To appear in the Proceedings *of The Second International Conference on Energy Efficiency in Household Appliances*, Naples (Italy), September 2000. *Also published as* LBNL-46212.

ENERGY USE OF U.S. CONSUMER ELECTRONICS AT THE END OF THE 20TH CENTURY

Karen Rosen, Lawrence Berkeley National Laboratory
Alan Meier, Lawrence Berkeley National Laboratory
June 2000

ABSTRACT

The major consumer electronics in U.S. homes accounted for over 10% of U.S. residential electricity consumption in 1999, which is comparable to the electricity consumed by refrigerators or lighting. We attribute 3.6% to video products, 3.3% to home office equipment, and 1.8% to audio products. Televisions use more energy than any other single product category, but computer energy use now ranks second and is likely to continue growing. In all, consumer electronics consumed 110 TWh in the U.S. in 1999, over 60% of which was consumed while the products were not in use.

INTRODUCTION

Until recently, energy analysts have dismissed the electricity use of consumer electronics as an insignificant portion of U.S. residential energy use (Meier et al. 1992). This view has changed as the stock of these products increased, and as research revealed higher than expected energy consumption levels for many of these devices. Recent U.S. research has focused on the electricity use of specific consumer electronics products (Rosen & Meier 1999a; Rosen & Meier 1999b; Rosen et al. 2000). Studies in Europe (Siderius 1995; Meyer & Schaltegger AG 1999; Sidler 2000), Australia (Harrington 2000), New Zealand (EECA 1999) and Japan (Nakagami et al. 1997) have produced similar results. To date, however, there have been no comprehensive estimates for the energy use of the entire category of consumer home electronics – that is, video, audio, telephone, and computer-related products.

We report here a preliminary estimate of total electricity consumption for the U.S. consumer electronics end use in 1999. Products included in this study are listed in Table 1.

Table 1. Consumer Electronic Products Included in this Study

Video	Audio	Set-top Boxes	Telephony	Office
Analog TV	Component stereo	Analog cable	Answering Device	Computer
Digital TV	Compact stereo	Digital cable	Cordless phone	Printer
VCR	Portable stereo	Digital satellite	Cordless/Ans. Dev.	Fax/Copier
DVD player	Clock radio	Game console	Cell phone charger	Peripherals

NOTES: TV = television; VCR = videocassette recorder; DVD = digital versatile disc. 'Analog TV' includes TV/VCR combos. 'Computer' includes monitors.

DATA GATHERING APPROACH

The ideal approach to estimating energy use would employ a long-term appliance-monitoring program involving a statistically representative group of homes. Findings of this program

could then be extrapolated to the whole country. Studies in France (Sidler 2000) and New Zealand (EECA 1999) have used this approach; however, this approach is both expensive and time consuming. Instead, we resorted to a bottom-up approach combining direct measurements of individual devices and survey data. The approach consists of four major steps for each device:

1. Determine the principal operating modes
2. Estimate the time spent in each mode
3. Measure the power use of actual products in each mode
4. Estimate the number of units of that product in U.S. homes

These steps are briefly described below. Details of the methodology can be found elsewhere (Rosen & Meier 1999a; Rosen & Meier 1999b; Rosen et al. 2000).

Power Modes

Many consumer electronics operate in different modes (or states) during normal usage. Typical TVs have just two modes, but an audio or computer system may have a dozen. An accurate estimate of energy consumption requires an estimate of the energy use for each mode. This entails identifying common modes, then estimating average power levels and usage for each.

This study covers a wide variety of product types, so we adopted a much cruder classification of modes than would be appropriate for a single appliance. This simple classification is consistent with the quality of the other data used in this study. The operating modes assumed for this report are listed in Table 2.

Table 2. Common Consumer Electronic Modes

Mode	Description
Active	The unit is performing a requested service, e.g. record, play, talk, etc.
Charge	The battery charger provides current to the battery
Idle	The unit is on but not Active. This includes computer Sleep modes.
Standby	The unit is plugged in and appears off to the user
Disconnected	The unit is unplugged

Note that Idle may occur (1) after the user switches the unit on but before requesting a service, or (2) after the service ends (e.g. end of tape or automatic “Sleep” modes) but before the user switches the unit off. Some consumers never switch off units with idle modes.

Time Spent in Each Mode

Of the three types of data needed for a bottom-up estimate of energy consumption, the usage profile is usually the most difficult to acquire. Conventional surveys are not helpful in estimating usage patterns for the Standby and Idle modes, which are critical for accurate estimates of unit energy use. Office equipment is particularly complicated because there are so many Standby and Idle modes and such a great range in the power consumption of the different modes.

Estimating usage patterns for this investigation involved a variety of data sources and usage assumptions that varied from product to product. In general, Active usage values were based on consumer surveys, while the remaining values were estimated from anecdotal data or best guesses.

