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Power measurements and national energy consumption of televisions and videocassette recorders in the USA

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Abstract

The combined energy consumption of US televisions and videocassette recorders was about 40 TW h per year in 1998, corresponding to 3.6% of national residential electricity consumption. The average household television energy consumption was about 310 kW h per year, 23% of which was used while the units were not active. The average household videocassette recorder energy use was about 100 kW h per year, 95% of which was used while the units were not active.

1. Introduction

In an effort to better understand the elements of nationwide energy consumption, the US Department of Energy recently commissioned studies to improve its understanding of what they call the 'miscellaneous' end-use category. This category includes the electricity consumption of appliances that do not fit well into the original end-use categories of lighting, heating, air-conditioning, etc. The study described here was conducted to estimate the residential energy consumption of two of the largest residential electricity consumers in the miscellaneous end-use category: color televisions (TVs) and videocassette recorders (VCRs). A full report was prepared for the US Department of Energy in March of 1999 [1].

2. Data

The three factors used in our analysis of national TV and VCR energy consumption are (1) number of units in the USA, (2) typical usage patterns, and (3) average power levels. This section describes the data used in this study.

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2.1. Number of units

According to the 1997 *Residential Energy Consumption Survey* (RECS), there are 211.5 million color TVs and 128 million VCRs in US homes [2]. There are also 10.8 million TV/VCR combination units in the USA [1]. Since the RECS survey counted TV/VCR combination units as both TVs and VCRs [3], we assume that 10.8 million units in each category are TV/VCR combination units.

2.2. Usage patterns

We calculated household TV usage as the sum of three different activities: watching broadcast television, watching videocassettes, and playing video games. Active power use for VCRs includes both play and record modes. Usage patterns for TVs and VCRs based on the *1998 Report on Television* [4] and *TV Dimensions 1998* [5] are summarized in Table 1.

2.3. Power measurements

Almost all appliances have more than one operating mode. To estimate energy use of an appliance from power levels and usage patterns, power requirements for each mode must be determined. Televisions sold in the USA generally have two modes: standby and active. VCR modes include standby, idle (on, but not active) and several active modes, such as play, record, fast-forward, rewind, pause, etc. Of the many VCR modes that could be considered active modes, this study includes only play and record modes. For this report, we will address the time spent in and power consumed during the active and standby modes of both appliances, and the idle mode of VCRs.

We contracted with two repair shops to measure and record the power draw levels of TVs and VCRs after repair. This enabled us to obtain a large number of reliable measurements very quickly and conveniently. Shops were given data log sheets and true RMS watt meters capable of measur-

Table 1
Contributions of TV, VCR and video game use to average household TV usage

	Homes with appliance (millions)	Average usage per home with appliance (h/day/home)	US total usage (million h/day)	Average usage per TV-home (h/day/TV-home)
Television (single set)	32.3[a]	7.1	228	7.1
Television (multiple sets)	67.9[a]	7.9	536	7.9
VCR	88.9[a]	0.57	51	0.51
Video game	33.3[b]	0.46	15	0.15
Total single set home	[Television (single set)+VCR+video game]			7.7
Total multiple set home	[Television (multiple sets)+VCR+video game]			8.6
US total			*830*	*8.3*

[a] USEIA [2].
[b] Media Dynamics, Inc. [5].

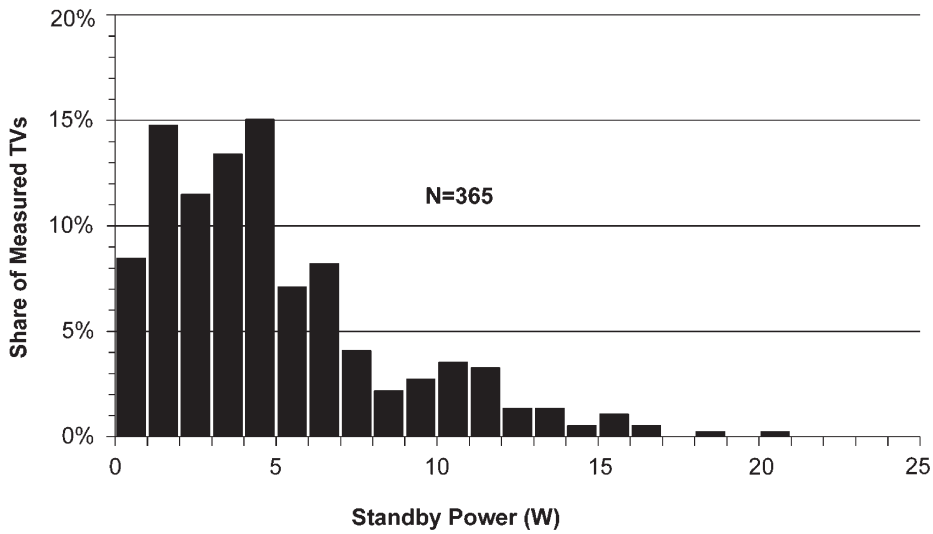

Fig. 1. Distribution of active power measurements for TVs.

