amplifying sound from a tuner, magnetic tape player, or CD player, respectively. We considered three idle modes for this study: “line-idle,” “tape-idle,” and “CD-idle.” Clock radios do not have idle modes.

According to the definition in Table 2-1, a system in play mode produces sound. Thus, the distinction between play and idle modes for portable and compact stereos is straightforward. The distinction is not so straightforward for separate components. For amplifiers, the distinction between play and idle is that the amplifier is receiving an audio signal in play mode and is not in idle mode. Components without amplifiers cannot produce sound if they are not connected to an amplifier, so we define "play" modes for these components as if they were connected to an amplifier. Thus, tape and CD players are in play mode when their rotors are turning at play speed. Technically, the tuner in a portable or compact stereo is active whenever the unit is on; however, it is not "playing" by our definition, unless the signal is being amplified. For consistency, we will consider a component tuner "idle" unless its signal is being amplified. In reality, however, the play and idle modes of tuners have the same power requirements.

Standby Mode

The standby mode occurs when the power switch is in the “off” position, and is generally the lowest power mode of an audio product. There are many reasons for an appliance to draw power in standby mode. Some components that require power to perform standby functions include sensors, displays, and memory. To supply this power, a non-trivial amount of energy is lost through the power supply. For example, an infrared sensor, which receives remote control signals, requires a fraction of a watt to recognize an incoming signal. To supply this fraction of a watt, the power supply must also be active. This typically adds one to five watts to the standby power needs, depending on the efficiency and maximum power rating of the transformer [4]. Since standby functions are standard in compact and component stereo systems, and are increasingly popular in portable stereos, very few audio systems are ever truly off.

3 APPROACH AND METHODS

The ideal approach to estimating audio equipment energy use would involve a national metering program in which all of the audio products in a statistically representative group of homes would be metered for a year or more. These measurements could then be extrapolated to the whole country, using procedures similar to those employed by the Residential Energy Consumption Survey (RECS). This approach would take years to complete and was not economically feasible for us. Instead, we resorted to a bottom-up approach that combines direct measurements and survey data.

Our approach can be summarized in the following steps:

1. Estimate the number of clock radios, portable stereos, compact stereos, and component stereos in U.S. homes. This involved collecting data from other sources, including:

- penetration, number of units per household, and number of U.S. households in 1998
- historical sales/shipments and product lifetime estimates

2. Estimate the typical system usage patterns for each type of audio product. This involved collecting data from other sources, including:

- radio and recorded media (tape and CD) listening statistics
- number of audio systems connected to TVs
- TV usage statistics

3. Estimate the average unit power consumption for each type of audio product. This required collecting a sample of power measurements for the standby, idle, and play modes, and then combining average power use for each mode with usage patterns.

4. Estimate average annual unit energy consumption for each type of audio product.

5. Estimate 1998 audio energy consumption in the U.S. residential sector.

This approach differs in a few ways from previous investigations of U.S. audio energy use. First, we relied on a larger number of measurements to estimate average power use for each product. Second, we utilized new survey data, which permitted more accurate characterizations of the stock and of consumer usage patterns. Finally, we recognized the power use of nine specific audio modes (Table 2-1), where previous studies recognized only the two vaguely defined modes of “on” and “off.”

Below we describe our approach in detail, along with assumptions necessary to proceed with the analysis. This approach follows closely the steps outlined above.

3.1 Estimating the Number of Audio Products in U.S. Homes

Because taking a national census of audio products is impractical, an accurate count of the existing residential stock is not directly available. Two methods can be used to estimate the residential stock count of a given product nationwide. One method involves counting the products in a representative number of homes and extrapolating to all U.S. homes. The other involves combining historical sales/shipment data and average product lifetimes in a stock turnover model. We expect the former to provide a more accurate count of the residential stock than the latter because of the uncertainties involved in estimating average product lifetimes, and because shipment and sales data include products purchased for both residential and non-residential uses.

Extrapolating Survey Results

Market research companies routinely conduct product surveys. These surveys commonly ask, "Do you own a (product)?" For the energy analyst, this type of question presents a serious problem. If the respondent replies "yes," it is unknown whether that respondent has one unit, two units, or perhaps three or more units. Therefore, the percentage of people responding "yes" represents the percentage of homes with *at least* one of the products in question. This statistic, which we call "penetration," can be used to estimate the minimum number of units in households nationwide as follows:

$$Stock_{Min} = (Households) \cdot (Penetration) \tag{1}$$

Estimating the actual stock count involves knowing the average number of units owned by each unit-home[2] as follows:

$$Stock = (Households) \cdot (Penetration) \cdot (Units / UnitHome) \tag{2}$$

In energy analysis, analysts often use the term "saturation" to express the ratio of units to homes. According to this definition, saturation is related to penetration as follows:

$$Saturation = (Penetration) \cdot (Units / UnitHome) \tag{3}$$

This implies that, if saturation is known, stock can be calculated:

$$Stock = (Households) \cdot (Saturation) \tag{4}$$

It is important to note that saturation and penetration are not equivalent unless all appliance owners have only one unit. On the other hand, Appliance Magazine—one of the most cited sources in stock estimation—refers to what we call penetration as "saturation" [5]. This has the potential to confuse energy analysts into estimating the minimum stock (Eq. 1) when they think they are the estimating actual stock (Eq. 4).

[2] A “unit-home” is a home that has at least one unit of a given appliance.

When saturation statistics are not available, penetration statistics must be used to estimate stock as shown in Equation 2. The missing variable in this equation then becomes units per unit-home. Only occasionally do consumer surveys collect this information.

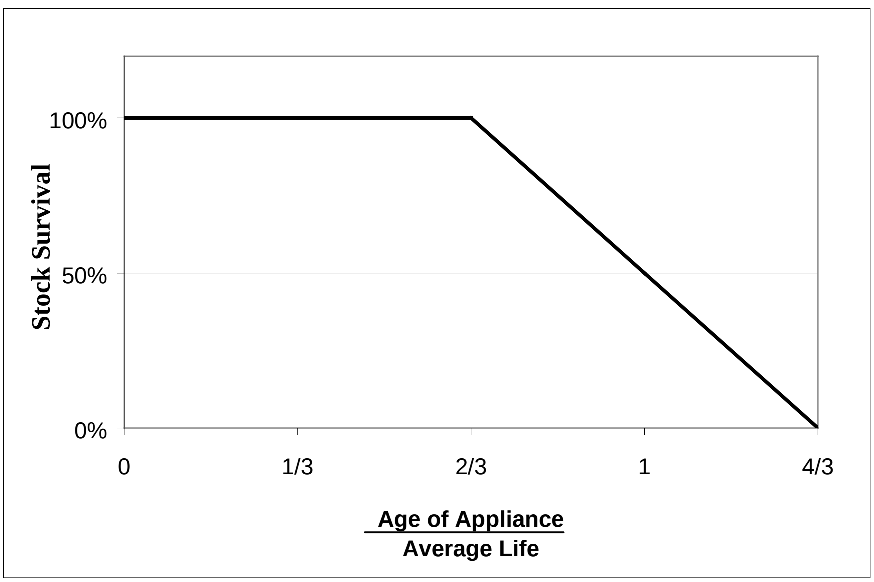
Estimating Stock using a Stock Turnover Model

It is possible to construct a stock turnover model where number of units sold or shipped and average product lifetimes are available. For this study, we used a simple model, the "4/3 Retirement Function" [6], which assumes that stock retires according to the function:

$$Stock\ Survival = \begin{cases} 1, & 0 < AGE \le \frac{2}{3} LIFE \\ 2 - \frac{1.5(AGE)}{LIFE}, & \frac{2}{3} LIFE < AGE \le \frac{4}{3} LIFE \end{cases} \tag{5}$$

where *AGE* is the age of the appliance and *LIFE* is the expected lifetime of the appliance. A graph of the 4/3 Retirement Function is shown in **Figure 3-1**.

Figure 3-1. The 4/3 Retirement Function



For example, using this equation for an appliance with an expected lifetime of six years, 100% of appliances sold one, two, three, or four years ago would still be in the stock, while 75% of units sold 5 years ago, 50% of appliances sold six years ago, and 25% of appliances sold seven years ago would still be in the stock.

3.2 Estimating System Usage from Per Person Usage

The term "usage" refers to the percentage of time that the appliance is used by the consumer. In this study, usage refers to the “play” modes of audio products. To estimate national energy consumption of a product, average per-system usage is needed. Often, however, media-research organizations report only average per-*person* listening statistics. While there is no easy way to convert per-person listening directly to per-system usage, upper and lower bounds on per-system listening can be estimated as follows.

To estimate a *minimum* system usage value, we assume that all household members listen to the appliance(s) simultaneously. In this case, the per-household usage is equal to the per-person usage. The minimum system usage is therefore calculated as:

$$(Usage/System)_{Min} = (Usage/Person)\cdot(Households)/(Systems) \tag{6}$$

For example, if each household member listens to the radio for one hour per day, the average national system usage would be the number of listening hours per person (1.0 hrs/day) times the number of households in the U.S. divided by the number of units capable of playing the radio.

To estimate a *maximum* system usage value, we assume that all household members listen to the appliance(s) separately. The maximum system usage is calculated as:

$$(Usage/System)_{Max} = (Usage/Person)\cdot(People)/(Systems) \tag{7}$$

Using the above example, let us again assume that each person in the U.S. listens to the radio for one hour per day, but this time, alone. The average system usage would then be the number of listening hours per person (1.0 hrs/day) times the number of *people* in the U.S. divided by the number of systems capable of playing the radio.

It is unlikely that all household members always listen to the same unit at the same time, so one can expect the true value to be higher than the value calculated using Equation 6. Similarly, it is unlikely that household members *never* listen to the same unit at the same time, so one can expect the true value to be lower than the value calculated using Equation 7. In addition, a good estimate of the true value must take into account the possibility that certain types of audio systems are more likely to be used than others, while maintaining an overall weighted average that lies between the calculated minimum and maximum values.

Other than the play mode, there are two commonly “used” operating modes: standby and idle. Surveys about usage of these modes do not exist. While calculating energy consumption for appliances with only one of these modes is straightforward (e.g. most clock radios), difficulty arises when the appliance in question has both modes, or more than one idle mode. In such cases, the percentage of time spent in the standby and idle modes must be estimated.

3.3 Estimating Average Unit Power Consumption

To calculate the average unit power consumption (UPC) of a product, the power use of all the modes of a sample of units must be measured. Average power values obtained from measurements are then weighted to reflect average usage values obtained as described above. The average UPC is calculated as:

$$UPC = \sum_{i=1}^{M} \overline{P_i} \cdot T_i \tag{8}$$

where M is the number of appliance modes, $\overline{P_i}$ is the average power draw of the unit in mode i, and T_i is the percentage of time that the unit is in mode i such that ΣT_i=100%.

3.4 Estimating Average Unit Energy Consumption

Once the average unit power consumption is known, energy use can be calculated simply as the product of the average UPC and the desired time period. Typically, average unit energy consumption (UEC) is given in terms of watt-hours per year (Wh/yr). In this case, UEC is calculated as the product of the average unit power consumption in watts (W), and the number of hours per year (h/yr) as follows:

$$UEC = (UPC) \cdot 8760\ h / yr \tag{9}$$

where *UPC* is the average unit power consumption calculated using Equation 8.

3.5 Estimating National Energy Consumption

National energy consumption of an appliance can be calculated as the sum of UEC values or as the sum of household energy use values [2]. Because summing UEC values is less complicated, the sum of household energy use should be used only where a large percentage of homes own more than one of the appliance in question, and where there are significant differences between the power use and usage patterns of each appliance.[3]

For audio equipment, the simpler method suffices. We calculated the national energy consumption (*E*) for each audio product as:

$$E = (Stock) \cdot (UEC) \tag{10}$$

where *Stock* is calculated using Equation 2 or 4, and *UEC* is calculated using Equation 9.

[3] This is the case, for example, with televisions, because there is typically more than one per household, power levels vary significantly with size, and some units are used more or less than others.

4 AUDIO PRODUCT STOCK, USAGE, AND POWER

The three factors we used to estimate national audio energy consumption are the number of products nationwide, usage patterns, and power use. The following sections describe the data used in this study.

4.1 Number of Audio Products in the U.S.

In Section 3.1 we described two methods of estimating the number of audio products nationwide. The first involved estimating the number of units per home based on survey data. The other combined historical shipment data and average lifetime estimates in a stock turnover model. We feel that the former results in a more accurate estimate of residential stock, and therefore use stock estimates based on this method. For comparison, however, we include stock estimates based on the second method in Appendix B.

Product Surveys and Stock Estimates

Saturation statistics were not available for audio products, so we used penetration statistics and the number of units per unit-home to estimate saturation using Equation 3. Penetration statistics for clock radios, portable stereos, compact stereos, and component stereo systems as reported by CEMA [7] are given in **Table 4-1**. Since this survey provides data that are central to our results, we included a description of the survey methods in Appendix C.

Table 4-1. Penetration of Audio Systems as Reported by CEMA [7]

Audio System	Penetration[a]
Clock radio	84%
Portable stereo	56%
Compact stereo	40%
Component stereo	65%

a. Penetration is the percentage of homes with *at least* one product.

Subsequent surveys report similar findings. The U.S. Energy Information Agency (EIA) reports that 68.8% of U.S. homes had a stereo system in 1997 [8]. A February 1999 survey of 1000 U.S. homes found that 66% of U.S. homes had separate component systems [9]. An April 1999 survey found that 49% of homes have compact or mini-stereo systems [10]. The same survey showed that 49% of homes have a portable CD boombox, slightly less than the percentage of all types of boomboxes (with or without a CD player) used in this report.

To translate penetration into saturation, we drew on a recent survey, which asked whether the purchase of the most used portable stereo, compact stereo, or stereo receiver was a first time, replacement, or additional purchase [10]. **Table 4-2** shows the percentage of audio product owners who responded that they had made an additional purchase. We assume that all additional purchases were the second unit in the home, and that the number of homes with more than two units was insignificant. The number of units per unit-home was therefore calculated by adding the percentage of "Additional Purchases" to 1.0, where 1.0 represents the average number of products in these homes before the additional purchases were made.

Table 4-2. Number of Portable Stereos, Compact Stereos, and Stereo Receivers per Unit-Home

Audio Product	Additional Purchases [10]	Units per Unit-home
Portable CD boombox	20%	1.20
Compact (or mini) stereo	16%	1.16
Stereo receiver	12%	1.12

We used the numbers for portable CD boomboxes to represent all portable stereos, and the numbers for receivers to represent all component stereo systems. Clock radios were not included in this survey. We estimate that, on average, each home has 1.5 clock radios. The uncertainty associated with this estimate is discussed in Section 6.1.

According to Equation 4, the only information needed to estimate the number of products nationwide, other than penetration and the number of units per unit-home, is the number of U.S. households. For this data we consulted U.S. Census Bureau, which estimates that there were 101.5 million households in the U.S. in 1998 [11].

Our final stock estimates and a summary of the data used to determine them are given in **Table 4-3**. Note that saturation values were calculated using Equation 3 and total U.S. units calculated using Equation 4.

Table 4-3. Number of Audio Products in the U.S. in 1998

Audio System	Penetration [7]	Units per Unit-Home [10]	Saturation	Total Number of Units in the U.S.[a] (millions)
Clock radio	84%	1.5[b]	126%	128
Portable stereo	56%	1.20	67%	68
Compact stereo	40%	1.16	46%	47
Component stereo	65%	1.12	73%	74

a. Based on 101.5 million U.S. households [11]

b. Estimated value

Number of Audio Products Used for TV Sound

While most people think of tapes, CDs, and radio programs as the main uses for audio equipment, many consumers also use their stereo systems to enhance TV sound. We adjusted for this by dividing the stock estimates according to whether they were used for this purpose.

For this study, we considered audio/video connections involving either a compact or component stereo system. According to a recent survey, 6% of homes use a compact stereo system and 38% of homes use a component stereo system for TV sound [7].[4] We divided these products into two sub-categories each: those connected to a TV and those not connected to a TV, as shown in **Table 4-4**.

Table 4-4. Division of Compact and Component Stereos based on TV Connection

Product	TV Connection	Penetration [7]	Units per Unit-Home [10]	Saturation	Total Number of Units in the U.S.[a] (millions)
Compact Stereo	No	34%	1.16	39%	40
	Yes	6.4%		7.4%	7.5
Component Stereo	No	27%	1.12	30%	31
	Yes	38%		43%	43

a. Based on 101.5 million U.S. households [11]

4.2 Audio System Usage Patterns

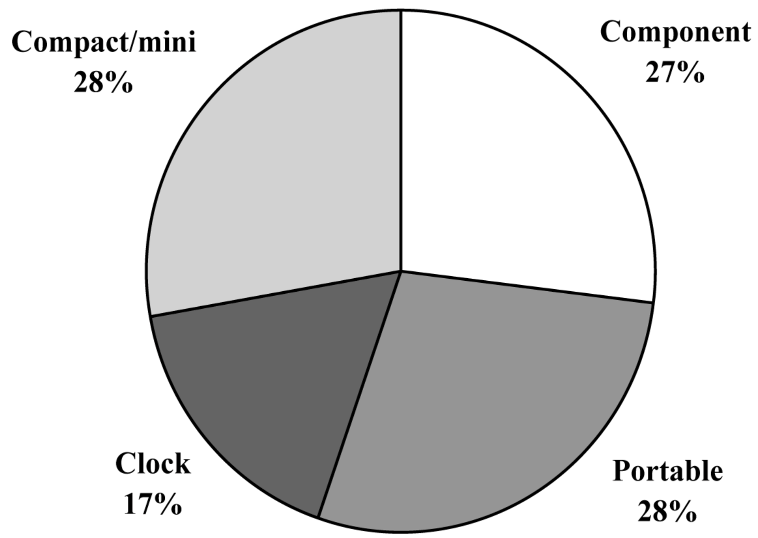
We collected two types of information to aid us in determining system usage patterns: information about the regularity of use for different types of audio products, and information about the usage of different functions and modes of audio products.

Regularity of Product Use

One factor we used to determine system play usage was the regularity with which products are likely to be used. In a recent survey, people were asked, “What types of devices do you regularly use to listen to the radio?” [12]. After adjusting to reflect saturation of these products, results show that component, compact, and portable stereos were equally likely to be used regularly, while clock radios were about half as likely as the stereo systems to be used regularly, as shown in **Figure 4-1**

[4] Based on the original survey data, we assumed that audio-video connections involved the highest quality product available. We assumed that no clock radios are connected to television sets. Only 2% of respondents with audio/video hookups had no better than a portable stereo.

Figure 4-1. Percentage of Consumers that "Regularly" Use Certain Audio Products to Listen to the Radio, Adjusted to Compensate for Differences in Saturation Levels



Based on these results, we assume that consumers use clock radios roughly half as often as portable, compact, or component stereos to listen to the radio. We also assume that portable, compact, and component systems are equally likely to be used for listening to recorded music.

Play Usage

We derived tuner-, tape-, and CD-play usage for audio products from per-person radio and recorded music listening, and derived line-play usage from TV usage statistics. This section describes these data and calculations.

One of the essential variables in our calculations was the number of radio listening hours. The average American, 12 or older, listens to the radio for 2.75 hours per day [13], 37.2% of which takes place in the home [14]. We therefore assume that the average American listens to the radio for about one hour per day in the home.

To estimate average system tuner-play (radio) usage, we first determined minimum and maximum system usage values. This involved using the above per-person listening statistics and population estimates as described in Section 3.2. Since this study investigates national audio energy use in 1998, we use 1998 U.S. population statistics of 101.5 million households and 272 million people [11].