Power Measurements

We compiled measurements of appliance power consumption from many sources, including stores, homes, and repair shops. Most measurements were performed by LBNL staff using the following procedure:

1. Identify the operational modes to measure
2. Plug the power cord of the unit into the power meter
3. Record the Standby power draw before switching the unit on
4. Record the power draw, in watts, of the unit in all other modes studied
5. Switch the unit off, and confirm the Standby mode power consumption

We used a true RMS wattmeter that was custom-built for measuring low power levels with high resolution (0.1W) and accuracy (±0.5%+0.1W). This meter displays average power every second. Where readings fluctuated, we visually estimated the average power draw based on the readings. Readings typically fluctuate only one or two tenths of a watt.

Number of Units in U.S. Homes

We employed two methods in estimating the number of units in U.S. stock; one used ownership surveys and the other recent sales data. In most cases, the two methods resulted in similar stock estimates. Where results differed significantly, we chose the estimate that seemed more probable.

Energy Consumption

To calculate the average unit energy consumption (UEC) for each product type, we weighted the arithmetic mean of the measured power levels to reflect the average usage profile, and then multiplied by the number of hours per year. National energy consumption values were calculated as the product of UEC and the number of units nationwide.

RESULTS: NATIONAL ENERGY USE OF CONSUMER ELECTRONICS

Using the methods described in the previous section, we collected over one thousand product measurements. Table 3 shows the average measured power levels in watts (W), estimated usage patterns, and average annual UEC values.

Table 3. Usage, Power, and Unit Energy Consumption of Consumer Electronics

Product	Units Measured	Standby		Idle		Charge		Active		UEC
		W	Time	W	Time	W	Time	W	Time	kWh/yr
Analog TV	372	4.6	84%					75	16%	140
Digital TV	14	8.8	84%					177	16%	320
VCR	126	5.9	77%	13	24%			17	4%	74
DVD	18	4.1	72%	15	24%			17	4%	64
Component Stereo	119[b]	3.0	65%	43	16%			44	19%	150
Compact Stereo	19	9.8	72%	20	18%			22	10%	110
Portable Stereo	22	1.8	51%	4.9	13%			6.1	6%	17
Clock Radio	33	1.7	99%					2.0	2%	15
Analog Cable Box	42	11	78%					12	22%	95
Digital Cable Box	5	23	78%					23	22%	200
Satellite Receiver	31	16	78%					17	22%	150
Game Console	12	1.1	78%					7.9	22%	23
Answering Device	27	3.2	99%					3.6	1%	28
Cordless Phone	30	2.6	35%			3.6	60%	3.1	5%	28
Cordless/Ans. Dev.	23	1.1	35%			3.7	60%	3.1	5%	24
Cell Phone Charger	7	1.0	75%			5.0	5%			9
Computers	13	2.2	35%	80	50%			125	5%	410
Printers	4	3.6	39%	12.1	50%			361	1%	100
Fax/Copiers	5	4.0	0%	30	99%			100	1%	270
Peripherals	20	--	--	--	--			--	--	--

NOTE: Peripherals include a variety of products, so average values are not appropriate.

Estimates sensitive to our assumptions are discussed below. Estimates of stock and national energy consumption, by mode and total, are given in Table 4.

Table 4. Number of Units and National Energy Consumption of Consumer Electronics

Product	Units in 1999	Standby Energy	Idle Energy	Charge Energy	Active Energy	Total Product Energy Use	Share of U.S. Residential Electricity Use in 1999
	M	TWh/yr	TWh/yr	TWh/yr	TWh/yr	TWh/yr	%
Analog TV	220	7.3			23.5	30.8	2.7%
Digital TV	1	0.1			0.3	0.3	0.0%
VCR	130	5.2	3.7		0.7	9.6	0.9%
DVD	3	0.1	0.1		0.0	0.2	0.0%
Component Stereo	75	1.3	4.6		5.5	11.4	1.0%
Compact Stereo	50	3.1	1.6		0.9	5.6	0.5%
Portable Stereo	70	0.6	0.4		0.2	1.2	0.1%
Clock Radio	130	1.9			0.0	1.9	0.2%
Analog Cable Box	40	2.9			0.9	3.8	0.3%
Digital Cable Box	3	0.5			0.1	0.6	0.1%
Satellite Box	13	1.5			0.4	2.0	0.2%
Game Console	54	0.4	0.0		0.8	1.2	0.1%
Answering Device	77	2.1			0.0	2.1	0.2%
Cordless Phone	87	0.7		1.6	0.1	2.5	0.2%
Cordless/Ans.Dev.	35	0.1		0.7	0.0	0.8	0.1%
Cell Phone	70	0.5		0.2	0.0	0.6	0.1%
Computers	61	0.4	21.2		3.3	24.9	2.2%
Printers	74	0.9	3.9		2.3	7.2	0.6%
Fax/Copiers	10	0.0	2.7		0.1	2.8	0.2%
Peripherals	186	1.9	0.7		0.5	3.2	0.3%
Total		**32**	**39**	**2.6**	**40**	**113**	**10%**

DISCUSSION

We briefly discuss the results below for each product and for the category as a whole. We also include discussions of confidence in our estimates.