ing power to the nearest one-tenth of a Watt. We provided technicians with instructions for measuring power draw in the standby and active modes of TVs, and the standby and idle modes of VCRs. For practical reasons, VCR active power was not measured at the repair shops. Instead, the average active VCR power level was derived from measurements taken separately by Lawrence Berkeley National Laboratory (LBNL).

To offset a lack of newer units measured at the repair shops, we supplemented the data set with measurements of 51 new TVs and 20 new VCRs taken at retail shops. Figs. 1 and 2 show the

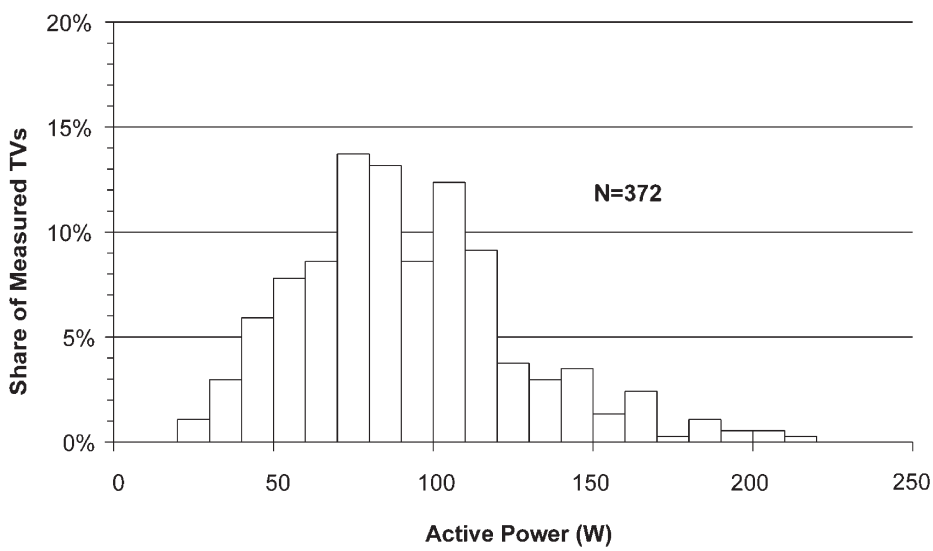

Fig. 2. Distribution of standby power measurements for TVs.

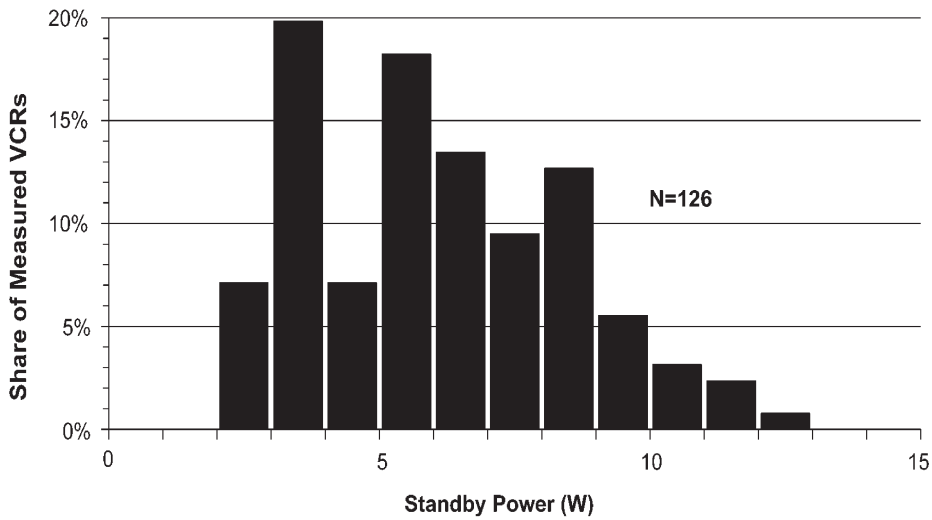

Fig. 3. Distribution of active power measurements for VCRs.

power measurement distributions for the 372 TVs, and Figs. 3 and 4 show the power measurement distributions for the 126 VCRs measured for this study.