Our goal was then to estimate average usage values for each product such that the average usage of all systems (weighted to reflect number of each type of product) was approximately midway between the minimum and maximum values calculated previously. We found that a tuner-play usage of 1.5% for clock radios and 3% for portable, compact and component stereos achieved this goal. **Table 4-5** summarizes these calculations and assumptions.

Table 4-5. National Radio (Tuner-Play) Usage

Scenario	Household Usage Assumptions	Average Per-System Usage (% of time)
Minimum	All household members listen for 4.2% of the time (1.0 hr/day) simultaneously.	1.3%
Recommended	**Clock radios are used 1.5% of the time (0.36 hr/day) to play the radio. Portable, compact and component stereos are used 3.0% of the time (0.72 hr/day) to play the radio.**	**2.4%**
Maximum	All household members listen for 4.2% of the time (1.0 hr/day) separately.	3.6%

NOTE: Values used for this study in bold type.

Next, we estimated the percentage of time audio products are used to play recorded music. The average American listens to recorded music for about 50 minutes each day [15]. It is likely that not all recorded music listening takes place in the home, so we estimate that the average person listens to recorded music for about 40 minutes per day (0.67 hrs/day) at home.

We used the same technique to estimate average system usage for recorded-music as we did for radio. In this case, we estimate an average tape and CD usage of 3.0% for portable, compact, and component systems as shown in **Table 4-6**.

Table 4-6. National Tape/CD-Play Usage

Scenario	Household Usage Assumptions	Average Per-System Usage (% of time)
Minimum	All household members listen for 2.8% of the time (0.67 hr/day) simultaneously.	1.5%
Recommended	**Portable, compact and component stereo systems are used 3.0% of the time (0.72 hr/day) to play tapes or CDs.**	**2.9%**
Maximum	All household members listen for 2.8% of the time (0.67 hr/day) separately.	4.0%

NOTE: Values used for this study in bold type.

Line-play usage for compact and component systems that are connected to a TV were derived from TV usage statistics. In a previous study, we estimated that the primary TV in the home is used for an average of 5.9 hours per day (about 24% of the time), while the secondary TV is used for 1.9 hours per day (about 8.1% of the time) [2]. We assume that all primary audio-video connections involve the primary TV, and that the stereo is in line-play mode whenever the primary TV is active. In homes with two audio-video connections, we assume that the second system involves the secondary TV, and that the stereo is in line-play mode whenever the secondary TV is active.

Final System Usage Values

Based on per-person listening statistics, TV usage statistics, and the regularity of product usage, we estimated system usage values as shown in **Table 4-7**. A detailed explanation of these numbers follows.

Table 4-7. Average Time Audio Products Spend in Different Modes Each Day

Audio System	Disconnected	Standby	Idle	Tuner/Line Play	CD/Tape Play	Total
Clock radio	0%	99%	--	1.5%	--	100%
Portable stereo	30%	51%	13%	3.0%	3.0%	100%
Compact stereo only	0%	75%	19%	3.0%	3.0%	100%
Compact stereo + TV	0%	56%	14%	27%	3.0%	100%
Component stereo only	0%	75%	19%	3.0%	3.0%	100%
Component stereo + TV	0%	57%	14%	26%	3.0%	100%

NOTE: Figures may not add due to rounding

Disconnected. We assume that all audio products are plugged in at all times with the exception of portable stereos. When asked, "Have you listened to your boombox using batteries?" 45% responded that they had not [7]. We assume that these 45% of portable stereos (boomboxes) are plugged in at all times. We assume that the rest are plugged in roughly half of the time. Thus, averaging over all units in the U.S., we estimate that portable stereos are connected to the mains 70% of the time and disconnected roughly 30% of the time.

Standby. We assume that clock radios are in standby mode whenever they are not being used to play the radio. While some might argue that this mode should not be called “standby” because the unit is performing the function of keeping the time, this mode clearly falls into our definition of standby as given in Table 2-1. We assume that all other products are in standby mode for 80% of the time that they are not disconnected or in a play mode.

Idle. Excluding clock radios, which have no idle mode, we assume that all products are idle for 20% of the time that they are not disconnected or playing.[5] Where there are multiple idle modes, we assume they are used equally.

Play. A detailed explanation of the estimation of tuner, tape, CD, and line-play usage is described above. Although a few clock radios on the market have tape or CD players, tape- and CD-play modes for clock radios are not considered.

4.3 Power Levels

Average power requirements for each operational mode are needed to calculate unit energy consumption. We used a PLM-1-LP wattmeter (see Appendix D) to measure 190 audio products in each mode. The final power measurement database contained over 500 measurements. Most of these measurements were recorded at retail shops, and therefore represent the stock of audio equipment currently being sold. Measurements were taken randomly; no conscious effort was taken to select a representative sample of manufacturers or quality levels. For a complete list of the power data collected for this study, see Appendix E.

Power Measurements of Individual Audio Products

Clock radios, portable stereos, and compact stereos are sold as complete systems, so power measurements of these products were straightforward. Component stereo systems, on the other hand, cannot be measured directly because, excluding the 10% that are rack systems, they are not sold as a unit. For this study, components, including amplifiers, receivers, tuners, tape players, and CD players, were each measured separately. These measurements were then used to estimate the power draw levels of typical combinations of components.

We measured power levels of the play and idle modes as shown in **Table 4-8**. Standby power requirements were measured for all audio products.

[5] While there are no thorough studies that investigate the amount of time audio products are left in the idle mode, we conducted a brief survey of employees in the Energy Analysis Department at LBNL. The average amount of time the 30 respondents left their audio systems in the idle mode was 19%.

Table 4-8. Play and Idle Modes Measured for This Study

	Play	Idle
Clock Radio	Tuner	(not applicable)
Portable Stereo	Tuner, Tape, CD	Tape, CD
Compact Stereo	Line/Tuner[a], Tape, CD	Line/Tape[b], CD
Rack Audio System	([c])	Line
Receiver (Component)	([d])	Line
Amplifier (Component)	([d])	Line
Tuner (Component)	Tuner[e]	Tuner[e]
Tape Deck (Component)	Tape	Tape
CD Player (Component)	CD	CD

a. There is no measurable difference between tuner-play and line-play power needs.

b. There is no measurable difference between tape-idle and line-idle power needs.

c. Rack audio system power measurements were taken from existing records that did not include the play modes. Rack audio system play modes (line/tuner, tape, CD) were be estimated using the average power increase from line-idle to play modes seen in other types of component systems.

d. We were not able to measure the power requirements of play modes for amplifiers and receivers directly. Our methods of estimating these power values are discussed at the end of this section.

e. There is no difference between tuner-play and tuner-idle power needs. The only difference between the two modes is whether the output is amplified by an external amplifier.

Below, we present the measurements of audio products we collected from second-hand and retail shops. The vast majority of these measurements were of new units, recorded early in 1999 at retail shops. No effort was taken to include a representative distribution of age, manufacturer, or performance quality.

It is very important to keep in mind that lower power levels, particularly in the play and idle modes, do not necessarily imply better efficiency. Power level differences between units may also indicate differences in functionality. This applies to standby modes for only a few cases. For example, audio products in standby mode typically require power for remote control capability, timekeeping, displays, and/or memory refresh. While standby power requirements may differ noticeably due to different-sized clock displays, other standby functions require insignificant amounts of power [4]. Unless display sizes are noticeably different, it is probably safe to compare standby mode requirements for audio products in terms of efficiency.

One feature of current amplifier technology is that idle and play mode power requirements, unlike standby power requirements, are almost always higher for units with higher-quality sound. In fact, high quality audio products are commonly advertised by their maximum power output, in terms of “watts per channel,” where the number of channels corresponds to the number of speakers that can be connected to the device. In most cases, a higher maximum rated power level translates directly to better sound quality—and also to higher idle and play mode power requirements. As a result, idle and play mode power requirements of high quality audio equipment have more to do with the quality of the output than with the efficiency of the device. Until the amplifier technologies used in the majority of audio products change, it may be that little can be done to improve the power efficiency of the play and idle modes. For a discussion about a more efficient amplifier technology, see Section 6.4.

Figure 4-2 shows measurements of 33 clock radios in the standby and tuner-play modes. Standby power requirements range from less than one to nearly four watts. Active power was only slightly more than standby in most cases. During the standby mode of a clock radio, the unit performs two important functions: timekeeping and displaying the time. Some argue that, because these functions are integral to the main purpose of the device, this mode should not be considered a “standby” mode. In previous research, however, we have always considered the clock display of any product, including a clock, to be a standby function. By no means do we intend to imply that the clock display is unnecessary.

Figure 4-2. Measured Power Use of 33 Clock Radios in Standby and Tuner-Play Modes

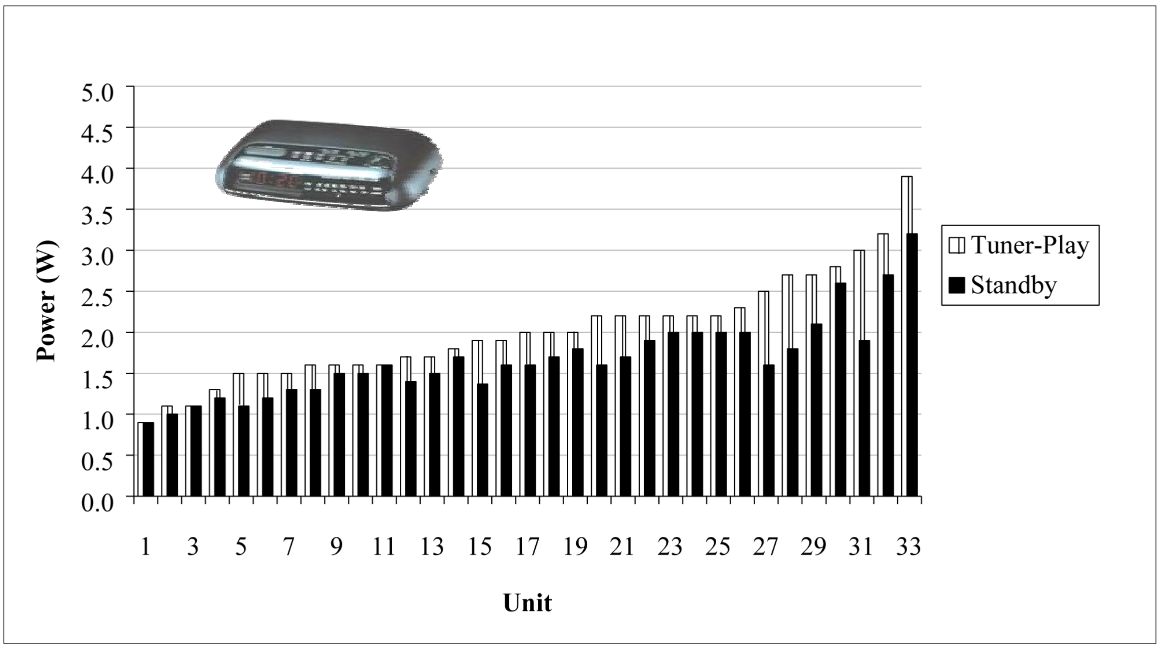


Figure 4-3 is a graph of the power requirements for the 22 portable stereos measured for this study. Standby power levels of these devices are similar to that of the clock radios. This may seem counterintuitive, since clock radios tend to use high-power displays, while most portable stereos use low-power displays or no display at all. We attribute most of the standby power use of portable stereos to their transformers. In many cases, these transformer losses occurred in the absence of any standby functions.

Figure 4-3. Measured Power Use of 22 Portable Stereos in Standby, Tape-Idle, CD-Idle, Tuner-Play, Tape-Play, and CD-Play Modes

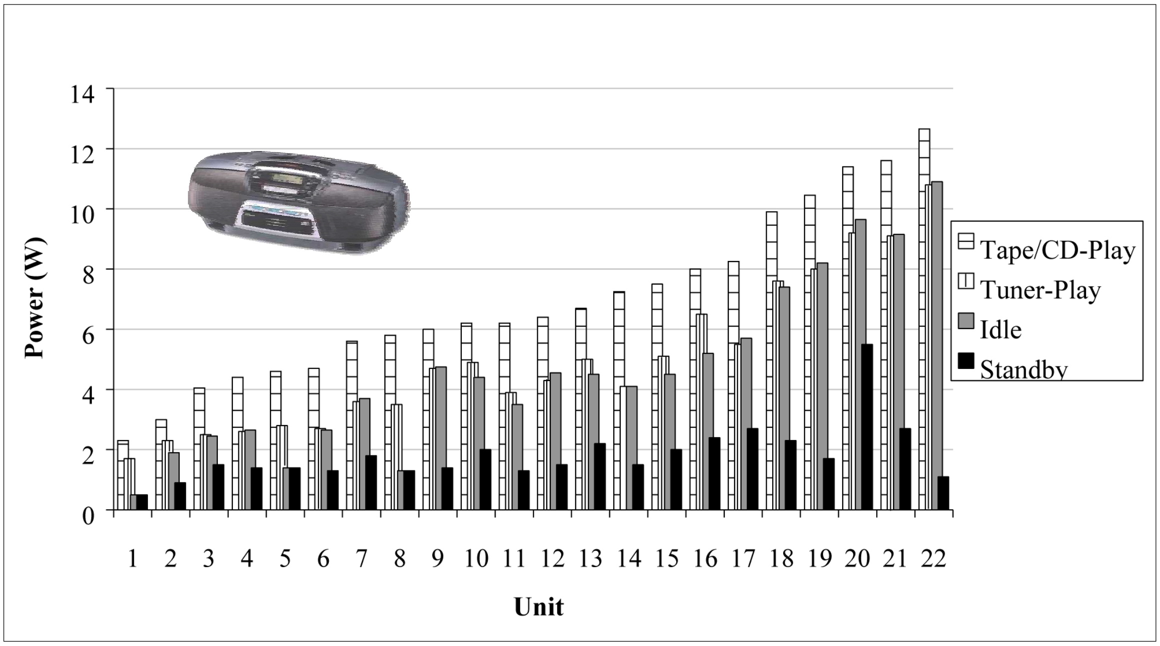
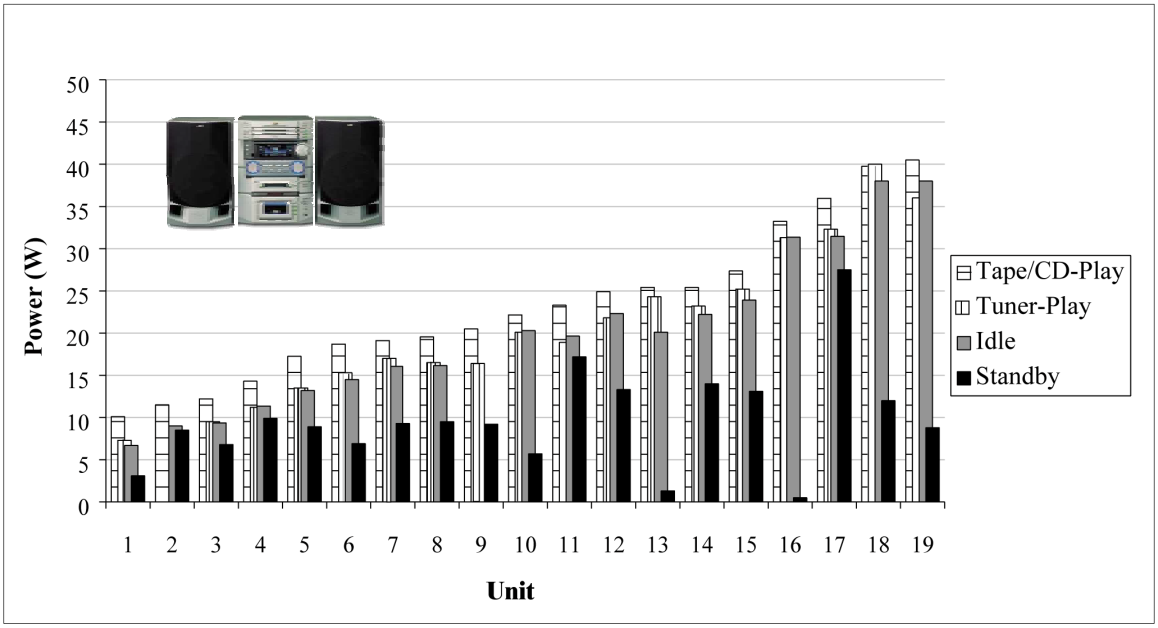


Figure 4-4 shows the power levels of the 19 compact stereos measured for this study. Although standby functionality of portable stereos and compact stereos are similar, standby power levels for most of these units are considerably higher than those of the portable stereos shown in Figure 4-3.

Figure 4-4. Measured Power Use of 19 Compact Stereo Systems in Standby, Tape/Line-Idle, CD-Idle, Tuner-Play, Tape-Play, and CD-Play Modes



It is interesting to note that unit 16 in Figure 4-4 is an Energy Star® labeled product. For more information about the Energy Star® program, see Section 6.3.

Figure 4-5 shows power measurements of the 13 amplifiers recorded for this study. Amplifiers are perhaps the simplest of audio components. A "power amplifier," for example, does nothing more than amplify an audio signal from an external source. Usually, these devices have only one button (the power switch) and no display. As a result, many power amplifiers have no standby power needs. The more popular "integrated amplifiers," on the other hand, in addition to amplifying audio signals, allow the user to switch from one audio source to another. Recently, amplifiers of both types are being manufactured with remote control capability, and instance of standby power use is increasing.

Figure 4-5. Measured Power Use of 13 Amplifiers in Standby and Line-Idle Modes

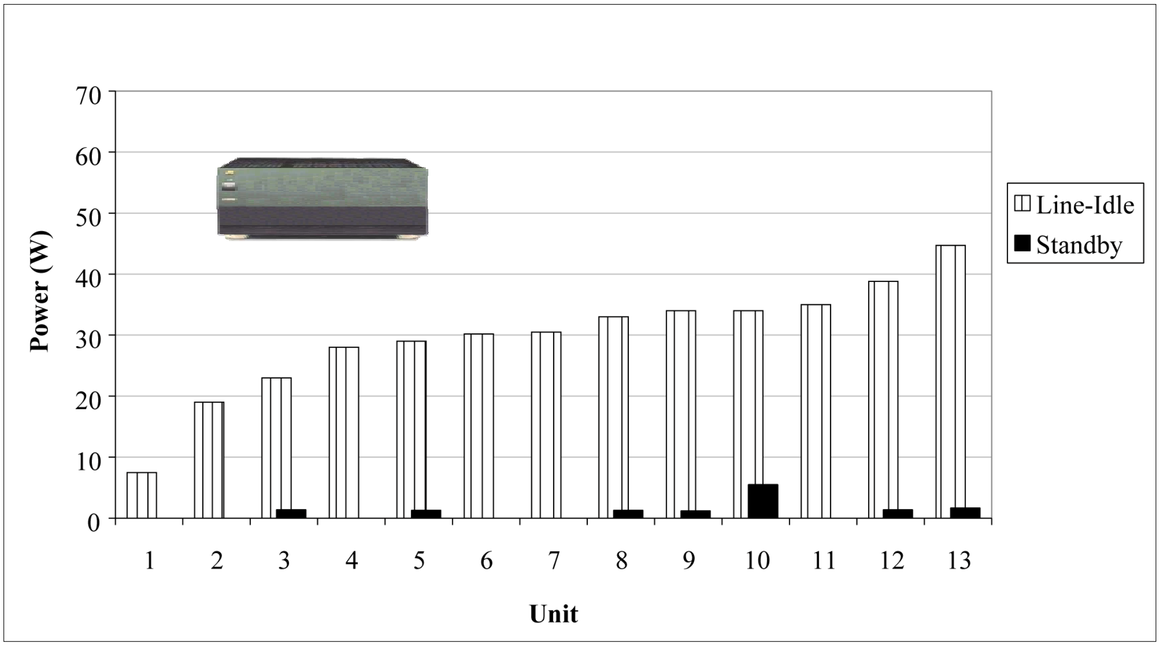


Figure 4-6 shows the power levels of the 46 receivers we measured for this study. Nearly all units used power in the standby mode. These units typically came with remote controls, displays, and preset channels; yet, with few exceptions, standby power requirements remained relatively low. Although we were not allowed to disassemble the products in the stores where they were measured, we expect that the majority of these units have two power supplies: one for the high-power amplifier, and one for the standby functions.

