Before the

CALIFORNIA ENERGY COMMISSION

Sacramento, California

In the Matter of

Invitation to Participate in the Development of Appliance Energy Efficiency Measures	))))	Title 20 CCR §§1601 – 1608
Docket No. 12-AAER-2A	)	

COMMENTS OF THE CONSUMER ELECTRONICS ASSOCIATION

I. Introduction and Summary

The Consumer Electronics Association® (CEA) appreciates the opportunity to submit comments in response to the Energy Commission's Invitation to Participate (ITP) issued March 25, 2013. CEA appreciates this "pre-rulemaking" opportunity to provide data and comments regarding the CEC's interest in the development of new regulatory measures for the four consumer electronics product categories listed in the ITP: computers, displays, game consoles and set-top boxes.

CEA is the preeminent trade association promoting growth in the $209 billion U.S. consumer electronics industry. CEA represents more than 2,000 companies across the consumer electronics industry, including manufacturers and retailers of computers, displays, game consoles and set-top boxes, as well as component suppliers and service providers.

For many years, CEA has been on the vanguard of energy efficiency initiatives related to the consumer electronics industry and has supported and advanced energy efficiency as part of the industry's broader commitment to environmental sustainability. CEA's comprehensive approach to energy efficiency includes initiatives related to public policy, consumer education, research and analysis, and industry standards. CEA supports the U.S. Environmental Protection Agency's (EPA's) ENERGY STAR program, and our members' cooperation and participation in this successful program goes back more than 20 years.

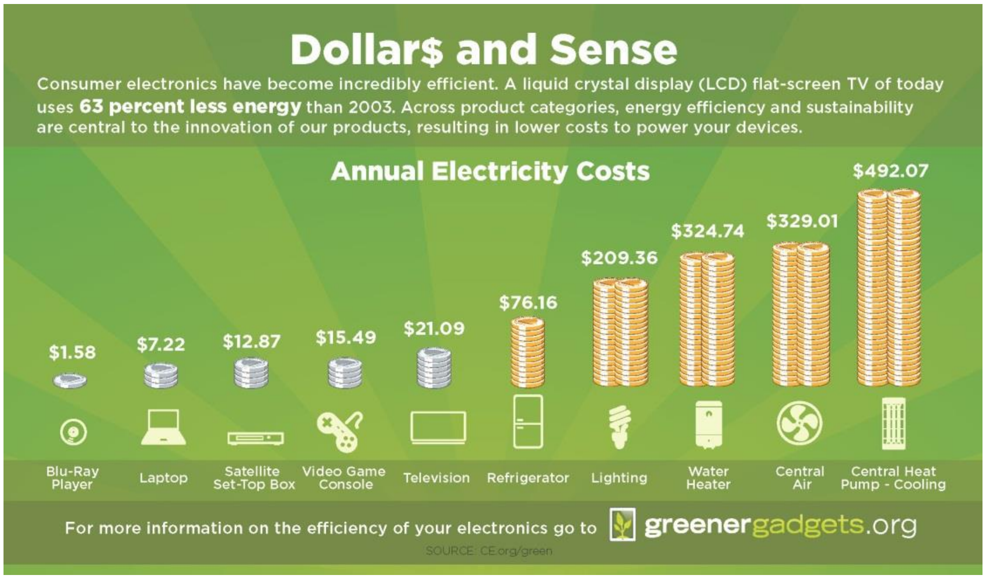
While we recognize and appreciate the CEC's solicitation of information on the products of interest, we note the CEC's statement in the ITP that this outreach is an opportunity to "shape the development of draft efficiency standards and measures." CEA opposes the development of unnecessary, California-specific minimum operating efficiency standards, test procedures, marking and labeling requirements for computers, displays, game consoles and set-top boxes. The purpose of these comments is to explain at a high policy level why we have this view and how it fits into California's economic, energy, and statutory interests. Other commenters from industry will provide more in depth technical comments.

Rather than generate new regulations that add to California's burdensome regulatory environment for businesses, CEC should defer to more cost-effective and appropriate policies, programs and industry initiatives that already exist for these electronics product categories, or explore new measures that rely on market-oriented incentives rather than regulatory mandates. Industry and policymakers share the goal of energy efficiency and conservation, but there are many paths to that goal.

II. <u>Consumer Electronics Are Already Among the Most Energy Efficient Products in the Home Today</u>.

Thanks to industry innovation, competition and the U.S. EPA's ENERGY STAR program, consumer electronics are already among the most energy efficient products in the home today, with devices typically consuming just a few cents of electricity a week. Additionally, the share of residential electricity use for consumer electronics in the average home is relatively low at 13 percent.[1] As illustrated below in Figure 1, the annual energy cost of operating many popular consumer electronics products is substantially less than home appliances and equipment used for heating, cooling and lighting.

Figure 1: Annual Electricity Costs



With its frequent new model introductions, changing product definitions and technology transitions, the consumer electronics industry is admittedly a challenging sector for energy efficiency policies and programs. To date, the federal ENERGY STAR program has been the only public policy supporting and advancing energy efficiency that is able to keep pace with the rapid rate of change in the consumer electronics industry. Figure 2 illustrates how frequently ENERGY STAR specifications for consumer electronics have been revised during the past several years in order to keep pace with the rapidly-evolving consumer electronics market.

[1] See Energy Consumption of Consumer Electronics in U.S. Homes in 2010 – Final Report to the Consumer Electronics Association (CEA) – December 2011, B. Urban, V. Tiefenbeck and K. Roth, Fraunhofer Center for Sustainable Energy Systems, attached as an appendix to these comments.

Figure 2: ENERGY STAR Product Specification Revisions (Source: EPA)

Product Category	**Year Introduced (and Revised)**	**Status of Activity in 2013**
Audio/Video Equipment	1999 (2003, 2009, 2010)	*Version 3.0 effective May 1, 2013*
Computers	1992 (1995, 1999, 2004, 2008)	*New version in development*
Imaging Equipment	1993 (1995, 2000, 2001, 2007, 2009)	*New versions effective January 1, 2014*
Monitors/Displays	1992 (1995, 1998, 1999, 2005, 2006, 2009, 2010)	*Version 6.0 effective June 1, 2013*
Set-top Boxes	2001 (2005, 2008, 2011)	*New version in development*
Televisions	1998 (2002, 2004, 2005, 2008, 2010, 2011, 2012)	*Version 6.0 effective June 1, 2013*

III. High Tech Electronics Products Should Not be Considered "Appliances" to be Regulated Along with Electromechanical Equipment and Plumbing Fixtures.