Video Products

Televisions consume more energy than any other product in the consumer home electronics category. We are confident in the accuracy of this estimate, because it is based on over 300 measurements and extensive survey data. The digital TVs in our database draw twice the Active power of the analog sets because the average digital TV is about twice the size of the average analog TV. The apparent average Standby power of digital TVs may also be misleadingly high. Excluding three outliers, the average Standby power of the measured digital TVs was nearly two watts *lower* than that of analog sets measured.

VCRs and DVD players are nearly identical with respect to energy use of individual units, but because there are forty times more VCRs than DVDs in U.S. homes, overall energy consumption of VCRs is much higher. VCRs and DVDs spend 96% of time in Standby and Idle modes, where we estimate that 90% of energy use occurs. The distribution of usage within this 96% is the greatest source of uncertainty here, because surveys cannot easily collect this information.

Audio Products

Component stereos have the highest per-unit energy consumption in this product group, with compact stereos taking a close second. One source of uncertainty for the component stereo estimate is the extent to which they are connected to video systems. When connected, the components may be Active whenever the video system is Active. In homes where this occurs, Active energy use increases dramatically. Note also the large energy consumption that occurs in Standby/Idle modes for compact audio systems. Portable stereos and clock radios are among the lowest energy consumers in our study, with UEC values under 20 kWh/yr.

Set-Top Boxes

The power needs of cable and satellite boxes in Standby and Active modes are considerable – and nearly identical. As a result, the set-top boxes often consume more energy per year than the TVs they supplement. Digital cable boxes have particularly high UEC values. At 200 kWh/yr, these units use more than twice the energy of an analog box and 40% more energy than the average TV set.

We observed a wide range of cable and satellite set-top power requirements. Traditionally, service providers in the U.S. rent set-top boxes to customers. We measured set-top boxes from each of several service providers. Unfortunately, we could not determine which boxes were most frequently supplied to customers, so we can not be confident about the distribution of power needs in the set-top box stock. As a result, our estimates have a high degree of uncertainty. In any event, the market is changing so rapidly that greater certainty will be difficult to achieve.

Some of the newer set-top boxes not included in this study are remarkably power-hungry. For example, one new personal video recorder has no power switch and consumes 60 W at all times. Another new product, a combination high definition TV/satellite receiver box, used over 30 W in all modes. These devices contribute little to current U.S. residential electricity use because there are so few, but could have a noticeable effect over the next decade as they proliferate.

Telephony Products

Telephones, answering machines, and closely related devices use very little power – typically less than 5 watts regardless of the tasks they are performing. But because there are over 250 million in the U.S., total energy consumption adds up to 6 TWh/yr.

Office Equipment in the Home

Results for office equipment products are based on incomplete information. We are relatively confident in the Active values, but less confident about estimates for other modes because usage values were unavailable. As a result, we were forced to estimate usage for the Idle, Standby and Disconnected modes based solely on anecdotal evidence. We expect to improve our estimates in the near future, following further power measurement campaigns and usage surveys.

Computers (including monitors) were responsible for about 25 TWh in 1999, or a little over 2% of residential electricity use. Thus, the energy use of computers is now second only to TVs within the consumer home electronics category.

Printer energy use ranked second in the home office group at 7.2 TWh. We combined ink-jet and laser printers to form this group, but energy use for these two printer technologies differ markedly, with ink-jet printers using significantly less energy than laser printers.

Combination facsimile/copier machines accounted for less than 3 TWh in 1999. These products are becoming harder to distinguish because multi-function devices provide printing, copying, faxing, and scanning features. Future studies will probably combine all the paper-processing devices into one product group.

The average computer has three or four separate peripherals. Together, power speakers, scanners, network hubs, external disk drives, external modems and power strips consumed over 3 TWh of electricity in 1999. This estimate is probably low because we did not include all peripherals. For example, digital subscriber line (DSL) modems, which hardly existed when we began this study, have already achieved significant market penetration. We found one DSL modem setup, supplied by the local phone company, with a UEC of over 70 kWh/yr.

Total Electricity Use

The national electricity use of each of these products is relatively small: no single product accounts for more than 3% of residential electricity consumption. Combined, however, electricity use of the twenty different product groups investigated here exceeds 10%. This equals the electricity used by lighting or refrigerators (Office of Building Technology 1999).

