

# Residential Consumer Electronics Energy Consumption in 2013

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## ABSTRACT

We performed a comprehensive characterization of consumer electronics (CE) energy consumption in homes in 2013 that evaluated 17 product categories in greater detail. Our bottom-up approach drew upon a wide variety of existing data sources, including field measurement campaigns, energy consumption characterization studies for individual product categories, ENERGY STAR measurement databases, targeted measurements by Fraunhofer, and manufacturer product specifications. To better understand CE usage, we also surveyed 1,000 demographically representative U.S. households about how they used different CE. Our analysis shows that approximately 3.8 billion CE devices consumed 169 TWh in 2013, representing about 12 percent of all U.S. household electricity use. This estimate is about 12 percent lower than the estimate for residential CE energy consumption 2010 (Urban et al. 2011). Together, the top three device categories, televisions, computers, and set-top boxes, accounted for about 65 percent the energy consumed. Relative to the evaluation of CE energy consumption in 2010, the annual electricity consumption (AEC) of televisions has decreased by more than 20 percent, reflecting a decrease in the installed base of older CRT TVs and average TV power draw in all modes. Since 2010, the installed base of all computers, including tablets, has increased by 21 percent and their installed base has shifted away from desktop and portable computers to tablets. Due to the much lower unit energy consumption of tablets relative to these other computer architectures, we estimate that total computer AEC has decreased by 29 percent. In a related trend, we estimate that the installed base and AEC of monitors have decreased by 26 and 54 percent, respectively.

## Introduction

Consumer electronics (CE) are the most dynamic energy-consumption end use in buildings. Relative to other energy end uses, CE characteristics typically change very quickly due to product innovation, short product cycles and lifetimes, evolving usage patterns, and rapid technology adoption that can strongly influence device power draw by mode. As a result, the characteristics of the installed base of many CE have changed appreciably since the last comprehensive evaluation of residential CE energy consumption (for the year 2010; Urban et al. 2011). Such rapid changes in the energy consumption characteristics of CE make it essential to develop up-to-date and accurate assessments of CE energy consumption. If older data are used to analyze potential energy policy decisions, such as voluntary or mandatory regulatory energy-efficiency programs, they can lead to less effective policy decisions that may not achieve their end goals. Consequently, the Consumer Electronics Association (CEA) commissioned Fraunhofer to perform this study to provide high-quality data to inform CE policy decisions.

# National Energy Consumption Calculations

## Unit Energy Consumption (UEC) and Annual Electricity Consumption (AEC) Calculation Methodology

We used a bottom-up approach to evaluate the AEC of most CE device categories (see Figure 1). For those, 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) in each mode (in kWh/year). 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, Roth and McKenney 2007, Urban et al. 2011).

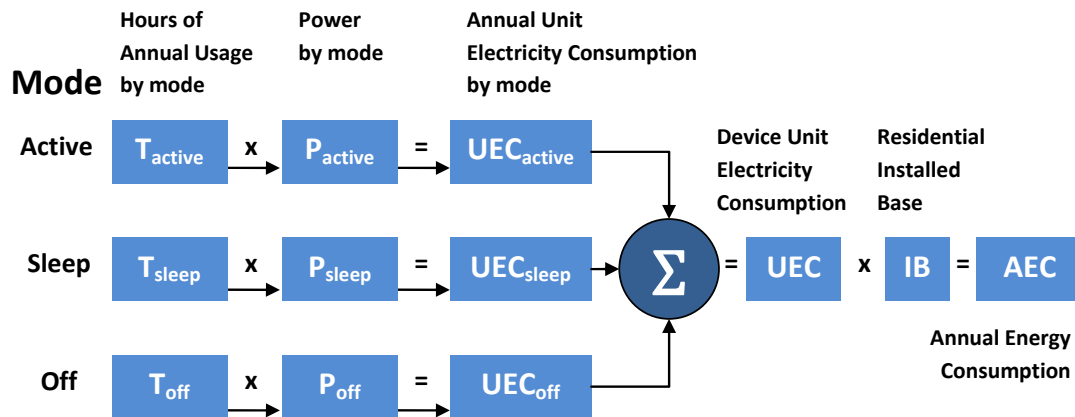


Figure 1. UEC and AEC calculation methodology (Roth et al. 2002).

We used a different approach to calculate the UEC of mobile devices, as they are typically used while running on batteries. For smart phones and tablet computers, we calculate the UEC by estimating the energy consumed to charge their batteries. In addition, we also evaluated the energy consumed by their battery chargers while plugged into the wall outlets.

