# Televisions, Computers, and Set-top Boxes: The Big Three of 2010 Home Consumer Electronics Energy Consumption

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**ABSTRACT**

Consumer electronics (CE) consumed 193 TWh in 2010, representing about 13% of all U.S. household electricity use. Together, the top three device categories – televisions, computers, and set-top boxes – consumed about 122 TWh in 2010, more than 60% of the total. We evaluated residential CE electricity consumption in the U.S. for mid-2010 using a detailed bottom-up approach. This paper characterizes the energy use of the top three device categories and explores important trends affecting their electricity consumption.

## Introduction

Consumer electronics (CE) represent about 13% of household electricity use (Urban et al. 2011). Relative to other end uses, the characteristics of consumer electronics (CE) typically change quickly due to relentless product innovation, rapid technology adoption, short product cycles and lifetimes, and evolving usage patterns and dynamics. Together, these factors often create significant changes in all three components of annual electricity consumption (AEC): installed base, power draw by mode, and usage by mode. To ensure that energy policy decisions are based on relevant data, CE electricity consumption must be evaluated regularly. Since the last comprehensive study of CE electricity consumption was completed several years ago (for 2006; Roth and McKenney 2007), the Consumer Electronics Association (CEA) commissioned a similar study (Urban et al. 2011). This paper summarizes the findings of this new study for the "big three" device categories of CE: televisions, computers, and set-top boxes. It also explores key trends from 2006 to 2010 that have had a significant effect on the AEC of these categories.

## Methodology

We used a bottom-up approach to evaluate the annual electricity consumption (AEC) of each CE device category. For each device we developed usage estimates or annual average time spent in each power mode (in hours). Multiplying usage by average power draw (in Watts) in each mode yields the annual unit electricity consumption (UEC) by mode (in kWh/unit). The sum of the UEC over all modes equals the total device UEC, and the product of the UEC and the installed base (number of units) equals the AEC. Prior studies of CE energy consumption describe this methodology in further detail (e.g., Kawamoto et al. 2001, Roth et al. 2002, 2006). The product-specific subsections describe how all values were derived for each product type.

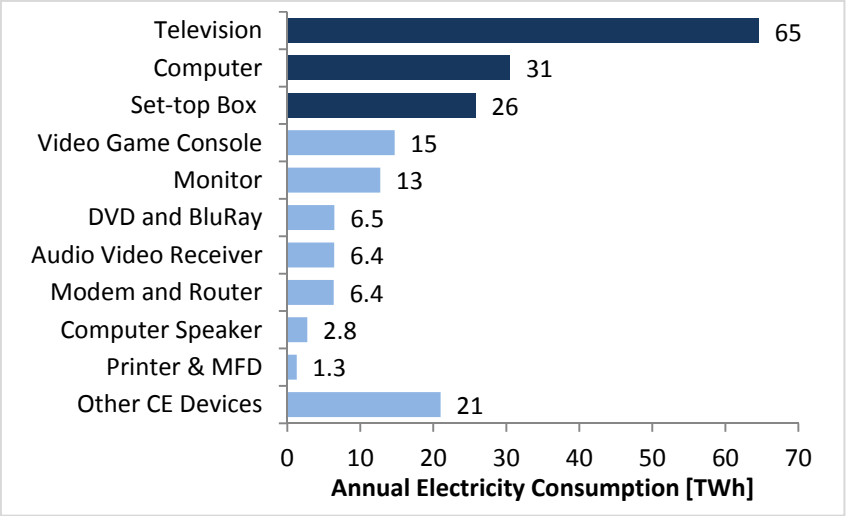
Usage by mode was the most challenging to quantify. We organized a survey of 1,000 demographically representative U.S. households to develop new information about CE usage (henceforth referred to as the CE Usage Survey; see Urban et al. 2011). We posed especially detailed questions to determine computer and monitor usage because their AEC values depend

strongly on usage patterns that may vary significantly among owners (e.g., daytime and nighttime usage, and power management settings).

## Results

We estimate that residential CE consumed 193 TWh[1] in 2010. The "big three" account for almost 63 percent of the total AEC (see Figure 1). We discuss the findings for the "big three" in more detail in the following subsections.

**Figure 1. Residential consumer electronics annual energy consumption in 2010**




### Televisions

**Installed base.** Televisions are the most widely owned consumer electronic device in the U.S. at 95-99% household penetration in 2010 (CEA 2010a; CE Usage Survey). TV energy consumption varies most strongly with display type, screen size, and year of manufacture. The recent widespread adoption of flat panel displays and the subsequent disappearance of the cathode ray tube (CRT) from the marketplace have significantly altered TV energy consumption.

Our TV energy use estimates are based primarily on usage and ownership data from household phone surveys, manufacturer-reported power draw measurements, and industry sales data. The Consumer Electronics Association (CEA) and Fraunhofer arranged two national phone surveys, each asking 1,000 representative households about their (up to) 3 most-used TVs. The first survey (August 2009) identified installed base, display technology, screen size, TV age, and usage; while the second (referred to as the CE Usage Survey, October 2010) identified only installed base and usage. We determined 2010 energy usage estimates by modeling 2009 usage and adjusting for changes to the next year's installed base – mainly the installation of new TVs, retirement of old TVs, and shifting of TVs among usage categories.

Televisions outnumber people in U.S. homes with 353 million installed in 2010 (Table 1). Our 2010 estimate is based on the October 2010 phone survey data and Nielsen's 2009 penetration rate (99.2%) for 2009, as Nielsen's 2010 value (99.1%) agreed with the October

[1] TWh stands for terawatt-hours. 1 TWh is equivalent 1 billion kWh.