Electronics products such as computers, displays, game consoles and set-top boxes are not appropriately considered as "appliances" to be regulated along with pool pumps, urinals and other utilitarian equipment. Such electromechanical equipment and plumbing fixtures channel energy and water for well-defined purposes and are not dependent on other equipment and software for their uses, as electronics typically are. In addition, pumps, urinals and other such appliances are stable products with set designs, long product lives, and typically one set purpose or function. This also sets appliances apart from electronics. Appliances also do not evolve during their product lifetimes, but electronics often do.

Computers, game consoles, displays and set-top boxes are an integral and relatively indivisible part of the broad, diverse and often-changing information technology and audiovisual entertainment experience in most American households. Consumers acutely perceive –and manufacturers and service providers expend huge resources refining– the differences in product model offerings in these categories of electronics, and these differences matter deeply to consumers. Subjecting all products in these four electronics product categories to a rigid energy performance standard, for example, ignores that information technology and entertainment devices are neither static nor monolithic. Moreover, the Warren-Alquist Act does not give explicit authority to the Energy Commission to regulate products that are not energy- or water-using appliances.[2]

Regarding electronics, CEA's focus on behalf of its members is on consumer channel products. It is important to recognize that in two of the four categories of electronics of interest to the Energy Commission in the ITP, computers and displays, there is a significant share of the market that is commercial. We recognize CEC's interest in the entire market (consumer plus commercial) for the named product categories, but CEA's contributions of information and comments are focused on the consumer market.

IV. The Markets for Computers, Displays, Game Consoles and Set-top Boxes Continue to Evolve Rapidly.

CEA's report entitled *U.S. Consumer Electronics Sales & Forecasts*[3] provides market data on sales to dealers and product trends for many categories of consumer electronics, including personal computers, computer monitors, game consoles and set-top boxes. Twice each year, CEA updates this report which includes CEA's forecast for more than 100 consumer electronics product categories. The report and forecast serve as the benchmark for the consumer electronics industry, charting the size and growth of underlying categories and the industry as a whole. The *Sales & Forecasts* report is derived from U.S. shipment data that CEA collects as part of CE MarketMetrics program and from a consensus forecast process in which CEA asks its members to submit their best estimates for the total industry size and growth in a series of categories for a five year time period. This report yields the following data types: U.S. factory unit sales, dollar sales, and average unit price.

CEA produces another document entitled *CE Ownership and Market Potential Study*[4] which ascertains the degree of ownership (market penetration) and purchase intent of consumer electronics (CE) devices and technologies among U.S. households. Among the categories

[2] PRC 25402(c)(1).
[3] Consumer Electronics Association® *U.S. Consumer Electronics Sales and Forecasts 2008-2013*, January 2013.
[4] Consumer Electronics Association® *15th Annual CE Ownership and Market Potential Study*, April 2013.

covered in this study are personal computers and game consoles. The study is a survey of roughly 2,000 consumers about their household ownership of various consumer electronics devices and their intentions to purchase devices in the coming years. The *Ownership* study is consumer-reported data, and the study yields the following data types: installed base, purchase intent, and household penetration rate.

Since the *Sales & Forecasts* report and the *Ownership* study are copyrighted documents available for sale to nonmembers of CEA, we are not able to provide it as an appendix to these public comments. However, we look forward to discussing how best to make the contents of these documents available to the Energy Commission staff in the context of their request for information.

V. CEA Provides for Consideration Our Most Recent Study Regarding Energy Use Trends Covering the Four Electronics Categories of Interest.

One of CEA's ongoing initiatives in support of energy efficiency for consumer electronics is the contribution of research, data and analysis on the energy use of consumer electronics. To date, CEA has commissioned two studies of energy use for products of our industry in order to inform policy makers and other interested stakeholders. CEA's most recently commissioned study was published in December 2011, and our practice has been to update this research about every three years. Later this year, we expect to begin work on the next such study, assessing 2013 product models. We would welcome the opportunity to make our next study available to the CEC and other interested parties as we have done previously. In the meantime, we provide as an appendix to these comments a copy of our 2011 study.[5]

As noted above, consumer electronics differ from household appliances in several meaningful ways, including in how they are configured and used. Unlike appliances, consumer electronics may be used in ways that offset energy consumption and carbon emissions in other

[5] *Energy Consumption of Consumer Electronics in U.S. Homes in 2010 – Final Report to the Consumer Electronics Association (CEA) – December 2011*, B. Urban, V. Tiefenbeck and K. Roth, Fraunhofer Center for Sustainable Energy Systems.

areas. In the ITP, we note that the Energy Commission did not ask questions about the energy-saving benefits of using the electronics products in question, nor has the CEC considered the savings impacts of such usage in rulemakings concerning electronics products to date. We urge the Energy Commission to consider such factors, which are particularly relevant to the use of information technology products such as computers and home entertainment devices such as game consoles. For example, computers and displays are used for telecommuting or teleworking, which reduces energy consumption associated with transportation to and from the office and, in some cases, a portion of the energy associated with commercial office space. In 2007, CEA commissioned a study which investigated the impact of telecommuting as well as e-commerce on U.S. energy consumption, greenhouse gas emissions, and fuel consumption, and the findings of this study are available online.[6]

VI. Policy recommendations.

As the Energy Commission reviews the product and energy market trends in computers, displays, game consoles and set-top boxes, CEA urges the CEC to consider more innovative approaches to supporting energy efficiency than it has pursued in appliance efficiency standards rulemakings to date. If new measures or programs are needed at all, we urge the Energy Commission to pursue voluntary, market-oriented programs and policies, building upon existing models and programs wherever possible.