### Residential Installed Base

The residential installed base equals the total number of devices actively used in homes, excluding devices that are not used (e.g., those stored, unplugged in basements or closets). Most installed base estimates came from market research studies (most notably CEA 2013a,b), the CE Usage Survey (described below), and, to a lesser extent, CE sales data. To ensure that the CE Usage Survey questions about ownership did not capture devices in storage, we specifically asked about the ownership of devices that have been plugged in within the last month. Typically, the installed base estimates have the lowest uncertainty of any AEC component.

## Usage by Mode

Usage by mode was the most challenging aspect of UEC to quantify. For some products, we used field monitoring data to evaluate usage patterns. Unfortunately, few field studies evaluating CE usage have been completed that included larger, random sample sizes. Consequently, we organized surveys of 1,000 demographically representative U.S. households to develop new information about CE usage (henceforth referred to as the CE Usage Survey; more in Urban et al. 2014). The surveys asked respondents questions about CE installed in their household and how they are used. The questions ultimately posed were developed by Fraunhofer in close consultation with the CEA Market Research Team, which regularly performs surveys on a variety of topics. Subsequently, we processed the responses received in category-specific models to estimate the installed base of CE and CE usage. The surveys focused on CE categories with the highest energy consumption and/or greatest usage uncertainty (see Table 1), and were fielded in late 2013 and early 2014 (see Urban et al. 2014 for details).

## Power Draw by Mode

All consumer electronics have at least two basic operating modes, e.g., on and off, and most have more. For many CE, the operational power draw can vary appreciably due to changes in operation, e.g., computer microprocessor utilization scaling. For each CE category, we identified the most relevant power modes and developed estimates for the average power draw of its installed base in each mode.

Ideally, our assessment would use measurements of CE deployed in a larger sample (of at least several hundred) of demographically representative U.S. households to generate the power draw by mode estimates. Unfortunately, the cost and time required to perform such a study was beyond the scope of this project. Instead, we relied upon several different sources to estimate power draw by mode, including:

- Field measurement campaigns
- CE energy consumption characterization studies
- ENERGY STAR measurement databases
- Targeted measurements by Fraunhofer
- Manufacturer product specification
- Measurements by CEA member companies

We were able to consult multiple sources for most CE categories, which increased our confidence in our power draw by mode estimates. Urban et al. (2014) provides further detail about how the power draw by mode estimates were developed for specific categories.

## Categories Selected for Further Study

Although this study would have, ideally, evaluated the annual electricity consumption (AEC) of all CE in greater detail, time and scope constraints required that we focus our effort on the CE categories where a more refined analysis would provide the greatest value. Consequently, in conjunction with CEA, we selected 17 distinct CE products for more refined AEC analysis based on preliminary AEC estimates (higher more likely to be selected) and uncertainty in the

preliminary AEC estimate (higher more likely to be selected). In addition, we used the preliminary AEC estimates to characterize the products not selected for more refined analysis.

Table 1 summarizes the products selected for further analysis. Since a relatively small number of CE categories account for the vast majority of all CE energy consumption, this approach does not have a major impact on the accuracy of our estimate for total residential AEC.

Table 1. CE categories selected for more refined analysis

Cable Set-top Box (STB)	Included in CE Usage Survey?
Compact Audio	Yes
Computer Speaker	Yes
Desktop Computer	Yes
Internet Access Device (IAD)	No
Modem	No
Monitor	No
Portable Computer	Yes
Router	No
Satellite STB	No
Smart Phone	Yes
Speaker Dock	Yes
Stand-alone STB	No
Tablet	Yes
Telco STB	No
Television	Yes
Video Game Console	Yes

Stand-alone STBs include digital media adaptors, stand-alone digital video recorders (DVRs), and over-the-air digital television adaptors (OTA-DTA)

## Results

We estimate that about 3.8 billion CE devices in 119 million U.S. households (CEA 2013a) consumed 169 TWh of electricity in 2013. This equals about 12 percent of residential electricity consumption and 8.4 percent of residential primary energy consumption<sup>1</sup>. Figure 2 shows the breakdown of CE energy consumption by category. Three product categories, televisions, computers (including monitors and computer speakers), and set-top boxes together accounted for about 65 percent of CE electricity consumption.

<sup>1</sup> Based on DOE/EIA (2014 a,b) and DOE (2012).