It is interesting to observe the 20 W range in TV standby power use, especially since different TVs provided identical services in standby mode. Much of this variation can be attributed to differences in the efficiencies of the power supplies.

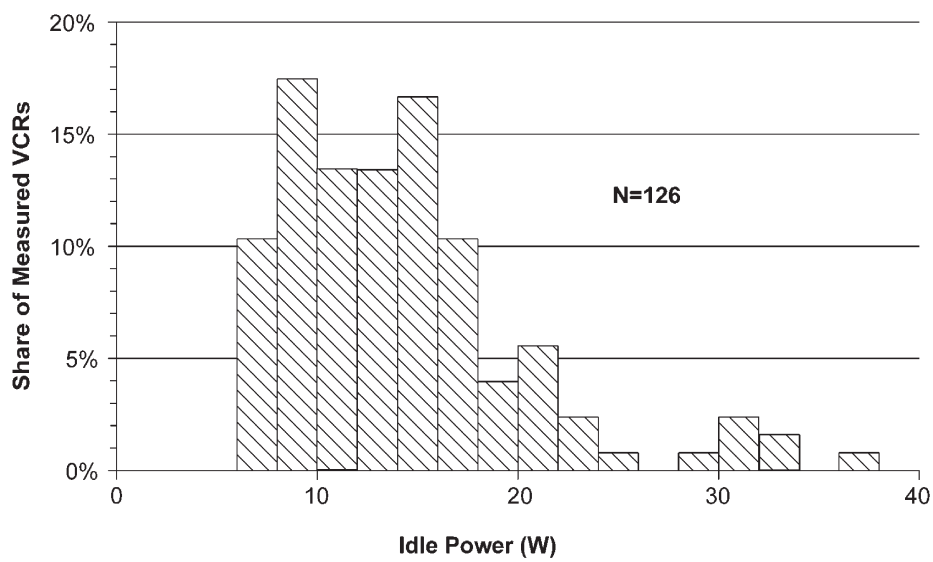

Fig. 4. Distribution of standby power measurements for VCRs.

3. Analysis

We used a bottom-up approach to estimate national TV and VCR energy use. We derived stock and usage patterns from surveys and obtained power measurements from repair and retail shops as described above. Since many homes have more than one unit, a range of usage patterns and power measurements were used to calculate average unit energy consumption (UEC) values of units used more or less often. These UEC values were then combined with stock estimates to estimate total US TV and VCR energy consumption.

We suspected that the samples of TVs and VCRs measured at repair shops were not representative of US stock. Before estimating TV and VCR energy use, we first determined whether the characteristics of age, manufacturer or screen size influenced TV or VCR power levels. For those characteristics that did influence power levels, we compared our data distributions with industry-published distributions. For those characteristics that were not representative of US stock, we used these industry-published distributions to weight average unit power levels.

Since most homes have more than one TV and many have more than one VCR, we accounted for differences in power requirements and usage patterns between the units in a home. First, we divided all US TVs and VCRs into categories of the most used unit, the second most used unit, etc. Average annual unit energy consumption for each category was calculated as:

$$UEC_j = \sum_{i=1}^{M} P_i \cdot T_i, \tag{1}$$

where UEC_j is the average annual UEC of units with usage rank j, M is the number of modes, P_i is the average power draw in mode i, and T_i is the number of hours per year spent in mode i. For this study, we investigated two modes for TVs and three modes for VCRs; so for TVs, M=2, and for VCRs, M=3.

Average household energy consumption values for homes with N units (HEC_N) were then calculated as the sum of the N UEC values:

$$HEC_N = \sum_{j=1}^{N} UEC_j \tag{2}$$

and national energy consumption (E) was calculated as the weighted average of the HEC values:

$$E = \sum_{N=1}^{U} H_N \cdot HEC_N, \tag{3}$$

where U is the maximum number of units in a home, H_N is the number of homes in the USA with N units, and HEC_N is the average aggregate energy consumption for homes with N units. For this study, we consider homes with up to five TVs and up to three VCRs; so for TVs, U=5, and for VCRs, U=3.