Mandatory requirements based on artificial energy use limits are not the best approach for high tech products such as consumer electronics, where product definitions, underlying technology, feature sets and usage patterns are in constant flux. Regulations will inevitably regulate "last year's" product and also run the risk of stifling or hampering development of this year's and future product innovations. The risk of negative impacts to innovation increases as the information technology and home entertainment systems and services involving the covered

[6] *The Energy and Greenhouse Gas Emissions Impact of Telecommuting and e-Commerce – Final Report by TIAX LLC to the Consumer Electronics Association (CEA) – July 2007*. See: http://www.ce.org/CorporateSite/media/Government-Media/Green/The-Energy-and-Greenhouse-Gas-Emissions-Impact-of-Telecommuting-and-e-Commerce.pdf.

products evolve into whole-home or even Internet or "cloud"-based configurations. Unknown, evolving, inchoate and proprietary future product designs risk being undermined or destroyed in this important part of the American economy –and the California economy in particular.

The U.S. Environmental Protection Agency's ENERGY STAR program has been the preferred public policy for supporting and advancing energy efficiency in consumer electronics. For more than 20 years, the program has offered an incentive to manufactures and a signal to consumers for energy efficient products. As indicated in Figures 3 and 4 below, the ENERGY STAR program has yielded substantial savings for consumers as well as significant reductions in carbon emissions for many covered product categories, including computers, displays and set-top boxes. As the Energy Commission considers the impact of any new policies and programs, it must take current and projected ENERGY STAR program savings into account.

Figure 3: ENERGY STAR Data for Energy Savings for IT Equipment in 2011 (Source: EPA)

Product Category	Net Savings ($ millions 2011)	2011 Emissions Avoided (Million metric tons CO2 equivalent)
Computers	$312	2.24
Copier	$98	0.66
Displays (Monitors)	$2,478	16.78
Fax	$14	0.10
Multifunction Device	$786	5.26
Printer	$817	5.48
Professional Displays	$3	0.02
Scanner	$14	0.09
Servers	$42	0.28
Total	*$4,564*	*30.9*

Figure 4: ENERGY STAR Data for Energy Savings for Various Electronics Products in 2011 (Source: EPA)

Product Category	Net Savings ($ millions 2011)	2011 Emissions Avoided (Million metric tons CO2 equivalent)
Audio Equipment	$35	0.3
Battery Charging Systems	$38	0.2
Digital Picture Frames	$3	0.02
Digital TV Adapters	$66	0.4
DVD Players	$85	0.6
External Power Supplies	$1,090	6.4
Set-top Boxes	$606	3.6
Telephony	$309	1.8
TVs	$1,181	9.4
Total	*$3,412*	*22.7*

Voluntary measures built upon existing and successful programs and partnerships can be an opportunity for significant savings. A recent cable and consumer electronics industry initiative for set-top boxes, which goes above and beyond the ENERGY STAR program, provides an excellent example. A Set-Top Box Energy Conservation Agreement ("Voluntary Agreement" or "VA") entered into by the key purchasers and manufacturers of set-top boxes in December 2012[7] ensures enormous short-term and long-term energy savings while allowing set-top boxes and related technology and networks to innovate and drive toward system wide efficiencies. CEA and the National Cable & Telecommunications Association estimate that the VA will result in annual residential electricity savings of $1.5 billion or more as the commitment is fully realized.

The essence of the Voluntary Agreement is that 90 percent of all new set-top boxes that a service provider signatory purchases and deploys after December 31, 2013, shall meet the efficiency standards established in the ENERGY STAR Version 3.0 specification. In addition,

[7] http://www.ce.org/News/News-Releases/Press-Releases/2012-Press-Releases/Set-Top-Box-Energy-Conservation-Agreement-Expected.aspx .

the relevant sectors –cable, satellite and telecommunications service providers– have made their own specific, additional undertakings. Critically, the agreement allows for the commitments to be revised and additional goals established over time in order to keep pace with the technological capabilities and architectural evolutions occurring within subscription video delivery sector.

The VA has been adopted with specific intent not only to save energy but to ensure there are no restrictions on future innovation, technology or competition to the detriment of the U.S. economy or consumers. There are also strong provisions in place to ensure reasonable transparency, public reporting and verified compliance with these commitments. Under the VA, an organization has been created with a steering committee and rules. These provisions enable, among other things, establishment of an independent administrator and auditors to verify that data submitted are reliable and demonstrate that key commitments of the VA are met. The VA also provides for not only laboratory testing but also testing in the home environment to better assure energy efficiencies are delivered. No federal or state standard can accomplish all this in such a short period of time while being sufficiently agile to adjust to market and technological realities and changes.

From a legal viewpoint, the Energy Commission must consider these initiatives under the requirements of section 25402(c)(1) of the Warren-Alquist Act, which requires consideration of alternatives, including incentive programs and consumer education. Similarly, a correct consideration of full life cycle costs will include the entire networks, existing and future, to ensure all systems costs are captured. We also note the compelling federal preemption considerations the cable industry has raised with the Energy Commission regarding set-top boxes.

Where an ENERGY STAR program specification has not had sufficient marketplace adoption, we would welcome the opportunity to work with the Energy Commission and other state and national interests in exploring additional energy efficiency program requirements or incentives. As the Energy Commission knows, some electric utilities have run rebate programs designed to support purchases of products that meet or exceed ENERGY STAR program specifications. The efficacy, modification or expansion of such rebate programs should be carefully considered. Another example of an incentive-based approach is at the national and international levels, where the U.S. and other governments recently have developed recognition programs to encourage the sale of highly energy efficient products, including televisions, computer monitors and displays. The Super-efficient Equipment and Appliance Deployment Initiative, an international coalition of national energy agencies, oversees these recognition programs. CEA's 2013 International CES trade show was the venue for announcing the SEAD program's most recent competition for the electronics industry.[8]

Any initiatives for electronics products, federal or state, must take into account the global nature of the consumer electronics market. Policy makers must ensure there are not undue burdens to selling consumer electronics worldwide as a result of uneconomic state or national product designs and requirements.

VII. Conclusion.

Computers, displays, game consoles and set-top boxes are not suitable products for conventional appliance efficiency standards regulation. Nonetheless, these high tech products can and do fit within energy efficiency programs and initiatives that reduce their energy footprint while protecting innovation and maintaining existing and future product function and value. We urge the Energy Commission to consider working with industry on our voluntary initiatives and discussing creative, new approaches rather than turning to traditional command and control regulation.