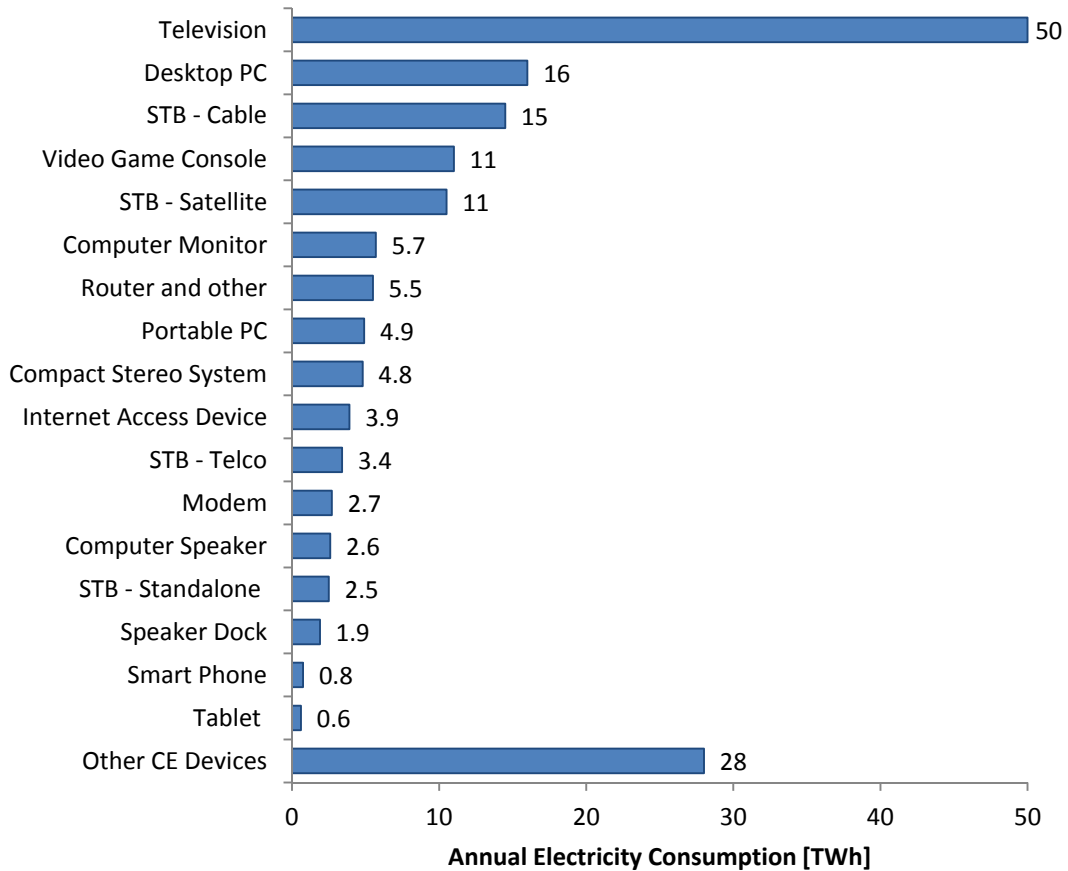


Figure 2. Residential CE electricity consumption in 2013, by category.

Figure 3 summarizes the installed base<sup>2</sup> breakdown of the categories evaluated in more detail. In addition, we estimate that there are 2.1 billion “other” CE devices in U.S. homes. Although these “other” devices account for a majority (55 percent) of the CE installed base, we estimate that they represent about 17 percent of total AEC.

<sup>2</sup> For most of the categories evaluated in more detail, the installed base estimates represent the number of devices plugged in sometime in the past month.