3.1. TVs

To investigate the impact of screen size, age and manufacturer on TV power use, we performed an analysis of covariance on the TV power measurement database, with main effect ‘manufacturer’

and covariates 'screen size' and 'year of manufacture'. Not surprisingly, perhaps, the results implied that some manufacturers consistently make more efficient TVs than do other manufacturers, and that larger TVs use more power when they are active than do smaller TVs. We were surprised, on the other hand, to find that the results also implied that TV power levels have not changed significantly since 1985. Fig. 5 shows changes in average power levels of TVs through time.

Comparisons with industry-published distributions showed that the distributions of size and manufacturer in our database were not representative of US stock. Since TV power levels are influenced by both screen size and manufacturer, average power values were weighted to reflect the actual distributions. Thus, average TV power draw values ($\overline{P_{\mathrm{TV}}}$) were calculated as:

$$\overline{P_{\mathrm{TV}}} = \sum_{s=1}^{S} \sum_{m=1}^{M} f_s f_m \overline{P_{sm}}, \tag{4}$$

where S is the number of screen size categories, M is the number of manufacturers, f_s is the frequency of TVs with screen size s (based on industry data), f_m is the frequency of TVs made by manufacturer m (based on industry data), and $\overline{P_{sm}}$ is the mean power draw for all of the size s units shipped by manufacturer m (based on TV power measurements).

Two-thirds of US homes have more than one television set and nearly one-third have more than two [2], so we considered TV size distributions within homes and the relationship between screen size and viewing hours. First, we divided US TVs into five categories according to screen size. The distribution and average power levels for each of these categories are shown in Fig. 6.

Next, we separated US households into five categories: those with one, two, three, four and five TVs. We ranked units in each home category according to usage, such that TV1 was the most watched unit, TV2 the next most watched unit, etc. Because people prefer to watch larger TVs [6], we assumed higher active power levels for the TVs used more often. Numbers of TVs

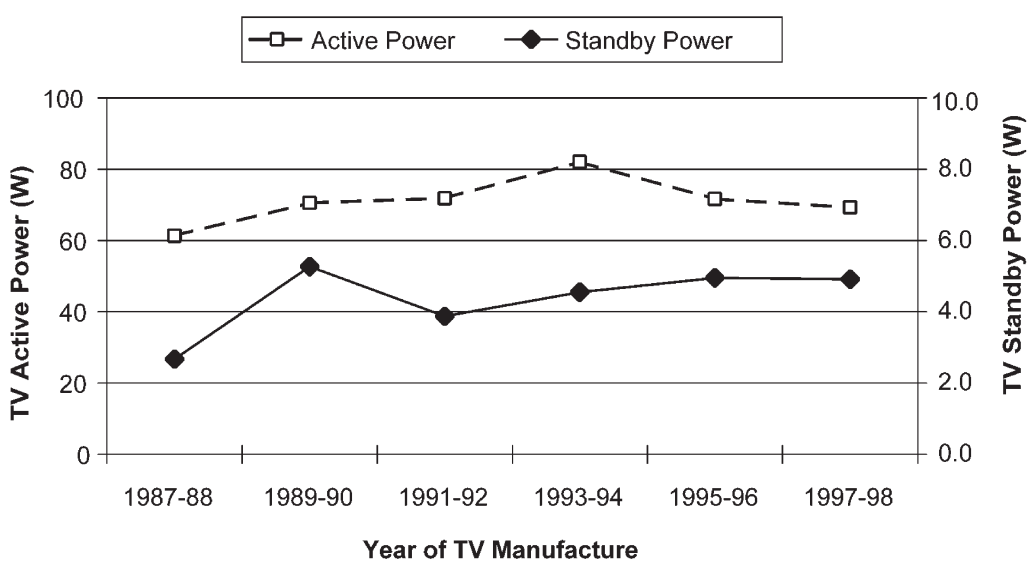

Fig. 5. Average power levels for TVs, 1987–1998.