Figure 4-6. Measured Power Use of 46 Receivers in Standby and Line-Idle Modes

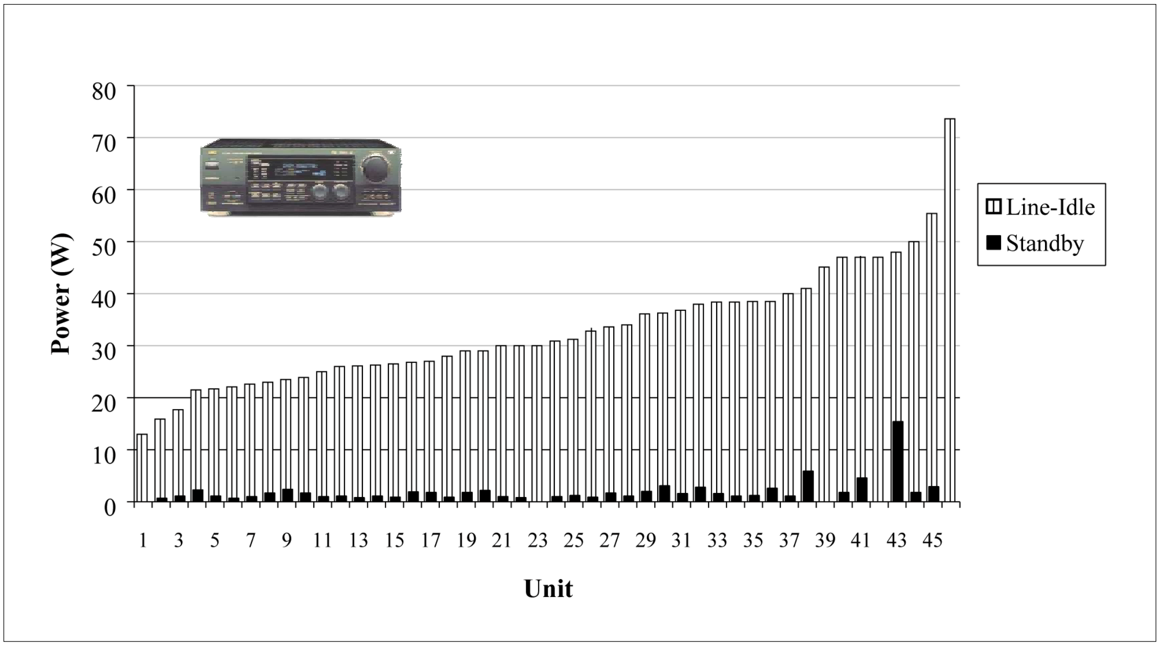
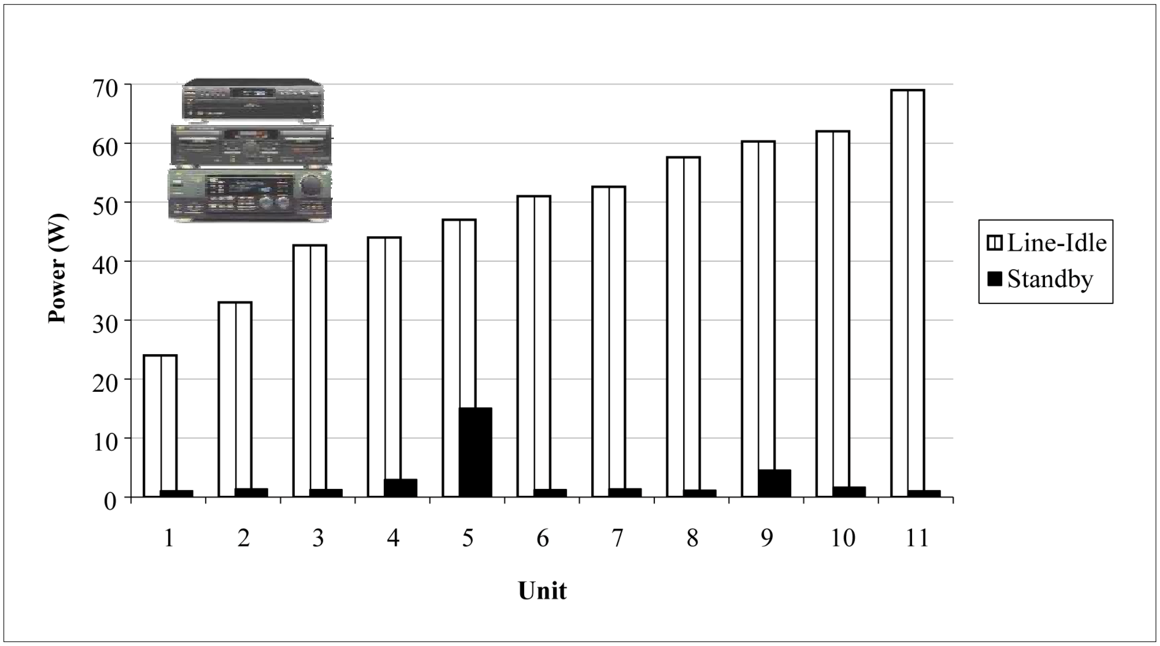


Figure 4-7 shows the rack audio system power measurements used in this study. All 11 rack audio systems measured for this study had a receiver as a base component. The power cords of all other components were plugged into the switched outlets on the receiver, so the standby power levels include only the standby power of the receiver. We assume that an insignificant portion of rack system owners reconfigure their systems in some other way. Idle power measurements were taken with all components in the idle mode, and the receiver in the line-idle mode.

Figure 4-7. Measured Power Use of 11 Rack Audio Systems in Standby and Line-Idle Modes



Power measurements of 17 tuners, 14 tape players, and 15 CD players are shown in **Figures 4-8**, **4-9**, and **4-10**, respectively. Unlike base units, these components do not have amplifiers, so their idle and active power consumption levels are relatively low.

Figure 4-8. Measured Power Use of 17 Tuners in Standby and Tuner-Idle/Play Modes

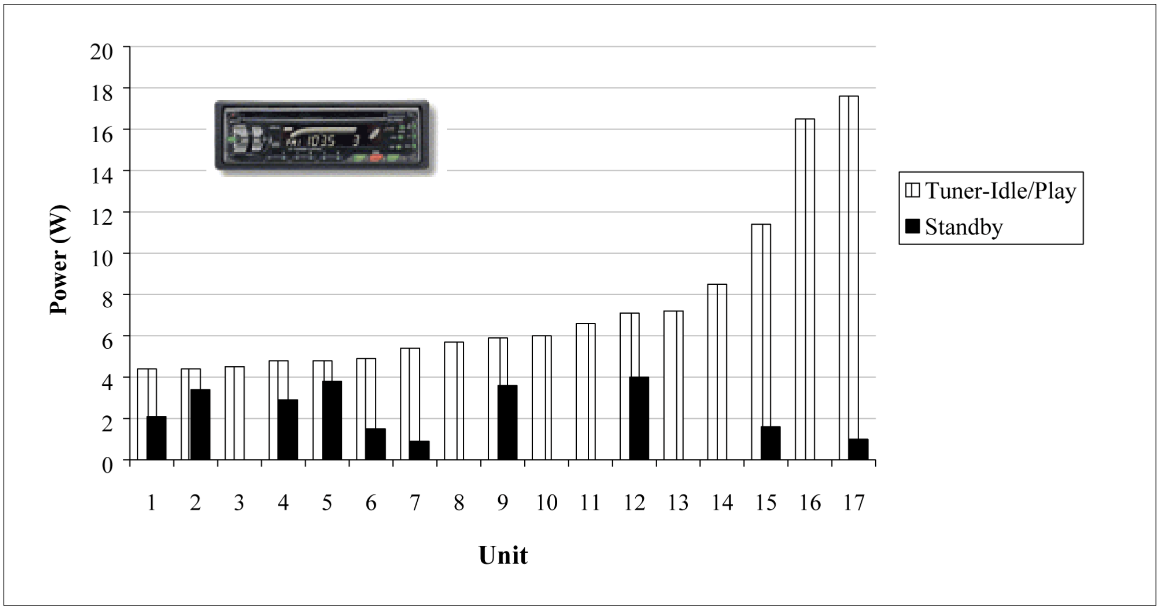


Figure 4-9. Measured Power Use of 14 Tape Players in Standby, Tape-Idle, and Tape-Play Modes

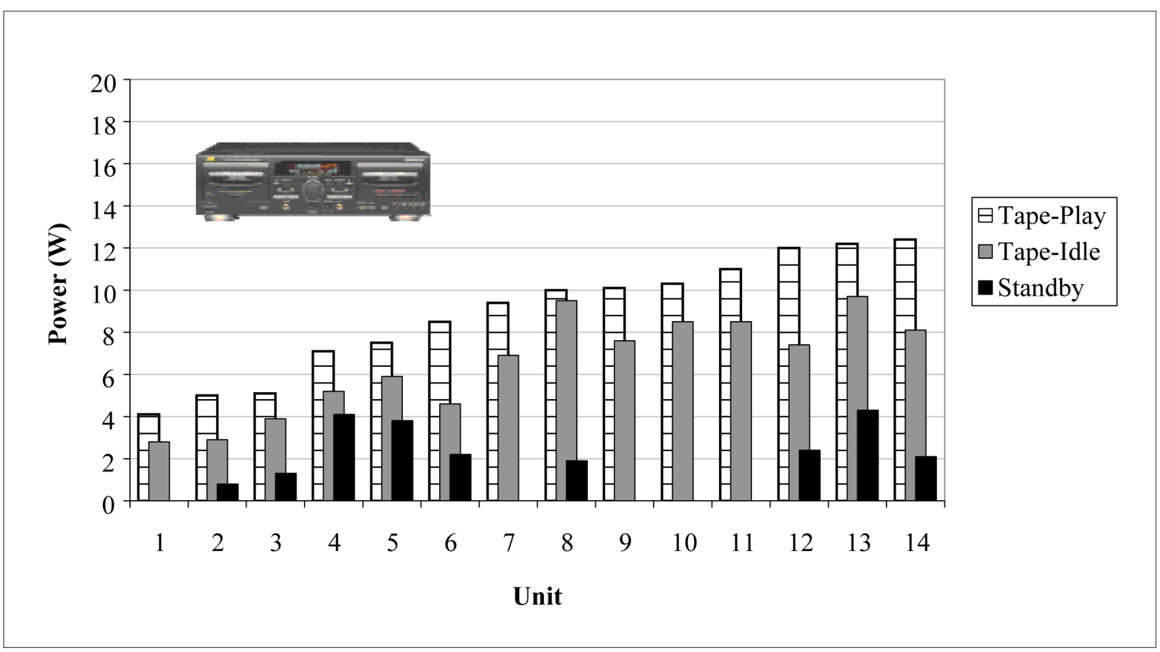
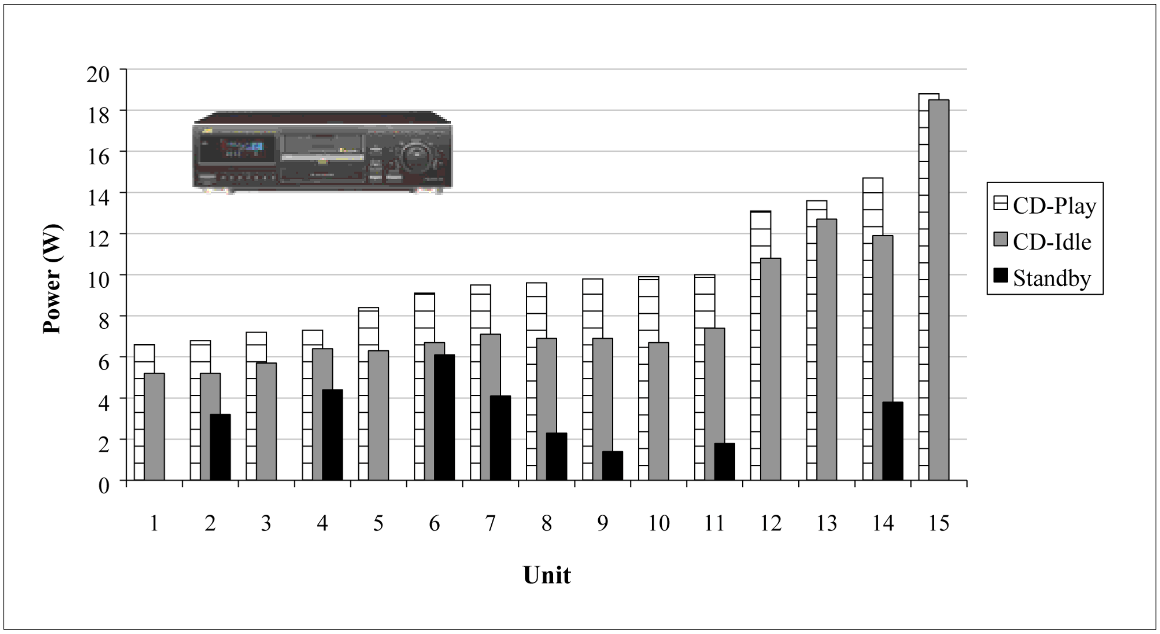
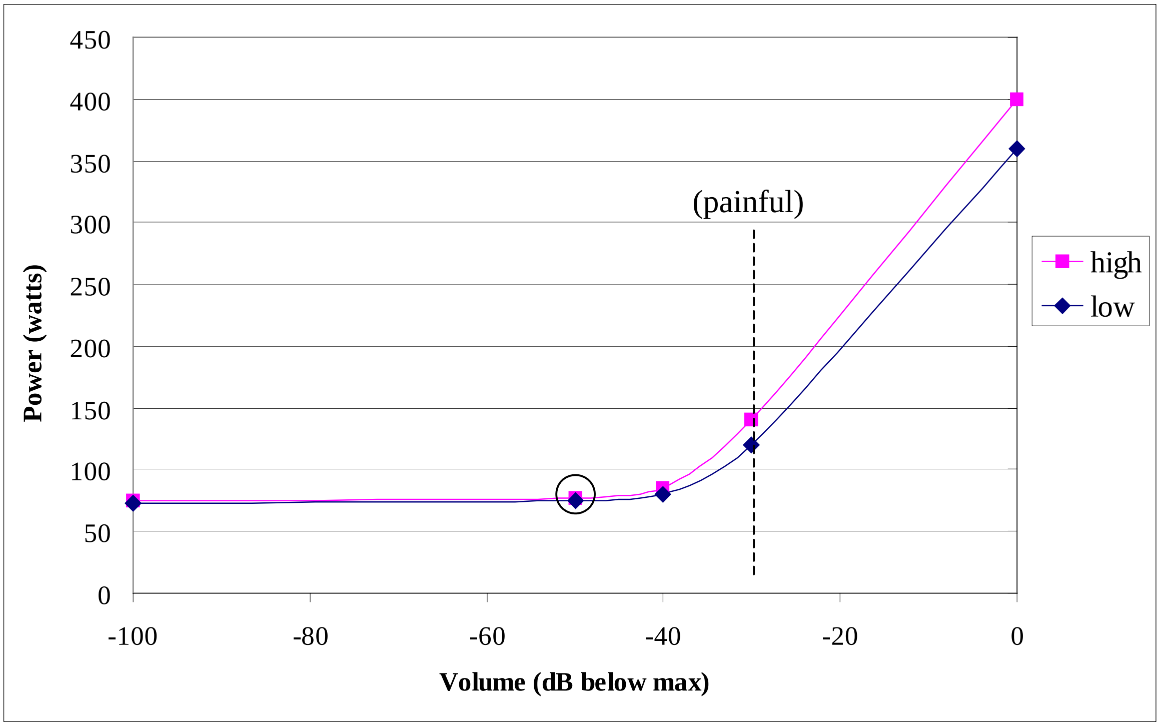


Figure 4-10. Measured Power Use of 15 CD Players in Standby, CD-Idle, and CD-Play Modes



Note that power requirements of play modes are not graphed for amplifiers or receivers in Figures 4-5 and 4-6. In retail stores, where most measurements took place, amplifiers and receivers are not typically set up in such a way as to allow power measurements of play modes. To estimate play mode power requirements of base components, we measured the power requirements of the amplifier in an amplifier-based component stereo system at different volume levels. We noted both the volume display on the preamp and the power requirements of the amplifier, as shown in **Figure 4-11**. The high and low lines in the graph represent the range of power needed at each volume. The dotted line indicates the level at which the loudness of the music became painful to the ears. The circled value indicates the volume we considered to be most "pleasant."

Figure 4-11. Effect of Volume on Power Draw for the Harman Kardon Signature 1.5



Of the listening levels measured, we found the lower-middle listening level (-50 dB) to be the most "pleasant" and assumed that this was the average listening level. Based on these findings, we assume that a component amplifier or receiver requires about 2 watts more to play the radio or line source sound than it requires in idle mode. Uncertainties associated with this assumption are discussed in Section 6.1.

Average Power Requirements for Common Audio Modes

Higher volumes require more power. A complete analysis should therefore consider the volume at which audio products are used. Since a full analysis of typical listening levels and power requirements was beyond the scope of this study, we measured power use of clock radios, portable stereos, and compact stereos at a very low listening level. Play mode power requirements of component systems were estimated based on anecdotal data as described above.

Table 4-9 shows the average power levels of each audio product type measured for this study as derived from our database of power measurements.

Table 4-9. Average Power Levels of Audio Products in Different Modes

Audio Product	Standby (watts)	Idle (watts) Tuner/Line	Idle Tape	Idle CD	Play (watts) Tuner/Line	Play Tape	Play CD
Clock radio	1.7	--	--	--	2.0	--	--
Portable stereo	1.8	--	4.0	5.8	5.0	5.9	8.6
Compact stereo	9.8	20	20	21	21	22	24
Rack system	3.0	49	49	49	51	54[a]	53[b]
Receiver	1.8	33	--	--	35	--	--
Amplifier	1.1	30	--	--	32	--	--
Tuner	1.5	7.4	--	--	7.4	--	--
Tape Player	1.6	--	6.5	--	--	8.9	--
CD Player	1.8	--	--	8.3	--	--	10.3

a. Estimated using the average idle to play difference for tape players.

b. Estimated using the average idle to play difference for CD players.

Calculating average power levels for audio products with a single power cord was straightforward. Clock radios, portable stereos, and compact stereos have just one power cord. Rack stereo systems consist of separate components, each having a power cord. The rack audio systems in our power measurement database were all measured via the power cords of the base units, with the tape and CD players properly plugged into the base unit.

Excluding rack systems, component systems are not sold as a unit. One component stereo system may consist of several components made by different manufacturers, bought at different times. There are also a variety of possible combinations of components, and a variety of wiring configurations. As a result, determination of average power use of component systems was not straightforward.

