Fraunhofer USA Center for Sustainable Energy Systems

ENERGY CONSUMPTION OF CONSUMER ELECTRONICS IN U.S. HOMES IN 2013

FINAL REPORT TO THE CONSUMER ELECTRONICS ASSOCIATION (CEA®)

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by Bryan Urban, Victoria Shmakova, Brian Lim, and Kurt Roth

PI
Dr. Kurt Roth, Building Energy Efficiency Group Leader
kroth@fraunhofer.org 617 575-7256

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List of Acronyms and Abbreviations

AEC	Annual electricity consumption
AVR	Audio-video receivers
CE	Consumer electronics
CEA	Consumer Electronics Association
DOE	U.S. Department of Energy
DTA	Digital terminal adapters[1]
DVD	Digital versatile disc
DVR	Digital video recorder
EP	Electro-photographic
EPA	U.S. Environmental Protection Agency
HD	High definition
IAD	Integrated Access Device
LBNL	Lawrence Berkeley National Laboratory
MFD	Multi-function device
NA	Not applicable
NRD	Natural Resources Defense Council
PC	Personal Computer
STB	Set-top box
TEC	Total energy consumption, Typical energy consumption
TV	Television
TWh	Terawatt-hour
UEC	Unit electricity consumption
USB	Universal Serial Bus
VCR	Video cassette recorder

[1] Also called digital-to-analog converter boxes, digital transport adapters, and digital television adapters.

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Executive Summary

The Consumer Electronics Association (CEA®) commissioned this study to quantify the electricity consumption of consumer electronics (CE) in U.S. households in 2013. Relative to other energy end uses, the characteristics of CE typically change very quickly due to short product cycles and lifetimes, evolving usage patterns and dynamics, and rapid technology adoption that can strongly influence device power draw by mode. As a result, the characteristics of the installed base of most CE can change dramatically in a few years. 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 programs, they can lead to less effective policy decisions that may not achieve their end goals.

We used a bottom-up approach to characterize U.S. residential consumer electronics (CE) energy consumption in 2013. Our effort focused on 17 priority categories, shown in Table ES-1. We selected these 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 developed preliminary estimates for 29 other CE categories. For each CE category, we used a range of sources to develop estimates for the installed base and average power draw and annual usage by mode.

Table ES-1: Consumer electronics analyzed in further detail.

Audio-Visual Equipment		**Computers & Peripherals**	
Home Audio	Set Top Boxes	Desktop PC	Networking Equipment
Speaker Dock	Cable	Portable PC	Integrated Access Device
Compact Stereo System	Standalone	Computer Speakers	Modem
Televisions	Satellite	Computer Monitor	Router
Video Game Consoles	Telco	Smart Phone	
		Tablet	

Notably, we developed five (5) phone surveys to assess the usage of CE in greater detail, with a particular focus on refining our understanding of audio personal computer, smart phone, tablet, television, and video game console usage by mode. Subsequently, we used the survey responses as inputs into detailed usage-by-mode models.

Overall, we estimate that the 3.8 billion CE in homes consumed 169 TWh in 2013, an amount equal to 12% of residential electricity consumption and 8.4% of residential primary[2] energy consumption. Figures ES-1 and ES-2 show the breakdown in annual electricity consumption (AEC) by category and device.

[2] Residential primary energy is the total energy content of the fuel required to meet all end uses. Primary energy includes the fuel consumed at the home, as with non-electric space heating applications and appliances (e.g., oil or gas furnaces, gas powered clothes dryers, etc.), as well as fuel consumed at the power plant to generate electricity and to overcome transmission and distribution losses. For example, when a home consumes 1 kWh of electricity, the power plant must consume an average of 3.1 kWh of primary energy (DOE 2012).

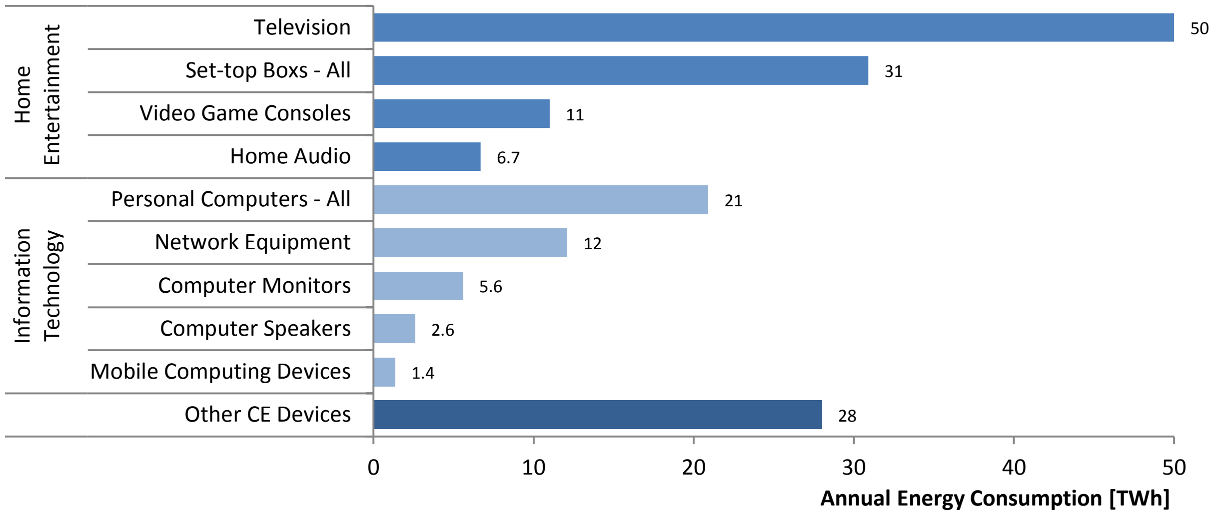


Figure ES-1: Residential CE annual electricity consumption by category.

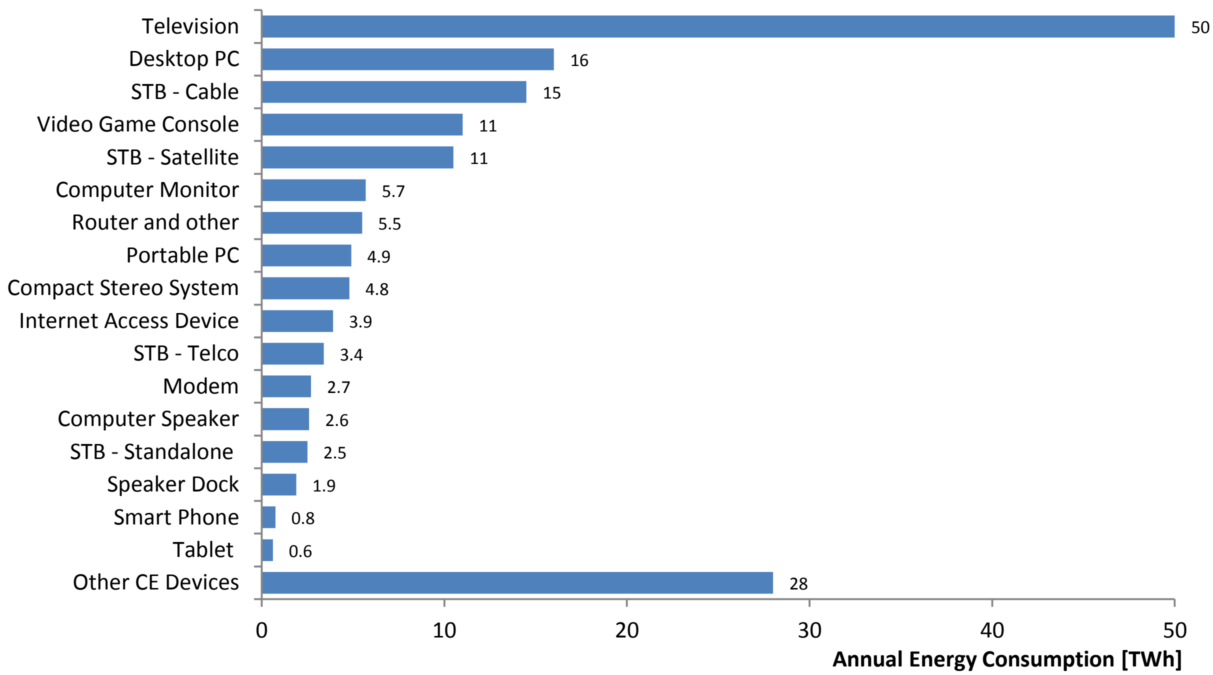


Figure ES-2: Residential CE annual electricity consumption by device.

A limited number of CE categories accounted for the majority of CE electricity consumption. Notably, televisions accounted for 30% of residential CE electricity consumption, set-top boxes 18%, and computers 13%. The AEC of all the categories analyzed in further detail equals 83% of the estimated total residential CE AEC.

The average unit electricity consumption (UEC) of the categories evaluated in detail varies greatly among categories, with more than an order of magnitude difference between the categories with the highest and lowest UEC, shown in Figure ES-3.

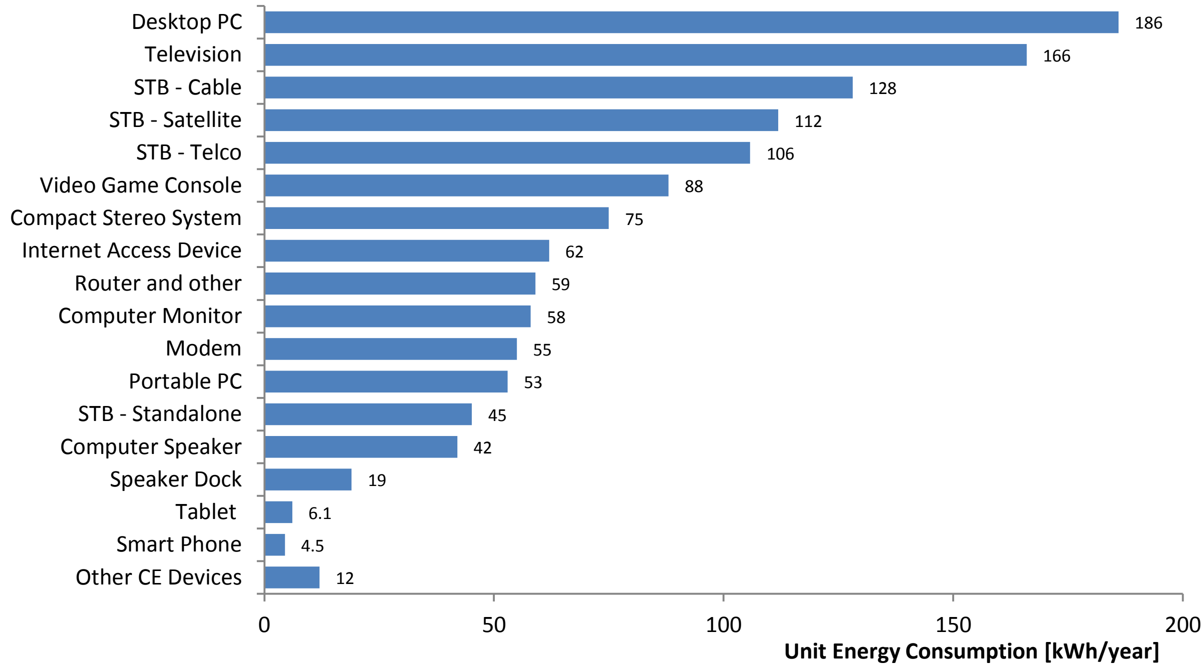


Figure ES-3: Annual unit electricity consumption for categories evaluated in detail.

The active mode accounts for 70% of the total AEC of all the categories evaluated in more detail, while the idle, sleep, and off modes account for 12, 11, and 7 percent, respectively. This masks large differences in the distribution of UEC by mode among different CE categories.

1 Introduction

The Consumer Electronics Association (CEA) commissioned this study to quantify the electricity consumption of consumer electronics (CE) in U.S. households in 2013 as a follow-up to the two prior studies it commissioned for 2006 (Roth and McKenney 2007) and 2010 (Urban et al. 2011). Relative to other energy end uses, the CE end use characteristics typically change very quickly due to innovation, short product cycles and lifetimes, evolving usage patterns and dynamics, and rapid technology adoption that can strongly influence device power draw by mode. As a result, the characteristics of the installed base of most CE have changed dramatically since the first study.

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 programs, they can lead to less effective policy decisions that may not achieve their end goals. Consequently, CEA commissioned this follow-up study to provide high-quality data to inform public policy decisions affecting CE.

1.1 Approach

This study used the same approach as the first two CE energy consumption studies:

1. Develop preliminary Annual Energy Consumption (AEC) estimates for a long list of CE
2. Select a subset of priority CE for more refined analysis
3. Develop more refined AEC estimates for the priority categories
4. Compare current energy consumption characteristics with prior estimates
5. Compose a Final Report to CEA suitable for widespread distribution

1.2 Report Organization

The report has the following organization:

Section 2 describes the methodology used to characterize CE energy consumption.

Section 3 presents an overview of CE energy consumption and the detailed analyses for the priority CE categories.

Section 4 presents the conclusions of this study.

Appendix A contains the CE Usage Survey.

Appendix B explains our methodology for estimating computer and monitor usage by mode based on the CE Usage Survey responses.

2 Energy Consumption Calculation Methodology

We used a bottom-up approach to evaluate the annual electricity consumption (AEC) of each CE category shown in Figure 2-1. For each device we developed estimates for the annual average usage in each power mode (in hours) and multiplied them by the estimated average power draw in that mode (in watts) to calculate the unit electricity consumption (UEC) by mode. The sum of the UEC over all modes equals the total device UEC, and the product of the UEC and installed base equals the AEC. The modes shown in Figure 2-1 are illustrative and were tailored for the analysis of each specific category.

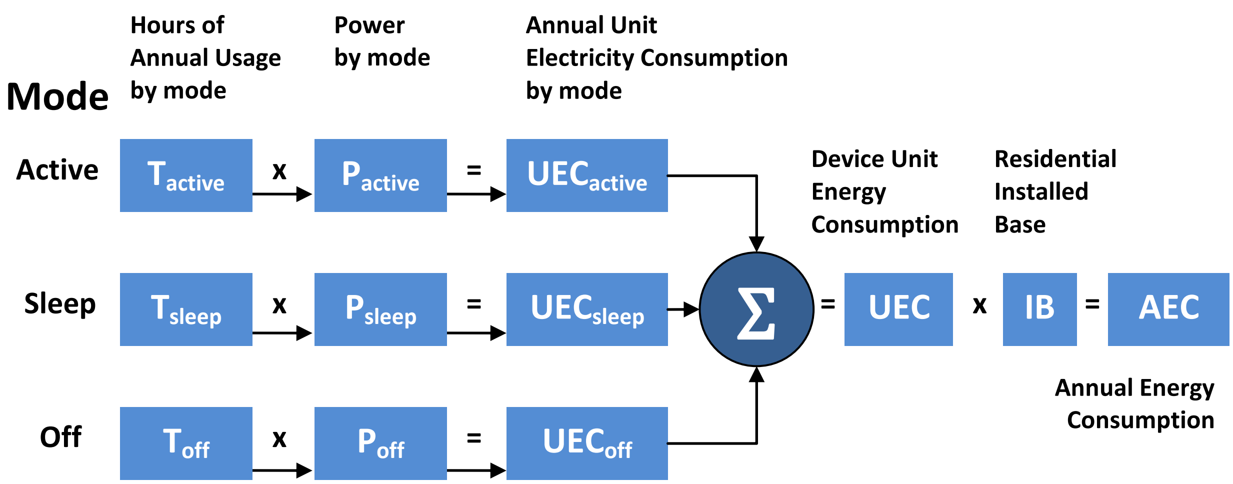


Figure 2-1: UEC and AEC calculation methodology (ADL 2002).

Prior studies of CE energy consumption describe the methodology in further detail (Kawamoto et al. 2001, Roth et al. 2002, Roth et al. 2006, etc.). A succinct overview of how we typically evaluated each component of the AEC calculation follows.

2.1 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 2013 a,b), the CE Usage Survey (see Appendix A), and, to a lesser extent, CE sales data. Typically, the installed base estimates have the lowest uncertainty of any AEC component.

2.2 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, imaging equipment activity, and (in some cases) display brightness. 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. Regrettably, the cost and time required to perform such a study lies well 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
- 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.

2.3 Annual Usage by Mode

For most CE categories, the annual number of hours that an average device spends in different power modes is the most difficult aspect of the UEC calculation to accurately estimate. Ideally, the usage estimates would be based on a sustained field measurement campaign that accurately recorded the time that all CE spent in different modes from a sample of at least several hundred demographically representative U.S. households, over the course of weeks or months. Unfortunately, such a thorough evaluation is beyond the scope of this study.

We used instead a combination of approaches to estimate annual usage by mode, including:

- The CE Usage Survey (see Appendix A)
- Data from prior field measurement campaigns[3]
- Data from prior CE energy consumption characterization studies

Notably, we used the CE Usage Survey responses as inputs into more refined models to assess computer and monitor usage (see Appendix B). We posed more questions for computers and video game consoles because they have higher AEC values that have particularly high – and are highly sensitive to – uncertainties in their usage. In addition, we included several questions about smart phone and tablet usage because their energy consumption had not been thoroughly characterized in the past. Finally, we also fielded surveys about audio products and televisions.

[3] Although very useful, prior field measurement campaigns usually fall short of the ideal described due to a limited and biased (i.e., non-random and unrepresentative) sample of households used and devices measured.

3 Energy Consumption of Consumer Electronics in U.S. Homes

3.1 Summary

We estimate that 3.8 billion residential consumer electronics consumed approximately 169 TWh of electricity in 2013 (see Table 3-1 and Figure 3-1), an amount equal to 12% of residential electricity consumption and 4.5% of total U.S. electricity consumption in 2013 (DOE/EIA 2014a,b). This translates into 8.4 and 1.8 percent of residential and U.S. total primary energy consumption[4], respectively (DOE/EIA 2014a,b).

Table 3-1: Residential CE energy consumption summary.

Device	UEC [kWh/yr]	Installed Base [millions]	AEC [TWh]
Computers			
Desktop	186	88	16
Portable	53	93	4.9
Computer Speakers	42	63	2.6
Computer Monitors	58	97	5.7
Network Devices			
Integrated Access Device	62	64	3.9
Modem	55	49	2.7
Router	59	94	5.5
Set-top Boxes	75	67	5.0
Cable	128	113	15
Standalone	45	55	2.5
Satellite	112	94	11
Telco	106	32	3.4
Shelf-Stereo / Compact Audio	75	64	4.8
Smart Phone	4.5	166	0.8
Speaker Dock	19	98	1.9
Tablet Computer	6.1	100	0.6
Television	166	301	50
Video Game Consoles	88	128	11
Other CE Devices	12	2,110	28
Total	**NA**	**3,809**	**169**

The remainder of this section presents the analyses for the devices selected for further analysis.

[4] Using 10,462 Btu of primary energy per kWh of electricity (DOE 2012).

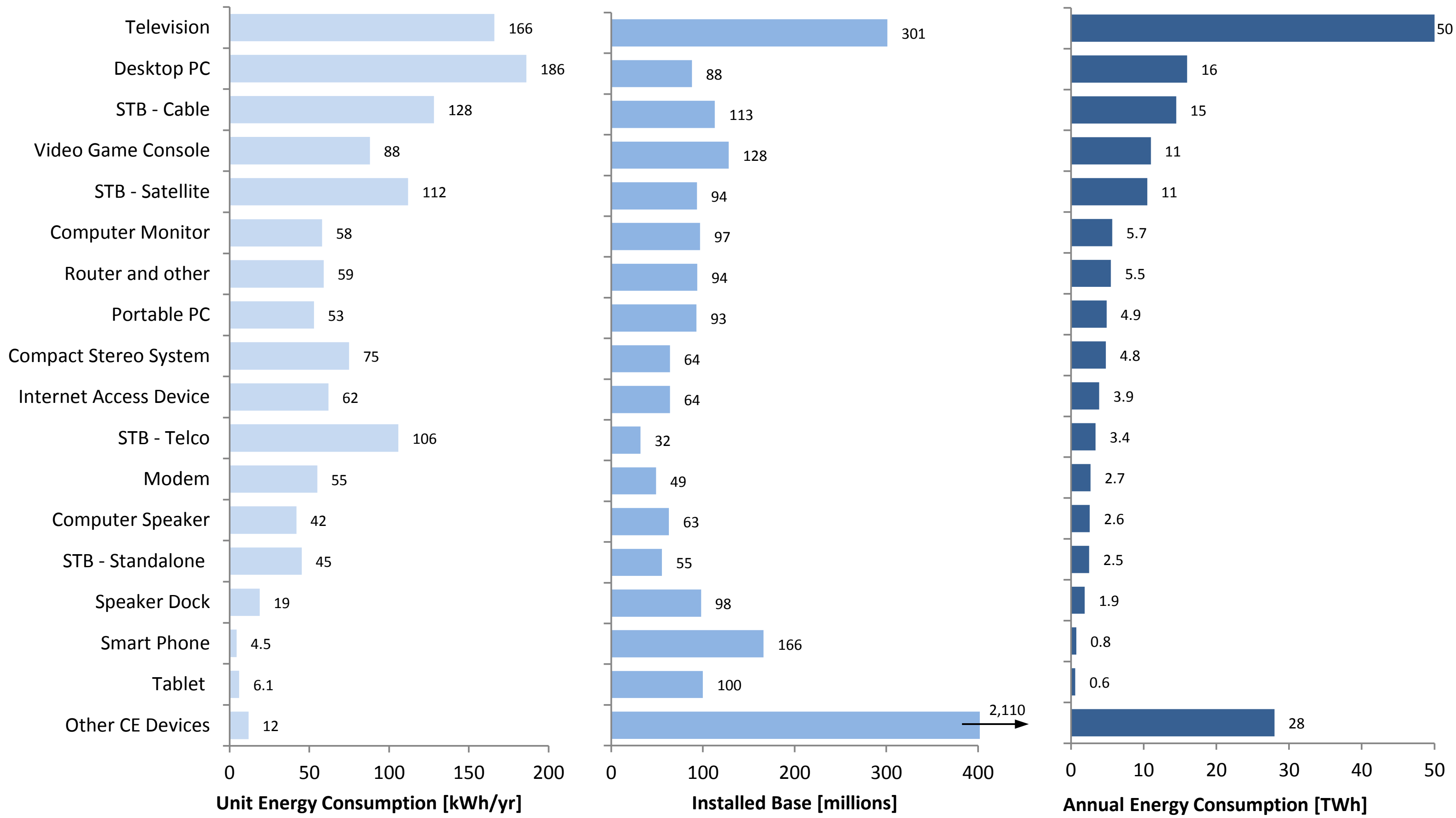


Figure 3-1 : UEC, installed base, and AEC of CE categories evaluated in detail.

3.2 Devices Selected for Further Analysis

Although this study would have, ideally, evaluated the AEC of all CE in greater detail, time and scope constraints required that we focus our effort on a subset of CE where a more refined analysis would yield the greatest value. Consequently, in conjunction with CEA, we selected 17 distinct CE categories for more refined AEC analysis based on:

- Preliminary AEC estimates (higher more likely to be selected)
- Uncertainty in the preliminary AEC estimate (higher more likely to be selected).

Table 3-2 summarizes the categories selected for further analysis. Since a relatively small number of CE categories account for the vast majority of all CE energy consumption (see Table 3-1), this approach does not have a major impact on the accuracy of our estimate for total residential AEC.

Table 3-2: CE analyzed in the current study.

Analyzed in Higher Detail	Analyzed in Lesser Detail
Computer Speaker	AV Receiver with surround sound processor
Computer - Desktop	Bluetooth Headset
Computer - Portable	Blu-ray player
Integrated Access Device	Boombox
Modem	Camcorder
Computer Monitor	Copy machine (stand-alone)
Router	Cordless phone
Set-top Box – Cable	Digital camera
Set-top Box – Standalone	Digital picture frame
Set-top Box – Satellite	DVD Player
Set-top Box – Telco	eReader
Shelf-Stereo / Compact Audio	External Storage Device
Speaker Dock	Fax Machine (stand-alone)
Smart Phone	Handheld GPS
Tablet Computer	Headphones
Television	Home Theater in a Box (HTIB)
Video Game Console	Internet Phone Device
	Mobile (non-smart) Phone
	Portable DVD or Blu-ray disc player
	Portable Game Devices
	Portable media/MP3 Player/CD Player
	Portable Wireless Speaker
	Printer + MFD (multi-functional device)
	Projector
	Radio
	Scanner (stand-alone)
	Soundbar
	Telephone Answering Device
	Video Cassette Recorder (VCR)

3.3 Computer Speakers

3.3.1 Current Energy Consumption

Computer speakers are defined as external, self-powered systems that reproduce audio signals generated by a computer. They typically incorporate a built-in amplifier powered by a dedicated internal or external power supply that draws less power than home theater and stereo systems. Some smaller systems, especially for portable computers, are powered directly through a USB port. This analysis excludes those devices, as in the previous report (FhCSE 2011). A typical computer speaker system configuration includes either two speakers without a subwoofer, or two or five speakers with a subwoofer (2.1 system/5.1 channel surround system). We were unable to find precise data on the breakdown of speaker systems by the number of channels they have; however, we were able to breakdown the installed base between speakers with and without a subwoofer in this study.

3.3.1.1 Installed Base

The 2013 CE Usage Survey included questions about two types of computer speaker systems in households, namely, computer speakers with and without a subwoofer. Figure 3-2 summarizes the results for the portion of desktop and portable computers with zero, one, two, three or four and more computer speaker systems with and without subwoofer connected. The CE Usage Survey found that 40% of primary computers (i.e., the most-used computer in a household) were connected to at least one computer speaker system without a subwoofer and 19% of primary computers were connected to a computer speaker system with a subwoofer. On average, secondary desktop computers had slightly fewer computer speaker systems without and with a subwoofer, 29% and 16%, respectively. We did not ask about speakers connected to a third computer. Instead, we assumed that the proportion of the remaining computers with a speaker system has not changed from 2010, i.e., we estimated that 16% of tertiary desktop computers had an external speaker (FhCSE 2011). In contrast, the survey responses indicated that less than 10% of primary and secondary portable computers were connected to any kind of computer speaker system. In total, we estimate that 72% of all residential computers are not connected to a computer speaker system.

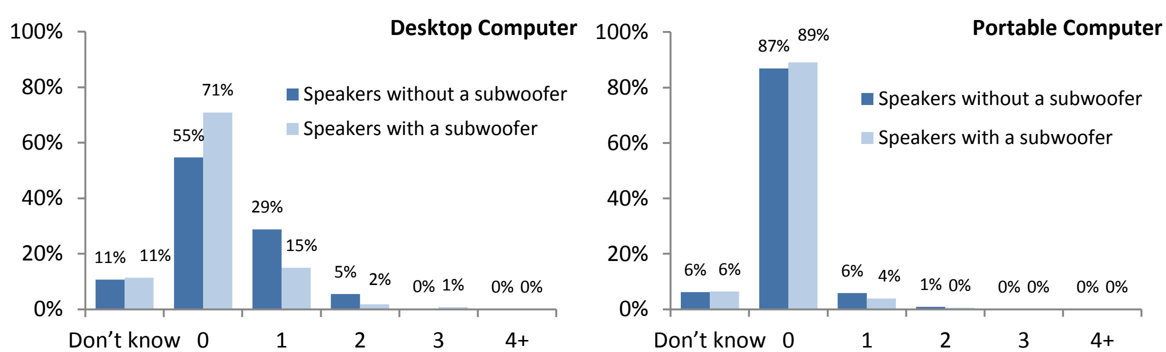


Figure 3-2: Distribution of computer speaker systems per desktop and portable computer.

The CE Usage Survey data for computers found an installed base of the 88 million home desktop computers and 93 million home portable computers, of which 60% and 57% are used as the primary desktop computer and primary portable computer, respectively. This yields an installed base of 63 million computer speaker systems (Table 3-3), and represents a 15 percent decrease in the installed base of computer speaker systems from 2010 (FhCSE 2011). This likely is due to the recent decrease in the installed base of desktop PCS (13% since 2010), since the survey indicates that most computer speakers are used with desktop PCs.

Table 3-3: Installed base of computer speaker systems (CE Usage Survey).

Type	Home Computers [millions]	% with speakers and no subwoofer	% with speakers and a subwoofer	Total [millions]
Desktop	88	39%	20%	**52**
Portable	93	7%	5%	**11**
Total/Avg.	**181**	**23%**	**12%**	**63**

The data indicate a household penetration rate of 35% for computer speaker systems without a subwoofer and 18% for speaker system with a subwoofer. We could not find other estimates for the installed base of computer speaker systems.

3.3.1.2 Unit Energy Consumption

3.3.1.2.1 Power Draw

Computer speaker systems can be characterized by three operating modes (FhCSE 2011):

- *Active* – Device is actively used, playing music or other audio
- *Active standby* – Device is neither playing audio, nor turned off manually
- *Off* – Device is turned off manually but remains connected to the energy source.

Since we could not find new data sources for computer speaker power draw by mode, we measured the power draw in Jan. 2014 of two computer speaker systems with a subwoofer (2.1 channel) and one computer system without a subwoofer (2.0). Specifically, we selected computer speaker systems to measure from the best-selling units sold at Amazon.com and Best Buy. The one 2.0 computer speaker system had a maximum power draw of 4 W at maximum volume, whereas in 2010 a 2.0 computer speaker system drew an average 6 W in active mode (Meister et al. 2011).

Due to the limited number of measurements, we used straight averages to calculate the power draw for computer speakers in different modes. The straight average power draws for computer speakers without a subwoofer, we estimated from 18 speakers[5] measured by ECOS (Meister et al. 2011), 6 speakers measured by ECW (Bensch et al. 2010), and the one 2.0 speaker system we measured in 2014. In contrast, a very small sample (n=4) of 2.1 system power draw measurements from Meister et al. (2011) and Fraunhofer[6] has an average power draw of 44W. Results are shown in Table 3-4.

[5] Meister et al. (2011) notes n=18 in the Appendix and n=20 in its Figure 17.
[6] Two 2.1 computer speaker systems were measured and had an average active-mode power draw of 15W.

Table 3-4: Power draw by mode for computer speaker systems.

Type	Power [W]			Sources
	Active	Active Standby	Off	
Without Subwoofer	5.5	2.4	1.6	Fraunhofer measurements, Meister et al. 2011, Bensch et al. 2010
With Subwoofer	44	7.5	1.2	Fraunhofer measurements, Meister et al. 2011

3.3.1.2.2 Usage

We did not ask about computer speaker usage in the 2013 CE Usage Survey, so we based our usage estimates on the findings from the 2010 CE Usage Survey (FhCSE 2011). Thus, we assumed that usage patterns have not changed appreciably since 2010. We did, however, scale the 2010 usage estimates with computer usage in 2013. In the 2010 CE Usage Survey, 61% of U.S. adults answered that their computer speakers are always on when the computer is used, i.e. 3.1 hours per day on average, another 30% are on often or half of the time the computer is used, which results in an active use of 2.7 hours per day. The data suggest in 2010 that 61% of computer speaker systems are not switched off over night. During the day when the computer is not in use, 39% of computer speakers are never off, while 54% are reported to be always or often off and 17% are reported off occasionally or half of the time. Overall, this suggests that the average speaker system spends 11% of the day in active mode, 47% of the time in active standby mode, and 42% of time in off mode (Table 3-5).

Table 3-5: Annual usage by mode of computer speaker systems (hours/year).

Active	Active standby	Off	Sources
986	4,125	3,649	Current study computer usage, FhCSE 2011

Versions 2.0 and 3.0 of the ENERGY STAR specifications for audio products both require qualifying devices to have auto power down (APD) functionality with a default setting of two hours or less. This would tend to decrease the time spent in active standby mode by ENERGY STAR devices (EPA 2013). As of May, 2014, the ENERGY STAR products database did not include any computer speakers; therefore we did not include APD in our computer speaker usage model.

3.3.1.2.3 Unit Energy Consumption

We calculate a computer speaker UEC of 42 kWh/year (see Table 3-6).

3.3.1.3 Annual Energy Consumption

We estimate that computer speakers consumed 2.6 TWh in 2013. Systems with a subwoofer accounted for about 65% of the AEC (see Figure 3-3 and Table 3-6).

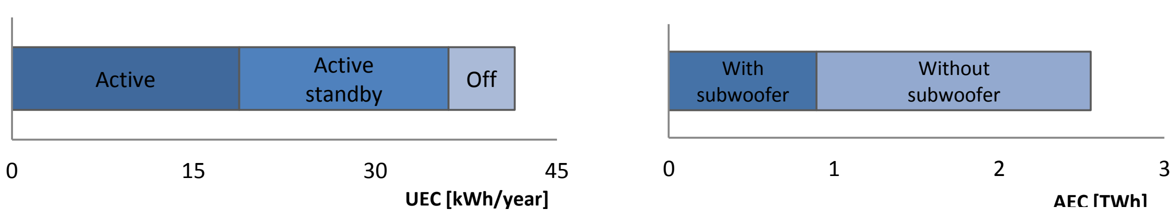


Figure 3-3: Unit Energy Consumption by mode and Annual Energy Consumption by computer speaker system type.

Table 3-6: UEC and AEC calculation for computer speaker systems.

Type	Installed [millions]	Percent	Power [W]			UEC [kWh/yr]				AEC [TWh]
			Active	Standby	Off	Active	Standby	Off	*Total*	
Without Subwoofer	42	65%	5.5	2.4	1.6	5.4	10	6.0	***21***	**0.9**
With Subwoofer	21	35%	44	7.5	1.2	44	31	4.5	***79***	**1.7**
Total/Wt. Avg.	**63**	**100%**	**19**	**4.0**	**1.5**	**19**	**17**	**5.5**	***42***	**2.6**

3.3.2 Comparison with Prior Energy Consumption Estimates

We estimate that the UEC value has increased from 2010 due to the integration of higher power speakers systems with subwoofers into our energy model. On the other hand, total AEC decreased 7% from 2010, reflecting a 15% decrease in the installed base of computer speakers systems (Table 3-7).

Table 3-7: Prior energy consumption estimates for computer speaker systems.

Year	Installed [millions]	Power [W]			Usage [h/yr]			UEC [kWh/yr]	AEC [TWh]	Source
		Active	Standby	Off	Active	Standby	Off			
2013	63	19	4	1.5	986	4,125	3,649	42	2.6	Current
2010	74	8	4	3	1,314	4,380	3,066	37	2.8	FhCSE 2011

3.3.3 References

ECW. Bensch, I., S. Pigg, K. Koski and R. Belshe. 2010. “Electricity Savings Opportunities for Home Electronics and Other Plug-In Devices in Minnesota Homes – A technical and behavioral field assessment.” Final Report by the Energy Center of Wisconsin, Report 257-1. May.

EPA. 2013. ENERGY STAR program requirements Audio/Video. Version 3.0. U.S. Environmental Protection Agency. http://www.energystar.gov/ia/partners/prod_development/revisions/downloads/audio_video/Final_Version_3_AV_Program_Requirements.pdf?5c24-7fe5. May.

FhCSE. Urban, Bryan, Kurt Roth, and Verena Tiefenbeck. 2011. “Energy Consumption of Consumer Electronics in U.S. Homes in 2010.” Final Report to the Consumer Electronics Association. http://www.ce.org/CorporateSite/media/Government-Media/Green/Energy-Consumption-of-CE-in-U-S-Homes-in-2010.pdf. Dec.

Meister, B.C., C. Scruton,V. Lew, L. ten Hope and M. Jones. 2011. “Office Plug Load Field Monitoring Report.” Final Field Project Report by Ecos Consulting to the California Energy Commission. http://www.energy.ca.gov/2011publications/CEC-500-2011-010/CEC-500-2011-010.pdf. Apr.

3.4 Desktop Computers

Desktop computers include personal computers (PCs) housed in a box and computers with built-in monitors called All-in-One (AIO) PCs (also known as integrated desktop computers), such as iMac.

3.4.1 Current Energy Consumption

3.4.1.1 Installed Base

We estimate an installed base of 88 million desktop PCs that have been used in the past month. This equals 83% of the ownership installed base of 105-113 million estimated reported by CEA (2013a,b). As with our 79% plugged-in rate in 2010 (FhCSE 2011), this difference likely reflects that some desktop PCs in homes have not been recently used. Indeed, our estimate of ownership penetration for desktop PCs of 62% agrees with other sources (see Table 3-8).

Although our plugged-in penetration estimate of 44% is lower than our previous report (62%, Fraunhofer 2011), we think it is more accurate, because the 2013 CE Usage Survey includes questions that more precisely distinguish between device ownership and plugged-in status during the past month. Therefore, these results provide a richer representation of the plugged-in and ownership installed bases.

Table 3-8 : Installed base estimates for desktop PCs from different data sources.

Year	Description	Household penetration	Households [millions]	Units/owner household	Installed Base [millions]	Source
2013	Desktop PCs plugged in last month	44%	53	1.67	88	CE Usage Survey
2013	Desktop PC ownership	62%*	74	-	-	CE Usage Survey
2013	Desktop PC ownership	63%	75	1.41	105	CEA 2013a
2013	Desktop PC ownership	-	-	-	113	CEA 2013c
2013	Desktop PC ownership	-	-	-	114	DRG 2013
2011	Desktop or portable PC ownership	76%†	-	-	-	U.S. Census 2013
2012	Desktop or portable PC ownership	-	-	1.80‡	-	A&E 2012
2013	Desktop PCs plugged in	-	-	-	88	*Representative*

* Estimated based on survey responses that indicated no ownership of desktop PCs (0 desktop PCs plugged in, but ≥1 owned, see Figure 3-4).

To understand PC usage, we asked about the most used (primary) and second-most used (secondary) desktop PCs. We classified desktop PCs without an external monitor as an AIO unit. In addition, we assumed that AIO desktop PCs will tend to be the primary or secondary desktops given their recent introduction into the market.

Table 3-9: Plugged-In installed base estimates for Tower and All-in-One (AIO) Desktop Computers from CE Usage Survey.

Type	Households [millions]							Plugged-In [million units]		
		PCs Plugged-In per Owner Household								
	Not Owned	0	1	2	3	≥4	≥1†	All	Primary	Second+
Tower	45	21	26	4.1	1.8	3.4	35	69.6	37	34
All-in-One	-	-	16	1.0	-	-	17	18.0	16	1.0
Any Desktop	45	21	42	5.1	1.8	3.4	53	87.6	53	35

† Equivalent to the household penetration of plugged-in PCs.
Primary: number of primary PCs.
Second+: number of PCs that are not primary, i.e., secondary, tertiary, etc.; treated as secondary in energy model.

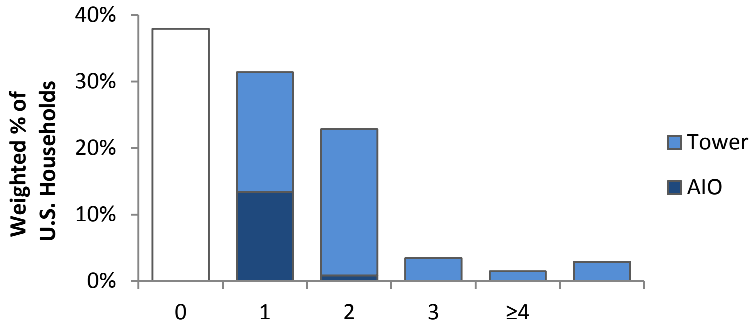


Figure 3-4: Distribution of households with numbers of desktop PCs plugged in during the past month (Nov 2013).

We compared the AIO installed base estimates with sales data from DisplaySearch (2011-2013). Given an average age of desktop PCs of 3.2 years (CEA 2014), we consider a retirement age of 4 years for AIO desktop PCs along with sales of AIO PCs since 2009 to develop another estimate of the installed base of AIO desktop PCs of 16.3 million. This assumes that no units sold since 2009 have been retired (see Table 3-10). This generally agrees with the 18 million units from the 2013 CE Usage Survey.

Table 3-10: Plugged-In installed base estimate for All-in-One Desktop Computers based on sales via consumer channels (DisplaySearch 2014).

	2009[e]	2010	2011	2012	2013 Q1-Q3
Sales (All North America)	-	3.6	3.2	3.1	3.7
Sales (U.S. Only)[†]	-	3.2	2.9	2.8	3.3
Installed Base since year (U.S.)	16.3	12.2	9.0	6.1	3.3

† Adjusted based on U.S. and Canada population ratios, 316M and 35M (U.S. Census 2013, Statistics Canada 2013).
e Estimated based on extrapolation from 2010-2013.

3.4.1.2 Unit Energy Consumption

3.4.1.2.1 Power Draw

PC power draw varies with operational mode. For our analysis, we use the modes defined in the ENERGY STAR requirements for Computer v6.0 (EPA 2013a):

- **Active:** When the PC is actively used, or idles for a short while awaiting user input and before entering lower power modes.
- **Short Idle**: When the PC has been idle for about 5 minutes and has entered a low power mode with the monitor still on.
- **Long Idle**: When the PC has been idle for about 15 minutes and has entered a low power mode with the monitor off.
- **Sleep**: Entered manually or automatically after about 30 minutes from which the PC can quickly wake.
- **Off**: PC is turned off but remains plugged in.

The main difference from the previous ENERGY STAR specification (v5.2) is the splitting of the idle state into Short and Long Idle to better characterize computers with integrated monitors (i.e., AIO desktop PCs).

Table 3-11 presents recent power draw estimates for desktop PCs. Together, these sources indicated that average power draw values have decreased for all modes since 2010. The much larger difference between short idle and long idle mode power draw of the AIOs relative to the Towers reflects the power draw of the integrated display.

Table 3-11: Power draw estimates for desktop computers from different data sources.

Type	Power Draw [W]					Year	Source
	Active	Short Idle	Long Idle*	Sleep	Off		
Tower	-	48	47	2.5	1.1	2012	EPA 2013b†
Tower	-	-	46	2.1	1.0	2013	NRDC 2013
AIO	-	63	36	1.9	0.9	2012	EPA 2013b†
AIO	-	-	30	1.8	0.9	2013	NRDC 2013
Any Desktop	-	51	45	2.4	1.0	2012	EPA 2013b†
Any Desktop	-	67	-	2.4	0	2012	LBNL 2013‡
Any Desktop	-	-	60	4	2	2010	Fraunhofer 2011

* The ENERGY STAR v6.0 specification for computers maps the Idle mode of v5.2 as equivalent to Long Idle in v6.0.
† Power draw of each test device in the dataset reweighted based on the portion of unit sales (21%) meeting the ENERGY STAR v6.0 specifications (EPA 2012).
‡ The field study (with 39 desktop PCs) had grouped modes as “high power”>10W, “low power”≤10W, and "off"=0W. This roughly maps to Short Idle and Sleep power draws, respectively, in the ENERGY STAR v6.0 specification for computers.

We use data from these data sets to derive a representative estimate of power draw for different modes (see Table 3-11). In particular, we consider a mixture of newer and older PCs in the total installed base. We use power draw values from the ENERGY STAR v6.0 dataset of qualified and unqualified PCs (EPA 2013b) to represent PCs sold from 2011 to 2013, and power draw values from our previous study (Fraunhofer 2011) to represent older PCs. We use the results of (CEA 2014) for the age of desktop PCs owned to derive a relative weight between newer and older PCs (Table 3-12).

Table 3-12: Estimated desktop PC installed base by computer vintage to evaluate relative power draw characteristics derived from Figure 3 of (CEA 2014). Average age: 3.2 years.

	“Older”		“Newer”		
Year of Purchase	2009	2010	2011	2012	2013
Age	≥4	3	2	1	<1
% of Desktop PCs Owned	10%	12%	19%	18%	41%
	41%		59%		
Source for Power Draw Model	Fraunhofer 2011		EPA 2013b		

Most of the data sources in Table 3-11 do not include estimates for power draw in active mode. Based on metered power draw of one notebook in a commercial setting, NRDC estimates an active power draw *overhead* of 30% more than in idle mode (NRDC 2013). This overhead is similar to that reported by CEC (2012), which metered one desktop PC purchased in 2007 running an office productivity benchmark test. A lab metering study of four desktop PCs browsing consumer-oriented websites and videos found lower overhead of 8-21% (Fraunhofer 2013). Therefore, we apply a scaling factor of 115%, i.e., active mode power draw is 15% higher than short idle mode power draw. Ultimately, the power draw values by mode that we use to represent the installed base agree quite well with the LBNL field monitoring study of 559 households (LBNL 2013).

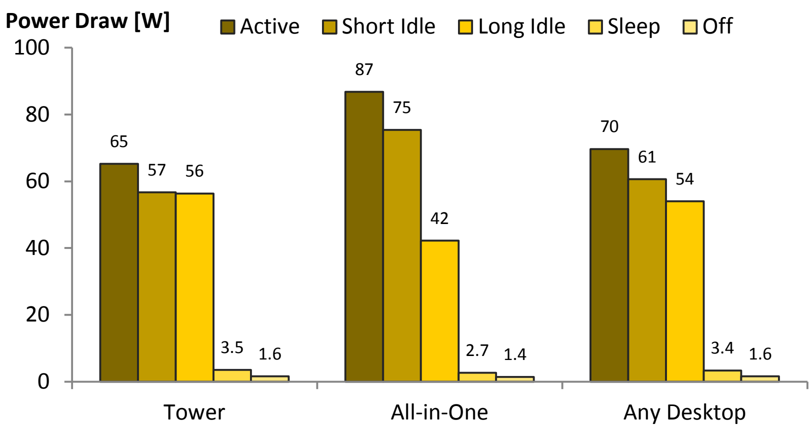


Figure 3-5: Representative power draw by mode of tower and AIO desktop PCs.

3.4.1.2.2 Usage

A desktop PC enters different operational modes depending on whether the user is currently using it, how recently it was last used, how the user manually manages its power, and its automatic power management settings. We compute the time each PC spends in different operational modes using the energy model presented in Appendix B.1. Our model draws heavily on the data gathered from the CE Usage Survey, where we asked respondents about their household use of the two most used desktop PCs. The subsequent subsections explain findings for key aspects of the model in more detail.

3.4.1.2.2.1 Usage per Session

We evaluated the *active* usage of PCs during the day for each session and for the whole day to account for the cumulative time desktop PCs spend in different operational modes. More specifically, we evaluated the usage for different periods of the day, pre-evening (morning and afternoon) and evening, via specific survey questions, and inferred usage for weekdays or weekends based on what day "yesterday" was for the survey response. On average, households' primary desktop PCs are used about two times before the evening, and about once in the evening. In contrast, secondary PCs are used about half as frequently. For both primary and secondary desktop PCs, we found that each session lasts for about one hour, and appears to be shorter on weekend days than on weekdays (Figure 3-6).

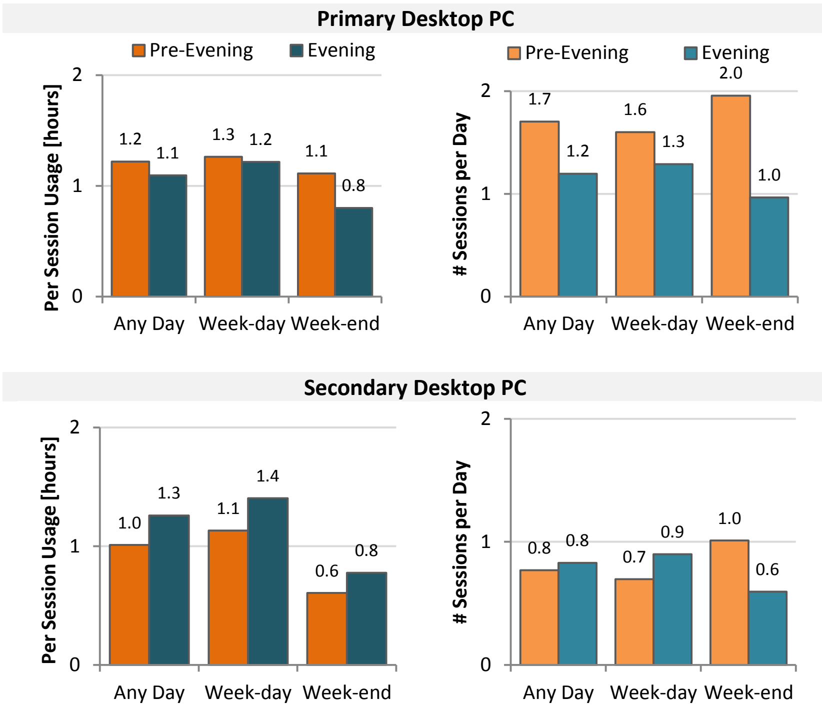
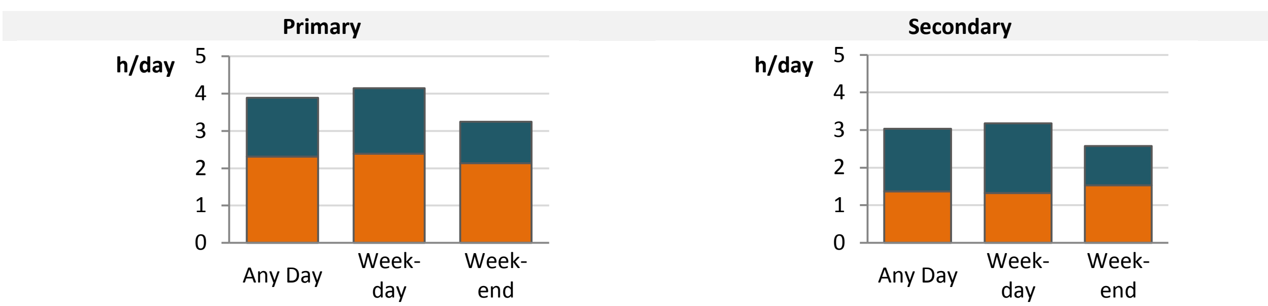


Figure 3-6: Average per session usage duration and number of sessions "yesterday" for primary and secondary desktop PCs.

3.4.1.2.2.2 Usage per Day

On average, households use primary and secondary desktop PCs for about 3 to 4 hours per day, with the primary desktop PC used somewhat more than secondary ones (3.9 vs. 3.0 hours).



	Primary: Any Day	Primary: Week-day	Primary: Week-end	Secondary: Any Day	Secondary: Week-day	Secondary: Week-end
Evening	1.6	1.8	1.1	1.7	1.9	1.0
Pre-Evening	2.3	2.4	2.1	1.4	1.3	1.5
Whole Day	3.9	4.1	3.2	3.0	3.2	2.6

Figure 3-7: Total usage duration "yesterday" for primary and secondary desktop PCs.

3.4.1.2.2.3 Power Management

PC energy consumption can be reduced through power management (PM). The user may do so using manual routines of power management (e.g., by putting the PC to sleep at night), or by enabling automatic PM settings (e.g., auto-hibernate to have the computer save its state and automatically turn off after a chosen period of inactivity). We discuss these two manual and automatic power management methods in the next section.

Manual Power Management

We asked U.S. adults how often they manually turned their PC off or put it to sleep. The survey results indicate that users tend to manually turn off their desktop PCs (40% of the time during the day and 56% at night), while leaving them on 37% of the time during the day. Desktop PCs are manually put to sleep about 22% of the time during the day. However, even if a PC is left on, automated PM may cause the PC down to a low power mode.

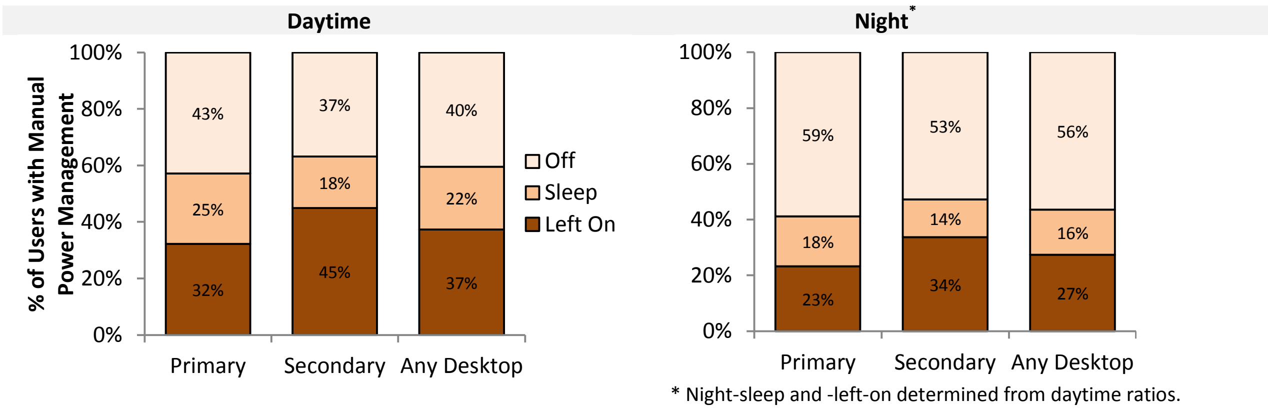


Figure 3-8: **Likelihood of users manually setting desktop PCs into various modes for the daytime or night.**

Automatic Power Management Setting

To infer the automatic PM settings, we asked U.S. adults about the initial state or start-up duration of their PC at the start of the day "yesterday" if they were the first to use it. For example, if the display is already on, this indicates that PM is disabled, while if the computer takes more than a few seconds to boot up, auto-hibernate is enabled. We also account for whether the U.S. adult shad manually turned the PC off. Our model assumes that PCs with auto-hibernate enabled also have auto-sleep enabled, and PCs with auto-sleep enabled have auto-screen off enabled. Based on the survey responses, 90% of desktop PCs have some level of power management enabled, particularly with auto-screen off (53%) where the PC enters short idle mode, followed by auto-sleep (31%), which engages the long idle mode.