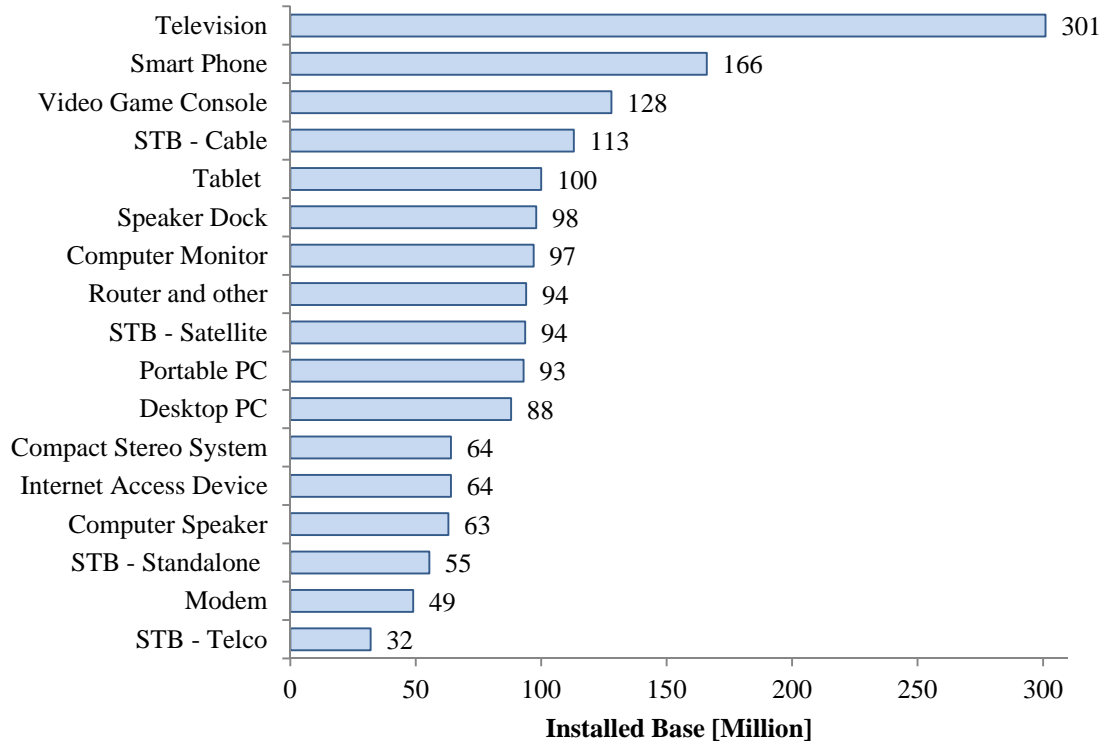


Figure 3. Residential CE installed base in 2013 for categories evaluated in more detail.

Tables 2 and 3 present the average usage and power draw by mode estimates for the categories evaluated in more detail. Please note that the mode categories presented are approximate for some CE categories. In addition, we used a different methodology to calculate the UEC of smart phones and tablets. Urban et al. (2014) contains further details about the specific operating modes used for different categories.

Table 2. Annual usage hours by mode for product categories investigated in more detail

Category	Active/On [h/year]	Idle [h/year]	Sleep [h/year]	Standby/Off [h/year]
Compact Stereo System	1,241	949		6,570
Computer Monitor	1,533		4,453	2,774
Computer Speaker	986	4,125		3,649
Desktop PC	1,248	1,541	2,088	3,883
Internet Access Device	7,826			934
Modem	7,826			934
Portable PC	1,139	620	2,202	3,601
Router and other	7,826			934
Speaker Dock	1,205	2,007		5,548
STB – Cable	5,475		3,285	
STB – Satellite	3,942		4,818	
STB - Standalone	6,826		1,935	
STB – Telco	4,818		3,942	
Television	1,606			7,154
Video Game Console	355	885		7,521

Table 3. Average power draw by mode for product categories investigated in more detail

Category	Active/On [W]	Idle [W]	Sleep [W]	Standby/Off [W]
Compact Stereo System	30	12		4.0
Computer Monitor	34		0.9	0.6
Computer Speaker	19	4.2		1.5
Desktop PC	70	56	3.4	1.6
Internet Access Device	7.7			1.5
Modem	7.1			0.1
Portable PC	30	17	1.6	1.1
Router and other	7.4			1.0
Speaker Dock	4.8	3.0		1.3
STB – Cable	16		14	
STB – Satellite	14		12	
STB - Standalone	6.1		3.1	
STB – Telco	13		11	
Television	90			1.6
Video Game Console	58	51		2.6

Figure 4 summarizes the UEC breakdown by operational mode for the categories evaluated in further detail.