To estimate average power draw levels of component systems, we first made some assumptions regarding typical wiring configurations. We assumed that half of all optional components (tuners, tape decks, and CD players) are properly plugged into the base in a way that they cannot draw power when the base is in standby mode. These components have no standby losses and are idle or active whenever the base component is idle or active. The other half of optional components are not plugged into the base. These components are in standby mode unless they have been or are being used. **Table 4-10** shows our assumptions regarding the effect of the base mode on optional components.

Table 4-10. Modes of Tuners, Tape Players and CD Players during Different Component System Base Modes

Base	Plugged into the Base		NOT Plugged into the Base	
	Tuner	Tape/CD Player	Tuner	Tape/CD Player
Standby	Disconnected	Disconnected	Standby	Standby
Line/Tape/CD-Idle	Idle	Idle	Standby	Standby or Idle[c]
Line/Tuner-Play	Idle/Play[a]	Idle	Standby or Play[b]	Standby
Tape/CD-Play	Idle	Play	Standby	Play

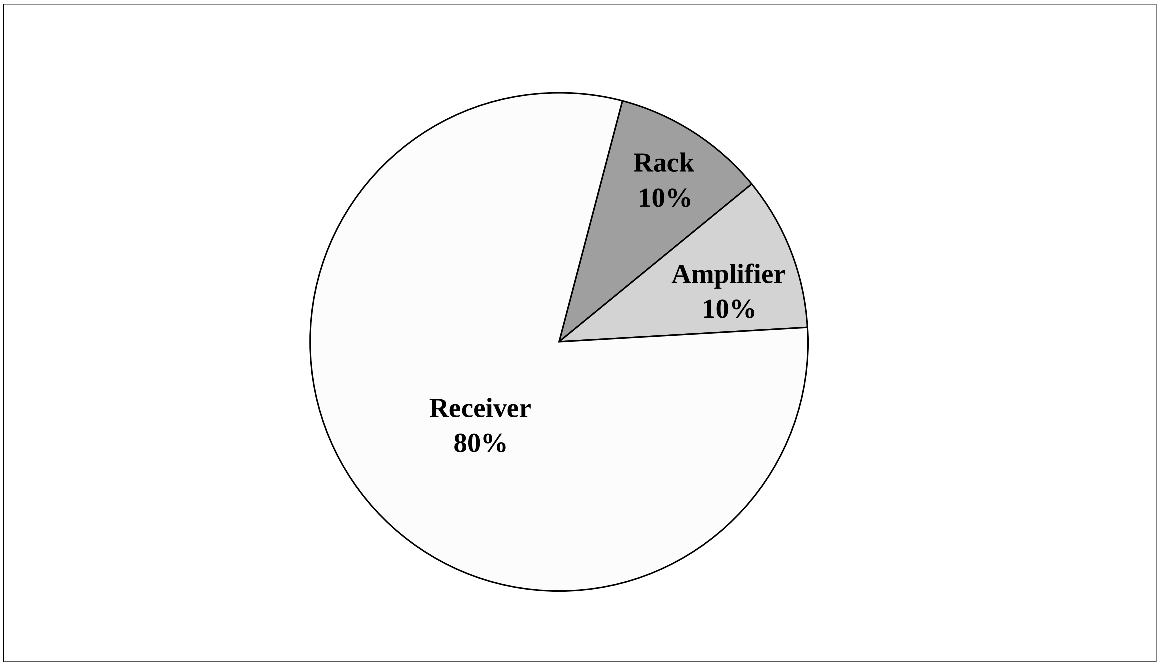
a. Tuner-idle and tuner-play have the same power requirements.

b. Tuners are in standby mode when the system is being used to play TV sound (line).

c. Tape and CD players are idle when the base is idle unless the system has both devices, in which case we assume that the tape and CD player share standby and idle mode time equally.

Next, we divided this category into three groups: rack systems, systems with a receiver, and systems with an amplifier. Based on historical shipment data (Appendix B), we estimate that component systems in the U.S. are comprised of roughly 10% rack systems, 10% amplifier systems, and 80% receiver systems, as shown in **Figure 4-12**.

Figure 4-12. Distribution of Different Types of Component Systems in 1998



A distribution of typical component system configurations was then created based on this distribution. We used a survey that reported that 15% of component systems did not have a CD player [7] to help create the distribution, shown in **Table 4-11**. Although these are rough estimates, significant variation in these values will not significantly affect the final results because power draw values are fairly similar among systems.

Table 4-11. Distribution of Component System Configurations and Average Power Levels

Component System	Share of U.S. Component Systems	System Standby (watts)	System Idle (watts)	Line/Tuner Play (watts)	Tape/CD Play (watts)
Receiver		1.8	33.1	35.1	35.1
+ Tape	12%	2.6	39.6	39.2	44.0
+ CD	34%	2.7	41.4	40.1	45.4
+ Tape/CD	34%	3.5	44.2	44.2	48.4
Receiver systems	**80%**	**3.1**	**42.3**	**41.7**	**46.5**
Amplifier		1.1	29.7	31.7	31.7
+ Tuner	1%	1.8	0.0	36.5	0.0
+ Tape	1%	1.9	36.3	0.0	40.7
+ CD	1%	2.0	38.0	0.0	42.0
+ Tuner/Tape	1%	2.6	40.7	43.2	45.1
+ Tuner/CD	2%	2.7	42.5	44.2	46.5
+ Tape/CD	2%	2.8	40.9	0.0	45.9
+ Tuner/Tape/CD	2%	3.5	45.3	48.3	50.3
Amplifier systems	**10%**	**2.6**	**41.4**	**44.1**	**45.9**
Rack systems	**10%**	**3.0**	**49.4**	**51.4**	**53.6**
All component systems	**100%**	**3.0**	**42.9**	**42.9**	**47.1**

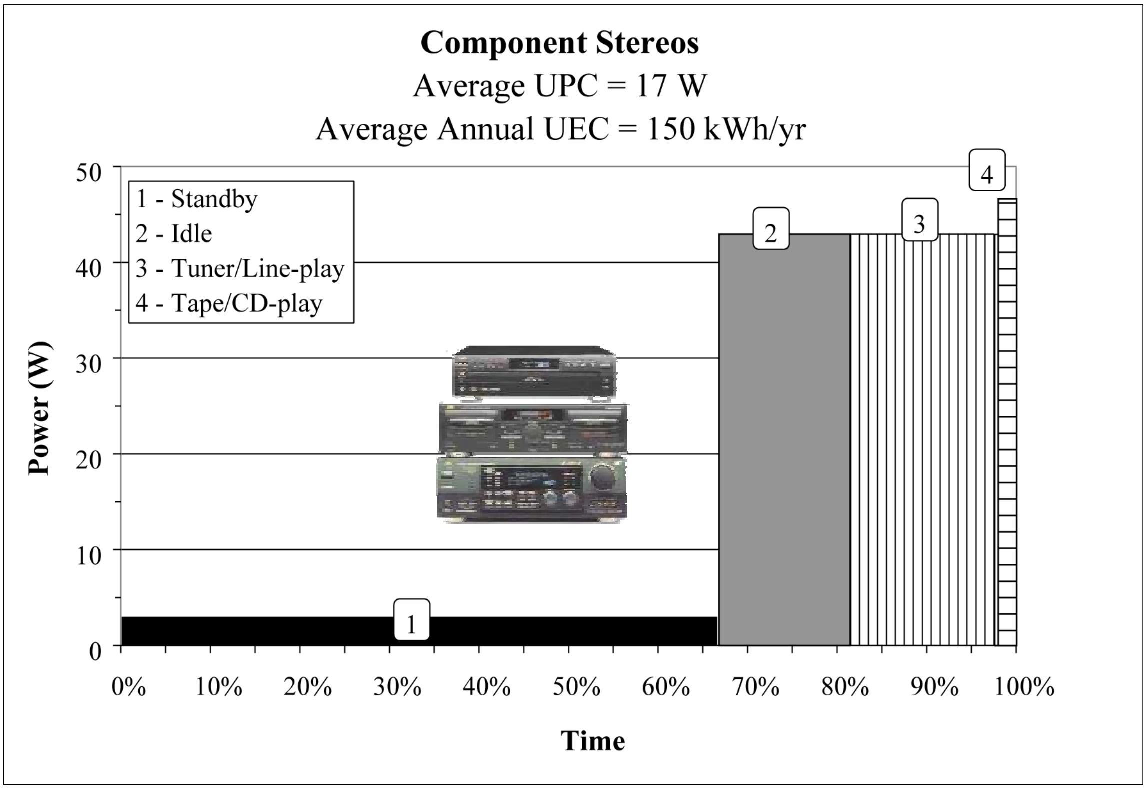
For simplicity, we used the power measurements of power amplifiers and integrated amps to represent all amplifier/preamplifier and integrated amplifier systems. We did not include the contribution of preamplifiers nor allow for the possibility of preamplifier/tuner combinations. The uncertainties associated with this assumption are discussed in Section 6.1.

5 NATIONAL AUDIO ENERGY CONSUMPTION

5.1 Average Unit Power and Energy Consumption Estimates

Our first task in estimating national audio energy consumption was to estimate typical usage patterns. We accomplished this by allocating a portion of time to the most commonly used operational modes of clock radios, portable stereos, compact stereos, and component stereos, as described in Section 4.2. We then determined average power requirements of each mode for each product as described in Section 4.3. Average unit power and energy consumption values were calculated using Equations 8 and 9, respectively. Below we summarize our findings.

Figure 5-1. Average Power Requirements for Common Component Stereo System Modes



We begin with the most powerful audio product, component stereo systems. Mode 1 shown in **Figure 5-1** is the standby mode. The average standby power consumption of these systems is about 3 watts. We estimate that component stereos are in this mode about 65% of the time. Mode 2 is the idle mode. We estimate that component stereo systems are idle about 16% of the time, using about 43 watts on average. The final two modes, labeled 3 and 4, are the play modes. Component systems are used to play the radio or TV sound about 16% of the time at 43 watts, and to play CDs and tapes about

3% of the time at 47 watts. According to these figures, the average power consumption of component systems is 17 watts, resulting in an average annual energy consumption of 150 kWh/yr.

Figure 5-2. Average Power Requirements for Common Compact Stereo System Modes

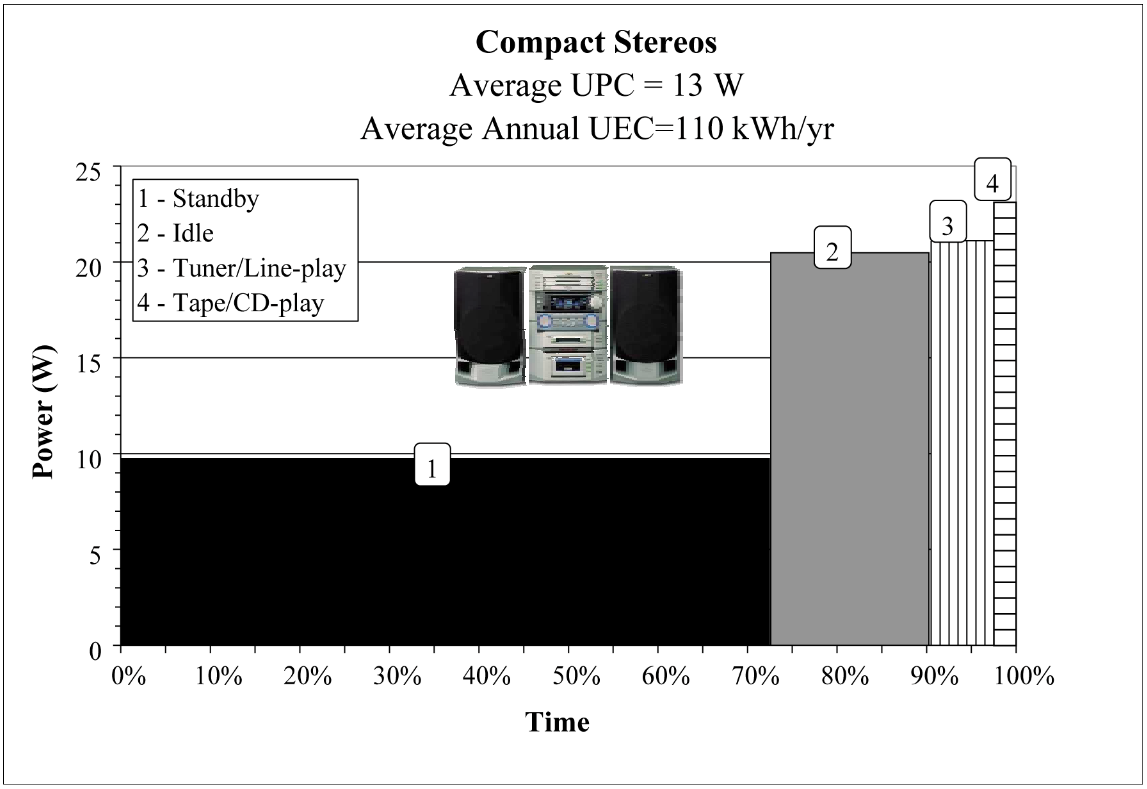


Figure 5-2 shows the mode-power graph for the second most powerful audio system, compact stereos. Perhaps the most striking feature of this graph is the high standby power consumption level. On average, the standby modes of these devices use nearly 10 watts. Since we estimate that compact stereos are in the standby mode over 70% of the time, we expect this mode to make a significant contribution to overall energy use. Idle modes, which are used about 19% of the time, also have relatively high average power requirements at just over 20 watts. These devices are used to play the radio or TV sound (line) about 7% of the time at 21 watts, and to play CDs or tapes about 3% of the time at 23 watts. Based on these figures, the average power consumption of compact stereos is 13.4 watts, for an average annual UEC of 110 kWh.

Figure 5-3. Average Power Requirements for Common Portable Stereo Modes

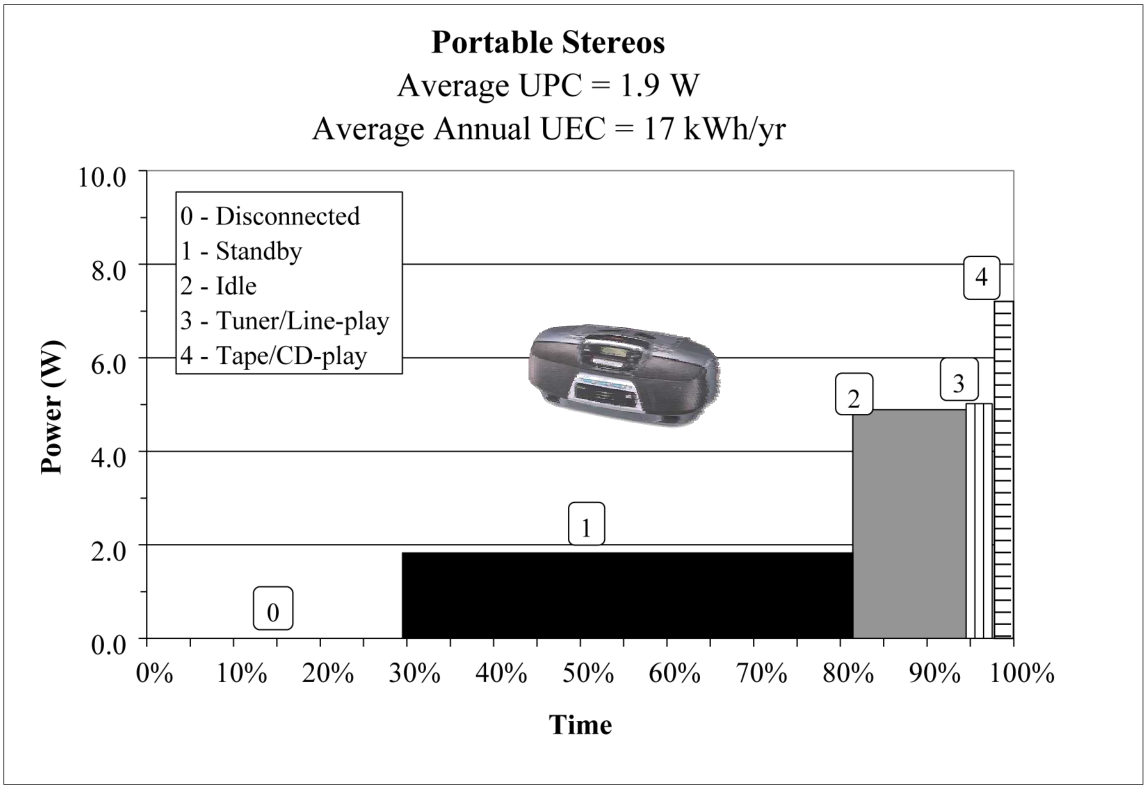
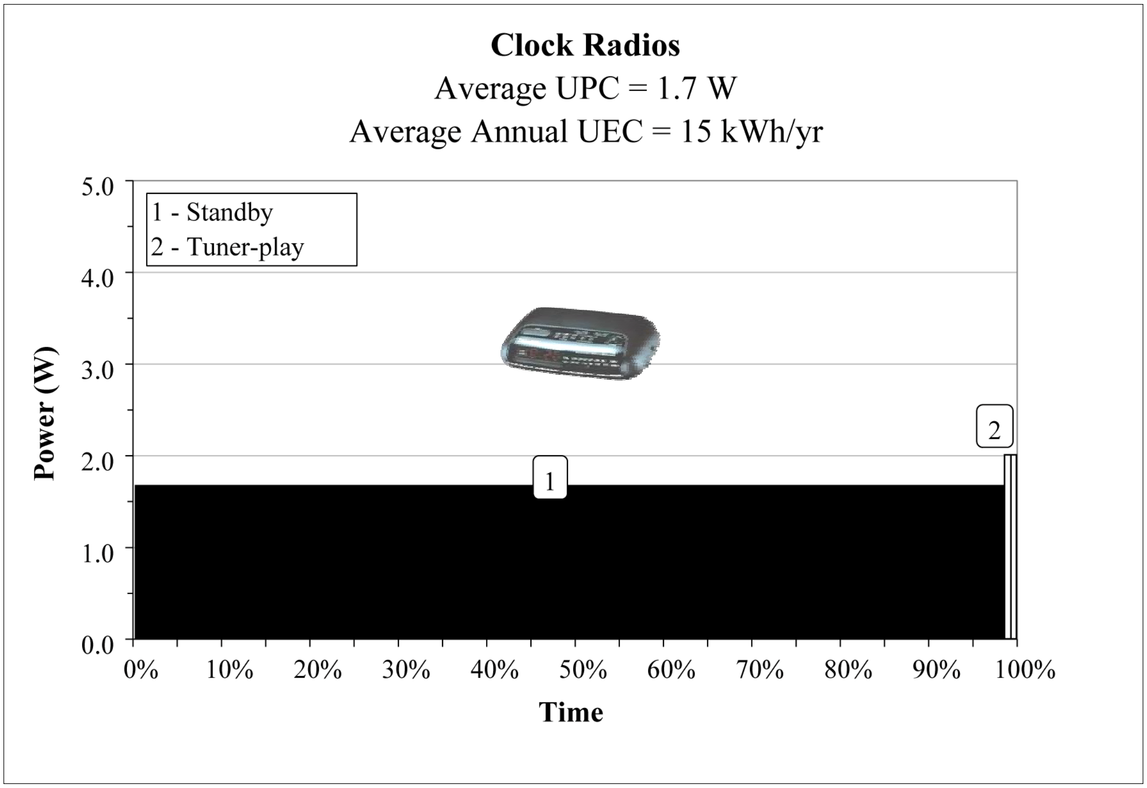


Figure 5-3 shows the average power levels of portable stereos. In Section 4.2, we estimated that portable stereos are not plugged in about 30% of the time. Standby mode, which requires an average of 1.8 watts, is utilized about 51% of the time. We estimate that portable stereos are left in idle modes about 13% of the time, drawing 4.9 watts on average. Radio and tape/CD play modes are each used 3% of the time, using 5.0 watts and 7.2 watts respectively. Based on these power and usage values, we estimate that the average portable stereo has an average power consumption of 1.9 watts, and consumes 17 kWh of electricity annually. This does not include the use of battery-supplied energy.