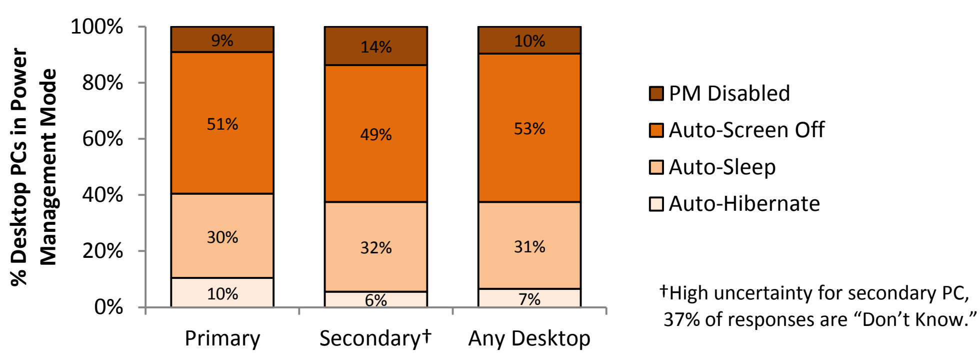
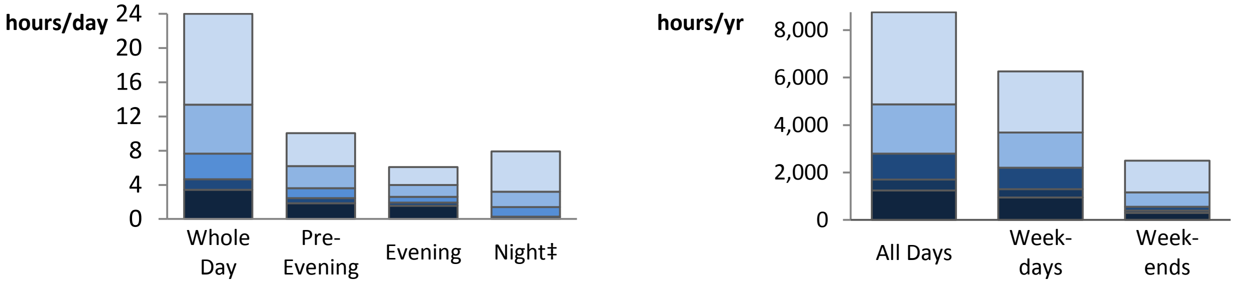


Figure 3-9: Percentage of desktop PCs with different automatic PM modes enabled.

3.4.1.2.2.4 Time in Operational Modes

Though not necessarily the same, the time distributions for different desktop types (Tower vs. AIO) and priorities (primary vs. secondary) are very similar. We present only their weighted average, but account for the differences in the energy model analysis.

Figure 3-10 shows the average amount of time each desktop PC spent in various operational modes. Desktop PCs spend a considerable amount of time in sleep and off modes (68%) mainly due to manual power management or automatic powering down after each session of use. Table 3-13 shows our results for the portion of time in Active + Idle modes; they are similar to those from other studies.



	Whole Day	Pre-Evening	Evening	Night‡
Off	11	3.8	2.1	4.7
Sleep	5.7	2.6	1.4	1.8
LongIdle	3.0	1.2	0.7	1.1
ShortIdle	1.3	0.6	0.4	0.3
Active	3.4	1.9	1.6	0.0
Total	24	10	6.1	7.9

	All Days	Week-days	Week-ends
Off	3,883	2,570	1,339
Sleep	2,088	1,484	604
LongIdle	1,083	902	161
ShortIdle	458	357	99
Active	1,248	944	300
Total Plugged In	8,760	6,257	2,503

‡ Our model defines night as when the household has gone to sleep, so we assume no active usage.

Figure 3-10: Average time spent in various operational modes in one day and in one year for desktop PCs. Weighted average across primary and secondary tower and AIO desktop PCs.

Table 3-13: Comparison of percentage of time desktop PCs spent in various operational modes with other data sources.

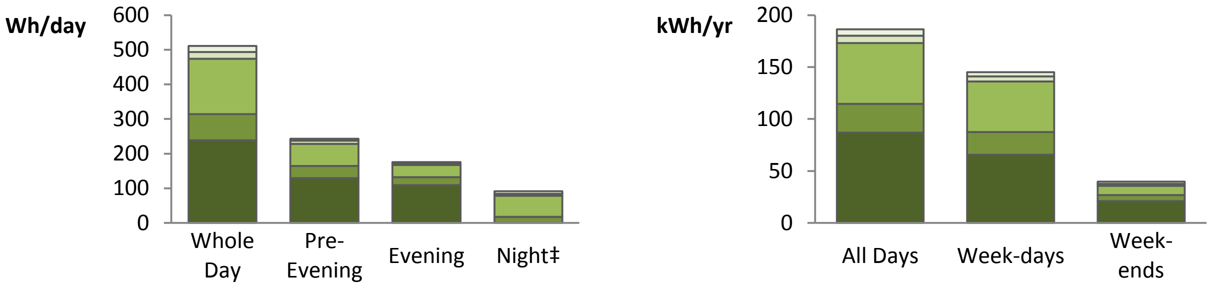
Time [%] in Operational Mode								
Active	**Short Idle**	**Long Idle**	**Active + Idle**	**Sleep**	**Off**	**Year**	**Setting**	**Source**
14%	5.2%	12%	**32%**	24%	44%	2013	Residential	CE Usage Survey
-	32%	-	**32%**	48%	20%	2012	Residential	LBNL 2013*
18%	-	21%	**39%**	25%	36%	2010	Residential	Fraunhofer 2011
-	35%	15%	**50%**	5%	45%	2013	Office	ENERGY STAR v6.0 (EPA 2013a)†
-	-	40%	**40%**	5%	55%	2009	Office	ENERGY STAR v5.2 (EPA 2009)†
41%	-	-	**41%**	48%	20%	2008	Office	Microsoft 2008

* Field measurement with a small sample size of 39 desktop PCs.

† ENERGY STAR values are based on studies of computer usage in office buildings (ECMA 2010, Microsoft 2009).

3.4.1.3 Unit and Annual Energy Consumption

We compute the energy consumption by multiplying the time a PC spends in each operational mode with the corresponding power draw in that mode. Figure 3-11 shows the energy consumption in various operational modes. Active usage accounts for the largest portion of energy consumption (47%), followed by long idle (31%), then short idle (15%). Together, sleep and off modes combine for 7% of energy consumption.



	Whole Day	Pre-Evening	Evening	Night‡
Off	17	6.2	3.4	7.6
Sleep	19	8.6	4.6	5.9
LongIdle	160	64	36	61
ShortIdle	76	35	23	18
Active	238	129	109	0
Total	511	243	175	92

	All Days	Week-days	Week-ends
Off	6.2	4.1	2.2
Sleep	7.0	5.0	2.0
Long Idle	58	49	9
Short Idle	28	22	6.0
Active	87	66	21
ALL	186	145	40

‡ Our model defines night as when the household has gone to sleep, so we assume no active usage.

Figure 3-11: Total energy consumed in various operational modes in one day and in one year for desktop PCs. Weighted average across primary and secondary tower and AIO desktop PCs.

We found that the Unit Energy Consumption (UEC) of a typical desktop PC is 186 kWh/year, with tower and AIO desktop PCs having similar UECs. The Annual Energy Consumption (AEC) for all desktop PCs is 16 TWh/year.

Table 3-14: UEC and AEC values for desktop PCs.

Type	Energy Consumption [Wh/day]	UEC [kWh/yr]						Installed Base [millions]	AEC [TWh/yr]
		Active	Short Idle	Long Idle	Sleep	Off	Total		
Tower	514	87	24	63	7.3	6.2	**188**	70	13
AIO	505	89	43	41	5.6	5.7	**184**	18	3.3
Any Desktop	511	87	28	58	7.0	6.2	**186**	88	16

3.4.2 Comparison with Prior Energy Consumption Estimates

We found a decrease in the both desktop PC UEC and AEC from 2010. A major reason is the drop in plugged-in installed base (101 to 88 million) driven by a sharp decrease in sales market share (22% in 2010 to estimated 8% in 2013, CEA 2013b) and resulting decreased household ownership installed base of desktop PCs (128 million (CEA 2010) to 105 million (CEA 2013a)) and almost a 10-fold increase in the ownership of tablets, from 4% (Fraunhofer 2011) to 39% (CEA 2013a). This trend could also explain the decrease in active use time which we found.

We refined our computer usage survey from 2010, and believe that it increases the accuracy of our estimates for time in operational modes for desktop PCs. Specifically, we have increased the precision of our survey questions by asking about three times of day (morning, afternoon, and evening) that are in better agreement with our analysis of usage patterns reported in ATUS (2012); see details in Appendix Section B.1.3. This provides a richer representation of usage throughout the whole day than our previous estimates (Fraunhofer 2011). In addition, breaking the day into more discrete time periods should increase the accuracy of peoples' responses for total computer usage.

On the other hand, our estimate for the portion of PCs with PM enabled is lower than our previous report (38% vs. 70%) due to several improvements in our energy model. First, we infer PM settings by asking about the PC state at the beginning of the day (vs. anytime during the day) and this better captures the PM settings by eliminating usage by other household members of which the respondent may be unaware. Next, to estimate the portion of PCs in auto-hibernate, we subtract responses that indicated that the PC was manually turned off at night from responses that indicated the PC is off at the beginning of the day. Therefore, assuming that users who manually turn off their PCs do not use auto-hibernate, this significantly reduces the portion of PCs with auto-hibernate enabled.

Table 3-15: Current and prior energy consumption estimates for desktop PCs.

Year	Units [millions]	Power Draw [W]			Time in Mode [hr/yr]			PM* Enabled	UEC [kWh/yr]	AEC [TWh/yr]	Source
		Active	Sleep	Off	Active	Sleep	Off				
2013	88	62†	3.4	1.6	2,789‡	2,088	3,883	38%	186	16	Current
2010	101	60	4	2	3,420	2,150	3,190	70%	220	22	Fraunhofer 2011
2006	90	75	4	2	2,954	350	5,456	20%	235	21	TIAX 2008
2005	85	75	4	2	2,950	350	5,460	20%	234	20	TIAX 2006
2005	108	58	-	3	2,116	-	183	15%	151	16	CCAP 2005
2001	68	50	25	1.5	1,495	163	7,102	20%	90	6.1	LBNL 2004
1999	54.5	50	25	2	717	65	7,978	25%	49	2.7	LBNL 2001

* Percent of computers with power management enabled, i.e., auto-sleep or auto-hibernate, but excluding auto-screen off.
† Weighed average of power draw for active, short idle, and long idle modes.
‡ Combined time in active, short idle, and long idle modes.

3.4.3 References

A&E. 2013. "The Infinite Dial 2013: Navigating Digital Platforms." Arbitron & Edison Research. Apr. 2, 2013. http://www.arbitron.com/downloads/InfiniteDial2013.pdf. Retrieved Sept. 16, 2013.

A&E. 2012. "The Infinite Dial 2012: Navigating Digital Platforms – Presentation Companion." Arbitron & Edison Research. April, 2012. http://www.edisonresearch.com/wp-content/uploads/2012/04/2012_infinite_dial_companion_report.pdf. Retrieved Sept. 16, 2013.

ATUS. 2012. "American Time Use Survey — 2012 Microdata Files." Jun. 20, 2013. United States Department of Labor. http://www.bls.gov/tus/datafiles_2012.htm. Retrieved Oct. 30, 2013.

CEA. 2010. "12th Annual household CE Ownership and Market Potential." CEA Market Research Report. Consumer Electronics Association. May, 2010. Consumer Electronics Association.

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.

CEA. 2013c. Steve Koenig. Private correspondence, Nov. 2013. Consumer Electronics Association.

CEA. 2014. "Consumer Outlook on Tablets – Jan. 2014 Edition." Jan.

CEC. 2012. "How low can you go? A White Paper on Cutting Edge Efficiency in Commercial Desktop Computers." Public Interest Energy Research (PIER) Program Final Project Report. Ecos Consulting. Mar. 2012. http://www.energy.ca.gov/2012publications/CEC-500-2012-065/CEC-500-2012-065.pdf. Retrieved Feb. 3, 2014.

DisplaySearch. 2014. "DisplaySearch Quarterly Desktop Monitor Shipment and Forecast Report, 2011-13." Jan. 2014.

ECMA. 2010. ECMA-383 3rd Edition - Majority Profile. Dec. 2010. http://www.ecma-international.org/publications/files/ECMA-ST/ECMA-383.pdf. Retrieved Dec. 9, 2013.

EPA. 2009. "ENERGY STAR Computer Program Requirements Version 5.2." https://www.energystar.gov/ia/partners/product_specs/program_reqs/Computers_Program_Requirements.pdf?0e9f-5a79. Retrieved Jan. 30, 2014.

EPA. 2012. "ENERGY STAR Unit Shipment and Market Penetration Report 2012." December, 2012. http://www.energystar.gov/ia/partners/downloads/unit_shipment_data/2012_USD_Summary_Report.pdf. Retrieved Sept. 16, 2013.

EPA. 2013a. "ENERGY STAR Computer Program Requirements Version 6.0." Sept. 12, 2013. http://www.energystar.gov/products/specs/computer_specification_version_6_0_pd. Retrieved Dec. 12, 2013.

EPA. 2013b. "ENERGY STAR Computers Draft 2 Version 6.0 Dataset." May 15, 2012. https://www.energystar.gov/products/specs/system/files/Computers_Draft_2_Dataset_masked.xlsx. Retrieved Sept. 16, 2013.

EPA 2013c. "ENERGY STAR Qualified Product List." Oct. 28, 2013. http://downloads.energystar.gov/bi/qplist/Computers_Product_List.xls. Retrieved Feb. 5, 2014.

FhCSE. Urban, Bryan, Kurt Roth, and Verena Tiefenbeck. 2011. "Energy Consumption of Consumer Electronics in U.S. Homes in 2010." Final Report to the Consumer Electronics Association. http://www.ce.org/CorporateSite/media/Government-Media/Green/Energy-Consumption-of-CE-in-U-S-Homes-in-2010.pdf. Dec.

FhCSE. 2013. Roth, K., S. Patel, and J. Perkinson. "The Impact of Internet Browsers on Computer Energy Consumption." Jun. 2013.

LBNL. 2013. Greenblatt, J. B. 2013. "Field data collection of miscellaneous electrical loads in Northern California: Initial results." Lawrence Berkeley National Laboratory. LBNL Paper LBNL-6115E. Jul. 22, 2013. http://escholarship.org/uc/item/5cq425kt. Retrieved Sept. 16, 2013.

Microsoft. 2008. "Microsoft Power Transition Report." Microsoft Corporation. http://www.energystar.gov/ia/partners/prod_development/revisions/downloads/computer/Microsoft_PowerTransitionReport.pdf?%20f0fe-40d2. Retrieved Dec. 9, 2013.

Pew. 2012. "Adult gadget ownership over time." Pew Internet surveys 2006-2013. April, 2012. http://www.pewinternet.org/Trend-Data-(Adults)/Device-Ownership.aspx. Retrieved Oct. 30, 2013.

Pew. 2013. "Demographics of internet users" Apr. 17 – May 19, 2013. http://pewinternet.org/Static-Pages/Trend-Data-(Adults)/Whos-Online.aspx. Retrieved Jan. 30, 2014.

NRDC. 2013. "NRDC's Response to CEC's Invitation to Participate in the Development of Appliance Energy Efficiency Measures. NRDC Computers Attachment 2. ENERGY STAR v6.0 Dataset v2 with additions from NRDC." May 9, 2013. http://www.energy.ca.gov/appliances/2013rulemaking/documents/responses/Consumer_Electronics_12-AAER-2A/NRDC_Response_to_CEC_Invitation_to_Participate_with_Excel_Spreadsheets_REFERENCES/NRDC_Computers_2_ESTAR-NRDC_v6.0_Dataset_v2.xlsx. Retrieved Dec. 12, 2013.

Statistics Canada. 2013. "Canada Population Estimates." http://www.statcan.gc.ca/start-debut-eng.html. Oct. 2013. Retrieved Jan. 30, 2014.

U.S. Census. 2012. State & County QuickFacts. http://quickfacts.census.gov/qfd/states/00000.html. Retrieved Jan. 25, 2014.

U.S. Census. 2013. "US Census 2011: Computer and Internet Use in the United States." May 1, 2013. http://www.census.gov/prod/2013pubs/p20-569.pdf. Retrieved Sept. 16, 2013.

3.5 Portable Computers

Portable computers includes both laptops (also known as notebooks) and netbook computers (smaller, less powerful laptops), but excludes mobile computing devices such as smart phones and tablets.

3.5.1 Current Energy Consumption

3.5.1.1 Installed Base

We estimate a plugged-in installed base of 93 million portable PCs used in the past month (Nov. 2013). The plugged-in installed base measured from CE Usage Survey is 63% of the ownership installed base of 148 million as reported by CEA (2013a). This is likely due to some portable PCs not being recently used. The survey also reports the ownership penetration for portable PCs of 64%, which is similar to other sources (see Table 3-16).

Although the estimate of plugged-in penetration of 44% is lower than in our previous report of 62% (Fraunhofer 2011), we think that it is accurate, because the 2013 CE Usage Survey included questions to distinguish between households that did not own a portable PC and households that have at least one but that had not plugged one in within the past month. Therefore, the results provide a richer representation of the plugged-in and ownership installed bases.

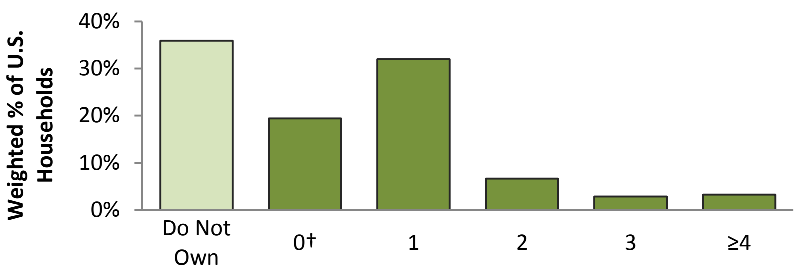
Table 3-16: Installed base estimates for portable PCs from different data sources.

Year	Description	Household penetration	Households [millions]	Units/owner household	Installed Base [millions]	Source
2013	Portable PCs plugged in last month	45%	53	1.75	93	CE Usage Survey
2013	Portable PC ownership	64%*	76	-	-	CE Usage Survey
2013	Portable PC ownership	65%	77	1.90	148†	CEA 2013a
2011	Desktop or Portable PC ownership	76%	-	-	-	U.S. Census 2013
2012	Desktop or Portable PC ownership	-	-	1.80§	-	A&E 2012
2013	Portable PCs plugged in	-	-	-	93	*Representative*

* Estimated based on survey responses that indicated no ownership of portable PCs (see Figure 3-12).

† 123.4 million notebook and 24.3 million netbook portable PCs.

§ Based on 61% of Online U.S. adults; 2012 U.S. population as 313.9M, 76.5% of population over 18 years old (U.S. Census 2012); 85% of U.S. adults use the Internet (Pew 2013).



	Do Not Own	0†	1	2	3	≥4
Plugged In	36%	19%	32%	6.6%	2.8%	3.2%
Ownership*	35%		33%	16%	9%	7%

† 0 portable PCs plugged in, but ≥1 owned. * Ownership data from (CEA 2013a).

Figure 3-12: Distribution of households by number of portable PCs owned or plugged-in during the past month (Nov. 2013).

According to CEA (2013), netbooks account for 17% of all portable PCs. Although we expect fewer netbooks to be used and plugged-in in 2013 due to their declining sales and discontinued production

(DigiTimes 2012), for an estimate, we use this ratio to compute the annual energy consumption of all portable PCs.

Table 3-17: Plugged-In installed base estimates for notebook and netbook portable PCs from the CE Usage Survey.

Type	Households [millions]							Plugged-In [million units]		
		PCs Plugged-In per Owner Household								
	Not Owned	0	1	2	3	≥4	≥1†	All	Primary	Second+
Notebook	36	19	32	6.6	2.8	3.2	44	77.7	44	33
Netbook	7	3.8	6.3	1.3	0.6	0.6	8.8	15.3	8.7	6.6
Any Portable	43	23	38	7.9	3.3	3.8	53	93.0	53	40

† Equivalent to the household penetration of plugged-in PCs.
Primary: number of primary PCs.
Second+: number of PCs that are not primary, i.e., secondary, tertiary, etc.; treated as secondary in energy model.

3.5.1.2 Unit Energy Consumption

3.5.1.2.1 Power Draw

We consider the same power draw modes (EPA 2013a) for portable PCs as for desktop PCs in Section 3.4.1.2: active, short idle, long idle, sleep, and off.

Table 3-18 presents recent power draw estimates for portable PCs. Overall, power draw has decreased compared to the 2010 estimate (Fraunhofer 2011) by about half for sleep and off modes, and about a quarter for idle mode.

Table 3-18: Power draw estimates for portable PCs from different data sources.

Type	Power Draw [W]					Year	Source
	Active	Short Idle	Long Idle*	Sleep	Off		
Notebook	-	14	9.4	1.0	0.5	2012	EPA 2013b†
Notebook	-	-	10	1.1	0.5	2013	NRDC 2013
Notebook	21	15	-	-	-	2013	Fraunhofer 2013§
Netbook	-	9.1	6.1	0.8	0.5	2012	EPA 2013b†
Any Portable	-	14	9.1	1.0	0.5	2012	EPA 2013b†
Any Portable	40	-	-	1.1	0	2012	LBNL 2013‡
Any Portable	-	-	19	2	1	2010	Fraunhofer 2011

* ENERGY STAR v6.0 specification for computers maps the Idle mode of v5.2 as equivalent to Long Idle in v6.0.
† Power draw of each test device in the dataset reweighted based on unit sales of 69% of unit shipments meeting the ENERGY STAR v6.0 specifications (EPA 2012). Netbook models identified by processor type (10% of dataset).
§ Lab metering of 6 notebook portable PCs.
‡ The field study (with 11 portable PCs) had grouped operational modes as “high power”>10W, “low power”≤10W, and "off"=0W. This roughly maps to a combined active, short idle and long idle power draw, sleep, and off power draws, respectively, in the ENERGY STAR v6.0 specification for computers.

Similar to Section 3.4.1.2, we derive a representative estimate of power draw for different modes with a weighted average of newer and older PCs in the total installed base (see Table 3-19).

Table 3-19: Determining relative power draw characteristics from age of portable PCs, derived from Figure 3 of (CEA 2014). Average age: 2.4 years.

	"Older"		"Newer"		
Year of Purchase	**2009**	**2010**	**2011**	**2012**	**2013**
Age [years]	**≥4**	**3**	**2**	**1**	**<1**
% of Portable PCs Owned	19%	22%	26%	17%	17%
	41%		60%*		
Source for Power Draw Model	Fraunhofer 2011		EPA 2013b		

* Total does not sum to 100% due to rounding.

Several data sources suggest a higher ratio of power draw in active to short idle mode for portable PCs than for desktop PCs, e.g., 1.4 for Fraunhofer (2013) and 1.3 for NRDC (2013). Therefore, we apply a scaling factor of 1.3 for active-mode power draw relative to short idle mode power draw. Furthermore, since Fraunhofer (2011) referred to ENERGY STAR v5.2 (EPA 2009) and does not include a power draw estimate for the short idle mode, we apply the same overhead ratio for short idle to long idle (1.5:1) as EPA (2013b).

Unlike a desktop PC, a portable PC may be disconnected from the wall socket and run on its battery. The battery will need to be charged with an external power supply (EPS). Therefore, in addition to the power modes for desktop PCs (see Section 3.4.1.2), we consider the following additional operational modes due to the power draw of the EPS:

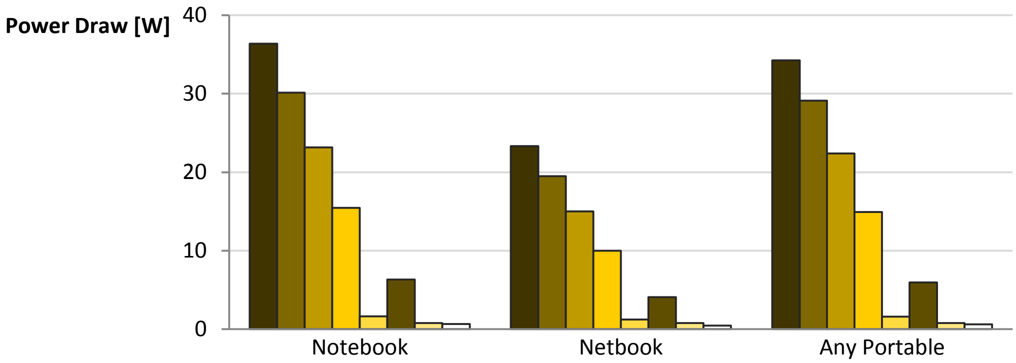
- **Active + Charging:** when the portable PC is actively used and charging its battery.
- **Off + Charging:** when the portable PC is off and charging its battery.
- **Unplugged:** when the portable PC is unplugged from its EPS.
- **EPS Unplugged:** when the EPS is also unplugged from the wall socket. There is no power draw (0W) in this "mode."

DOE (2012) provides an estimate for the power draw of the EPS of notebook and netbook portable PCs (see Table 3-20). According to the test method for ENERGY STAR v6.0 (EPA 2013b), we consider the EPS power draw to already be accounted for when the portable PC is not charging and not unplugged.

Table 3-20: Power draw estimates of the external power supply for portable PCs (DOE 2012), weighted by shipment distribution. This excludes the power draw due to the portable PC.

Type	**External Power Supply Power Draw [W]**					
	Active* + Charging	**Active***	**Sleep**	**Off + Charging**	**Off**	**Unplugged**
Notebook	11	4.6	0.8	6.3	0.7	0.7
Netbook	6.6	2.8	0.6	3.8	0.5	0.5

* We consider EPS active mode to correspond to the weighted average of the portable PC active, short- and long-idle modes.



	Notebook	Netbook	Any Portable
Active + Charging	36	23	34
Active	30	19	29
Short Idle	23	15	22
Long Idle	15	10	15
Sleep	1.6	1.2	1.6
Off + Charging	6.3	4.1	6.0
Off	0.8	0.8	0.8
Unplugged	0.6	0.5	0.6

Figure 3-13: Representative power draw by mode of notebook and netbook portable PCs.

3.5.1.2.2 Usage

A portable PC enters different operational modes depending on whether the user is currently using it, how recently it was last used, how the user manually manages its power, its automatic power management settings, how often it is charging, and how often it is unplugged from the EPS. We compute the time each PC spends in different operational modes using the energy model presented in Appendix B.1. Our model draws heavily on the data gathered from the CE Usage Survey where we asked U.S. adults about their household use of the most used (primary) portable PC and second-most used (secondary) portable PCs. The subsequent subsections explain findings for key aspects of the model in more detail.

3.5.1.2.2.1 Usage per Session

We evaluated the *active* usage of PCs during the day for each session and for the whole day to account for the cumulative time portable PCs spend in different operational modes. More specifically, we evaluated the usage for different periods of the day (morning and evening) via specific survey questions, and inferred usage for weekdays or weekends based on what day “yesterday” was for the survey response. We estimate that an average primary portable PC is used about 1.5 times before the evening, and about once in the evening. The secondary PC is used about half as much. We found that each session lasts about one hour, and is likely somewhat shorter on a weekend than on a weekday.

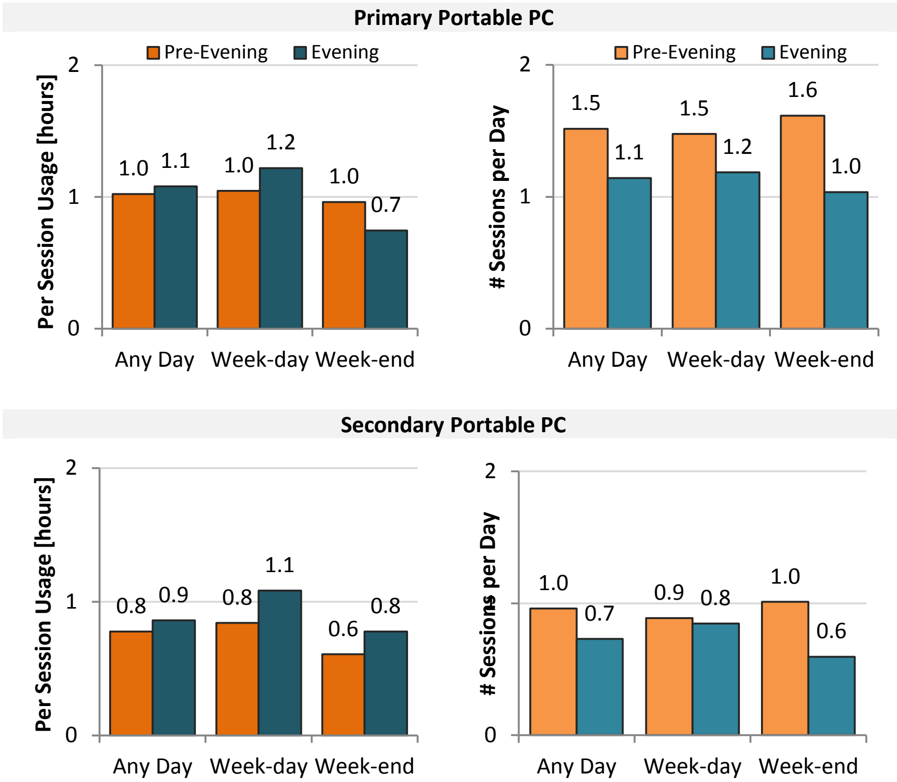


Figure 3-14: Average per session usage and number of sessions "yesterday" for primary and secondary portable PCs.

3.5.1.2.2.2 Usage per Day

On average, household occupants actively use portable PCs for 2.8 hours per day, using the primary portable PC more than secondary ones (3.4 vs. 2.4 hours), more before the evening than after (1.9 vs. 1.5 hours for primary), and more during the weekdays than weekends (3.6 vs. 2.8 hours for primary). We note that primary desktop PCs have a higher reported active usage per day than primary portable PCs (3.9 vs. 3.4 hours).

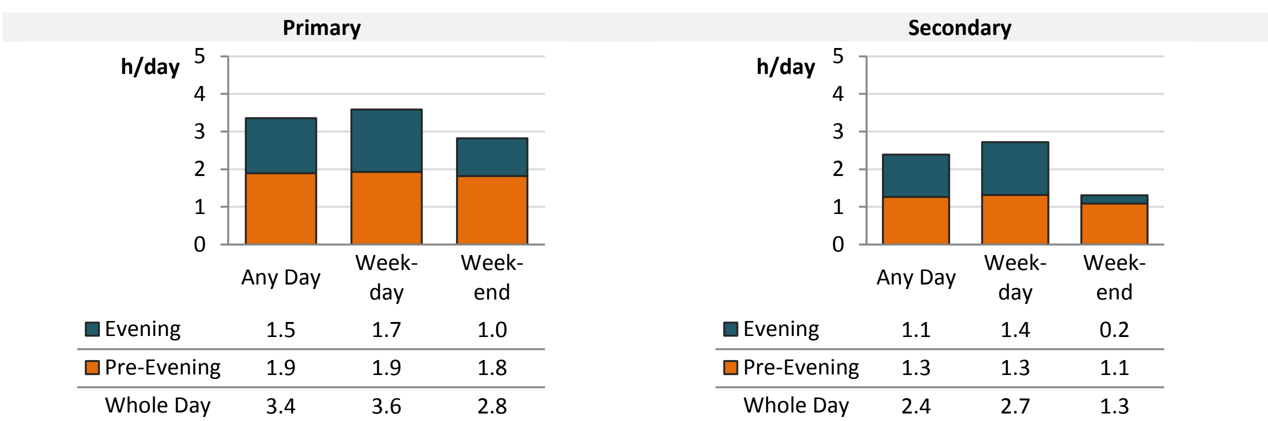


Figure 3-15: Average total usage "yesterday" for primary and secondary portable PCs.

3.5.1.2.2.3 Power Management

PC energy consumption can be reduced through power management. The user may do so manual routines of power management (e.g., by putting the PC to sleep at night), or by enabling automatic power management (PM) settings (e.g., auto-hibernate to have the computer save its state and automatically turn off after a chosen period of inactivity). We discuss these two manual and automatic power management methods in the next section.

Manual Power Management

We asked U.S. adults how often they manually turned off their PC or put it to sleep. Our survey results indicated that users tend to manually turn off their portable PCs (60% of the time during the day and 65% at night), while leaving them on for 19% of the time during the day. Portable PCs are manually put to sleep 21% of the time during the day. However, even if the PC is left on, automated PM can place the PC in a low-power mode. Relative to desktop PCs (see Section 3.4), users turn off a higher portion of portable PCs (e.g., 60% vs. 40%) during the daytime.

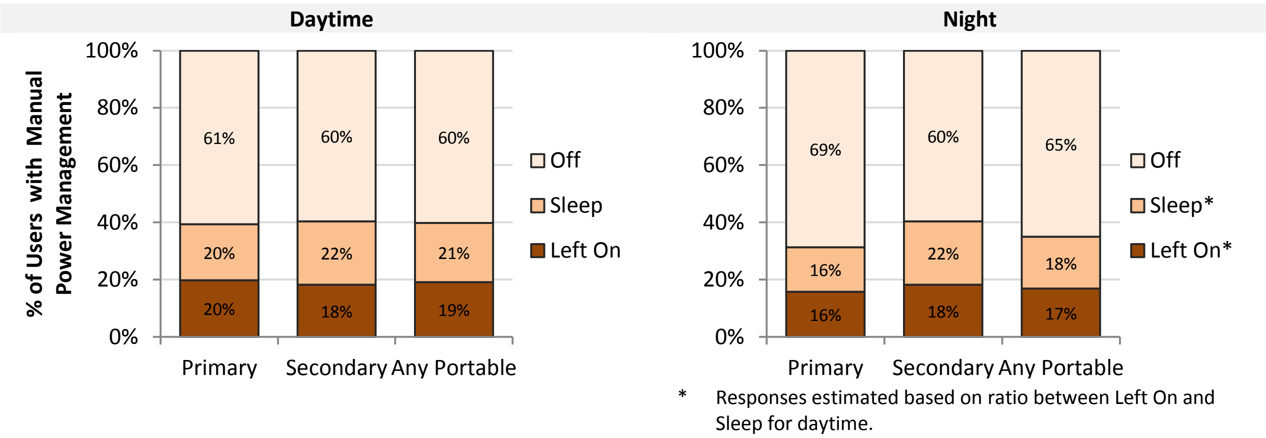


Figure 3-16: Portion of users manually setting portable PCs into various power modes for the daytime or nighttime.

Automatic Power Management

We infer automatic power management (PM) settings using the method described in . This indicates that most portable PCs have some level of PM enabled (94%), particularly with auto-screen off (52%), which engages the long idle mode, followed by auto-screen off (29%) where the PC enters short idle mode. Relative to desktop PCs (see Section 3.4), portable PCs have a higher rate of PM enabling (63 vs. 38% with auto-sleep or auto-hibernate enabled).

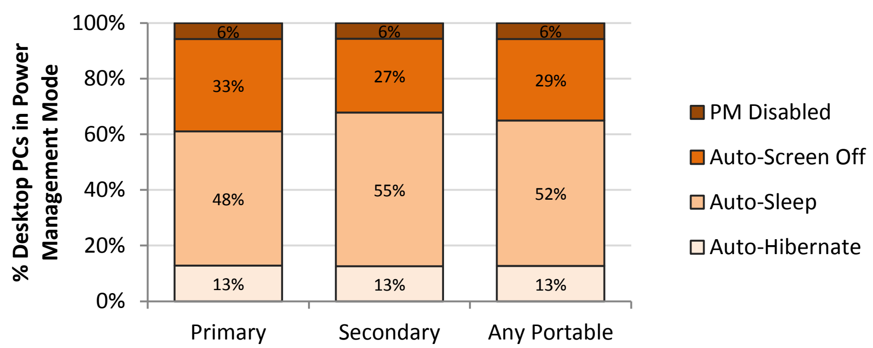


Figure 3-17: Percentage of portable PCs with various automatic PM modes enabled.

3.5.1.2.2.4 Time in Operational Modes

A portable PC enters different power modes depending on whether or not the user is currently using it, how recently it was last used, how the user manually manages its power, and its automatic PM settings. As with desktop PCs, we compute the time each PC spends in different power modes using the energy model presented in Appendix B.1. However, we use shorter default time thresholds for lower power modes to be triggered, i.e., 10 vs. 15min for short idle and 25 vs. 30min for long idle (values empirically determined from the ENERGY STAR qualified product list (EPA 2013c); see Appendix section B.1.2 for more details). Furthermore, because we do not have reliable data differentiating the usage time of netbooks and notebooks, we assume that notebooks and netbooks spend equal portions of time in different power modes.

To estimate the time portable PCs spend charging or unplugged, we draw on the DOE (2012) EPS and battery charger rulemaking analysis (see Table 3-21). Specifically, we re-scale our time estimates from the CE Usage Survey by applying ratios for the times charging to not charging, and unplugged to plugged.

Table 3-21: Time usage estimates of portable PC EPSs from DOE (2012). Weighted average by shipment distribution of the reference case.

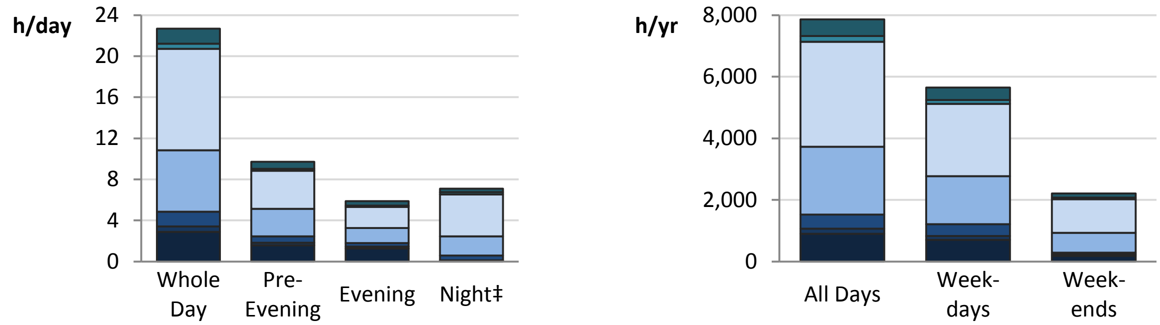
Type	Time of Day [%] in Operational Mode						
	Active* + Charging	Active*	Sleep	Off + Charging	Off	Unplugged†	EPS Unplugged
Notebook	2.5%	17%	13%	3.1%	48%	0.0%	16%
Netbook	3.4%	14%	3.6%	0.0%	54%	0.0%	25%

* The portable PC is plugged in to the charger in this mode. We consider the EPS active mode to correspond to the weighted average of the portable PC active, short idle, and long idle modes.

† Note that the reference case assumes no time spent with the portable PC unplugged from the EPS.

Figure 3-18 shows the average amount of time each portable PC spent in different operational modes. Portable PCs spend a large majority of time in sleep and off modes (77%) mainly due to manual PM or automatic powering down after each session of use. Table 3-22 shows our results for the portion of time spent in Active + Idle modes; they broadly agree with other studies on residential PC use.

Compared to desktop PCs, portable PCs spend more time in lower power modes (19 vs. 16 hours in sleep, off, or EPS unplugged modes), less time in short and long idle modes (2.0 vs. 4.2 hours), and less time in active mode (2.9 vs. 3.4 hours). This is due to portable PCs, being manually put into low power modes more frequently, having more aggressive automated PM settings, and lower power modes triggering after shorter time thresholds. Portable PCs also spend 2.0 hours charging (in both Active and Off modes), but are unplugged from the EPS for 3.3 hours a day on average.



	Whole Day	Pre-Evening	Evening	Night‡
Charging(Active)*	1.5	0.7	0.4	0.3
Charging (Off)*	0.5	0.2	0.1	0.2
Off	9.9	3.7	2.1	4.1
Sleep	6.0	2.7	1.5	1.9
LongIdle	1.4	0.6	0.3	0.5
ShortIdle	0.5	0.3	0.2	0.1
Active	2.9	1.6	1.3	0.0
Total Plugged In	21	8.8	5.3	6.5

	All Days	Week-days	Week-ends
Charging(Active)*	538	402	133
Charging (Off)*	184	126	58
Off	3,417	2,347	1,082
Sleep	2,202	1,561	645
LongIdle	452	385	58
ShortIdle	168	123	45
Active	900	702	189
Total Plugged In	7,861	5,647	2,210

‡ Our model defines night as when the household has gone to sleep, so we assume no active usage.
* Note that usage time for charging is already counted in usage times for active and off modes, so that does not count towards the total time plugged in.

Charging (Active): time spent charging while in active mode.
Charging (Off): time spent charging while in off mode.

Figure 3-18: Average time spent in various operational modes in one day (left) and in one year (right) for portable PCs.

Table 3-22: Comparison of percentage of time notebook PCs spent in various operational modes with other data sources.

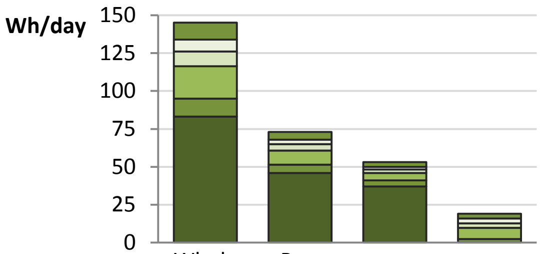
Time [%] in Operational Mode								
Active*	Short Idle	Long Idle	Active + Idle†	Sleep	Off**	Year	Setting	Source
14%	2.6%	6.9%	**23%**	29%	48%	2013	Residential	CE Usage Survey
-	16%	-	**16%**	42%	42%	2012	Residential	LBNL 2013‡
18%	-	15%	**33%**	25%	42%	2010	Residential	Fraunhofer 2011
-	35%	15%	**50%**	5%	45%	2013	Office	ENERGY STAR v6.0 (EPA 2013a)§
-	-	40%	**40%**	5%	55%	2009	Office	ENERGY STAR v5.2 (EPA 2009)§
41%	-	-	**41%**	48%	20%	2008	Office	Microsoft 2008

* Includes active + charging time.
** Includes charging (off) and unplugged, but excludes EPS unplugged time.
† Combined active and idle.
‡ Field measurement with a small sample size of 11 portable PCs.
§ ENERGY STAR Typical Energy Consumption values are based on studies of computer usage in office buildings (ECMA 2010, Microsoft 2009).

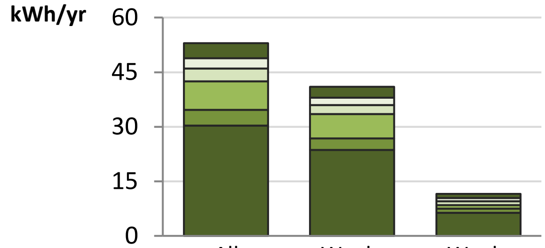
3.5.1.3 Unit Energy Consumption and Annual Energy Consumption

We compute the energy consumption by multiplying the time a PC spends in each power mode by the average power draw in that mode. Figure 3-19 shows the energy consumption for each day period due to the time in various operational modes. Active usage accounts for a considerable amount of energy consumption (57%), followed by long idle (15%), then short idle (8.2%). Lower power modes account for 6.6% and 5.5% of UEC, for sleep and off modes, respectively. Charging accounts for 7.7% of UEC.

Netbook PCs have considerably lower power draw values than notebook PCs for the active, short idle, and long idle modes (19 vs. 30W, 15 vs. 23W, 10 vs. 15W, respectively) , resulting in a 33% lower UEC for netbooks.



	Whole Day	Pre-Evening	Evening	Night‡
Charging*	11.2	5.1	3.1	3.0
Off	7.9	3.0	1.7	3.3
Sleep	9.6	4.3	2.3	3.0
Long Idle	21	9.2	4.8	7
Short Idle	12	5.6	4.0	2.4
Active	83	46	37	0.0
ALL	145	73	53	19



	All Days	Week-days	Week-ends
Charging*	4.1	3.0	1.1
Off	2.9	2.0	0.9
Sleep	3.5	2.5	1.0
Long Idle	7.8	6.7	1.0
Short Idle	4.4	3.2	1.2
Active	30	24	6.4
ALL	53	41	12

‡ Our model defines night as when the household has gone to sleep, so we assume no active usage then.
* Only accounting for energy sole due to charging while in active and off modes.

Figure 3-19: Total energy consumed in various operational modes in one day and in one year for portable PCs. Weighted average across primary and secondary notebook and netbook portable PCs.

Our calculations yield a UEC of 53 kWh/year for a typical portable PC and an AEC of 4.9 TWh/year. This reflects a conservative estimate that the same proportion of netbooks of all portable PCs is plugged in and used as the proportion owned. However, declining netbook sales (CEA 2013b) suggest a decrease in their use. If we assumed that the installed base of portable PCs consisted entirely of notebooks, i.e., included no netbooks, this would yield an AEC of 5.1 TWh/year. Furthermore, while the installed base for portable PCs exceeds that of desktop PCs (93 vs. 88 million), their AEC is lower (4.9 vs. 16 TWh/year), because they have a 72% lower UEC (53 vs. 186 kWh/year).

Table 3-23: Unit energy consumption (UEC), installed base, and annual energy consumption (AEC) of portable PCs.

	UEC [kWh/yr]							Installed Base	AEC
Type	**Charging**	**Active**	**Short Idle**	**Long Idle**	**Sleep**	**Off**	**Total**	**[millions]**	**[TWh/yr]**
Notebook	4.3	31	4.5	8.1	3.6	3.0	**55**	78	4.3
Netbook	2.9	20	2.9	5.2	2.7	2.5	**37**	15	0.6
Total/Wt.Avg.	4.1	30	4.4	7.8	3.5	2.9	**53**	93	4.9

3.5.2 Comparison with Prior Energy Consumption Estimates

We found a decrease in the both portable PC UEC and AEC from 2010. A major reason is the drop in plugged-in installed base (132 to 93 million) driven by a sharp decrease in the market share of portable PCs in the overall market for desktop PCs, portable PCs, and tablet computers (from 57% in 2010 to about 21% in 2013, CEA 2013b). To a large extent, this reflects around a ten-fold increase in the household ownership penetration of tablets, from 4% (Fraunhofer 2011) to 39% (CEA 2013a). This same trend could also explain the decrease in active use time that we found.

We refined our computer usage survey from 2010, and believe that it increases the accuracy of our estimates for time in operational modes for portable PCs. See Section 3.5.2 for a discussion on various refinements. In addition, for portable PCs our model explicitly calculates the power draw, time in modes, and energy consumption due to the external power supply (charging, unplugged, etc.).

Table 3-24: Current and prior energy consumption estimates for portable PCs.

Year	Units [millions]	Power Draw [W] Active	Sleep	Off	Time in Mode [hr/yr] Active + Idle	Sleep	Off	PM* Enabled	UEC [kWh/yr]	AEC [TWh/yr]	Source
2013	93	29[a]	1.6	0.8[b]	1,770‡	2,190	3,602§	64%	53	4.9	Current
2010	128	19	2	1	2,915	2,210	3,635	69%	63	8.3	Fraunhofer 2011
2009	76	-	-	-	-	-	-	-	43	3.1	CCAP 2009††
2006	39	25	2	2	2,368	935	5,457	40%	72	2.8	TIAX 2007
2005	36	25	2	2	2,368	935	5,457	40%	72	2.6	TIAX 2006
2001	16.6	-	-	-	-	-	-	-	77	1.3	RECS 2001
2001	17.3	15	3	0‡‡	1,007	651	7,102	-	-	-	LBNL 2004
1999	16	15	3	2	521	261	7,978	100%	9	0.14	LBNL 2001

* Percent of computers with power management enabled (auto-sleep or auto-hibernate, not including auto-screen off).
† Weighed average of power draw for active, short idle, and long idle modes.
§ Estimate for time in off mode excludes time unplugged from EPS.
‡ Combined time in active, short idle, and long idle modes.
†† Data for office equipment only.
‡‡ Disconnected.
a 30 W weighted average if charging included.
b 1.1 W weighted average if charging included.

3.5.3 References

ATUS. 2012. "American Time Use Survey — 2012 Microdata Files." Jun. 20, 2013. United States Department of Labor. http://www.bls.gov/tus/datafiles_2012.htm. Retrieved Oct. 30, 2013.

CEA. 2010. "12th Annual household CE Ownership and Market Potential." CEA Market Research Report. Consumer Electronics Association. May, 2010. Consumer Electronics Association.

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.

Digitimes. 2012. Chen, M. and J. Tsai. "Intel may need to adjust roadmap for PC-use Atom Processors." Sept. 3, 2012. http://www.digitimes.com/news/a20120903PD208.html. Retrieved Feb. 6, 2014.

DOE. 2012. "Rulemaking for Battery Chargers and External Power Supplies Energy Conservation Standard. Energy Use Analysis Spreadsheet." Feb. 17, 2012. http://www.regulations.gov/#!documentDetail;D=EERE-2008-BT-STD-0005-0084. Retrieved Feb. 6, 2014.

EPA. 2012. "ENERGY STAR Unit Shipment and Market Penetration Report 2012." December, 2012. http://www.energystar.gov/ia/partners/downloads/unit_shipment_data/2012_USD_Summary_Report.pdf. Retrieved Sept. 16, 2013.

EPA. 2013a. "ENERGY STAR Program Computer Specification Version 6.0." Sept. 12, 2013. http://www.energystar.gov/products/specs/computer_specification_version_6_0_pd. Retrieved Dec. 12, 2013.

EPA. 2013b. "ENERGY STAR Computers Draft 2 Version 6.0 Dataset." May 15, 2012. https://www.energystar.gov/products/specs/system/files/Computers_Draft_2_Dataset_masked.xlsx. Retrieved Sept. 16, 2013.

FhCSE. Urban, Bryan, Kurt Roth, and Verena Tiefenbeck. 2011. "Energy Consumption of Consumer Electronics in U.S. Homes in 2010." Final Report to the Consumer Electronics Association.

http://www.ce.org/CorporateSite/media/Government-Media/Green/Energy-Consumption-of-CE-in-U-S-Homes-in-2010.pdf. Dec.

LBNL. 2013. Greenblatt, J. B. 2013. "Field data collection of miscellaneous electrical loads in Northern California: Initial results." Lawrence Berkeley National Laboratory. LBNL Paper LBNL-6115E. Jul. 22, 2013. http://escholarship.org/uc/item/5cq425kt. Retrieved Sept. 16, 2013.

NRDC. 2013. "NRDC's Response to CEC's Invitation to Participate in the Development of Appliance Energy Efficiency Measures. NRDC Computers Attachment 2. ENERGY STAR v6.0 Dataset v2 with additions from NRDC." May 9, 2013. http://www.energy.ca.gov/appliances/2013rulemaking/documents/responses/Consumer_Electronics_12-AAER-2A/NRDC_Response_to_CEC_Invitation_to_Participate_with_Excel_Spreadsheets_REFERENCES/NRDC_Computers_2_ESTAR-NRDC_v6.0_Dataset_v2.xlsx. Retrieved Dec. 12, 2013.

Pew. 2012. "Adult gadget ownership over time." Pew Internet surveys 2006-2013. April, 2012. http://www.pewinternet.org/Trend-Data-(Adults)/Device-Ownership.aspx. Retrieved 30 Oct. 2013.

3.6 Home Audio: Shelf/Compact Audio and Speaker Docks

The home audio products evaluated in further detail include speaker docks and shelf stereo systems, also called Mini or Compact stereo systems. A speaker dock has a plug-in connection for an MP3 player, smartphone, or tablet. An ordinary speaker dock includes two speakers rated at about 5 W each, a docking station, and sometimes a clock and a tuner (see Figure 3-20, left). Some speaker dock models include more than two speakers and a subwoofer, and may draw about 100 W in active mode. [7]

A shelf stereo system consists of a central component with one or more media players (e.g., CD/DVD, radio tuner, and docking station for an MP3 player, smartphone or tablet), two or more detached speakers, and sometimes a subwoofer (see Figure 3-20, right).

Figure 3-20: Example of a speaker dock (left), and shelf stereo system (right), source: iHome, Sony.

3.6.1 Current Energy Consumption

3.6.1.1 Installed Base

According to the CE Usage Survey data, 45% of households have a speaker dock and 46% have a shelf stereo system. Multiplied by the average number of devices per household, this yields installed bases of 98 and 64 million respectively (see Table 3-25). We were unable to find data on the installed base of speaker docks and shelf stereo systems by rated power draw levels.

Table 3-25: Installed base of speaker docks and shelf stereo systems (CE Usage Survey).

Home Audio System	Installed Base [millions]	Household Penetration	Number of devices per Household	Source
Speaker dock	98	45%	1.8	CE Usage Survey
Shelf stereo system	64	46%	1.2	CE Usage Survey

3.6.1.2 Unit Energy Consumption

3.6.1.2.1 Power Draw

Speaker dock and shelf stereo systems can be characterized by the following three operating modes:

- *Active* – Device is actively being used, playing music or other audio content
- *Active standby* – Device is neither playing audio content, nor turned off manually

[7] Examples include the B&W Zeppelin Air (B&W Zeppelin Air-Specifications 2013) and JBL OnBEAT Xtreme (JBL OnBEAT Xtreme Owner's Manual 2011).

- *Standby* – Device is turned off manually but remains plugged in. Some devices have Auto-power down (APD) function and automatically enter a standby mode after a defined period of time (usually between 15 and 30 minutes).

Audio manufacturers use several terms to quantify the power of audio systems, such as peak power, total system output power, and continuous power. All of these usually quantify the maximum or peak power output, and do not accurately characterize the average active power draw of an audio system, which is much lower than the values in audio system specifications. Many product specifications also include a "power consumption" value; the test procedure to determine these values is not stated. Based on measurements[8] of three best-selling[9] speaker docks, we found that the actual operating power draw (~5W) equals approximately half of the "power consumption" values provided in product specifications. We did not measure speaker docks with high total output, as they were not sold in the store where we performed the measurements. Instead, we scaled the total output power to actual power by applying the same scaling factor (8) found for three shelf stereo systems that we measured. This suggests that speaker docks with a total output power of 100 and 120W would draw approximately 13 and 15 W, respectively, in active mode.

Unfortunately, we could not find data for the portion of the installed base of speaker docks with higher power draw. Nevertheless, we expect that the penetration of these speaker dock systems is likely very low. Notably, these speaker docks are not among "best selling" products listed on leading CE retailers such as Amazon.com and BestBuy.com. Second, these audio systems often cost much more than most speaker docks, typically between $300 and $600.[10] For these reasons, we did not include these models in the final power draw calculations. Nonetheless, the large difference in power draws between typical and high-power speaker docks makes the average power draw of speaker docks somewhat sensitive to the penetration of high-power devices. For example, if 5% of the speaker dock installed base drew 15W (total output system power 100 -120W) in active mode, that would increase the UEC in active mode by about 7%. The market share of high-power speaker docks and their actual power draw levels warrant further study.