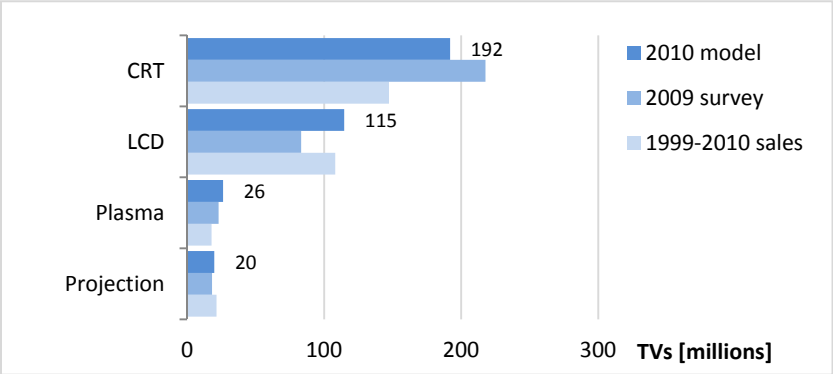
2010 survey (Nielsen 2010). Nielsen's ownership estimates of 2.86 and 2.93 TV sets per household in 2009 and 2010, respectively, however, were slightly lower than our survey suggested. To arrive at 2.99 TVs per owner household for 2009, we reduced our 2010 estimate of 3.07 by the 2.4% annual change reported by Nielsen.

**Table 1. Installed base estimates for TVs**

| Household penetration | Households [millions] | Units/owner household | Installed Base [millions] | Sources |
|---|---|---|---|---|
| 99.0% | 116.0 | 3.07 | 353 | CE Usage Survey; DOE/EIA 2009, Nielsen 2010b |

We used the display technology distributions shown in Figure 2 (labeled "2010 model") in our energy analysis. Even though LCD and plasma displays have held top market shares since 2006, they have not yet overtaken the installed base of CRTs.

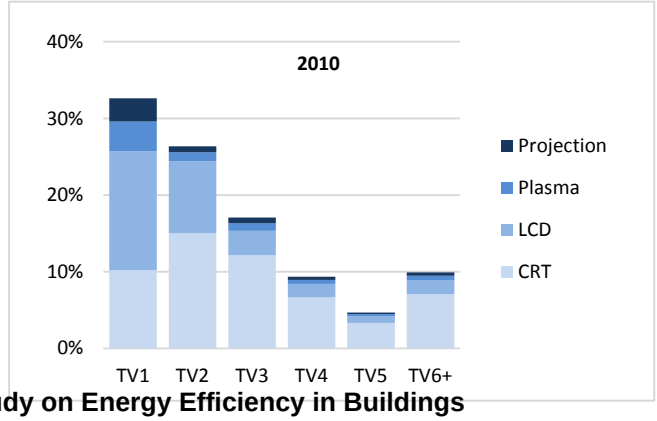
**Figure 2. Installed base estimates of TVs by display technology**




The average diagonal screen size of TVs has increased to 29.1 inches, up from 25.5 in 2006 (analog TVs only for 2006; Roth and McKenney 2007). The most-used TVs in households are larger, about 38 inches. The installed base of TVs has an average age of about 6.2 years.

**Usage.** Usage patterns greatly affect TV energy consumption. Newer, larger TVs, for instance, are used more frequently than older, smaller ones. We accounted for usage patterns by assigning TVs to a "usage priority group" where TV1 is the most used TV in a household, TV2 is the second most used, and so on. Flat panel displays are dominant among primary TVs (Figure 3).

**Figure 3. Distribution of TVs by usage priority and display technology**



**Power draw by mode.** TV power draw values have changed significantly in recent years due to the rapid adoption of digital and flat panel TVs. The EPA ENERGY STAR program develops voluntary TV energy efficiency specifications, and version 4.0, effective in 2010, sets varying limits on active mode power draw based on screen area and limits off-mode power to 1.0W for all TVs (EPA 2010a). Compliant TVs account for about 95% of the market (EPA 2011a).

We asked TV manufacturers and retailers to provide measured power draw values for their top selling models in various screen sizes, display technologies, and years of manufacture. Responders provided data for 385 models (320 LCD and 65 plasma) produced between 2008 and 2010. We used these data to compute linear regressions for active mode power draw for units by display technology and year of production. ENERGY STAR data for both qualified and non-qualified TVs were used to generate regressions for older LCD, plasma, and projection TVs.

CRT power draw was modeled using the values in TIAX (Roth and McKenney 2007), appropriate since CRT sales diminished rapidly after that study. Off-mode power draw for LCD and plasma TVs averaged 0.4W independent of screen size between 2008 and 2010. For TVs made prior to 2008, we assumed 4W for off-mode power draw (Roth et al. 2008).

To calculate UEC and AEC (see Table 2), we prepared estimates for both 2009 and 2010. The 2009 estimates were largely based on the August 2009 phone survey, in which participants provided estimates for TV display type, screen size, age, and usage for the three most used TVs per household. To this dataset we applied the energy usage regressions to determine power and energy usage characteristics for each TV usage group, subdivided by display technology. We then used the October 2010 survey results to determine the portion of TVs in each usage group, and applied our 2009 installed base estimate of 342 million TVs to obtain the AEC estimates.