[8] http://www.superefficient.org/en/Resources/News%20and%20Announcements/Press%20Release%20-%20Display%20awards%20launch.aspx

Respectfully submitted,

CONSUMER ELECTRONICS ASSOCIATION

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APPENDIX

Energy Consumption of Consumer Electronics in U.S. Homes in 2010 – Final Report to the Consumer Electronics Association (CEA) – December 2011

Fraunhofer USA

Fraunhofer Center for Sustainable Energy Systems

ENERGY CONSUMPTION OF CONSUMER ELECTRONICS IN U.S. HOMES IN 2010

FINAL REPORT TO THE CONSUMER ELECTRONICS ASSOCIATION (CEA)

December 2011

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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 recorders
EP	Electro-photographic
EPA	U.S. Environmental Protection Agency
EuP	Energy-using product, European Union Ecodesign Directive
HD	High definition
IAD	Integrated Access Device
LBNL	Lawrence Berkeley National Laboratory
MFD	Multi-function device
NA	Not applicable
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 2010. Relative to other energy end uses, the CE end use characteristics 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 2010. Our effort focused on 17 priority products, shown in Table ES-1. In addition, we developed preliminary estimates for 17 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**	
Audio Video Receivers	Set Top Boxes	Desktop PCs	Networking Equipment
Blu-ray Player	Cable	Portable PCs	Integrated Access Device
DVD Devices	Satellite	Computer Speakers	Modem
Televisions	Telco	Monitors	Router
Video Game Consoles	Stand-alone	Printers + MFDs	

Notably, we developed a phone survey to assess the usage of CE in greater detail, with a particular focus on refining our understanding of personal computer and monitor usage by mode. Subsequently, we used the survey responses from 1,000 demographically representative households as inputs into detailed usage-by-mode models.

Overall, we estimate that annual electricity consumption (AEC) of residential CE was 193 TWh in 2010, an amount equal to 13.2% of residential electricity consumption and 9.3% of residential primary[2] energy consumption. Figures ES-1 and ES-2 show the breakdown in 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 3.4 kWh of primary energy (DOE 2011).