Clock radios, shown in **Figure 5-4**, are very low power devices. We estimate that clock radios are in standby mode about 98.5% of the time, using an average of 1.7 watts. The remaining 1.5% of the time, these devices are used to play the radio, which requires about 2 watts on average. The average power of clock radios is therefore 1.7 watts. When multiplied by 8760 hours per year, the UEC of this device is 15 kWh/yr.

Figure 5-4. Average Power Requirements for Common Clock Radio Modes



Using the values presented in Figures 5-1 through 5-4, we were able to calculate the contributions of each audio mode to the energy use of each product. These values are presented in **Table 5-1**.

Table 5-1. Contributions of Audio Product Modes to Average Annual UEC

Audio Product	Standby	Line/Tape/CD Idle	Radio/Line Play	Tape/CD Play	Total
	(kWh/yr)	(kWh/yr)	(kWh/yr)	(kWh/yr)	(kWh/yr)
Clock radio	15		0.3		15
Portable stereo	8.2	5.5	1.3	1.9	17
Compact stereo	62	32.3	12.8	6.1	113
Component stereo	17	60.7	61.3	12.4	151
	(%of UEC)	(%of UEC)	(%of UEC)	(%of UEC)	(%of UEC)
Clock radio	98%	0%	2%	0%	100%
Portable stereo	49%	32%	8%	11%	100%
Compact stereo	55%	29%	11%	5%	100%
Component stereo	11%	40%	40%	8%	100%

NOTE: Figures may not add due to rounding.

5.2 National Audio Energy Consumption Estimates for 1998

Table 5-2 shows our final estimates of saturation, unit energy consumption, and total energy consumption of the audio products investigated for this study. Calculated values are rounded to two significant digits.

Table 5-2. Saturation, UEC, and National Energy Consumption Estimates for Home Audio Products in the U.S. in 1998

Audio Product	Saturation	UEC (kWh/yr)	National Audio Energy Use[a] (TWh/yr)	Share of Audio Energy Use	Share of U.S. Residential Electricity Use[b]
Clock radio	126%	15	1.9	10%	0.2%
Portable stereo	67%	17	1.2	6%	0.1%
Compact stereo only	*39%*	*110*	*4.3*	*22%*	*0.4%*
Compact stereo + TV	*7.4%*	*130*	*1.0*	*5%*	*0.1%*
Compact stereo total	46%	110	5.3	27%	0.5%
Component stereo only	*30%*	*110*	*3.5*	*18%*	*0.3%*
Component stereo + TV	*43%*	*180*	*7.7*	*39%*	*0.7%*
Component stereo total	73%	150	11	57%	1.0%
Average U.S. Household		**190**			
Total U.S.			**20**	**100%**	**1.8%**

a. Based on 101.5 million households in the U.S. in 1998 [11].

b. Based on the 1998 residential electricity consumption of 1,122 TWh [1]

Table 5-3 shows the contributions of each mode of each audio product to national audio energy consumption.

Table 5-3. National Energy Use of Home Audio Products in 1998, by Mode

Audio Product	Standby	Line/Tape/CD Idle	Radio/Line Play	Tape/CD Play	Total Product Energy Use
	(TWh/yr)	(TWh/yr)	(TWh/yr)	(TWh/yr)	(TWh/yr)
Clock radio	1.9		0.0		1.9
Portable stereo	0.6	0.4	0.1	0.1	1.2
Compact stereo only	*2.5*	*1.3*	*0.2*	*0.2*	*4.3*
Compact stereo + TV	*0.4*	*0.2*	*0.4*	*0.0*	*1.0*
Compact stereo total	2.9	1.5	0.6	0.3	5.3
Component stereo only	*0.6*	*2.2*	*0.3*	*0.4*	*3.5*
Component stereo + TV	*0.6*	*2.3*	*4.2*	*0.5*	*7.7*
Component stereo total	1.3	4.5	4.5	0.9	11
Total Mode Energy Use	**6.6**	**6.4**	**5.3**	**1.3**	**20**
	(% of TPE)	(% of TPE)	(% of TPE)	(% of TPE)	(% of TPE)
Clock radio	98%	0%	2%	0%	100%
Portable stereo	49%	32%	8%	11%	100%
Compact stereo only	*59%*	*31%*	*5%*	*6%*	*100%*
Compact stereo + TV	*37%*	*19%*	*39%*	*5%*	*100%*
Compact stereo average	55%	29%	11%	5%	100%
Component stereo only	*17%*	*62%*	*10%*	*11%*	*100%*
Component stereo + TV	*8%*	*30%*	*54%*	*7%*	*100%*
Component stereo average	11%	40%	40%	8%	100%
Total Mode Energy Use	**34%**	**33%**	**27%**	**7%**	**100%**

NOTE: TPE = Total Product Energy use

6 DISCUSSION

6.1 Uncertainties

For this study, we attempted to minimize uncertainties in average power estimates by collecting our own database of power measurements. Stock and usage estimates were taken from secondary sources, and where information was not available, assumptions were made. In addition, we chose to exclude a variety of products that we felt would not contribute significantly to our results. Below we summarize some of the uncertainties associated with our data and analysis.

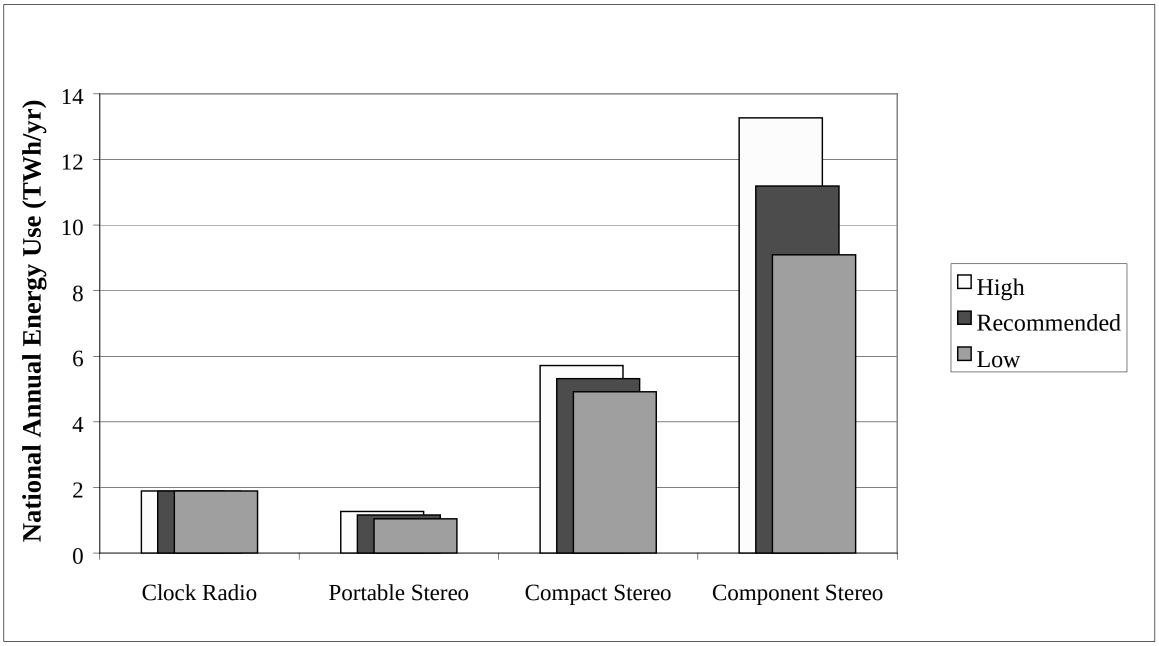
Products Not Included in This Study

Many appliances that could be considered audio products were not included in this study. We did not include subwoofers, DVD players, preamplifiers, power speakers, minidisk components, equalizer components, personal stereos, radios without clocks, or turntables. Combined, we expect that these products consumed about 2.5 TWh/yr in 1998. See Appendix A for a detailed description of each of these products and rough estimates of their national annual energy consumption values.

Idle Mode Assumption

For this study, we estimated that people leave audio products in idle modes for an average of 20% of the time. This assumption is based on a survey of employees in the Energy Analysis Program at LBNL for which the average of 30 responses was 19%. This sample was not representative of U.S. consumers. In addition, self-reporting for a survey question of this type is not likely to be accurate. While we have little reason to believe that 20% is an accurate estimate, more reliable information was not available. To estimate the effects of our assumption on the results of this study, we compared our results to those obtained using values 50% higher or lower than the value we used. **Figure 6-1** depicts these three scenarios.

Figure 6-1. Sensitivity of Results to Variation in Idle-Mode Usage Estimates



There is no change in the results for clock radios and little change in the results for portable and compact stereos. The effect on the estimated energy use of component stereo systems, however, is considerable. Values we estimate for component stereo energy consumption in the “low” and “high” energy scenarios are 9 and 13 TWh/yr, respectively. While this is a sizeable spread, we are unable to improve the accuracy of the idle mode usage estimate because no studies have addressed this issue thoroughly.

Representativeness of the Audio Product Sample Measured for this Study

In gathering power measurements, we did not take special effort to ensure representative samples of manufacturer, quality, or age of the audio products. In fact, most products in our database were less than three years old. It is somewhat likely that, due to technological improvements, these new products are more efficient than are their older counterparts. An example of this phenomenon can be seen in a recent study that found new 1997 and 1998 VCRs to be 22% more efficient in standby mode and 27% more efficient in idle mode than the national average [2].[6] If we assume similar improvements for audio equipment over the same period of time, our national audio energy estimate for 1998 would increase by about 25%.

[6] This study also found that the efficiency of TVs had not changed over the same 15-year period.

Effect of Volume on Power

Audio product power requirements increase as volume increases. We measured the "play" power use of clock radios, portable stereos, and compact stereo systems at very low listening levels. We expect that actual listening and power levels for these products will be higher than the levels used for this study. For clock radios, portable stereos, and most compact stereos, higher average listening levels for these products should not have a significant effect on our results because they are such low-power devices.

For high-power component stereo systems, a change in the average listening level may have a more noticeable effect on power use. Based on anecdotal evidence, we estimated that the average power requirement at a typical listening level is about 2 watts higher than the average power requirement at the zero volume level. If our estimate of the average listening level is too high, it will have very little effect on our final results (~0.2 TWh/yr) because it can drop by at most 2 watts per system. If our estimate is too low, effects on our results may be more noticeable. For example, increasing our average listening level to the -40 dB level (see Figure 4-11) would have increased our annual component stereo energy use estimate by about 0.8 TWh/yr. It is highly unlikely that the average listening level exceeds this volume.

Audio Systems Used for TV Sound

We assume that all audio systems that are connected to TV sets are used whenever the TV is used. If instead these systems are used for only half of TV use, our component stereo energy use estimate would drop from 12 to 10 TWh/yr, and our final audio energy estimate would drop to 18 TWh/yr. If we assume that these systems are never used for TV sound, our component stereo energy use estimate would drop to 8.4 TWh/yr, and our final audio energy estimate would drop to 17 TWh/yr.

Audio Systems Used for Computer Sound

In a recent survey, 15% of respondents indicated that they use their audio systems for computer sound [7]. If we assume that 10% of the U.S. population uses a compact audio system for computer sound, 5% use a component system for computer sound, and that these consumers use their computer for 3 hours per day, inclusion of computer usage would increase our estimate of national audio energy consumption by about 1 TWh/yr. This does not include the energy used by the computer.

Assumption Regarding Recorded Music Listening in the Home

We assumed that the average American listens to recorded music in the home for 40 of the 50 minutes per day listening to recorded music anywhere. If all 50 minutes takes place in the home, our final results would not increase noticeably. If none takes place in the home, our final national audio energy consumption estimate would be reduced by less than 1.0 TWh/yr.

DBS Used for Radio Listening

Nearly 6% of U.S. homes say they listen to audio-only programs using a direct broadcast system (DBS) [7]. Removing this non-audio product usage from our usage estimates does not affect our results significantly.

Home Audio Products used outside the Residential Sector

This study did not include the energy use of home audio products used outside the residential sector, for example, those used in coffee shops, waiting rooms, or offices. We expect that the energy use of all audio products in the U.S. is higher than what was estimated for the residential sector alone. A detailed estimate of the energy use of home audio products outside the residential sector was beyond the scope of this study; however, we feel that this energy use probably does not exceed 2 TWh/yr.

Listening Population

Our analysis assumes that radio, tape, and CD listening of persons under the age of 12 was the same as for those over the age of 12 because we could find no estimates of usage for this subset of the population. If we instead assume that this segment of the population spends no time listening to radio, tapes, or CDs, the effect on our results is insignificant.

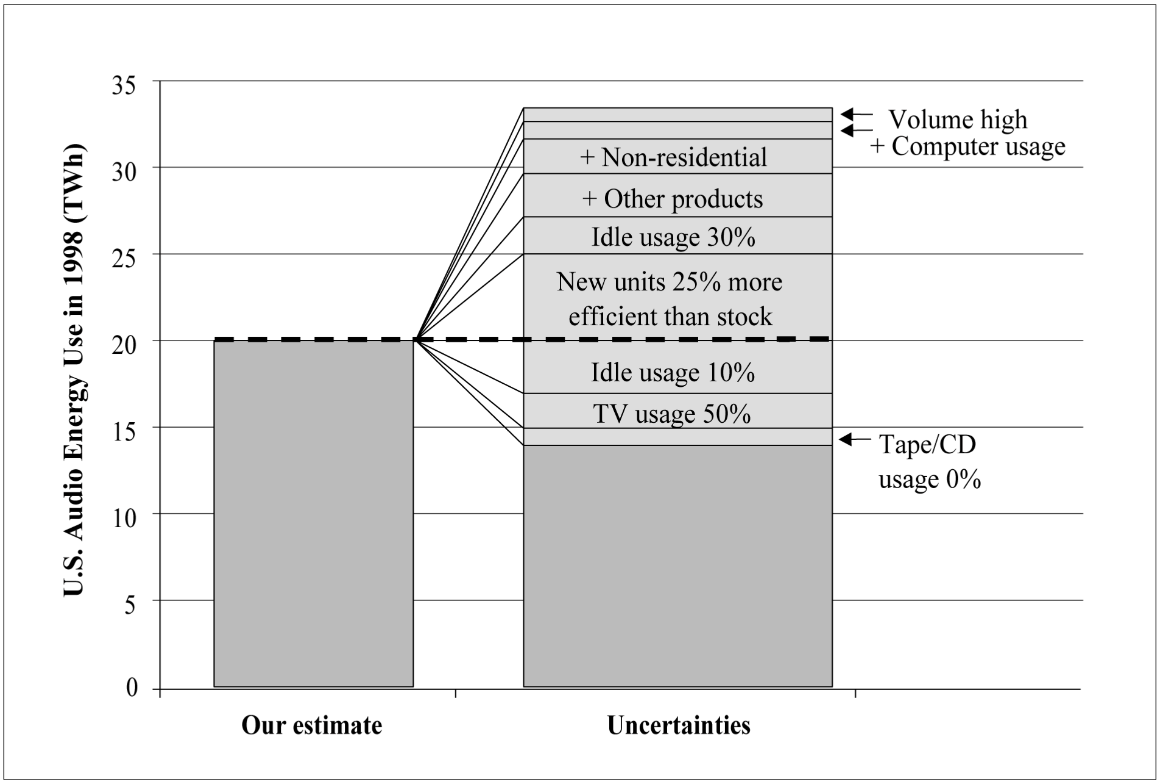
Audio Books

This study did not include the time that audio products are used to listen to tapes or CDs that do not have musical content, for example, books on tape, foreign language tapes, etc. Since audio books are primarily listened to in the car [16], we believe that this omission has not significantly affected our results.

Range of Uncertainties

Figure 6-2 shows the magnitude of the uncertainties described above compared to our estimate for annual U.S. audio energy consumption. If we exclude other audio products, non-residential uses, and computer usage, and in addition assume that the idle mode is used only 10% of the time the product is not used, TV sound is played only 50% of TV viewing time, and tape/CD-play is never used, we estimate an lower limit of 14 TWh/yr. If instead, we include other audio products, non-residential uses, and computer usage, and in addition assume that the idle mode is used 30% of the time the product is not used, and that products are played at a higher volume than we assumed, we estimate an upper limit of 33 TWh/yr.

Figure 6-2. Range of Uncertainties in Audio Energy Consumption Estimate for 1998



6.2 Comparison to Other Results

Two previous studies have estimated the energy use of residential audio products.

The Lawrence Berkeley National Laboratory (LBNL) report *Miscellaneous Electricity Use in U.S. Residences* by Sanchez el al. provides “back of the envelope” estimates of annual energy consumption for nearly 100 domestic appliances including "home radios," "boom boxes," "compact audio," and "RACK audio" systems [17]. Energy consumption estimates were calculated as the product of stock, usage, and average power levels. Stocks were estimated using historical shipment data and expected product lifetimes. The authors estimated usage values for two modes: on and standby. Average power levels of these two modes were taken from a previous LBNL study [18].

The Arthur D. Little, Inc. (ADL) report *Electricity Consumption by Small End Uses in Residential Buildings* by Zogg et al. [19] investigates the energy use of 16 domestic appliances, including "compact audio" and "rack audio" systems. Most or all of the stock, usage, and power consumption statistics for these audio products were taken from the aforementioned LBNL report. Two audio modes, on and standby, were considered.

These two studies provided useful first estimates of energy use for a large number of electrical devices. Because of the broad scope of these projects, however, the analyses of audio energy consumption were not thorough in many respects. For example, both of these reports included the usage and power draw levels for only two of the many possible audio modes. In addition, usage values did not reflect the number of U.S. homes that use audio systems to amplify TV sound. As a result, usage estimates for some audio systems were underestimated.

Table 6-1 shows our estimates of stock, average annual UEC, and national audio energy use compared to the estimates presented in Sanchez et al. [17] and Zogg et al. [19].

Table 6-1. Comparison of the Results of This Study with the Results of Similar Studies

	Clock Radios		Portable Stereos		Compact Stereos			Component (Rack) Stereos		
	This Study	[17]	This Study	[17]	This Study	[17]	[19]	This Study	[17]	[19]
Units (millions)	128	105	68	73	47	53	55	74	55	56
Average UEC (kWh/yr)	15	18	17	19	110	94	95	150	81	71
Total U.S. Electricity Consumption (TWh/yr)	1.9	1.9	1.2	1.5	5.3	5.0	5.2	11	4.4	4.0

NOTE: [17] = Sanchez et al.; [19] = Zogg et al.

Although methods and data were different, the results of this study, the Sanchez study, and the Zogg study are similar with the exception of the results given for component (rack) stereo systems. See Appendix F for a more detailed discussion of these reports.

6.3 Trends Affecting Audio Energy Consumption

This study provides only a snapshot of the energy consumption of U.S. home audio equipment in 1998. Many of the underlying stock, usage, and power assumptions on which we base our results have the potential to change in the near future.

Changes in Consumer Behavior

To complement the "bigger is better" philosophy of television buyers, audio equipment buyers appear to believe that more powerful is better. Sales of smaller, less powerful audio systems such as radios and portable stereos are falling, while sales of compact stereos are growing and component system sales have remained relatively constant. (See Appendix B).