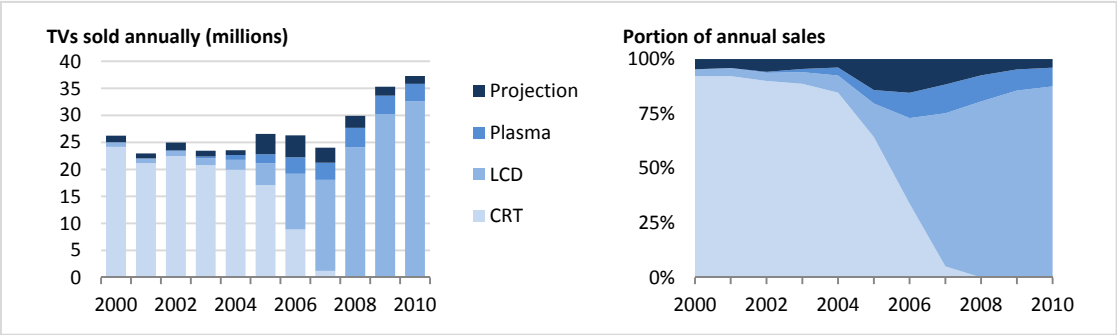
To obtain results for 2010, we began with the 2009 model and introduced 36.3 million new TVs based on CEA sales and screen size data for Q3-4 of 2009 and Q1-2 2010, applying the 2010 power draw regressions. We introduced most of these new TVs (25.7 million) into the primary usage group; however, to preserve the average primary LCD TV screen size, 34% of new LCD TVs (10.6 million, all with screen sizes below 29") were introduced into the TV2 usage slot. Next, we assumed that each usage group would retain the same proportion of TVs in 2010 as 2009, so we "demoted" CRT TVs to a lower usage group to maintain the balance. For example, 25.7 million new TVs were introduced into the TV1 usage slot, and nearly the same amount of CRT TV1s were demoted to TV2s, which then bumped some CRT TV2s to TV3s, and so on, with 25.8 million CRT TVs being retired from the lowest usage categories.

**Table 2. UEC and AEC calculations for TVs**

| Usage Group | Installed Base [millions] | [%] | Usage [h/day] | Size [in] | Age [yr] | Power [W] Active | Off | UEC [kWh/yr] | AEC [TWh/yr] | AEC Fraction |
|---|---|---|---|---|---|---|---|---|---|---|
| TV1 | 116 | 33% | 6.5 | 38 | 4.6 | 133 | 2.9 | 330 | 38.0 | 59% |
| TV2 | 92 | 26% | 3.1 | 29 | 6.2 | 104 | 3.2 | 149 | 13.8 | 21% |
| TV3 | 60 | 17% | 2.6 | 23 | 7.5 | 83 | 3.4 | 107 | 6.4 | 10% |
| TV4 | 32 | 9% | 2.5 | 21 | 7.6 | 79 | 3.4 | 100 | 3.3 | 5% |
| TV5 | 18 | 5% | 1.6 | 21 | 7.6 | 79 | 3.4 | 74 | 1.2 | 2% |
| TV6+ | 35 | 10% | 0.9 | 21 | 7.6 | 79 | 3.4 | 56 | 2.0 | 3% |
| **Avg/Total** | 353 | 100% | 3.8 | 29 | 6.2 | 103.8 | 3.2 | 183 | 64.7 | 100% |

A major shift is taking place as older CRTs are replaced with newer, more efficient digital flat panel TVs (see Figure 4). At least 75% of the more than 35 million TVs sold per year are flat panel LCD displays, and these should become the most prevalent display technology.

**Figure 4. Annual TV sales to dealers by display technology**




Source: CEA 2010

Finally, about 88% of TV AEC occurs in active mode compared with 12% for off mode. Naturally a TV's usage priority has a major influence: 95% of TV1 energy usage is from active mode, compared to about 50% for TVs 6 and beyond.

## Computers

Our analysis included both desktop and portable computers. External monitors were evaluated separately, since both desktop and portable computers use them. Although the average number of desktop computers in households with at least one desktop computer has increased from 1.2 in 2005 to 1.5 in 2010, their share relative to all computers has declined from 70% to 56%. Considering only plugged-in units, their share has decreased to 43%, while their portion of sales dropped from 54% in 2006 to 24% in 2009 (CEA 2010b).

## Desktop Computers

We estimate an installed base of 101 million desktop computers (see Table 3).

**Table 3. Installed base of desktop computers**

| Installed Base [millions] | Household Penetration | Sources |
|---|---|---|
| 101 | 75% own at least one<br>60% have at least one plugged in | CE Usage Survey 2010,<br>CEA 2010a |

We characterized desktop computer energy use with three operating modes:

- *Active mode* includes both times when the computer is being used by a person (actively-used) and times when the computer is on but has not entered sleep mode (active-idle)
- *Sleep mode* occurs when the computer is in a power-saving mode, but has not been turned off
- *Off mode* occurs when the computer is turned off but remains plugged in

The *active mode* power draw values we used are similar to what the ENERGY STAR program calls active-idle mode. Prior studies suggest that the idle mode accounts for most active mode energy consumption by computers (e.g., Herb et al. 2006).

Average desktop computer power draw by mode is given in Table 4. These values are based on EPA data (EPA 2010b) and several recent studies; according to EPA (2010b), 27% of desktop computers shipped in 2009 met the ENERGY STAR specification.