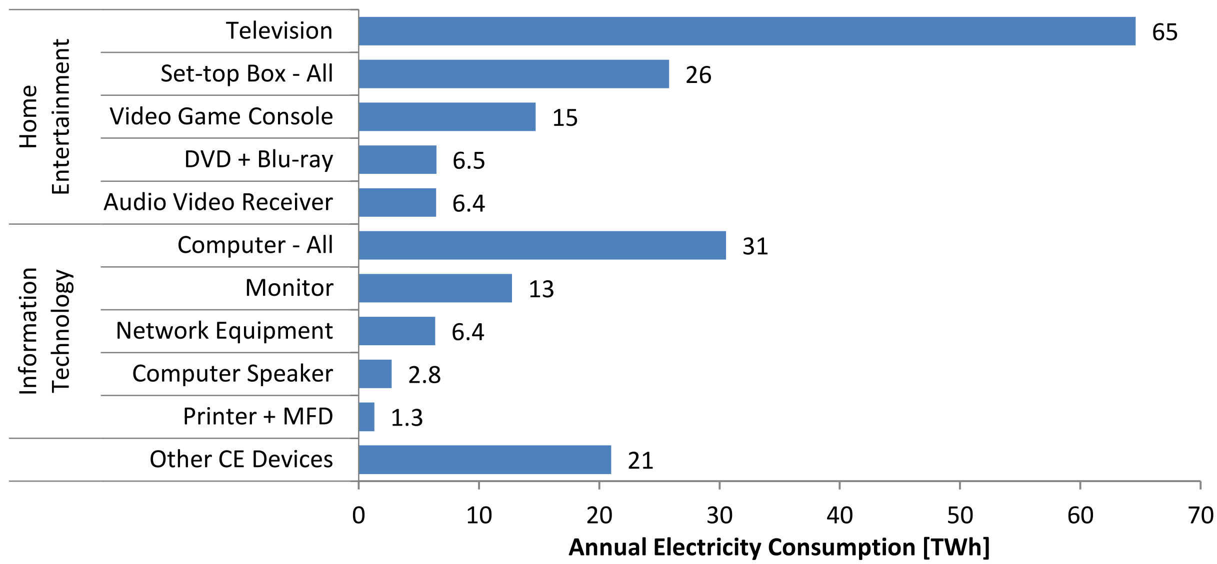

Figure ES-1: Residential CE annual electricity consumption by category

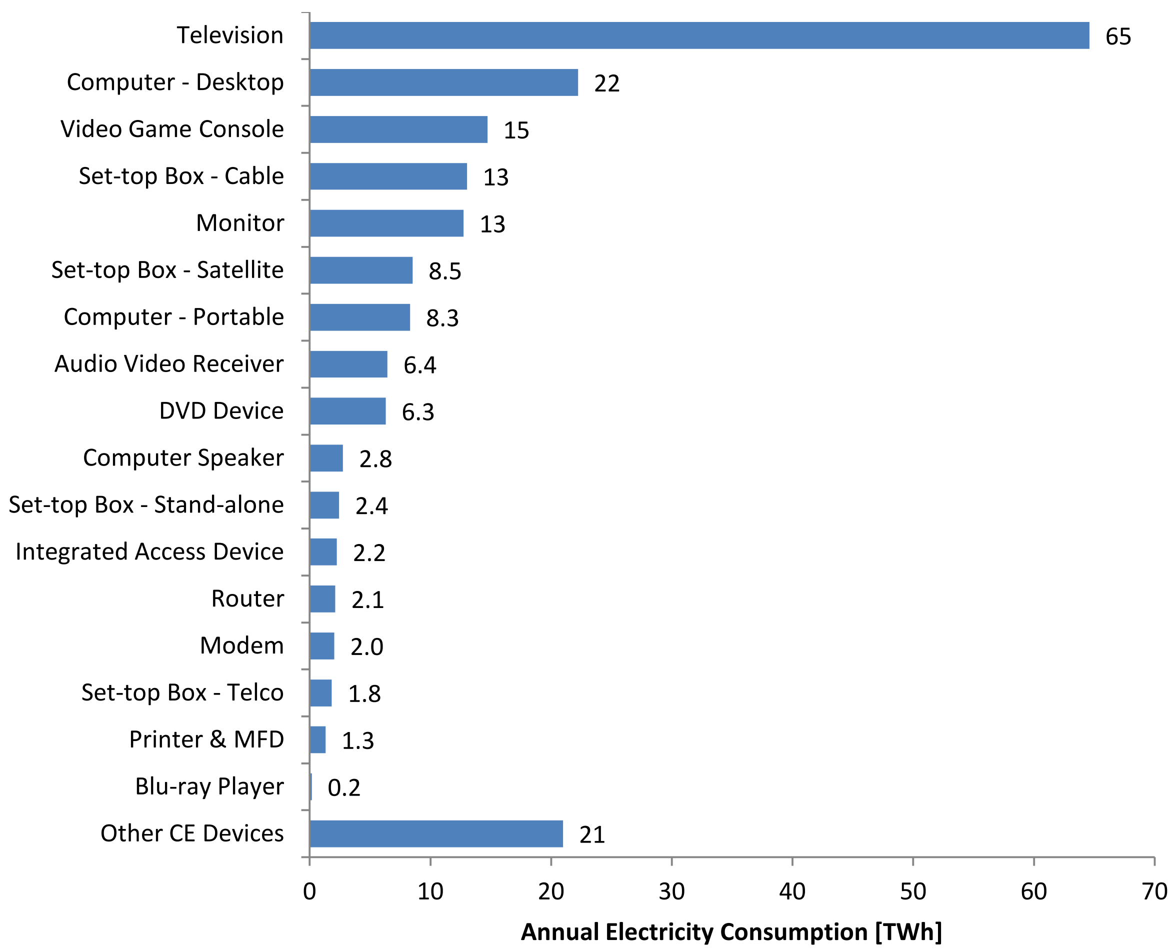

Figure ES-2: Residential CE annual electricity consumption by device

A limited number of CE categories accounted for the majority of CE electricity consumption. Notably, televisions accounted for 34% of residential CE electricity consumption, PCs 16%, and set-top boxes 13%. The AEC of all the priority categories equals 90% of 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 lower UEC, shown in Figure ES-3.

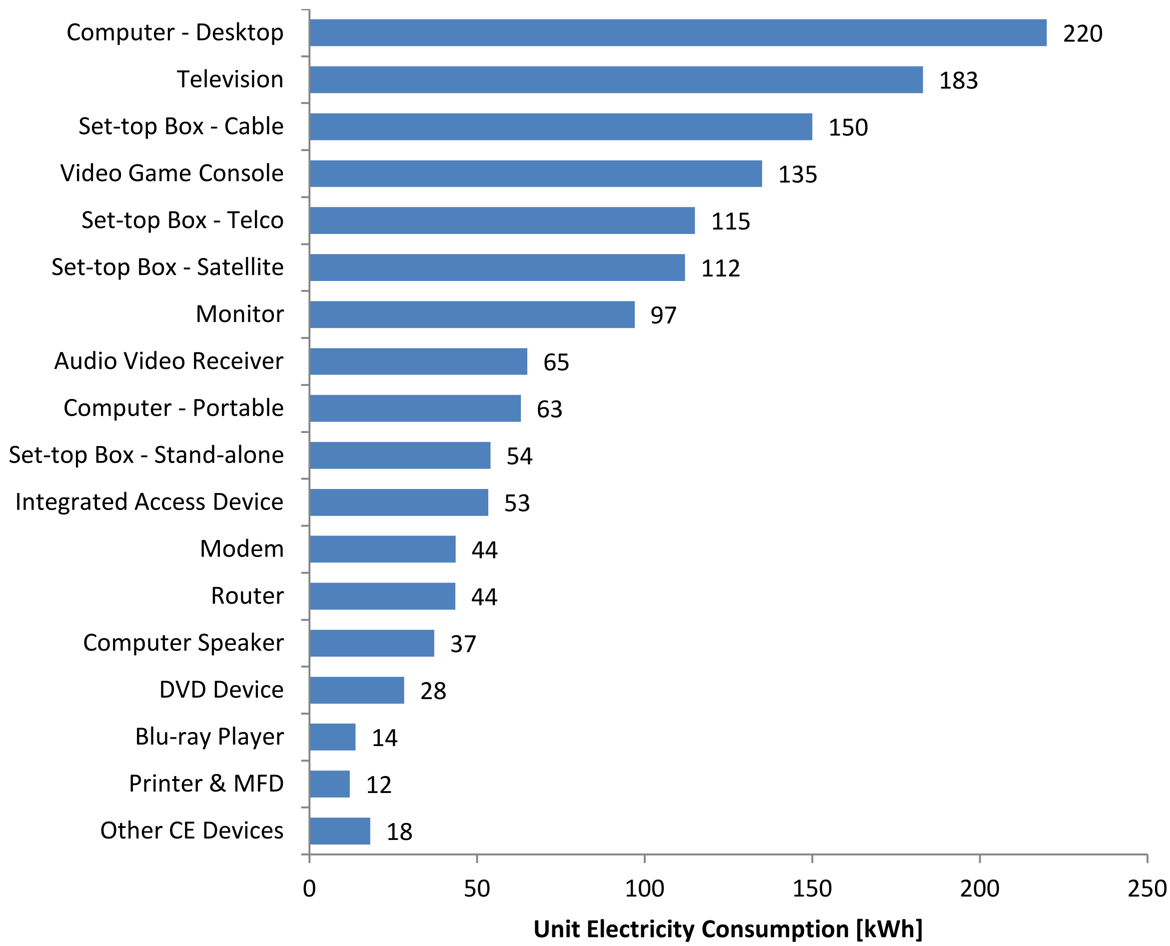

Figure ES-3: Unit electricity consumption (annual) values for categories evaluated in detail

The active mode accounts for 76% of the total AEC of all the categories evaluated in more detail, while the idle, sleep, and off modes account for 5%, 2%, and 17%, respectively. This masks large differences in the distribution of UEC by mode among different CE products.

1 Introduction

The Consumer Electronics Association (CEA) commissioned this study to quantify the electricity consumption of consumer electronics (CE) in U.S. households in 2010 as a follow-up to the initial study it commissioned in 2006 (Roth and McKenney 2007). 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 CE energy consumption study:

1. Develop preliminary Annual Electricity 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 products
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 described 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.