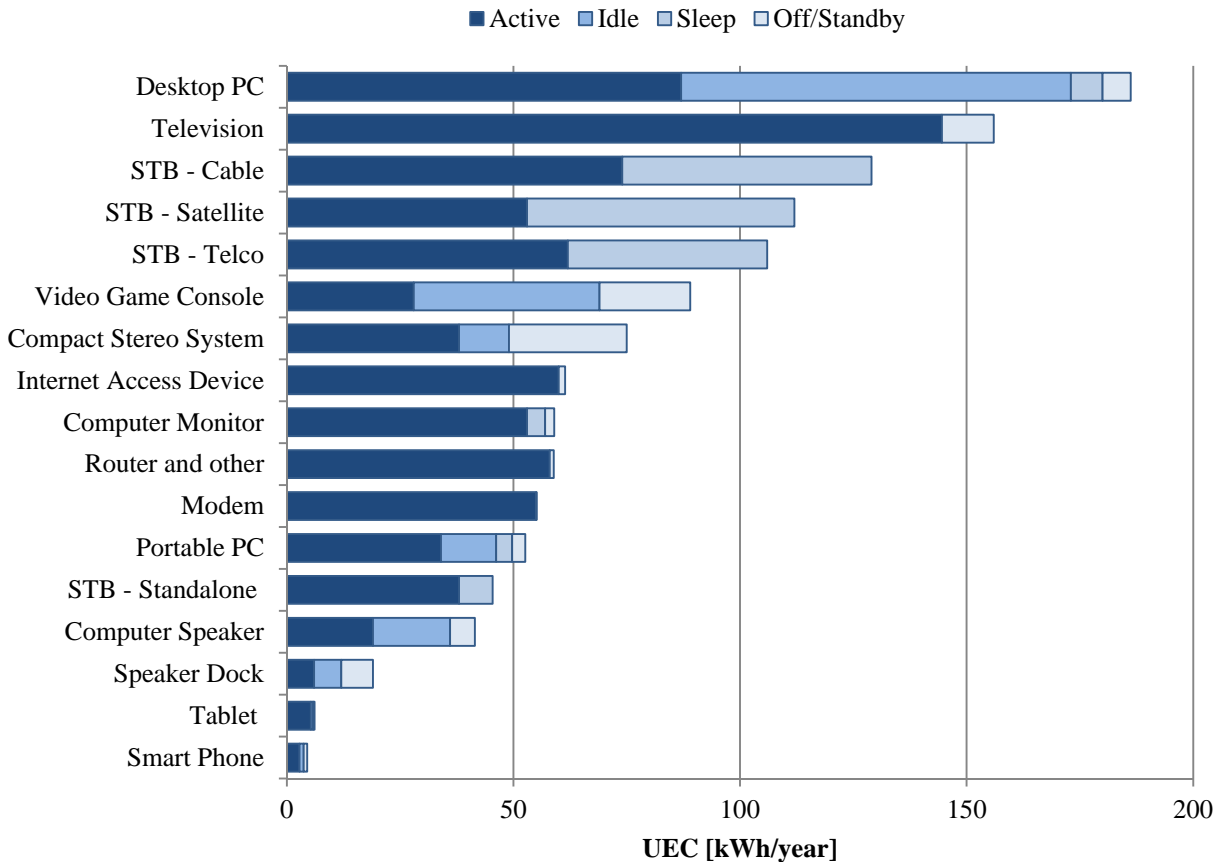


Figure 4. Breakdown of UEC by operational mode.

## Key Trends

Our estimate for residential CE electricity consumption is 12 percent lower than that for 2010 (Urban et al. 2011). The following subsections describe the key changes from 2010 responsible for this decrease for the three product categories that accounted for a majority of electricity consumption in both 2010 and 2013: televisions, computers, and set-top boxes.

### Televisions

Since the first evaluation of CE energy consumption (for 2006; Roth and McKenney 2007), televisions have always accounted for the largest portion of CE energy consumption. For the first time in over a decade, the estimated number of plugged-in TVs has decreased significantly, by 52 million units (15 percent) from 2010 to 2013. This, together with a shift from CRT to LCD TVs resulted in more than a 20% decline in estimated TV AEC from 2010 to 2013. Around 90% of the 40 million TVs sold per year are flat-panel LCD displays (CEA 2013b), and these have overtaken CRTs as the most prevalent display technology deployed in homes. Our best understanding of this decrease of TVs plugged in within the last month is that a large



portion of older, less-efficient CRT displays have been removed from service and not replaced (see Figure 5). Since our only indication of this change comes from our phone survey, its precise magnitude has some uncertainty.