After reviewing product documentation (e.g. owner's manual, product specification, etc.) for shelf stereo systems[11], we found that these products have total system power outputs from 40 to 700 W. To estimate the typical power draw of shelf stereo systems, we measured the power draw of three of the most popular mini-shelf stereo systems with total output powers of 220, 500, and 700 W while playing a CD with the volume set at minimum, medium and maximum levels. We found that the average active-mode power draw of three mini-shelf stereo systems with a total output power exceeding 200 W was less than 20 W for all systems except for one that exceeded that level at maximum volume (see Figure 3-21).

[8] We measured the average power draw at min., middle, and max. volume while playing music and took the average.
[9] Top 10 best-selling models on Amazon.com and bestbuy.com.
[10] The price for speaker docks we measured varies between 60 and 80 US dollars.
[11] Based upon reviews of products from LG, Panasonic, Samsung, Sony, and Yamaha.

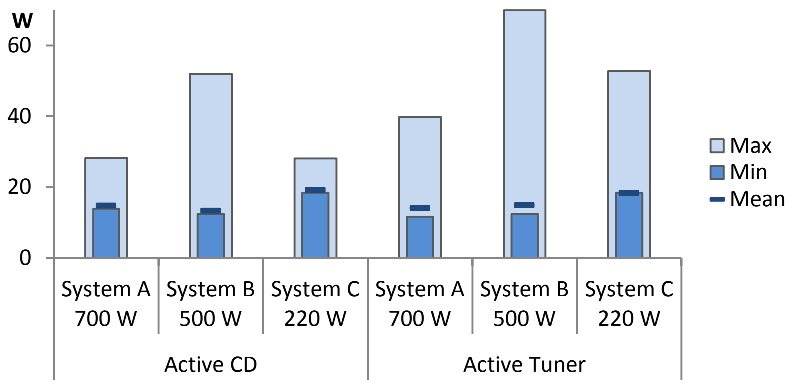


Figure 3-21: Active power draws of different mini-shelf stereo systems (Fraunhofer measurements).

Our measurements of standby power draw for speaker docks averaged 1.3 W, while those for mini-shelf stereo systems did not exceed 0.5W. We found different ways of putting stereo systems into standby mode. First of all, it can be achieved by using the "sleep" function which allows system to enter standby mode after defined period of time. This defined period of time usually vary from 10 to 90 minutes and set up by default to the maximum. Secondly, switching a stereo system off manually will also allow it to enter the standby mode. Lastly, two of three systems we measured had auto-power down, which puts the system into standby mode after a defined period of time[12]. We did not find a correlation between total output power draw and standby power draw.

Based on these data, we estimate the average power draw by mode values shown in Table 3-26. The power draw values in both active- and standby-modes were calculated using a weighted average of pre-2010 (92%) and post-2010 systems (8%, CEA 2013). The active power draw for pre-2010 systems comes from Bensch et al. (2010) and the active power draw for post-2010 system were calculated based on our measurements 2013 as weighted average based on the system's popularity on the market. Since we did not find active standby power draw measurements for post-2010 shelf stereo systems, we used the average of our power measurements of post-2010 systems.

Table 3-26: Power draw by mode for audio systems

Audio System	Power [W]			Sources
	Active	Active Standby	Standby	
Speaker dock	5	3	1.3	Fraunhofer measurements
Shelf stereo system	30	12	4.0	FhCSE 2011, Fraunhofer measurements

3.6.1.2.2 Usage

We evaluated speaker dock and shelf stereo system usage through the CE Usage Survey (see Figure 3-22, left). Based on all responses, we estimated that the average speaker dock spends 3.3 hours per day in active mode (see Table 3-27). The data also indicate that 66% of U.S. adults turn their speaker dock off with a power switch or remote control after they finish using it. Only 6% leave their speaker dock always on and 11% responded that their speaker dock does not have a power switch[13].

[12] Usually between 15 and 25 minutes.
[13] We treated these responses as people who never turn off their speaker docks

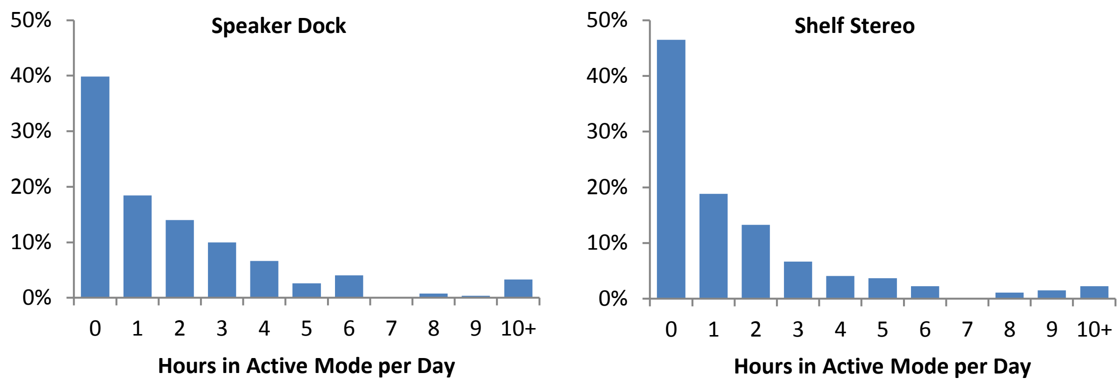


Figure 3-22: Frequencies of responses regarding the active daily usage of speaker systems.

A review of product documentation revealed that some speaker dock systems have an auto power-shutdown (APD) feature that automatically places the system into standby mode after about 20 minutes of inactivity (e.g. Sony 2013a, Samsung 2013, Sony 2013b). The U.S. adults' replies indicate that nine percent of speaker docks have the APD feature and eight percent answered "don't know".

The CE Usage Survey found similar usage for mini-shelf stereo systems (see Figure 3-22, right), and the average time spent listening to music or other audio is 3.4 hours a day. Eighty-six percent of U.S. adults answered that they turn their shelf stereo system off manually using a power switch or remote control. Only four percent of mini-shelf stereo systems reported having APD. This is generally consistent with the portion of the installed base accounted for by post-2010 shelf stereo models (8%), which would be the units most likely to have APD functionality.

Table 3-27: Annual usage by mode of speaker dock and shelf stereo systems

	Usage [h/year]			
Home Audio System	**Active**	**Active standby**	**Standby**	**Sources**
Speaker dock	1,205	2,007	5,548	CE Usage Survey
Shelf stereo system	1,241	949	6,570	CE Usage Survey

The ENERGY STAR specification version 3.0 for Audio Products that came into effect in May, 2013 requires qualifying devices to have a default APD setting of two hours, maximum. Thus, the time spent in active standby mode by very new ENERGY STAR devices might be smaller. We do not, however, have data on the market penetration of ENERGY STAR speaker dock and shelf stereo systems for 2013.

3.6.1.2.3 Unit Energy Consumption

Our calculation for speaker dock system UEC yields 19 kWh/year, with no mode accounting for a majority of the UEC. The UEC of a mini-shelf stereo system equals 75 kWh/year, with 51% and 34% of UEC occurring in active and standby mode, respectively. See Table 3-28 and Figure 3-23. Although the newer mini-shelf stereo systems draw less than 0.5 W in standby mode, a large installed base of pre-2010 unit (92% of units) results in an average 4 W power draw in standby mode.

Table 3-28: UEC calculation for speaker systems.

	Speaker Dock			Shelf Stereo		
	Power [W]	Usage [hr/yr]	UEC [kWh/yr]	Power [W]	Usage [hr/yr]	UEC [kWh/yr]
Active	5	1,205	6.0	30	1,241	38
Active Standby	3	2,007	6.0	12	949	11
Standby	1.3	5,548	7.2	4.0	6,570	26
Total	**-**	**8,760**	**19.2**	**-**	**8,760**	**75**

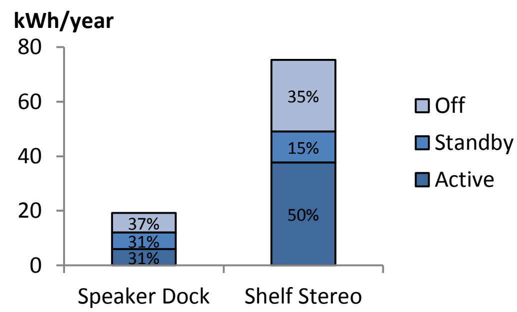


Figure 3-23: Speaker dock UEC distribution among different modes

3.6.1.3 Annual Energy Consumption

Speaker dock and mini-shelf stereo systems consumed approximately 2.0 and 5.0 TWh respectively, in 2013 (Table 3-29).

Table 3-29: AEC summary for speaker systems.

Audio System	UEC [kWh/yr]	Installed Base [millions]	AEC [TWh]
Speaker dock	19	98	1.9
Shelf stereo system	75	64	4.8

3.6.2 Comparison with Prior Energy Consumption Estimates

Our prior study (FhCSE 2011) estimated that speaker docks consumed 1.2TWh in 2010 (see Table 3-30). Thus, our current estimate for speaker dock AEC is more than 50 percent higher despite a decrease in average active-mode power draw. This largely reflects that the installed base has more than doubled since 2010. Although the active-mode usage estimate has increased by about 50 percent, it is not clear how real this effect is, since the current usage estimates are more refined than those for 2010.

In contrast, the estimated AEC of mini-shelf stereo systems has decreased 27% since 2010. This primarily reflects about a 50 percent decrease in estimated active usage in 2013 relative to 2010. We believe that the 2013 usage estimates are more accurate, as they are based on several hundred survey responses and closer to survey-based usage estimates for 2006. In contrast, the 2010 usage estimates comes from field monitoring of a small number (15) of systems.

Table 3-30: Prior energy consumption estimates for speaker docks.

Year	Units [millions]	Power [W] Active	Power [W] Active Standby	Power [W] Standby	Usage [h/yr] Active	Usage [h/yr] Active Standby	Usage [h/yr] Standby	UEC [kWh/yr]	AEC [TWh/yr]	Source
2013	98	5	3	1.3	1,205	2,007	5,548	19	1.9	Current
2010	48	10	3	NA	800	100	7,860	25	1.2	FhCSE 2011

Table 3-31: Prior energy consumption estimates for mini-shelf stereo system.

Year	Units [millions]	Power [W] Active	Power [W] Active Standby	Power [W] Standby	Usage [h/yr] Active	Usage [h/yr] Active Standby	Usage [h/yr] Standby	UEC [kWh/yr]	AEC [TWh/yr]	Source
2013	64	30	12	4.0	1,241	949	6,570	75	4.8	Current
2010	63	32	NA	4.3	2,482	NA	6,278	105	6.6	Bensch et al. 2010
2006	76	23	16	7.0	840	730	7,190	81	6.2	TIAX 2007

3.6.3 References

Bensch, I., S. Pigg, K. Koski and R. Belshe. 2010. "Electricity Savings Opportunities for Home Electronics and Other Plug-In Devices in Minnesota Homes – A technical and behavioral field assessment." Final Report by the Energy Center of Wisconsin. ECW Report 257-1. http://www.state.mn.us/mn/externalDocs/Commerce/CARD_Plugging_into_Savings_Study_052710014507_MN_Home_Elect_Devices.pdf. May.

Bowers & Wilkins. 2013. "Zeppelin Air-Specifications." http://www.bowers-wilkins.com/Wireless-Music-Systems/Wireless-Music-Systems/Zeppelin-Air/product-details.html#productSpec.

CEA S&F. 2013. "U.S. Consumer Electronics Sales & Forecasts 2009-2014." CEA Market Research Report. Consumer Electronics Association. Jul.

EPA. 2013. ENERGY STAR program requirements Audio/Video. Version 3.0. Environmental Protection Agency. http://www.energystar.gov/ia/partners/prod_development/revisions/downloads/audio_video/Final_Version_3_AV_Program_Requirements.pdf?5c24-7fe5 May.

FhCSE. Urban, Bryan, Kurt Roth, and Verena Tiefenbeck. 2011. "Energy Consumption of Consumer Electronics in U.S. Homes in 2010." Final Report to the Consumer Electronics Association. http://www.ce.org/CorporateSite/media/Government-Media/Green/Energy-Consumption-of-CE-in-U-S-Homes-in-2010.pdf. Dec.

JBL. 2011. "OnBEAT Xtreme Owner's Manual." http://www.jbl.com/images/media/ONBEATXT_OM_EN.pdf

Roth, K. and K. McKenney. 2007. "Energy Consumption by Consumer Electronics (CE) in U.S. Residences." Final Report by TIAX LLC to the Consumer Electronics Association. Dec.

Samsung 2013. Wireless Audio with Dock. User Manual for DA-E570.

Sony. 2013a. Reference Guide for ICFCS515IP personal audio docking system. Ref. 4-286-722-15(1)

Sony. 2013b. Reference Guide for RDPM15IP personal audio docking system. Ref. 4-274-302-22(1)

3.7 Monitors

3.7.1 Current Energy Consumption

The computer monitors category includes displays that must be plugged into a computer, such as external or stand-alone monitors. It excludes integrated displays, such as those built into laptop computers or all-in-one PCs, as well as multimedia projectors.

3.7.1.1 Installed Base

We estimate an installed base of 97 million monitors in 2013 (see Table 3-32) based on the CE Usage Survey (Appendix A). U.S. adults were asked how many monitors were plugged into the two most-used desktop and portable computers, producing the distributions in Figure 3-24. We estimate that 42% of all households had at least one monitor (68% of households with a computer).

Table 3-32: Installed base of monitors.

	Computers [millions]	Monitors per Computer	Monitors [millions]
Desktop primary	53	0.9	**47**
Desktop secondary	10	0.8	**8**
Portable primary	53	0.2	**13**
Portable secondary	15	0.1	**2**
Other*	50	0.5	**27**
Total/Average	**181**	**0.5**	**97**

* Refers to desktop and portable computers that are not primary and secondary, i.e. tertiary, quaternary, etc.

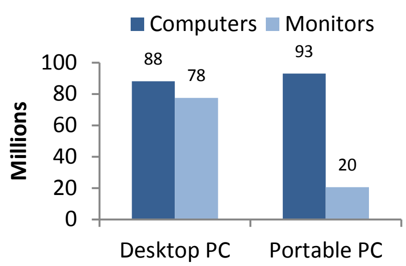


Figure 3-24: Installed base of monitors and computers.

We found a 26 percent decline in the installed base of external monitors since 2010 (FhCSE 2011). Similarly, monitor sales decreased 24% from 2010 to 2013 (Display Search 2014). As shown in Figure 3-25, 27% of desktop computers in 2013 had no external monitor, about 10% higher than in 2010. The portion of desktop and portable computers with at least one external monitor decreased by 13% and 9% (absolute), respectively, from 2010 to 2013. One reason for the decrease in the number of external monitors associated with desktop PCs is the increase in the installed base of all-in-one PCs, i.e., those with integrated displays. Their cumulative sales[14] equaled about 18 million from 2007 to mid-2013 (FhCSE 2011, Display Search 2013, 2013 CE Usage Survey), or about 21% of all plugged-in desktop computers in 2013[15] relative to 14% of desktops circa 2010.

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[14] We did not find estimates for the fraction of all-in-one PCs sold to consumers; however, we assumed that AIO computers were mostly purchased for in-home use.

[15] We estimate an installed base of 88 Million desktop computers plugged in 2013 (see Section 3.4).

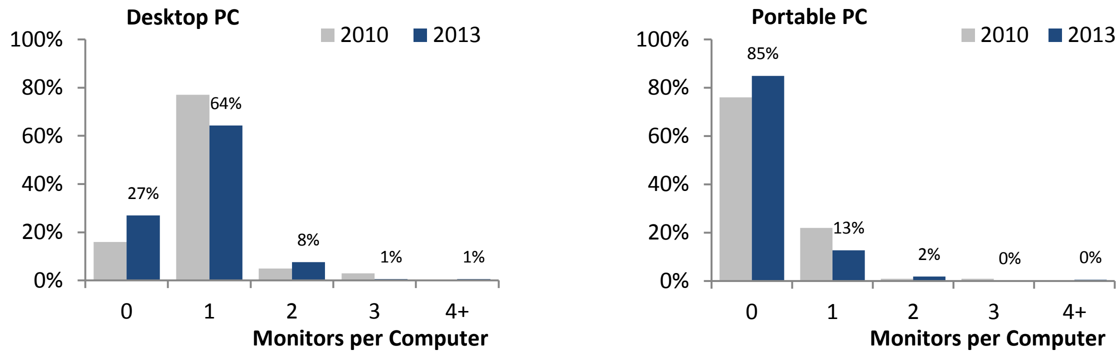


Figure 3-25: Distribution of monitors per desktop and portable computer.

3.7.1.2 Unit Energy Consumption

3.7.1.2.1 Power Draw

Monitors have three primary power modes: active, sleep, and off. Active mode occurs whenever the monitor is on and displays an image. Monitor active-mode power draw depends most strongly on display technology, screen size, and default settings from manufacturer (e.g., brightness and contrast). In addition, display resolution can also affect active-mode power draw. Sleep mode is a low-power state entered after a period of inactivity, typically 15 minutes, when power management (PM) is enabled (see Appendix B.1.2). User input from a keyboard or mouse awakens a sleeping monitor to active mode. Off mode is the lowest plugged-in power mode and is entered when the user powers down the monitor by manually switching it off or the computer's power settings are set for auto turn off the display.

The CE Usage Survey (see Appendix A) shows that LCDs dominate the installed base of monitors, accounting for 83 percent of the installed base. [16] Thus, the portion of CRT monitors has not changed appreciably since 2010 (Table 3-33). The average display size of the installed base has increased to 20.9 inches[17] in 2013 (NPD DisplaySearch 2012), compared to 18 inches in 2010 (FhCSE 2011) and 17 inches in 2006 (TIAX 2007). Figure 3-26 shows the estimated size distribution of the installed base of LCDs.

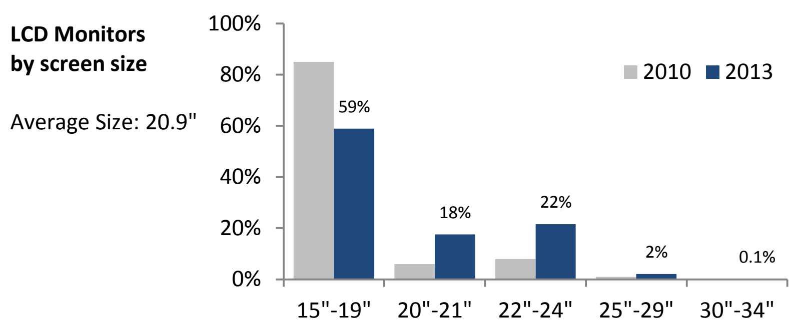


Figure 3-26: Distribution of LCD monitors installed base in 2013 by diagonal screen size (FhCSE 2011, DisplaySearch 2014).

We also found about a seven-fold increase in the installed base portion of LCD monitors with LED backlights, from 10% in 2010 (Kim & Semenza 2012) to 2013 69% (IDC 2013; This change also influences

[16] Since monitor responses were given only for up to two desktop and portable computers, we assumed the proportions of LCD and CRTs were the same for less-used computers. In the limiting case, i.e., if all monitors for computers three and beyond were CRTs, the split would shift to 60% LCD and 40% CRT. For reference, CEA (2014) estimated there were 35 million CRT monitors in U.S. households in February 2014, *including units* **not** *plugged in* (e.g., in storage).

[17] Projected screen size for 2013.

the average active-mode power draw (see Figure 3-28). On average, an LCD monitor with LED backlight draws about 30% less power than one with a CCFL backlight, and this difference increases with diagonal size (ENERGY STAR 2013, Fraunhofer measurements 2013, Dell 2013, Cnet 2010a, Cnet 2010b).
For this study, we assume that all monitors purchased before 2006 have been retired. Since monitors with LED backlights only began to have a significant market share in 2011, we divide the installed base into pre- and post-2010 models. Adjusted[18] industry sales data (Display Search 2014) show that 27 million LCD displays were shipped to U.S. consumers between 2011 to mid-2013, and that 63% of these monitors have LED backlights (see Figure 3-27).

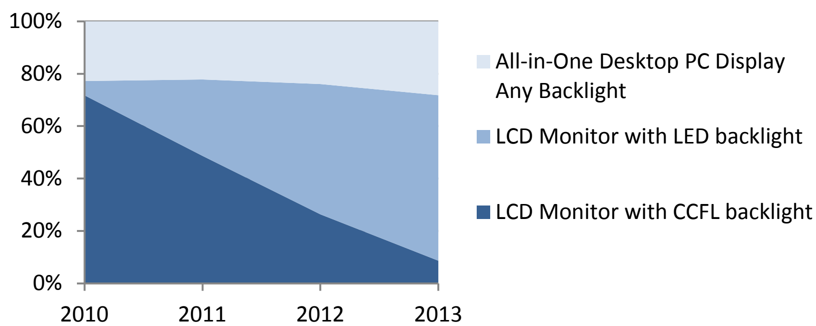


Figure 3-27: Portion of monitor sales by backlight technology (DisplaySearch 2014).

For all CRT monitors and 2006-2010 LCDs, we used power draw characteristics from the previous CE study (FhCSE 2011). For post-2010 LCDs, we assumed that all LCD-LED monitors met the ENERGY STAR specification and used the average power draw values for each size range from the ENERGY STAR Displays Product List (2013). For LCD- CCFLs, we divided them among ENERGY STAR and non-ENERGY STAR units. Since LCD-LEDs account for 69% of the market and 83% of monitor products sold met ENERGY STAR performance requirements in 2012 (ENERGY STAR 2012), we estimate that approximately 55% (=17%/(14%+17%)) of post-2010 LCD-CCFL monitors did not meet ENERGY STAR and 45% did. Then, we used 2006-10 LCD-CCFL power draw characteristics to model the power draw of the non-ENERGY STAR LCD-CCFLs and data from the ENERGY STAR Displays Product List (2013) for the ENERGY STAR units. For most ENERGY STAR LCD-CCFL monitors, we used the average LCD-CCFL power draw value from the database for each size bin. Since the list had no power measurements for 28- and 29-inch LCD-CCFL monitors, we estimated the power draw in that size range using correlations between power draw and screen area (see Figure 3-28).

Although the average screen size of installed monitors in homes increased, which tends to increase active-mode power draw, we estimate that post-2010 LCDs draw 22W[19] in active mode as compared to 33 W for 2006-2010. This reflects improvements in display technology over that period, most notably from LED backlights. Average power draw in sleep and off modes also have decreased since 2010, as the ENERGY STAR specification allows a 0.5W maximum power draw for monitors in both modes (EPA 2013). Table 3-33 shows our power draw estimates by display type and screen size.

[18] We scaled the total North American unit shipment data (commercial and consumer) by the U.S. population fraction (90%) – based on 35 million people in Canada (Statistics Canada 2013) and 317 million in the U.S. (U.S. Census Bureau 2013) – and by the average consumer fraction (38%;Display Search 2011-2013).
[19] We estimated power draw for post-2010 monitors based on a 69% share of the installed base for monitors with LED backlight.

Table 3-33: Average power draw estimates for monitors.

	Year	Screen Size [inches]	% of installed base	Units [millions]	Power [W] Active	Sleep	Off
LCD	2010-2013	15-19	35%	9.5	15	0.4	0.3
	2010-2013	20-21	29%	7.8	22	0.4	0.3
	2010-2013	22-24	33%	8.9	26	0.5	0.3
	2010-2013	25-29	4%	1.1	38*	0.7*	0.4*
	2010-2013	30-34	0.2%	0.1	72	0.7	0.6
Subtotal/Wt. Avg.		**20.9**	**28%**	**27.5**	**22**	**0.4**	**0.3**
LCD	2006-2010	19.1	55%	53.5	33	0.9	0.6
LCD	**Wt. Avg.**	**20.9**	**83%**	**81**	**30**	**0.8**	**0.5**
CRT	**Wt. Avg.**	**17**	**17%**	**16**	**61**	**2.0**	**1.0**
Total/Avg.	**-**	**17.7**	**100%**	**97**	**34**	**0.9**	**0.6**

* Values have higher uncertainty than other values in table.

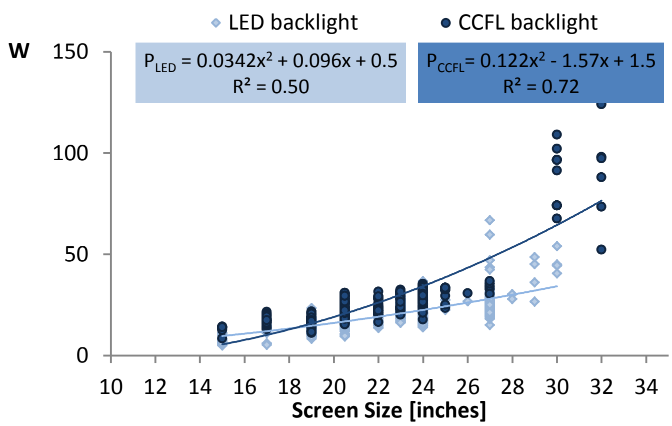


Figure 3-28: Active-mode power draw measurements for ENERGY STAR LCD monitors by backlight technology (EPA 2013).

3.7.1.2.2 Usage

Although we did not ask about monitor usage in the current study we did adjust the usage estimates from our prior study according to the computer usage estimates developed from the 2013 CE Usage Survey (see discussion below). This showed a decrease in active usage of external monitors in 2013 (see Table 3-34). The time an external monitor spends in sleep mode is very similar to the findings of an LBNL field-monitoring study[20] (LBNL 2013). Furthermore, the time in off mode in 2013 is similar to our 2010 study, mainly because we assumed that the same percentage of monitors are manually switched off in 2010 and 2013 (Desktop: 36%, Portable: 40%; FhCSE 2011).

[20] LBNL (2013) measured 23 monitors using Watts Up? And Kill-A-Watt power meters for between three and ten (or more) weeks. It divided the time spent in each mode into High Power, Low Power and Off. Hours were assigned to Off mode if the power meter reported 0 W power draw. This assumption may create errors in dividing time between off and sleep modes, because most monitors draw more than 0W in off mode, in which case those hours were attributed to sleep mode. Because active-mode power draw dominates monitor energy consumption, this effect has a very small impact on monitor UEC.

Table 3-34: Daily usage of monitors by mode.

Year	Monitor Usage [h/day] Active	Sleep	Off	Source
2013	4.2	12.2	7.7	Current study
2013	6.6	12.4	5	LBNL 2013
2010	6.9	9.7	7.4	FhCSE 2011

The main reason for decrease in the active usage of monitors in 2013 is that we changed some aspects of the monitor usage model. In the current model, active-mode usage equals the sum of computer active usage and computer time in short idle mode, with the time to auto-screen off assumed to be 15 minutes in 2013 and 20 minutes in 2010. After these 15 minutes the computer monitor turns off automatically even if the computer remains on. This yields active-mode usage estimates of 4.7 hours/day for desktop computers and 3.5 for portable computers (see Computer Sections 3.4.1.2.2 and 3.5.1.2.2). To estimate monitor usage for the remaining hours (Desktop: 19.3 h/day; Portable: 20.5 h/day), we first identified the portion of monitors that are always on. This was calculated based on the following assumptions, including the computer auto-power management (APM) state (Figure 3-29):

- If a computer has APM enabled, i.e., if a computer is sleeping, hibernating, turned off automatically, or has auto-screen off, then the monitor enters either a sleep or off mode.
- If a computer has APM disabled but was manually put into sleep mode or was manually switched off, then the monitor is either in sleep or off mode.
- If a computer has APM disabled and was not manually put into sleep mode or manually switched off, then the monitor remains on the whole day.

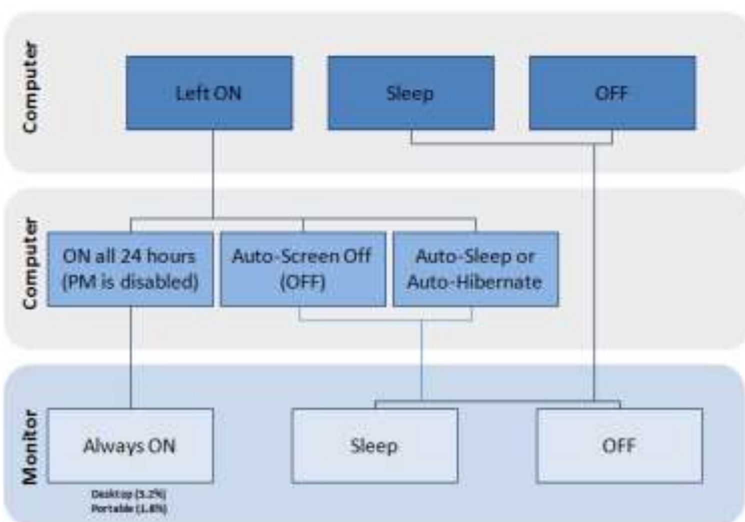


Figure 3-29: Decision diagram for determining monitor operational mode.

Following this methodology, we found a much lower portion of monitors left on for 24 hours a day in 2010 than 2013, i.e., 3.2%and 1.8% of those associated with desktops and portable computers, respectively, as compared to 15% and 10% in 2010. The amount of monitors that were 24 hours on is much higher in 2010 compared to 2013 because the 2010 methodology assumed that if a computer does not have APM enabled and the monitor was not turned off manually then the monitor is always on. Based on monitor power-draw measurements in 2013, we changed this so that a monitor associated with a computer in sleep or switched off manually is either in sleep or off mode.

3.7.1.3 Unit and Annual Energy Consumption

Monitor AEC equals 5.7TWh in 2013, with most of the energy consumption occurring in active mode (about 5.2TWh). Sleep and off modes account for a very small portion of AEC (0.4 TWh and 0.1 TWh, respectively). Table 3-35 shows UEC and AEC breakdowns by display technology and screen size. LCD monitors with CCFL backlight technology account for a majority of monitor AEC.

Table 3-35: UEC and AEC estimates for monitors.

	Year	Screen Size [inches]	Units [millions]	UEC [kWh/yr]				AEC [TWh/yr]
				Active	Sleep	Off	*Total*	
LCD	2010-2013	15-19	9.5	23	1.6	0.7	*25*	0.2
	2010-2013	20-21	7.8	34	1.8	0.8	*36*	0.3
	2010-2013	22-24	8.9	40	2.2	0.8	*43*	0.4
	2010-2013	25-29	1.1	58	3.0	1.2	*62*	0.1
	2010-2013	30-34	0.1	110	3.1	1.7	*115*	<0.05
Subtotal/Wt. Avg.		**20.9**	**27.5**	**33**	**1.9**	**0.8**	***36***	**1.0**
LCD	2006-2010	19.1	53.5	51	4.0	1.7	*56*	3.0
LCD	**Wt. Avg.**	**19.7**	**81**	**46**	**3**	**1**	***51***	**4.0**
CRT	**Wt. Avg.**	**17**	**16**	**94**	**8.9**	**2.8**	***105***	**1.7**
Total/Avg.	**-**	**19.3**	**97**	**53**	**4**	**2**	***58***	**5.7**

3.7.2 Comparison with Prior Energy Consumption Estimates

Table 3-36 summarizes prior estimates for residential monitor energy consumption. Our estimated UEC (58 kWh/yr) is lower than both FhCSE (2011) and LBNL (2013). Unfortunately, we do not know the screen size and technology of monitors metered by LBNL (2013), and therefore cannot readily evaluate the difference in UEC.

Table 3-36: Prior energy consumption estimates for monitors.

Year	Units [millions]	Power [W]			Usage [h/yr]			UEC [kWh/yr]	AEC [TWh/yr]	Source
		Active	Sleep	Off	Active	Sleep	Off			
2013	97	33	0.9	0.6	1,533	4,453	2,774	58	5.7	Current
2013	-	26	1.0	0.0	2,409	4,526	1,825	67	-	LBNL 2013
2010	131	39	1.2	0.9	2,519	3,541	2,701	97	12.7	FhCSE 2011
2010	-	43	1.2	-	1,935	6,825	-	84	-	Bensch et al. 2010
2008-CRT	-	71	46	3	-	-	-	-	-	ECOS 2011
2008-LCD	-	34	6	0.9	-	-	-	-	-	ECOS 2011
2006	90	42	1	1	1,865	875	6,020	85	7.6	TIAX 2007
2005	89	45	2	1	1,860	880	6,020	101	9	TIAX 2006

Overall, our AEC estimate in 2013 is 54% lower than in 2010 (FhCSE 2011). Decreases in the installed base accounts for the largest portion of this change (51%), followed by decrease in active-mode usage (34%), and improvements in the technology (15%). As discussed in the installed base subsection, the decrease in the installed base of desktop PCs and an increase in the installed base of all-in-one PCs are primarily responsible for the 27% decrease in the installed base of external monitors. The decrease in active-mode usage reflects an updated model for both PC and monitor usage that we believe yields more accurate usage estimates (see above).

3.7.3 References

CEA. 2014. "2014 CRT Television and Monitors per U.S. Household". CEA Market Research Report. April.

Cnet. 2010a. ASUS VE276Q 27-inch Review. Oct. http://reviews.cnet.com/lcd-monitors/asus-ve276q/4507-3174_7-34139489.html

Cnet. 2010b. BenQ M2700HD 27-inch Review. Sep. http://reviews.cnet.com/lcd-monitors/benq-m2700hd/4507-3174_7-34069077.html

Dell. 2013. Dell UltraSharp 30 PremierColor Monitor – U3014. Technical specifications. http://accessories.us.dell.com/sna/productdetail.aspx?c=us&l=en&cs=04&sku=225-4429

DisplaySearch. 2014. "Quarterly Desktop Monitor Shipment and Forecast Report, 2011-13"

Energie-Atlas Bayern 2.0. Computer, TV & Co. http://www.energieatlas.bayern.de/buerger/konsum/computer.html

ENERGY STAR. 2013. Displays Product List. Jun.

ENERGY STAR. 2012. Unit Shipment and Market Penetration Report Calendar Year 2012 Summary. http://www.energystar.gov/ia/partners/downloads/unit_shipment_data/2012_USD_Summary_Report.pdf

ENERGY STAR. 2013. Displays Product List. http://downloads.energystar.gov/bi/qplist/displays_prod_list.xls. Jun.

EPA. 2008. Displays Specification. Draft Final Dataset & Analysis. Environmental Protection Agency. Dec. http://www.energystar.gov/ia/partners/prod_development/revisions/downloads/monitors/Draft2_Dataset_Analysis.xls.

EPA. 2013. ENERGY STAR program requirements for displays. Version 6.0. Environmental Protection Agency. Jan. http://www.energystar.gov/products/specs/sites/products/files/Final_Version_6%200_Displays_Program_Requirements.pdf

FhCSE. Urban, Bryan, Kurt Roth, and Verena Tiefenbeck. 2011. "Energy Consumption of Consumer Electronics in U.S. Homes in 2010." Final Report to the Consumer Electronics Association. http://www.ce.org/CorporateSite/media/Government-Media/Green/Energy-Consumption-of-CE-in-U-S-Homes-in-2010.pdf. Dec.

IDC. 2013. IDC Lowers Forecast Growth for PC Monitors While Average Screen Size Increases. Jun. http://www.idc.com/getdoc.jsp?containerId=prUS24163113

LBNL. Greenblatt, J. 2013. "Field data collection of miscellaneous electrical loads in Northern California: initial results." Lawrence Berkeley National Laboratory Final Report, LBNL-6115E. Jul.

NPD DisplaySearch. 2012. Quarterly Worldwide FPD Shipment and Forecast Report. http://techcrunch.com/2012/10/16/study-average-display-size-climbing-on-all-devices-except-for-mobile-pcs/

SID. Kim, J. and P. Semenza. 2012. How LEDs Have Changed the LCD Industry. Technical Paper. Apr.

Statistics Canada. 2013. "Canada Population Estimates." http://www.statcan.gc.ca/start-debut-eng.html

TIAX. Roth, K., R. Ponoum, and 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.

TIAX. Roth, K., K. McKenny. 2007. "Energy consumption by consumer electronics in U.S. Residences." Final report to the Consumer Electronics Association (CEA). Jan.

U.S. Census Bureau. 2013. "U.S. Population." http://www.census.gov/#

3.8 Network Equipment

3.8.1 Current Energy Consumption

Residential network equipment can be classified in three categories: (1) **broadband modems** without integrated routers; (2) broadband modems with integrated routers called **Integrated Access Devices (IADs) or Broadband Gateways**; and (3) **routers and other devices**. Devices from all categories may support wired connections, wireless connections (Wi-Fi), or both.

Broadband modems and IADs are collectively known as broadband access devices, and subscribers use these to connect to a high-speed Internet service provider (ISP). Our installed base estimates include cable, digital subscriber line (DSL) (including asymmetric digital subscriber line (ADSL) and very-high-bit-rate digital subscriber line (VDSL)), fiber optic, and satellite modems in the broadband modem and IAD categories. Less common modems, including stationary WiMAX, 3G, 4G modems and wireless mobile hotspot devices, are included in the routers and other devices category.

Devices listed in the routers and other category are used to establish a local area network (LAN) for communication between household consumer electronics. Routers, the most common and feature-rich devices, can manage data transfer between multiple computer networks and can provide security, Internet connection sharing, and other advanced features. We did not include switches and hubs in the routers and other devices category in 2013 because of their very low initial estimated AEC of 0.01 TWh for less than 1 million units.

3.8.1.1 Installed Base

Broadband subscription penetration in 2013 was 75% according to the CE Sales and Forecasts (2013), an 8% increase from 2010 (FhCSE 2011). This estimate generally agrees with the 70% from another survey-based estimate, PEW (2013). Growth in broadband penetration has slowed since 2010, while in-home network penetration has grown steadily (see Figure 3-30), i.e., from between 40 and 54 percent of households in 2010 (FhCSE 2011) to 62% in 2013. Internet access penetration has remained constant at 78% of households over the past three years (CEA 2013a).

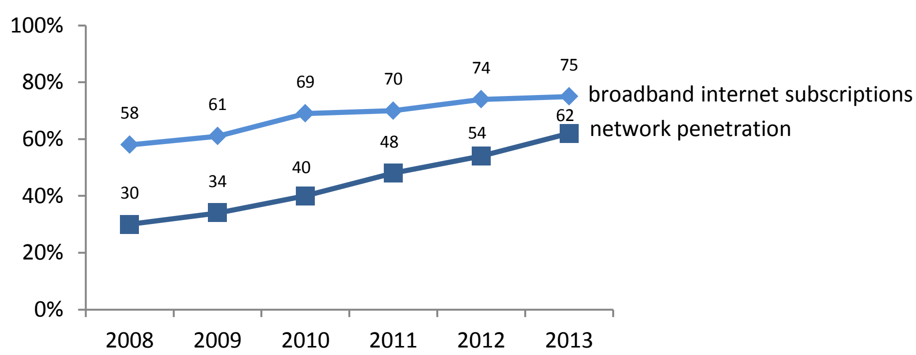


Figure 3-30: Portion of households with broadband Internet subscriptions and home networks (CEA 2013b).

Among the estimated 207 million network devices installed in 2013, 49 million were modem-only, 64 IAD, and 94 routers and other (NRDC 2013, LBNL 2010, CEA 2013a; see Table 3-37). In the modem category, the installed base of cable modems decreased by 49% from 2010, whereas the installed base of DSL modems increased by 11%. The installed base of fiber and satellite modem installed base increased three-fold and nine-fold, respectively. We estimate that the installed base of cable IADs tripled from 2010 to 2013, while there are 13% fewer DSL IAD devices in 2013 than in 2010.

Of the network equipment studied in less detail, mobile wireless hotspots underwent the largest growth in household penetration from 2011, reaching 21% in 2013. The installed base of wireless mobile hotspots together with 3G and 4G modems totaled 35 million devices in 2013 (CEA 2013a).The installed base of wireless routers comes from NRDC (2013), a 15% increase from 2010. Finally, we estimate that the installed base of WiMAX devices remains low (approximately 2% of households[21]).

Table 3-37: Installed base of network devices (LBNL 2010, CEA 2013a, NRDC 2013).

	Installed Base [millions]				Category
	2010	**2011**	**2012**	**2013***	**[%]**
Modem-only					
Cable modem	35	32	27	18	37%
DSL modem	5.4	4	4	6	12%
Fiber optic terminal (all)	5.4	7	10	16	33%
Satellite modem	1.0	-	-	9	18%
Subtotal/Wt. Avg.	**46**	**-**	**-**	**49**	**100%**
IAD (Modem + Router)					
Cable IAD	12	17	27	37	58%
DSL IAD	31	35	37	27	42%
Subtotal/Wt. Avg.	**42**	**-**	**-**	**64**	**100%**
Router and Other					
Wireless router	46	45	42	53	56%
Wired-only router/other	1.7	-	-	1.7	2%
WiMAX	1	-	-	2.4	3%
Access point†	-	-	-	2	2%
Wireless mobile hotspot‡	-	-	-	35	37%
Subtotal/Wt. Avg.	**49§**	**-**	**-**	**94**	**100%**
Total/ Weighted Avg.	**139**	**-**	**-**	**207**	**-**

* Adjusted based on projections from LBNL (2010) and internet subscriptions (CEA 2013a).

† Hardy et al. (2013) defines an access point as "a device that provides Institute of Electrical and Electronics Engineers (IEEE) 802.11 (Wi-Fi) connectivity to multiple clients as its primary function. An access point …extends the range of a wireless signal but does not assign IP addresses to networked devices and therefore cannot be used to connect multiple edge devices in the absence of a wired or wireless router."

‡ This category includes 3G and 4G CPE and wireless mobile hotspots devices.

§ Fraunhofer (2011) did not include wireless mobile hotspot devices in the installed base; their penetration started to grow rapidly in 2011.

The installed base estimates for network equipment in Table 3-37 show a higher penetration of network equipment for cable than for DSL or fiber-optic. This agrees with the results from a recent CEA survey (CEA 2013a) shown in Figure 3-31 (left). Our estimates of installed base of routers indicate that 96% had wireless functionality. According to the CEA ownership survey (CEA 2013a), 51% of households had a wireless connection at their homes in 2013.

[21] Assuming that 2% of US households who answered "some other way" on the question "What type of Internet service do you have at home?" in CEA Ownership Survey (2013a) have WiMAX internet service.

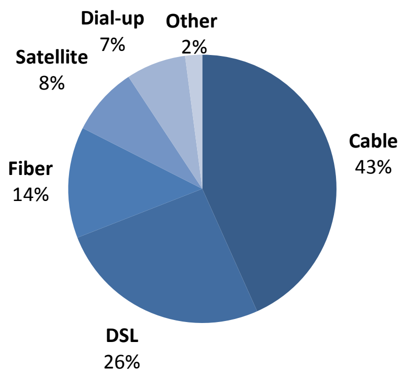


Figure 3-31: Type of Internet service at home (CEA 2013a).

3.8.1.2 Unit Energy Consumption

3.8.1.2.1 Power Draw

Our evaluation of the power draw of network equipment is based upon the ENERGY STAR dataset of measurements for 198 small network equipment devices (EPA 2013b) and measurements from laboratory testing and in-home monitoring using the ENERGY STAR test procedures (NRDC 2013, Hardy et al. 2013). Together, these studies provided a larger measurements data set than we used in the 2010 study. Generally, the active power draw measurements for cable and DSL network equipment by NRDC (2013) and EPA (2013b) are higher than the FhCSE (2011) estimates for 2010. For fiber optic terminals (ONTs), we relied on EPA measurements of 19 ONTs that draw, on average, 6.7 W. To evaluate the active power draw of wired routers, we took the average power draw of 19 wired routers measured by ECCJ (2008).[22] Active power draws for wireless routers and access points we took as average power of measured devices by EPA (wireless routers: n=50, access point: n=13). We could not find new measurements for satellite modems, WiMAX network equipment and wireless mobile hotspot devices in 2013; therefore we used the active power draw values from our previous study (FhCSE 2011) and values from manufacturers' specifications (Motorola 2013, Greenpacket 2013, Fritzbox 2013, CMAX 2013).

Standby power draw estimates are based on values from the previous Fraunhofer CSE study (FhCSE 2011) because neither NRDC nor EPA measured power draw in standby mode. We assumed that standby power draws have not changed appreciable since 2010. In practice, the standby mode has a small impact on network equipment UEC since these devices spend most of the time in on mode. Table 3-38 presents active mode and standby mode power draw values.

The first ENERGY STAR specification for small network equipment took effect in Sept. 2013. Thus, this may have shaped the energy consumption characteristics of network equipment sold right before the point in time for this analysis (i.e., mid-2013) (EPA 2013a).

[22] We were unable to find shipment data for wired routers between 2010. We expect, however, that the installed base of wired routers has not changed from 2010 due to growing wireless connections in US homes. Therefore, power draws estimates from ECCJ (2008) represent most of the installed base.

Table 3-38: Power draws for network equipment (NRDC 2013, EPA 2013b)

	Devices [millions]	Overall [%]	Power [W] Active	Power [W] Standby
Modem-only				
Cable modem	18	9%	6.7	0.1
DSL modem	6	3%	5.4	0.1
Fiber optic terminal (all)	16	8%	6.7*	0.1
Satellite modem	9	4%	9.5	0.1
Subtotal/Wt. Avg.	**49**	**24%**	**7.1**	**0.1**
IAD (Modem + Router)				
Cable IAD	37	18%	8.0	1.5
DSL IAD	27	13%	7.3	1.5
Subtotal/Wt. Avg.	**64**	**31%**	**7.7**	**1.5**
Router and Other				
Wireless router	53	26%	7.5	1.8
Wired-only router / other	1.7	<1%	6.7	0.0
WiMAX	2.4	1%	12†	0.0‡
Access point	2	1%	5.5	0.0‡
Wireless mobile hotspot devices	35	17%	7.0†	0.0‡
Subtotal/Wt. Avg.	**94**	**45%**	**7.4**	**1.0**
Total/ Weighted Average	**207**	**100%**	**7.4**	**0.9**

* The active power draw of a fiber optic terminal varies significantly and depends on the data transmitting by device. Some in-home fiber network equipment also provides TV contents in addition to internet and phone service (NRDC 2013).
† These values have a high uncertainty.
‡ We were unable to find these data.

3.8.1.2.2 Usage

Field monitoring studies indicate that broadband Internet modems and network devices are normally always on and ready to use, and most units automatically turn and remain on when plugged in. The 2010 CE Usage Survey found that 12% of U.S. adults reported that their modems were switched off when not in use, 86% reported always on, and 2% didn't know. Thus, we estimate that an average modem is on 21.4 hours per day, or 7,826 hours per year and turned off the remaining hours (FhCSE 2011). We assume that the time spend in active mode has not changed significantly from 2010 and did not perform an updated usage survey for small network equipment. In the case of wireless mobile hotspot devices, this almost certainly overestimated their active-mode usage.

3.8.1.3 Unit and Annual Energy Consumption

We estimate that network equipment consumed 12 TWh in 2013: 2.7 TWh from modems, 3.9 TWh from IADs, and 5.5 TWh from routers and other (see Table 3-39). In 2013, cable, satellite modems and fiber optic terminals consumed the largest portion of modem energy consumption. Among IAD devices, cable modems with integrated routers consumed more energy than DSL IADs due to a higher installed base. Wireless routers accounted for a majority (58%) of router and other energy consumption due to their high penetration, with increasingly common wireless mobile hotspot devices accounting for much of the remaining energy in this category (see Figure 3-32).

Table 3-39: UEC and AEC calculations for network equipment.

	Devices [millions]	Overall [%]	UEC [kWh/yr]			AEC [TWh/yr]
			Active	Standby	Total	
Modem-only						
Cable modem	18	9%	52	0.1	53	0.9
DSL modem	6	3%	42	0.1	42	0.3
Fiber optic terminal (all)	16	8%	52	0.1	53	0.8
Satellite modem	9	4%	74	0.1	74	0.7
Subtotal/Wt. Avg.	**49**	**24%**	**55**	**0.1**	**55**	**2.7**
IAD (Modem + Router)						
Cable IAD	37	18%	63	1.4	64	2.4
DSL IAD	27	13%	57	1.4	59	1.6
Subtotal/Wt. Avg.	**64**	**31%**	**60**	**1.4**	**62**	**3.9**
Router and Other						
Wireless router	53	26%	59	1.7	60	3.2
Wired-only router / other	1.7	<1%	52	0.0	52	0.1
WiMAX	2.4	1%	94	0.0	94	0.2
Access point	2	1%	43	0.0	43	0.1
Wireless mobile hotspot devices	35	17%	55	0.0	55	1.9
Subtotal/Wt. Avg.	**94**	**45%**	**58**	**0.9**	**59**	**5.5**
Total/Weighted Average	**209**	**100%**	**58**	**0.9**	**58**	**12**

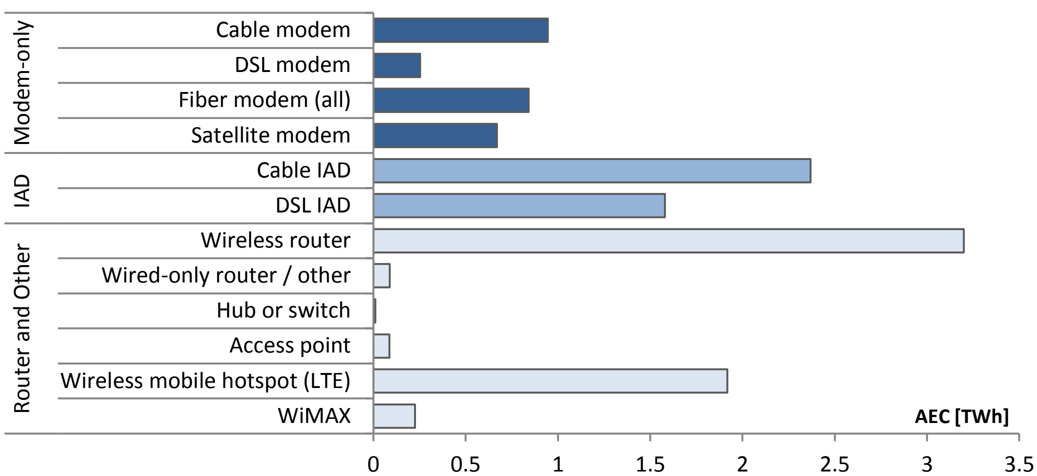


Figure 3-32: AEC for small network equipment.

3.8.2 Comparison with Prior Energy Consumption Estimates

Table 3-40 and Table 3-41 summarize prior estimates for broadband modems and network device energy consumption. Our current estimates are higher than our previous study (FhCSE 2011), primarily due to significant growth in the installed base of fiber optic terminals, wireless routers and wireless mobile hotspot devices.

Table 3-40: Prior energy consumption estimates for broadband access devices (modems and IADs)

Year	Units [millions]	Power [W] Active	Power [W] Standby	Usage [h/yr] Active	Usage [h/yr] Standby	UEC [kWh/yr]	AEC [TWh/yr]	Source
2013	113	7.4	0.9	7,826	934	59	6.7	Current
2012	88	7.5	-	8,760	0	65	5.7	NRDC 2013
2010	88	6.1	0.8	7,826	934	48	4.3	FhCSE 2011
2010	87	6.0	-	8,760	0	53	4.6	LBNL 2010
2008	71	5.8	-	8,760	0	51	3.6	LBNL 2010
2006	46	6.0	-	8,760	0	53	2.4	TIAX 2007
2005	32	6.0	-	8,760	0	53	2.6	TIAX 2006

Table 3-41: Prior energy consumption estimates for routers and other devices (non-modem)

Year	Units [millions]	Power [W] Active	Power [W] Standby	Usage [h/yr] Active	Usage [h/yr] Standby	UEC [kWh/yr]	AEC [TWh/yr]	Source
2013	57	7.4	1.0	7,826	934	57	3.4*	Current
2012	56	5.5	-	8,760	0	48	2.8	NRDC 2013
2010	49	5.4	1.7	7,826	934	44	2.1	FhCSE 2011
2010	50	5.5	-	8,760	0	48	2.4	LBNL 2010
2008	45	5.5	-	8,760	0	48	2.2	LBNL 2010
2005	15	6.0	-	8,760	0	53	0.8	TIAX 2006

* AEC does not include wireless mobile hotspot devices and WiMAX modems, but does include hubs and switches (not shown in prior tables).

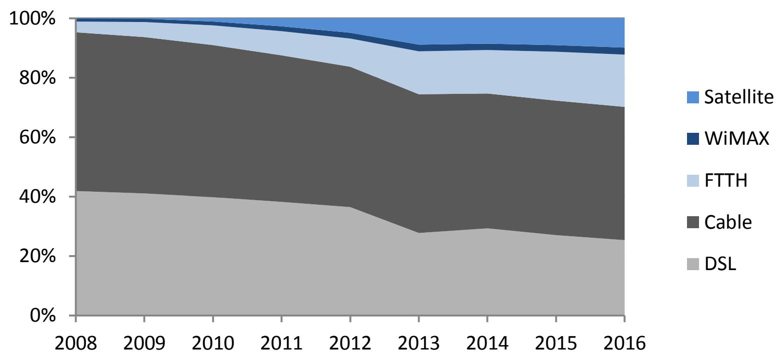


Figure 3-33: U.S. broadband household subscribers by technology type (LBNL 2010, TIA 2013, CEA 2013a).

3.8.3 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.

Cisco. 2011." IEEE 802.3az Energy Efficient Ethernet: Build Greener Networks." White paper. http://www.cisco.com/en/US/prod/collateral/switches/ps5718/ps4324/white_paper_c11-676336.pdf

CMAX. 2013. Technical specifications CMC-100Li. http://www.cmaxwireless.co.kr/pro0104.html?part=4

DisplaySearch. 2014. "Quarterly Desktop Monitor Shipment and Forecast Report, 2011-13"

ECCJ. "Small Routers & L2 Switches." Final report. The Energy Conservation Center Japan. Apr. 2008 https://www.eccj.or.jp/top_runner/pdf/tr_small_routers-apr_2008.pdf

EPA. 2013a. ENERGY STAR program requirements for Small Network Equipment. Version 1.0. Environmental Protection Agency. Nov.

http://www.energystar.gov/products/specs/sites/products/files/SmallNetworkEquipment_V1_ENERGYSTAR_ProgramRequirements_Nov2013_0.pdf

EPA. 2013b. "SNE Version1.0 Draft 3 Dataset."