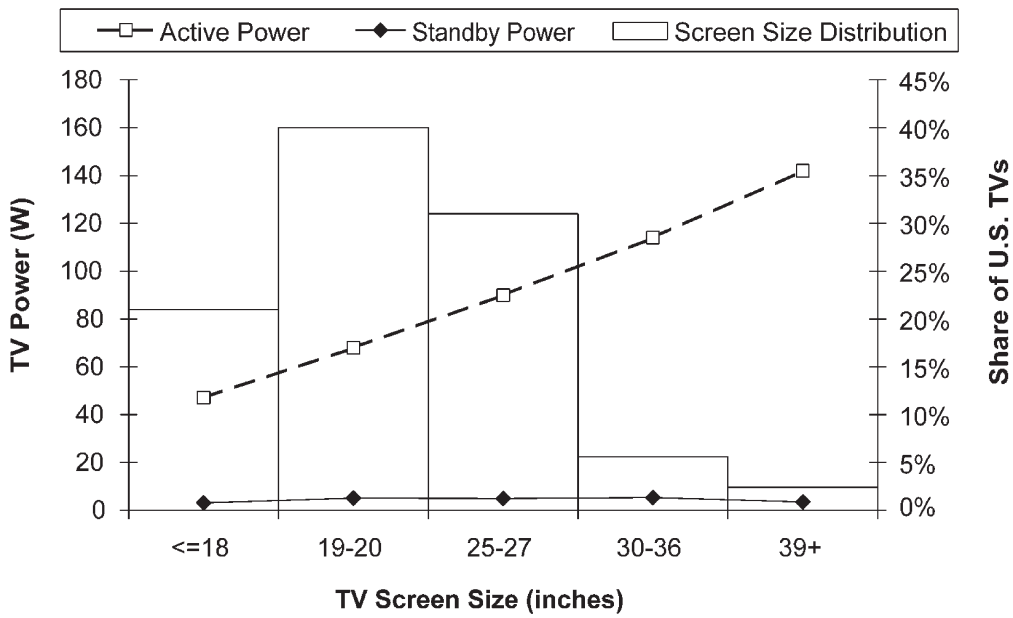

Fig. 6. TV screen size distribution and average power levels.

in each of the five TV categories and their corresponding average power levels are presented in Table 2.

Specific information about the percentage of time spent watching the different sized TVs was not available, so we were required to make some assumptions about usage. We allocated a percentage of total household usage (Table 1) to each TV in the home. TV usage estimates are given in Table 3.

3.2. VCRs

To investigate the influence of VCR age and manufacturer on power use, we performed an analysis of covariance on the VCR power measurement database, with main effect 'manufacturer'

Table 2
Number of TVs in US homes and power use assumptions

Usage rank[a]	Number of TVs [2] (millions)	Share of US TVs (%)	Average active power (W/unit)	Average standby power (W/unit)
TV1	100.2	47.4	83	4.7
TV2	67.9	32.1	71	4.8
TV3	30.0	14.2	61	3.8
TV4	10.6	5.0	61	3.8
TV5	2.8	1.3	61	3.8
Total/*Average*	211.5	100	*75*	*4.5*

[a] TV1 is the most used TV, TV2 the second most used TV, etc.

Table 3
Average TV usage

	Active (h/day)	Standby (h/day)	Total (h/day)
1-TV home total	*7.7*	*16.3*	*24*
TV1	7.7	16.3	24
2-TV home total	*8.6*	*39.4*	*48*
TV1	5.4	18.6	24
TV2	3.2	20.8	24
3-TV home total	*8.6*	*63.4*	*72*
TV1	4.6	19.4	24
TV2	2.5	21.5	24
TV3	1.4	22.6	24
4-TV home total	*8.6*	*87.4*	*96*
TV1	4.4	19.6	24
TV2	2.2	21.8	24
TV3	1.2	22.8	24
TV4	0.7	23.3	24
5-TV home total	*8.6*	*111.4*	*120*
TV1	4.3	19.7	24
TV2	2.1	21.9	24
TV3	1.1	22.9	24
TV4	0.64	23.4	24
TV5	0.43	23.6	24

and covariate 'year of manufacture'. The results implied that some manufacturers consistently make more efficient VCRs, and that the power use of VCRs has declined significantly since 1985.

Comparisons with industry-published data indicated that the age distribution of the VCRs in our power measurement database was not representative of US stock. Since power levels are related to the year of manufacture, we calculated average VCR power draw values ($\overline{P_{\mathrm{VCR}}}$) as:

$$\overline{P_{\mathrm{VCR}}} = \sum_{y=1985}^{1998} f_y \overline{P_y}, \tag{5}$$

where is f_y is the actual frequency of VCRs manufactured in year y (based on industry data) and $\overline{P_y}$ is the mean power draw for all VCRs in our database manufactured in year y. Fig. 7 shows the age distribution and average power draw values for VCRs.