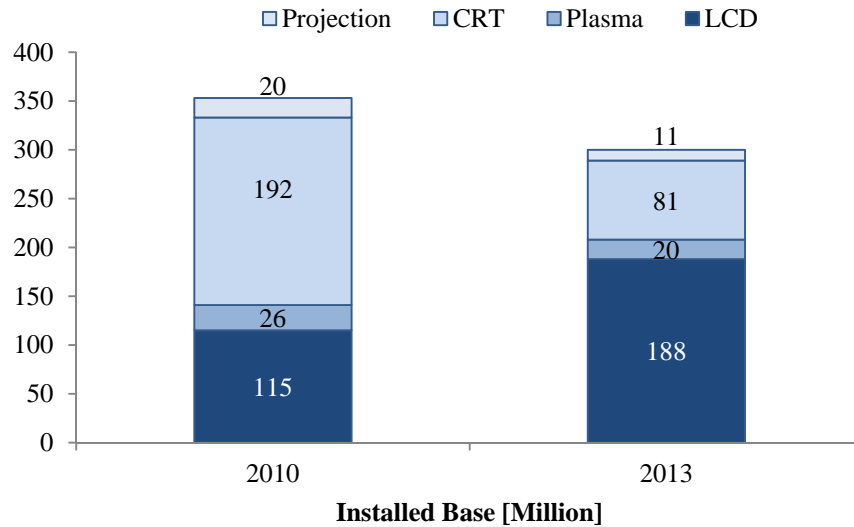


Figure 5. Breakdown of TV installed base by display technology in 2010 and 2013.

Total active TV usage has remained fairly consistent over time, while per-TV on-time has increased somewhat from 2010. Active-mode power draw has continued to decrease (from an average of 104 W in 2010 to 90 W), even while average screen size continues to increase (34 inches in 2013, up from 29 inches in 2010 [Urban et al. 2011] and 26 inches in 2006 [Roth and McKenney [2007]]), owing to the greater efficiency of newer displays.

## Computers

We evaluated three computer types as well as smart phones in more depth. Overall, the estimated total AEC of all computers has decreased by 29 percent since 2010 (see Figure 6). A migration of the installed base to much less energy-intensive tablet computers (i.e., about nine-fold lower UEC than portable PCs) and application of more refined methods to evaluate computer usage are the main drivers for this decrease.

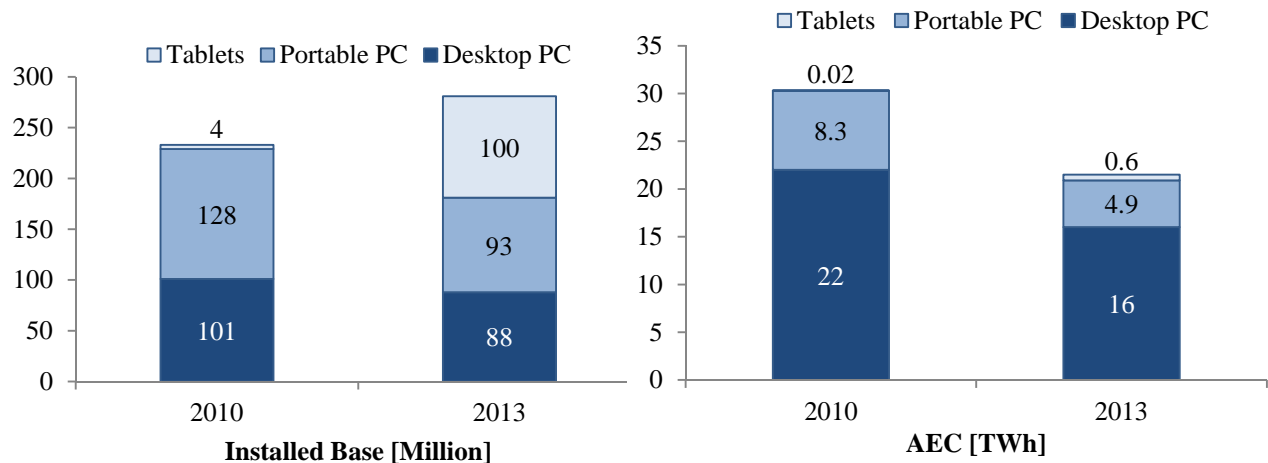


Figure 6. Breakdown of computer installed base in 2010 and 2013.

The plugged-in installed base of both desktop and portable computer decreased from 2010 to 2013 (desktop: 101 to 88 million, portable: 132 to 93 million). We believe that this is due to the 25-fold increase in the ownership of tablets, from 4 million (Urban et al. 2011) to 100 million (CEA 2013a). Including tablet computers, the installed base of all computers categories in 2013 was 19 percent higher than in 2010.