FhCSE. Urban, Bryan, Kurt Roth, and Verena Tiefenbeck. 2011. "Energy Consumption of Consumer Electronics in U.S. Homes in 2010." Final Report to the Consumer Electronics Association. http://www.ce.org/CorporateSite/media/Government-Media/Green/Energy-Consumption-of-CE-in-U-S-Homes-in-2010.pdf. Dec.

Fritzbox. 2013. Product description Fritz box 6810. http://www.4gltemall.com/fritz-box-6810-lte-cpe.html

Greenpacket. 2013. Technical specifications EX 250. http://www.digicel4gbroadband.com/assets/uploads/WiMAX_CPE_Standard_Modem_______EX_250_Technical_Spec.pdf

Hardy, G., D. Denkenberger, J. Swofford, S. Foster Porter, A. Pawashe, K. Dayem, and D. Driscoll. 2013. "Analysis of Standards Proposal for Small Network Equipment". Codes and Standards Enhancement (CASE) Initiative for PY 2013: Title 20 Standards Development. Ecova. Jul. http://www.energy.ca.gov/appliances/2013rulemaking/documents/proposals/12-AAER-2A_Consumer_Electronics/California_IOUs_Response_to_the_Invitation_for_Standards_Proposals_for_Small_Network_Equipment_2013-07-29_TN-71761.pdf

LBNL. Lanzisera, S. and Nordman, B. 2010. EEDN Task 2.2.3: Network equipment scoping report. Lawrence Berkeley National Laboratory. Mar.

LBNL. Meier, A., Nordman, B., Busch, J., and Payne, C. 2008. "Low-power mode energy consumption in California homes." CEC-500-2008-035. Lawrence Berkeley National Laboratory. Sept. http://www.energy.ca.gov/2008publications/CEC-500-2008-035/CEC-500-2008-035.PDF.

Motorola. 2013. Datasheet for Motorola CPE i800. http://www.motorolasolutions.com/web/Business/Product%20Lines/Motowi4/CPEi_800/Images/StaticFiles/CPEi_800_DataSheet.pdf

NRDC. 2013. "Small Network Equipment Energy Consumption in U.S. Homes." NRDC Issue Paper. Jun. http://www.nrdc.org/energy/files/residential-network-IP.pdf

Pew. Zickuhr,K., A. Smith. 2013. "Home Broadband 2013." Aug. http://pewinternet.org/Reports/2013/Broadband/Findings.aspx

Statistics Canada. 2013. "Canada Population Estimates." http://www.statcan.gc.ca/start-debut-eng.html

U.S. Census Bureau. 2013. "U.S. Population." http://www.census.gov/#

TIA. 2013. "Market Review and Forecast." Mar.

TIAX. Roth, K., R. Ponoum, and 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.

TIAX. Roth, K., K. McKenny. 2007. "Energy consumption by consumer electronics in U.S. Residences." Final report to the Consumer Electronics Association (CEA). Jan.

3.9 Smart Phones

Smartphones are mobile phones with Internet connectivity. They include phones with operating systems running iOS, Android, Windows Mobile and BlackBerry.

3.9.1 Current Energy Consumption

3.9.1.1 Installed Base

We estimate an installed base of 166 million smartphones that have been used in the past month (Nov. 2013). Some U.S. adults indicated that their households owned smartphones, but that they personally did not use any. Given the nascence of smartphones, as a lower bound, we assume that such households have one smartphones which is used by others. Our estimate from late 2013 is higher than the estimate from early 2013 by CEA (2013a), due to the high sales volume of smartphones in 2013 (estimated 127 million by CEA 2013b). Our installed base is consistent with other recent estimates (see Table 3-42).

Table 3-42: Installed base estimates for smartphones from different data sources.

Data Date	Household penetration	Households [millions]	Units / owner household	Installed Base [millions]	Source
Dec 2013	66%	79	2.1	166*	CE Usage Survey
Feb 2013	58%	69	2.2	152	CEA 2013a
Jun 2013	-	-	-	164†	Magid 2013
Jun 2013	-	-	-	151‡	Pew 2013b
Q2 2013	-	-	-	142§	Nielsen 2013a

* Sum of our estimates for smartphones which U.S. adults personally used (152 million) and smartphones which are owned in their households, but not personally used by the U.S. adult, assuming one for each of those households (14 million).

† Lower bound estimate based on 61% of U.S. population (ages 8-65), 316.1 million U.S. population in 2013 (U.S. Census 2013), 85% of U.S. adults use the Internet (Pew 2013).

‡ Lower bound estimate based on 56% of U.S. adults.

§ Lower bound estimate based on 53% of U.S. online users aged 13+.

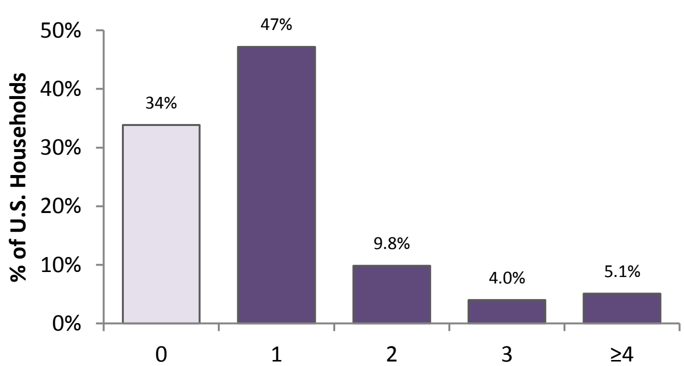


Figure 3-34: Distribution of households with smartphones used during the past month (Nov. 2013) vs. Ownership (Feb. 2013, CEA 2013).

Unlike for tablets, we asked only about the (primary) smartphones most used by the U.S. adult, since they are personal devices; respondents are unlikely to know how other smartphones are used in the household.

Table 3-43: Plugged-In installed base estimates for smartphones from the CE Usage Survey.

	Households [millions]				
		Smartphones Used per Owner Household			
Device	**Not Owned**	**1**	**2**	**3**	**≥4**
Smartphones	40	42	12	4.8	6.1

3.9.1.2 Usage

We estimate that smartphones are used for 4.1 hours/day on average (Median=2.0 hours/day). Our median estimate is similar to other estimates of 2.6 hours for smartphones by DOE (2012) and the measured average of 2.6 hours/day for smartphones or tablets by Flurry Analytics (2013). However, our estimate is higher than that of Experian (2013) of 58 minutes/day. Experian (2012) also found phone usage to vary with phone type, e.g., iPhones are used more than Android smartphones (1.25 vs. 0.82 hours/day).

3.9.1.3 Energy Consumption

We use the same energy model to evaluate smart phone energy consumption as we did for tablets (see Section 3.10.1.2). The model considers energy consumption due to battery charging, including the impact of charger inefficiency and power draw when the smartphone is idle or unplugged from the charger but the charger remains plugged into the wall. Appendix B.2 presents additional details. We measured power draws by metering 5 smartphone units with Watts Up? .Net and Yokogawa WT210 power meters. Based on survey responses, we estimate that original chargers are used 82% of the time, and other chargers 18% of the time.

Table 3-44: Representative battery capacity for smartphones, and power draw estimates for original and other chargers.

Charger Type	Relative Usage Time	Battery Capacity [Wh]	Charger Efficiency [%]	Power Draw [W]	
				Idle	Unplugged
Original	82%	6.5	76%	0.49	0.13
Others	18%	-	67%	0.55	0.19
Weighted Average	-	**6.5**	**74%**	**0.50**	**0.14**

3.9.1.3.1 Charging

We calculate the energy consumption due to charging smartphones by multiplying the number of times the battery is charged in a day by the average increase in battery level (from pre-charging to post-charging) for each charge session, and the additional energy consumed due to charger inefficiency (see Table 3-45). Our estimate of 0.92 charge cycles/day is similar to the estimate by DOE (2012) of 0.80 charges cycles/day and the assumption by OPower (2012) of one charge cycle/day.

Table 3-45: Energy consumption estimates due to charging smartphones.

Device	Battery Level		Number Per Day		Battery Capacity [Wh]	Charger Efficiency [%]	Energy Consumption	
	Pre-Charge	Post-Charge	Charge Sessions	Charge Cycles			Full Charge [Wh]	Per Day [Wh/day]
Smartphone	29%	95%	1.5	0.92	6.54	76%	8.8	7.7

3.9.1.3.2 Idle

We calculate the energy consumption in idle mode by multiplying the remaining time plugged in after charging to partial battery capacity in one day by the power draw while idle. As for tablets, for simplicity we average the charging rates for <90% and ≥90% battery levels to estimate the average time for a full charge, and assume a linear relationship for the time to partial charging. Based on survey responses, we estimate that 64% of smartphones are charged *only* with the original charger and 11% are charged *only* with other chargers, and the remaining 25% of smartphones are charged with *both* the original and other chargers. DOE (2012) estimated higher time and power draw in idle mode, that yield a higher energy consumption estimate (3.6 vs. 2.5 Wh/day).

Table 3-46: Energy consumption estimates due to smartphones being plugged into chargers after being fully charged (idle).

Device	Time [hr/day]						Power Draw Idle Mode [W]	Energy Consumption [Wh/day]
	Connected to Charger			Charging		Idle		
	Original Charger	Others	All Chargers	Full Charge [hr]	Per Day [hr/day]			
Smartphone	**4.1**	**1.0**	**5.2**	**2.1**	**1.9**	**3.3**	**0.50**	**2.5**
(DOE 2012)	-	-	7.2	-	2.6	4.6	0.78	3.6

3.9.1.3.3 Unplugged

We estimate that on average smartphone chargers plugged into the wall socket for 15 hours/day, but 49% of users leave them plugged in all the time (24 hours/day). Averaged over all smartphones, including those that do not use another charger, "other" smartphone chargers are plugged into the wall socket for 6 hours/day. Therefore, for smartphones in the unplugged mode, the total energy consumption of their chargers is 3.6 Wh/day. DOE (2012) estimated that users leave their smartphones plugged in for a shorter amount of time, and therefore have a higher unplugged time (6.6 vs. 11 hours/day). The DOE (2012) energy consumption is about half our estimate for the original charger (0.7 vs. 1.3 Wh/day).

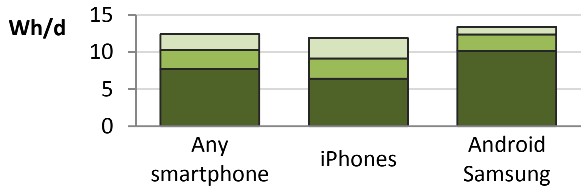
Table 3-47: Energy consumption estimate for smartphones in unplugged mode.

Charger Type	Time [hr/day]		Power Draw [W]	Energy Consumption [Wh/day]
	Charger Plugged Into Wall	Device Unplugged		
Original Charger	15	11	0.13	1.3
Others*	6.0	4.4	0.18	0.8
All Chargers	-	-	-	**2.2**
(DOE 2012)	14	6.6	0.11	0.7

* Since we did not ask about other chargers, we assume that if other chargers are used (>0 hours/day), then they are left plugged in the same amount of time as the original charger. Note that mean estimates include responses indicating no use of other chargers (0 hours/day).

3.9.1.4 Unit and Annual Energy Consumption (UEC and AEC)

Our calculations yield an average smartphone UEC of 4.5 kWh/year and an AEC of 0.75 TWh/year. Our estimates show that non-charging modes account for about one-third of energy consumption (see Figure 3-35). Although the UEC of smartphones is 74% of that of tablets (see Section 3.10), smartphones have a 66% greater installed base, resulting in a somewhat (24%) higher AEC.



	Any smartphone	iPhones	Android Samsung
Unplugged	2.2	2.7	1.0
Idle	2.5	2.7	2.2
Charging	7.7	6	10
Total	12	12	13

Figure 3-35: Energy consumption of smartphones in different operational modes.

Table 3-48: UEC and AEC values for smartphones.

Type	Energy Consumption [Wh/day]	UEC [kWh/year]				Installed Base [millions]	AEC [TWh/yr]
		Charging	Idle	Unplugged	Total		
iPhones	12	2.4	1.0	1.0	4.3	70*	0.30
Android Samsung	13	3.7	0.8	0.4	4.9	22*	0.11
All Smartphones	12	2.8	0.9	0.8	4.5	166	0.75

* Installed base for various iPhone and Android Samsung smartphone models estimated by representative weights of selected most popular smartphones scaled to the total installed base of smartphones. Note that this does not sum to the estimate for total installed base, since there are other smartphone models.

3.9.2 Comparison with Prior Energy Consumption Estimates

Our UEC estimates for smartphones are similar to those of other sources (see Table 3-49). Our estimates verify commonly held assumptions that smartphones are charged about once a day. OPower (2012) estimated slightly higher energy consumption for charging (indicating lower efficiencies compared to manufacturer specifications and product reviews, i.e., 57% for iPhone 5 and 65% for Samsung Galaxy S3). However, we account for additional modes that consume additional energy, specifically the idle and unplugged modes.

Table 3-49: Current and prior energy consumption estimates for smartphones.

Year	Units* [millions]	UEC [kWh/yr]				AEC [TWh/yr]	Device Model	Source
		Charging	Idle	Unplugged	Total			
2013	166	2.8	0.9	0.8	4.5	0.75	All smartphones	Current
2013	26	2.4	1.3	1.1	4.8	0.12	iPhone 5	Current
2013	14	2.3	0.7	1.1	4.0	0.06	iPhone 4	Current
2013	13	3.4	0.8	0.4	4.5	0.06	Samsung Galaxy S3	Current
2012	170†	3.5	0	0	3.5	0.59†	iPhone 5	OPower 2012
2012	-	4.5	0	0	4.5	-	Samsung Galaxy S3	OPower 2012
2012	-	-	-	-	3.3	-	iPhone 4	EPRI 2012
2012	-	-	-	-	2.2	-	iPhone 3G	EPRI 2012
2012	-	5.3‡	-	0.3	5.5	-	Smartphones	DOE 2012

* Installed base for select smartphones estimated by aggregated usage share and total installed base of smartphones.
† Based on projected global sales in 2012.
‡ Combined UEC for charging and idle.

3.9.3 References

CEA. 2010. "12th Annual household CE Ownership and Market Potential." CEA Market Research Report. Consumer Electronics Association. May, 2010. Consumer Electronics Association.

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.

CEA. 2013c. Steve Koenig. Private correspondence, Nov. 2013. Consumer Electronics Association.

CEA. 2014. "Consumer Outlook on Tablets – Jan. 2014 Edition." Jan. 2014.

DOE. 2012. "Rulemaking for Battery Chargers and External Power Supplies Energy Conservation Standard. Energy Use Analysis Spreadsheet." Feb. 17, 2012. http://www.regulations.gov/#!documentDetail;D=EERE-2008-BT-STD-0005-0084. Retrieved Feb. 6, 2014.

EPRI. 2012. "iPad Electricity Consumption in Relation to Other Energy Consuming Devices - Executive Summary." Jun. 21, 2013. http://www.epri.com/Our-Work/Documents/Energy%20Efficiency/iPadEnergyConsumeExecSummary6-2012Final.pdf. Retrieved Sept. 20, 2013.

Experian. 2013. Fetto, J. "Americans spend 58 minutes a day on their smartphones" May 28, 2013. http://www.experian.com/blogs/marketing-forward/2013/05/28/americans-spend-58-minutes-a-day-on-their-smartphones/. Retrieved Oct. 24, 2013.

Flurry Analytics. 2013. Khalaf, S. "Flurry Five-Year Report: It's an App World. The Web Just Lives in It." Apr. 3, 2013. http://blog.flurry.com/bid/95723/Flurry-Five-Year-Report-It-s-an-App-World-The-Web-Just-Lives-in-It. Retrieved Nov. 12, 2013.

Magid. 2013. "Tablets Find a Home in More U.S. Homes." Jun. 9, 2013. http://www.magid.com/node/250. Retrieved Sept. 20, 2013.

Nielsen. 2013. "The Mobile User." Feb. 25, 2013. http://www.nielseninsights.it/wp-content/uploads/2013/03/03.-global_mobile_report_02_25.pdf. Retrieved Aug. 6, 2013.

NPD. 2013. "Internet Connected Devices Surpass Half a Billion in U.S. Homes, According to The NPD Group." Mar. 18, 2013. https://www.npd.com/wps/portal/npd/us/news/press-releases/internet-connected-devices-surpass-half-a-billion-in-u-s-homes-according-to-the-npd-group/. Retrieved Jan. 24, 2014.

OPower. 2012. Fischer, B. "How much does it cost to charge an iPhone 5?" Sept. 27, 2012. http://blog.opower.com/2012/09/how-much-does-it-cost-to-charge-an-iphone-5-a-thought-provokingly-modest-0-41year. Retrieved Oct. 17, 2013.

Pew. 2013b. Smith, A. "Smartphone Ownership 2013." Jun. 5, 2013. http://pewinternet.org/Reports/2013/Smartphone-Ownership-2013/Findings.aspx. Retrieved Oct. 17, 2013.

3.10 Tablet Computers

Tablets include the iPad, Android tablets, and Windows 8 tablets, but exclude notebook or ultra-portable PCs with touch screens. While individually these devices do not consume much energy, collectively their energy consumption is notable due to a large and rapidly growing install base.

3.10.1 Current Energy Consumption

3.10.1.1 Installed Base

We estimate an installed base of 100 million tablets that have been used in the past month. Some U.S. adults indicated that their households owned tablets, but that they personally did not use any. Given the relatively recent market entry of tablets, as a lower bound, we assume that such households have one tablet which is used by others. Our estimate from late 2013 exceeds that from early 2013 by CEA (2013a), due to the high sales volume of tablets in 2013 (estimated at 113 million by CEA 2013b). Our installed base agrees with other recent estimates (see Table 3-50).

Table 3-50: Recent installed base estimates for tablets.

Data Date	Household penetration	Households [millions]	Units / owner household	Installed Base [millions]	Source
Dec 2013	57%	67	1.47	100*	CE Usage Survey
Feb 2013	39%	46	1.50	70	CEA 2013a
Jul 2013	-	41†	-	-	Parks Associates 2013
Jun 2013	-	-	-	118††	Magid 2013
Jun 2013	-	-	-	91§	Pew 2013b
Q1 2013	-	49	-	-	NPD 2013
2013				100	Representative

* Sum of our estimates for tablets that U.S. adults personally used (73 million) and tablets owned by their households but not personally used by the respondent, assuming one for each of those households (26 million).

† Lower bound estimate based on 48% of U.S. broadband households, 119 million U.S. households in 2011 (U.S. Census 2011), 72% of U.S. Internet household penetration in 2011 (U.S. Census 2011).

†† Lower bound estimate based on 44% of U.S. online population (ages 8-65), 316.1 million U.S. population in 2013 (U.S. Census 2013), 85% of U.S. adults use the Internet (Pew 2013).

‡ Lower bound estimate based on 57% of U.S. online households indicating they own at least one tablet.

§ Lower bound estimate based on 35% of U.S. adults indicating they own at least one tablet, 75.6% adults in U.S. population in 2012 (U.S. Census 2012), 313.9 million U.S. population in 2012 (U.S. Census 2012).

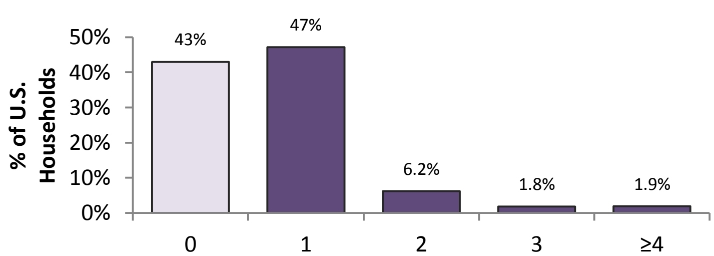


Figure 3-36: Percentage of households with tablets used during the past month (Nov. 2013) vs. Ownership (Feb. 2013) (CEA 2013).

Similar to portable PCs, we asked about the most used (primary) tablet and second most used (secondary) tablets.

Table 3-51: Plugged-In installed base estimates for tablets from the CE Usage Survey.

Device Type	# Used [million households]				Usage Base [million units]		
	1*	2	3	≥4	All	Primary	Second+
Tablets	56	7.3	2.2	2.3	100	68	32

* We include estimates where the U.S. adult indicated using 0 tablets, but whose household owns >0 tablets.
Primary: number of primary, i.e., most-used, tablets.
Second+: number of tablets that are not primary, i.e., secondary, tertiary, etc.; treated as secondary in energy model.

3.10.1.2 Usage

We asked respondents how long their tablets were used yesterday. We estimate that tablets are used 2.5 hours a day on average (Median=1.5 hours). Our mean estimate is similar to the measured average of 2.6 hours for smartphones or tablets by Flurry Analytics (2013).

3.10.1.3 Energy Consumption

Mobile devices are typically used while running on their batteries. Using the energy usage model described in Appendix B.2, we calculate the energy consumption for their usage by estimating the energy consumed to charge their batteries. Their battery chargers (BC) also consume energy while plugged into the wall outlets. Therefore, we consider the energy consumption due to charging and the charger in the following modes:

- **Charging:** When recharging the battery of the mobile device to its full capacity with an additional energy loss due to charging inefficiencies. DOE's battery charger rulemaking refers to this mode as "active."
- **Idle:** When the mobile device screen is off and the device is connected to its charger but not charging. The power draw in this mode is higher than the power draw on the battery when the mobile device is running on its battery and disconnected from the charger. DOE's battery charger rulemaking refers to this mode as "maintenance."
- **Unplugged:** When the mobile device is unplugged from its charger, but the charger remains plugged into the wall socket. If the user uses multiple chargers, then the energy consumption is due to all these chargers. DOE's battery charger rulemaking refers to this mode as "no battery."
- **BC Unplugged:** When the charger is unplugged from the wall socket. The power draw is 0W.

To get representative estimates for power draw, we identified the 8 most popular tablets models and measured their power draw of 7 units using Watts Up? .Net and Yokogawa WT210 power meters. Measurements were taken after five seconds of the device entering the relevant operational mode and when the power draw has stabilized. Representative battery capacities and charger efficiencies were aggregated from review articles and manufacturer specifications of the selected device models. See Appendix Table B-8 for more details.

We consider that users charge their mobile devices using the *original* (OEM) charger that came purchased with the product, and *other* chargers, such as after-market chargers, charging via the USB ports of PCs and speaker docks, and car chargers. Based on survey responses, we estimate that original chargers are used 90% of the time, and other chargers 10% of the time.

Table 3-52: Representative capacity and efficiency of original and aftermarket batteries and chargers for tablets.

Charger Type	Relative Usage Time	Battery Capacity [Wh]	Charger Efficiency [%]	Power Draw [W]	
				Idle*	Unplugged
Original	90%	25.6	79%	0.36	0.08
Aftermarket	10%	-	68%	0.40	0.13
Weighted Average	**-**	**25.6**	**78%**	**0.36**	**0.09**

* Based on average measurements of several metered devices.

3.10.1.3.1 Charging

We calculate the energy consumption due to charging tablets by calculating the number of charge cycles per day, i.e., the number of full battery charges per day. This equals the product of the number of charge sessions per day, i.e., the number times the battery is charged in a day, and the average increase in battery charge level (from pre-charging to post-charging) for each charge session plus the added energy consumed due to charger losses (see Table 3-53). Our estimate of 0.44 charge cycles/day is higher than the estimate by DOE (2012) of 0.29 charges cycles/day, but similar to that of EPRI (2012) of 0.5 charge cycles/day (every other day).

Table 3-53: Energy consumption estimates due to charging tablets.

Device Type	Battery Level		Number Per Day		Battery Capacity [Wh]	Charger Efficiency [%]	Energy Consumption	
	Pre-Charge	Post-Charge	Charge Sessions	Charge Cycles			Full Charge [Wh]	Per Day [Wh/day]
Primary	29%	95%	0.81	0.53	25.6	78%	33	16
Secondary*			0.49	0.32				11
Weighted Average	29%	95%	0.67	0.44	25.6	78%	33	14

* Energy consumption and amount of charging estimated by the relative (weighted) usage between primary and secondary tablets (2.2 vs. 1.4 hours). For example, the number of charge sessions = 2.2h×0.81 + 1.4h×0.49 / (2.2h + 1.4h) = 0.67.

3.10.1.3.2 Idle

We calculate the energy consumption due to the tablet being idle while plugged into the charger by multiplying the remaining time plugged in after charging to partial battery capacity in one day, and the power draw while idle. Tablet chargers do not charge at a constant rate for different battery levels; e.g., fast chargers charge faster at lower battery levels than higher levels. For simplicity we average the charging rates for <90% and ≥90% battery levels to estimate the average time to for a full charge, and assume a linear relationship for the time to partial charging.

We estimate that 84% of tablets are charged *only* with the original charger, 11% are charged *only* with other chargers, and the remaining 5% of tablets are charged with *both* the original and other chargers. Our energy consumption estimate is lower than the 2010 estimate by DOE (2012) (0.9 vs. 5.3 Wh/day) because of our lower estimate for the time in idle mode (3.9 vs. 6.1 hours) and lower power draw (0.36 vs. 0.87W).

Table 3-54: Energy consumption estimates of tablets in idle mode.

	Time [hr/day]							
	Connected to Charger			Charging				Energy
Device Type	Original Charger	Others	All Chargers	0 to 100% Full [hr]	Per Day [hr/day]	Idle	Power Draw [W]	Consumption [Wh/day]
Primary	5.3	0.8	6.0	4.2	2.0	3.9	0.36	1.1
Secondary*	3.2	0.5	3.6		1.4	2.8		0.8
Wt. Avg.	**4.4**	**0.6**	**5.0**	**4.2**	**1.8**	**3.4**	**0.36**	**0.9**
(DOE 2012)	-	-	7.5	-	1.4	6.1	0.87	5.3

* Energy consumption and amount of charging estimated by the relative usage between primary and secondary tablets (2.2 vs. 1.4 hours).

3.10.1.3.3 Unplugged

Tablets still contribute to energy consumption even when unplugged from the wall socket, because their chargers may still be plugged in. We estimate that, on average, original tablet chargers are plugged into the wall socket for 14 hours/day, but 49% of users leave the charger plugged in all of the time (24 hours/day). Averaged over all tablets, including those that do not use another charger, “other” tablet chargers are plugged into the wall socket for 3 hours/day. Therefore, for tablets in the unplugged mode, the total energy consumption of their chargers is 0.9 Wh/day. Our estimates for time spent and the energy consumption for tablets in the unplugged mode are similar estimates by DOE (2012). Since we did not ask about secondary tablets, we assume that both primary and secondary tablet chargers are plugged into the wall socket for the same amount of time.

Table 3-55: Energy consumption estimate for tablets in unplugged mode.

	Time [hr/day]			Energy
Charger Type	Charger Plugged Into Wall	Device Unplugged	Power Draw [W]	Consumption [Wh/day]
Original Charger	14	8.5	0.08	0.7
Others*	2.9	1.2	0.13	0.2
All Chargers	**17**	**10**	**-**	**0.9**
(DOE 2012)	16	8.5	0.13	1.1

* Since we did not ask about other chargers, we assume that if other chargers are used (>0 hours/day), then they are left plugged in the same amount of time as the original charger.

3.10.1.4 Unit and Annual Energy Consumption (UEC and AEC)

Our calculations yield a UEC of 6.1 kWh/year for a typical tablet and an AEC of 0.61 TWh/year. Charging accounts for 86% of tablet UEC. Tablets with smaller screens (<8.9”) have a lower UEC, installed base, and AEC than tablets with larger screens (≥8.9”). Our estimates show that non-charging operational modes account for a notable portion of energy consumption (13%). Compared to portable PCs (see Section 3.5), we estimate that tablets have a UEC that is 8.8 times lower, a 11% higher installed base, and an AEC 8.2 times lower. If we assume that secondary tablets have the same usage and energy consumption as primary tablets, the UEC and AEC estimates would be 6.7 kWh/year and 0.67 TWh/year, respectively.

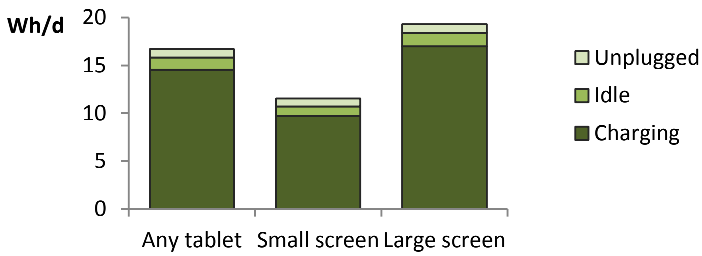


Figure 3-37: Energy consumption of tablets in different operational modes.

Table 3-56: UEC and AEC values for tablets.

Device Type	Energy Consumption [Wh/day]	UEC [kWh/year]				Installed Base* [millions]	AEC [TWh/yr]
		Charging	Idle	Unplugged	Total		
Small screen	12	3.6	0.4	0.3	4.2	32	0.14
Large screen	19	6.2	0.5	0.3	7.0	68	0.48
All Tablets	17	5.3	0.5	0.3	6.1	100	0.61

* Installed base for small and large screen tablets estimated by representative weights of selected most popular tablets scaled to the total installed base of tablets.

3.10.2 Comparison with Prior Energy Consumption Estimates

Our UEC estimates for several specific tablet models are slightly lower than estimates from other sources. Referring to our UEC and AEC estimates for desktop and portable PCs (see Sections 3.4 and 3.5, respectively), we discuss some comparisons with those for tablets. While the plugged-in installed base of desktop and portable PCs have decreased since 2010 (by 13 and 39 million, respectively), the installed base for tablets has increased about 30-fold since 2010, i.e., from 4 million to 100 million. Thus, it appears that tablets are, to some extent, displacing some of the usage of desktop and portable PCs.

Applying our current UEC for desktop and portable PCs for our 2010 installed base estimates (Fraunhofer 2011), the AEC for desktop and portable PCs decreased by 2.5 and 1.9 TWh/year, respectively. On the other hand, applying our current UEC estimate for tablets, the AEC for tablets increased from 0.02 TWh/year to 0.6 TWh/year. This represents a net decrease in the total AEC of 3.7 TWh/year for all computing devices, excluding smartphones.

Table 3-57: Current and prior energy consumption estimates for tablets.

Year	Units [millions]	UEC [kWh/yr]	AEC [TWh/yr]	Device Model	Source
2013	100	6.1	0.6	All tablets	Current
2012	67†	11.9	0.6†	iPad 3	EPRI 2012
2012	-	7.2	-	iPad 2	EPRI 2012
2012	-	7.1	-	iPad 1	EPRI 2012
2012	-	8	-	iPad 2	NRDC 2012
2010	2.5	-	-	iPad 1	Forrester 2010

† Based on sale reports of all iPads since Q2 2010 with no device retirement.

3.10.3 References

CEA. 2010. “12th Annual household CE Ownership and Market Potential.” CEA Market Research Report. Consumer Electronics Association. May, 2010. Consumer Electronics Association.

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.

CEA. 2013c. Steve Koenig. Private correspondence, Nov. 2013. Consumer Electronics Association.

CEA. 2014. "Consumer Outlook on Tablets – Jan. 2014 Edition." Jan. 2014. Consumer Electronics Association.

DRG. 2013. "United States PC, Tablet, & Mobile Phone Market Size and Forecast, Jul. 2013." Daniel Research Group. http://www.danielresearchgroup.com/LinkClick.aspx?fileticket=1ejALRMAUbk%3D&tabid=122&mid=522. Rerieved Oct. 30, 2013.

EPRI. 2012. "iPad Electricity Consumption in Relation to Other Energy Consuming Devices - Executive Summary." Jun. 21, 2013. http://www.epri.com/Our-Work/Documents/Energy%20Efficiency/iPadEnergyConsumeExecSummary6-2012Final.pdf. Retrieved Sept. 20, 2013.

Flurry Analytics. 2013. Khalaf, S. "Flurry Five-Year Report: It's an App World. The Web Just Lives in It." Apr. 3, 2013. http://blog.flurry.com/bid/95723/Flurry-Five-Year-Report-It-s-an-App-World-The-Web-Just-Lives-in-It. Retrieved Nov. 12, 2013.

Forrester . 2010. Rotmann Epps, S. "U.S. Tablet Buyers Are Multi-PC Consumers." Aug. 19, 2010. http://www.wired.com/images_blogs/gadgetlab/2010/08/US-Tablet-Buyers-Are-Multi-PC-Consumers.pdf.

FhCSE. Urban, Bryan, Kurt Roth, and Verena Tiefenbeck. 2011. "Energy Consumption of Consumer Electronics in U.S. Homes in 2010." Final Report to the Consumer Electronics Association. http://www.ce.org/CorporateSite/media/Government-Media/Green/Energy-Consumption-of-CE-in-U-S-Homes-in-2010.pdf. Dec.

Magid. 2013. "Tablets Find a Home in More U.S. Homes." Jun. 9, 2013. http://www.magid.com/node/250. Retrieved Sept. 20, 2013.

Nielsen. 2013. "Q2 2013 Cross-platform report: viewing on demand." Sept. 9, 2013. http://www.nielsen.com/us/en/reports/2013/q2-2013-cross-platform-report.html. Retrieved Oct. 17, 2013.

NPD. 2013. "Internet Connected Devices Surpass Half a Billion in U.S. Homes, According to The NPD Group." Mar. 18, 2013. NPD Group. https://www.npd.com/wps/portal/npd/us/news/press-releases/internet-connected-devices-surpass-half-a-billion-in-u-s-homes-according-to-the-npd-group/. Retrieved Jan. 24, 2014.

NRDC. 2012. Sullivan, D. "Consumer electronics programs: what can the Midwest do?" Jan. 12, 2012. Midwest Energy Solutions Conference 2012 presentation. http://mwalliance.org/sites/default/files/uploads/meeaconference/MES-2012_presentations_Sullivan.pdf. Retrieved Feb. 2014.

Parks Associates. 2013. "Tablets: Disrupting Mobile Computing and the Digital Home." Park's Associates. Jul. 25, 2013. http://www.parksassociates.com/blog/article/pr-jul2013-tablets. Retrieved Sept. 2013.

Pew. 2013a. "Tablet Ownership 2013." Jun. 10, 2013. http://www.pewinternet.org/~/media//Files/Reports/2013/PIP_Tablet%20ownership%202013.pdf. Retrieved 18 Sept. 2013.

Pew. 2013b. "Tablet and E-reader Ownership Update." Jun. 10, 2013. http://www.pewinternet.org/~/media/Files/Reports/2013/PIP_Tablets%20and%20e-readers%20update_101813.pdf. Retrieved 18 Sept. 2013.

3.11 Set-top Boxes

3.11.1 Current Energy Consumption

Set-Top Boxes (STBs) receive and decode signals for playback on televisions. Features and services can vary according to service provider, subscription package, and device hardware, and may include high definition (HD) or standard definition (SD) tuners, video-on-demand, digital video recording (DVR) capabilities, multiple tuners, format conversion, and more. We divide STBs into two major categories: pay TV STBs and standalone STBs. Pay TV STBs are generally leased to consumers by multichannel (cable, satellite, and telco[23]) TV providers and enable a variety of services and features. On the other hand, standalone STBs may be purchased directly by consumers, and generally provide alternative services to those of pay TV STBs. Standalone STBs include digital media streaming devices[24], standalone DVRs, and OTA-DTAs. Digital media streaming adapters stream digital media from computer servers or the Internet to a television or audio system. DTAs are STBs that decode digital signals for TV viewing, and these exist in two forms: (1) cable digital transport adapters[3] that may decode digitally encrypted cable signals for viewing on subscriber TVs, and (2) over-the-air digital-to-analog adapters (OTA-DTAs) that decode unencrypted over the air digital broadcast signals transmitted via antenna for viewing on older analog TVs that lack a digital tuner.

Set-top box power draw depends on its features, and today there is more variety and complexity in features than ever before. In our prior study we divided subscription STBs into three feature categories: (1) DVR with any tuner; (2) non-DVR with Standard Definition (SD) tuner, and (3) non-DVR with High Definition (HD) tuner (FhCSE 2011). Since 2010, new device categories have emerged that affect power draw and usage. Among these are (4) multi-room/video server STBs that may have DVR capabilities; and (5) video client STBs that receive programming from multi-room server STBs. Some STBs, called *thin clients*, are designed to interface with and obtain content primarily from a multi-room video server STB or gateway that is connected directly to the service provider, rather than directly with the service provider. Since there are presently relatively few thin clients and video clients in service, we collectively label them thin clients in this study.

Although there are relatively few manufacturers and models of STBs, the actual power draw of a specific device depends on what combinations of features are enabled for that particular household. Service providers can change the activated features of deployed STBs through software updates. For example, a service provider might launch multi-room DVR capability in compatible set-top boxes STBs through a software update. Some STBs include five or more tuners that can enable simultaneous viewing or recording of several programs, though not all of these tuners may be enabled or activated. While, such configuration decisions may influence power draw to some extent, there is limited publically available information about the distribution of features enabled by different providers.

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[23] Other studies have referred to Telco TV as IPTV, but Telco TV includes subscription TV services that are not provided via IP, most notably Verizon FiOS. It does not include the streaming of video over an internet connection.

[24] Sometimes called over-the-top (OTT) STBs, these refer to devices that receive media over the internet without a multiple system operator involved in content distribution.

3.11.1.1 Installed Base

To gain better understanding of the complex landscape of hardware and features, we conducted the CE Usage Survey to estimate the number of subscribers and different types of STBs in service. We combined those results with market research and industry specific data to estimate the feature distribution among households.

3.11.1.1.1 Pay TV Set-top Boxes

The CE Usage Survey found that 95 million households subscribe to at least one multichannel video service (80% of all households, 83% of TV households). Of subscriber households, 91% claimed to have exactly one service, 8% two, and 1% three, for a total of 105 million TV subscriptions. Our survey results are comparable to other industry estimates, shown in Table 3-58. Since our survey appears to slightly over-represent cable and telco subscribers, we form a best estimate of the subscriber base by taking an average of values from Nielsen, SNL, and LRG sources[25].

We asked U.S. adults about STBs connected to their four most-viewed televisions, see Table 3-59. Because we asked only about STBs associated with the first four TVs, we assumed that the ratio of STBs to TVs was constant in a given household to make a reasonable upper-bound estimate[26] of STBs per household. Thus, if a household had 8 TVs, and reported 3 STBs on the first four TVs, we would compute 3STBs/4TVs x 8TVs = 6 STBs. Based on this analysis, we found that depending on service type there are between 1.3 and 2.3 STBs (DVR + non DVR) and 0.5 to 0.7 DVR STBs per subscriber household. About 53% of subscriber households reported having at least one DVR, which is close to the 52-55% found by other industry sources (Nielsen 2013, LRG 2013d). Of reporting DVR households, we estimate that 90% had one, 8% had two, and 1% had 3 or more DVRs.

Table 3-58: Pay TV customers by service, millions.

Service	Survey Nov. 2013	Nielsen 2013 Q2 2013	SNL 2013b-c Q2 2013	LRG 2013a-b Q3 2013	Estimate	[%] of Total
Cable	62	56	55	56	56	55%
Satellite	31	34	34	34	35	34%
Telco	12	10	11	10	11	11%
Total	**105**	**100**	**99**	**101**	**101**	**100%**

Table 3-59: Installed base of pay TV STBs by service (Nov. 2013 survey).

Service	Subscribers [millions]	STBs per Subscriber	STBs, [millions]	[%] of Pay TV STBs	DVRs per Subscriber	DVRs [millions]	DVR:STB by Service
Cable*	56	1.33	74	44%	0.49	28	37%
Satellite	35	1.99	69	41%	0.67	23	34%
Telco	11	2.32	25	15%	0.58	6	25%
Total/Wt.Avg.**	**101**	**1.66**	**167**	**100%**	**0.56**	**57**	**34%**

* Does not include cable DTAs.

** Some subscribers have more than one service and some households are not subscribers.

All satellite and telco subscribers require at least one STB to receive any service in the home, but for cable customers this is not always true. Some cable providers offer basic unencrypted service, and customers can receive basic unencrypted service without any STBs. Other cable providers require either

[25] The original LRG data included subscribers from only the largest providers, which they claim account for 94% of all pay TV subscribers. We adjusted the cable values to include the missing 6%, since satellite and telco providers are principally comprised of two providers each.

[26] If we had instead assumed that households could have only a maximum of four STBs, the totals would be about 8% lower.

an STB or a cable DTA for viewing digitally encrypted channels or for viewing digital channels on analog televisions. The CE Usage Survey indicates that cable subscribers had the fewest STBs per household, compared with satellite and telco subscribers. Because of the survey question wording and because of the low number of STBs per cable household, it is unlikely that U.S. adults included cable DTAs in their responses. By 2013 there were about 28 million cable DTAs in service (SNL 2013a), and adding these to the cable STBs from our survey we find 1.8 STBs per cable household.

Survey responses suggest potential for misunderstanding among the STB questions[27] , so these survey results should be considered only as approximate estimates of the installed base. First, about 28% of cable, 20% of satellite, and 30% of telco subscribers indicated they had no STBs, even though both satellite and telco customers require at least one STB to receive service. We excluded those unviable responses for satellite and telco subscribers when estimating STBs per subscriber. Second, about 5% of single-service subscribers indicated having both a DVR and non-DVR STB connected to the same TV. We counted these unusual responses as a single non-DVR STB, since they may represent the presence of a standalone DVR in conjunction with a pay-TV STB. We also assumed that households with a multi-room STB configuration had at most one DVR. Not doing so led to a DVR count that was about 27% higher than the SNL (2013a) estimate. Table 3-60 shows estimates from several sources by technology.[28]

Table 3-60: Installed base of pay TV STBs, millions.

		SNL 2013a Q2 2013	Survey Nov 2013	FhCSE 2011 Q2 2010	Notes
Cable	Non DVR	58.6	46.6	50.3	
	SD	*33.8*	-	*35.4*	
	HD	*24.7*	-	*14.9*	
	IP Client	*0.1*	-	-	
	DVR	26.8	27.5	22.5	No breakdown in survey by SD/HD.
	SD	*2.8*	-	-	
	HD	*22.4*	-	-	
	IP Gateway	*1.6*	-	-	
	Cable DTA	27.6	27.6	14.0	Not asked in 2013 survey, assume SNL value.
Satellite	**Non DVR**	**74.7**	**45.5**	**59.8**	
	SD	*44.2*	-	*49.2*	
	HD	*30.5*	-	*10.6*	
	DVR	**18.9**	**23.0**	**16.3**	No breakdown in survey by SD/HD.
Telco	**Non DVR**	**21.8**	**18.6**	**12.1**	
	SD	*3.8*	-	*5.0*	
	HD	*18.0*	-	*7.1*	
	DVR	**10.2**	**6.1**	**3.7**	No breakdown in survey by SD/HD.
Total		**238.5**	**195.0**	**178.7**	
Subtotals	Cable	113.0	101.7	86.8	
	Satellite	93.6	68.6	76.1	
	Telco	32.0	24.7	15.8	
	DVRs	55.9	56.6	42.5	
	Non-DVRs	182.7	138.4	136.2	

Whole-home or multi-room STBs are growing in popularity and offer customers the flexibility of viewing or recording programming throughout their home without needing a fully-featured STB for each TV. We

[27] We asked participants to select all types of set top boxes connected to each of their TVs, including DVR STB, non-DVR STB, streaming media device with DVR, and streaming media device without DVR. It is likely that participants had trouble making the distinction among these devices.
[28] We do not consider the 0.6M digital cable ready devices that receive programming without an STB using a CableCARD (SNL 2013a).

asked pay TV subscribers about the multi-room features of their set top boxes. Households indicated if they could (1) record in one room and playback in another, (2) pause live TV and resume watching in another room, and (3) record five or more shows at once. Positive responses to either of the first two questions indicate that a household is likely to have a multi-room DVR setup, while the third indicates that at least one STB that is capable of serving multiple rooms. About 4% of U.S. adults reported having multi-room features (1) or (2) despite owning only one TV, so we counted these responses as single-room DVRs. Many STBs ship with features that can be enabled through software updates issued by service providers. A major cable provider announced in Jun. of 2013 that it would be launching multi-room DVR capability to 8 million of its STBs through a software update (Multichannel 2013). This means that asking users about features may not always correctly identify multi-room STBs hardware if those features have not yet been activated or if the user is unaware such features exist. Still, we can use the responses to estimate the number of multi-room STBs. Table 3-61 shows our estimates for multi-room STBs among different service providers. Notably, a smaller portion of cable customers have a multi-room setup than do satellite and telco customers, partially because about 28% of cable households reported having no STBs installed. In total, we estimate that up to 26% of pay TV households have a multi-room setup (2 or more TVs and yes to questions (1) or (2)) and that 30.7% have at least one multi-room STB (1 or more TVs and yes to questions (1), (2), or (3)). We estimated the number installed by applying the percentage to the subscriber count, assuming at most one multi-room server STB per household.

Table 3-61: Subscribers with multi-room STBs, millions (Nov. 2013 survey).

	Cable	Satellite	Telco	All
All Pay TV Subscribers	55.7	34.5	10.7	100.8
Multi-room households, % of subscribers	15.1%	34.7%	40.6%	25.9%
Multi-room ready households, % of subscribers	20.2%	40.0%	43.2%	30.7%
Multi-room server STBs	**11.3**	**13.8**	**4.6**	**30.9**

Table 3-62: Cumulative STB shipment projections from Q2-2010 to Q4-2013 (DOE 2013a).

	Base STB	Base DVR	Multi-Room	Multi-Room with DVR	Video Client	Total	Pct.
Cable	47.0	8.4	3.3	7.2	0.4	66.3	42%
Satellite	21.6	12.1	5.0	10.7	0.4	49.8	32%
Telco	5.8	2.1	0.8	1.8	0.6	11.1	7%
Thin Client	2.5	-	-	-	-	2.5	2%
Digital Media Streaming	27.1	-	-	-	-	27.1	17%
Total	**104**	**22.6**	**9.1**	**19.7**	**1.5**	**156.8**	**100%**
	66%	14%	6%	13%	1%	100%	-

* Thin clients are combined for cable and satellite providers.

Pay TV STB shipments from the previous three years (DOE 2013a) totaled 127 million units, slightly more than half of the current installed base. STBs with servers totaled 29 million, of which 68% had DVRs. This total is consistent with the 31 million found in our survey, and as such, these data will be used to weight the power draw values in the subsequent analysis. In the DOE dataset, the *video client* category represents STBs that receive video from a multi-room video server STB. Since there are relatively few in service, we consider these with thin client STBs in our analysis.

3.11.1.1.2 Standalone Set-top Boxes

Standalone STBs are those obtained independently of TV service providers, such as digital media streaming devices and standalone DVRs. Digital media streaming devices enable TV users to view content delivered over the Internet.[29] Though many newer smart TVs and Blu-ray players have this functionality built-in, here we are only concerned with non-integrated streaming devices.[30]

We estimate there were at most 40 million digital media streaming devices installed by the end of 2013 – about four times higher than in 2010 (FhCSE 2011) – based on cumulative sales data from 2006-2013 (CEA S&F 2013, BI 2014). Sales of the top three streaming media devices exceeded 15.2 million units in 2013 and these make up more than 85% of the market (BI 2014). DOE forecasts for 2013 were lower, at 10 million units (DOE 2013a). Our survey indicated that there were 57.1 million digital media streaming devices in service, and the average household had 0.48 such devices (1.7 devices per owner household, 30% ownership). This is somewhat higher than a recent CEA survey (O&M 2013) that found 46.6 million digital streaming media devices (1.6 devices per owner household, 24% ownership). A 2013 survey of 10,000 broadband households found that only 14% had a streaming media device (Parks 2013). Both survey estimates exceed the likely maximum installed base value and suggest potential confusion among consumers about what constitutes a digital streaming device. For instance, about 50% of owners reported that their streaming media devices had DVR capabilities; however the majority of devices do not offer this feature.

Standalone DVRs comprise a small part of the installed base, as most DVRs are integrated with subscription STBs. Standalone TiVo subscribers numbered 1 million in Q3 2013, down from a peak of 1.7 million in 2007 (LRG 2013) and 1.5 million in 2010 (Gorman 2010). We estimate a similar decline in standalone DVRs from the 3 million in 2010, for a total of 2 million in 2013.

Over-the-air (OTA) DTAs are devices that enable analog TVs to receive digital OTA broadcast signals. Since all new TVs must include a digital tuner, the number of these devices is expected to decline as older TVs are retired. An appreciable number of analog CRT TVs have been retired in the previous three years, and based on analysis of survey responses[31] the number of households with at least one CRT TV was 60% lower in Dec. 2013 than in Aug. 2009 (CEA 2014, FhCSE 2009). We estimate that the installed base of OTA-DTA has declined at the same rate, and conclude that there are now 13 million units in service compared with 33 million units in 2010.

Table 3-63: Installed base of standalone STBs, millions.

Device	Units	% of Standalone STBs
Digital Streaming	40.2	72.5%
Standalone DVR	2.0	3.6%
OTA-DTA	13.2	23.8%
Total	**55.4**	**100%**

[29] Such as Netflix or Hulu.
[30] Such as Apple TV, Roku, or Chromecast.
[31] As noted in the Television section of this report, people may incorrectly identify television types in surveys, so these numbers should serve only as approximate indicators.

3.11.1.2 Unit Energy Consumption

STB power draw generally depends on its available features. We consider power draw across multiple feature categories including: provider type, ability to serve video content to multiple rooms (e.g., multi-room), HD or SD tuners, and DVR capability. STBs can have multiple tuners, allowing more than one TV to use the same STB simultaneously, or allowing viewers to record a program while watching another. Minimalist STBs, called thin-clients, draw less power than ordinary STBs by relying on a full-featured STB for their signal instead of communicating with the provider directly.

STBs may have several power modes: (1) on- or active-mode, (2) sleep mode, and (3) deep sleep mode. Deep sleep is a sub-state of sleep mode that draws even less power, but may cause the device to require more time to respond when returning to active mode. Few STBs include a deep sleep mode, and many have similar power draw in both active and sleep modes. STBs lack a true off mode, and we believe it is uncommon for users to unplug or use power strips to completely power down STBs, since doing so may provoke a disruptive automatic reprogramming period.

3.11.1.2.1 Power Draw

To determine power draw across providers, features, and usage modes, we relied on several sources. EPA (2012) provided measurements of on- and standby- mode power draw for many subscription STBs, and we used these to represent STBs manufactured and installed since mid 2010, see Figure 3-38. We used the power draw values from (FhCSE 2011) to represent units manufactured before 2010. For each feature combination – provider, DVR/non-DVR, single/multi-room, HD/SD – we averaged power draw across the measured devices. We did not have access to the installed base data for each model, and were therefore unable to further refine our model by weighting power draw by the prevalence of specific models. Figure 3-38 shows how power draw varies among devices in similar categories.

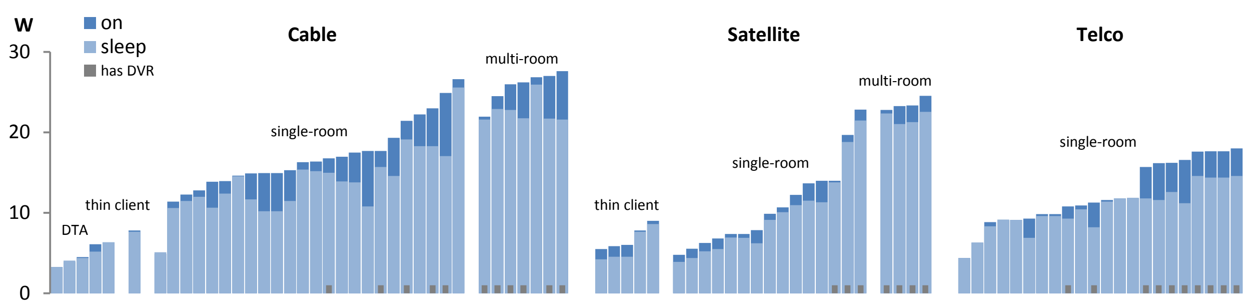


Figure 3-38: Power draw of subscription set-top boxes by provider type and selected features, n=84 (EPA 2012).

Using a combination of installed base figures for 2010 (FhCSE 2011) and 2013 (based primarily on SNL data and secondarily on phone survey results), and industry sales data and projections (DOE 2013a, SNL 2013a-c), we estimated the total number of devices of each type. We further subdivided the installed base for each category by year of manufacture (pre- or post- 2010) to enable power draw weighting by vintage. We retained the power draw values from FhCSE (2011) for standalone DVRs and OTA-DTAs. For digital streaming media devices, we used sales data (BI 2014) and power draw measurements (FhCSE 2012, EPA 2012, AnandTech 2013, Roku 2011) to calculate a weighted average power draw by mode.

Next, we weighted power draw by manufacture date (pre- or post- 2010) to produce the estimates shown in Table 3-64 and Table 3-65. In cases where the sum of older devices (from 2010) and newly sold devices (from 2010-2013) was greater than the 2013 installed base (according to the FhCSE survey), we assumed that older devices were retired to account for this difference. In cases where the installed base in 2013 exceeded the sum of older devices and newly sold devices, we assumed that the projected sales figures were too low, and increased their number accordingly.

Average[32] on- and (standby-) mode power draw values were 15.6 W (13.7) for cable, 13.5 W (12.2) for satellite, and 12.9 W (11.1) for telco providers. These values are each about 1-2 W lower than in 2010, even as the portion of units with HD, DVR, and video streaming capabilities have increased.

Table 3-64: Power draw and installed base by device.