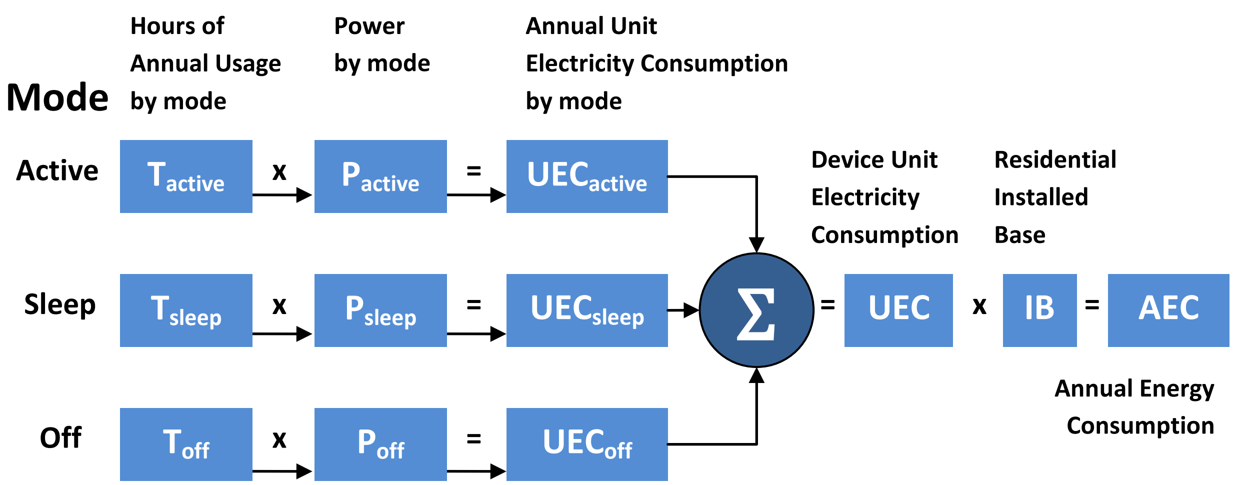

Figure 2-1: UEC and AEC calculation methodology (ADL 2002)

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 2010 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
- Measurements by CEA member companies (foremost for TVs)
- Targeted measurements by Fraunhofer

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

In particular, we used the CE Usage Survey responses from 1,000 demographically representative U.S. households as inputs into more refined models to assess computer and monitor usage (see Appendix B). We posed more questions for both computers and monitors because they have higher AEC values that have notably high – and are highly sensitive to – uncertainties in their usage (e.g., whether or not they are left on overnight and during the day, and whether or not their power management is enabled to enter a low-power sleep mode).

[3] Although very useful, prior field measurement campaigns have fallen 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 by Consumer Electronics in U.S. Homes

3.1 Summary

Residential consumer electronics consumed approximately 193 TWh of electricity in 2010 (see Table 3-1 and Figure 3-1), an amount equal to 13.2% of residential electricity consumption and 5.1% of total U.S. electricity consumption in 2010. This translates into 9.3 and 2.1% of residential and U.S. total primary energy consumption[4], respectively (DOE 2011).

Table 3-1: Residential CE energy consumption summary

Device	UEC [kWh/yr]	Installed Base [millions]	AEC [TWh]
Audio Video Receivers	65	99	6.4
Blu-ray Players	14	12	0.2
Computers			
Desktop	220	101	22
Portable	63	132	8.3
Computer Speakers	37	74	2.8
DVD Devices	28	223	6.3
Monitors	97	131	13
Network Devices			
Integrated Access Device	53	42	2.2
Modem	44	46	2.0
Router	44	49	2.1
Printers & Multi Function Devices	12	113	1.3
Set-top Boxes			
Cable	150	87	13
Satellite	112	76	8.5
Stand-alone	54	45	2.4
Telco	115	16	1.8
Televisions	183	353	65
Video Game Consoles	135	109	15
Other CE Devices	18	1,160	21
Total	**-**	**2,870**	**193**

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

[4] Using 10,686 Btu of primary energy per kWh of electricity (DOE 2011).