Televisions still consume more electricity (31 TWh/yr) than any other consumer electronics device, but computer energy use (25 TWh/yr) is close behind and increasing faster.

There is considerable uncertainty associated with the energy use of each product. The largest source of uncertainty is the time operated in the Standby and Idle modes. Nevertheless, actual energy consumption is likely to be higher than our estimate because several consumer electronic products were not included.

The data presented in this report comprise a preliminary estimate of the electricity use for each of twenty distinct consumer electronics products. In the future, however, it will be more

difficult to categorize these devices because the trend is towards combining the functions of several devices into a single product. For example, new set-top boxes incorporate features found in VCRs and personal computers. Components are often shared between video and audio applications. Telephone and fax services often rely on personal computers for all or part of their functionality. We believe future analyses will need to treat consumer home electronics in a more unified manner because it will be difficult, if not misleading, to estimate the energy use for individual products in this category.

CONCLUSIONS

We presented here preliminary estimates of electricity use by consumer electronics in the U.S. residential sector. Consumer electronics now account for at least 10% of residential electricity use. This is similar to the electricity consumed by all residential refrigerators or lighting. There is strong evidence (though not presented here) that energy consumption in nearly all home electronic product groups is still growing rapidly, especially in the home office product group.

This is the first time that energy consumption of home office equipment has been estimated in a procedure consistent with other consumer electronics devices. Its inclusion revealed that the national energy use of home computers is now second only to TVs. Energy use of computers could easily overtake televisions in the next decade, although the distinction may be completely blurred by then.

This study also reveals the complexities of estimating the energy use of devices with multiple operating modes. TVs represent an old-style appliance, where the majority of energy use occurs during the Active mode. Computer systems represent the new multi-mode device, which may have as many as a dozen significantly different power modes. While energy use estimates often include only Active modes, our study shows the importance of including the non-Active modes, which comprise nearly two-thirds of consumer electronics energy use.

In the future, many consumer electronics devices will be combined with others into a single product. We believe future analyses will need to treat consumer home electronics in a more unified manner because it will be difficult, if not misleading, to estimate the energy use for individual products.

ACKNOWLEDGEMENT

This work was supported by the Assistant Secretary for Energy Efficiency and Renewable Energy, Building Technologies, of the U.S. Department of Energy under Contract No. DE-AC03-76SF00098.

REFERENCES

EECA. 1999. Energy Use in New Zealand Households, Report on the Year Three Analysis for the Household Energy End Use Project (HEEP). Wellington (New Zealand): Energy Efficiency and Conservation Authority.

Harrington, Lloyd. 2000. Study of greenhouse gas emissions from the Australian residential building sector to 2010. Canberra: Prepared by Energy Efficiency Strategies, Inc.

Meier, Alan, Leo Rainer and Steve Greenberg 1992. “The Miscellaneous Electrical Energy Use in Homes.” *Energy - The International Journal* **17**(5): 509-518.

Meyer & Schaltegger AG. 1999. Bestimmung des Energieverbrauchs von Unterhaltungselectronikgeraeten, Buerogeraeten und Automaten in der Schweiz. St. Gallen (Switzerland): Meyer & Schaltegger AG.

Nakagami, Hidetoshi, A. Tanaka, Chiharu Murakoshi, et al. 1997. "Standby Electricity Consumption in Japanese Houses" In the *Proceedings of* First International Conference on Energy Efficiency in Household Appliances. Florence (Italy): Association of Italian Energy Economics.

Office of Building Technology. 1999. *BTS Core Data Book*. Washington, D.C.: U.S. Department of Energy.

Rosen, Karen and Alan Meier. 1999a. *Energy Use of Televisions and Videocassette Recorders in U.S. Homes*. LBNL-42393. Berkeley, California: Lawrence Berkeley National Laboratory.

Rosen, Karen and Alan Meier. 1999b. *Energy Use of Home Audio Products in the U.S. (Draft).* LBNL-43468. Berkeley: Lawrence Berkeley National Laboratory.

Rosen, Karen and Alan Meier. 2000. *Energy Use of Set-top Boxes and Telephony Products in the U.S.* LBNL-45305. Berkeley: Lawrence Berkeley National Laboratory.

Siderius, Hans-Paul. 1995. *Household Consumption of Electricity in the Netherlands*. Delft (Netherlands): Van Holsteijn en Kemna.

Sidler, Olivier. 2000. *Campagne de mesures sur le fonctionnement en veille des appareils domestiques*. Report No. 99.07.092. Sophia-Antipolis (France): ADEME.

Suggested Citation for this paper:

Rosen, Karen B. and Alan K. Meier. 2000. "Energy Use of U.S. Consumer Electronics at the End of the 20th Century". In the Proceedings of *The Second International Conference on Energy Efficiency in Household Appliances (27-29 September)*. Naples (Italy): Association of Italian Energy Economics (Rome).