**Table 4. Power draw by mode of desktop computers**

| Power [W] | | | |
|---|---|---|---|
| **Active** | **Sleep** | **Off** | Sources |
| 60* | 4 | 3 | EPA 2009a, EPA 2010, Bensch et al. 2010, Selina 2010, Foster Porter et al. 2006, Roth & McKenney 2007, Quack 2007 |

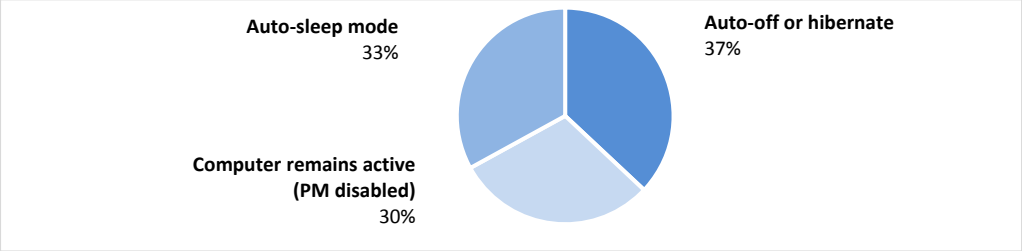
We developed usage by mode estimates based on the CE Usage Survey and the usage model explained in Appendix B of Urban et al. (2011); see Table 5.

**Table 5. Daily usage (actively-used) of desktop computers**

| Usage | Computer Usage Priority | | |
|---|---|---|---|
| [hours/day] | **Primary** | **Secondary** | **Third** |
| Weekday | 4.6 | 4.2 | 2.6 |
| Weekend-day | 4.2 | 3.5 | 2.9 |
| **Weighted Average** | **4.5** | **4.0** | **2.7** |

The usage survey indicates that approximately 60% of desktop computers are always or often powered down at night, which is less than for portable computers (70%). The median default time to sleep of ENERGY STAR qualified desktop models submitted to EPA as of February 2010 is 15 minutes (EPA2010b). As with desktop computers, we used the delay time for the computer to respond reported by survey respondents as a proxy for power management settings (see Urban et al. 2011). This yields the breakdown for desktop computer power management settings shown in Figure 5, which are quite similar to portable computers.

**Figure 5. Power management settings of desktop computers**

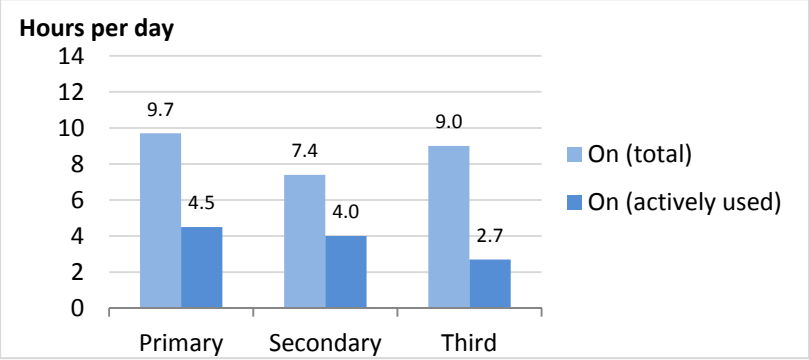



Source: CE Usage Survey 2010

Figure 6 compares the calculated time spent by desktop computers in on-mode to the usage indicated by the survey respondents. On average, 54% of the time spent in on-mode occurs while the computer is not actively being used, compared to 45% for portable computers. These findings are consistent with previous reports (Roth and McKenney 2007). On average, this

additional time spent in on-mode accounts for about 111 kWh per desktop computer per year. Table 6 summarizes annual desktop computer usage by mode for all desktop computers.

**Figure 6. On-mode usage of desktop computers by usage priority**




Source: CE Usage Survey 2010

**Table 6. Annual usage by mode for desktop computers**

| Usage [h/year] | Primary | Secondary | Third | Weighted Average |
|---|---|---|---|---|
| Active | 3,530 | 2,717 | 2,503 | **3,420** |
| Sleep | 2,159 | 2,321 | 2,519 | **2,150** |
| Off | 3,071 | 3,363 | 3,525 | **3,190** |

Together, the breakdown of desktop computers installed and their estimated power draw by mode and the time spent in each mode calculated with our computer usage model yield a UEC of 224 kWh/year (see Table 7), the highest UEC of all CE products studied.

**Table 7. UEC calculation for desktop computers**

| | Active | Sleep | Off | Sources |
|---|---|---|---|---|
| Power [W] | 60 | 4 | 2 | Power draw: (EPA 2009a) |
| Usage [hr/yr] | 3,420 | 2,150 | 3,190 | Model based on CE Usage Survey (2010) |
| UEC [kWh/yr] | 205 | 9 | 6 | |

The current AEC estimate of 22 TWh is marginally higher than other estimates for 2006. The main underlying trends are a 12% growth in installed base despite the market shift from desktop to portable computers, a decrease in average power draw by mode, and an increase in active mode usage.

### Portable Computers

This category includes notebook/laptop computers, netbooks, and tablets, and excludes eBook readers and smart phones. According to the CE Usage Survey data and EIA (2009), the installed base of portable computers is 132 million units (Table 8), a dramatic increase from 39 million units in 2005 (Roth et al. 2006). With an average number of 1.7 notebook computers and 1.3 netbook computers among owner households, respectively, the household penetration rate for notebook computers from 25% in 2005 to 58% in 2010 (Roth et al. 2006, Urban et al. 2011). In

2007 portable PC sales exceeded desktop PC sales for the first time (CEA 2010c), and their share continues to increase, representing 76% of computers shipped in 2009, compared to 46% in 2006 (CEA 2010b). We used the same three modes to characterize portable and desktop computer energy consumption (see above); Table 9 summarizes the average power draw by mode.