As was done in the analysis of TV energy use, we needed to account for greater use of the primary VCR. We divided US household into three categories: homes with one, two and three or more VCRs. For each home category, we ranked VCRs according to usage, such that VCR1 is the most used, VCR2 is the next most used, etc. The numbers of VCR1s, VCR2s and VCR3s and their estimated power levels are shown in Table 4. Note that, unlike TVs, the power levels of VCR1s, VCR2s and VCR3s are the same. This is because we assumed that VCR age does not affect the likelihood of it being the most used VCR in the home.

The critical factor in our estimates of national VCR energy consumption is the amount of time VCRs are left in the idle mode. Some VCRs may be left idling out of habit or to record at a

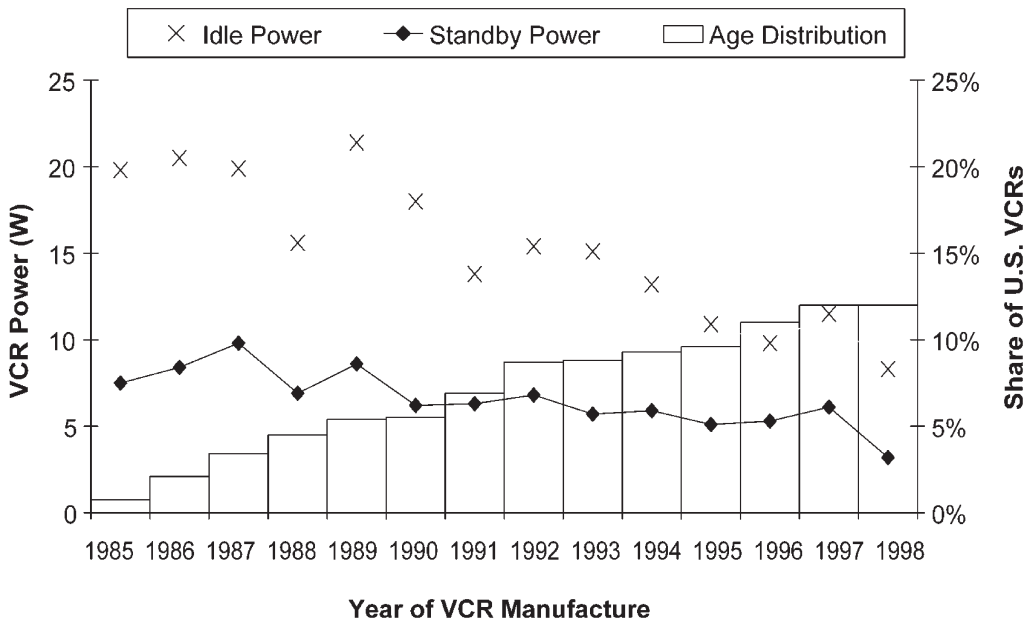

Fig. 7. VCR age distribution and average power levels.

Table 4
Number of VCRs in US homes and power use assumptions

Usage rank[a]	VCRs in the USA [2] (millions)	Percentage of US VCRs	Active power (W)	Idle power (W)	Standby power (W)
VCR1	88.9	69.1	17.0	13.4	5.9
VCR2	32.5	25.3	17.0	13.4	5.9
VCR3	7.3	5.7	17.0	13.4	5.9
Total/*Average*	128.7	100	*17.0*	*13.4*	*5.9*

[a] VCR1 is the most used VCR, VCR2 the second most used, etc.

preset time, while others are used for cable signal reception in the absence of a cable box. Since we were unable to find information about the percentage of time that this occurs, we assumed a 1:3 ratio of idle to standby usage. Estimated VCR usage patterns are given in Table 5.

4. Results

Using average TV power values (Table 2) and usage patterns (Table 3), we calculated UEC values for each unit in each home according to Eq. (2). Table 6 shows the average household TV energy use values for homes with one, two, three, four and five TVs calculated using Eq. (3). We concluded that the average annual UEC of US TVs is about 150 kW h, and that all TVs in

Table 5
Average VCR usage

	Active (h/day)	Idle (h/day)	Standby (h/day)	Total (h/day)
1-VCR home total	*0.84*	*5.8*	*17.4*	*24*
VCR1	0.84	5.8	17.4	24
2-VCR home total	*0.84*	*11.8*	*35.4*	*48*
VCR1	0.70	5.8	17.5	24
VCR2	0.14	6.0	17.9	24
3-VCR home total	*0.84*	*17.8*	*53.4*	*72*
VCR1	0.67	5.8	17.5	24
VCR2	0.12	6.0	17.9	24
VCR3	0.05	6.0	18.0	24

Table 6
National TV energy consumption

	TV homes (millions)	National TV energy consumption		
		Active (TW h/yr)	Standby (TW h/yr)	Total (TW h/yr)
1-TV homes	32.3	7.6	0.9	8.5
2-TV homes	37.9	9.3	2.6	11.9
3-TV homes	19.4	4.6	2.0	6.6
4-TV homes	7.8	1.8	1.1	2.9
5+-TV homes	2.8	0.7	0.5	1.1
Total US	*100.2*	*24*	*7.0*	*31*

the USA consumed about 31 TW h of electricity in 1998, accounting for about 2.8% of residential electricity consumption.