		2010 Installed Base			New Units from 2010-2013			2013 Installed Base		
		Installed	Power Draw [W]		Sales	Power Draw [W]		Installed	Power Draw [W]	
Type	**Features**	**millions**	**Active**	**Sleep**	**millions**	**Active**	**Sleep**	**millions**	**Active**	**Sleep**
Cable	SD	35.4	16.5	15.9	27.1	15.6	13.1	31.0	15.7	13.4
	HD	14.9	14.9	13.5	19.8	15.6	13.1	22.6	15.5	13.1
	DVR (SD or HD)	22.5	29.6	27.3	8.4	20.8	17.0	19.6	25.8	22.9
	Multi-room	0.0	NA	NA	3.3	26.9	26.0	3.3	26.9	26.0
	Multi-room+DVR	0.0	NA	NA	7.2	25.5	22.1	7.2	25.5	22.1
	Thin Client	0.0	NA	NA	1.7	7.8	7.7	1.7	7.8	7.7
	Cable DTA	14.0	4.4	4.4	13.6	4.8	4.7	27.6	4.6	4.5
Satellite	SD	49.2	8.5	7.6	12.8	6.5	5.4	40.3	7.9	6.9
	HD	10.6	20.7	18.2	8.8	11.3	10.0	27.8	14.9	13.1
	DVR (SD or HD)	16.3	24.0	21.8	12.1	18.8	18.0	8.2	18.8	18.0
	Multi-room	0.0	NA	NA	5.0	23.5	21.8	5.0	23.5	21.8
	Multi-room+DVR	0.0	NA	NA	10.7	23.5	21.8	10.7	23.5	21.8
	Thin Client	0.0	NA	NA	1.7	6.6	5.5	1.7	6.6	5.5
Telco	SD	5.0	10.7	10.5	1.0	9.4	9.1	3.5	10.3	10.1
	HD	7.1	13.5	11.8	4.8	9.4	9.1	16.8	11.1	10.2
	DVR (SD or HD)	3.7	19.3	14.9	2.1	15.8	12.3	8.4	17.3	13.4
	Multi-room	0.0	NA	NA	0.8	9.4	9.1	0.8	9.4	9.1
	Multi-room+DVR	0.0	NA	NA	1.8	15.8	12.3	1.8	15.8	12.3
	Thin Client	0.0	NA	NA	0.6	9.4	9.1	0.6	9.4	9.1
Standalone	Digital Streaming	8.9	8.0	6.0	27.1	3.7	1.5	40.2	4.7	2.5
	DVR	3.0	33.0	30.0	0	NA	NA	2.0	33.0	30.0
	OTA-DTA	33.0	6.5	0.8	0	6.5	0.8	13.2	6.5	0.8
Total/Weighted Avg.		**223.6**	**14.2**	**12.2**	**170.4**	**13.4**	**11.5**	**294.0**	**12.8**	**10.9**
Subtotals	Cable	86.8	17.7	16.6	81.2	15.5	13.3	113.0	15.6	13.7
	Satellite	76.1	13.5	12.1	51.0	15.5	14.2	93.6	13.5	12.2
	Telco	15.8	14.0	12.1	11.1	11.6	10.2	32.0	12.9	11.1
	Standalone	44.9	8.6	3.8	27.1	3.7	1.5	55.4	6.1	3.1

3.11.1.2.2 Usage and Consumer Behavior

The power draw of most pay TV STBs in 2013 varies weakly with power mode, so knowing precisely the number of hours spend in on vs. sleep mode does not strongly influence the energy consumption estimates. If deep sleep mode becomes more prevalent, or if light sleep begins to deliver deeper reductions in power, it may be necessary to develop updated estimates of time spent in each mode.

[32] Weighted average according to number of units in each device category.

Consequently, we continue to apply the usage estimates from FhCSE (2011) to calculate unit energy consumption, as shown in Table 3-65.

3.11.1.2.3 Unit Energy Consumption

We estimate that, on average, pay TV STBs consume 119 kWh/yr and standalone STBs consume 45 kWh/yr. Unit energy consumption (UEC) by device is given in Table 3-65. Cable units continued to consume more energy per device, at 128 kWh/yr, compared with 112 and 106 for satellite and telco, though most figures were lower than in 2010 – 20% lower for cable, no change for satellite, and 10% lower for telco. Cable saw the largest UEC decrease mainly because of the uptake of low-power cable DTAs.

DVR-enabled STBs (including multi-room DVRs), account for about 37% of the total consumption of pay-TV STB energy use. Although their overall numbers have increased, their installed fraction remains steady at about 23% of the installed base of pay TV STBs, mainly due to the simultaneous increase in the number of cable DTAs. The UEC of DVR STBs has declined by about 16% since 2011. Multi-room server STBs consume on average 196 kWh/yr, account for about 20% of total pay-TV STB energy use, and comprise 12% of installed pay TV STBs.

3.11.1.3 Annual Energy Consumption

The total annual energy consumption (AEC) of all STBs is 31 TWh, Table 3-65. About 90% is attributed to pay TV STBs and 10% to standalone STBs.

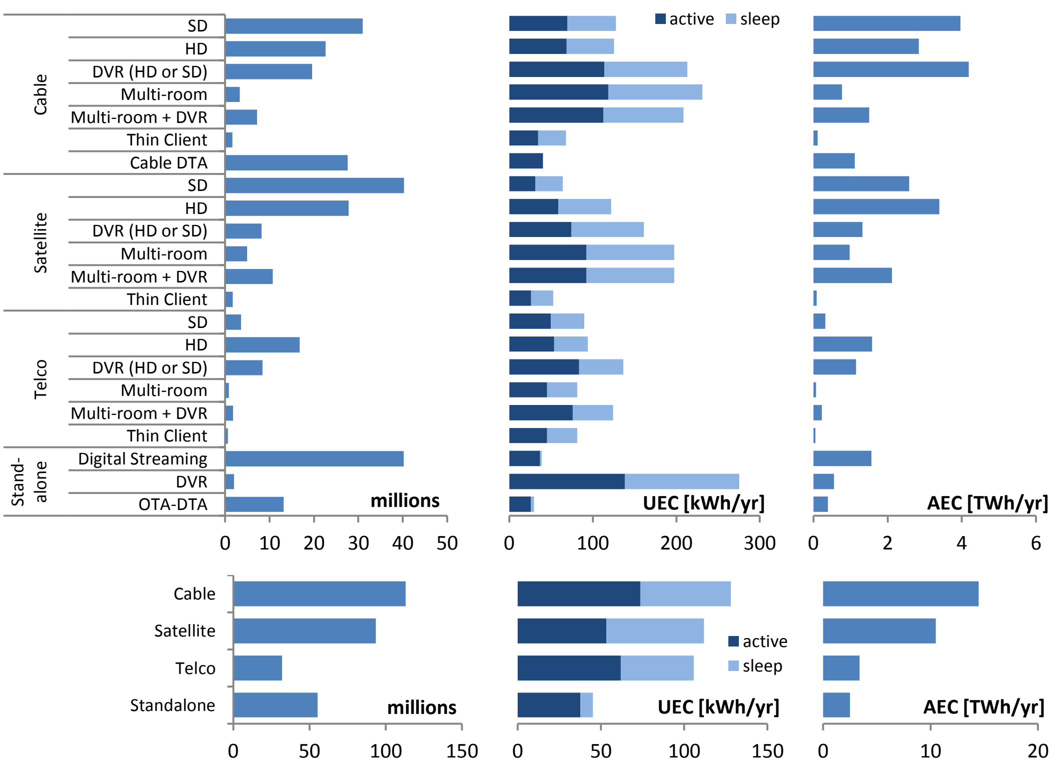


Figure 3-39: Summary of installed base, UEC and AEC for STBs.

Table 3-65: UEC and AEC summary for STBs.

Type	Features	Units [millions] 2013 Installed	*Pre-2010*	*Post-2010*	Power Draw [W] Active	Sleep	Usage [h/day] Active	Sleep	UEC [kWh] Active	Sleep	Total	AEC [TWh]
Cable	SD	31.0	*3.8*	*27.1*	15.7	13.4	12.1	11.9	69.5	58.2	127.7	4.0
	HD	22.6	*2.8*	*19.8*	15.5	13.1	12.1	11.9	68.6	56.9	125.6	2.8
	DVR (HD or SD)	19.6	*11.2*	*8.4*	25.8	22.9	12.1	11.9	114.0	99.4	213.4	4.2
	Multi-room	3.3	*0.0*	*3.3*	26.9	26.0	12.1	11.9	118.6	112.8	231.4	0.8
	Multi-room+DVR	7.2	*0.0*	*7.2*	25.5	22.1	12.1	11.9	112.8	95.8	208.6	1.5
	Thin Client	1.7	*0.0*	*1.7*	7.8	7.7	12.1	11.9	34.4	33.4	67.9	0.1
	Cable DTA	27.6	*14.0*	*13.6*	4.6	4.5	24.0	0.0	40.3	0.0	40.3	1.1
Satellite	SD	40.3	*27.5*	*12.8*	7.9	6.9	10.8	13.2	30.9	33.2	64.1	2.6
	HD	27.8	*10.6*	*17.2*	14.9	13.1	10.8	13.2	58.7	63.3	122.0	3.4
	DVR (HD or SD)	8.2	*0.0*	*8.2*	18.8	18.0	10.8	13.2	74.3	86.9	161.2	1.3
	Multi-room	5.0	*0.0*	*5.0*	23.5	21.8	10.8	13.2	92.6	105.1	197.7	1.0
	Multi-room+DVR	10.7	*0.0*	*10.7*	23.5	21.8	10.8	13.2	92.6	105.1	197.7	2.1
	Thin Client	1.7	*0.0*	*1.7*	6.6	5.5	10.8	13.2	26.0	26.5	52.5	0.1
Telco	SD	3.5	*2.5*	*1.0*	10.3	10.1	13.2	10.8	49.8	39.8	89.6	0.3
	HD	16.8	*7.1*	*9.7*	11.1	10.2	13.2	10.8	53.7	40.3	94.0	1.6
	DVR (HD or SD)	8.4	*3.7*	*4.7*	17.3	13.4	13.2	10.8	83.5	52.9	136.4	1.1
	Multi-room	0.8	*0.0*	*0.8*	9.4	9.1	13.2	10.8	45.3	35.8	81.2	0.1
	Multi-room+DVR	1.8	*0.0*	*1.8*	15.8	12.3	13.2	10.8	76.0	48.4	124.4	0.2
	Thin Client	0.6	*0.0*	*0.6*	9.4	9.1	13.2	10.8	45.3	35.8	81.2	0.1
Standalone	Digital Streaming	40.2	*8.9*	*31.3*	4.7	2.5	21.6	2.4	36.7	2.2	38.9	1.6
	DVR	2.0	*2.0*	*0.0*	33.0	30.0	11.5	12.5	138.5	136.9	275.4	0.6
	OTA-DTA	13.2	*13.2*	*0.0*	6.5	0.8	10.8	13.2	25.6	3.9	29.5	0.4
Total/Weighted Avg.		**294.0**	***107.4***	***186.6***	**12.8**	**10.9**	**14.2**	**9.8**	**59.1**	**45.8**	**104.9**	**30.8**
Subtotals	Cable	113.0	*31.8*	*81.2*	15.6	13.7	15.0	9.0	73.6	54.5	128.1	14.5
	Satellite	93.6	*38.1*	*55.5*	13.5	12.2	10.8	13.2	53.2	58.7	111.9	10.5
	Telco	32.0	*13.3*	*18.7*	12.9	11.1	13.2	10.8	61.9	43.8	105.8	3.4
	Standalone	55.4	*24.1*	*31.3*	6.1	3.1	18.7	5.3	37.7	7.4	45.2	2.5

3.11.2 Comparison with Prior Energy Consumption Estimates

Our pay TV STB energy use estimate of 28.3 TWh/yr is about 18% higher than our prior estimate of 24 TWh/yr (FhCSE 2011) and close to that of 27 TWh/yr (NRDC 2011), both for 2010. The adoption of new features, such as HD, DVR, and multi-room video server, and the overall increase in deployed STBs is driving changes in STB energy consumption in the pay TV category. Even as new features become adopted, the power draw of individual devices categories appears to be on a slight decline (see Table 3-64). Figure 3-40 and Figure 3-41 show trends in device sales. Annual sales of pay TV STBs is about 33 million units per year, suggesting an average product lifespan of about 7 years, based on a 238 million unit installed base.

In Dec. 2012, fifteen multichannel video providers and STB manufacturers signed a voluntary agreement that aims to reduce the energy consumption of set-top boxes (NCTA 2014). As part of the agreement, 90% of devices purchased after Jan. 1, 2014 will need to meet ENERGY STAR v3.0 efficiency standards. In Dec. 2013, a non-regulatory consensus agreement was signed with the addition of efficiency advocates, and endorsed by DOE, that added an additional Tier 2 requirement for 2017 (NCTA 2014). According to DOE (2013), "these new standards – developed through a voluntary agreement between the pay-TV industry, the consumer electronics industry, and U.S. Energy Advocacy organizations (NRDC, ACEEE) – will improve set-top box efficiency by 10-45% (depending on box type) by 2017." The voluntary agreement also includes additional energy efficiency provisions, including light sleep capabilities, automatic power down features, and whole-home DVR solutions being made available as an alternative to multiple in-home DVRs for subscribers. These changes will likely affect energy consumption going forward and will need to be considered in future analyses.

In the standalone STB category, the major shift is a large increase in the installed base of digital media streaming devices. Power draw for these devices, while already low, has declined slightly from 2010. Comparisons with prior estimates are given in Table 3-66 and Table 3-67.

Table 3-66: Prior energy consumption estimates for subscription STBs.

Year	Units [millions]	Power [W] Active	Power [W] Off	Usage [h/yr] Active	Usage [h/yr] Off	UEC [kWh/yr]	AEC [TWh/yr]	Source
Cable								
2013	113	16	14	5,475	3,285	128	14.5	Current
2010	87	18	17	4,526	4,234	150	13.0	FhCSE 2011
2008	52	-	-	-	-	173	9.0	LBNL 2010
2006	77	16	15	2,730	6,030	134	10.0	TIAX 2007
2003	35	16	16	1,825	6,935	140	4.9	NRDC 2005
2003	-	-	23	2,555	6,205	-	-	DEG 2004
2003	65	23	22	-	-	-	-	ACEEE 2004
2000	49	13	11	-	-	103	5.0	LBNL 2001
Satellite								
2013	94	14	12	3,941	4,819	112	10.5	Current
2010	76	14	12	3,941	4,819	112	8.5	FhCSE 2011
2008	51	-	-	-	-	206	10.5	LBNL 2010
2006	70	15	14	3,240	5,520	129	9.0	TIAX 2007
2003	32	-	-	-	-	-	-	NRDC 2005
2003	-	-	16	2,555	6,205	-	-	DEG 2004
2003	32	18	17	-	-	-	-	ACEEE 2004
2000	13	17	16	-	-	140	1.9	LBNL 2001
Telco								
2013	32	13	11	4,834	3,926	106	3.4	Current
2010	16	14	12	4,834	3,926	115	1.8	FhCSE 2011
2008	3	-	-	-	-	164	0.5	LBNL 2010

Table 3-67: Prior energy consumption estimates for standalone STBs.

Year	Units [millions]	Power [W] Active	Power [W] Off	Usage [h/yr] Active	Usage [h/yr] Off	UEC [kWh/yr]	AEC [TWh/yr]	Source
Digital Streaming								
2013	42	4.7	2.5	7,884	876	36	1.6	Current
2010	9	8.0	6.0	7,884	876	68	0.6	FhCSE 2011
OTA-DTA								
2013	13	6.5	0.8	3,942	4,818	29	0.4	Current
2010	33	6.5	0.8	3,942	4,818	29	1.0	FhCSE 2011
2008	35	6.5	0.8	4,745	4,015	27	0.9	LBNL 2011
DVR								
2013	2.0	33	30	4,198	4,562	275	0.6	Current
2010	3.0	33	30	4,198	4,562	275	0.8	FhCSE 2011
2006	1.5	27	27	2,080	6,680	237	0.4	TIAX 2007
2003	-	24	24	-	-	-	-	NRDC 2005

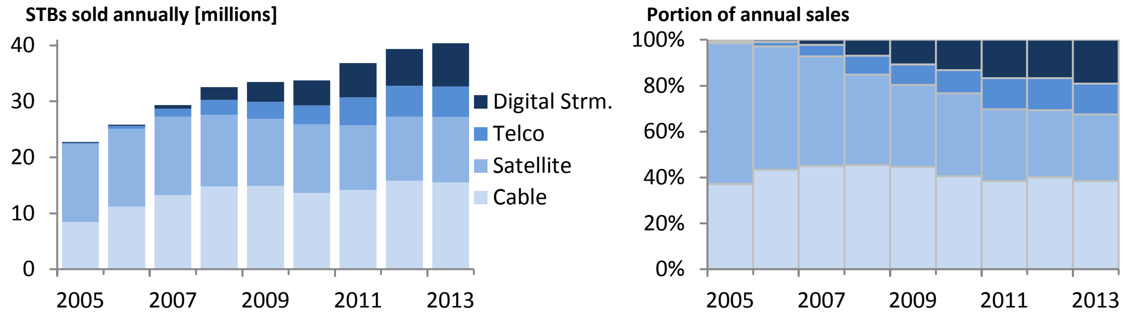


Figure 3-40: Annual STB sales to dealers by display technology.

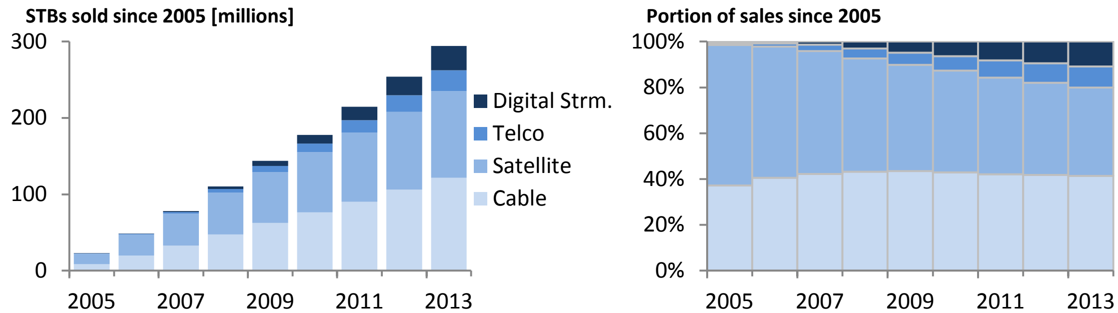


Figure 3-41: Cumulative STB sales to dealers by display technology since 2005.

3.11.3 References

ACEEE. Amann, J.T. 2004. "Set-top boxes: Opportunities and issues in setting efficiency standards." American Council for an Energy-Efficient Economy. Report No. A041. Jul.

AnandTech. 2013. Google Chromecast Review. http://www.anandtech.com/show/7186/google-chromecast-review-an-awesome-35-hdmi-dongle/2. Retrieved Mar. 2014.

BI. Hoelzel, Mark. 2014. "The Connected TV Landscape." Business Insider Australia. http://www.businessinsider.com.au/the-connected-tv-landscape-why-smart-tvs-and-streaming-gadgets-are-conquering-the-living-room-2014-2. Feb.

CEA S&F. 2013. "U.S. Consumer Electronics Sales & Forecasts 2009-2014." CEA Market Research Report. Consumer Electronics Association. Jul.

CEA O&M. 2013. "15th Annual Household CE Ownership and Market Potential." CEA Market Research Report. Consumer Electronics Association. May.

CEA. 2014. "CRT Television Ownership and Usage Update." Consumer Electronics Association. Jan.

DEG. 2004. "Analysis of standards options for consumer electronics standby losses." Codes and Standards Enhancement Initiative for PY2004: Title 20 Standards Development. Davis Energy Group Report for Gary Fernstrom, Pacific Gas and Electric Company. May.

DOE. 2013a. "National Impact Analysis." Rulemaking for Set-top Boxes Energy Conservation Standards and Test Procedure. U.S. Department of Energy. http://www1.eere.energy.gov/buildings/appliance_standards/rulemaking.aspx/ruleid/33. Retrieved Feb. 2014.

DOE. 2013b. "U.S. Energy Department, Pay-Television Industry and Energy Efficiency Groups Announce Set-Top Box Energy Conservation Agreement; Will Cut Energy Use for 90 Million U.S. Households, Save Consumers Billions" U.S. Department of Energy. Dec.

EPA. 2012. Draft 2 Version 4.1 Set Top Box Dataset. U.S. Environmental Protection Agency. http://www.energystar.gov/products/specs/sites/products/files/Draft_2_Version_4_1_Set_top_Box_Dataset.xlsx

FhCSE. Roth, Kurt and Bryan Urban. 2009. "Assessment of the Energy Savings Potential of Policies and Measures to Reduce Television Energy Consumption." Final Report to the Consumer Electronics Association. Fraunhofer Center for Sustainable Energy Systems. Oct.

FhCSE. Urban, Bryan, Kurt Roth, and Verena Tiefenbeck. 2011. "Energy Consumption of Consumer Electronics in U.S. Homes in 2010." Final Report to the Consumer Electronics Association. http://www.ce.org/CorporateSite/media/Government-Media/Green/Energy-Consumption-of-CE-in-U-S-Homes-in-2010.pdf. Dec.

FhCSE. 2012. Craig Akers, Linda Mayer, and Kurt Roth. Power Measurements of Selected Set Top Boxes.

Gorman, Bill. 2010. "TiVo loses 96,000 subscribers in most recent quarter." TV by the Numbers. http://tvbythenumbers.com/2008/05/28/quarterly-net-new-tivo-subscribers-2001-april-2008/3945. May.

LBNL. Cheung, H.Y., A.Meier, and R.Brown. 2011. Energy savings assessment for digital-to-analog converter boxes. Lawrence Berkeley National Laboratory. Prepared for U.S. Department of Energy. Mar.

LBNL. Rosen, K., A. Meier, and S. Zandelin. 2001. "Energy use of set-top boxes and telephony products in the U.S." Lawrence Berkeley National Laboratory. Report No. LBNL-45305. Jun.

LBNL. Sanchez, Marla, Steven Lanzisera, Bruce Nordman, Alan Meier, Rich Brown. 2010. "EEDN: Set top box market assessment report." Lawrence Berkeley National Laboratory. Feb. http://efficientnetworks.lbl.gov/pubs/EEDN_task_2-4-1_STB_Market_Assessment_Report.pdf.

LRG. 2013a. "Major Multi-Channel Video Providers Lost About 25,000 Subscribers in Q3 2013." Leichtman Research Group. http://www.leichtmanresearch.com/press/111813release.html. Nov.

LRG. 2013b. Major multi-channel video providers lost about 345,000 subscribers in 2Q 2013. FierceCable. http://www.fiercecable.com/press-releases/major-multi-channel-video-providers-lost-about-345000-subscribers-2q-2013. Aug.

LRG. 2013c. "The Rise and Plateau of DVRs." http://www.leichtmanresearch.com/research/notes12_2013.pdf

LRG. 2013d. "DVRs Leveling Off at About Half of All TV Households." http://www.leichtmanresearch.com/press/120613release.html.

Multichannel News. Jeff Baumgartner. 2013. "Comcast Tees Up Multi-Room DVR for X1." http://www.multichannel.com/distribution/comcast-tees-multi-room-dvr-x1/143670. Jun.

NCTA. 2014. Voluntary Agreement for Ongoing Improvement to the Energy Efficiency of Set-Top Boxes. http://www.ncta.com/energyagreement. National Cable and Telecommunication Association.

Nielsen. 2013. "The Cross-Platform Report | Q2 2013." Sept.

NRDC. Foster, S. 2005. "Cable and Satellite set-top boxes: opportunities for energy savings." Ecos Consulting report for the Natural Resources Defense Council. Mar.

NRDC. Horowitz, Noah. 2011. Better viewing, lower energy bills, and less pollution: improving the efficiency of television set-top boxes. National Resources Defense Council. Jun.

Roku. 2011. "Roku's Power Consumption when Idle." Roku Forums. http://forums.roku.com/viewtopic.php?p=287461&sid=08c945a0ae6dc63df0d99a9e52d1cd13. Retrieved Mar. 2014.

SNL. 2013a. Set Top Box Installed Base. Private communication of industry research. SNL Kagan. Nov.

SNL. 2013b. SNL Kagan Releases 2nd-Quarter U.S. Multichannel Subscriber Report. SNL Kagan. PR Web. http://www.prweb.com/releases/2013/9/prweb11070470.htm. Sept.

SNL. 2013c. "U.S. Multichannel Subscriber Update and Programming Cost Analysis." SNL Kagan White Paper. Jun.

3.12 Televisions

3.12.1 Current Energy Consumption

Televisions continue to be the most widely owned consumer electronic device in the U.S. at 97-98% household penetration in 2013 (CEA O&M 2013, 2013 CE Usage Survey). TV energy consumption varies with display type, screen size, and year of manufacture. High-definition flat-panel displays continue to dominate the marketplace (74% household penetration), while displays with ultra-high definition (UHD) are now becoming available. Newer features such as Internet capable TVs and 3DTVs are increasing in popularity, with 15% and 9% household penetration (CEA O&M 2013). At the same time, unit energy consumption is declining due to improvements in display technologies.

As in prior studies, our TV energy use estimates are based primarily on usage and ownership data from the CE Usage Survey, manufacturer-reported power draw measurements, and industry sales data.

3.12.1.1 Installed Base

Televisions slightly outnumber people in U.S. homes with 338 million owned (CEA O&M 2013) and 301 million plugged in (2013 CE Usage Survey). A review of recent TV ownership surveys is presented in Table 3-68. Figure 3-42 shows the distribution of TVs per household for 2013 and 2010.

Table 3-68: Installed base estimates for TVs in 2013.

Year	Household Penetration	Households [millions]	Units/Owner Household	Installed Base [millions]	Sources
2013	96.8%	119	2.6	301*	2013 CE Usage Survey
2013	98.0%	119	2.9	338	CEA O&M 2013
2012	99.0%	119	2.9	340	CEA O&M 2012
2011	96.0%	119	3.0	343	CEA O&M 2011
2010	99.0%	116	3.1	353*	CE Usage Survey Oct-2010
2010	99.1%	116	2.9	328	Nielsen 2010
2010	95.0%	114	3.0	325	CEA O&M 2010
2009	95.8%	116	2.4	271**	CE Usage Survey Aug-2009
2009	99.0%	114	3.0	339	CEA O&M 2009
2009	99.2%	115	2.9	335	Nielsen 2010

* Indicates TVs that were plugged into an electrical outlet during the past month.
** Indicates TVs that were used to watch television at least once in the past week.

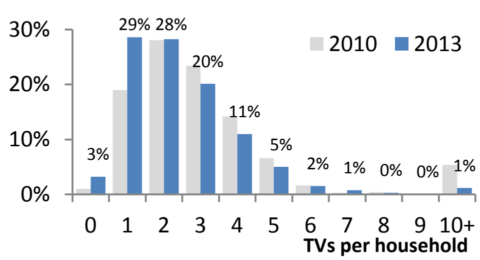


Figure 3-42: TV ownership distribution (CE Usage Survey).

Plugged-in TVs appear to have declined by 50 million units or 14% since 2010, and while sharp, this decrease may be reasonable. Previous estimates place household TV ownership in slight excess of the U.S. population. It is plausible that many older and lesser-used TVs (primarily CRTs) are being discarded without being replaced. Nielsen found that about 1 million households own no TVs (Nielsen 2013), while our survey indicated this was closer to 4 million. Even though the number of households has increased from about 116 to 119 million households, the number owning at least one TV has remained constant at about 115 million.

According to EPA estimates, 23.6 million TVs were disposed of in 2010 and a further 28.5 million were ready for end of life management (EPA 2011). Assuming a consistent disposal rate during the 3.5-year period since the 2010 study, 83-100 million TVs would have been removed from the installed base during this period. Consistent with that, a recent phone survey-based study of CRT TVs in U.S. households estimated that during the past five year 91 million CRT TVs were disposed by U.S. households (CEA 2014).During the same 3.5 year period, sales to dealers were 131 million units (CEA S&F 2013), which is at least enough to maintain prior installed base levels.

U.S. adults indicated the display technology and screen size of their four most-used TVs. Though many display types exist, we limited the options to avoid confusion. The LCD category represents both LED, OLED, and fluorescent lit displays. Consumers did not know or specify their display type for 13% of TVs and screen size for 4% of TVs. Our survey and modeling identified 80 million CRTs plugged in in U.S homes in 2013.For comparison, CEA (2014) found that 41 percent of households had at least one CRT TV, with an average of 1.86 CRT units per household. This yields a total of 91 million CRT TVs in homes *including units in storage*, in February 2014.

To verify the consistency of survey reported screen sizes, we compared the distribution reported size with sales data from an industry source for TVs sold from 2010-2012. LCD screen size agreed very well; however, many people reported owning plasma displays smaller than 35 inches even though nearly all plasma displays are greater than 37 inches. Historically, survey-based plasma ownership estimates have been higher than cumulative sales figures (FhCSE 2011), necessitating some adjustment. To compensate, we reclassified all reported plasma displays with screen sizes 37 inches or below as LCD TVs. In total we reclassified 15.3 million plasma TVs as LCD TVs, which greatly improved the plasma TV size distribution's agreement with sales data, without appreciably affecting the already good agreement of the LCD screen size distribution, see Figure 3-43. The breakdown of TVs by display type is given in Table 3-69.

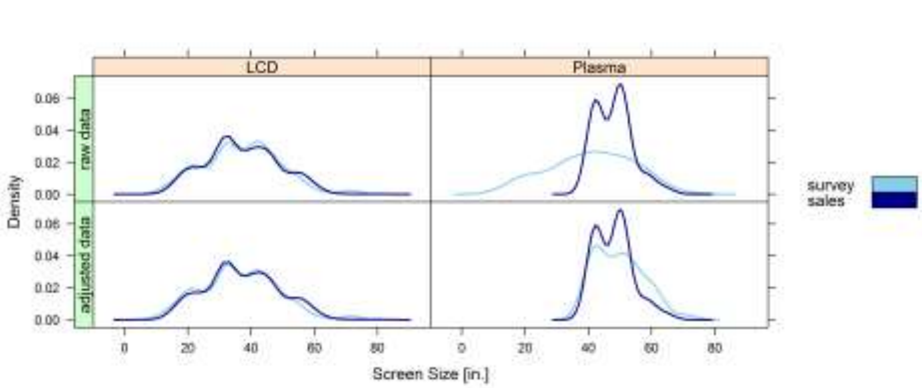
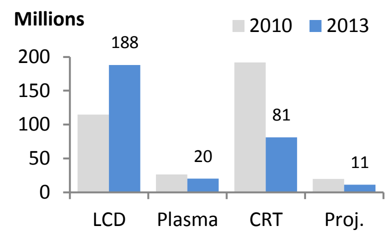


Figure 3-43: Screen size for LCD and Plasma TVs from 2010 to 2012. Reclassifying survey responses for Plasma TVs of 37 in. or lower as LCD TVs improves survey agreement with sales data.

Table 3-69: Distribution of TVs by display type.

	Source	LCD	Plasma	CRT	Proj.
2013	FhCSE Model	63%	7%	27%	4%
2013 Nov.	CE Usage Survey	57%	12%	27%	4%
2013	CEA O&M Survey	39%	19%	42%	-
2010	FhCSE Model	33%	7%	54%	6%
2010	CEA O&M Survey	21%	13%	62%	5%
2009 Aug.	CE Usage Survey	25%	7%	62%	5%

Figure 3-44: TVs by display type.



TV size continues to increase, with an average diagonal screen size of 34 inches, up from 29 inches in 2010[33] (FhCSE 2011) and 26 inches in 2006 (TIAX 2007). In Figure 3-45 we show the distribution of screen size and age according to the Aug. 2009 survey. Primary TVs, those used most in a household, are substantially larger at about 41 inches (38 in 2010). TVs averaged about 5.5 years old (6.2 in 2010)[34] according to the CE Usage Survey.

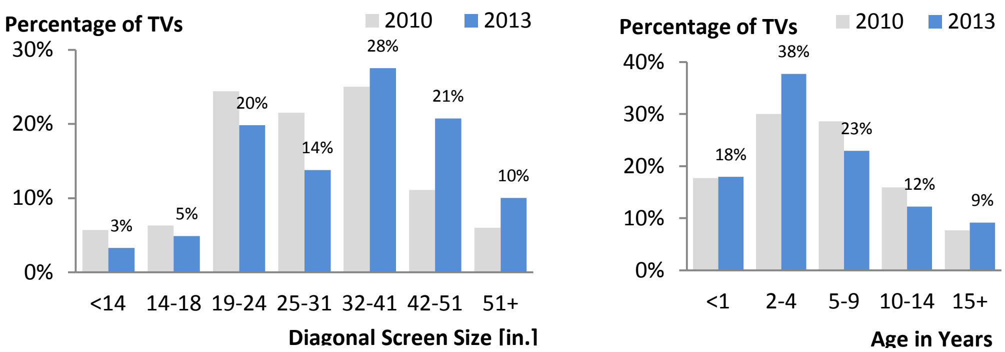


Figure 3-45: TVs by screen size and age (Nov. 2013 survey). Bin ranges not of equal size.

Usage patterns greatly affect TV energy consumption estimates, and newer, larger TVs tend to be 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. The assignments, based on survey responses, are indicated in Figure 3-46.

[33] Average display size is approximate. In the 2013 survey, responders gave their best estimate in inches, while in 2010, we asked only about discrete size ranges.
[34] The figure was obtained by assuming that TVs in the 15+ category were exactly 15 years old. Since discrete size ranges were recorded, average age is approximate.

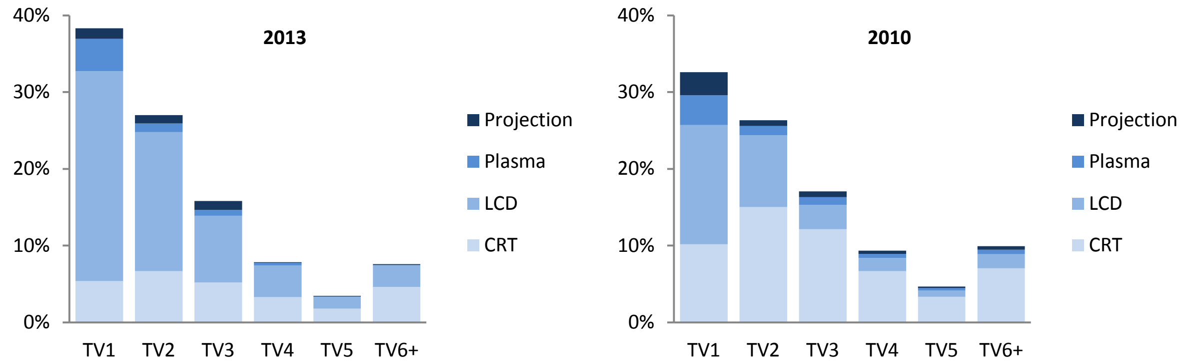


Figure 3-46: Distribution of TVs by display technology and usage priority.

3.12.1.2 Unit Energy Consumption

3.12.1.2.1 Power Draw

Since our previous study in 2010, two new ENERGY STAR specifications have gone into effect (v5.3 and v6.0), setting more stringent requirements for maximum on mode power draw based on screen area and summarized in Table 3-70 (EPA 2013). ENERGY STAR-compliant TVs accounted for 84% of the units sold in 2012 and 96% in 2011 (EPA 2010-12).

Table 3-70: ENERGY STAR power draw requirements for TVs.

ENERGY STAR	Screen Area [in^2]	Max. On Mode Power [W]	Max. Sleep Power [W]	Manufacture Date
v6.0	A	P_{max} = 100·tanh(0.00085·(A–140) + 0.052) + 14.1	1.0	May 15, 2013
v5.3	A < 275	P_{max} = 0.130·A + 5	1.0	May 1, 2012
v5.3	275≥ A ≥ 1068	P_{max} = 0.084·A + 18	1.0	May 1, 2012
v5.3	A > 1068	P_{max} = 108	1.0	May 1, 2012
v4.0	A < 275	P_{max} = 0.190·A + 5	1.0	May 1, 2010
v4.0	A ≥ 275	P_{max} = 0.120·A + 25	1.0	May 1, 2010

We assessed TV power draw as a function of display type, screen size, and production year, developing linear regressions based on several data sources, see Table 3-71. For TVs sold until 2010, we used power regressions from our 2010 study (FhCSE 2011). For TVs sold between 2010 and 2013, we developed new regressions from a combination of California Energy Commission appliance database (CEC 2013) and the EPA ENERGY STAR list of qualified TVs (EPA 2013). The CEC database provides active mode power draw and linear screen size (n= 4,829 models, 96% LCD or OLED and 4% Plasma), but it does not provide year of manufacture or standby power draw. Of the listed units, 69% of LCD displays had active mode power draw that met ENERGY STAR v5.3 (95% for v4.0), while 37% of Plasma displays met v5.3 (89% for v4.0). These compliance levels suggest that the CEC database is representative of TVs sold during the 2011-2013 period, and we use their values to generate new linear active mode power regressions given in Table 3-71.

The ENERGY STAR 6.0 draft development dataset (n=430, 83% LCD, LED, or OLED; 17% Plasma) includes ENERGY STAR qualified TVs on the market in Q4 of 2010 through 2011 (EPA 2013). Off-mode power draw for these TVs averaged 0.27 W, and the current list (Dec 2013) of qualified TVs contains 998 models, for which the average standby mode power draw is 0.29 W. These figures are slightly lower than the 0.41 W found in the 2010 study. For TVs made prior to 2008, we assume 4 W for off-mode power draw (TIAX 2008).

The ENERGY STAR v6.0 draft 2 development dataset (n=1,697, 94% LCD+LED+OLED and 6% Plasma) includes active but not standby power draw for ENERGY STAR qualified TVs that went on the market in Q1 2011 through Q2 2012 (EPA 2013).

Table 3-71: Active mode power regressions by TV screen area, display, and production year.

		$P[W]=C_1+C_2 \cdot A[in^2]$				
Display	**Year**	**C_1**	**C_2**	**R^2**	**N**	**Source**
LCD	2011-3 ES	16.47	0.05	0.74	3,208	CEC
	2011-3 non-ES	28.59	0.10	0.69	1,419	CEC
	2011-3 ALL*	12.58	0.08	0.54	4,627	CEC
	2010*	24.06	0.09	0.71	123	Fraunhofer 2010
	2009	17.15	0.17	0.74	98	Fraunhofer 2010
	2008	11.59	0.20	0.91	99	Fraunhofer 2010
	2008-9*	15.98	0.18	0.81	197	Fraunhofer 2010
	2005-7*	19.23	0.25	0.93	121	ENERGY STAR
Plasma	2011-3 ES	52.19	0.04	0.42	72	CEC
	2011-3 non-ES	105.50	0.04	0.15	124	CEC
	2011-3 ALL*	58.26	0.06	0.24	196	CEC
	2010*	4.77	0.14	0.53	24	Fraunhofer 2010
	2009	-15.78	0.24	0.91	22	Fraunhofer 2010
	2008	35.32	0.21	0.90	19	Fraunhofer 2010
	2008-9*	8.48	0.22	0.89	41	Fraunhofer 2010
	2005-7*	80.54	0.29	0.58	33	ENERGY STAR
Projection	2005-7*	87.45	0.07	0.61	10	ENERGY STAR
CRT	2006*	59.97	0.10	0.91	-	TIAX 2007

* Regression used in the energy model. Other data provided for reference.
ES=ENERGY STAR qualified product; non-ES=Non ENERGY STAR qualified product; ALL=ES + non-ES products.

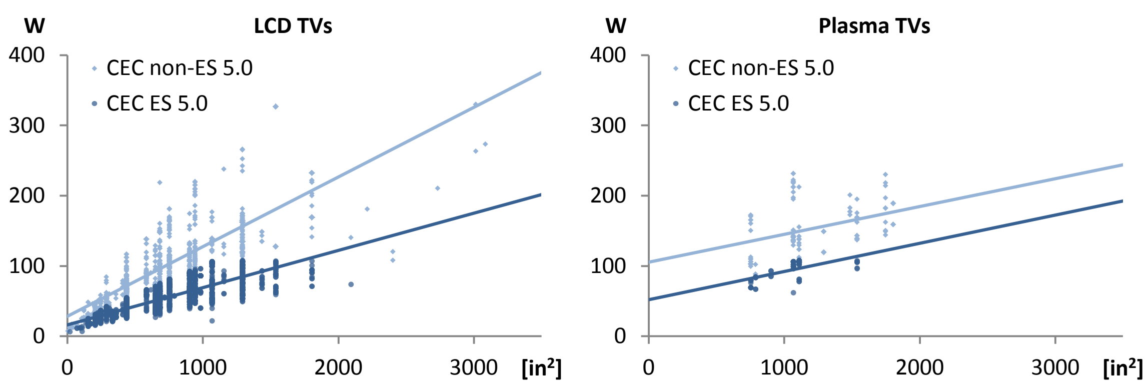


Figure 3-47: Power regressions for LCD and Plasma TVs (CEC 2013).

Internet connected TVs, if they remain connected during standby mode, could significantly increase energy consumption; one model drawing 24W in inactive mode compared with less than 1 W for most non-connected TVs (NRDC 2012). About 3% of TVs in the v6.0 development dataset offered Internet connectivity, though there were insufficient power draw data for connected-standby mode. It is also unknown what portion of Internet ready TVs are (1) connected to the Internet and (2) maintain their connection while the display is off, both of which would affect the standby power draw. Internet capable TVs have a 15% household penetration as of 2013 (CEA O&M 2013).

TV power draw may be influenced by other factors, such as screen resolution, brightness settings, and other features, though without better installed base and power draw data, these factors could not be evaluated. For instance, Figure 3-48 shows how much more power is needed in a bright room vs. the baseline of a dark room, when using automatic brightness control. On average, power draw was about 50 W higher and nearly twice for the bright room case. About 70% of TVs in the ENERGY STAR v6.0 development dataset offer automatic brightness control, though it is not clear how many users actually implement this feature (EPA 2013), adding some uncertainty to the actual power draw measurements.

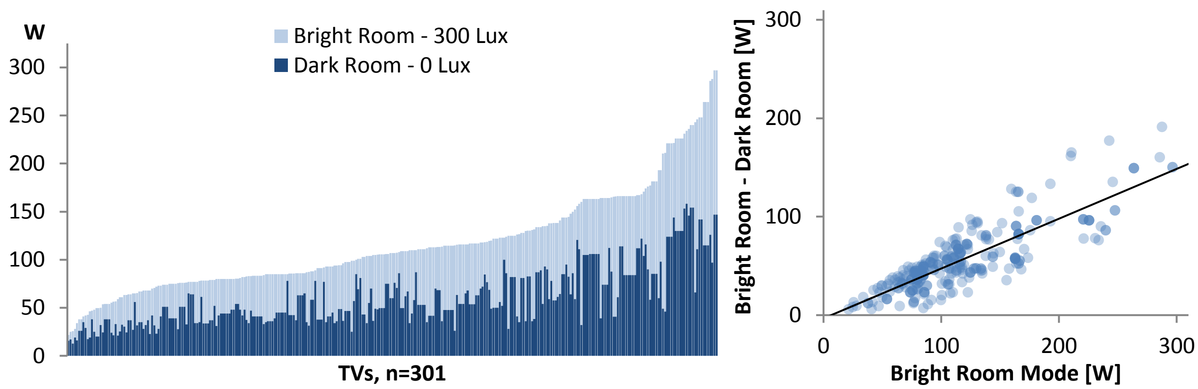


Figure 3-48: Impact of TV brightness on power draw (EPA 2013).

3.12.1.2.2 Usage

Average usage per-TV appears steady at 3.2 h/day (5.2 for the primary TV), while on-time has increased slightly to 4.4 h/day (from 3.8 in Aug. 2009). This apparent 10% increase in unit on-time was more than offset by the 14% decrease in the installed base during the same period, suggesting a 4% decrease in total TV active usage.

We determined usage from the CE Usage Survey. Active usage includes the time when users engage in any TV-related activities (viewing TV, DVD, game consoles, etc.), while "on time" also includes the time when the TV is left on but unused. Our surveys asked for the usage of the four most used televisions per household. We derived usage estimates for lesser-used TVs using a proportional scaling[35] by usage priority. The precision of usage estimates for TVs beyond the four most-used per household is not so important, since we estimate they represent only a small portion of the total usage (3%) and installed base (11%). Their usage occurs mainly in the off mode, so energy estimates for these lesser-used TVs is more sensitive to off-mode power draw and less sensitive to active mode usage and power draw estimates.

Lawrence Berkeley National Laboratory (LBNL) calculated TV usage profiles from Nielsen's metered usage data in over 12,000 representative U.S. households from May 2007 to 2011 (DOE 2012). Metering devices were installed on each TV of a participating household and measured TV on-time for each TV, though TVs that were not used at all were excluded from the dataset. They found that the average TV viewing time was 5.5 h/day, about 7 h/day for primary TVs and less than 2.5 h/day for non-primary TVs.

[35] For each TV display category, we calculated the average usage for TVs 4 and 5 using a proportional scaling by TV usage priority (e.g., usage of TV5 = average(TV1/TV2, TV2/TV3, TV3/TV4)·TV4).

These values are generally similar to our values of 7.0 and 2.9 h/day for primary and non-primary TVs, respectively. The LBNL study also compared results with data from the 2009 Renewable Energy Consumption Survey (EIA 2011) and noted that the survey method produced lower usage values than the Nielsen data set, which was based on in-home metering of TV on-time. According to Nielsen (2013), *per-person* TV usage in 2013 amounts to 5.6 h/day (2,049 h/yr), of which 86% is traditional TV, 7% is time-shifted TV, 3% is DVD/Blu-Ray, and 4% is video game console usage. These per-person usage figures remain relatively unchanged in recent years (5.5 h/day in 2012 and 2011).

Of the TVs represented in our survey, Plasma TVs had the highest usage at about 5.8 h/day, followed by LCD (4.8), Projection (4.7), and CRT (3.1). Newer TVs had higher usage than TVs that were 3 or more years old (5.3 vs. 4.7 h/day), and larger TVs had higher usage than those less than 40 inches (6.1 vs. 4.4 h/day).

3.12.1.2.3 Unit Energy Consumption

To calculate UEC and AEC for TVs, we combined input from the CE Usage Survey with the power draw regressions from Table 3-71 to determine energy usage by mode for each TV usage group, subdivided by display technology and screen size. We then applied our 2013 installed base estimate of 300.7 million TVs to obtain the AEC estimates shown in Table 3-72. We estimate average unit energy consumption at 166 kWh/yr in 2013 and about 9% lower than in 2010. Even though screen sizes of newly purchased TVs continue to increase, per-unit consumption has continued to drop stemming from the major fall of less-efficient CRT displays.

Table 3-72: UEC and AEC calculations for TVs for 2013.

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	115	38%	7.0	41	4.4	105	1.1	274	31.6	63%
TV2	81	27%	3.8	32	5.6	81	1.6	125	10.1	20%
TV3	48	16%	2.6	29	6.0	78	1.9	89	4.2	9%
TV4	24	8%	2.4	29	6.5	80	2.0	84	2.0	4%
TV5	11	3%	1.6	28	7.3	81	2.4	65	0.7	1%
TV6+	23	8%	1.1	28	8.0	84	2.6	57	1.3	3%
Total/Avg.	**301**	**100%**	**4.4**	**34**	**5.5**	**90**	**1.6**	**166**	**50**	**100%**

Estimates based on CE Usage Survey (Nov. 2013), CEA 2013 sales data, CEA partner surveys, and EPA power data.

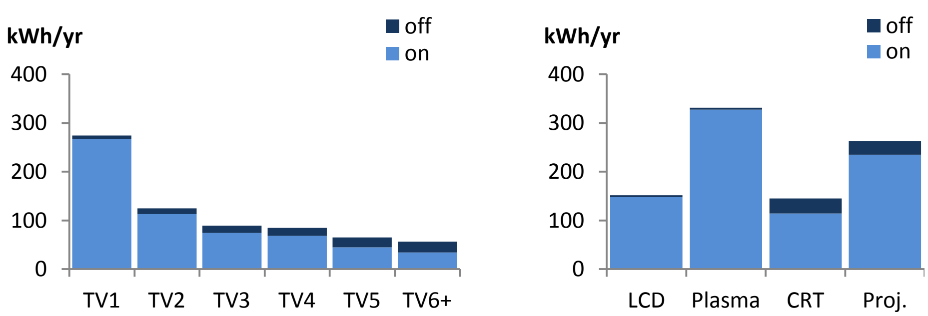


Figure 3-49: TV unit energy consumption by usage priority and display type.

3.12.1.3 Annual Energy Consumption

We estimate that TVs consume 50 TWh/yr, with primary TVs responsible for 63% of the total AEC, as summarized in Table 3-72 and Table 3-73. This 23% decline from 2010 consumption comes primarily from the 15% drop in the installed base and from the massive decline of CRTs in favor of more efficient LCD displays.

About 93% of TV energy usage occurs in active mode, while the remaining 7% occurs in off mode. The shift toward lower off-mode consumption is a result of improved off-mode efficiency of newer TVs (the large majority under 1 W) and the concurrent retirement of older, unused TVs with higher off-mode power draw. Naturally a TV's usage priority has the biggest influence: 98% of TV1 energy usage is from active mode, compared to less than 70% for TV5 and beyond.

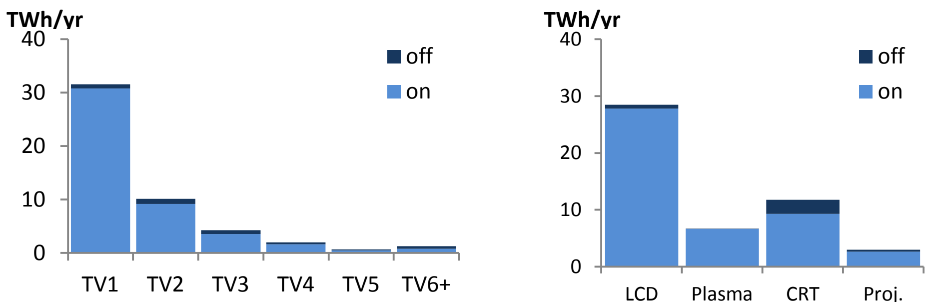


Figure 3-50: Active and off mode AEC by TV priority and display type.

3.12.2 Comparison with Prior Energy Consumption Estimates

Prior estimates of television AEC are given in Table 3-73 together with our estimates of 50 TWh for 2013. For the first time in over a decade, the number of plugged-in TVs has decreased significantly, with a shift from CRT to LCD TVs contributing to a sharp 20% decline in AEC. Our best understanding of this decline is that older, less-efficient TVs and primarily CRT displays are being taken out of service – either to be recycled, disposed of, or set aside. Since our only indication of these changes come from our phone survey, there remains some uncertainty. Active TV usage remained fairly consistent, while TV on-time has increased somewhat from previous estimates. Active mode power has continued to decrease, even while average screen size continues to increase, owing to the greater efficiency of newer displays.

Table 3-73: Prior energy consumption estimates for TVs.

Year	Units [millions]	Power [W] Active	Power [W] Off	Usage [h/yr] Active	Usage [h/yr] Off	UEC [kWh/yr]	AEC [TWh/yr]	Source
2013	301	90	1.6	1,606	7,154	166	50	Current
2010	353	104	3.0	1,392	7,368	183	65	FhCSE 2011
2009	342	105	3.3	1,392	7,368	188	64	FhCSE 2011
2006	275	111	4.0	1,882	6,878	244	67	TIAX 2008
2006*	237	98	4.0	1,882	6,878	222	53	TIAX 2007
2004*	234	100	3.9	1,278	7,483	156	37	NRDC 2005
1998*	212	75	4.5	1,443	7,317	150	31	LBNL 1999
1997*	229	60	4.0	1,460	7,300	117	27	ADL 1998
1995*	191	77	4.0	1,498	7,262	141	26	LBNL 1998

* Analog TVs only.

Older CRTs continue to be replaced with newer, more efficient digital flat panel TVs, as indicated by Figure 3-51 and Figure 3-52. About 91% of the 40 million TVs sold per year are flat panel LCD displays, and these have overtaken CRTs as the most prevalent display technology in homes.

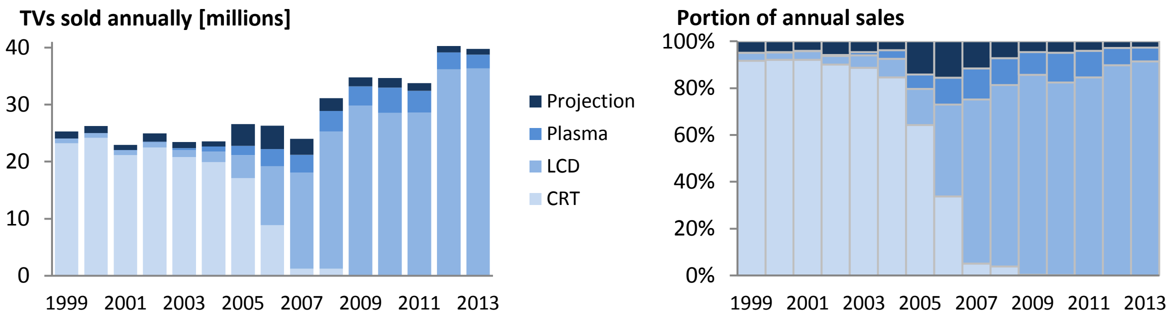


Figure 3-51: Annual TV sales to dealers by display technology (CEA 2013, 2010).

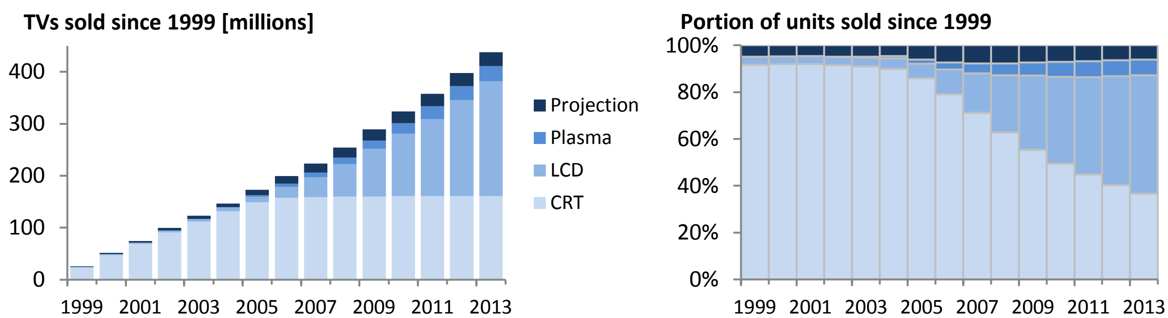


Figure 3-52: Cumulative TV sales to dealers by display technology since 1999 (CEA 2013, 2010).

3.12.3 References

ADL. 1998. "Electricity consumption by small end uses in residential buildings." Final Report by Arthur D. Little for the U.S. Department of Energy, Office of Building Equipment. Aug.

CEA. 2014. "2014 CRT Television and Monitors per U.S. Household". CEA Market Research Report. April.