**Table 8. Installed base of portable computers**

| Device Type | Installed Base [millions] | Penetration | Sources |
|---|---|---|---|
| Notebook | 110 | 58% | CEA 2010b |
| Netbook | 18 | 12% | |
| Tablet | 4 | 2% | Rotmann Epps 2010 |

**Table 9. Power draw by mode of portable computers**

| Power [W] | | | |
|---|---|---|---|
| **Active** | **Sleep** | **Off** | Sources |
| 19 | 2 | 1 | EPA 2010a, Bensch et al. 2010, Selina 2010, Foster Porter 2006, Roth & McKenney 2007, Quack 2007 |

We developed usage estimates, summarized in Table 10, based on households' responses to questions about residential CE usage (CE Usage Survey; see Urban et al. 2011). Values shown indicate actively-used time only, and do not include active-idle time.

**Table 10. Daily usage (actively-used) of portable computers**

| Usage [h/day] | Computer Usage Priority | | |
|---|---|---|---|
| | **Primary** | **Secondary** | **Third** |
| Weekday | 4.9 | 4.6 | 3.6 |
| Weekend-day | 3.8 | 3.4 | 3.8 |
| **Weighted Average** | **4.6** | **4.3** | **3.7** |

We did not directly ask phone survey participants about power management settings since many people are likely unaware of them and/or their responses might be influenced by a social desirability bias. Instead, we asked how long it typically takes the computer to respond after it has not been used for one hour or more, and we used the reported delay time as a proxy for power management settings. Based on peoples' responses, we estimate that approximately 70% of portable computers are always or often powered down at night, which is comparable to the 63% indicated for residential computers in Alliance to Save Energy (2009). These numbers seem reasonable given that more recent operating systems (e.g., Windows 7) have power management enabled by default. On average, we estimate that 45% of the time spent in on-mode occurs while the computer is idle. Annual usage by mode is shown in Table 11.

**Table 11. Annual usage by mode for portable computers**

| Usage [h/year] | Primary | Secondary | Third | Weighted Average |
|---|---|---|---|---|
| Active | 3,035 | 3,077 | 2,503 | **2,915** |
| Sleep | 2,258 | 2,321 | 1,997 | **2,210** |
| Off | 3,467 | 3,363 | 4,260 | **3,635** |

Considering the breakdown of desktop computers installed, their average power draw by mode and time spent in each mode, we obtain a UEC of 63 kWh/year (Table 12). In total, we calculate that portable computers consumed approximately 8.3 TWh in 2010.

**Table 12. UEC calculation for portable computers**

| | Active | Sleep | Off | Sources |
|---|---|---|---|---|
| Power [W] | 19 | 2 | 1 | See above |
| Usage [hr/yr] | 2,915 | 2,210 | 2,726 | Based on CE Usage Survey (2010) |
| UEC [kWh/yr] | 55 | 4 | 3 | |

The current AEC estimate of 8.3 TWh is much higher than reported by previous studies, with the AEC increasing by over 190% since 2006 primarily due to a nearly three-fold larger installed base. Despite a considerable increase in the usage of portable computers, their UEC has decreased, reflecting reductions in average power draw in active and off modes.

**Set-Top Boxes**

Set-Top Boxes (STBs) receive and decode signals for playback on televisions. They may offer services and applications that vary by service provider and STB, including high definition (HD) programming, video-on-demand, digital video recording (DVR) capabilities, multiple tuners, format conversion, home networking, and a variety of additional applications. Digital-to-Analog Adapters[2] (DTAs) are basic STBs that decode digital signals for TV viewing; they provide less functionality and use less power than full-featured STBs. DTAs exist in two forms: (1) Cable-DTAs decode digitally encrypted cable signals for viewing on subscriber TVs, and (2) Over-the-Air (OTA)-DTAs decode unencrypted digital signals transmitted via antenna for older TVs that lack a digital tuner. Finally, Digital Media Adapters (DMAs) are stand alone devices that stream digital media from computer servers or the Internet to a television or audio system.

We divide STBs into two major categories: Subscription TV STBs and Stand-Alone STBs. Subscription TV STBs are generally leased to consumers by cable, satellite, and telco TV service providers to provide a variety of services and features. Stand-Alone STBs may be purchased independently, and generally provide alternative services to those of Pay-TV STBs. Stand-Alone STBs include OTA-DTAs, stand-alone DVRs, and DMAs. We evaluated stand-alone DVRs and DMAs in less detail than the other categories.

There were almost 180 million subscription STBs as of mid-2010, with the breakdown by subscriber shown Table 13. We used three sources to estimate the installed base of subscription STBs: the CE Usage Survey, market research data, and consultation with industry experts. The estimates were built upon market research data (SNL Kagan 2010, 2011) that gave subscriber count and STB installed base by provider type. Based on data provided by industry sources (Langille 2011), we reduced the SNL Kagan estimate for satellite STBs per household from 2.8 to 2.3. The total installed base in Table 13 agrees with our CE Usage Survey to within 3%.

[2] Also called digital terminal adapters, digital transport adapters, and digital television adapters.

**Table 13. Installed base of subscription STBs by service**

| Service | Subscribers of TV hh | Subscribers [millions] | STBs per subscriber | STBs [millions] | Percentage of STBs by service |
|---|---|---|---|---|---|
| Cable | 59% | 54.8 | 1.6 | 86.8 | 49% |
| Satellite | 36% | 33.1 | 2.3 | 76.1 | 43% |
| Telco | 6% | 5.7 | 2.8 | 15.9 | 9% |
| **Total/Avg.*** | **101%** | **93.6** | **1.9** | **179** | **100%** |

* Totals exceed 100% as some subscribers may have more than one service and some households are not subscribers.