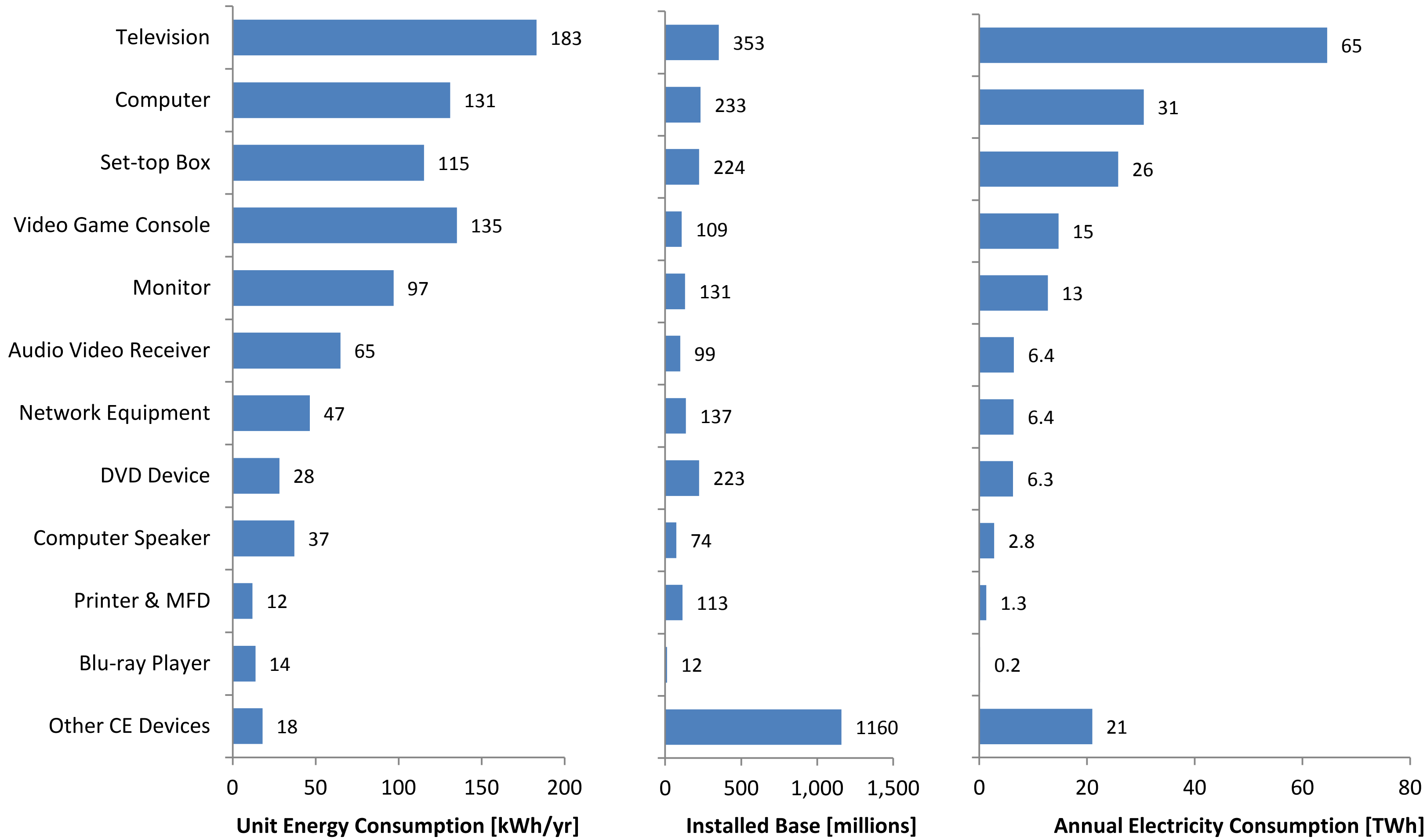

Figure 3-1 : UEC, installed base, and AEC of CE categories evaluated in detail

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 products 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 products selected for further analysis. Since a relatively small number of CE products 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 selected for analysis

Analyzed in Highest Detail	Analyzed in Lesser Detail
Audio-Video Receiver	Camcorder
Blu-ray Player	Compact Audio
Computer Speaker	Copy Machine - Stand-alone
Computer - Desktop	Cordless Phone
Computer - Portable	Digital Camera
DVD Player	Digital Picture Frame
DVD Player & Recorder	Fax Machine - Stand-alone
Modem	External Storage Device
Monitor	Home Theater in a Box
Printer - Multi-function Device	Mobile Phone
Printer - Stand-alone	Personal Video Recorder - Stand-alone
Router	Portable Audio
Set-top Box – Cable	Projector
Set-top Box – Telco	Radio
Set-top Box – Satellite	Scanner - Stand-alone
Set-top Box - Stand-alone	Telephone Answering Device
Television	Video Cassette Recorder
Video Game Console	

3.3 Audio Video Receivers

3.3.1 Current Energy Consumption

Audio video receivers (AVRs) combine the functions of three components: a radio tuner, a preamplifier, and a multi-channel amplifier. The preamplifier switches the selected audio/video source, processes the signals, and routes the signals to the selected TV or monitor and distributes the sound signals to the correct amplifier channels. The multi-channel amplifier powers the speaker system (Silva 2011). In general AVRs come as part of a bundled group of devices called a home theater in a box (HTIB), or they may be connected to separately-purchased audio and video components. In both cases the AVRs typically powers the speakers, whereas the subwoofer is powered separately. Stereo receivers have two channels of amplification, while AVRs may have more than two. This section does not cover AVRs that are part of a HTIB package, as these are analyzed separately in the "other devices" section.

3.3.1.1 Installed Base

The installed base of AVRs is difficult to determine from surveys directly, as many survey respondents might be aware of having paired speakers in their household, but not necessarily of the presence of an AVR. Therefore, we compared different data sources to develop our estimate for the installed base of AVRs.

According to CEA market research (CEA 2010), 61% of U.S. households had surround sound capabilities as of May 2010, "either through home theater-in-a-box (HTIB) packages, soundbars or a combination of AVRs with surround sound processors, subwoofers and paired speakers that are used in a surround sound setup." The report indicates a household penetration rate for "A/V Receiver w/ surround sound processor" of 38% and 1.3 devices per owner household, which is substantially lower than the reported household penetration rate for paired speakers (56%, 2.2 units per owner household), which includes HTIBs. The household penetration rate of 38% for AVRs with surround sound reflects a lower bound for AVRs, as it does not include stereo receivers. The more recent CE Usage Survey (Appendix A, question M1B) asked if the household had an amplifier or speaker system, such as external speakers for a TV or a stereo system (excluding portable stereos or speakers used with computers) plugged in. The numbers, shown in Figure 3-2 are consistent with the (CEA 2010) data: 53% of the respondents report having such a system; including HTIBs, the average number of systems per owner households is 2.1 AVRs. Thus we estimate an installed base of 129 million AVRs (including 30 million HTIBs), of which 57 million have surround sound capabilities (CEA 2010) and 42 million are stereo receivers.

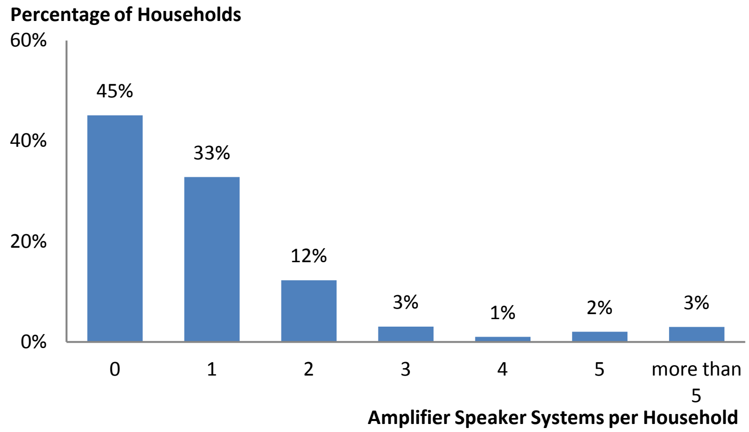

Figure 3-2: Ownership of amplifiers and speaker systems (CE Usage Survey)

Whereas the installed base of HTIBs has not increased, the number of stand-alone AVRs has increased in over the last years. CEA reports that individual components have experienced significant gains in household penetration rates, which "suggests that consumers may be trying to complement their HDTV viewing with better quality audio" (CEA 2010).