According to a recent survey, 27% of U.S. homes have a home theater system consisting of a 25-inch or larger television set, a surround sound processor, and separate speakers, while 14% planned to buy one within the year [7]. Dolby Digital (AC-3), the new standard for home theater setups, has the capability to drive five speakers plus a subwoofer. Since each channel used demands a certain amount of power, we expect the increasing popularity of home theater to increase audio energy consumption.

Like many other consumer electronics devices, audio products can be used in tandem with computers. Alternatively, computers can also perform functions typically associated with audio products. Currently, about 15% of U.S. homes own a computer that is connected to an audio system [7], and about half of all home computers are connected to power speakers [20]. Among households owning a PC equipped with a CD drive and external speakers, 70% use the device to play audio CDs [21]. With new digital audio formats, such as MP-3, consumers can now simply download music from the Internet, while new sound cards allow them to play the audio files in full 5-speaker plus subwoofer surround sound. These trends are likely to increase both stock and usage of power speakers. On the other hand, if this behavior consistently offsets usage of more powerful audio products, like component stereo systems, audio energy usage may actually decrease as a result.

Trends in Power Consumption

Energy efficiency in audio products has not been a priority of manufacturers or of policy makers in the U.S. While we expect that active (play mode) power consumption has not changed significantly in the past two or three decades, it is likely that standby power use is on a downward trend. A recent study showed that the standby power requirements of VCRs have decreased significantly over the past fifteen years [2]. Assuming that the standby functions of audio products are similar to those of VCRs, we expect that the standby modes of audio products have also become more efficient.

In the past few years, the influence of policy makers on standby power use has been on the rise. In the U.S., the Environmental Protection Agency (EPA) now has an Energy Star® program for audio equipment. This program encourages voluntary agreements between the EPA and industry to limit the standby power use of audio products to 2 watts until the end of 2001. In 2002, the compliance limit will be lowered to only 1 watt [22].

6.4 Opportunities for Energy Savings

Reducing the energy use of any appliance can be accomplished by reducing the stock, usage, or power requirements. Reducing the stock, while quite effective, would probably not be acceptable to the manufacturers or to the consumers. Instead, energy savings are more likely to be achieved through design changes, such as those that achieve reductions in power requirements or idle usage.

Reduce Standby Power Requirements

According to our estimates, the standby mode of audio equipment accounts for about one-third of all audio energy use. Of the individual audio products investigated for this study, only compact and rack audio systems had an average standby power use above two watts. If manufacturers were to reduce the standby power of these systems to the same level as that of other systems, standby energy consumption could be reduced by over 2 TWh per year in the U.S., saving energy customers over 160 million U.S. dollars.[7]

Technology exists to reduce the standby power requirements of any audio product to less than one watt [23]. Even among the typically standby-inefficient compact stereo systems, examples of standby power levels under 1-watt exist. If manufacturers implemented efficient technologies in all new audio products, standby energy consumption of home audio equipment could be reduced by at least 4 TWh/yr, saving U.S. energy customers over 300 million dollars annually. We expect that these savings estimates are conservative, because improved standby mode efficiency for many products would improve efficiency in other modes as well.

Incorporate Simple Power Management to Reduce Idle Usage

We estimate that one-third of audio energy consumption is used during the idle modes of portable, compact, and component stereos. In most cases, audio products are left in these modes simply because consumers forget to turn the units off after use. In portable and compact stereo systems, a simple power management system could be incorporated, which would turn the unit off when not in use for a specified period of time. Such power management systems are already common in many products, including calculators, coffee makers, and irons. Using this type of automatic shut-off in portable and compact audio systems could save as much as 2 TWh/yr.[8]

At present, power management systems would be more difficult to implement in component stereos. Portable and compact stereo systems are housed in a single casing, but component stereos consist of separate units. For the entire system to shut itself off, the base unit would need to know that the other units were not in use. Manufacturers could accomplish this through networking or by simply programming the base unit to respond to the power use of the components plugged into the base unit. We estimate that reducing the average idle mode usage of component stereos to one-half hour per day would reduce national audio energy consumption by over 4 TWh/yr.

[7] Assumes average electricity cost of $0.08 per kWh.
[8] Using current standby power levels, standby energy use would increase by 0.2 TWh because the decrease in idle mode usage would shift to standby mode usage.

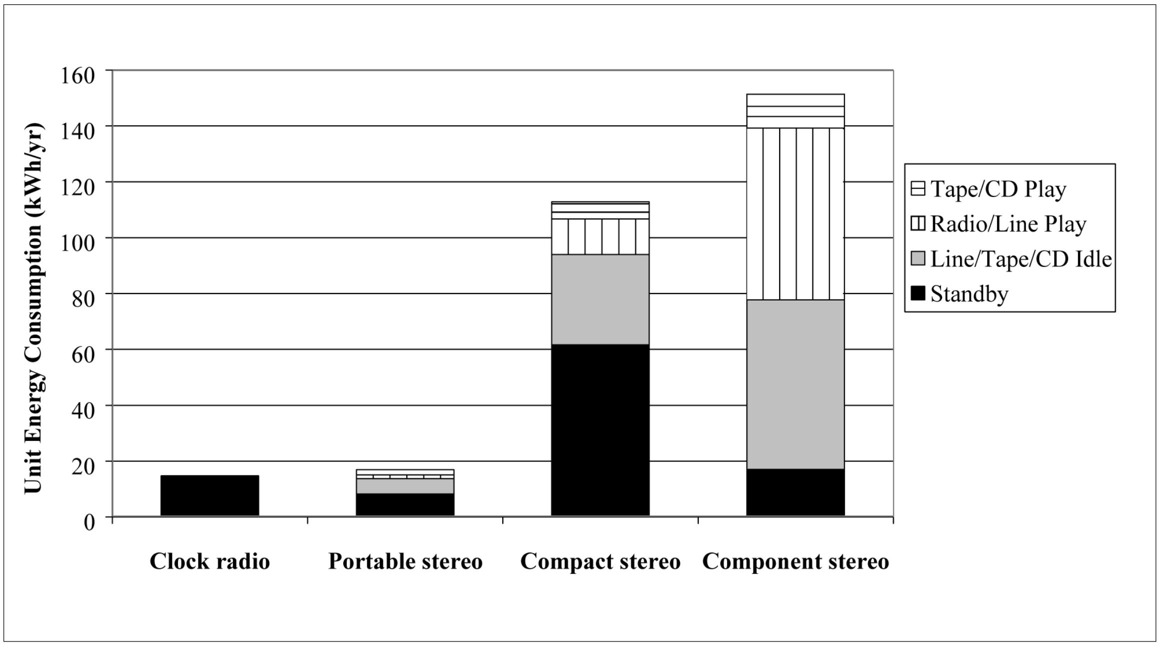
Efficient Amplifiers

The two types of amplifiers used in most home audio systems are Class AB and Class D amplifiers. Class D amplifiers, sometimes called "digital" amplifiers, typically use 50% less electricity than Class AB amplifiers. Now, however, the vast majority of amplifiers used in televisions and home audio systems are Class AB amplifiers. Although Class D amplifiers are more expensive than Class AB amplifiers, they are currently cost-effective in high power audio systems, because the higher efficiencies allow for the use of smaller, less expensive power supplies.

7 CONCLUSIONS

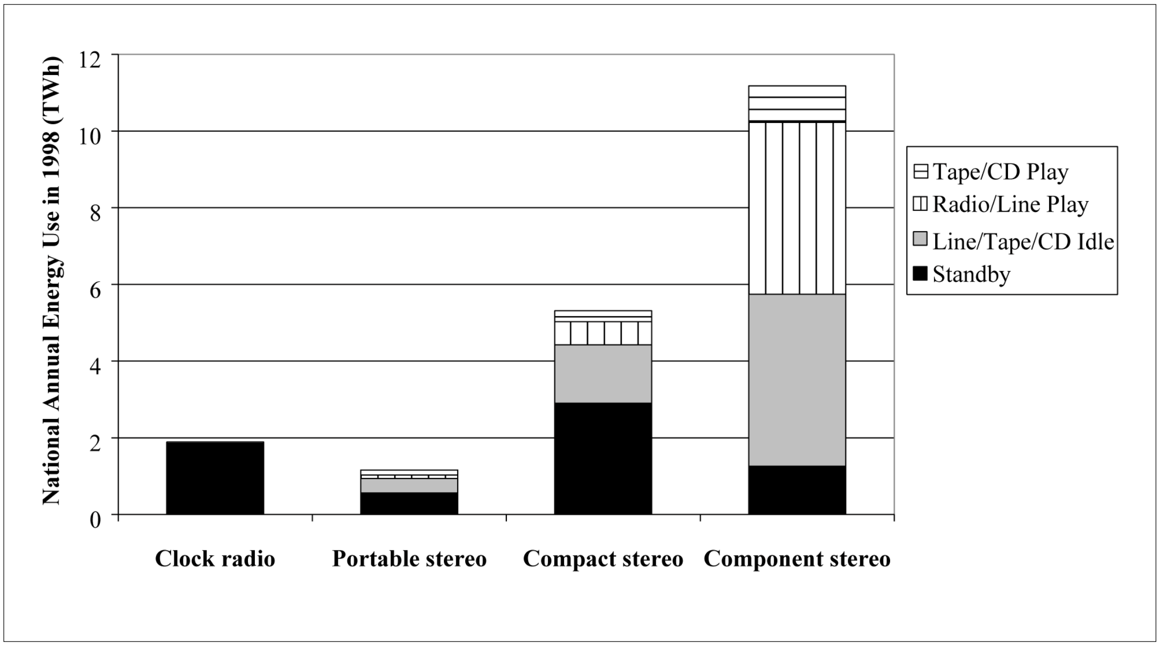
Of the four audio products investigated for this study, we found that component stereos had the highest annual UEC at 150 kWh/yr, with compact stereos not far behind at 110 kWh/yr. Portable stereos and clock radios use just a fraction of this UEC at 17 and 15 kWh/yr, respectively. **Figure 7-1** shows the contribution of each operational mode to the UEC values of these audio products.

Figure 7-1. Contributions of Modes to Average Annual UEC Values



Based on these UEC values, we estimate that the 128 million clock radios, 68 million portable stereos, 47 million compact stereos, and 74 million component stereos in the U.S. consumed about 20 TWh/year in 1998, or 1.8% of total residential electricity use for that year. This corresponds to an average audio energy use of about 190 kWh per year per home. National annual energy use for each of these audio products is shown in **Figure 7-2**. The contributions of each mode, including standby, idle, and play modes, are also indicated.

Figure 7-2. Contributions of Modes to 1998 Energy Use of Home Audio Products in the U.S. Residential Sector



Together, compact and component stereos are responsible for 84% of audio energy consumption, as shown in **Figure 7-3**. In addition to higher power requirements for these systems, this high fraction is caused in large part by the roughly 44% of homes that use these audio products to listen to television sound. In comparison, clock radios and portable stereos each consume a relatively minor fraction of national audio energy.

Figure 7-3. Contributions of Individual Products to 1998 Audio Energy Consumption

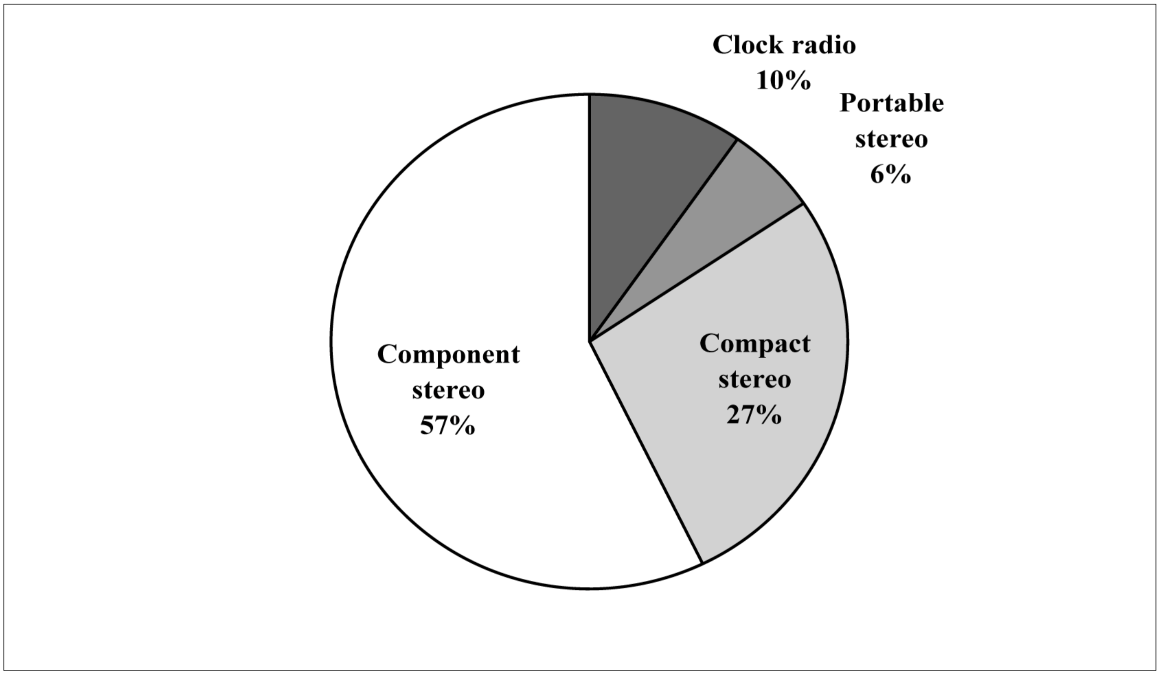
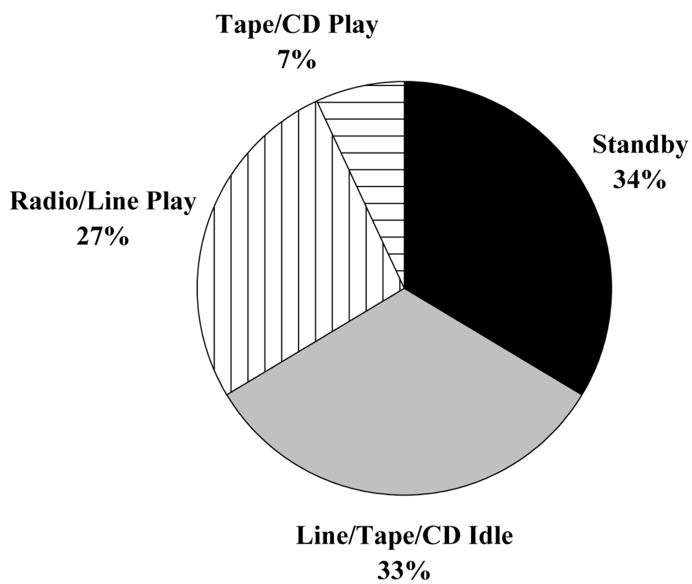


Figure 7-4 shows the contribution of each audio mode to overall U.S. audio energy use. These results demonstrate the value of investigating the energy use of all the frequently used modes of an appliance. Nearly two thirds of audio equipment energy is consumed while the equipment is in standby or idle modes, and only about one third occurs while the products are in use. These estimates would not vary significantly unless our assumptions regarding listening time were dramatically changed. For example, even if we doubled our tape, CD, and radio listening estimates, our estimate of the fraction of energy consumed during audio product use would still not surpass 50%.

Figure 7-4. Contributions of Individual Modes to 1998 Audio Energy Consumption



Through direct measurements and other information collection, we gained a sense of the energy savings potential in audio equipment. We observed a wide range in power levels—especially for standby modes—among similar types of audio equipment. Redesigning audio equipment to consume less than one watt in standby mode could save as much as 4 TWh of residential electricity use annually. Furthermore, new technologies may gradually replace existing equipment and reduce active power needs. These improvements could reduce audio equipment energy consumption by as much as 50%.

A previous study found that TVs and VCRs consume 2.8% and 0.8% of national residential electricity consumption, respectively [2]. **Figure 7-5** shows the contribution of those devices and of audio equipment to miscellaneous electricity use, and to total U.S. residential electricity consumption. These home electronics together account for over 5% of residential electricity consumption.

Figure 7-5. Miscellaneous End-Use as an Uncertain Fraction of 1998 Residential Electricity Use, with Portions Attributed to TVs, VCRs, and Audio Products

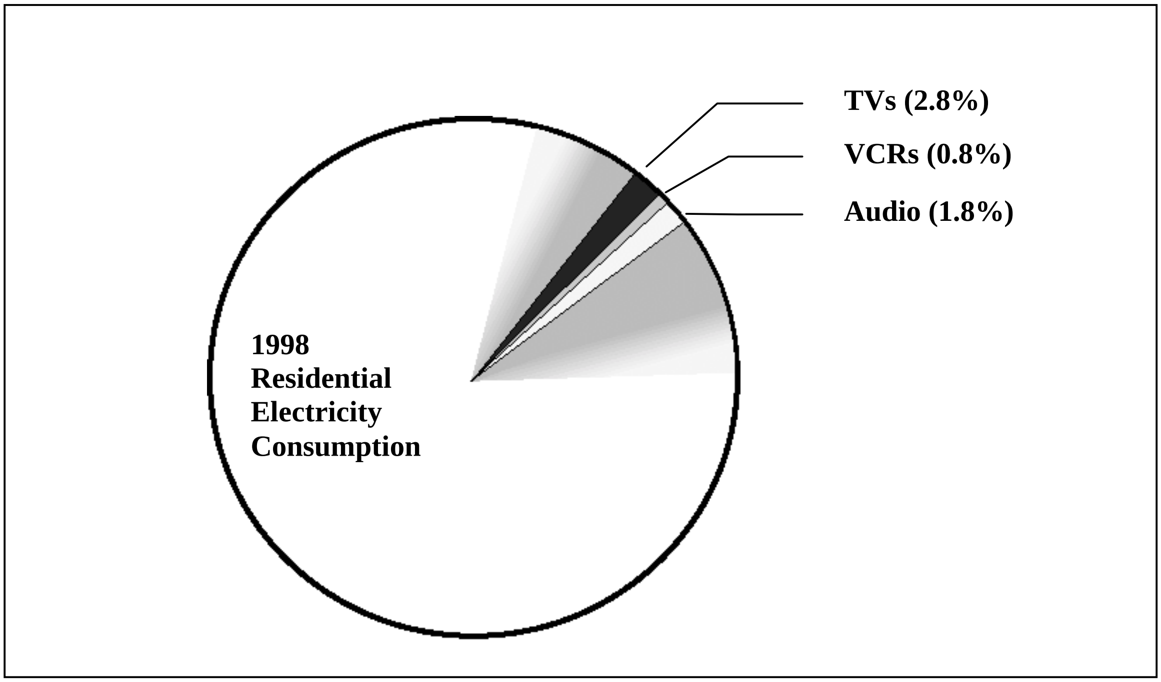


Figure 7-5 shows that a significant portion of miscellaneous electricity use has yet to be labeled. In future work, we will estimate electricity consumption of the remaining major home electronic equipment: telephony, set-top boxes, and home office equipment.

8 ACKNOWLEDGEMENTS

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Appendix A. Audio Products Not Covered in this Study

Several products that could be considered audio products were not included in our investigation. To avoid a gross underestimation of audio energy consumption, we estimated values for stock, usage, and power based on industry information and our own power measurements. **Table A-1** shows these values and our final estimates of average annual UEC and national energy use for each product. These estimates are not included in the main text of this report.