Cable subscribers have the fewest STBs per household, since not all cable subscribers require STBs to receive basic service, while satellite and telco subscribers require STBs to receive any level of service. Some cable providers use digital signals for basic service, which may also require a Cable-DTA to view digitally-encrypted channels or for viewing digital channels on analog televisions. Cable DTAs numbered 14 million by mid-2010 (SNL Kagan 2011), and their number is increasing as more providers switch to digital programming.

### Stand-Alone Set-Top Boxes

OTA-DTAs are stand-alone devices that enable analog TVs to view digital broadcasts. To facilitate the DTV transition in 2009, the U.S. Government ran a coupon program for OTA-DTAs, and by the program's end 34.9 million coupons had been redeemed (DTV.gov 2010). About 51 million OTA-DTAs were sold to U.S. dealers from 2006 to mid 2010 (CEA 2010b).

Of the 11% of households that reported watching over-the-air TV service during the previous month, 69% had at least one OTA-DTA with an average of 1.1 per owner-household, or 14.2 million installed (CE Usage Survey). Since we asked about only participant's three most-used TVs, it is likely that OTA-DTAs used with older, lesser-used TVs were not represented in our survey. Without better data we estimate there are about 33 million OTA-DTAs (halfway between the bounding estimates of 14.2 and 51 million) in service as of mid-2010. Newer digital TVs receive over-the-air signals without additional hardware, so as older TVs are retired, the number of OTA-DTAs should decrease.

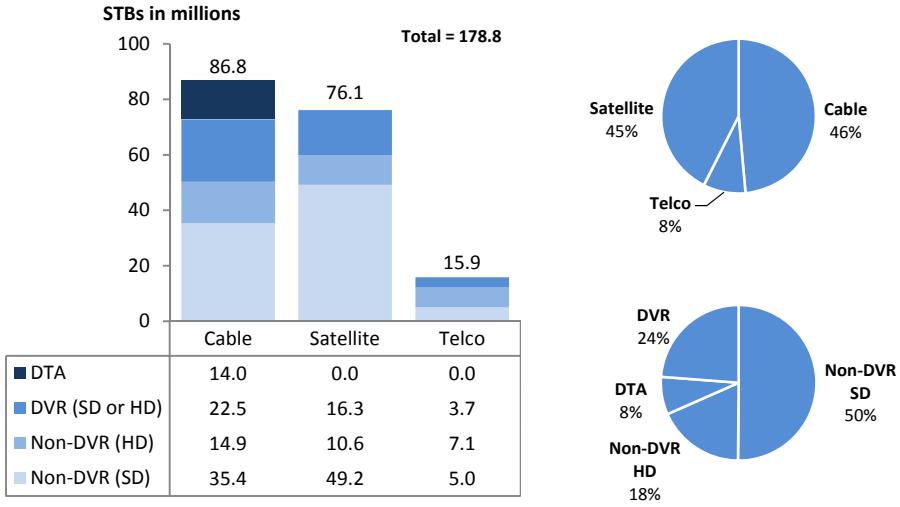
Stand-alone DVRs, those obtained independently of TV service providers, are few in number since most DVRs are now integrated with subscription STBs (see Table 14). Only 5% of DVR households had a stand-alone DVR as of March 2009 (Nielsen 2009), suggesting about 3 million in service. DMA sales totaled 8.9 million from 2006 to mid-2010 (CEA 2010a).

**Table 14. Installed base of stand-alone STBs**

| Device | Units [millions] |
|---|---|
| OTA-DTA | 33.0 |
| DMA | 8.9 |
| DVR | 3.0 |
| **Total** | **45** |

STB power draw depends on service type and features. Based on available segmentation and power data, we split subscription STBs into three feature categories: (1) DVR-enabled with any tuner; (2) non-DVR with standard definition (SD) tuner, and (3) non-DVR with high definition (HD) tuner. Within these categories, variations in features may affect power draw, such as number of tuners, processing power, multi-room, and home networking capabilities. We used installed base data from SNL Kagan (2011) to evaluate the AEC (see Figure 7).

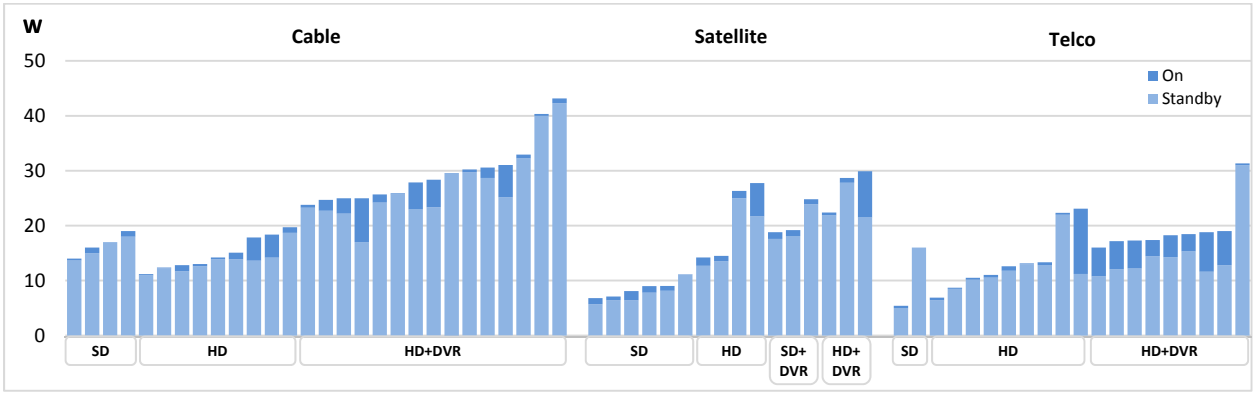
**Figure 7. Installed base of subscription STBs by provider and select capabilities**




Subscription STBs have two primary power modes: (1) on- or active-mode and (2) off-standby mode. When manually turned off, most STBs continue communicating with the service provider, so the two modes have similar power draw, making the energy analysis less sensitive to user behavior than for other devices.