Likewise, we used the average VCR power levels (Table 4) and usage patterns (Table 5) to calculate UEC values for each VCR in each home using Eq. (2). Table 7 shows average household

Table 7
National VCR energy consumption

	VCR homes (millions)	National VCR energy consumption			
		Active (TW h/yr)	Idle (TW h/yr)	Standby (TW h/yr)	Total (TW h/yr)
1-VCR homes	56.3	0.29	1.6	2.1	4.0
2-VCR homes	25.2	0.13	1.5	1.9	3.5
3-VCR homes	7.3	0.04	0.6	0.8	1.5
Total	*88.9*	*0.46*	*3.7*	*4.9*	*9.1*

Table 8
Average household TV and VCR energy consumption (kW h/yr/home)

Number of units in home	TVs[a]	VCRs[a]
1	260	71
2	310	140
3	340	210
4	370	
5	400	
Weighted average	*310*	*100*

[a] Values have been rounded to two significant digits.

VCR energy use for homes with one, two or three VCRs, calculated using Eq. (3). We estimate that the average annual UEC of VCRs in the US is about 71 kW h, and that all VCRs in the USA consumed about 9.1 TW h of electricity in 1998, accounting for about 0.8% of residential electricity consumption.

Because we calculated individual UEC values for multiple-unit homes, we were able to estimate household TV and VCR energy consumption based on the number of units in the home. Table 8 shows the average household TV and VCR energy consumption for homes with one or more units.

According to our analysis, about 23% of TV energy use and 95% of VCR energy use occurs while the devices are not active. Fig. 8 shows the allocation of energy use for the two TV modes and three VCR modes, respectively.

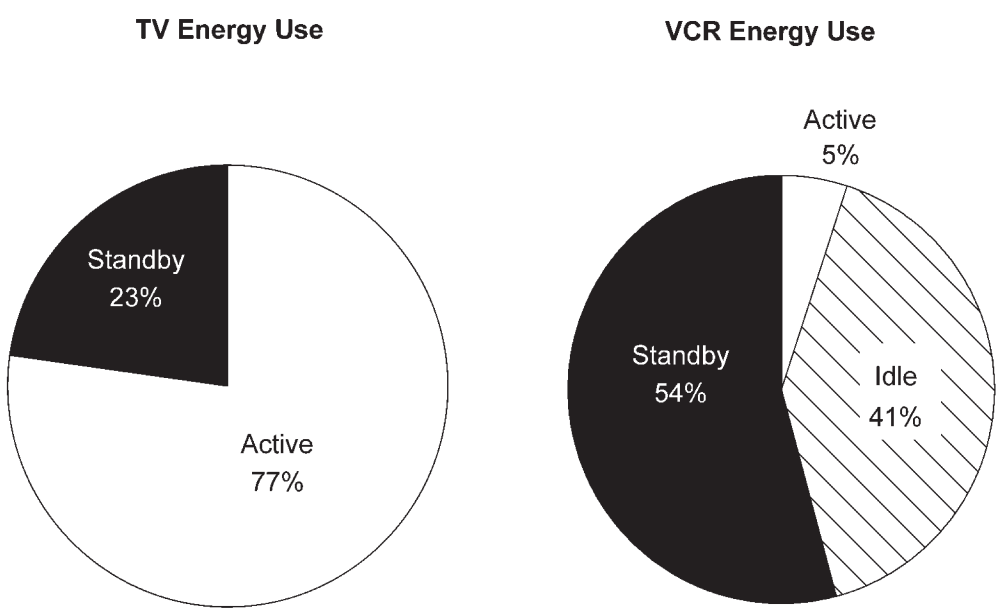

Fig. 8. Contributions of different modes to TV and VCR energy use.