We also estimated lower annual hours spent in active mode for both desktop (18%) and portable (39%) computers in 2013 than in 2010. This primarily reflects refinements in the computer usage survey and models that we think improve the accuracy of our estimates for time in operational modes for desktop PCs. Specifically, the current approach increases the precision the survey questions posed by asking about three times of day (morning, afternoon, and evening). This provides a richer representation of usage throughout the whole day than in Urban et al. (2011). In addition, we think that breaking the day into more discrete time periods increases the accuracy of respondents' estimates for total computer usage.

One consequence of the decreased installed base of desktop and portable computers is a 26 percent decrease in the installed base of monitors<sup>3</sup>. In addition, our estimate of active-mode usage (tied to the enhanced computer usage models described above) decreased by 39 percent. That, combined with a decrease in the average power draw in all modes (due to the rise of LED backlit monitors since 2010; DisplaySearch 2014) resulted in a 40 percent decrease in UEC. Taken all together, the estimated monitor AEC decreased by 54 percent.

### Set-top Boxes (STBs)

Figure 7 depicts the breakdown of the AEC of all STBs by type in both 2010 and 2013. Since 2010, total STB AEC has increased by about 20 percent, while the installed base has increased by about 31 percent.

<sup>3</sup> Another factor is the increased portion (from 14 to 21 percent) of desktop computers that are all-in-one computers, i.e., devices with an integrated display.

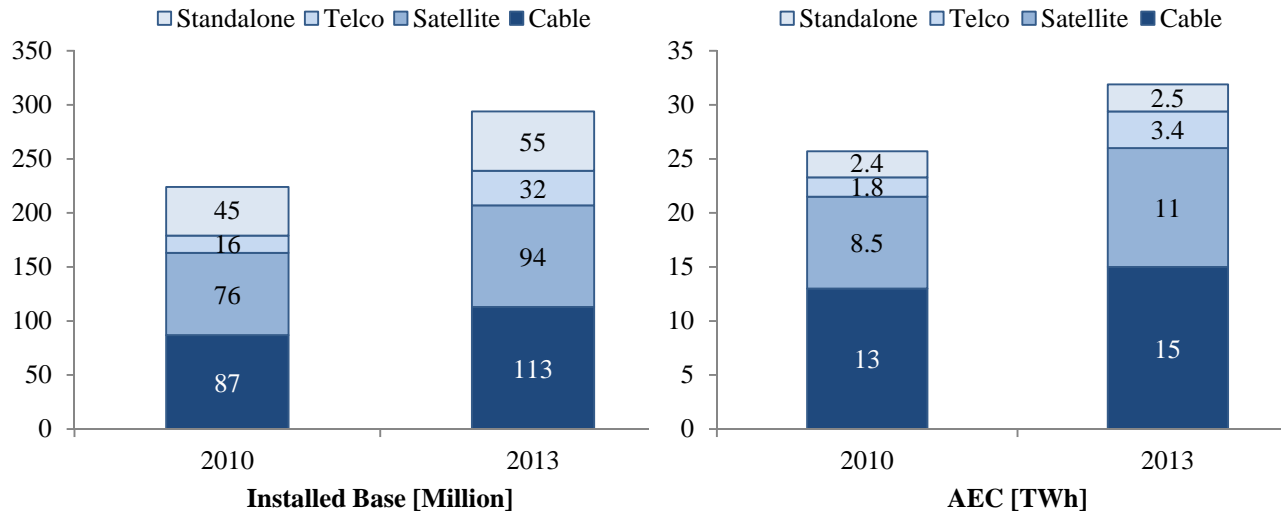


Figure 7. Breakdown of STB AEC by type in 2010 and 2013.

The installed base of cable STBs increased by about 30 percent since 2010. This mainly reflects that the number of cable digital television adaptors has almost doubled in that period, driven by providers transitioning to digital cable service. Meanwhile, the number of satellite STBs has increased by 24 percent. For both cable and satellite STBs, the portion of high-definition units has increased. In addition, the telco STBs has doubled since 2010. The average power draw by mode values for pay-TV<sup>4</sup> STBs has not changed greatly since 2010.