Figure 8 presents measurements of on- and standby-power for 64 devices (EPA 2010c), as a function of subscription type and features (SD=standard definition, HD=high definition, DVR=digital video recorder). The slight difference between on- and standby-mode power draw for most subscription STBs is apparent, with average values for all features and categories summarized in Tables 15 and 16. Most measured devices were introduced between 2007 and 2010, and since average service life is nearly 6 years, based on sales of 30 million units per year (CEA 2010a), older units may be under-represented. Even though the sample size is limited, there are not many major STB manufacturers so results may still be representative.

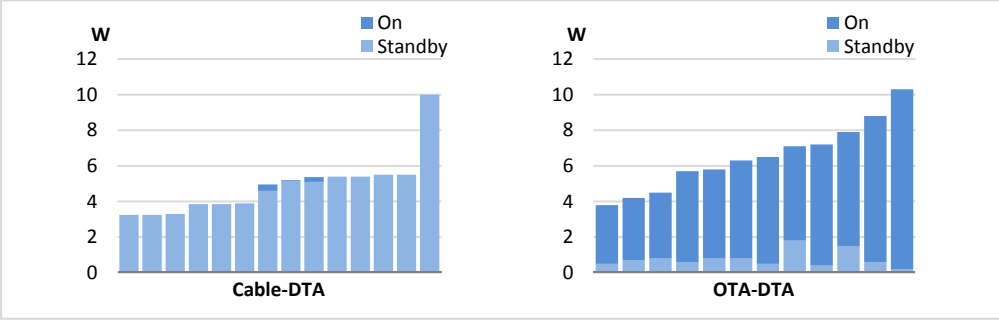
**Figure 8. Power draw of subscription set-top boxes by technology**




Power measurements for DTAs are shown in Figure 9 (EPA 2010b, 2011c; Cheung et al. 2011). The ENERGY STAR specifications for STBs do not require automatic power down for

DTAs; however, to be eligible for the government coupon program, OTA-DTAs must power down within four hours by default and have a maximum standby power of 2 W. Furthermore, 13 coupon-eligible devices made up 90% of the 2009 sales according to an industry representative (Cheung et al. 2011). As of mid-2010 the average Cable DTA draws 4.4 W (Glist 2011), and we assumed these were on all the time since most lack an off button or power switch. Limited data for stand-alone DVRs and DMAs were available (see Urban et al. 2011).

**Figure 9. Power draw of Cable-DTA and OTA-DTA devices**




Most STB energy consumption depends weakly on time spent in each mode, yet if lower power standby modes become more prevalent, a deeper understanding of consumer habits and mode times may prove useful. We used data from the CE Usage Survey to estimate the hours spent in on- and standby-modes for the first three subscription STBs per household. Participants answered questions about their (up to) three most used TVs and corresponding STBs. They were asked to indicate if their STBs were left on when the TV was not in use (daytime power state), and if they had to turn on their STB when first using their TV (nighttime power state).

On average cable units used the most energy per device. DVR-enabled STBs, at 24% of the installed base, were responsible for 41% of the energy consumption. This is because DVR-enabled STBs consumed on average 222 kWh/yr, roughly twice as much as non-DVRs (109 kWh/yr). Due to differences in features, the UEC for OTA-DTAs (29 kWh/yr) and Digital Media Adapters (68 kWh/yr) were both much lower than subscription STBs (131 kWh/yr), while stand-alone DVRs (275 kWh/yr) were comparable to DVR-enabled STBs (222 kWh/yr). Figure 10 and Tables 15 and 16 summarize energy consumption estimates for set-top boxes, with a total AEC of 25.6 TWh/yr. Subscription STBs account for most (91%) of the total.