CEA. 2013. Second Annual Report of the eCycling Leadership Initiative. Consumer Electronics Association. http://www.ce.org/CorporateSite/media/Government-Media/Green/eCycling-Leadership-Initiative-Year-Two-Report.pdf. Apr.

CEA O&M. 2009. "11th Annual Household CE Ownership and Market Potential." CEA Market Research Report. Consumer Electronics Association. May.

CEA O&M. 2010. "12th Annual Household CE Ownership and Market Potential." CEA Market Research Report. Consumer Electronics Association. May.

CEA S&F. 2013. "U.S. Consumer Electronics Sales & Forecasts 2009-2014." CEA Market Research Report. Consumer Electronics Association. Jul.

CEA S&F. 2010. "U.S. Consumer Electronics Sales & Forecasts 2006-2011." CEA Market Research Report. Consumer Electronics Association. Jul.

CEC. 2013. Appliance Efficiency Database. California Energy Commission. http://www.appliances.energy.ca.gov/QuickSearch.aspx. Retrieved Dec. 2013.

DOE. 2012. "Television Usage Analysis: Energy Efficiency Program for Consumer Products: Television Sets." U.S. Department of Energy. http://www1.eere.energy.gov/buildings/appliance_standards/pdfs/tv_tpnopr_usageanalysis.pdf. Mar.

EIA. 2011. "2009 Residential Energy Consumption Survey." U.S. Energy Information Administration. http://www.eia.gov/consumption/residential/index.cfm.

EPA. 2013. "ENERGY STAR program requirements for televisions." Partner commitments Versions 4.0 and 5.0. Environmental Protection Agency. Oct.

EPA. 2012, 2011, and 2010. ENERGY STAR Unit Shipment and Market Penetration Report. Calendar Year Summaries. Environmental Protection Agency.

EPA. 2011. "Electronics Waste Management in the United States Through 2009." Environmental Protection Agency. May

FhCSE. Urban, Bryan, Kurt Roth, and Verena Tiefenbeck. 2011. "Energy Consumption of Consumer Electronics in U.S. Homes in 2010." Final Report to the Consumer Electronics Association. http://www.ce.org/CorporateSite/media/Government-Media/Green/Energy-Consumption-of-CE-in-U-S-Homes-in-2010.pdf. Dec.

FhCSE. Roth, Kurt and Bryan Urban. 2009. "Assessments of the energy savings potential of policies and measures to reduce television energy consumption." Final report to the Consumer Electronics Association. Oct.

LBNL. Rosen, K. and A. Meier. 1999. "Energy use of televisions and videocassette recorders in the U.S." Lawrence Berkeley National Laboratory. Report LBNL-42393. Mar.

LBNL. Sanchez, M.C., J.G. Koomey, M.M. Moezzi, and W. Huber. 1998. "Miscellaneous electricity use in the U.S. residential sector." Lawrence Berkeley National Laboratory. Report LBNL-40295.

Nielsen. 2010. "Television audience 2009." Apr. http://blog.nielsen.com/nielsenwire/wp-content/uploads/2010/04/TVA_2009-for-Wire.pdf.

Nielsen. 2012. Viewing on Demand. The Cross-Platform Report Q2: 2012. http://www.nielsen.com/us/en/reports/2012/state-of-the-media--cross-platform-report-q2-2012.html. Nov.

Nielsen. 2013. "No TV? 5 million U.S. households bid boob tube goodbye." USA Today. http://www.usatoday.com/story/money/business/2013/04/07/zero-tv-homes/2061127.

Nielsen. 2013. State of the Media U.S. Consumer Usage Report.

Nielsen. 2013. Viewing on Demand. The Cross-Platform Report Q2: 2013. http://www.nielsen.com/us/en/reports/2013/q2-2013-cross-platform-report.html. Sept.

NRDC. Horowitz, N. 2012. NRDC Comments on ENERGY STAR's Final Draft Version 6.0 Eligibility Criteria for Televisions. National Research Defense Council. Jul.

NRDC. Ostendorp, P., S. Foster, and C. Calwell. 2005. "Televisions: active mode energy use, new horizons for energy efficiency." National Research Defense Council. Mar.

TIAX. Roth, K., K. McKenny. 2007. "Energy consumption by consumer electronics in U.S. Residences." Final report to the Consumer Electronics Association (CEA). Jan.

TIAX. 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." Apr.

3.13 Video Game Systems

3.13.1 Current Energy Consumption

The video game systems described in this section refer to video game consoles, such as the Sony PlayStation 3, Nintendo Wii, or Microsoft Xbox 360, and includes consoles in the installed base as of Jul. 2013. Hence, the Sony PlayStation 4 and Xbox One gaming consoles were not included as they were released in fall of 2013. Handheld devices, such as the Sony Playstation Portable and the Nintendo DS are not covered in this report.

3.13.1.1 Installed Base

We estimate an installed base of 128[36] million video game consoles in 2013 (see Table 3-74) based on the CE Usage Survey (see Appendix A). This is 17 percent higher than in 2010 (FhCSE 2011). We also asked in this survey about the ownership of recently released video game consoles such as Xbox One and PlayStation 4; however, the 128 million installed base estimate excludes those consoles. Appendix B.3.1 presents an installed base estimate for video game consoles in early 2014 that includes the Xbox One and PlayStation 4.

Table 3-74: Installed base of video game consoles.

Installed Base [millions]	Penetration	Sources
128	51%	2013 CE Usage Survey

We estimate the installed base of different video game console models from the CE Usage Survey. Each video game console model has several vintages, defined by the year of release, that have different power draws in operational modes. Consequently, we estimate the installed base distribution by model and vintage using sales data provided by Microsoft, Nintendo and Sony (Calland 2014, Jessop 2014, Boxleitner 2014, Nintendo 2013). If the sum of the sales of a particular video game console model exceeds the installed-base estimate from the CE Usage Survey , we adjusted the installed base estimates for different vintages of specific models by eliminating units of the oldest vintage(s) until the installed based estimates agreed. For example, the survey yielded a lower installed base estimate of Microsoft Xbox 360 units than cumulative Xbox 360 sales, so we removed units sold in 2005 and 2006 from the installed base. We also found that all owners of the Nintendo GameCube console had not used the console for any purpose “yesterday” (see Figure 3-54). Thus, we assumed that no more units remained in the installed base.

Figure 3-53 shows that so-called 7th generation consoles, i.e. the Nintendo Wii (Wii), Sony PlayStation 3 (PS3), and Microsoft Xbox360 (Xbox 360), account for 77% of the installed base. The Sony PlayStation 2 (PS2), released in March, 2000, remains one of the most popular (17% of installed base) video game consoles (Figure 3-53); this is consistent with the 20% estimate in 2012 of Nielsen (2012). The Nintendo Wii U, released in Nov. 2012, introduced the 8th generation of video game consoles. As of mid-2013, we estimate that it accounted for approximately 1% of the installed base.

[36] We adjusted final installed base results using sales data provided by Nintendo, Sony and Microsoft (Calland 2014, Jessop 2014, Boxleitner 2014, Nintendo 2013).

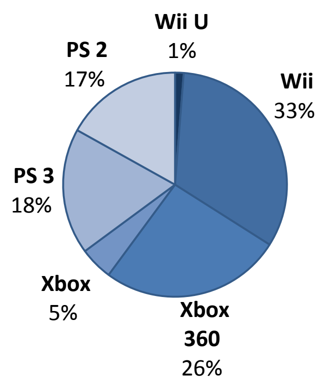


Figure 3-53: Fraction of video game systems installed in U.S. homes by platform.

3.13.1.2 Unit Energy Consumption

We used several modes to characterize gaming system energy consumption. Collectively, we refer to "Active-Gaming", "Active-Video streaming", and "Active-Video playback" as active modes.

- **Active – Gaming:** The system is on and a game is being played.
- **Active – Video streaming:** The system is on and video or audio is being played from a network.
- **Active - Video playback:** The system is on and video or audio is being played using its built-in DVD/Blu-ray drive.
- **Navigation:** The console is on, but the user is not providing input to the console via the controller, i.e., the console is not being actively used.
- **Standby:** The power has been switched off by the user, but the system remains plugged in.

The number of video game console owners who use consoles for video streaming is increasing (Nielsen 2013), so our assessment considers separate modes for "Video streaming" and "Video playback." The energy consumption characteristics of "Navigation" mode used in our previous study (FhCSE 2011) are very similar to those of the "Idle" mode as defined in Hittinger et al. (2012) and in EPA's specification for game consoles (EPA 2013). Consistent with our prior study, we decided to use only the "Navigation" mode in this study.

3.13.1.3 Power Draw

Table 3-75 summarizes the estimated power draw of video game consoles as a function of console platform, vintage, and operational mode. The power draw values for the 7th and 8th generations of video game consoles presented in this table were provided by video game console manufacturers (Calland 2014, Jessop 2014, Boxleitner 2014). They are consistent with power draw measurements from other studies analyzing video game console energy consumption (LBNL 2013, Hittinger et al. 2012, NRDC 2010). In addition, we used the power draw values for the Microsoft Xbox and Sony PlayStation 2 from NRDC (2010).

Table 3-75: Installed base and power draw by mode of video game systems.

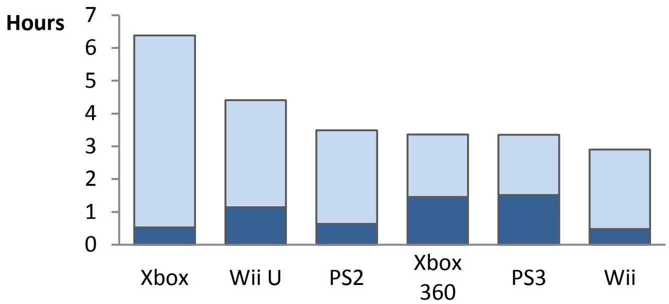
	Years	Installed Base [millions]	Installed Base [%]	Power [W] Gaming	Video Streaming	Video Playback	Navigation	Standby
Nintendo								
Wii U	2012-2013	1.6	1.2%	33	31	-	32	0.4
Wii	2006-2013	42	33%	16	16	-	14	5.8 *
Microsoft								
Xbox 360 S/E	2010-2013	21	17%	86	67	67	67	0.4
Xbox 360	2007-2009	12	9%	121	97	96	97	1.8
ALL Xbox 360/Wt. Avg.	***2007-2013***	***33***	***26%***	***99***	***78***	***77***	***77***	***0.9***
Xbox	2001-2008	6.1	5%	64	-	-	60	1.7
Sony								
PS3 Super Slim	2012-2013	4.3	3%	82	62	74	68	0.2
PS3 Slim	2009-2011	12	9%	102	77	94	91	0.7
PS3	2008	4.4	3%	137	112	126	115	1.3
PS3	2007	2.3	2%	190	160	178	165	1.4
PS3	2006	0.6	0.5%	220	166	209	188	1.5
ALL PS3/Wt. Avg.	***2006-2008***	***23***	***18%***	***117***	***92***	***108***	***101***	***0.8***
PS2	2000-2013	22	17%	24	24 **	24	24	1.7
Total/Wt. Avg.	**-**	**128**	**100%**	**60**	**49**	**72**	**51**	**2.6**

* Calculated as the weighted average based on the portion of different vintages of the Nintendo Wii gaming consoles by year (1.7, 1.7 and 0.7 watts if connect24 disabled, 10, 7 and 5watts if enabled for Wii gaming consoles released since 2006, 2009 and 2010, respectively (Boxleitner 2014)) and assuming that 30% of users have the Wii connect24 disabled (FhCSE 2011). Wiiconnect24 is not available on the newer Wii U console.

** We used power draws for video streaming and playback the same as for active mode and navigation because we did not find power draw values for these modes.

3.13.1.3.1 Usage

We asked about video game console usage in the CE Usage Survey (2013). Based on the responses received and our usage estimation models (see Appendix B.3.4 for more details), we estimate that systems spend an average of 1 hour total per day in all active modes, i.e., in active-gaming, active-video streaming and active-video playback modes. In addition, we estimate that video game consoles were *left on* for an additional 2.4 hours/day in 2013 (i.e., navigation mode). Among different video game console platforms, the most actively used video game consoles were the Xbox 360, PlayStation 3 and Wii U, for 1.5, 1.5 and 1.1 hours/day, respectively (see Figure 3-54). Our estimates of average active usage and time spent in navigation mode in 2013 are less than the 3.1 hours/day active usage and 4.0 hours/day in on mode found in our study in 2010 (FhCSE 2011).



	Xbox	Wii U	PS2	Xbox 360	PS3	Wii
Left ON	5.9	3.3	2.9	1.9	1.8	2.4
Actively used	0.5	1.1	0.6	1.5	1.5	0.5

Figure 3-54: Turned ON and actively used hours/day for different video game console platforms.

Table 3-76: Usage by different video game consoles (CE Usage Survey).

	Years	Usage [h/yr]				
		Gaming	**Video Streaming**	**Video Playback**	**Navigation**	**Standby**
Nintendo						
Wii U	2012-2013	108	293	-	1,205	7,154
Wii	2006-2013	100	82	-	876	7,702
Microsoft						
Xbox 360 S/E[a]	2008-2013	365	146	37	693	7,519
Xbox 360	2007	402	146	-	693	7,519
Xbox	2001-2008	183	-	-[b]	2,154	6,424
Sony						
PS3 Slim & Super Slim	2006-2013	394	115	44	657	7,550
PS2	2000-2013	197	-	22	1,059	7,483
Total/Wt. Avg.	-	**245**	**89**	**21**	**885**	**7,521**

a Xbox 360 S and Xbox 360 E are two redesigned model released in 2010 and 2013, respectively, of the Xbox 360 video game console (released in 2005).

b The Xbox has an accessory that enables the playing of DVDs. Eight percent of CE Usage Survey (2013) respondents reported that they played DVDs on their Xbox "yesterday" (See AppendixB.3). However, we did not use this data in our usage and energy consumption estimates because we did not have power draw data for Xbox gaming consoles using this accessory.

Table 3-77: Annual hours by mode for video game consoles for LBNL 2013, FhCSE 2011 and current study.

Year	Active Modes	Standby	Source
2013	1,240	7,521	Current study
2013	1,704	7,070	LBNL 2013
2010	1,450	7,310	ResCE 2010

Table 3-78 compares the breakdown of console usage between gaming and other active modes in 2013, 2012 and 2010. We found a similar breakdown of time spend in active modes in 2013 and 2010. According to Nielsen (2013), game console users spent about 8% less of their total active time gaming in 2012 than in 2011.

Table 3-78: Comparison of different estimates for the portion of active time in gaming and other modes.

Year	Active:Gaming	Active:Other	Source
2013	69%	31%	Current study
2012	54%	46%	Nielsen Newswire 2013
2010	66%	34%	CEA Gaming and Energy Study 2010

The CE Usage Survey found that the Nintendo Wii and Wii U gaming consoles were used more than 50% of the time for other purposes than gaming (Figure 3-55).

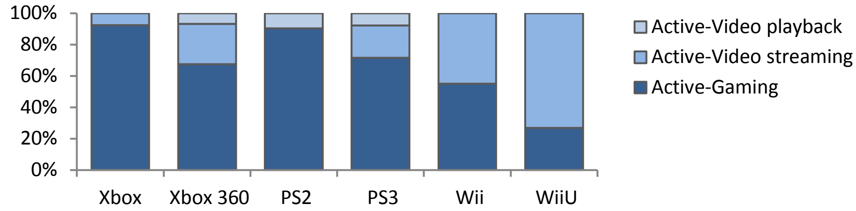


Figure 3-55: Distribution of active usage among gaming and video (streaming and playback) by platform.

3.13.1.3.2 Unit Energy Consumption

Our calculations of video game console UECs for different platforms are summarized in Table 3-79.

Table 3-79: UEC calculation for video game systems.

			UEC [kWh/yr]					
	Years	**Installed Base [millions]**	**Gaming**	**Video Streaming**	**Video Playback**	**Navigation**	**Standby**	**Total**
Nintendo								
Wii U	2012-2013	1.6	3.5	9.2	-	39	2.6	54
Wii	2006-2013	42	1.6	1.3	-	13	45	60
Microsoft								
Xbox 360 S/E	2010-2013	21	32	9.5	2.6	46	2.9	93
Xbox 360	2007-2009	12	45	14	2.9	67	14	143
ALL Xbox 360/Wt. Avg.	***2007-2013***	***33***	36	***11***	***2.7***	***53***	***6.3***	***109***
Xbox	2001-2008	6.1	***12***	-	-	129	11	152
Sony								
PS3 Super Slim	2012-2013	4.3	32	7.1	3.3	45	1.7	89
PS3 Slim	2009-2011	12	40	8.9	4.1	60	5.1	118
PS3	2008	4.4	54	13	5.5	76	9.8	158
PS3	2007	2.3	75	18	7.8	108	11	220
PS3	2006	0.6	87	19	9.2	124	11	250
ALL PS3/Wt. Avg.	***2006-2008***	***23***	***46***	***11***	***4.7***	***66***	***6.1***	***134***
PS2	2000-2013	22	4.7	-	0.5	25	13	43
Total/Wt. Avg.	**-**	**128**	**20**	**5.3**	**2.7**	**41**	**20**	**88**

Figure 3-56 shows the breakdown of UEC and annual hours in 2013 by different modes compared with usage. On average, navigation mode accounts for the largest portion of UEC in 2013.

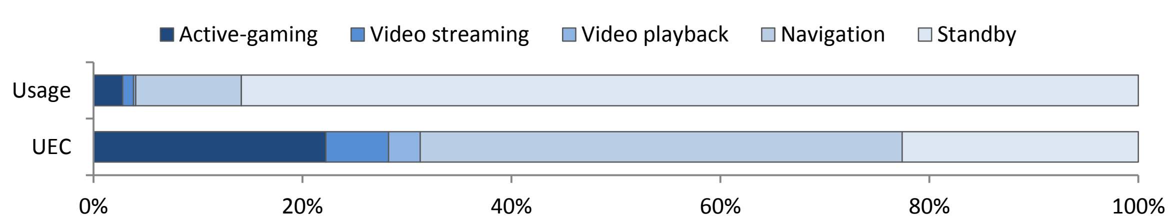


Figure 3-56: Video game console UEC and usage by mode.

3.13.1.4 Annual Energy Consumption

Video game systems consumed 11TWh in 2013 (see Table 3-80).

Table 3-80: AEC summary for video game systems

UEC [kWh/yr]	Installed Base [million]	AEC [TWh]
88	128	11

Seventh-generation consoles, e.g. Microsoft Xbox 360, Nintendo Wii and Sony PlayStation 3, account for the largest portion of AEC (Figure 3-57) as well as the installed base.

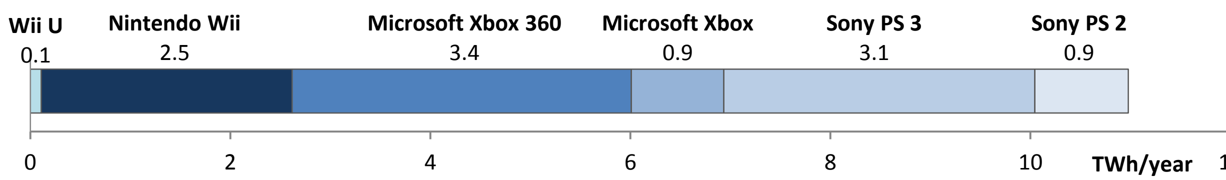


Figure 3-57: Annual Energy Consumption by different video game consoles

3.13.2 Comparison with Prior Energy Consumption Estimates

Table 3-81 summarizes prior energy consumption estimates for video game systems.

Table 3-81: Prior energy consumption estimates for video game systems.

Year	Units [millions]	Power [W] Active All	Power [W] Idle + Navigation	Power [W] Standby	Usage [h/yr] Active All	Usage [h/yr] Idle + Navigation	Usage [h/yr] Standby	UEC [kWh/yr]	AEC [TWh/yr]	Source
2013	128	58[a]	51	2.6	355	885	7,521	88	11	Current
2013	105	46	-	1	1,704[c]	-	7,056	68	7.1	LBNL 2013
2010	75	93[d]	79	3.4	382	2,514[e]	5,865	213	16	Hittinger et al. 2012
2010	109	85[a]	75	2	1,120	330	7,310	135	14.7	FhCSE 2011
2008	63	-	-	-	-	-	-	-	16.3[b]	NRDC 2008
2006	64	36	31	0.8	406	558	7,796	36	2.4	TIAX 2007
1999	54	8	-	1	175	-	8,585	10	0.5	LBNL 2001
1995	64	20	-	2	365	-	8,395	24	1.5	LBNL 1998

a Weighted average of gaming and other uses.
b Assumes that 50% of users leave on their system all the time.
c Includes time console is actively used and time console spends in navigation mode.
d Does not include power draw for Sony PlayStation 2.
e Assumed that 30% of users leave their console idle when not in use.

All three components of the AEC calculations have changed appreciably since 2010. First, the installed base increased by 17 percent. Relative to LBNL (2013), the current study found a higher proportion of PS2 consoles and fewer PS3 consoles; this could reflect differences due to the sample (households undergoing energy audits) and sample size (n=113) of that study (2013).

Second, the average power draw in all modes decreased for the more recent versions of the 7th-generation game consoles, which account for 77% of the installed base (Figure 3-58). In general, game console active gaming-mode power draw increased until it peaked around 2005/2006. Since then, the original versions of the two consoles with the highest active-mode power draw, the PS3 and Xbox 360, have been replaced by versions that, ultimately, drew about 65 and 52 percent less power than their original versions, respectively. On the other hand, the active-gaming mode power draw of the new Wii U console is higher than that of the Wii it replaced. Nonetheless, the Nintendo Wii U still draws less power than the other two video game console platforms, and only accounts for about 1 percent of the 2013 installed base.

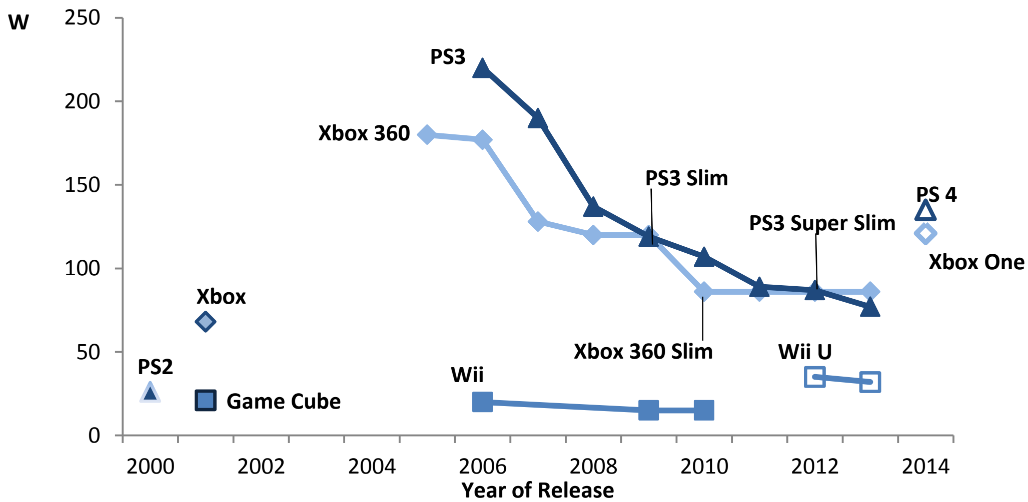


Figure 3-58: Historical active-gaming mode power draw values for video game systems (Calland 2014, Jessop 2014, Boxleitner 2014, NRDC 2010)

Lastly, the estimated annual total active hours is almost three times smaller than in 2010, while the total number of active-all plus navigation hours decreased by about 18 percent (FhCSE 2011). The reason for the large decrease in estimated active-use hours is not clear. First, the active-all hours estimate is similar to the estimate derived in Hittinger et al. (2012) from Nielsen usage data for 2010 and that of another phone survey (5.8 hours/week *per respondent*; PWC 2012). The difference in active-all estimates between our current and prior study (FhCSE 2011) could be due to several reasons. First, in the 2013 survey we asked about the respondent's usage "yesterday" instead of "per week" as in 2010. Asking about active weekly usage instead of one particular day (i.e. yesterday) could create biases in average active usage estimates because U.S. adults may not accurately recollect their weekly usage. Second, in 2013, we asked for a response in hours and minutes, which can give a more granular answer than asking about "only hours", which was survey method in 2010. Moreover, we found that our estimate (2.7 hours/day) for active usage in 2013 *excluding* U.S. adults who answered zero hours/day is close to the 2010 estimate (3.1 hours/day) including U.S. adults who answered zero hours/week. This suggests that in 2013 more U.S. adults answered that they did not use their video gaming console at all than in 2010. Potential explanations for a reduction in the total time spent in all active modes include the migration of some gaming activity to portable devices (i.e., smart phones and tablets) and higher penetration of video game consoles with auto power down (APD) functionality.

The field-metering study performed by Lawrence Berkeley National Laboratory (LBNL 2013) monitored the power draw of 113 game consoles for three to ten weeks. The study measured an average time in all active modes that exceeds our estimate by more than 40 percent. This is mainly due to large differences in usage for the Wii consoles, i.e., LBNL (2013) estimates that the average Wii console spent more than four times more time in all active modes than non-Wii consoles. The reason for the difference in Wii usage is not clear; however, both studies estimated similar time spent in active mode for the PS3 and Xbox 360.

3.13.3 References

Boxleitner, W. 2014. Personal Communication. Nintendo of America Inc. Feb.

Calland, T. 2014. Personal Communication. Microsoft. Feb.

CEA. 2013. "15^{ft} Annual household CE Ownership and Market Potential." CEA Market Research Report. Consumer Electronics Association. Apr.

EPA. 2013. "Game Console Version 1.0 Recognition Program." Mar. https://www.energystar.gov/products/specs/game_console_version_1_0_recognition_program_pd

FhCSE. Urban, Bryan, Kurt Roth, and Verena Tiefenbeck. 2011. "Energy Consumption of Consumer Electronics in U.S. Homes in 2010." Final Report to the Consumer Electronics Association. http://www.ce.org/CorporateSite/media/Government-Media/Green/Energy-Consumption-of-CE-in-U-S-Homes-in-2010.pdf. Dec.

Hittinger, E., K.A. Mullins, I. Azevedo. 2012. "Electricity consumption and energy savings potential of video game consoles in the United States." Energy Efficiency. Mar.

Jessop, J. 2014. Personal Communication. Sony Computer Entertainment America. Feb.

LBNL. Desroches, L., J. Greenblatt, and S. Pratt. 2013. "Video game console usage and national energy consumption: Results from a field-metering study" Lawrence Berkeley National Laboratory Report. LBNL- 6251E. Jun.

Matthews, M. 2013. "U.S. video game hardware in 2012: Winners, losers and retirees." Gamasutra. Jan. http://www.gamasutra.com/view/news/184714/US_video_game_hardware_in_2012_Winners_losers_and_retirees.php

Nielsen Newswire 2013, "Play vs. stream: the modern gaming console." Mar. http://www.nielsen.com/us/en/newswire/2013/play-vs--stream--the-modern-gaming-console.html.

Nielsen. 2012. "U.S. Gaming: A 360° View." Feb. http://www.nielsen.com/us/en/newswire/2012/the-latest-trends-in-us-video-gaming.html

Nintendo. 2013. "Consolidated Sales Transition by Region." Sept. http://www.nintendo.co.jp/ir/library/historical_data/pdf/consolidated_sales_e1309.pdf

NRDC. 2008. "Lowering the Cost of Play: Improving the Energy Efficiency of Video Game Consoles." Ecos Consulting. http://www.nrdc.org/energy/consoles/files/consoles.pdf.

PWC. 2012."The Evolution of Video Gaming and Content Consumption". PricewaterhouseCoopers LLP. http://www.pwc.com/us/en/industry/entertainment-media/publications/assets/pwc-video-gaming-and-content-consumption.pdf .

Sony. 2010. "PS3 System Software Update v3.40 And PlayStation Plus Available Later Today." http://blog.eu.playstation.com/2010/06/28/ps3-system-software-update-v3-40-and-playstation-plus-available-later-today/.

Sony. 2012. "PS3 System Software Update (v4.20)." http://blog.us.playstation.com/2012/06/25/ps3-system-software-update-v4-20/.

3.14 Other Devices

We estimate that other CE devices not analyzed in detail consumed about 28 TWh of electricity in 2013, an amount equal to 17 percent of total residential CE AEC. Table 3-82 through Table 3-87 and Figure 3-59 summarize the AEC estimates and the data used to calculate the AEC of these products. In general, these estimates have a higher degree of uncertainty than the estimates for CE products analyzed in greater detail.[37] The "other" category in 2013 includes several products evaluated in depth in the 2010 study that were not evaluated in further detail in this study. Typically such products had moderate or lower AECs in 2010, and our initial analysis suggested that their UEC was not likely to have changed greatly in 2013.

Table 3-82: UEC and installed base estimates for other products.

Product	UEC [kWh/yr]	Installed Base [millions]	AEC [TWh]
AV Receiver with surround sound processor	65	48	3.1
Bluetooth Headset	5.4	67	0.4
Blu-ray player	14	52	0.7
Boombox	25	109	2.7
Camcorder	2.3	58	0.1
Copy machine (stand-alone)	14	9	0.1
Cordless phone	12	128	1.5
Digital camera	0.3	156	0.05
Digital picture frame	6.5	50	0.3
DVD Player	22	142	3.1
eReader	2.7	45	0.1
External Storage Device	17	89	1.5
Fax Machine (stand-alone)	46	10	0.5
Handheld GPS	1.3	79	0.1
Headphones	0.6	267	0.2
Home Theater in a Box (HTIB)	89	20	1.8
Internet Phone Device	36	60	2.2
Mobile (non-smart) Phone	2.2	121	0.3
Portable DVD or Blu-ray disc player	2.7	80	0.2
Portable Game Devices	4.1	61	0.3
Portable media/MP3 Player/CD Player	5.6[a]	149	0.8
Portable Wireless Speaker	1.0	48	0.05
Printer + MFD (multi-functional device)	22	93	2.0
Projector	55	4	0.2
Radio	9.2	81	0.7
Scanner (stand-alone)	0.8	9	0.01
Soundbar	82	16	1.3
Telephone Answering Device	14	16	0.2
Video Cassette Recorder (VCR)	34	43	1.5
Total/Wt. Avg.	**13**	**2,110**	**28**

a UEC from Roth and McKenney (2007).

[37] In addition, the uncertainty in the estimates for "other" products can vary significantly among products.

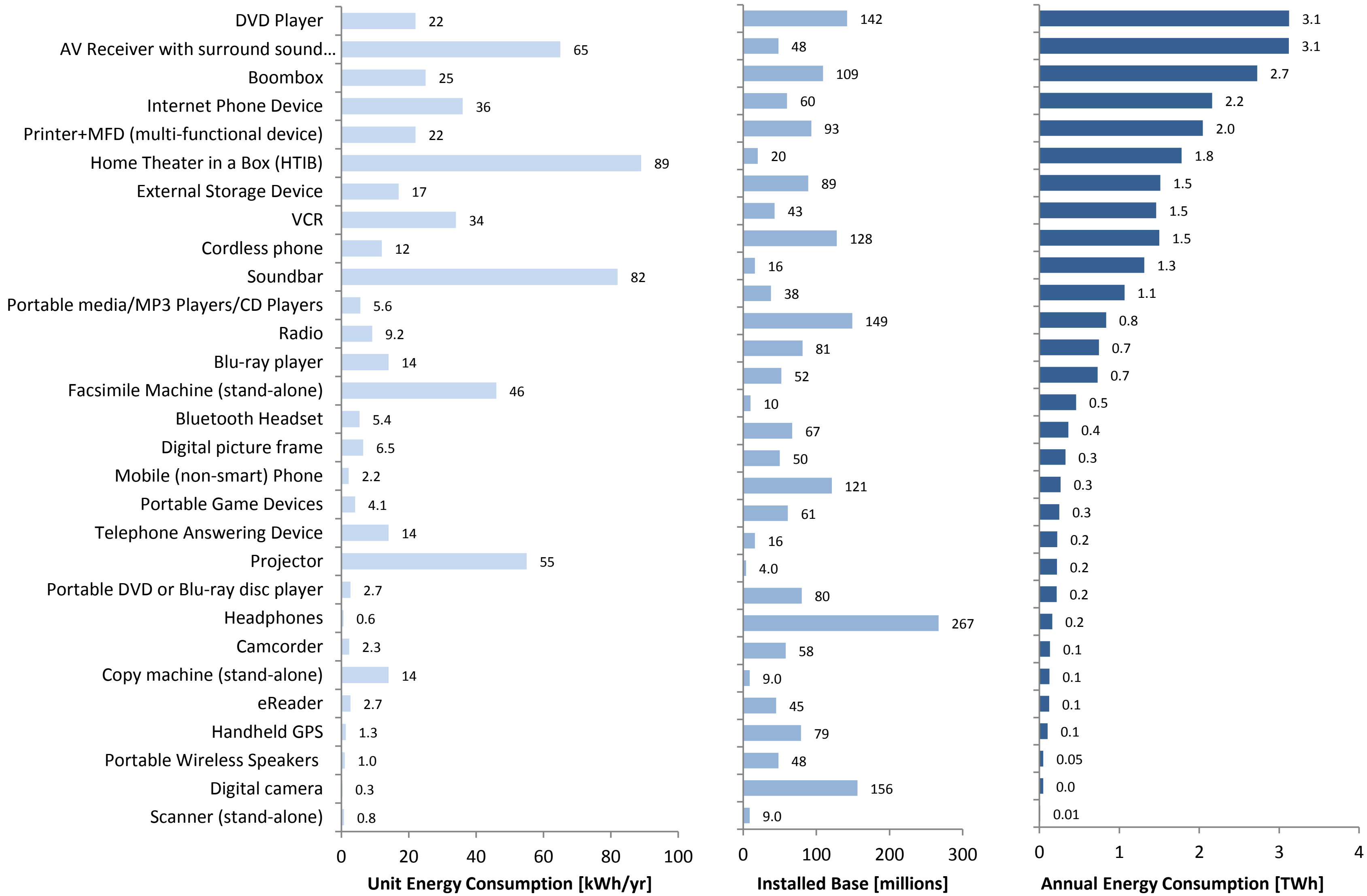


Figure 3-59: UEC, installed base, and AEC of other CE devices evaluated in less detail.

Table 3-83: Average power draw by mode estimates for other products.

Product	Power [W]		
	Active/Charging	Sleep/Idle	Standby/Off
AV Receiver with surround sound processor	52	2	1
Bluetooth Headset	NA / 2.0[a]	1.2	0.3
Blu-ray player	30	16	0.5
Boombox	5.2	4.1	2.1
Camcorder	NA / 9.6	0.4	0.4
Copy machine (stand-alone)	9.6	NA	1.5
Cordless phone	1.9	NA	0.5
Digital camera	NA / 4.0	NA	0.3
Digital picture frame	3.1	NA	0
DVD Player	10	0.6	0
eReader	NA / 1.4[a]	1.2	0.3
External Storage Device	1.2	NA	NA
Fax Machine (stand-alone)	6.5	5.2	0.4
Handheld GPS	NA / 1.4[a]	1.2	0.3
Headphones	NA / 2.4 [a]	1.2	0.3
Home Theater in a Box (HTIB)	37	33	1.3
Internet Phone Device	6	4	NA
Mobile (non-smart) Phone	4	2.2	0.2
Portable DVD or Blu-ray disc player	NA / 3.2[a]	1.8	1.0
Portable Game Devices	NA / 1.8[a]	1.2	0.3
Portable media/MP3 Player/CD Player	5	3	1.7
Portable Wireless Speaker	NA / 5.1[a]	2.3	1.4
Printer+MFD (multi-functional device)	28	4	2.4
Projector	182	10	4.6
Radio	4.3	NA	1.6
Scanner (stand-alone)	10	NA	1.5
Soundbar	30[b]	12 [b]	4.0 [b]
Telephone Answering Device	2	NA	NA
Video Cassette Recorder (VCR)	6.6	NA	1.2

a Power draw for charging is estimated from the battery energy capacity [Wh] of a battery charger divided by charging efficiency and charge time [hours] (DOE 2012a, DOE 2012b). DOE did not provide the charger efficiency for some consumer electronics devices (DOE 2012b); therefore, we used the average charger efficiency of the devices from the same classes defined in DOE (2012a). For example, for Handheld GPS and Headphones we used Mobile Phone charging efficiency, for Portable Wireless Speakers we used Computer Speaker charging efficiency, and for eReaders we used Tablet charging efficiency.

b Because the basic functionality and total system output power of soundbar systems are similar to those of mini shelf stereo systems, we assumed that soundbars have the same power draw values as Mini Shelf Stereo System.

Table 3-84: References for power draw by mode estimates for other products

Product	Sources
AV Receiver with surround sound processor	FhCSE (2011)
Bluetooth Headset	DOE (2012a), DOE (2012b)
Blu-ray player	FhCSE (2011)
Boombox	Bensch et al. (2010), Fraunhofer Measurements 2014
Camcorder	McAllister and Farrell (2004)
Copy machine (stand-alone)	LBNL (2008)
Cordless phone	Bensch et al. (2010)
Digital camera	McAllister and Farrell (2004), Foster Porter et al. (2006), Wood (2011)
Digital picture frame	Bensch et al. (2010)
DVD Player	LBNL (2013)
eReader	DOE (2012a), DOE (2012b)
External Storage Device	Bensch et al. (2010)
Fax Machine (stand-alone)	Bensch et al. (2010)
Handheld GPS	DOE (2012a), DOE (2012b)
Wireless Headphone	DOE (2012a), DOE (2012b)
Home Theater in a Box (HTIB)	Roth and McKenney (2007)
Internet Phone Device	YouSustain (2009), Ooma (2009), Roth et al. (2006)
Mobile (non-smart) Phone	Bensch et al. (2010), LBNL (2008)
Portable DVD or Blu-ray disc player	DOE (2012a), DOE (2012b)
Portable Game Device	DOE (2012a), DOE (2012b)
Portable media/MP3 Player/CD Player	Bensch et al. (2010), SELINA (2010)
Portable Wireless Speaker	DOE (2012a), DOE (2012b)
Printer+MFD (multi-functional device)	FhCSE (2011)
Projector	Meister et al. (2011)
Radio	Bensch et al. (2010)
Scanner (stand-alone)	Bensch et al. (2010)
Soundbar	FhCSE (2013)
Telephone Answering Device	Bensch et al. (2010)
Video Cassette Recorder (VCR)	Bensch et al. (2010)

Table 3-85: Annual usage by mode estimates for other products.

Product	Active/Charging	Sleep/Idle	Standby/Off
AV Receiver with surround sound processor	950	7,610	200
Bluetooth Headset	314 [b]	3,217 [c]	0[d]/4,015[e]
Blu-ray player	300	30	8,430
Boombox	1,971	NA	6,789
Camcorder	NA	NA	NA
Copy machine (stand-alone)	50[a]	NA	8,710 [a]
Cordless phone	7,044	NA	1,716
Digital camera	13	NA	8,752
Digital picture frame	4,781	NA	3,979
DVD Player	2,044	1,861	4,855
eReader	526 [b]	752 [c]	548[d]/6,935 [e]
External Storage Device	8,760	NA	NA
Fax Machine (stand-alone)	146	NA	8,614
Handheld GPS	73 [b]	110[c]	0[d]/8,578[e]
Headphone	146 [b]	219 [c]	0[d]/4,015[e]
Home Theater in a Box (HTIB)	1,580	730	6,450
Internet Phone Device	365	8,395	0
Mobile (non-smart) Phone	110	NA	8,650
Portable DVD or Blu-ray disc player	58 [b]	1,402 [c]	0[d]/7,300[e]
Portable Game Devices	204 [b]	2,738 [c]	3,103[d]/2,920[e]
Portable media/MP3 Player/CD Player	657	NA	8,103
Portable Wireless Speaker	146 [b]	219 [c]	0[d]/4,015[e]
Printer+MFD (multi-functional device)	103	1,212	7,445
Projector	694	613	7,453
Radio	620	NA	8,140
Scanner (stand-alone)	146	NA	8,614
Soundbar	1,580[f]	730 [f]	6,450 [f]
Telephone Answering Device	8,760	NA	NA
Video Cassette Recorder (VCR)	1,497	NA	7,263

a Notably high uncertainty for this value.

b Hours/year the device spends charging. Calculated as a product of charges/year and charge time (DOE 2012a).

c Hours/year the device spends in maintenance state, i.e. the device is fully charged but still connected to its charger (DOE 2012a).

d Time in hours/year the device charger spends plugged into an electrical socket but without any device connected to it ("No Battery" in DOE spreadsheet 2012a).

e Time in hours/year the device charger spends unplugged (DOE 2012a).

f Usage in all operational modes for Soundbar is taken the same as for HTiB because of a similar usage pattern for these audio systems (see HTiB usage).

Table 3-86: References for annual usage by mode estimates for other products.

Product	Sources
AV Receiver with surround sound processor	FhCSE (2011)
Bluetooth Headset	DOE (2012a), DOE (2012b)
Blu-ray player	FhCSE (2011)
Boombox	Bensch et al. (2010)
Camcorder	NA
Copy machine (stand-alone)	FhCSE (2011)
Cordless phone	Bensch et al. (2010)
Digital camera	Roth and McKenney(2007)
Digital picture frame	Bensch et al. (2010)
DVD Player	LBNL (2013)
eReader	DOE (2012a), DOE (2012b)
External Storage Device	Bensch et al. (2010)
Fax Machine (stand-alone)	Bensch et al. (2010)
Handheld GPS	DOE (2012a) , DOE (2012b)
Wireless Headphone	DOE (2012a) , DOE (2012b)
Home Theater in a Box (HTIB)	Roth and McKenney (2007)
Internet Phone Device	Roth et al. (2006)
Mobile (non-smart) Phone	Bensch et al. (2010)
Portable DVD or Blu-ray disc player	DOE (2012a) , DOE (2012b)
Portable Game Devices	DOE (2012a) , DOE (2012b)
Portable media/MP3 Player/CD Player	Bensch et al. (2010) for CD players
Portable Wireless Speaker	DOE (2012a) , DOE (2012b)
Printer+MFD (multi-functional device)	FhCSE (2011)
Projector	FhCSE (2011)
Radio	Bensch et al. (2010)
Scanner (stand-alone)	Bensch et al. (2010)
Soundbar	Assumed the same as HTIB usage
Telephone Answering Device	Bensch et al. (2010)
Video Cassette Recorder (VCR)	Bensch et al. (2010)

Table 3-87: References for installed base estimates for other products.

Product	Sources
AV Receiver with surround sound processor	CEA (2013a)
Bluetooth Headset	CEA (2013a)
Blu-ray player	CEA (2013a)
Boombox	Roth and McKenney (2007), CEA (2013b)
Camcorder	CEA (2013a)
Copy machine (stand-alone)	FhCSE (2011)
Cordless phone	Scaled 2010 estimate (FhCSE 2011) based on ratio of landline subscriptions in 2010 and 2013 (Marketingcharts 2012, Axvoice 2012)
Digital camera	CEA (2013a)
Digital picture frame	CEA (2010), CEA (2013b)
DVD Player	CEA (2013a)
eReader	CEA (2013a)
External Storage Device	CEA (2013a)
Fax Machine (stand-alone)	DOE/EIA RECS (2009)
Handheld GPS	CEA (2013a)
Wireless Headphone	CEA (2013a)
Home Theater in a Box (HTIB)	Koenig (2013)
Internet Phone Device	FCC (2011), CEA (2013b)
Mobile (non-smart) Phone	CEA (2013a)
Portable DVD or Blu-ray disc player	CEA (2013a)
Portable Game Device	CEA (2013a)
Portable Headset Audio	CEA (2010), CEA (2013b)
Portable media/MP3 Player/CD Player	CEA (2013a)
Portable Wireless Speaker	CEA (2013a)
Printer+MFD (multi-functional device)	CEA (2013a)
Projector	Extrapolated to U.S. from German data (Statistica 2011)
Radio	Bensch et al. (2010)
Scanner (stand-alone)	RASS (2009)
Soundbar	CEA (2013a)
Telephone Answering Device	DOE/EIA RECS (2009), CEA (2013b)
Video Cassette Recorder (VCR)	Bensch et al. (2010), CEA (2013b)

3.14.1 References

Axvoice. 2012. "US telecom industry from 2010 to 2015." May. http://blog.axvoice.com/us-telecom-industry-from-2010-to-2015-a-research-by-axvoice/ .

Bensch, I., S. Pigg, K. Koski and R. Belshe. 2010. "Electricity Savings Opportunities for Home Electronics and Other Plug-In Devices in Minnesota Homes – A technical and behavioral field assessment." Final Report by the Energy Center of Wisconsin, ECW Report 257-1. May. http://www.state.mn.us/mn/externalDocs/Commerce/CARD_Plugging_into_Savings_Study_052710014507_MN_Home_Elect_Devices.pdf.

CEA. 2010. "12th Annual household CE Ownership and Market Potential." CEA Market Research Report. Consumer Electronics Association. May.

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.

DOE. 2012a. "Rulemaking for Battery Chargers and External Power Supplies Energy Conservation Standard. Energy Use Analysis Spreadsheet." Feb. 17, 2012. http://www.regulations.gov/#!documentDetail;D=EERE-2008-BT-STD-0005-0084.

DOE. 2012b. “Test Results for External Power Supply Energy Conservation Standards Preliminary Analysis. http://www.regulations.gov/#!documentDetail;D=EERE-2008-BT-STD-0005-0080. Apr.

DOE/EIA RECS. 2009. “Residential Energy Consumption Survey (RECS) – Computers & other electronics: Table HC5.1 Computers and Other Electronics in U.S. Homes, By Housing Unit Type, 2009.” http://www.eia.gov/consumption/residential/data/2009/#undefined.

FCC. 2011. “Local telephone competition: status as of Jun. 30, 2010.” Federal Communications Commission. Mar. http://hraunfoss.fcc.gov/edocs_public/attachmatch/DOC-305297A1.pdf.

FhCSE. Urban, Bryan, Kurt Roth, and Verena Tiefenbeck. 2011. “Energy Consumption of Consumer Electronics in U.S. Homes in 2010.” Final Report to the Consumer Electronics Association. http://www.ce.org/CorporateSite/media/Government-Media/Green/Energy-Consumption-of-CE-in-U-S-Homes-in-2010.pdf. Dec.

Foster Porter, S., L. Moorefield, P. May-Ostendorp. 2006. “Final Field Research Report.” Final Field Research Report by Ecos Consulting to the California Energy Commission. 31 Oct.

Koenig, S. 2013. Personal Communication. Consumer Electronics Association, Director of Industry Analysis. Oct.

LBNL 2008. “Low-Power Mode Energy Consumption in California Homes.” Pier Final Project Report prepared by Lawrence Berkeley National Laboratory for California Energy Commission Public Interest Energy Research Program. Sept. http://www.energy.ca.gov/2008publications/CEC-500-2008-035/CEC-500-2008-035.PDF.

LBNL. 2013. “Field data collection of miscellaneous electrical loads in Northern California: initial results.” Lawrence Berkeley National Laboratory Final Report, LBNL-6115E. Jul.

Marketingcharts. 2012. “Landline Phone Penetration Dwindles as Cell-Only Households Grow.” Jul. http://www.marketingcharts.com/wp/traditional/landline-phone-penetration-dwindles-as-cell-only-households-grow-22577/.

McAllister, J. and A. Farrell. 2004. “Power in a Portable World: Usage Patterns and Efficiency Opportunities for Consumer Battery Chargers”, *Proc. ACEEE Summer Study on Energy Efficiency in Buildings*, 22-27 August, Pacific Grove, CA.

Meister, B.C., C. Scruton,V. Lew, L. ten Hope and M. Jones. 2011. “Office Plug Load Field Monitoring Report.” Final Field Project Report by Ecos Consulting to the California Energy Commission. Apr. http://www.energy.ca.gov/2011publications/CEC-500-2011-010/CEC-500-2011-010.pdf.

RASS. 2009. “Massachusetts Residential Appliance Saturation Survey (RASS).” Prepared by Opinion Dynamics Corporation for Cape Light, National Grid, Nstar Electric Unitil, Western Massachusetts Electric Company. Apr. http://www.env.state.ma.us/dpu/docs/electric/09-64/12409nstrd2af.pdf.

Roth, K. and K. McKenney. 2007. “Energy Consumption by Consuer Electronics (CE) in U.S. Residences.” Final Report by TIAX LLC to the Consumer Electronics Association (CEA). Dec. http://www.ce.org/pdf/Energy%20Consumption%20by%20CE%20in%20U.S.%20Residences%20%28January%202007%29.pdf

Roth, K., R. Ponoum, and 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.

SELINA. 2010. “Standby and Off-mode Energy Losses In New Appliances Measured in Shops: Consumption Monitoring Campaign of Standby and Off-Mode Energy Losses in New Equipments.” 30 Jun. http://www.selina-project.eu/files/ Measurements%20of%20standby%20energy%20losses%20in%20new%20equipment.pdf.

Statistica. 2011. “Beamer, Projektoren im Haushalt: Anzahl der Personen, bei denen ein Beamer bzw. Projektor zur Darstellung von Fernseh- oder Computerbildern im Haushaltvorhanden ist, von 2008 bis 2010 (in Millionen).” Available (in German) at: http://de.statista.com/statistik/daten/studie/169550/umfrage/beamer-projektoren-im-haushalt/.

Wood, R.W. 2011. Personal Communication. Eastman Kodak Company. Sept.

4 Conclusions

We used a bottom-up approach to characterize U.S. residential consumer electronics (CE) energy consumption in 2013. Our effort focused on the 17 priority products listed in Table 4-1. In addition, we developed preliminary estimates for 29 other CE categories. For each CE category, we used a range of sources to develop estimates for the installed base and average power draw and annual usage by mode.

Table 4-1: Consumer electronics analyzed in further detail.

Audio-Visual Equipment		Computers & Peripherals	
Home Audio	Set Top Boxes	Desktop PC	Networking Equipment
Speaker Dock	Cable	Portable PC	Integrated Access Device
Compact Stereo System	Standalone	Computer Speakers	Modem
Televisions	Satellite	Computer Monitor	Router
Video Game Consoles	Telco	Smart Phone	
		Tablet Computer	

We estimate that residential CE consumed about 169TWh of electricity in 2013, an amount equal to 12% of residential electricity consumption and 8.4% of residential primary[38] energy consumption, respectively (see Figure 4-1 and Figure 4-2; DOE/EIA 2014a,b, DOE 2012[39]). For comparison, DOE (2012) estimates that "computers" and "electronics" accounted for just under 15 percent of residential electricity consumption in 2010.

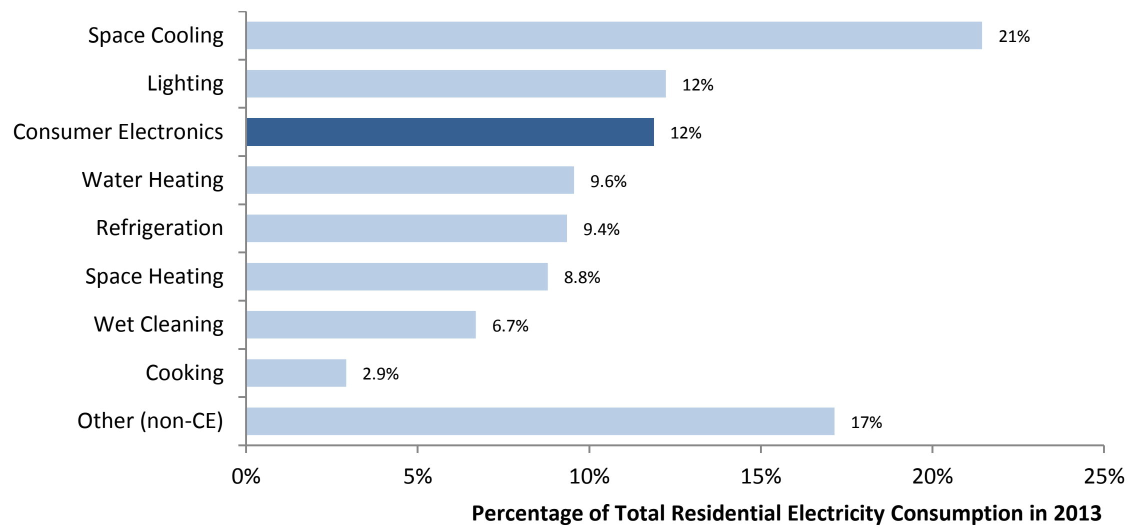


Figure 4-1: Residential electricity consumption in 2013 by major end uses (DOE 2012, Current Study).

[38] Residential primary energy is the total energy content of the fuel required to meet all end uses. Primary energy includes fuels consumed at the home, e.g., natural gas and oil for space and water heating, and fuel consumed at the power plant to generate electricity and to overcome transmission and distribution losses. On average, a power plant must consume an average of 3.1 kWh of primary energy to deliver 1kWh to a building (DOE 2012).

[39] Breakdown of electricity consumption based on DOE 2012, percentage of residential primary energy consumption from DOE/EIA 2014a,b.

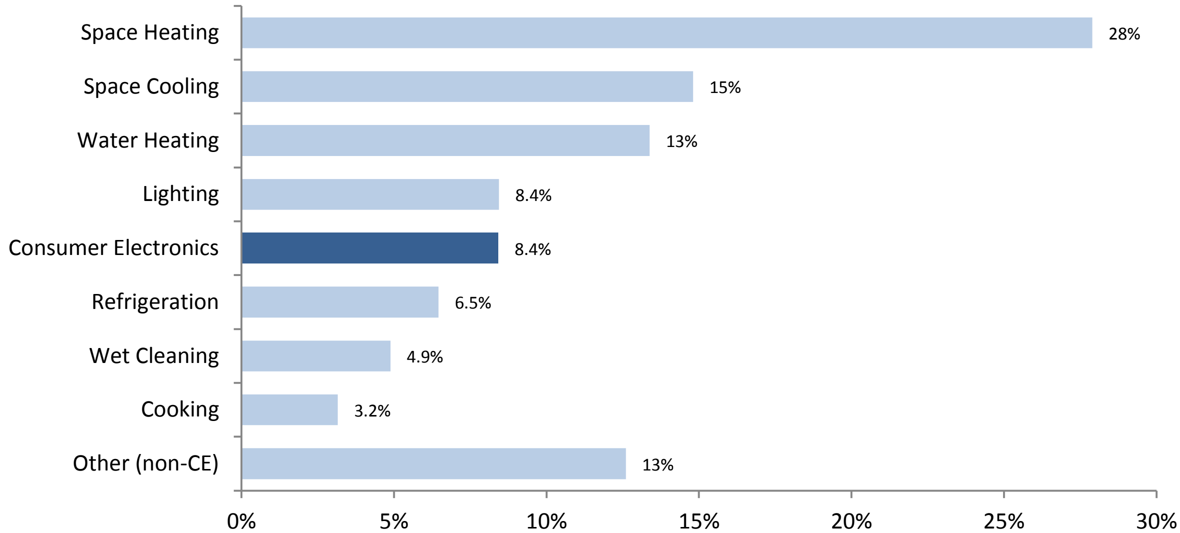


Figure 4-2: Residential primary energy consumption in 2013 by major end uses (DOE 2012, Current Study).