Table A-1. National Energy Use Estimates for Other Audio Products

Audio Product	1998 Stock (M)	USAGE			POWER			ANNUAL ENERGY USE	
		Standby (time)	Idle (time)	Active (time)	Standby (watts)	Idle (watts)	Active (watts)	UEC (kWh/yr)	Total U.S. (TWh/yr)
Subwoofer	10	10%	60%	30%	0	8	10	68	0.7
DVD	2	72%	24%	4%	4	15	17	64	0.1
Preamplifier	2	72%	24%	4%	2	17	17	54	0.1
Speakers	30	69%	23%	8%	2	4	6	24	0.7
Minidisk	5	72%	24%	4%	2	4	6	23	0.1
Equalizer	5	72%	24%	4%	0	6	6	15	0.1
Personal stereo[a]	10	35%	11%	4%	1	4	4	8	0.1
Radio	50	96%		4%	1		2	5	0.2
Turntable	5	96%	0%	4%	0		5	3	0.0
TOTAL									**2.5**

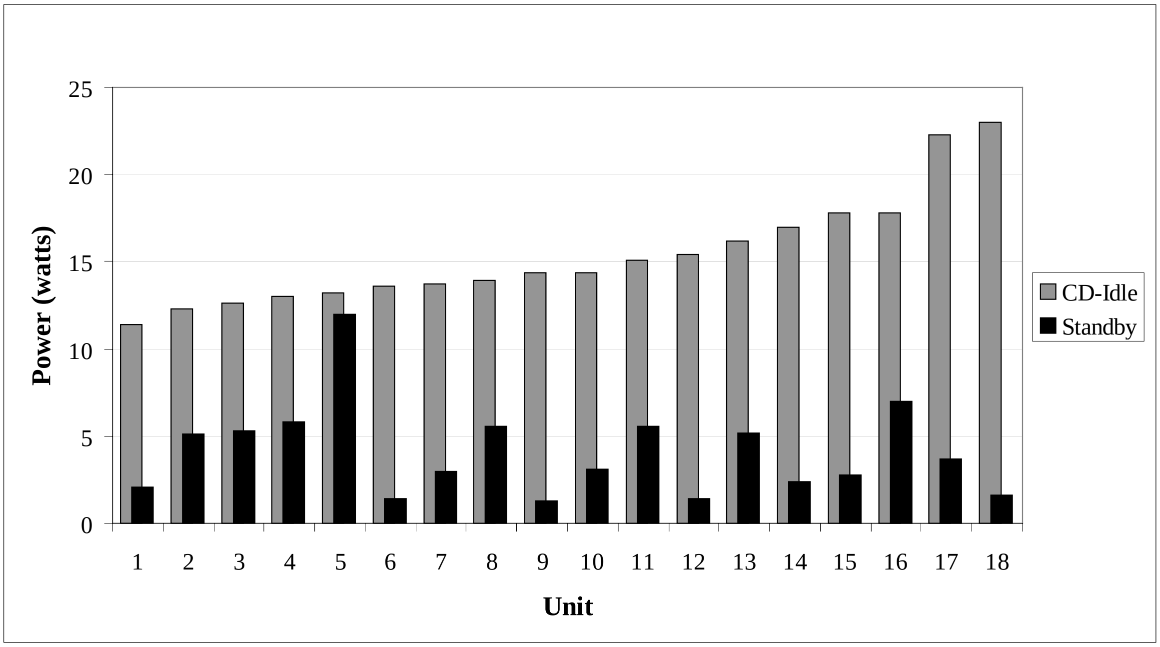
a. Includes only battery chargers associated with personal stereos that are sold with rechargeable batteries. We estimate that battery chargers for personal stereos are disconnected roughly 50% of the time.

We estimate that turntables, radios without clocks, personal stereos, equalizers, minidisk players, and preamplifiers do not now, nor will they in the future, contribute significantly to audio energy consumption.

We estimate that power speakers and subwoofers each account for about 0.7 TWh of annual residential electricity consumption. Power speakers are small speakers that come as a pair and are typically used with computers. Subwoofers are large, single speakers that enhance the bass sound and vibrations of stereo systems. While most speakers do not require power from the mains, these speakers have built-in amplifiers. They have power switches, but in the case of subwoofers, we think it is unlikely that consumers ever switch them off because the switches are on the back and because there is no indication that the units are on. These products appear to be gaining in popularity. Future studies of audio energy use may want to include powered speakers and subwoofers.

We expect that DVD players will contribute significantly to national audio energy use in the future. They began selling in retail stores in November of 1996, and by March 1998 had sold over 2 million units. The consumer electronics industry expects that DVD players will one day be as widespread as are VCRs today. In anticipation of the popularity of DVD players, we measured the standby and idle power consumption of eighteen DVD players at retail stores. These measurements are shown in **Figure A-1**.

Figure A-1. Measured Power Use of DVD Players in Standby and Idle Modes



It is interesting to note that the average DVD player uses less power than the average VCR in the standby mode, but more power than VCRs in the idle mode. We expect that future generations of this product will be more efficient as the technology matures and as manufacturers become increasingly aware of standby power issues.

Appendix B. Estimates of Stock Based on Historical Shipments, Sales, and Product Lifetime Estimates

The stock turnover model we used for this study required historical shipment or sales data and average product lifetimes. As noted above, uncertainties in the data and the stock turnover model were high, compelling us to use the stock estimates based on the data described above. For the sake of comparison, however, we felt it was worthwhile to describe the data, analysis, and results of this method as well.

Appliance Magazine publishes life expectancy estimates for many products. These estimates are based on first-owner use of the product, so they do not necessarily reflect the full life cycle of the appliance [5][24]. As a result, we assume that the average lifetime estimates published by Appliance Magazine are slightly low. Appliance Magazine does not publish estimates for portable stereos, receivers, or amplifiers.

To fill in missing lifetime estimates, and to provide a comparison for the Appliance Magazine data, we inquired with a local merchant who had 23 years of experience dealing in used stereo equipment [25]. His answers are compared to Appliance Magazine's 1996 and 1997 estimates in **Table B-1**.

Table B-1. Expected Lifetimes of Audio Products

	Home Radios	Portable	Compact	Rack	Receivers	Amplifiers & Preamplifiers
Bencangey [25]	10	**5**	7	7	**20**	**12**
Appliance 1997 [24]	**8**	--	7	--	--	--
Appliance 1998 [5]	6	--	**9**	**9**	--	--

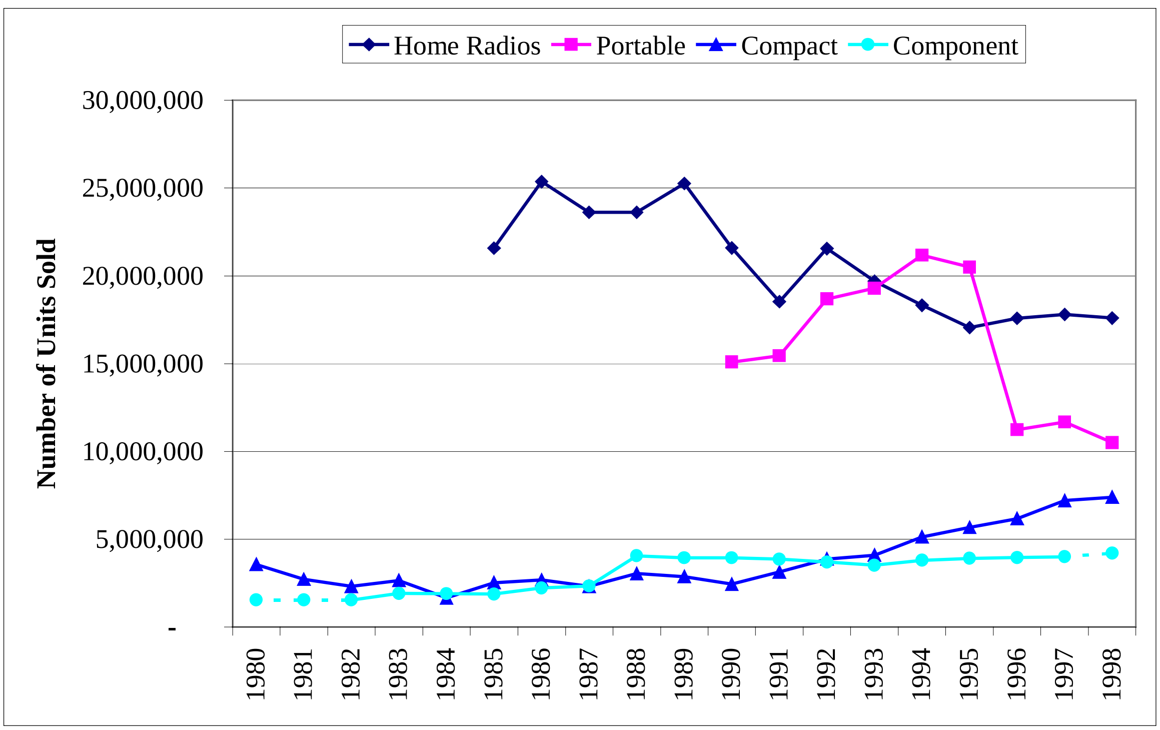
NOTE: Values used for this study in bold type.

The lifetime estimates shown in Table B-1 vary substantially. In 1997, Appliance Magazine estimated that the average lifetime of a compact audio system was seven years. The following year, they estimated that the average lifetime of a compact audio system was nine years. Because stock estimates are sensitive to differences in product lifetime estimates, this change results in a noticeable difference in the stock estimate. Assuming level sales, 31% more units are estimated using the 1997 estimate than are estimated using the 1996 estimate. This would translate directly into a 31% difference in the national energy use estimate.

Using the 4/3 Retirement Function to estimate current U.S. stock of audio equipment requires shipment or sales data dating back to approximately four-thirds the estimated product lifetime. In searching for this data, however, we found that available shipment and sales data were insufficient. What was available came from CEMA [26], Appliance Magazine [27], and the U.S. Census [11]. Of the products we investigated for this study, only CEMA’s sales data for compact systems were adequate. While CEMA publishes sales data for home radios, they do not distinguish between radios with and without clocks. Neither CEMA nor Appliance Magazine published data for portable stereos, and very scanty data was available for audio components.

Figure B-1 shows our estimates of audio product sales/shipments. Note that the home radio sales from CEMA include clock radios as well as radios without clocks. We estimated portable stereo sales from CEMA data as the sum of tape/radio players, tape recorders, and portable CD equipment sales minus the number of personal stereos sold. We estimated the number of component systems in the U.S. as the sum of rack system sales, amplifier shipments, and receiver shipments. While CEMA sales figures for rack systems were sufficient, Appliance Magazine's shipment data for receivers and amplifiers were available only for the years 1983-1992. We used amplifier shipments from the U.S. Census [11] for the years 1993-1997 and assumed no change in shipments from 1997 to 1998. We estimated receiver shipments from 1980 to 1982, and assumed that sales of receivers grew 10% per year after 1992.

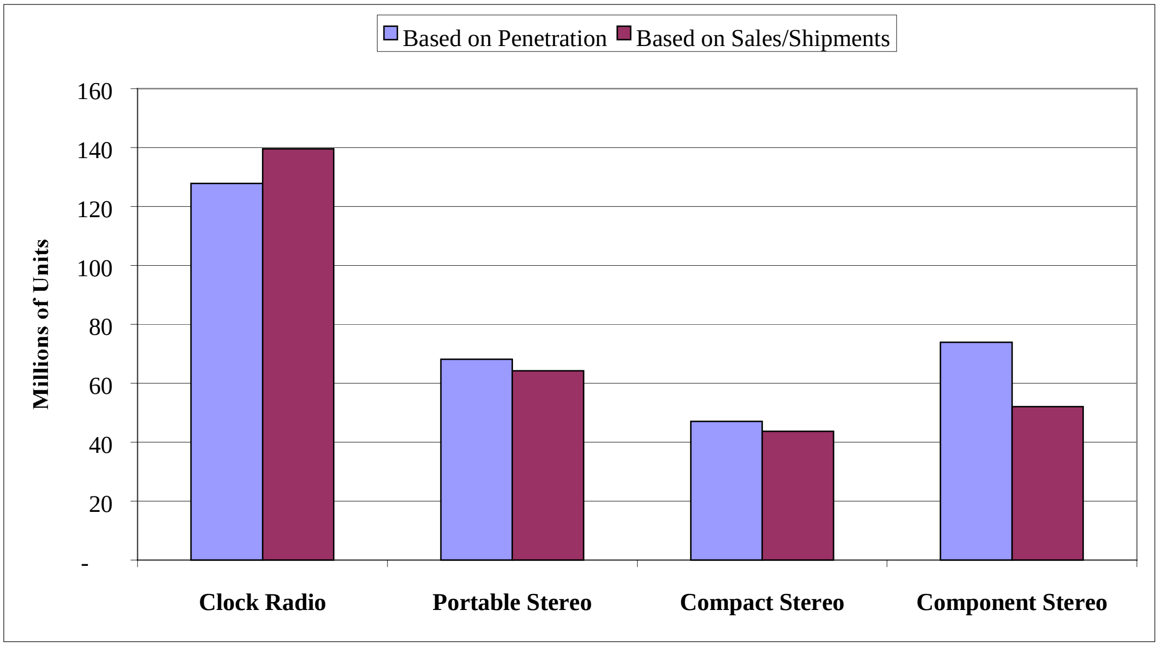
Figure B-1. Historical Sales/Shipments of Audio Products, 1980-1998



Because of the many assumptions required to produce the estimates shown in Figure B-1, we believe that the uncertainties associated with these historical shipment and sales figures are very high. While we feel that these estimates are a useful addition to this investigation, we present them only for comparison and do not recommend they be used where a high level of certainty is critical.

Figure B-2 compares the stock estimates obtained using the two methods described in Section 3.1 and the data described above.

Figure B-2. Comparison of U.S. Audio Product Stock Estimates Calculated Using Two Different Methods



We do not have much faith in the accuracy of the estimates based on shipments/sales for this study because we feel that the data used to generate these estimates were not reliable. Sales and shipment data were inadequate, and life expectancy estimates varied significantly from year to year and from source to source. Instead, we use the stock estimates based on penetration levels in our estimate of U.S. audio energy use, because uncertainties were comparatively low.

Appendix C. CEMA Audio Equipment Usage Report

Many vital statistics used in this report were taken from a December 1998 telephone survey [6] published by the Consumer Electronics Manufacturers Association (CEMA), a sector of the Electronics Industry Association. According to CEMA, calls were made to a representative sample of 1,000 U.S. households using industry standard random-digit-dialing techniques, and respondents were screened to identify a head of household involved in purchasing household items [6]. **Table C-1** compares the gender, age, income, and regional characteristics of the CEMA report to U.S. Census data [11].

Table C-1. Representativeness of the Sample Surveyed by CEMA

Source	Gender		Age (years)				Income (thousands of US$)					U.S. Region			
	M	F	18-31	32-51	52+	NR	<20	20-39	40-59	60+	NR	NE	MW	S	W
CEMA [7]	48%	52%	26%	41%	30%	3%	14%	27%	19%	17%	23%	20%	23%	35%	22%
Census [11]	49%	51%	18%	42%	40%	—	27%	26%	18%	29%	—	19%	24%	36%	21%

NOTE: M=Male, F=Female, NR = No Response, NE=Northeast, MW=Midwest, S=South, W=West

Table C-1 shows that the age and income sub-categories, were substantially different. To check that this discrepancy would not affect our results, we weighted the CEMA survey results using age and income distribution taken from the U.S. Census Bureau. Results of the check, shown in **Table C-2** and **Table C-3**, show that there is no significant difference between the results CEMA reported and those reflecting the actual U.S. age and income distributions. We conclude that there is little or no effect resulting from the age and income bias in CEMA's survey sample.

Table C-2. Comparison between CEMA survey results and results that reflect the actual U.S. age distribution

Category	CEMA Survey [7]					U.S. Census Weighted Average[b]
	N.R.[a]	Age 18-31	Age 32-51	Age 52+	Weighted Average	
Survey Respondents	3.1%	26%	41%	30%		
Clock Radio Owners		83%	86%	81%	**84%**	**84%**
Portable Stereo Owners		62%	63%	44%	**56%**	**55%**
Compact Stereo Owners		52%	43%	28%	**40%**	**39%**
Component Stereo Owners		66%	70%	56%	**65%**	**64%**

a. N.R. = No Response

b. Based on the U.S. head of household distribution: 18-31 yrs: 18% | 32-51 yrs: 42% | 52+ yrs: 40% [11]

Table C-3. Comparison between CEMA survey results and results that reflect the actual U.S. income distribution

	CEMA Survey [7]						U.S. Census
	N.R.[a]	Under $20K	$20K-$39K	$40K-$59K	Over 60K	Weighted Average	Weighted Average[b]
Survey Respondents	23%	14%	27%	19%	17%		
Clock Radio Owners		81%	81%	87%	90%	**84%**	**85%**
Portable Stereo Owners		48%	52%	62%	64%	**56%**	**56%**
Compact Stereo Owners		36%	37%	43%	49%	**40%**	**41%**
Component Stereo Owners		59%	59%	71%	79%	**65%**	**67%**

a. N.R. = No Response

b. Based on the U.S. head of household distribution: Under $20K: 27% | $20-$30K: 26% | $40-50K: 19% | Over 60K 29% [11]

Appendix D. Single Phase Power Multimeter, Model PLM-1-LP

Electronic Product Design, Inc., 2145 Debra Drive, Springfield, Oregon 97477

The Single Phase Power Multimeter (model PLM-1-LP) is an electronic instrument used to measure parameters associated with power consumption by an electrical load that is normally operated from a 50 or 60 hertz power line. Power is supplied to the load via a permanent power cord exiting the rear panel and a 15 amp, 120-volt outlet on the front panel. An internal 0.1-ohm shunt, wired in series with the neutral wire, senses the current. The voltage is measured between the hot and neutral wires. Power is provided to the measuring electronics via the same power cord. Current is limited to three amps RMS with an inline, 3 amp, slow-blow fuse accessible at the rear panel.

The Single Phase Power Multimeter measures; true RMS voltage and current; true power; and peak voltage, current, and power. This meter also calculates Power-Factor, Volt-Amps, and VARS. In addition the PLM-1-LP accumulates Time and Watt-Hours.

Display information, time, and accumulations of power are stored away in a non-volatile memory. If measuring power is lost, when it returns, the meter will power up and still retain the latest recorded information. Reset of Watt-hours and Time is accomplished via the front panel momentary switches.

A dual line, 16 character per line, LCD provides a visual output to the operator. Two front-panel pushbuttons allow sequencing through the different displays of values. All measurements and calculations are updated at 1 second intervals, and if your meter includes the RS232 option, all the measurements and calculations are output at 9600 baud, once each second. RS232 isolation is a minimum of 1500 volts.

Operating temperature: 25 $\pm$ 10 degrees C. Bandpass: 100th harmonic of 60 Hz (6Khz).

Crest factor: Peak current (10 amps) divided by measured RMS current.

MEASUREMENT	RANGE	ACCURACY
RMS Voltage	0.1 to 140.0 volts	0.5% +1 LSD
RMS Current	0. 001 to 3.000 amps	0.5% +1 LSD
Watts	0.1 to 420.1 watts	0.5% +1 LSD
Peak Voltage	0.1 to 200.0 volts	1% +1 LSD
Peak Current	0.01 to 10.00 amps	1% +1 LSD
Peak Power	1 to 2,000 watts	1% +1 LSD
Volt-Amps	0.1 to 420.0 VA	1% + 1 LSD
Power Factor	0.00 to 1.00	1.5%
VARS	1 to 420 VARS	1.5% (PF = 0.1 to 0.9)
Accumulate Power (Wh)	0.01 to 999999.99	05% + 1LSD
Hours	0.01 to 655.36	0.01% + 1LSD

Appendix E. Audio Data

Tables E-1 through E-9 list the manufacturers, model numbers, power levels and years of manufacture for the audio products measured for this study. We collected these data at retail shops early in 1999 using a PLM-1-LP watt meter, described in Appendix D. Nearly all audio products in the database were new when measured, with the exception of a few older products measured at a used stereo shop.