**Figure 10. Set-top box AEC by type**

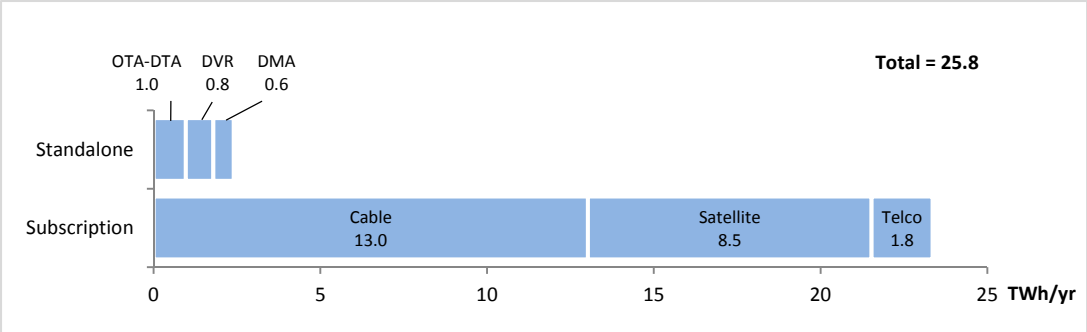


**Table 15. UEC and AEC calculations for subscription STBs**

| | Units [millions] | Type % | *All %* | Usage [h/day] | Power [W] | | UEC [kWh/yr] | | | AEC [TWh/yr] |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Active | Off | Active | Off | *Total* | |
| **Cable** | | | | | | | | | | |
| Cable DTA | 14.0 | 16% | *8%* | 24.0 | 4.4 | 4.4 | 39 | 0 | *39* | 0.5 |
| Non-DVR (SD) | 35.4 | 41% | *20%* | 12.1 | 16.5 | 15.9 | 73 | 69 | *142* | 5.0 |
| Non-DVR (HD) | 14.9 | 17% | *8%* | 12.1 | 14.9 | 13.5 | 66 | 59 | *125* | 1.9 |
| DVR (SD or HD) | 22.5 | 26% | *13%* | 12.1 | 29.6 | 27.3 | 130 | 119 | *249* | 5.6 |
| **Subtotal/Wt. Avg.** | **86.8** | | ***49%*** | **12.6** | **17.7** | **16.6** | **81** | **69** | ***150*** | **13.0** |
| **Satellite** | | | | | | | | | | |
| Non-DVR (SD) | 49.2 | 65% | *28%* | 10.8 | 8.5 | 7.6 | 34 | 37 | *70* | 3.5 |
| Non-DVR (HD) | 10.6 | 14% | *6%* | 10.8 | 20.7 | 18.2 | 82 | 88 | *169* | 1.8 |
| DVR (SD or HD) | 16.3 | 21% | *9%* | 10.8 | 24.0 | 21.8 | 94 | 105 | *199* | 3.3 |
| **Subtotal/Wt. Avg.** | **76.1** | | ***43%*** | **10.8** | **13.5** | **12.1** | **53** | **58** | ***112*** | **8.5** |
| **Telco** | | | | | | | | | | |
| Non-DVR (SD) | 5.0 | 32% | *3%* | 13.2 | 10.7 | 10.5 | 52 | 41 | *93* | 0.5 |
| Non-DVR (HD) | 7.1 | 45% | *4%* | 13.2 | 13.5 | 11.8 | 65 | 46 | *112* | 0.8 |
| DVR (SD or HD) | 3.7 | 23% | *2%* | 13.2 | 19.3 | 14.9 | 93 | 59 | *152* | 0.6 |
| **Subtotal/Wt. Avg.** | **15.9** | | ***9%*** | **13.2** | **14.0** | **12.1** | **68** | **48** | ***115*** | **1.8** |
| ***Total/Weighted Avg.*** | ***179*** | ***100%*** | **-** | ***11.9*** | ***15.6*** | ***14.3*** | ***68*** | ***63*** | ***131*** | **23.4** |

**Table 16. UEC and AEC calculations for stand-alone STBs**

| | Units [millions] | Type % | Usage [h/day] | Power [W] | | UEC [kWh/yr] | | | AEC [TWh/yr] |
|---|---|---|---|---|---|---|---|---|---|
| | | | | Active | Off | Active | Off | *Total* | |
| OTA-DTA | 33.0 | 73% | 10.8 | 6.5 | 0.8 | 26 | 4 | ***29*** | 1.0 |
| DVR | 3.0 | 7% | 11.5 | 33.0 | 30.0 | 139 | 137 | ***275*** | 0.8 |
| Digital Media Adapter | 8.9 | 20% | 21.6 | 8.0 | 6.0 | 63 | 5 | ***68*** | 0.6 |
| ***Total/Weighted Avg.*** | **44.9** | **100%** | **13.0** | **8.6** | **3.8** | **41** | **13** | ***54*** | **2.4** |

With DVR and HD features becoming popular, unit energy consumption relative to 2006 has increased by 12% for cable STBs and has decreased by 13% for satellite STBs. Telco STBs were too new to observe trends. OTA-DTA consumption has likely peaked, as all new TVs must have digital tuners. Likewise, stand-alone DVRs are few in number, owing to the popularity of integrated DVRs.

## Conclusions

We evaluated the electricity consumption of consumer electronics in U.S. homes and found that they consumed 193 TWh in 2010. The *big three*: televisions, computers, and set-top boxes, consumed a total of 122 TWh, more than 60 percent of total CE electricity consumption. TVs consumed more energy than computers and set-top boxes combined.

Our study reveals several trends for the “big three” relative to similar prior study completed for 2006 (Roth and McKenney 2007).

1. *Televisions*: The TV market has fully transitioned to digital and flat-screen displays. Although the installed base increased by 28%, TV AEC appears to have decreased by about 10% for two main reasons. First, the estimated on-mode time was lower by about 26%; it is not clear to what extent this decrease is real or indicative of uncertainty in estimating usage. Second, the average on-mode power draw decreased by 6% as the average screen area grew by 30%, as more-efficient LCD dominated TV sales between 2006 and 2010.
2. *Personal Computers*: Computer energy consumption has grown by only 27% despite the 79% growth in installed base. Portable computer sales have driven this growth, increasing from 39 to 132 million and surpassing desktop computers. Active mode power draw decreased for both portable and desktop devices, by 20% and 24%, respectively. Usage has increased in both active and sleep modes, with increases in power management-enabled rates to 70% (from 20% and 40%) due to new default settings in recent versions of a popular operating system.
3. *Set-top Boxes*: Although new STB categories have come to market (OTA-DTA, TelcoTV, DMA), cable and satellite STBs continue to account for most (>80%) of STB electricity consumption. We estimate that the average active mode power draw of cable STBs increased by about 25% because more units have HD and DVR features, while the average active mode power draw of satellite units has decreased by about 14%. Most cable and satellite STBs continue to have minimal difference in power draw between active and standby modes. The installed base of both cable and satellite STBs increased by around 10%.

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