As with the prior two residential CE energy consumption studies (Roth and McKenney 2007, FhCSE 2011), three product categories accounted for a majority of residential CE AEC, televisions (30%), set-top boxes (18%), and computers (13%; see Figure 4-3).

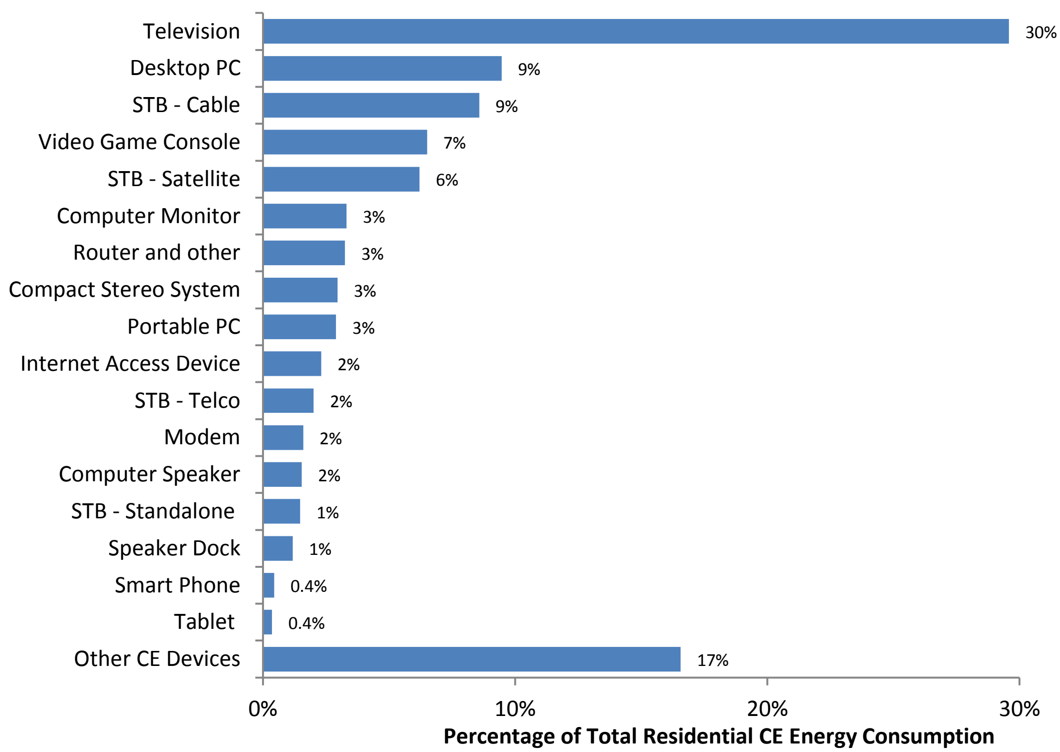


Figure 4-3: Residential CE electricity consumption by category.

The unit electricity consumption (UEC) of the categories studied in more detail varies greatly among categories (see Figure 4-4).

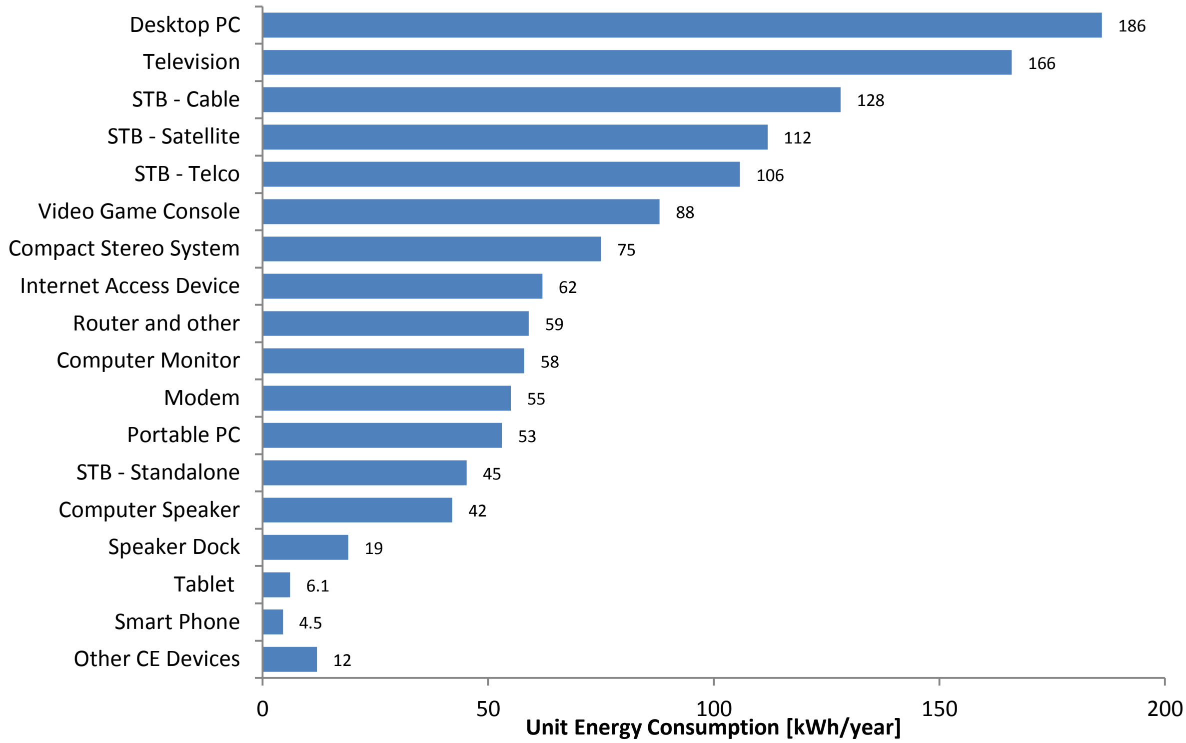


Figure 4-4: Unit electricity consumption for the CE categories evaluated in detail.

As in prior studies, active modes accounted for a large majority of residential CE AEC (70%; see Figure 4-5), although the UEC breakdown by mode varied significantly among categories (see Figure 4-6).

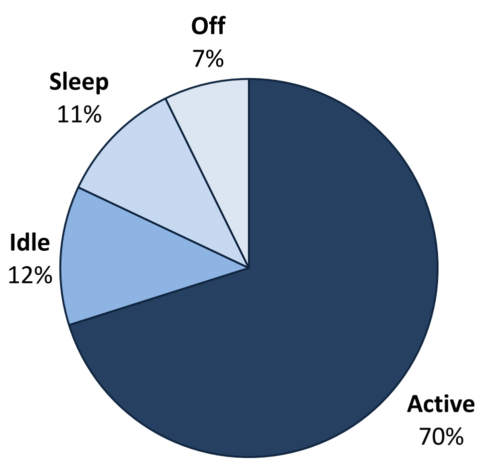


Figure 4-5: AEC by operational mode for the categories evaluated in detail.

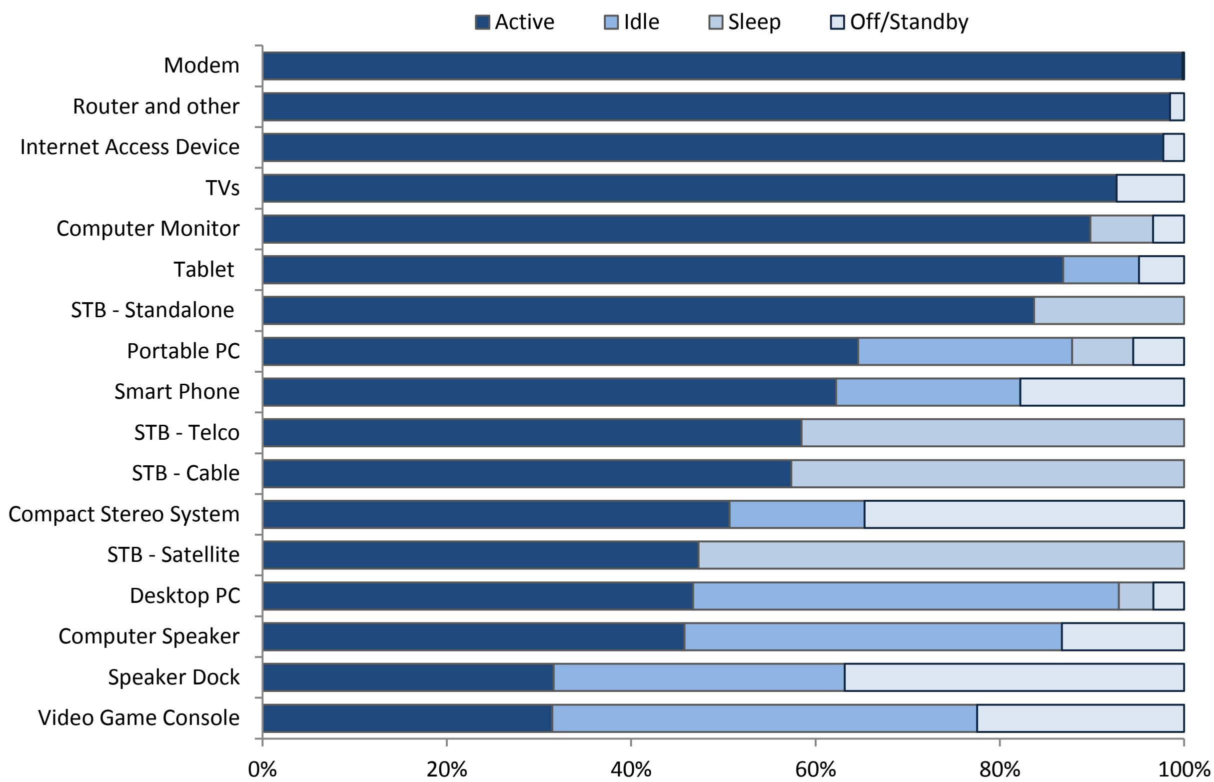


Figure 4-6: Breakdown of UEC by operational modes for the categories evaluated in detail.

4.1 Key Trends

Although the installed base of CE in homes increased to 3.8 billion devices in 2013 from 2.9 billion in 2010, our estimate for residential CE electricity consumption is 12 percent lower than that for 2010 (Urban et al. 2011). To a large extent, this decrease reflects a few key trends for televisions and computers; together, these two categories account for about 43 percent of residential CE AEC.

4.1.1 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 number of plugged-in TVs has decreased significantly, with a shift from CRT to LCD TVs contributing to more than a 20% decline in their estimated 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 installed base decrease of about 50 million TVs plugged in within the last month is that a large portion of older, less-efficient CRT displays have been removed from service. Since our only indication of this change come from our phone survey, there remains some uncertainty in its precise magnitude.

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.

4.1.2 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 25 percent since 2010. A migration of the installed base to much less energy-intensive tablet computers (i.e., about nine-fold less than portable; see Figure 4-4) and application of more refined methods to evaluate computer usage are the main drivers for this decrease.

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 (13%) and portable (36%) computers in 2013 than in 2010. This primarily reflects refinements in the CE 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 peoples' responses for total computer usage.

One consequence of the decreased installed base of desktop and portable computers is a 27 percent decrease in the installed base of monitors. In addition, our estimate of active-mode usage (tied to the enhanced computer usage models described above) decreased by 36 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.

References

CEA. 2010a. "12th Annual household CE Ownership and Market Potential." CEA Market Research Report. Consumer Electronics Association. May.

CEA. 2010b. "U.S. Consumer Electronics Sales & Forecasts 2006-2011." CEA Market Research Report. Jul.

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 Data Book." Prepared for the Building Technologies Program, Energy Efficiency and Renewable Energy, U.S. Department of Energy by D&R International, Ltd. Mar.

DOE/EIA. 2014a. "Electric Power Monthly: Table 5.1. Retail Sales of Electricity to Ultimate Customers". U.S. Department of Energy, Energy Information Administration. Feb. 21.

DOE/EIA. 2014b. *Annual Energy Outlook 2014 Early Release: Energy Consumption by Sector and Source*. U.S. Department of Energy, Energy Information Administration. Retrieved Mar. 6.

FhCSE. Urban, Bryan, Kurt Roth, and Verena Tiefenbeck. 2011. "Energy Consumption of Consumer Electronics in U.S. Homes in 2010." Final Report to the Consumer Electronics Association. http://www.ce.org/CorporateSite/media/Government-Media/Green/Energy-Consumption-of-CE-in-U-S-Homes-in-2010.pdf. Dec.

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 Office of Building Equipment (DOE). 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. McKenney. 2007. "Energy Consumption by Consuer Electronics (CE) in U.S. Residences." Final Report by TIAX LLC to the Consumer Electronics Association (CEA). Dec. http://www.ce.org/pdf/Energy%20Consumption%20by%20CE%20in%20U.S.%20Residences%20%28January%202007%29.pdf.

Roth, K., K. McKenney, 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 U.S. Department of Energy.

Appendix A – CE Usage Surveys

As part of this study, the CEA funded phone surveys that asked respondents questions about CE installed in their household and how they are used. The questions ultimately posed were developed by Fraunhofer CSE in close consultation with the CEA Market Research Team, which regularly performs surveys on a variety of topics. CEA is a member of the Marketing Research Association (MRA) and adheres to the MRA's Code of Marketing Research Standards. The CEA employed the services of Opinion Research Corporation (ORC) to conduct telephone interviewing. The telephone interviewing employed industry standard random-digit dialing and computer assisted telephone interviewing (CATI).

A total of five surveys were administered via dual-frame telephone interview to a random national sample of U.S. adults. Specific fielding dates and sample sizes are:

- Video Game Consoles - February 27-March 2, 2014. 654 interviews were from the landline sample and 350 interviews from the cell phone sample.
- Home Audio Devices - December 19-22, 2013. 679 interviews were from the landline sample and 352 interviews from the cell phone sample.
- Desktop and Portable Computers - December 19-22, 2013. 679 interviews were from the landline sample and 352 interviews from the cell phone sample.
- Mobile Devices – Smart phones and Tablets - December 19-23, 2013. 661 interviews were from the landline sample and 350 interviews from the cell phone sample.
- Televisions - November 14-17, 2013. 654 interviews were from the landline sample and 350 interviews from the cell phone sample.

As is common practice in survey research, the data were weighted to reflect the known demographics of the population under study. In this survey, weights were applied to cases based on gender, age, race and geographic region. As a result, these data can be generalized to the entire U.S. adult population. All findings presented in this report derived from the surveys were based on weighted data.

Subsequently, we processed the responses received in category-specific models to estimate the installed base of CE and CE usage. The category-specific models are discussed in their respective sections, with the more involved computer and monitor usage models described in Appendix B.

The complete phone survey scripts fielded follow.

A.1 Personal Computers (Desktops and Portables)

On another subject…

C1 Thinking about the following COMPUTER products you may have in your home, please indicate how many were PLUGGED INTO an electrical outlet in YOUR HOME at some point during the PAST MONTH. If you do not have this product, please tell me.

(RECORD A NUMBER FOR EACH. RANGE IS 0-10, DON'T KNOW/NOT SURE, DO NOT HAVE THIS PRODUCT)

A. Personal desktop computer
B. Personal portable computer, such as notebooks, laptops or netbook computers

IF ANY COMPUTER WAS PLUGGED IN, C1A OR B (1-10), CONTINUE.

ALL OTHERS SKIP TO NEXT SECTION.

IF C1A (1-10), ASK 'A' (PRIMARY DESKTOP) SERIES.

IF C1A (2-10), ASK 'B' (SECONDARY DESKTOP) SERIES.

IF C1B (1-10), ASK 'C' (PRIMARY PORTABLE) SERIES.

IF C1B (2-10), ASK 'D' (SECONDARY PORTABLE) SERIES.

C2-C5 PROGRAMMING NOTE:

ASK 'A' (PRIMARY DESKTOP) SERIES BEFORE MOVING ON TO 'B' (SECONDARY DESKTOP) SERIES, ETC.

[DISPLAY IF C1A (1-10)]

The next set of questions are about DESKTOP COMPUTERS in your household, including those used in home offices [DISPLAY IF C1A (2-20)] (starting with the PRIMARY or MOST USED DESKTOP COMPUTER).
[DISPLAY IF C1A (2-10) BEFORE 'B' SERIES]

Now, for the next set of questions, please think about the SECONDARY DESKTOP COMPUTER in your household.

[DISPLAY IF C1B (1-10) BEFORE 'C' SERIES]

The next set of questions are related to PORTABLE COMPUTERS, such as notebooks, laptops or netbook computers in your household [DISPLAY IF C1B (2-20)] (starting with the PRIMARY or MOST USED PORTABLE COMPUTER).

[DISPLAY IF C1B (2-10) BEFORE 'D' SERIES]

Now, for the next set of questions, please think about the SECONDARY PORTABLE COMPUTER, such as notebooks, laptops or netbook computers in your household.

C2 I'd like to ask you about how long the [INSERT] computer is used by YOU OR OTHERS in your household. Please consider all activities such as email, searching the Internet, watching videos, gaming, playing music, etc. Also please include time when the computer is doing any of these activities even if no one is at the computer.

How much time was the [INSERT] computer used YESTERDAY during the following times? Please answer in hours and minutes.

(RECORD A NUMBER. RANGE FOR A IS 0-24, DON'T KNOW; RANGE FOR B IS 0-59, DON'T KNOW. SEPARATE PUNCH FOR EACH FOR 'NOT USED')

01 During the MORNING hours, before 12:00 noon
02 During the AFTERNOON hours, between 12:00 and 5:00 pm
03 During the EVENING hours, between 5:00 pm and when you go to sleep at night
04 In ONE SESSION OR SITTING of use, BEFORE the EVENING
05 In ONE SESSION OR SITTING of use, in the EVENING
06 Over the whole day

A. HOURS
B. MINUTES

a. Primary desktop
b. Secondary desktop
c. Primary portable
d. Secondary portable

C3 After you or someone in your household finishes a session or sitting, that is, one instance of use, how often is the [INSERT] computer…

(READ ENTIRE LIST BEFORE RECORDING ONE ANSWER)

01 Always
02 Often
03 About half of the time
04 Occasionally
05 Or, never
99 DON'T KNOW

A. Left ON, during the DAYTIME
B. Put into STANDBY or SLEEP, during the DAYTIME
C. TURNED OFF or SHUT DOWN, during the DAYTIME
D. TURNED OFF or SHUT DOWN, OVERNIGHT

a. Primary desktop
b. Secondary desktop
c. Primary portable
d. Secondary portable

C4 Think of a time you were the FIRST person of the day to use the [INSERT] computer. What did you do to begin using it?

(READ LIST UNTIL STOPPED. RECORD ONE ANSWER)

01 The computer and monitor were already ON showing the previous screen image
02 The computer was already ON, but the monitor was off. You pressed a key or moved the mouse, and INSTANTLY the computer was READY
03 You [DISPLAY FOR C-D SERIES ONLY] (opened the computer lid,) pressed a key, moved the mouse or pressed a POWER button, and after a FEW SECONDS the computer was ready to use
04 You pressed the POWER BUTTON on the computer, and WAITED more than 15 seconds until it was ready to use
99 DON'T KNOW

a. Primary desktop
b. Secondary desktop
c. Primary portable
d. Secondary portable

C5 How many of the following devices, if any, does the [INSERT] computer have connected to it?

(RECORD A NUMBER. RANGE IS 0-99, DON'T KNOW)

A. LCD flat monitors including LED. DO NOT COUNT displays that are built in to the computer, such as the screen on a laptop, netbook or all-in-one desktop
B. CRT or Tube monitors
C. Computer speaker systems without Subwoofer
D. Computer speaker systems with Subwoofer

a. Primary desktop
b. Secondary desktop
c. Primary portable
d. Secondary portable

A.2 Home Audio

A1 For each of the following AUDIO products, you may have in your home, please indicate how many were PLUGGED INTO an electrical outlet in YOUR HOME at some point in the PAST MONTH. If you do not have this product, please tell me.

(RECORD A NUMBER FOR EACH. RANGE IS 0-10, DO NOT HAVE THIS PRODUCT, DON'T KNOW/NOT SURE)

A. Speaker dock that has a plug-in connection for an MP3 player, smartphone or tablet
B. Shelf stereo system, also called Mini or Compact stereo systems

IF HAVE ANY SPEAKER DOCKS, A1A (1-10), CONTINUE. ALL OTHERS SKIP TO INSTRUCTIONS BEFORE A4

Now, please answer the next few questions about a speaker dock that has a plug-in connection that you use with your MP3 player, smartphone or tablet. [DISPLAY IF A1A (2-10)] (Please answer thinking about your PRIMARY speaker dock, meaning the one you or your household uses MOST OFTEN.)

A2 About how long did you or others in your household use your PRIMARY speaker dock to listen to any audio YESTERDAY?

Please give your answer in hours and minutes.

(RECORD A NUMBER FOR EACH. RANGE FOR A IS 0-24, DON'T KNOW, RANGE FOR B IS 0-59, DON'T KNOW)

A. Hours
B. Minutes

A3 After you finished using your speaker dock YESTERDAY, how did you turn it OFF? If you did not use your speaker dock yesterday, please answer about the LAST DAY YOU USED IT.

(READ LIST UNTIL STOPPED. RECORD ONE ANSWER)

01 The power switch or remote control
02 It turns off automatically if you leave it for more than 20 minutes without any audio playing
03 You did not turn it off, you left it on
04 Or, there is no power switch on the speaker dock
99 DON'T KNOW

IF HAVE ANY SHELF STEREO SYSTEMS, A1B (1-10), CONTINUE. ALL OTHERS SKIP TO NEXT SECTION

Now, please answer the next few questions about a shelf stereo system, also called a Mini or Compact stereo system. [DISPLAY IF A1B (2-10)] (Please answer thinking about your PRIMARY shelf stereo system, meaning the one you or your household uses MOST OFTEN.)

A4 About how long did you or others in your household use your PRIMARY shelf stereo system to listen to any audio YESTERDAY?

Please give your answer in hours and minutes.

(RECORD A NUMBER FOR EACH. RANGE FOR A IS 0-24, DON'T KNOW, RANGE FOR B IS 0-59, DON'T KNOW)

A. Hours
B. Minutes

A5 After you finished using your shelf stereo system YESTERDAY, how did you turn it OFF? If you did not use your shelf stereo system yesterday please answer about the LAST DAY YOU USED IT.

(READ LIST UNTIL STOPPED. RECORD ONE ANSWER)

01 The power switch or remote control

02 It turns off automatically if you leave it for more than 15 minutes without any audio playing
03 You did not turn it off, you left it on
04 Or, there is no power switch on the stereo system
99 DON'T KNOW

A.3 Mobile Devices (Smartphones and Tablets)

On another subject…

M1 Thinking about all the devices you may have in your home, how many of each of the following did YOU USE in the PAST MONTH? If you do not have this product, please tell me.

(RECORD A NUMBER FOR EACH. RANGE IS 0-20, DON'T KNOW/NOT SURE, DO NOT HAVE THIS PRODUCT)

A. Smartphones, such as an iPhone, Android, Windows Phone, etc.
B. Tablet computers, such as an iPad, Kindle Fire, Galaxy, etc.

IF USED EITHER DEVICE, M1A OR M1B (1-20), CONTINUE WITH INSTRUCTIONS BELOW.

ALL OTHERS SKIP TO NEXT SECTION

ASK 'B' (PRIMARY TABLET) SERIES IF M1B (1-20)

ASK M2C (SECONDARY TABLET) IF M1B (2-20)

M2-M6 PROGRAMMING NOTE:

ASK 'A' (SMARTPHONE) SERIES BEFORE MOVING ON TO 'B' (PRIMARY TABLET) SERIES.

ASK M2C (SECONDARY TABLET) AFTER M2A/B SERIES, BUT NOT FOR M3-M6

[DISPLAY IF M1A (1-20)]

For the next few questions, please think about the smartphone that YOU USE MOST OFTEN.

[DISPLAY IF M1B (1-20) BEFORE 'B' SERIES]

Now, for the next set of questions, please think about the primary tablet that YOU USE MOST OFTEN.

[DISPLAY IF M1B (2-20) BEFORE M2C]

For the next question, please think about the secondary tablet that YOU USE SECOND MOST OFTEN.

M2 How much time did you or someone else in your household USE your [INSERT] YESTERDAY?

(RECORD A NUMBER. RANGE FOR A IS 0-24, DON'T KNOW; RANGE FOR B IS 0-59, DON'T KNOW)

A. HOURS
B.MINUTES

a. Smartphone
b. Primary tablet
c. Secondary tablet

M3 How many TIMES LAST WEEK did you or someone else in your household plug in and CHARGE your [INSERT]? Please include any time charging at home or anywhere else. Also, please include any times you have charged more than once in a day.

(RECORD A NUMBER. RANGE IS 0-70, DON'T KNOW)

a. Smartphone
b. Primary tablet

M4 Thinking about the LAST TIME YOU charged your [INSERT], what was the battery level…

[RECORD ONE ANSWER]

01 Fully charged
02 75% to 99% charged
03 50% to 74% charged
04 25% to 49% charged
05 1% to 24% charged
06 Or, fully drained
99 DON'T KNOW

A. Just BEFORE you charged it
B. Just AFTER you charged it

a. Smartphone
b. Primary tablet

M5 Now, thinking only about YESTERDAY, or the LAST DAY YOU charged your [INSERT] before today, for how much time was your [INSERT] plugged in for charging through the following power sources? Please answer in hours and minutes.

(RECORD A NUMBER. RANGE FOR A IS 0-24, DON'T KNOW; RANGE FOR B IS 0-59, DON'T KNOW)

01 Using the original brand name charger that came with your device
02 Using a replacement or aftermarket charger, a car charger, or a USB port charging from a computer, speaker system, etc.

A. HOURS
B. MINUTES

a. Smartphone
b. Primary tablet

[ASK IF M5 (01-02)A (1-24) OR M5(01-02)B (1-59)]

M6 Again, thinking only about YESTERDAY, or the LAST DAY YOU charged your [INSERT], how much time was your [INSERT]'s CHARGER PLUGGED INTO THE WALL, regardless of whether the device was connected to the charger or not? Please answer in hours and minutes.

(RECORD A NUMBER. RANGE FOR A IS 0-24, DON'T KNOW; RANGE FOR B IS 0-59, DON'T KNOW)

A. HOURS
B. MINUTES

a. Smartphone
b. Primary tablet

A.4 Televisions

How many of each of the following devices were PLUGGED INTO an electrical outlet in your home at some point during the PAST MONTH?

(RECORD NUMBER FOR EACH. RANGE IS 0-20, DON'T KNOW/NOT SURE)

[DO NOT RANDOMIZE ITEMS]

01 Televisions
02 Amplifier or home speaker systems, such as external speakers for a TV or a stereo system. Do not include portable stereos or speakers used with computers.

03 Digital media streaming device which streams video content from the Internet or networked computer, such as Apple TV, Roku or Chromecast. Do not count Blu-Ray or DVD players that have this feature.

[ASK IF V1A (1-20)]

V2 Please think about all the different TVs in your household and the ways in which you receive television programming such as cable, satellite, fiber to the home, Internet or an antenna that may mount on your roof or an antenna that sits on or near the TV.

In which of the following ways, if any, do you receive television programming on the TVs in your home?

(READ LIST. RECORD AS MANY AS APPLY. WAIT FOR YES OR NO FOR EACH. IF YES TO MORE THAN ONE OF RESPONSES 1-3, SAY: 'Please confirm that you subscribe to more than one service')

[DO NOT RANDOMIZE ITEMS]

01 Cable TV service
02 Satellite TV service
03 Fiber to the home TV service, such as Verizon Fios or AT&T U-verse
04 Antenna TV service
05 Internet TV service
98 I DON'T RECEIVE PROGRAMMING ON ANY OF MY TVS
99 DON'T KNOW

IF TELEVISION WAS PLUGGED IN DURING PAST MONTH, V1A (1-20), CONTINUE.

ALL OTHERS SKIP TO INSTRUCTIONS BEFORE V13

IF ONLY ONE TELEVISION, V1A (1), ONLY ASK FOR PRIMARY.

IF TWO TELEVISIONS, V1A (2), ASK FOR PRIMARY AND SECONDARY.

IF THREE TELEVISIONS, V1A (3-10), ASK FOR PRIMARY, SECONDARY, THIRD,

IF FOUR OR MORE TELEVISIONS, V1A (4-20), ASK FOR PRIMARY, SECONDARY, THIRD, AND FOURTH

The next questions are about TELEVISIONS in your household, starting with the PRIMARY, or most-watched TV.

[SHOW IF V1A (2-20)]

For the next few questions, please answer for up to four TVs owned by your household. Please consider the one used the MOST the PRIMARY TV, the one used the SECOND most the SECOND TV, the one used the THIRD most as the THIRD TV and the one used the FOURTH most as the FOURTH TV.

ASK V3-V8 'A' SERIES BEFORE GOING TO THE 'B' SERIES, ETC.

V3 Is the [INSERT] television that you own a . . .

(READ ENTIRE LIST BEFORE RECORDING ONE ANSWER.]

[DO NOT RANDOMIZE LIST OR ITEMS]

01 LCD or LED Flat-panel TV
02 Plasma Flat-panel TV
03 Tube TV, also known as a direct-view CRT
04 Front or Rear Projection TV

99 DON’T KNOW/NOT SURE

A. Primary
B. Second
C. Third
D. Fourth

V4 What is the approximate screen size IN INCHES of the [INSERT] TV that you own? If you are not sure, please use your best estimate.

(RECORD NUMBER. RANGE IS 5-72, DON’T KNOW/NOT SURE)

(PROBE FOR BEST GUESS BEFORE ACCEPTING DON’T KNOW)

A. Primary
B. Second
C. Third
D. Fourth

V5 What is the age IN YEARS of the [INSERT] TV that you own? If you are not sure, please use your best estimate.

(RECORD NUMBER. RANGE 1-50, DON’T KNOW/NOT SURE)

(IF RESPONDENT SAYS THE TV IS NEW, AS IN LESS THAN ONE YEAR, RECORD AS 1. PROBE FOR BEST GUESS BEFORE ACCEPTING DON’T KNOW)

A. Primary
B. Second
C. Third
D. Fourth

PROGRAMMING NOTE: THIS WORDING SHOULD ONLY BE DISPLAYED DURING THE ‘A’ SERIES (PRIMARY TELEVISION)

Next, I am going to ask you a couple of questions about how you and those in your household use the TVs you currently have plugged into an electrical outlet. I am going to use two terms that I will define for you.

The first term is ‘turned on’. ‘Turned on’ means that the television’s power is in the ON mode regardless of whether someone is actually using it. For example, a TV is turned on when there is a picture on the screen or sound being emitted, as well as when it has a screen saver on while waiting for users.

The second term is ‘active use’. ‘Active use’ means that the television is on AND being used by someone. For example, when a TV is in active use, someone is using it to watch TV, a movie, play games or is actively listening to the TV.

V6A Now, thinking of the [INSERT] TV that you own, during the PAST 24 HOURS, how much time was it turned on? If you are not sure, please give your best estimate.

(RECORD NUMBER. RANGE FOR HOURS (a) IS 0-24, DON’T KNOW AND RANGE FOR MINUTES (b) IS 0-59, DON’T KNOW)

A. Primary
B. Second
C. Third
D. Fourth

a. Hours
b. Minutes

[ASK FOR EACH V6A A-D ([a (HOURS) IS 1-24] OR [b (MINUTES) IS 1-59)]]

[IF V6A A-D a (0), AUTOPUNCH V6B A-D a AS 0]

V6B And during the PAST 24 HOURS, how much time was the [INSERT] TV in active use? If you are not sure, please give your best estimate.

(RECORD NUMBER. RANGE FOR HOURS (a) IS 0-ANSWER GIVEN IN V6A, DON'T KNOW AND RANGE FOR MINUTES (b) IS 0-59, DON'T KNOW)

A. Primary
B. Second
C. Third
D. Fourth

a. Hours
b. Minutes

V7 Which of the following devices, if any, are connected to your [INSERT] television?

(READ LIST. RECORD AS MANY AS APPLY. WAIT FOR YES OR NO FOR EACH)

[DO NOT RANDOMIZE LIST]

01 Receiver or set-top-box with DVR functionality
02 Receiver or set-top-box WITHOUT DVR functionality
03 Digital media streaming device with DVR functionality
04 Digital media streaming device WITHOUT DVR functionality
98 NONE OF THESE
99 DON'T KNOW

A. Primary
B. Second
C. Third
D. Fourth

[ASK FOR EACH MENTION, V7A-D (01-02)]

V8 Which of the following features, if any, does your receiver or set-top box connected to your [INSERT] television have?

(READ LIST. RECORD AS MANY AS APPLY. WAIT FOR YES OR NOT FOR EACH)

01 Ability to record shows in one room and play them back in another room
02 Ability to pause and rewind LIVE TV in one room and resume viewing in another room
03 Ability to record FIVE or more shows at once
98 NONE OF THESE
99 DON'T KNOW

A. Primary
B. Second
C. Third
D. Fourth

V9A and V10 OMITTED

IF A DIGITAL MEDIA PLAYER WAS PLUGGED IN DURING PAST MONTH, V1C (1-20), CONTINUE. ALL OTHERS SKIP TO INSTRUCTION BEFORE V13

The next questions are about streaming video from your digital media streaming device which streams video content from the Internet or networked computer, such as Apple TV, Roku or Chromecast. For this section, DO NOT count Blu-Ray or DVD players that have this feature.

V11 Please think of the most recent occasion when you were the FIRST person in your household to use the digital media streaming device, to watch streaming video. Did you need to turn ON the digital media streaming device, for example, by using a remote control or power switch?

01 YES
02 NO
99 DON'T KNOW

V12 How long did you or anyone in your household watch streaming video content YESTERDAY using a DIGITAL MEDIA STREAMING DEVICE such as Apple TV or Roku? Please do not include video content streamed on other devices such as the computer including tablets and laptops, Smart TV or DVD/Blu-Ray player.

(RECORD NUMBER. RANGE IS 0-24 HOURS AND 0-59 MINUTES, DON'T KNOW)

IF HOME SPEAKER SYSTEM WAS PLUGGED IN DURING PAST MONTH, V1B (1-20), CONTINUE.

ALL OTHERS SKIP TO NEXT SECTION

IF ONLY ONE HOME SPEAKER SYSTEM, V1B (1), ONLY ASK FOR PRIMARY.

IF TWO HOME SPEAKER SYSTEMS, V1B (2), ASK FOR PRIMARY AND SECONDARY.

IF THREE HOME SPEAKER SYSTEMS, V1B (3), ASK FOR PRIMARY, SECONDARY AND THIRD.

IF 4 OR MORE HOME SPEAKER SYSTEMS, V1B (4-20), ASK FOR PRIMARY, SECONDARY, THIRD, AND FOURTH

The next questions are about HOME SPEAKER SYSTEMS, starting with the PRIMARY or most used HOME SPEAKER SYSTEMS. Home speaker systems include speakers that are used with TVs, such as 'Home Theater Systems', 'sound-bars,' amplifiers or stereo systems. They do NOT include portable stereos or speakers used with computers.

ASK V13 AND V14 IN SEQUENCE FOR EACH SPEAKER SYSTEM

V13 Please think of the most recent occasion you used the [INSERT] HOME SPEAKER SYSTEM for the FIRST TIME THAT DAY. Did you need to turn ON the speaker system, for example, by using a remote control or power switch?

01 YES
02 NO
99 DON'T KNOW

A. Primary
B. Secondary
C. Third
D. Fourth

V14 How long was the [INSERT] speaker system used YESTERDAY, by you or anyone else in your household?

(RECORD NUMBER. RANGE IS 0-24 HOURS (a) AND 0-59 MINUTES (b), NOT USED DON'T KNOW)

A. Primary
B. Secondary
C. Third
D. Fourth

a. Hours
b. Minutes

A.5 Video Game Consoles

E1 For each of the following VIDEO GAME CONSOLES, please indicate how many you or someone in your household owns.

(RECORD NUMBER FOR EACH. RANGE IS 0-10, DON'T KNOW)

[RANDOMIZE ITEMS]

A. Microsoft Xbox
B. Microsoft Xbox 360
C. Microsoft Xbox One
D. Sony PlayStation 2
E. Sony PlayStation 3
F. Sony PlayStation 4
G. Nintendo GameCube
H. Nintendo Wii
I. Nintendo Wii U

IF OWN ANY VIDEO GAME CONSOLE, E1A-I (1-10), CONTINUE.

ALL OTHERS SKIP TO NEXT SECTION

E2-E7 PROGRAMMING NOTES:

ASK FOR **UP TO 4** CONSOLES, E1A-I (1-10), WITH PRIORITY ON:

1. E1B (MICROSOFT XBOX 360)

2. E1H (NINTENDO Wii)

3. E1E (SONY PLAYSTATION 3)

4. E1D (SONY PLAYSTATION 2)

IF NECESSARY, ASK FOR REMAINING ITEMS (A, C, F, G, I) ACCORDING TO LEAST FILL PRIORITY

NOTE: MORE THAN ONE OF THE SAME CONSOLE CAN BE ASKED ABOUT IN THIS SEQUENCING, AND SHOULD ALWAYS TAKE GREATER PRIORITY BEFORE A NON-PRIORITY SYSTEM IS CONSIDERED

ASK E2-E7 FOR ONE ITEM BEFORE MOVING ONTO E2-E7 FOR THE NEXT ITEM

E2 Please indicate in what year your [INSERT ITEM] was purchased or received as a gift, if you got it BRAND NEW.

(RECORD YEAR FOR EACH. RANGE IS 2000-2014, WAS NOT BRAND NEW, DON'T KNOW)

[RANDOMIZE ITEMS]

A. Microsoft Xbox
B. Microsoft Xbox 360
C. Microsoft Xbox One
D. Sony PlayStation 2
E. Sony PlayStation 3
F. Sony PlayStation 4
G. Nintendo GameCube
H. Nintendo Wii
I. Nintendo Wii U

i. First console

ii. Second console
iii. Third console
iv. Fourth console

[ONLY DISPLAY BEFORE FIRST SERIES]

The next few questions will be about the USAGE of your video game console.

Next, we will ask you about HOW you and those in your household use your gaming console(s), in one of the following states:

- TURNED ON—the gaming console's power is in the ON mode REGARDLESS of whether someone is actually using it. This includes time when the console is paused.
- ACTIVE USE—the gaming console is ON AND BEING USED by someone. For example, when a gaming console is in active use, someone is using it to play games, watch a movie, etc.
- TURNED OFF—the gaming console is OFF. You turned OFF your gaming console manually or by using a voice command.

E3 How much time did your [INSERT ITEM] spend YESTERDAY in each of the following states? Please give your answer in hours and minutes. If you did not use your [INSERT ITEM] yesterday, please say so.

(RECORD A NUMBER. RANGE FOR A IS 0-24, DON'T KNOW; RANGE FOR B IS 0-59, DON'T KNOW)

[RANDOMIZE ITEMS]

07 Turned on
08 Actively used

C. HOURS
D. MINUTES

a. Microsoft Xbox
b. Microsoft Xbox 360
c. Microsoft Xbox One
d. Sony PlayStation 2
e. Sony PlayStation 3
f. Sony PlayStation 4
g. Nintendo GameCube
h. Nintendo Wii
i. Nintendo Wii U

i. First console
ii. Second console
iii. Third console
iv. Fourth console

[ASK IF E3 A OR B IS 1 OR MORE FOR 'ACTIVELY USED'- 02]

E4 During the [INSERT E3A] [DISPLAY IF E3A (1-24)] (hours and) [INSERT E3B] [DISPLAY IF E3B (1-59)] (minutes) your [INSERT ITEM] was actively used YESTERDAY, approximately how much of this time was used to do each of the following? If you are not sure, please use your best estimate. Please give your answer in hours and minutes.

(RECORD A NUMBER. RANGE FOR A IS 0-ANSWER FROM E3A (02), DON'T KNOW; RANGE FOR B IS 0-59, DON'T KNOW)

[RANDOMIZE ITEMS]

01 Play games
02 Stream media from the video game console or Internet
03 DVD and/or Blu-Ray playback

A. HOURS
B. MINUTES

a. Microsoft Xbox
b. Microsoft Xbox 360
c. Microsoft Xbox One
d. Sony PlayStation 2
e. Sony PlayStation 3
f. Sony PlayStation 4
g. Nintendo GameCube
h. Nintendo Wii
i. Nintendo Wii U

i. First console
ii. Second console
iii. Third console
iv. Fourth console

E5 Thinking about the last time when you were the FIRST PERSON to 'actively use' the [INSERT ITEM] on a day, which statement best describes your gaming console?

(READ ENTIRE LIST BEFORE RECORDING ONE ANSWER)

01 It was already turned ON and ready to use
02 It was turned OFF and you needed to turn it on to use it
99 DON'T KNOW

A. Microsoft Xbox
B. Microsoft Xbox 360
C. Microsoft Xbox One
D. Sony PlayStation 2
E. Sony PlayStation 3
F. Sony PlayStation 4
G. Nintendo GameCube
H. Nintendo Wii
I. Nintendo Wii U

i. First console
ii. Second console
iii. Third console
iv. Fourth console

E6 Does your [INSERT ITEM] automatically turn off after a sustained period of inactivity?

[RANDOMIZE ITEMS]

01 YES
02 NO
99 DON'T KNOW

A. Microsoft Xbox
B. Microsoft Xbox 360
C. Microsoft Xbox One
D. Sony PlayStation 2
E. Sony PlayStation 3
F. Sony PlayStation 4
G. Nintendo GameCube
H. Nintendo Wii

I. Nintendo Wii U

i. First console
ii. Second console
iii. Third console
iv. Fourth console

[ASK FOR EACH MENTION E6A-I (01)]

E7 After approximately how many hours does the [INSERT ITEM] automatically turn off?

(RECORD A NUMBER. RANGE IS 1-24, DON'T KNOW)

[RANDOMIZE ITEMS]

A. Microsoft Xbox
B. Microsoft Xbox 360
C. Microsoft Xbox One
D. Sony PlayStation 2
E. Sony PlayStation 3
F. Sony PlayStation 4
G. Nintendo GameCube
H. Nintendo Wii
I. Nintendo Wii U

i. First console
ii. Second console
iii. Third console
iv. Fourth console

Appendix B – Energy and Usage Models

We discuss in detail several models used to calculate the usage time and energy consumption for desktop and portable computer, smart phones, tablets, and video game consoles.

B.1 Energy Models — Personal Computers (Desktops and Portables)

In this appendix, we describe the energy model used to calculate the unit and annual energy consumption for desktop and portable personal computers (PCs).

We reference specific questions in the survey to obtain values certain variables in the energy model. These are indicated in bold green, e.g., **<C5.A>** references survey question 5, sub-question A in the computer survey. See Appendix A.1 for the survey questions.

Table B-1: Variables directly measured in the CE Usage Survey.

	Survey Question	Purpose	Measure	Variable
C1.#	Number of plugged-in …	Installed base	Count	
A	Desktop PCs			$n_{desktop}$
B	Portable PCs			$n_{portable}$
C2.##	Usage time …	Usage time	Time (hh:mm)	
01	During the morning hours (before 12 noon)			$t_{usage}^{morning}$
02	During the afternoon hours (between 12 and 5pm)			$t_{usage}^{afternoon}$
03	During the evening hours (between 5pm and when you go to sleep at night)			$t_{usage}^{evening}$
04	In one session of use, before the evening			$t_{session}^{preEvening}$
05	In one session of use, in the evening			$t_{session}^{evening}$
06	Over the whole day			$t_{session}^{wholeDay}$
C3.#	Frequency that the PC is …	Manual power management (PM) routines	Probability	
A	Left on, during the daytime			p_{leftOn}
B	Put into sleep, during the daytime			p_{sleep}
C	Turned off, during the day time			p_{off}
D	Turned off, at night			p_{off}^{night}
C4	Initial state of the PC for the day	Auto PM settings	Choice	PM
C5.#	Number of devices connected to PC …	Indirect accounting of AIO desktop PCs	Count	
A	LCD monitors			n_{lcd}
B	CRT monitors			n_{crt}
C	Speakers without subwoofer			-
D	Speakers with subwoofer			-

B.1.1 Plugged-In Install Base

The installed base is calculated from the total sum of desktop or portable PCs reported by each respondent ($n_{desktop}$ and $n_{portable}$), and weighted to the U.S. household distribution.

$$N_{desktop} = \frac{N_{households}}{N_{weights}} \sum_{s}^{S} \omega_s n_{s,desktop}$$

$$N_{portable} = \frac{N_{households}}{N_{weights}} \sum_{s}^{S} \omega_s n_{s,portable}$$

where

- $N_{weights}$ is the sum of weights of each survey response to all U.S. households
- $N_{households}$ is the number of U.S. households
- S is the set of survey responses
- ω_s is weight of the sth survey response
- $n_{s,desktop}$ is number of desktop PCs reported by the sth survey response **<C5.A>**
- $n_{s,portable}$ is number of desktop PCs reported by the sth survey response **<C1.B>**

We also distinguish All-in-One (AIO) desktop PCs from tower desktop PCs by noting, for each primary or secondary PC, if the PC has no monitor (LCD or CRT) connected to it, i.e., $n_{lcd} + n_{crt} = 0$ **<C5.A=0 and C5.B=0>**.

B.1.2 Operational Modes

PCs can enter different operational modes with different power draws after various time durations. We previously defined the modes used in our energy model (see Section 3.4). We declare these as variables in this model (see Table B-2).

Table B-2: Variables for power draw and time threshold of various operational modes.

Operational Mode	Active	Short Idle	Long Idle	Sleep	Off
Power Draw	P_{active}	$P_{shortIdle}$	$P_{longIdle}$	P_{sleep}	P_{off}
Time Threshold	τ_{active}	$\tau_{shortIdle}$	$\tau_{longIdle}$	τ_{sleep}	τ_{off}

We define the threshold time durations after which the lower power modes are triggered in Table B-3. These thresholds are calculated based on the ENERGY STAR specification and as measured in the ENERGY STAR Qualified Product List (QPL) (EPA 2013).

Table B-3: Time Thresholds at the start of a post-session after which the PC enters various operational modes.

Time Threshold	ENERGY STAR Spec. (minutes)	Default in QPL (minutes)				Representative	
		Desktops		Portables			
		Average	Median	Average	Median	Desktops	Portables[§]
τ_{active}[†]						0	0
$\tau_{shortIdle}$	5	-	-	-	-	5	5
$\tau_{longIdle}$	15	25	15	23	10	15	10
τ_{sleep}	30	13	30	112	25	30	25
$\tau_{off} \equiv 2\tau_{sleep}$	60[*]	-	-	-	-	60	60
τ_{∞}[‡]						∞	∞

§ We choose shorter time thresholds for portable PCs which are consistent with their behavior to conserve energy when occasionally running on battery.
† Zero-valued variable introduced for consistency in some equations.
‡ Infinity-valued variable introduced for consistency in some equations.
* Assumed, specified for our analysis.

B.1.2.1 Operational Modes for External Power Supplies of Portable PCs

Portable PCs have additional operational modes due to their external power supplies (EPS) which charge the portable PC batteries, from which the PCs may be unplugged, and which may be unplugged from the wall socket altogether. This leads to increased energy consumption for charging, and decreased energy consumption when the portable PC is unplugged. In our model, we calculate the time spent in these modes as a fraction of the usage time of the portable PC in various base operational modes (see Table B-4; see Section B.1.7.2 for more details). These modes are originally defined by DOE (2012).

Table B-4: Variables for power draw and portion of time of various operational modes for portable PCs due to their external power source (EPS).

Base Portable PC Mode	Active, Short Idle, and Long Idle	Off			
EPS Mode	**Charging (Active)**	**Charging (Off)**	**Off**	**Unplugged**	**EPS Unplugged**
Portable PC + EPS Power Draw	$P_{chargeActive}$	$P_{chargeOff}$	P_{off}	$P_{unplugged}$	$P_{epsUnplugged}$
% time of PC mode in EPS mode	$\rho_{chargeActive}$	$\rho_{chargeOff}$	ρ_{off}	$\rho_{unplugged}$	$\rho_{epsUnplugged}$

where

- $P_{epsUnplugged} = 0\text{W}$, i.e., no power draw
- $\rho_{chargeActive} + \text{NOT}(\rho_{chargeActive}) = 1$
- $\rho_{chargeOff} + \rho_{off} + \rho_{unplugged} + \rho_{epsUnplugged} = 1$

B.1.3 Usage Modeling

We expect usage to vary at different times of the day. Therefore, we identify several day periods and model the usage and energy consumption for each period. Then, we sum them to get the total usage and energy consumption for the whole day, and, ultimately, the UEC for the whole year and AEC for the installed base.

B.1.3.1 Day Periods

Based on our analysis of the amount of computer usage across a day (ATUS 2012), we model computer usage by period during the day: Pre-Evening (morning and afternoon), Evening, and Night. Restricting to Home/Yard (TEWHERE = 1), we considered activities with potentially major components of computer usage [TRCODE]:

- Financial management [20901], n=355
- Work, main job [50101], n=9720
- Work, other job(s) [50102] , n=370
- Playing Games [120307], n=1381
- Computer use for leisure (exc. Games) [120308], n=1902
- Computer use (Volunteering) [150101] , n=157

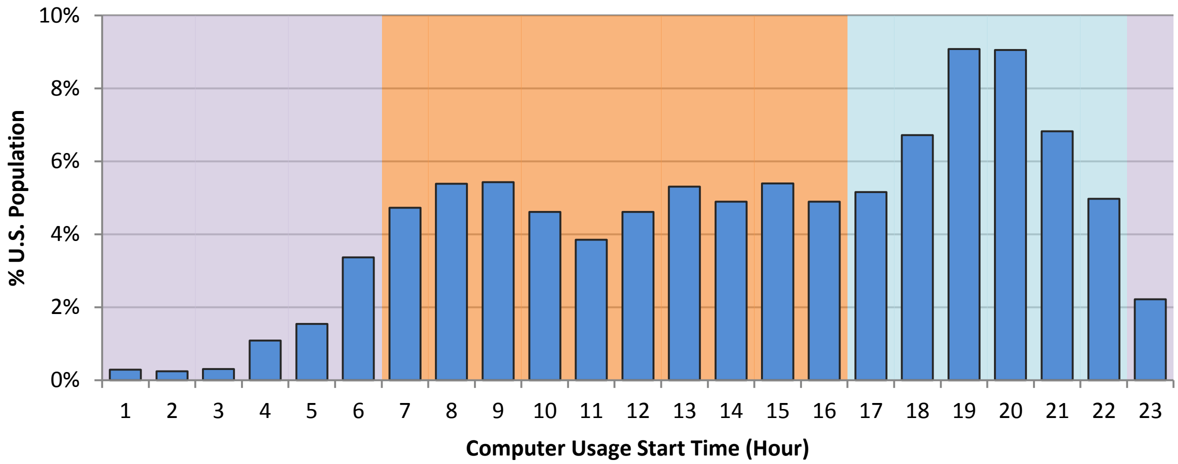


Figure B-1: Probability density of performing activities related to using computers (ATUS 2012).

From Figure B-1, we can estimate default boundaries and durations for the three day periods. However, some survey responses indicated that the active use duration within certain periods exceed the defined bounds. Therefore, we allow for the day periods to be adjustable by formulas presented in Table B-5.

Table B-5: Time durations for different day periods.

Day Period τ_{period}	Formula	Default Range	Default Duration [hours]	Example Survey Response Reported t_{used}	Example Survey Response Adjusted τ_{period}
$\tau_{preEvening}$	$\max(10, t_{usedPreEvening})$	7am-5pm	10	11	11
$\tau_{evening}$	$\max(6, t_{usedEvening})$	5pm-11pm	6	7	7
τ_{night}	$1 - \tau_{evening} - \tau_{preEvening}$	11pm-7am	8	-	6

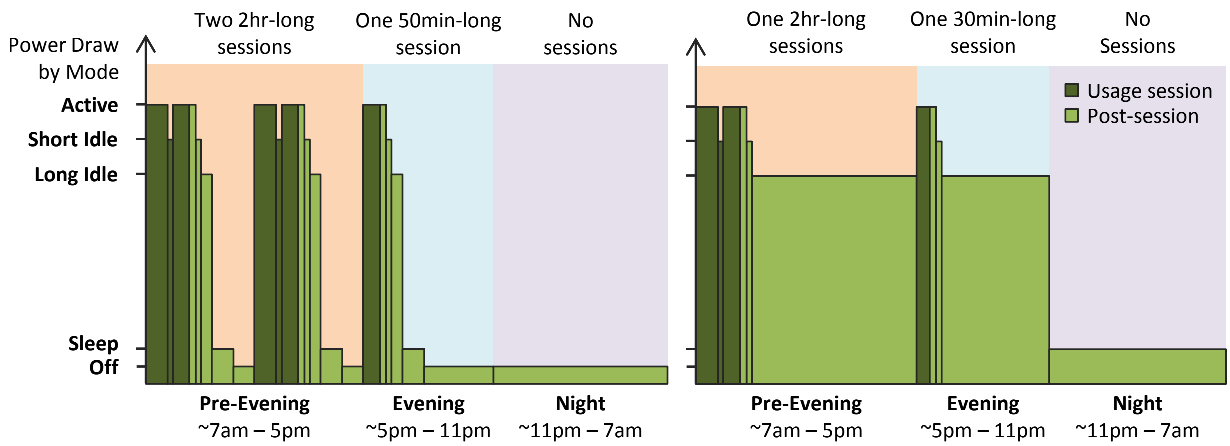
The time periods sum to 24 hours in a whole day, i.e.,

$$\tau_{preEvening} + \tau_{evening} + \tau_{night} = \tau_{wholeDay} = 24 \text{ hrs}$$

Next, we describe how we compute energy consumption for the pre-evening, evening, and night periods. The calculations for the pre-evening and evening periods are similar and will henceforth be called daytime periods.