Table E-1. Power Measurements of Radios

Type	Brand	Model	Standby	Tuner-Play	Year of Mfr
Radio	Sony	ICF-25	0.9	0.9	1998
Radio	Sony	ICF-C233	1.0	1.1	1998
Radio	Sony	ICF-C370	1.1	1.1	1998
Radio	Sony	ICF-C122	1.2	1.3	1998
Radio	Radio Shack	12-1613	1.1	1.5	1998
Radio	Craig		1.2	1.5	
Radio	GPX	D501D	1.3	1.5	1998
Radio	Radio Shack	12-1619	1.3	1.6	1998
Radio	GE	7-4915A	1.5	1.6	1998
Radio	Sony	ICF-C620	1.5	1.6	1998
Radio	Sony	ICF-C740	1.6	1.6	1998
Radio	Radio Shack	12-1589	1.4	1.7	1998
Radio	Radio Shack	12-1617	1.5	1.7	1998
Radio	Magnavox	AJ 3440	1.7	1.8	1998
Radio	Lloyd’s	J202B	1.4	1.9	1997
Radio	Radio Shack	12-1605	1.6	1.9	1998
Radio	Radio Shack	15-1590	1.6	2.0	1998
Radio	Radio Shack	12-1608	1.7	2.0	1998
Radio	Magnavox	AJ3840	1.8	2.0	1998
Radio	Zenith	ZG320M	1.6	2.2	1998
Radio	Soundesign	75251V	1.7	2.2	1998
Radio	GPX	D519	1.9	2.2	1998
Radio	Sonic	CR1008	2.0	2.2	1996
Radio	Aiwa	FR A37	2.0	2.2	1998
Radio	Timex	TX220B	2.0	2.2	1998
Radio	Radio Shack	12-1612	2.0	2.3	1998
Radio	Zenith	Z222W	1.6	2.5	1998
Radio	Radio Shack	12-1610	1.8	2.7	1998
Radio	Soundesign	3818W	2.1	2.7	1998
Radio	Radio Shack	12-1614	2.6	2.8	1998
Radio	Zenith	ZG120M	1.9	3.0	1998
Radio	Radio Shack	12-1593	2.7	3.2	1998
Radio	GE	7-4852A	3.2	3.9	1998

Table E-2. Power Measurements of Portable Stereos

Type	Brand	Model	Standby	Tape-Idle	CD-Idle	Tuner-Play	Tape-Play	CD-Play	Year of Mfr
Portable	Sony	CFM10	0.5	0.5		1.7	2.3		1999
Portable	Sony	CFS1055	0.9	1.9		2.3	3		1999
Portable	Magnavox	AZ1110	1.5	1.5	3.4	2.5	3.3	4.8	1999
Portable	Magnavox	AZ10002	1.4	1.4	3.9	2.6	3.3	5.5	1999
Portable	Magnavox	AZ100017	1.4	1.4	1.4	2.8	3.4	5.8	1998
Portable	Aiwa	CSDEX111	1.3	1.3	4	2.7	2.9	6.5	1999
Portable	Sanyo	MCDS736	1.8	2.7	4.7	3.6	4	7.2	1999
Portable	Aiwa	CSDED70U	1.3	1.3	1.3	3.5	3.6	8.0	1997
Portable	Magnavox	AZ2407	1.4	4.4	5.1	4.7	5.6	6.4	1999
Portable	Magnavox	AZ1518	2	4.4	4.4	4.9	5.6	6.8	1999
Portable	Aiwa	CSDED87	1.3	1.3	5.7	3.9	4.3	8.1	1999
Portable	Sony	CFDZW750	1.5	4.1	5	4.3	5.4	7.4	1999
Portable	Magnavox	AZ2805	2.2	4.5	4.5	5	6.5	6.9	1999
Portable	Aiwa	CADW235	1.5	1.5	6.7	4.1	5	9.5	1999
Portable	JVC	PCX550	2	4.5	4.5	5.1	6	9	1999
Portable	JVC	PCX202	2.4	5.2	5.2	6.5	6.7	9.3	1999
Portable	JVC	RCQC7	2.7	4.7	6.7	5.5	7.5	9	1999
Portable	Aiwa	CADW630	2.3	6.6	8.2	7.6	7.9	11.9	1999
Portable	Sony	CFD577	1.7	7.8	8.6	8	9.4	11.5	1999
Portable	Sony	CFD646	5.5	8.8	10.5	9.2	10.3	12.5	1999
Portable	Sony	CFDZW165	2.7	8.9	9.4	9.1	10.6	12.6	1999
Portable	JVC	RVB99BK	1.1	10	11.8	10.8	12.3	13	1999

Table E-3. Power Measurements of Compact Stereos

Type	Brand	Model	Standby	Tape-Idle	CD-Idle	Tuner-Play	Tape-Play	CD-Play	Year of Mfr
Compact	Panasonic	RAK-RX309	3.1	6.7		7.3	8.6	11.6	
Compact	Sharp	CD-C200	8.5	9.0			10.5	12.5	1998
Compact	Aiwa	XRM33	6.8	8.1	10.6	9.5	10.1	14.3	1999
Compact	Sharp	CDC1800	9.9	11.2	11.5	11.2	12.8	15.8	1999
Compact	Aiwa	CXNA115	8.9	11.6	14.8	13.5	14.5	20.0	1999
Compact	JVC	MXD302T	6.9	14.4	14.6	15.3	17.9	19.5	1999
Compact	Denon	DC35	9.3	15.8	16.3	17.0	18.2	20.0	1999
Compact	Denon	DC35	9.5	15.8	16.5	16.5	18.6	20.5	1999
Compact	Aiwa	CX-LM10U	9.2			16.4	18.2	22.8	1998
Compact	Panasonic	SAPM15	5.7	19.2	21.4	20.1	20.8	23.5	1999
Compact	Sony	MHCRXD3	17.2	18.5	20.8	18.9	21.7	24.9	1999
Compact	Sony	LBTD390	13.3	21.6	23.0	21.8	24.1	25.7	1999
Compact	Aiwa	CXNA555	1.3	18.9	21.3	24.3	25.2	25.6	1999
Compact	Sony	MHCRX66	14.0	22.0	22.4	23.2	25.0	25.8	1999
Compact	JVC	MXJ50	13.1	23.6	24.2	25.2	26.5	28.2	1999
Compact	Panasonic	SAAK27	0.5	30.9	31.8	31.3	32.8	33.7	1999
Compact	Aiwa	CXNA888	27.5	31.7	31.2	32.3	34.4	37.5	1999
Compact	Pioneer	XRP970F	12.0	37.2	38.8	40	41.4	38.1	1999
Compact	Panasonic	SU-CH92	8.8	38.0		36.0	41.0	40.0	1995

Table E-4. Power Measurements of Receivers

Type	Brand	Model	Standby	Line-Idle	Tuner-Play	Year of Mfr
Receiver	Sherwood	RX1010	0.0	13.0		
Receiver	Yamaha	RXV496	0.7	15.9		1999
Receiver	Sherwood	RX2030R	1.1	17.7		
Receiver	Pioneer	SX-255R	2.3	21.5		1998
Receiver	Sherwood	RX4030R	1.1	21.7		1997
Receiver	Yamaha	RXV293	0.7	22.1		1999
Receiver	Rotel	RX-950AX	1.0	22.6		
Receiver	Onkyo	TX8511	1.7	23.0		1997
Receiver	Rotel	RX-950AX	2.4	23.5		1998
Receiver	Sony	STR-DE315	1.7	23.9		1998
Receiver	Kenwood	KEN 105VR	1.0	25.0		1997
Receiver	Kenwood	104AR	1.1	26.0		1997
Receiver	Yamaha	R-V902	0.8	26.1		1998
Receiver	JVC	RX-552V	1.1	26.3		1998
Receiver	Yamaha	R-V502	0.9	26.5		1998
Receiver	Sony	STR-DE415	1.9	26.8		1998
Receiver	Sony	STR-DE415	1.8	27.0		1998
Receiver	JVC	RX-517V	0.9	28.0		1998
Receiver	Sony	STR-DE505	1.8	29.0		1998
Receiver	Pioneer	VSX-305	2.2	29.0		1998
Receiver	Yamaha	RV-702	1.0	30.0		1998
Receiver	JVC	RX-662V	0.8	30.0		1998
Receiver	Marantz		0.0	30.0	32.0	1983
Receiver	Yamaha	RXV495	1.0	30.9		1999
Receiver	Kenwood	VR205	1.2	31.2		1999
Receiver	Technics	SA-EX310	0.9	32.8		1998
Receiver	Sony	STR-DE515	1.7	33.6		1998
Receiver	Kenwood	KR897	1.1	34.0		1998
Receiver	Sony	STR-DE515	2.0	36.1		1998
Receiver	Sony	STR-DE715	3.1	36.3		1998
Receiver	Optimus	STAV3770	1.6	36.8		1998
Receiver	Pioneer	VSX-605S	2.8	38.0	44.7	1998
Receiver	Sony	STRDE525	1.6	38.4		1999
Receiver	Kenwood	VR357	1.1	38.4		1999
Receiver	Kenwood	106VR	1.2	38.5		1998
Receiver	Sony	STRDE605	2.6	38.5		1997
Receiver	Kenwood	VR305	1.1	40.0		1999
Receiver	Marantz	SR680	5.9	41.0		1998
Receiver	Harmon Kardon	AVR 55	0.0	45.1	46.2	1998
Receiver	Harman/Kardon	AVR-25II	1.8	47.0		1997
Receiver	Sony	STRDE805G	4.6	47.0		1997
Receiver	Sunsui	9090DB	0.0	47.0	48.0	1998
Receiver	Harman Kardon	BK3500	15.4	48.0		
Receiver	Harman Kardon	AVR20MKII	1.8	50.0		1998
Receiver	Sony	STR-DE915	2.9	55.4		1998
Receiver	Kenwood	KRV990D	0.0	73.6		1997

Table E-5. Power Measurements of Amplifiers

Type	Brand	Model	Standby	Tape-Idle	Year of Mfr
Amplifier	Rotel	RA-931	0.0	7.5	1998
Amplifier	Sansui	B3000	0.0	19.0	1990
Amplifier	Sony	TA-AV571	1.4	23.0	1998
Amplifier	Yamaha	RX500U	0.0	28.0	1996
Amplifier	Onkyo	ASV210	1.3	29.0	1997
Amplifier	Fisher	CA271	0.0	30.2	1988
Amplifier	NAD	2400	0.0	30.5	1998
Amplifier	Onkyo	ASV240	1.3	33.0	1998
Amplifier	Fisher	CA-9535	1.2	34.0	1997
Amplifier	Kenwood	KM-897	5.5	34.0	1998
Amplifier	Rotel	RA-970BX	0.0	35.0	1998
Amplifier	Kenwood	KA-896	1.4	38.8	1997
Amplifier	Sony	TA-AV561	1.7	44.7	1997

Table E-6. Power Measurements of Rack Audio Systems

Type	Brand	Model	Standby	Tape-Idle	Tuner-Play	Year of Mfr
Rack	Pioneer	RX521	1.1	24.0	25.8	1993
Rack	Sony	R-5700-W	1.4	33.0		1998
Rack	Onkyo		1.3	42.7		1997
Rack	Fisher	TAD-9725	3.0	44.0		1998
Rack	Pioneer	D4310K	15.1	47.0		1998
Rack	Onkyo	AVF3141	1.3	51.0		1998
Rack	Kenwood		1.4	52.6		1997
Rack	Fisher		1.2	57.6		1997
Rack	Sony		4.6	60.3		1997
Rack	Sony		1.7	62.0		1997
Rack	Kenwood	SPEC860AV	1.1	69.0		1998

Table E-7. Power Measurements of Tuners

Type	Brand	Model	Standby	Tuner-Play	Year of Mfr
Tuner	Technics	STK50	2.1	4.4	
Tuner	Sony	ST-JX661	3.4	4.4	1998
Tuner	Kenwood	KT5300	0.0	4.5	1980
Tuner	Kenwood	KT57	2.9	4.8	
Tuner	Sony	ST-JX661	3.8	4.8	1997
Tuner	Fisher	FM-9535	1.5	4.9	1997
Tuner	Marantz	TR2242	0.9	5.4	
Tuner	Rotel	RT-935AX	0.0	5.7	1998
Tuner	Rotel	RT-940AX	3.6	5.9	1998
Tuner	Fisher	FM271	0.0	6.0	
Tuner	Onkyo	T4040	0.0	6.6	1998
Tuner	Kenwood	KT-596	4.0	7.1	1997
Tuner	Onkyo	T-4010	0.0	7.2	1997
Tuner	Denon	TU-660	0.0	8.5	
Tuner	Pioneer	TX608	1.6	11.4	1980
Tuner	Kenwood	KT6007	0.0	16.5	1980
Tuner	Sherwood	RX2030R	1.0	17.6	1998

Table E-8. Power Measurements of Tape Players

Type	Brand	Model	Standby	Tape-Idle	Tape-Play	Year of Mfr
Tape	Rotel	RD845	0.0	2.8	4.1	1995
Tape	JVC	TDW11	0.8	2.9	5.0	
Tape	Kenwood	CT201	1.3	3.9	5.1	1999
Tape	Yamaha	KXW321	4.1	5.2	7.1	1999
Tape	Denon	DRW585	3.8	5.9	7.5	1999
Tape	Sony	TCWE305	2.2	4.6	8.5	1999
Tape	Denon	DRM740	0.0	6.9	9.4	1999
Tape	Kenwood	KX66W	1.9	9.5	10.0	1989
Tape	Denon	TRM740	0.0	7.6	10.1	1999
Tape	Nakamichi	RX202	0.0	8.5	10.3	
Tape	Kenwood	CT203	0.0	8.5	11	1999
Tape	Sony	TCWE625	2.4	7.4	12	1999
Tape	JVC	TDW354	4.3	9.7	12.2	1999
Tape	Sony	TCKA1ES	2.1	8.1	12.4	1999

Table E-9. Power Measurements of CD Players

Type	Brand	Model	Standby	CD-Idle	CD-Play	Year of Mfr
CD	Philips	CDC751	0.0	5.2	6.6	
CD	JVC	XLF254	3.2	5.2	6.8	1999
CD	Yamaha	CDC565	0.0	5.7	7.2	1999
CD	Pioneer	PDF100	4.4	6.4	7.3	1994
CD	Kenwood	DP560	0.0	6.3	8.4	1987
CD	Denon	DCM260	6.1	6.7	9.1	1998
CD	Sony	CDPCX681	4.1	7.1	9.5	1997
CD	Denon	DCM560	2.3	6.9	9.6	1999
CD	Denon	DCD425	1.4	6.9	9.8	1999
CD	Carver	MV5	0.0	6.7	9.9	
CD	Sony		1.8	7.4	10.0	1996
CD	Sony	XA20ES	0.0	10.8	13.1	1999
CD	Toshiba	XRZ50X	0.0	12.7	13.6	
CD	Harman Kardon	FL8300	3.8	11.9	14.7	1997
CD	Mission	DAD7000	0.0	18.5	18.8	

Appendix F. Comparison of this Study to Previous Studies

Two studies, the results of which are discussed briefly in Section 6.2, provided estimates of audio energy consumption. This section compares the data and methods used in these studies to the data and methods used in this study.

Clock Radios

Before this study, Sanchez et al. [17] investigated the energy use of "Home radio, small/clocks." The report does not say what devices are included in this category. Stock was taken from historical shipments of "home radios," which according to the original source includes table, clock, and portable radios [27], but average power estimates were derived from power measurements of clock radios only [18].

The number of clock radios in the U.S. was estimated using shipment data and an average lifetime of 5 years. Our estimate of clock radio stock is about 25% higher. We explain this by noting that Sanchez used Appliance Magazine's *low* estimate for average lifetime of radios.[9] Using similar methods and Appliance Magazine's *average* lifetime estimate of 8 years, we estimate about 140 million units (Figure B-2). Since not all radios have clocks, it is logical that our estimate of clock radio stock is lower than this value.

Portable Stereos

Due mainly to differences in usage values, our UEC estimate for portable stereos is slightly lower than that of Sanchez et al. We assumed that some portion of portable stereos are not always connected to the mains, while Sanchez et al. assumed that all portable stereos are connected to the mains at all times. We were unable to confirm Appliance Magazine as the source of shipment data for portable stereos.

Compact Stereos

Both Sanchez et al. and Zogg et al. [19] covered compact stereos in their reports. Their results are nearly identical because Zogg et al. cites Sanchez et al. or uses the same data sources for all input data. Note that Zogg's results are slightly higher because the authors estimated an increase of stock between 1995 and 1997.

To estimate stock, Sanchez uses shipment data and estimates a lifetime of 15 years. We think that this is high, which in turn causes the estimated stock to be too high. Appliance Magazine estimates that the average lifetime of a compact stereo is 9 years. This value and shipment data results in an estimated stock of about 44 million units, which is much closer to our estimate of 46 million.

[9] Appliance Magazine publishes low, average, and high estimates of average lifetime.

Component Stereos

In this study, we estimated energy consumption of all component stereo systems. Sanchez et al. and Zogg et al., on the other hand, present energy consumption estimates for what are called “rack” audio systems. In this study, we define rack audio systems as component stereo systems that are sold as a unit. This definition is consistent with the definition used by CEMA. In our study, rack audio systems constitute only ten percent of all component stereo systems. Sanchez et al. and Zogg et al. do not define rack audio systems. At first it appeared that the definitions did not agree, since our estimate of the number of rack audio systems in the U.S. was tiny compared to the estimates of Sanchez et al. and Zogg et al. We investigated this discrepancy and found that Appliance Magazine reported a penetration of 55% for rack audio systems in 1996. They also reported a penetration of 70% for compact audio systems in the same year [24]. The following year, however, they reported a penetration of only 36% for both compact and rack audio systems *combined* [5].

Based on this evidence, we suspect that the 55% penetration mistakenly reported by Appliance Magazine as rack audio systems was actually the penetration of component systems reported by CEMA for that year [26]. Thus, the Sanchez et al. and Zogg et al. stock estimates did, in fact, represent all component stereo systems. Unfortunately, power estimates for both reports were derived from a sample of rack audio systems only; therefore, power measurements exclude component systems that were not sold as a unit. Since we estimate that rack audio systems make up only about 10% of all component systems, this is a significant omission.

In addition, Sanchez et al. did not take into account the fact that Appliance Magazine reports penetration levels, not saturation levels, thereby assuming that all homes having a component stereo have only one. Assuming that the number of “rack” audio systems reported in Sanchez et al. actually represents the number of component audio systems, we believe that this estimate is too low.

Average usage values for rack audio systems were estimated by Sanchez as one hour per day. There is no distinction between radio and recorded music usage, and usage of stereo systems for TV sound is not considered. In addition, idle modes were omitted from the study. Both Sanchez et al. and Zogg et al. used power estimates reported in Huber [18]. The difference between the UEC values published in these two reports is a result of an inconsistency in the original source: Huber reports an average standby power of 5.8 watts on page 11, and 7.0 watts on page A-5. Zogg et al. used the former value, and Sanchez et al. the latter. The discrepancy in Huber most likely occurred as a result of averaging over a different number of power measurements, but it is unknown which of the two values represents a larger number of units.

Because Sanchez et al. and Zogg et al. underestimated stock and usage, and omitted idle modes, we believe that these studies also underestimated the energy use of component audio systems.