## Conclusions

We performed a comprehensive characterization of consumer electronics energy consumption in homes in 2013, evaluating 17 priority product categories in greater detail. For all products evaluated, we used a bottom-up methodology to evaluate AEC, developing estimates for installed base and power draw and usage by mode. The installed base estimates largely came from market research studies and the CE Usage Survey. We used power draw estimates from a wider range of sources, including field measurement campaigns, energy consumption characterization studies for individual product categories, ENERGY STAR measurement databases, targeted measurements by Fraunhofer, and manufacturer product specifications. Usage estimates were largely derived from the CE Usage Survey, a survey of 1,000 demographically representative U.S. households about how they used different CE. Notably, we refined the computer usage survey and models to improve the accuracy of our usage by mode estimates for computers. In addition, we also incorporated estimates from field monitoring studies.

We found that the approximately 3.8 billion CE devices in U.S. homes in 2013 consumed 169 TWh, representing about 12% of all U.S. household electricity use. This estimate is 12 percent lower than our 2010 estimate (Urban et al. 2011). Together, the top three device categories, televisions, computers, and set-top boxes, accounted for about 65 percent of the energy consumed. Relative to the evaluation of CE energy consumption in 2010, the AEC of televisions has decreased by more than 20 percent, reflecting a decrease in the installed base of

<sup>4</sup> Pay-TV services include cable, satellite, and telco.

older CRT TVs and average TV power draw in all modes. Since 2010, the installed base of all computers, including tablets, has increased by 19 percent. Their installed base has shifted away from desktop and portable computers to tablets. Due to the much lower UEC of tablets relative to these other computer architectures, e.g., about a nine-fold lower UEC than portable computers, we estimate that total computer AEC has decreased by 29 percent. In a related trend, we estimate that the installed base and AEC of monitors have decreased by 26 and 54 percent, respectively. Finally, the estimated AEC of STBs increased by 20 percent, while the installed base of STBs grew by about 31 percent.

## References

- CEA. 2013a. "15th Annual CE Ownership and Market Potential Study." CEA Market Research Report, April, 2013. Consumer Electronics Association.
- CEA. 2013b. "U.S. Consumer Electronics Sales & Forecasts 2009-2014." CEA Market Research Report, July, 2013. Consumer Electronics Association.
- DisplaySearch. 2014. "Quarterly Desktop Monitor Shipment and Forecast Report, 2011-13".
- DOE. 2012. **2011 Buildings Energy Databook**. U.S. Department of Energy, Energy Efficiency and Renewable Energy. March.
- DOE/EIA. 2014a. "Electric Power Monthly: Table 5.1. Retail Sales of Electricity to Ultimate Customers". U.S. Department of Energy, Energy Information Administration. February 21.
- DOE/EIA. 2014b. *Annual Energy Outlook 2014 Early Release: Energy Consumption by Sector and Source*. U.S. Department of Energy, Energy Information Administration. Accessed March 6.
- Kawamoto, K., J. Koomey, B. Nordman, R. Brown, M.A. Piette, M. Ting, and A. Meier. 2001. "Electricity used by office equipment and network equipment in the U.S.: Detailed report and appendices." Lawrence Berkeley National Laboratory Final Report, LBNL-45917. Feb.
- Roth, K., F. Goldstein, and J. Kleinman. 2002. "Energy Consumption by Office and Telecommunications Equipment in Commercial Buildings - Volume I: Energy Consumption Baseline." Final Report by Arthur D. Little, Inc. to U.S. Department of Energy, Office of Building Equipment. Jan.
- Roth, K., R. Ponoum, F. Goldstein. 2006. "U.S. Residential Information Technology Energy Consumption in 2005 and 2010." Final Report by TIAX LLC to the U.S. Department of Energy, Building Technology Program. Mar.
- Roth, K., and K. McKenny. 2007. "Energy consumption by consumer electronics in U.S. Residences." Final Report to the Consumer Electronics Association (CEA). Jan.
- Roth, K., K. McKenny, R. Ponoum, and C. Paetsch. 2008. "Residential miscellaneous electric loads: energy consumption characterization and savings potential in 2006 and scenario-

based projections for 2020.” Final Report by TIAX LLC to the U.S. Department of Energy, Building Technology Program. Apr.

Urban, B., V. Shmakova, B. Lim, and K. Roth. 2014. “Energy Consumption of Consumer Electronics in U.S. Homes in 2013”. Final Report by the Fraunhofer Center for Sustainable Energy Systems to the Consumer Electronics Association. June.

Urban, B., V. Tiefenbeck, and K. Roth. 2011. “Energy Consumption of Consumer Electronics in U.S. Homes in 2010”. Final Report by the Fraunhofer Center for Sustainable Energy Systems to the Consumer Electronics Association. Dec.