B.1.3.1.1 Sample Energy Consumption across Daytime Periods

For daytime periods, we model the number of active use sessions, which include “micro-breaks” within each session, and post-sessions between them. After each session, the PC may gradually go into a lower power operational mode. The minimum power mode depends on the automatic power management (PM) settings, and whether household occupants manually put the PC into sleep or turn it off. We model the night period as having no active use sessions, so its energy consumption is only due to automatic PM settings and manual power management. Figure B-2 shows two examples of the energy consumption as calculated by the energy usage model.



Based on power draw by mode, survey responses of usage duration for each session and how many sessions per day period. Left: PC left on during the day time, PM auto-hibernate. Right: PC left on during the daytime, PM long idle enabled, manually put to sleep at night.

Figure B-2: Examples of energy consumption modeling for a day.

B.1.3.2 Daytime Periods

We model usage in the day time (pre-evening and evening) as consisting of active use *sessions* separated by *post-session* periods. The number of sessions is:

$$n_{sessions} = \frac{t_{usage}}{t_{session}}$$

where

- t_{usage} is the total usage duration in the daytime period **<C2.01, C2.02, C2.03>**
- $t_{session}$ is the typical session duration **<C2.04, C2.05>**

B.1.3.3 Usage Session

We assume that users take a “micro-break” after one hour during each active use session (OSHA 1997, UC Berkeley 2014). We assume that each break lasts about 10 minutes (average of short and long idle thresholds). This gives 5 minutes for short-idle mode to activate and 5 minutes to be in that mode. The usage time for each operational mode in each session computed as:

Daytime: Usage Session
$t_{session} = t_{active}^{session} + t_{shortIdle}^{session} + t_{longIdle}^{session} + t_{sleep}^{session} + t_{off}^{session}$
$t_{active}^{session} = t_{session} - n_{breaks}\tau_{shortIdle}$ $t_{shortIdle}^{session} = n_{breaks}\tau_{shortIdle}$ $t_{longIdle}^{session} = 0$ $t_{sleep}^{session} = 0$ $t_{off}^{session} = 0$

where

- $n_{breaks}(\boldsymbol{t_{session}}) = \left\lfloor \frac{\boldsymbol{t_{session}}}{\tau_{beforeBreak}} \right\rfloor$ is the number of breaks per session

- $\tau_{beforeBreak} = 1$ hour is the active usage time threshold until a short break

B.1.3.4 Post-Session

A post-Session is defined as the following unused period until the next active usage session. This calculation only applies if there is at least one active use session in the daytime period, i.e., $n_{sessions} \geq 1$. See Section B.1.3.5 for how we calculate for cases with no active session. Each post-session is defined with:

$$n_{postSessions} = \lceil n_{sessions} \rceil$$

$$t_{postSession} = \frac{\tau_{period} - n_{sessions} t_{used}}{n_{postSessions}}$$

where

- τ_{period} is the duration of the daytime period ($\tau_{preEvening}$ or $\tau_{evening}$)

After a usage session, i.e., post-session, the PC may enter into lower power modes after a series of time thresholds. These depend on the total time of the post-session before the next usage session, and the power management routines (manual user behavior) and automated settings.

B.1.3.4.1 Manual Power Management Routines

We asked U.S. adults how often they manually turned their PC off or put it to sleep **<C3>** to get measures for the following variables:

- p_{off} is the probability of manually switching OFF after each daytime use **<C3.C, C3.D>**
- p_{sleep} is the probability of manually putting computer into SLEEP during daytime **<C3.B>**
- p_{leftOn} is the probability of leaving computer ON after use during daytime **<C3.A>**

$$p_{off} + p_{sleep} + p_{leftOn} = 1$$

We map numeric probability values from discrete option values in the survey responses with:

$$p_{manualPM} = \begin{cases} 100\% & 01, \text{Always} \\ 75\% & 02, \text{Often} \\ 50\% & 03, \text{About half of the time} \\ 25\% & 04, \text{Occasionally} \\ 0\% & 05, \text{Never} \\ \bar{p}_{manualPM} & 99, \text{DON'TKNOW} \end{cases}$$

where

- $\bar{p}_{manualPM}$ is the average of the probability metric
- $manualPM \in \{off, sleep, leftOn\}$

B.1.3.4.2 Automated Power Management Settings Modes

The automated power management settings, PM, measured in **<C4>** is defined as:

$$PM = \begin{cases} 01 & \text{Short Idle Only} \equiv \text{No PM} \equiv \text{Always On} \\ 02 & \text{Long Idle Enabled} \equiv \text{Screen Off Enabled} \\ 03 & \text{Sleep Enabled} \\ 04 & \text{Off/Hibernate Enabled} \\ 99 & \text{DON'TKNOW} \end{cases}$$

Note that $PM = 04$ is enabled by using auto-hibernate under advanced power management settings[40]. Also, it is not defined in ENERGYSTAR, so there would not be a default time for it to activate.

B.1.3.4.3 Usage Time by Operational Mode in Post-Session

The usage time for each operational mode in each post-session is:

Daytime: Post-Session
$t_{postSession} = t_{active}^{postSession} + t_{shortIdle}^{postSession} + t_{longIdle}^{postSession} + t_{sleep}^{postSession} + t_{off}^{postSession}$
$t_{active}^{postSession} = p_{leftOn} t_{active}(t_{postSession}, PM)$ $t_{shortIdle}^{postSession} = p_{leftOn} t_{shortIdle}(t_{postSession}, PM)$ $t_{longIdle}^{postSession} = p_{leftOn} t_{longIdle}(t_{postSession}, PM)$ $t_{sleep}^{postSession} = p_{leftOn} t_{sleep}(t_{postSession}, PM) + p_{sleep} t_{postSession}$ $t_{off}^{postSession} = p_{leftOn} t_{off}(t_{postSession}, PM) + p_{off} t_{postSession}$

where

t_{active}, $t_{shortIdle}$, $t_{longIdle}$, t_{sleep}, and t_{off} are the time durations the PC is in active, short idle, long idle, sleep, and off modes, respectively, in a post-session. These are functions of $\boldsymbol{t} = t_{postSession}$ and $\boldsymbol{PM}$:

$$\begin{aligned}
t_{active}(\boldsymbol{t}, \boldsymbol{PM}) &= p(\boldsymbol{PM} > 00)(min(\boldsymbol{t}, \tau_{shortIdle}) - \tau_{active}) + p(\boldsymbol{PM} = 00)(\boldsymbol{t} - \tau_{active}) \\
t_{shortIdle}(\boldsymbol{t}, \boldsymbol{PM}) &= p(\boldsymbol{PM} > 01)\left(min(\boldsymbol{t}, \tau_{longIdle}) - \tau_{shortIdle}\right) + p(\boldsymbol{PM} = 01)(\boldsymbol{t} - \tau_{shortIdle}) \\
t_{longIdle}(\boldsymbol{t}, \boldsymbol{PM}) &= p(\boldsymbol{PM} > 02)\left(min(\boldsymbol{t}, \tau_{sleep}) - \tau_{longIdle}\right) + p(\boldsymbol{PM} = 02)\left(\boldsymbol{t} - \tau_{longIdle}\right) \\
t_{sleep}(\boldsymbol{t}, \boldsymbol{PM}) &= p(\boldsymbol{PM} > 03)\left(min(\boldsymbol{t}, \tau_{off}) - \tau_{sleep}\right) + p(\boldsymbol{PM} = 03)\left(\boldsymbol{t} - \tau_{sleep}\right) \\
t_{off}(\boldsymbol{t}, \boldsymbol{PM}) &= p(\boldsymbol{PM} > 04)\left(min(\boldsymbol{t}, \tau_{\infty}) - \tau_{sleep}\right) + p(\boldsymbol{PM} = 04)\left(\boldsymbol{t} - \tau_{off}\right)
\end{aligned}$$

B.1.3.5 Non-Session

If there is no active use session during a daytime period, then power draw depends only on the power management settings. We define one "non-Session" for that period with the following characteristics:

$$n_{nonSessions} = [n_{sessions} = 0] = \begin{cases} 1 & \text{, if } n_{sessions} = 0 \\ 0 & \text{, otherwise} \end{cases}$$

[40] For example, in Windows XP: http://www.microsoft.com/resources/documentation/windows/xp/all/proddocs/en-us/pwrmn_automatic_hibernation.mspx?mfr=true

Daytime: Non-Session

$$t_{nonSession} = t_{active}^{nonSession} + t_{shortIdle}^{nonSession} + t_{longIdle}^{nonSession} + t_{sleep}^{nonSession} + t_{off}^{nonSession}$$

$$\begin{aligned} t_{active}^{nonSession} &= 0 \\ t_{shortIdle}^{nonSession} &= p_{leftOn}\tau_{daytime}p(PM = 01) \\ t_{longIdle}^{nonSession} &= p_{leftOn}\tau_{daytime}p(PM = 02) \\ t_{sleep}^{nonSession} &= p_{leftOn}\tau_{daytime}p(PM = 03) + p_{sleep}\tau_{daytime} \\ t_{off}^{nonSession} &= p_{leftOn}\tau_{daytime}p(PM = 04) + p_{off}\tau_{daytime} \end{aligned}$$

where

- $\tau_{daytime}$ is the total duration for the daytime period, $daytime \in \{preEvening, evening\}$

B.1.3.6 Total Usage by Operational Mode in Daytime Period

Combining the usage time for all sessions and post-sessions, we get the total usage by operational mode for the daytime period:

Daytime

$$\begin{aligned} t_{daytime} &= t_{active}^{daytime} + t_{shortIdle}^{daytime} + t_{longIdle}^{daytime} + t_{sleep}^{daytime} + t_{off}^{daytime} \\ &= n_{sessions}t_{session} + n_{postSessions}t_{postSession} + n_{nonSessions}t_{nonSession} \end{aligned}$$

$$t_{powerMode}^{daytime} = n_{sessions}t_{powerMode}^{session} + n_{postSessions}t_{powerMode}^{postSession} + n_{nonSessions}t_{powerMode}^{nonSession}$$
$$powerMode \in \{active, shortIdle, longIdle, sleep, off\}$$

B.1.4 Pre-Evening Period

To determine the usage time in the evening period, we use the calculations for daytime periods with the following substitutions:

- $t_{session} \equiv t_{session}^{preEvening}$ **<C2.03>**
- $t_{usage} \equiv t_{usage}^{preEvening} = t_{usage}^{morning} + t_{usage}^{afternoon}$ **<C2.01, C2.02>**
- $t_{daytime} \equiv t_{preEvening}$

B.1.5 Evening Period

To determine the usage time in the evening period, we use the calculations for daytime periods with the following substitutions:

- $t_{session} \equiv t_{session}^{evening}$ **<C2.03>**
- $t_{usage} \equiv t_{usage}^{evening}$ **<C2.05>**
- $t_{daytime} \equiv t_{evening}$

B.1.6 Night Period

We assume that the computer is not actively used at night, so this period does not have any sessions and power draw depends only on the power management settings. Since we asked U.S. adults only whether or not they turned off the PC at night, we estimate the probability of leaving the PC on or putting it to sleep at night based on the ratio between leaving on and sleep for the day:

$$p_{sleep}^{night} = \frac{p_{sleep}}{p_{leftOn} + p_{sleep}}\left(1 - p_{off}^{night}\right)$$

$$p_{leftOn}^{night} = 1 - p_{sleep}^{night} - p_{off}^{night}$$

Therefore, we calculate the time in operational modes at night as:

Night
$t_{night} = t_{active}^{night} + t_{shortIdle}^{night} + t_{longIdle}^{night} + t_{sleep}^{night} + t_{off}^{night}$
$\begin{aligned} t_{active}^{night} &= 0 \\ t_{shortIdle}^{night} &= p_{leftOn}^{night}\tau_{night}p(PM = 01) \\ t_{longIdle}^{night} &= p_{leftOn}^{night}\tau_{night}p(PM = 02) \\ t_{sleep}^{night} &= p_{leftOn}^{night}\tau_{night}p(PM = 03) + p_{sleep}^{night}\tau_{night} \\ t_{off}^{night} &= p_{leftOn}^{night}\tau_{night}p(PM = 04) + p_{off}^{night}\tau_{night} \end{aligned}$

where

- p_{leftOn}^{night} is the probability of leaving the PC on at night
- p_{sleep}^{night} is the probability of putting the PC to sleep at night
- p_{off}^{night} is the probability of manually turning the PC off at night **<C3.D>**
- $p(PM = i) = \begin{cases} 1 & \text{, if } PM = i \\ p_{PM}(PM = i) & \text{, if } PM = 99\text{, i.e., Don't Know} \\ 0 & \text{, otherwise} \end{cases}$
- $p_{PM}(PM = i)$ is the empirical probability distribution of power management modes

B.1.7 Whole Day

The usage time and energy consumption for desktop and portable PCs differ slightly due to the external power modes of portable PCs.

B.1.7.1 Desktop PC

The usage time for the whole day is the sum of the energy consumption for the pre-evening, evening, and night sessions for desktop PCs are:

Whole Day — Desktop PCs: Usage Time
$t_{wholeDay} = t_{preEvening} + t_{evening} + t_{night} = \tau_{wholeDay}$

B.1.7.2 Portable PCs

For portable PCs, we model additional operational modes due to the external power supply (EPS) and apply the following adjustments to calculate the usage time for several modes:

- $t_{charging} = \rho_{chargeActive}(t_{active} + t_{shortIdle} + t_{longIdle}) + \rho_{chargeOff} t_{off}$ the total time spent charging during active-idle and off modes.
- $t_{off} \leftarrow \rho_{off} t_{off}$ where we scale the time in off mode by ρ_{off} down to accommodate for the times in additional modes: charging (off), unplugged, EPS unplugged
- $t_{unplugged} = \rho_{unplugged} t_{off}$
- $t_{epsUnplugged} = \rho_{epsUnplugged} t_{off}$

The usage times for the following modes are unchanged: t_{active}, $t_{shortIdle}$, $t_{longIdle}$, and t_{sleep}.

We define the total time plugged in for the whole day as:

Whole Day — Portable PCs: Usage Time

$$\begin{aligned} t_{pluggedIn} &= t_{preEvening} + t_{evening} + t_{night} \\ &= t_{active} + t_{shortIdle} + t_{longIdle} + t_{sleep} + t_{off} + t_{unplugged} \\ &\leq \tau_{wholeDay} \end{aligned}$$

This excludes the time when the EPS is unplugged from the wall socket, $t_{epsUnplugged}$, i.e.,

$$t_{pluggedIn} + t_{epsUnplugged} = \tau_{wholeDay}$$

Also, note that the usage time for charging overlaps with active and off modes, i.e.,

$$t_{pluggedIn} + t_{charging} \geq \tau_{wholeDay}$$

B.1.8 References

ATUS. 2012. "American Time Use Survey — 2012 Microdata Files." Jun. 20, 2013. United States Department of Labor. http://www.bls.gov/tus/datafiles_2012.htm. Retrieved Oct. 30, 2013.

UC Berkeley. 2014. "Safe Computer Use Tips." University of California Ergonomics. http://ergo.berkeley.edu/services/computer_use.php. Retrieved Mar. 7, 2014.

DOE. 2012. "Rulemaking for Battery Chargers and External Power Supplies Energy Conservation Standard. Energy Use Analysis Spreadsheet." Feb. 17, 2012. http://www.regulations.gov/#!documentDetail;D=EERE-2008-BT-STD-0005-0084. Retrieved Feb. 6, 2014.

EPA. 2013. "ENERGY STAR Computer Specification Version 5.2 — Qualified Product List." Sept. 6, 2013. http://www.energystar.gov/products/specs/computer_specification_version_6_0_pd. Retrieved Sept. 16, 2013.

OSHA (Occupational Safety and Health Administration). 1997. "Working Safely with Video Display Terminals." U.S. Department of Labor. https://www.osha.gov/Publications/osha3092.pdf. Retrieved Sept. 16, 2013.

UC Berkeley. 2014. "Safe Computer Use Tips." University of California Ergonomics. http://ergo.berkeley.edu/services/computer_use.php. Retrieved Mar. 7, 2014.

B.2 Energy Usage Models — Mobile Devices (Tablets and Smartphones)

In this appendix, we describe the energy model used to calculate the unit and annual energy consumption for mobile devices: tablets and smartphones.

We reference specific questions in the survey to obtain numeric values certain variables in the energy model. These are indicated in bold green, e.g., **<M1.A>** references survey question 1, sub-question A in the mobile survey. See Appendix A – CE Usage Surveys for the survey questions.

Table B-6: Variables directly measured in the CE Usage Survey.

	Survey Question	Purpose	Measure	Variable
M1.#	Number of plugged-in …	Installed base	Count	
A	Smartphones			$n_{smartphone}$
B	Tablets			n_{tablet}
M2	Usage time over the whole day	Usage time	Time (hh:mm)	t_{usage}
M3	Number of charge sessions / week	Charge cycles	Count	$n_{chargesPerWeek}$
M4.#	Battery life level …	Charge cycles	0-100	
A	Before charging			$\rho_{preCharge}$
B	After charging			$\rho_{postCharge}$
M5.##	Time device is plugged into …	Charger preference	Time (hh:mm)	
01	Original charger			$t_{original}$
02	Other chargers			t_{others}
M6	Plugged-in time of charger	Unplugged mode	Time (hh:mm)	$t_{originalBCPluggedIn}$

B.2.1 Plugged-In Install Base

The installed base is calculated from the total sum of desktop or portable PCs reported by each respondent ($n_{desktop}$ and $n_{portable}$), and weighted to the U.S. household distribution.

$$N_{smartphone} = \frac{N_{households}}{N_{weights}} \sum_{s}^{S} \omega_s n_{s,smartphone}$$

$$N_{tablet} = \frac{N_{households}}{N_{weights}} \sum_{s}^{S} \omega_s n_{s,tablet}$$

where

- $N_{weights}$ is the sum of weights of each survey response to all U.S. households
- $N_{households}$ is the number of U.S. households
- S is the set of survey responses
- ω_s is weight of the sth survey response
- $n_{s,smartphone}$ is number of smartphones reported by the sth survey response **<M1.A>**
- $n_{s,tablet}$ is number of tablets reported by the sth survey response **<M1.B>**

B.2.2 Energy Consumption

We model the energy consumption by how much energy is consumed to charge the battery, how much is consumed while idle, and how much is consumed because the battery charger is left plugged into the wall socket after charging. Specifically, we consider the following modes:

- **Charging:** when replenishing the battery of the mobile device to its fully capacity with an additional energy loss due to the inefficiency in the charger.
- **Idle:** when the mobile device has its screen off, is connected to its charger, but not charging. The power draw in this mode is higher than the *standby* power draw when the mobile device is running on its battery unplugged from the charger.
- **Unplugged:** when the mobile device is unplugged from its charger, but the charger is still plugged into the wall socket. The power draw is solely due to the charger.
- **BC Unplugged:** when the charger is unplugged from the wall socket. The power draw is 0W.

B.2.2.1 Charging

The energy consumed for charging the mobile devices depends on how many times it is charged, and how much it is charged each time from before charging (pre-charge) to after charging (post-charge), represented by the battery level (state of charge). The energy consumption for charging per day, $E_{charging}$, is calculated as:

Charging: Energy Consumption

$$E_{charging} = N_{chargeCycles} E_{charge}$$

$$N_{chargeCycles} = \frac{n_{chargesPerWeek}}{7} (\rho_{postCharge} - \rho_{preCharge})$$

$$E_{charge} = E_{battery} \left(\frac{p_{original}}{\varepsilon_{original}} + \frac{p_{others}}{\varepsilon_{others}} \right)$$

where

- $N_{chargeCycles}$ is the number of full charge cycles per day as the average sum of partial charge cycles
- $n_{chargesPerWeek}$ the number of times the mobile device is charged per week **<M3>**
- $\rho_{preCharge}$ the average battery level before a typical instance of charging **<M4.A>**
- $\rho_{postCharge}$ the average battery level after a typical instance of charging **<M4.B>**

and where E_{charge} is the energy used for each charging session, which depends on how much energy is needed to fully charge the battery, which charger is used (original or others), and the efficiency of the chargers, with

- $E_{battery}$ the representative battery capacity in Wh
- $\varepsilon_{original}$ the representative original wall charger efficiency while charging
- ε_{others} the representative charger efficiency of other chargers (e.g., aftermarket charger, counterfeit charger, USB port of a computer or speaker system, in car 12V)
- $p_{original} = \frac{t_{original}}{t_{original} + t_{others}}$ the portion of time (%) spent charging with the representative original wall charger
- $p_{others} = 1 - p_{original}$ the portion of time of charging with the representative other wall charger

- $t_{original}$ the time plugged into the original wall charger **<M5.A>**
- t_{others} the time plugged into other chargers **<M5.B>**

B.2.2.2 Usage

Although not directly used in our energy model, we asked U.S. adults about how much they used their mobile devices yesterday **<M2>**. To validate our charging energy model, we found a moderate correlation between usage, and number of charge sessions (*r*=0.25) and number of full charge cycles (*r*=0.23).

B.2.2.3 Idle

The energy consumption when the mobile device is idle (plugged into the charger with screen off) is

Idle: Energy Consumption

$$E_{idle} = t_{idle} P_{idle}$$

$$P_{idle} = p_{original} P_{idle}^{original} + t_{others} P_{idle}^{others}$$

$$t_{idle} = t_{original} + t_{others} - t_{charging}$$

$$t_{charging} = N_{chargeCycles} t_{charge}$$

where

- $N_{chargeCycles}$ is the number of full charge cycles per day
- P_{idle} is the power draw in idle mode weighted for the portion of time using the original and other charges with $P_{idle}^{original}$ and P_{idle}^{others} power draws, respectively
- t_{idle} is the time spent per day idle mode
- $t_{charging}$ is the time spent per day charging the battery
- t_{charge} is the time to fully recharge the battery from 0-100%

B.2.2.4 Unplugged

The power draw of battery chargers with the device unplugged may account for a relatively significant portion of the mobile device energy consumption. We therefore account for this by evaluating the time that the chargers are left plugged into the wall after charging.

The energy consumption of the mobile device when unplugged from the charger is

Unplugged: Energy Consumption

$$E_{unplugged} = t_{originalUnplugged} P_{original} + t_{othersUnplugged} P_{others}$$

$$t_{originalUnplugged} = t_{originalBCPluggedIn} - t_{original}$$

$$t_{othersUnplugged} = \begin{cases} t_{originalBCPluggedIn} - t_{others} & \text{, if } t_{others} > 0 \\ 0 & \text{, otherwise} \end{cases}$$

where

- $P_{original}$ is the power draw of the representative original charger with the mobile device unplugged
- P_{others} is the power draw of the representative alternative charger (others)
- $t_{originalUnplugged}$ is the amount of time yesterday the original charger was plugged into the wall while not charging
- $t_{originalBCPluggedIn}$ is the amount of time yesterday the original charger was plugged into the wall (with and without charging) <M6>
- $t_{othersUnplugged}$ is the plugged-in time for other chargers after charging, where we assume that other chargers are plugged in for the same amount of time as the original charger if they are used

B.2.2.5 Representative Weights for Mobile Device and Charger Models

We estimate the representative weights, ω_m, from an analysis of the *usage share* of popular mobile device models (see

Table B-10 for smartphones and Table B-7 for tablets). Usage share is similar to installed base, but refers to the distribution of device models by their usage popularity instead of survey reported ownership. We refer to data sources which measured app usage or website visits of unique users to get an estimate for the usage share of mobile device models.

The representative battery and chargers depend on the estimated usage share, ω_m, of various popular mobile devices and their respective chargers:

$$E_{battery} = \sum_{m \in models} \omega_m E_m$$

$$\varepsilon_{original} = \sum_{m \in models} \omega_m \varepsilon_m$$

$$\sum_{m \in models} \omega_m = 1$$

where

- $models$ is the set of models of the mobile device category, e.g., $\{iPhone5, samsungS3, \ldots\}$
- E_m is the battery capacity of the mth mobile device model
- ε_m is the efficiency of the original charger of the mth mobile device model

We represent the efficiency of other chargers by an average of several documented aftermarket chargers:

$$\varepsilon_{others} = \sum_{o \in otherChargers} \varepsilon_o$$

where

- ε_o is the efficiency of the oth alternative charger

We calculate the representative power draws as:

$$P_{original} = \sum\nolimits_{m \in models} \omega_m P_m$$
$$P_{others} = \sum\nolimits_{o \in otherChargers} P_o$$

where

- P_m is the power draw of the mth original charger with the mobile device unplugged
- P_o is the power draw of the oth alternative charger with the mobile device unplugged; we assume equal weighting, for lack of data regarding the usage share of alternative chargers.

Table B-7: Usage share of popular tablet models used to derive weights, ω_m, to estimate the representative battery capacity and power draw values for tablets.

Model	OS	Usage Base Share							Aggregate	Representative Weights ω_m
		Dec 13	Dec 13	Dec 13	Sep 13	Sep 13	Jun 13	Dec 13		
		Mix-Panel 2014b	Fiksu 2014	Stat-Counter 2013b	Chitika 2013	Local-ytics 2013	Magid 2013	*CEA 2014*[*]		
iPad mini 2	iOS	0.8%	1.1%		-	-	-		0.7%	-
iPad Air	iOS	3.0%	4.3%		-	-	-		2.7%	-
iPad mini 1	iOS	16%	21%			-	-	*21%*[†]	14%	16%
iPad 4	iOS	14%	20%	79%		-	-	*20%*[†]	13%	15%
iPad 3	iOS	15%	16%		81%	-	-	*18%*[†]	12%	14%
iPad 2	iOS	32%	37%			-	-	*40%*[†]	26%	30%
iPad 1	iOS	3.4%	0.3%			-	-		1.4%	-
Kindle Fire HD	Android	-	-	8.0%	6.7%	56%	31%	*42%*[‡]	5.1%	10%
Kindle Fire HD 8.9”	Android	-	-					*22%*[‡]	11%	5.5%
Samsung Galaxy (7-8")	Android	13%	-	4.0%	5.1%	15%	19%	*23%*[‡]	2.9%	5.8%
Samsung Galaxy (>8)	Android		-					*12%*[‡]	6.2%	3.1%
B&N NOOK HD/HD+	Android	1.9%	-	0.6%	1.1%	17%	8.0%		0.9%	-
Google Nexus 7	Android	-	-	2.3%	1.6%	14%	8.0%		1.2%	-
Microsoft Surface	Windows	-	-	0.5%	1.0%	-	5.0%		0.6%	-
Other	-	-	-	5.8%	3.5%	-	19%		2.8%	-

* Usage share estimated based on distribution of all tablets by screen sizes (32% for 7-8”, 68% for 8.9-10.1”).
† Estimates normalized to 100% for iOS tablets only (16% for 7-8”, 59% for 8.9-10.1”).
‡ Estimates normalized to 100% for Android tablets only (16% for 7-8”, 8.6% for 8.9-10.1”).

Table B-8: Representative battery capacity and power draw estimates determined by a weighted average of the most popular tablet models.

Tablet Model	Screen Size [inches]	Release Year	Representative Weights	Battery Capacity[*] [Wh]	Charger Efficiency [%]	Battery Recharge Time [hr][†]	Power Draw [W] Idle[‡]	Power Draw [W] Unplugged[§]
iPad mini 1	7.9	2012	16%	16.5	75%[a]	4.1	0.27[a]	0.09
iPad 4	9.6	2012	15%	32.4	84%[a]	5.1	0.14[a]	0.08
iPad 3	9.6	2012	14%	43.0	81%[a]	5.5	0.65[a]	0.08[e]
iPad 2	9.6	2011-13	30%	25.0	81%[a]	3.5	0.41[a]	0.08
Kindle Fire HD 7”	7.0	2012	10%	16.5	75%[e]	3.1	0.27[e]	0.10
Kindle Fire HD 8.9”	8.9	2012	5.5%	22.2	81%[e]	4.5	0.40[e]	0.10
Galaxy Tab 3 7.0”	7.0	2013	5.8%	14.8	75%[e]	3.6[e]	0.27[e]	0.02
Galaxy Tab 3 10.1”	10.1	2012	3.1%	25.9	81%[e]	5.0	0.40[e]	0.09
Representative	**-**	**-**	**-**	**25.6**	**76%**	**4.2**	**0.27**	**0.08**

* Battery capacity estimates from iFixit (2012-2013).
† Recharge time estimates from Tom’s Hardware (2012)
§ Average metered power draw from 10 measurements with a Yokogawa W210 power meter on Jan. 27, 2014.

[a] Source: Apple environmental reports (Apple 2012).
[e] No data for estimate, estimated based on mean of smaller (7-8") and larger (≥8.9") screens of iPad models.

Table B-9: Representative power draw estimate determined by the average of several aftermarket tablet chargers.

Charger Model	Charger Efficiency [%]	Power Draw [W] Unplugged	Source
AmazonBasics Wall Charger (2.1A)	-	0.16	Measurement
Trent NT90C 10W 5V/2A Dual USB Ports	-	0.07	Measurement
Counterfeit iPad	66%	0.10	Shirriff 2012
KMS	69%	0.18	Shirriff 2012
Representative	**68%**	**0.13**	**Average**

Table B-10: Usage share of popular smartphone models used to derive weights, ω_m, to estimate the representative battery capacity and power draw values for smartphones.

		Usage Base Share							
		Jan 14	Dec 13	Dec 13	Sep 13	May 13	Q2 2013		
Model	OS	Chitika 2014	Mix-Panel 2014a	Stat-Counter 2013a	com-Score 2013	Magid 2013	Nielsen 2013	Aggregate	Represent-ative Weights ω_m
iPhone 5S	iOS	-	13%	60%	41%	41%	40%	6.0%	9.4%
iPhone 5	iOS	-	36%					16%	25%
iPhone 4S	iOS	-	27%					12%	19%
iPhone 4	iOS	-	19%					8.7%	14%
iPhone 5C	iOS	-	4.5%					2.0%	-
iPhone Other	iOS	-	1.8%					0.8%	-
Samsung Galaxy S4	Android	24%	-	16%	25%	26%	24%	5.4%	14%
Samsung Galaxy S3	Android	34%	-					7.7%	20%
Samsung Galaxy S2	Android	8.4%	-					1.9%	-
Samsung Galaxy S	Android	1.9%	-					0.4%	-
Samsung Galaxy Note 3	Android	3.8%	-					0.9%	-
Samsung Galaxy Note 2	Android	8.6%	-					1.0%	-
Samsung Galaxy Note	Android	0.9%	-					0.2%	-
Samsung Galaxy Other	Android	8.3%	-					1.9%	-
Samsung Other	Android	10%	-					2.4%	-
HTC	Android	-	-	2.8%	7.1%	9%	17%	6.7%	-
Motorola	Android	-	-	2.6%	6.8%	9%	10%	6.3%	-
LG	Android	-	-	3.1%	6.6%	7%	5.6%	6.4%	-
RIM	BlackBerry	-	-	3.6%	-	-	3.0%	5.3%	-
Other	-	-	-	12%	14%	11%	6.8%	9.9%	-

Table B-11: Representative battery capacity and power draw estimates determined by a weighted estimate of the most popular smartphone models.

Smartphone Model	Year Released	Representative Weights	Battery Capacity* [Wh]	Charger Efficiency [%]	Battery Recharge Time [hr]†	Power Draw [W] Idle	Power Draw [W] Unplugged§
iPhone 5S	2013	9.4%	5.9	75%[a]	-	0.09	0.02
iPhone 5	2012	25%	5.5	75%[a]	1.8	0.71	0.21
iPhone 4S	2011	19%	5.3	75%[a]	1.7	0.64	0.21
iPhone 4	2010	14%	5.3	75%[a]	-	0.35	0.21
Samsung Galaxy S4	2013	14%	9.9	77%	2.9	0.43[e]	0.02[f]
Samsung Galaxy S3	2012	20%	8.0	77%	2.5	0.43	0.01
Representative	-	-	6.5	76%	2.1	0.50	0.13

* Battery capacity estimates from iFixit (2012-2013).
† Recharge time estimates from Tom's Hardware (2012).
§ Average metered power draw from 10 measurements with a Yokogawa W210 power meter on Jan. 27, 2014.

[a] Source: Apple environmental reports (Apple 2012-2013).
[e] No data for estimate, so assumed similar to Galaxy S3.
[f] No data for estimate, but its charger is rated for 10W which is similar to tablets, so we assumed it is similar to the Samsung Galaxy Tab 3.

Table B-12: Representative power draw estimate determined by the average of several aftermarket smartphone chargers.

Charger Model	Charger Efficiency [%]	Power Draw [W] Unplugged	Source
Kyocera SSW-2001	-	0.06	Measurement
Counterfeit iPhone	63%	0.38	Shirriff 2012
Monoprice	72%	0.08	Shirriff 2012
Belkin	66%	0.23	Shirriff 2012
Smartphone dataset	63%	0.11	DOE 2012
Representative	67%	0.19	Average

B.2.2.6 Whole Day Energy Consumption

The total energy consumption for the whole day is:

$$E_{wholeDay} = E_{charging} + E_{idle} + E_{unplugged}$$

This estimate applies to the primary smartphones and primary tablets. However, we do not directly ask about charging behavior for secondary tablets. We estimate their energy consumption by assuming that the energy consumption between primary and secondary tablets follows the same ratio as usage time for the devices, i.e.:

$$E_{wholeDay}^{secondaryTablet} = E_{wholeDay}^{primaryTablet} \frac{t_{usage}^{secondaryTablet}}{t_{usage}^{primaryTablet}}$$

where

- $t_{usage}^{primaryTablet}$ is the usage time per day for the primary tablet **<M2b>**
- $t_{usage}^{secondaryTablet}$ is the usage time per day for the secondary tablet **<M2c>**

B.2.3 References

Apple. 2010. "iPhone 4 Environmental Report." Jun. 24, 2010. http://www.apple.com/environment/reports/docs/iPhone_4_Product_Environmental_Report.pdf. Retrieved Oct. 9, 2013.

Apple. 2011. "iPhone 4S Environmental Report." Oct. 4, 2011. http://images.apple.com/environment/reports/docs/iPhone4S_Product_Environmental_Report_2011.pdf. Retrieved Oct. 9, 2013.

Apple. 2012a. "iPad 2 Environmental Report." Mar. 7, 2012. http://images.apple.com/environment/reports/docs/iPad2_Product_Environmental_Report_2012.pdf. Retrieved Sept. 19, 2013.

Apple. 2012b. "iPad 3 Environmental Report." Mar. 7, 2012. http://images.apple.com/environment/reports/docs/iPad_Product_Environmental_Report_March2012.pdf. Retrieved Sept. 19, 2013.

Apple. 2012c. "iPad 4 Environmental Report." Oct. 23, 2012. http://images.apple.com/environment/reports/docs/iPad_Retina_PER_oct2012.pdf. Retrieved Sept. 19, 2013.

Apple. 2012d. “iPad mini Environmental Report.” Oct. 23, 2012. http://images.apple.com/environment/reports/docs/iPadmini_PER_oct2012.pdf. Retrieved Sept. 19, 2013.

Apple. 2012e. “iPhone 5 Environmental Report.” Sept. 12, 2012. http://images.apple.com/environment/reports/docs/iPhone5_product_environmental_report_sept2012.pdf. Retrieved Oct. 9, 2013.

Apple. 2013. “iPhone 5S Environmental Report.” Sept. 10, 2013. http://images.apple.com/environment/reports/docs/iPhone5s_product_environmental_report_sept2013.pdf. Retrieved Oct. 9, 2013.

CEA. 2014. “Consumer Outlook on Tablets – Jan. 2014 Edition.” Jan. 2014. Consumer Electronics Association.

Chikita. 2013. “Third Quarter End Tablet Update: iPad Usage Share at 81%, Other Tablets See Share Increases.” Oct. 22, 2013. http://chitika.com/insights/2013/Q3-tablet-update. Retrieved Jan. 24, 2014.

Chikita. 2014. “Samsung Status Report: Galaxy S III & IV Users Generate 57.7% of Samsung Smartphone Web Traffic in North America.” Jan. 14, 2014. http://chitika.com/insights/2014/samsung-update. Retrieved Jan. 17, 2014.

comScore. 2013b. “MobiLens Sep 2013 - Top Smartphone OEMs.” Nov. 5, 2013. http://www.comscore.com/Insights/Press_Releases/2013/11/comScore_Reports_September_2013_U.S._Smartphone_Subscriber_Market_Share. Retrieved Jan. 22, 2014.

DOE. 2012. “Rulemaking for Battery Chargers and External Power Supplies Energy Conservation Standard. Energy Use Analysis Spreadsheet.” Feb. 17, 2012. http://www.regulations.gov/#!documentDetail;D=EERE-2008-BT-STD-0005-0084. Retrieved Feb. 6, 2014.

Fiksu. 2014. “iPad, iPhone, and iOS 7 Adoption Trackers.” Dec. 23, 2013. http://www.fiksu.com/iOS-7-iPhone-5s-5c-Usage-Tracker#ipad-usage. Retrieved Jan. 21, 2014.

iFixit. 2010. “iPhone 4 Teardown.” http://www.ifixit.com/Teardown/iPhone+4+Teardown/3130/1. Retrieved Oct. 23, 2013.

iFixit. 2011a. “iPad 2 Wi-Fi EMC 2415 Teardown.” http://www.ifixit.com/Teardown/iPad+2+Wi-Fi+EMC+2415+Teardown/5071/2#s22967. Retrieved Oct. 4, 2013.

iFixit. 2011b. “iPhone 4S Teardown.” http://www.ifixit.com/Teardown/iPhone+4S+Teardown/6610/1. Retrieved Oct. 23, 2013.

iFixit. 2012a. “iPad 3 4G Teardown.” http://www.ifixit.com/Teardown/iPad+3+4G+Teardown/8277/3#s33152. Retrieved Oct. 4, 2013.

iFixit. 2012b. “iPad 4 Wi-Fi Teardown.” http://www.ifixit.com/Teardown/iPad+4+Wi-Fi+Teardown/11462/1. Retrieved Oct. 4, 2013.

iFixit. 2012c. “iPad mini Wi-Fi Teardown.” http://www.ifixit.com/Teardown/iPad+mini+Wi-Fi+Teardown/11423/2. Retrieved Oct. 4, 2013.

iFixit. 2012d. “iPhone 5 Teardown.” http://www.ifixit.com/Teardown/iPhone+5+Teardown/10525/2. Retrieved Oct. 23, 2013.

iFixit. 2012e. “Kindle Fire HD Teardown.” Sept. 14, 2012. http://www.ifixit.com/Teardown/Kindle+Fire+HD+Teardown/10457/1. Retrieved Oct. 4, 2013.

iFixit. 2012f. “Samsung Galaxy S3 Teardown.” http://www.ifixit.com/Teardown/Samsung+Galaxy+S+III+Teardown/9391/1. Retrieved Oct. 23, 2013.

iFixit. 2012g. “Samsung Galaxy Tab 3 7.0 3G Teardown.” http://www.ifixit.com/Teardown/Samsung+Galaxy+Tab+3+7.0+3G+Teardown/17357/2. Retrieved Oct. 4, 2013.

iFixit. 2013a. “iPhone 5S Teardown.” http://www.ifixit.com/Teardown/iPhone+5s+Teardown/17383/1. Retrieved Oct. 21, 2013.

iFixit. 2013b. “Kindle Fire HD 8.9.” http://www.ifixit.com/Guide/Kindle+Fire+HD+8.9-Inch+Battery+Replacement/12922. Retrieved Oct. 4, 2013.

iFixit. 2013c. “Samsung Galaxy S4 Teardown.” http://www.ifixit.com/Teardown/Samsung+Galaxy+S4+Teardown/13947/1#s46407. Retrieved Oct. 23, 2013.

iFixit. 2013d. “Samsung Galaxy Note 10.1 Teardown.” http://www.ifixit.com/Teardown/Samsung+Galaxy+Note+10.1+Teardown/10144/2. Retrieved Oct. 4, 2013.

Localytics. 2013. “Top Android Tablet Share (Global).” Nov. 7, 2013. http://www.localytics.com/blog/2013/fonblets-and-phablets-samsung-has-share-of-android-mobile-devices/. Retrieved Jan. 24, 2014.

Magid. 2013. “US Tablet Owners, by Model, 2013.” Jun. 19, 2013. http://www.emarketer.com/Article/With-More-Models-on-Market-How-Tablets-Stacking-Up/1009982. Retrieved Sept. 20, 2013.

MixPanel. 2014a. “iPhone Models.” Dec. 23, 2013. https://mixpanel.com/trends/#report/iphone_models. Retrieved Jan. 21, 2014.

MixPanel. 2014b. “Top tablets.” Dec. 23, 2013. https://mixpanel.com/trends/#report/top_tablets/from_date:-52,to_date:-30. Retrieved Jan. 21, 2014.

Nielsen. 2013. “Who's Winning the U.S. Smartphone Market?” Aug. 6, 2013. http://www.nielsen.com/us/en/newswire/2013/whos-winning-the-u-s-smartphone-market-.html. Retrieved Oct. 22, 2013.

Shirriff. 2012. “A dozen USB chargers in the lab: Apple is very good, but not quite the best.” Oct. 27, 2012. http://www.righto.com/2012/10/a-dozen-usb-chargers-in-lab-apple-is.html. Retrieved Oct. 7, 2013.

StatCounter. 2013a. “Top Mobile Vendors in the United States.” Dec. 2013. http://gs.statcounter.com/#mobile_vendor-US-monthly-201309-201309-bar. Retrieved Jan. 17, 2014

StatCounter. 2013b. “Top Tablet Vendors in the United States.” Dec. 2013. http://gs.statcounter.com/#tablet-vendor-US-monthly-201304-201312. Jan. 24, 2014.

B.3 Video Game Consoles

B.3.1 Installed Base

To estimate the installed base of video game consoles in the current study, we used the results from the CE Usage Survey (2013). In this survey we asked about the ownership of nine different video game consoles in U.S. households (see Appendix A.5 Q-E1). In the main body this study (see Section 3.13.1.1), we only presented the installed base of video game consoles available on the market before Jul. 2013. In this Appendix, we present an additional installed base estimate for Feb. 2014 that includes the recently released Sony PlayStation 4 and Microsoft Xbox One consoles (Figure B-1).

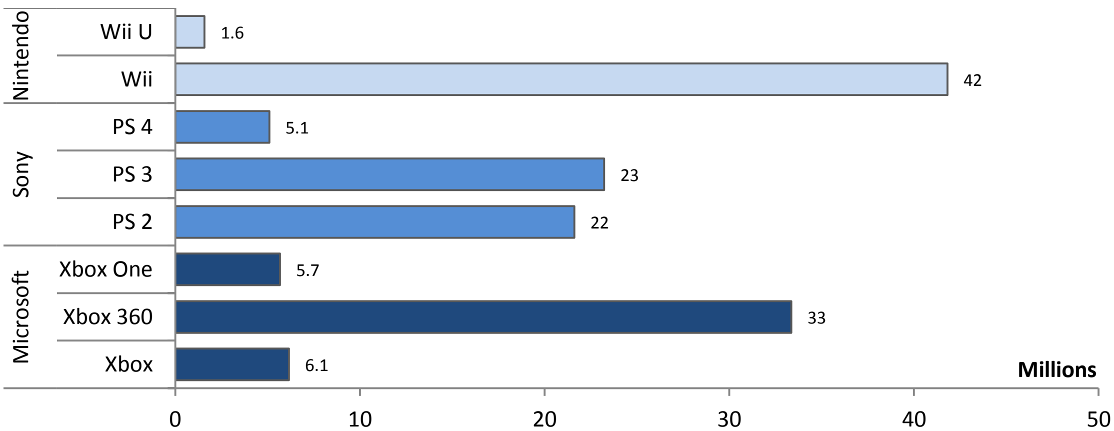
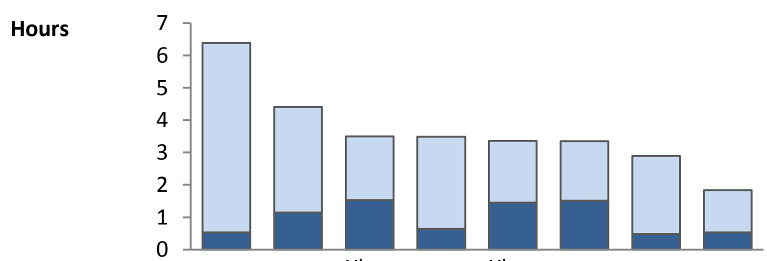


Figure B-1: Installed Base of video game consoles in Mar. 2014

B.3.2 Usage of video game consoles including 8th generation models

Figure B-2 depicts our usage estimates for gaming consoles in Feb. 2014.



	Xbox	Wii U	Xbox One	PS2	Xbox 360	PS3	Wii	PS4
Left ON	5.9	3.3	2.0	2.9	1.9	1.8	2.4	1.3
Actively used	0.5	1.1	1.5	0.6	1.5	1.5	0.5	0.5

Figure B-2: Turned ON and actively used time of video game consoles

Figure B-3 presents the estimated breakdown of active-all time among different activities.

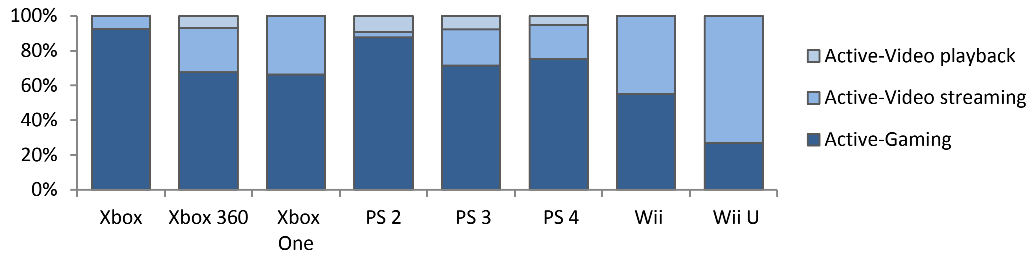


Figure B-3: Distribution of active usage among gaming, video streaming and video playback by video game console platform

B.3.3 Power Draw

Table B-13 summarizes the power draw values for the PlayStation 4 (PS4), included estimated pre-launch power draw (Sony 2013) and measured power draws by NRDC (2013). With the exception of active-media and networked standby modes, these two sources are consistent.

Table B-13: PS4 Power Draws (Sony 2013, NRDC 2013).

Mode	Manufacturer Power Draw [W]	NRDC (2013) Power Draw [W]
Active-gaming	135[a]	137
Active-media	110[b]	90[d]
Navigation	85	88
Peripheral charging	10[c]	-
Peripheral charging enabled	7	-
Networked standby	3.1	8.8
Standby	<0.5	0.5

a Average measured while playing “Motorstorm Apocalypse.”
b Average of power used for playback of audio CD, DVD, Blu-ray, and media streaming.
c PS4 peripherals can be recharged while the console is powered-down.
d Power Draw measured while streaming Netflix.

Table B-14 presents the comparison of power draw data received from Microsoft (Calland 2014, middle column) with power measurements performed by NRDC (2013). The data from the two sources are mostly consistent, with the exception of the Standby power mode, where the measured power draw is almost three-times higher than the power draw provided by Microsoft.

Table B-14: Xbox One Power Draws (Calland 2014, NRDC 2013).

Mode	Manufacturer Power Draw [W]	NRDC (2013) Power Draw [W]
Active-gaming	121	110
Active-video playback (DVD)	80	-
Active-video streaming	72	74
Navigation	72	72
Connected Standby	18[a]	18
Standby	0.45[a]	1.3

a Xbox One shipped with "Connected Standby " enabled -- wake-on-lan, wake-on-voice and instant-on (OS suspended to RAM). User can opt in to "energy saving" (0.5 watt) standby mode.

B.3.4 Usage estimates – Video Game Consoles

We reference specific survey questions to obtain values for variables in the usage model. These are indicated in bold green, e.g., **<E1.1>** references survey question 1, sub-question 01 in the video game console survey. See Appendix A – CE Usage Surveys for the survey questions. The following table includes the questions that we used in the energy model calculation (e.g. E3 – E5).

Table B-15: Variables directly measured in the CE Usage Survey.

	Survey Question	Purpose	Measure	Variable
E3.##	Turned ON and Active Usage time …	Active and ON time	Time (hh:mm)	
01	Turned ON			t_{On}
02	Actively used			$t_{actively\ used}$
E4.##	Distribution of active usage time…	Usage time	Time (hh:mm)	
01	Play games			t_{games}
02	Stream media from the video game console or Internet			$t_{streaming}$
03	DVD and/or Blu-Ray playback			$t_{playback}$
E5.##	Initial state of the Video Game Console in the morning…	Left ON 24 hours	Probability	
01	It was already turned ON and ready to use			p_{leftOn}
02	It was turned OFF and you needed to turn it on to use it			$p_{leftOff}$
99	Don’t know			$p_{don't\ know}$

B.3.4.1 Calculations of Time Spent in Operational Modes

Video game consoles have three primary operational modes, i.e., active, navigation and standby. In our study, the active mode includes time spent gaming, streaming video, and video playback (see Video Game Systems 3.13). We declare these as variables in this model (see Table B-16).

Table B-16: Variables for power draw and time threshold of various operational modes.

Operational Mode	Active-gaming	Active-streaming	Active-playback	Navigation	Standby
Power Draw	P_{games}	$P_{straming}$	$P_{playback}$	P_{nav}	P_{off}
Time in modes	t_{games}	$t_{streaming}$	$t_{playback}$	t_{nav}	t_{off}

In the CE Usage Survey (2013), we asked respondent to estimate the time each video game console was *on* “yesterday” and was used for gaming, streaming video, and video playback.

Not infrequently, the sum of times spent in the different active-use modes did not equal the active use estimate. Consequently, if $t_{actively\ used}$ is less than the sum of the time spent gaming, streaming, and video playback, we assumed that $t_{actively\ used}$ instead equaled that sum, i.e.:

- If $t_{actively\ used} \leq t_{games} + t_{streaming} + t_{playback}$ then $t_{actively\ used} = t_{games} + t_{streaming} + t_{playback}$.

Similarly, we then adjusted the on-mode time, t_{On}, for each individual response if t_{On} was less than $t_{actively\ used}$ so that t_{On} equals $t_{actively\ used}$.

To determine whether or not a video game console stayed on all the time, we analyzed each individual response to survey question **<E5>,** i.e., whether or not the console was already on the last time the respondent was the first person to use the console on a day. Our data analysis logic follows, where the answer "-1" represents a "don't know" reply by the respondent:

- If $t_{On} = 0 \; and \; t_{actively\ used} = 0, and \; p_{leftOn} = 1$ then $t_{On} = 24 \; hours$ and $t_{actively\ used} = 0$;
- If $t_{On} = 0 \; and \; t_{actively\ used} = 0, and \; p_{don'tknow} = 99$ then $t_{On} = 0 \; hours$ and $t_{actively\ used} = 0$, i.e. video game console was not used yesterday;
- If $t_{On} = -1 \; and \; t_{actively\ used} = -1, and \; p_{leftOn} = 1$ then $t_{On} = 24 \; hours$ and $t_{actively\ used} = average \; time$, where "average time" is the weighted average time video game console was actively used yesterday and is calculated as described above;
- If $t_{On} = -1 \; and \; t_{actively\ used} = -1, and \; p_{leftOff} = 2$ then $t_{On} = t_{On}$ before adjustments and $t_{actively\ used} = t_{actively\ used}$ before adjustments;
- If $t_{On} \leq 16 \; hours \; and \; p_{leftOn} = 1$ then $t_{On} = average \; (24 \; hours \; and \; t_{On})$ and $t_{actively\ used} = t_{actively\ used}$.

The weighted average hours spent in on and active modes equals the sum of the individual responses, applying the appropriate survey weight, N_w, for each respondent:

$$t_{On\ avg.} = \sum_{i=1}^{n} \frac{t_{On} i \times N_w i}{N_w i}$$

where

- $N_w i$ is weight of the ith survey response
- n is number of survey responses
- i is the number of a particular response

Finally, the time video game consoles spent in navigation mode was calculated as the difference between the time spent in on mode and the time video game consoles were actively used, i.e.,

$$t_{nav} = t_{On} - t_{actively\ used}.$$

B.3.5 References

Calland, T. 2014. Personal Communication. Microsoft. Feb.

Sony. 2013. Personal Communication. Dec.

NRDC. 2013. "New PS4 and Xbox One Game Consoles: A Mixed Bag for Energy Efficiency." Switchboard. Dec. http://switchboard.nrdc.org/blogs/nhorowitz/new_ps4_and_xbox_one_game_cons.html

B.4 Home Audio

In this appendix, we present in-store power measurements of speaker docks and stereo shelf systems performed in Jan. 2014.

B.4.1 Speaker Docks

Table B-17: Power draw measurements of speaker docks.

	Active Modes [W]							
	Active iPhone			Active Tuner			Active Standby	Off
	Min.	**Medium**	**Max.**	**Min.**	**Medium**	**Max.**	**[W]**	**[W]**
Stereo System 1[*]	5.6	5.4	6.6	4.1	6.3	3.3	1.9	5.6
Stereo System 2[**]	3.3	4.5	7.8	-	-	1.9	0.4	3.3
Stereo System 3[#]	-	-	-	-	-	-	1.1	-
Wt. Avg.	5.0	5.2	6.9	4.1	6.3	3.0	1.3	5.0
Wt. Avg.	**4.8**						**3.0**	**1.3**

* This speaker dock has a plug-in connection for an iPhone 5. Since we did not have an iPhone 5 available when making the measurements, we were unable to measure power draw in active modes.

B.4.2 Shelf Stereo Systems

Table B-18: Power draw measurements of shelf stereo systems.

	Active Modes [W]							
	Active iPhone			Active Tuner			Active Standby	Off
	Min.	**Medium**	**Max.**	**Min.**	**Medium**	**Max.**	**[W]**	**[W]**
Stereo System 1[*]	14	15	28	12	14	40	13	0.3
Stereo System 2[**]	12	13	52	12	15	70	10	0.1
Stereo System 3[#]	18	19	28	18	18	53	13	0.5
Wt. Avg.	15	16	34	14	15	51	12	0.3
Wt. Avg.	**17**						**12**	**0.3**

* Output power = 220W.
** Output power = 500W.
\# Output power = 700W.