4.1. Comparisons with other studies

Previous studies by Sanchez et al. [7] and Zogg and Alberino [8] have provided estimates of national TV and VCR energy consumption. This study differs in several ways. First, these earlier studies used relatively few or no actual power measurements, while we used an extensive database that included measurements of nearly 500 units. In addition, we adjusted our calculation of average power levels to reflect the characteristics of US stock. No efforts to ensure representative samples or adjust average power levels were conducted in previous studies. Finally, previous analyses assumed equal usage across all units in a home. The analysis presented here accounts for the fact that some units are used more often. Our methods also allowed us to estimate household TV and VCR energy consumption in homes with single or multiple units. We believe that the data and methods used in this study resulted in more accurate average power levels and a more realistic relationship between number of units and household TV and VCR energy use.

Although data sources and methods were substantially different, results were comparable. Table 9 shows our TV and VCR energy consumption estimates compared with the results of Sanchez et al., Zogg and Alberino, and the US Energy Information Administration (USEIA) [9].

For VCRs, our results are slightly higher than the results of both Sanchez et al. and Zogg and Alberino. We attribute this to two factors. First, we assume that VCRs are left in the idle mode about 25% of the time that they are not active, while the other studies appear to have used a figure closer to 15%. In addition, the database of VCR power measurements used in Sanchez et al. and cited by Zogg and Albernio consisted almost entirely of new units. As we found in this study, VCRs have become significantly more efficient over time.

5. Discussion

5.1. Sources of uncertainty

This study does not include monochrome TVs, or TVs and VCRs in the commercial sector. While the addition of monochrome TVs to our stock would not have a significant effect on our

Table 9
Comparison with other studies

	This study	Sanchez et al. [7]	Zogg and Alberino [8]	USEIA [9]
Average annual TV UEC (kW h/yr/unit)	150	141	117	
National TV energy (TW h/yr)	31	26	27	67
Average annual VCR UEC (kW h/yr)	71	57	57	
National VCR energy (TW h/yr)	9.1	7.6	6.9	

results, we estimate that the inclusion of commercial units would increase our estimate of national TV and VCR energy consumption by 10% to 15%.

According to the data collected at the repair shops, larger TVs are more likely to be repaired than smaller TVs. This implies either that smaller TVs are more likely to be retired than repaired, or that smaller TVs are less likely to malfunction. Since we assumed that all TVs, regardless of screen size, have the same lifetime, the distribution of screen sizes used for this study may not be accurate.

Another uncertainty involves the assumptions about TV screen sizes and usage. We assumed a tendency toward watching the largest TV in the home, but did not vary the usage distributions between different home categories. As a result, we assumed that the average size of TVs in one-TV homes was the same as the average size of all the largest TVs in homes with more than one TV. This is unlikely to be the case; however, correction of this assumption would reduce final results by less than 1 TW h/yr.

TV/VCR combination units are included in both the TV and the VCR results. Because the sum of separate TV and VCR standby power use values is about 2.6 W higher than that of a TV/VCR combination unit [1], these results are not additive. Adjustment of the analysis to account for this difference did not produce a noticeable effect.

For the VCR analysis, the idle usage is the critical assumption. While it is certain that VCRs are left in the idle mode, the exact percentage of time that this occurs is not known. Future studies may wish to address this issue.

5.2. Trends that may change these results

Several trends, including rising demand for larger TV screens and high-definition television (HDTV) sets, are expected to increase TV energy consumption through increased average power use. New TV usage options — such as the Internet, 'pay-per-view' and 'video-on-demand' — also have the potential to increase TV energy usage by encouraging consumers to spend more time watching TV.

Other trends may decrease energy consumption. For example, the trend in new display technologies is toward thinner and more energy-efficient TVs. In addition, sales of TV/VCR combination units continue to climb. These integrated units have smaller standby power requirements than separate units because they exploit common components. Integration of other appliances, such as TVs and set-top boxes, would have the same effect.

Energy efficiency regulations and voluntary programs are expected to decrease TV and VCR energy use. Currently, voluntary standards for standby power levels of TVs and VCRs are in place in the United States [10], Japan [11] and the European Union [12]. These standards are expected to improve the efficiency of units sold in the United States and elsewhere.

6. Conclusions

We estimate that residential TVs used 31 TW h of electricity in 1998, 23% of which was consumed while the TVs were not active. In the same year, residential VCRs used 9.1 TW h of

electricity, 95% of which was consumed while the units were not active. Combined, these two appliances accounted for 3.6% of national residential electricity consumption in 1998.

Acknowledgements

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