This trend is also visible in the number of channels in the past years; more households appear to install AVRs with multiple channels (5.x, 7.x or 9.x channel systems - x indicating the number of subwoofer channels, ranging from 0 to 2). Figure 3-3 shows the fraction of 7.1 channel receivers among the units sold since 2003 (CEA 2011; data for other system types not available). Figure 3-4 presents a breakdown of the current best-selling AV-receiver models on Amazon.com (by model type, not by units per model type; as of June 2011). The fraction of 7.1 channel units is clearly higher than according to the CEA data; in part, this may reflect the fact that types were only broken down in channel categories by number of model types among the top selling 50 models, not by the number of units sold of each model. We use the CEA data for our estimates; nonetheless, the Amazon.com data confirm the trend away from 2.0 channel units and towards models with multiple channels. For this analysis, we estimate that approximately one-third of AVR systems have multiple channels/at least one subwoofer channel, noting appreciable uncertainty in the estimate.

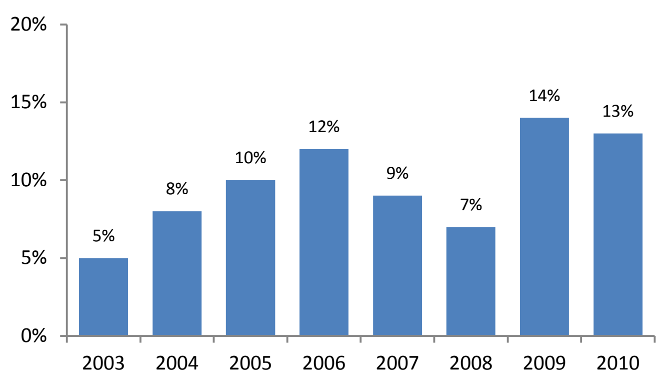

Figure 3-3: Percentage of 7.1 channel units among AVRs sold (CEA 2011)

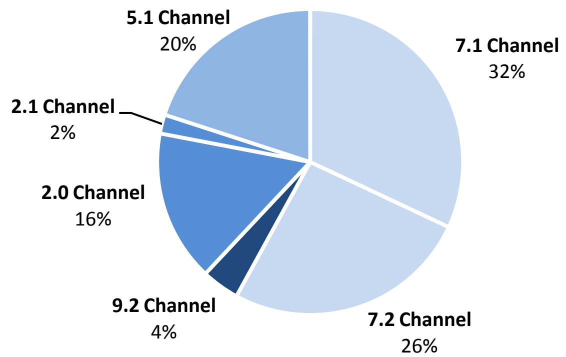

Figure 3-4: Speaker system configuration of 50 best-selling Amazon.com models (June 2011)

Based on these sources, we estimate the installed base and household penetration rates shown in Table 3-3.

Table 3-3: Installed base of audio video receivers

Installed Base [millions]	Penetration	Sources
99	50%*	CE Usage Survey, CEA 2010, CEA 2011

*Estimate; surround sound AVR penetration rate is 38%, HTIB+AVR penetration rate is 53%, 20% HTIB penetration rate (CEA 2010), 27% estimated stereo AVR penetration rate.

3.3.1.2 Unit Energy Consumption

We characterize amplifier energy consumption using three main operating modes:

- *Active* – the amplifier is receiving an audio signal
- *Sleep* – The AVR is plugged in, but not receiving an audio signal; it can be activated by remote switch, internal sensor or a timer
- *Off* – The amplifier has been turned off, but remains plugged in, and can only be activated by user actuation on a manual power switch

3.3.1.2.1 Power Draw

The power draw of the amplifier depends on its efficiency, on the speakers connected to it and, in active mode, on the listening volume. Prior study suggests that, within a reasonable listen volume range, the volume setting has limited impact on active power draw (Rosen and Meier 1999). A recent measurement study published by the German consumer organization, however, found an increase from 46 W (silent) to 75 W (loud) on average for 12 recent AVR models measured[5] (Stiftung Warentest 2009). Therefore, we also distinguish between active idle (active, volume muted) and active playing (at 18dB).

[5] The report measured the average power draw of 6-hour user profiles, 2 of which in stereo operation at 84dB at 1m from the speaker, 4 hours in several usage profiles (predefined music and films).

Foster Porter et al. (2006) reported an average power draw of 50 W in active mode for the 18 devices measured. A more recent in-store measurement campaign carried out in 2008-9 in Australia (EnergyConsult 2010) reports an average power draw of 43 W in active idle mode and 0.7W in sleep mode. Another in-store measurement campaign carried out in Australia (NAEEEP 2006) included 45 AVRs; they drew an average of 44 W (active idle), 1.8 W (sleep) and 0.2 W (off mode). Only 11 of the 45 models had, however, an off mode. Yet another Australian in-home measurement campaign (Energy Efficient Strategies 2005) that included 15 models found an average of 35.3 W in idle, 3.1 W in sleep, and 0.3 W in off mode.

We carried out an in-store measurement campaign at a local electronics retail store and measured all the units that were plugged in. We measured the power draw of nine AVRs in off, active idle and active playing mode; all were connected to the same speaker system. The sample set consisted of three 7.0 channel receivers, four 7.1 channel receivers, one 7.2 channel unit and one 2.1 channel receiver, thus the sample clearly overrepresented the fraction of 7.x channel speakers as compared to the installed base. The in-store measurements were carried out with a calibrated sensor system consisting of a computer and National Instruments LabVIEW software, a signal conditioning and sensor circuit and a NI Data Acquisition (DAQ) device (NI USB-6353). The DAQ has a maximum sampling rate of 1MS/second for multichannel sampling, and 16-bit resolution. The voltage sensing circuit is a voltage divider made from two resistors (100kOhm resistor and a 1kOhm). The current sensor is a Pearson Current Monitor model # 411 (Palo Alto, CA). All measurements were carried out one after the other by the same team at the same location (conditioned store environment).

The values measured in off mode are consistent with the values found by previous studies. The active (both active playing and active idle) mode consumption, however, was substantially higher. We found an average active idle consumption of 74 W for these units, and similar to the results of the German consumer organization study, we found that the volume has a significant impact on the power draw: the average power consumption when playing at normal room volume was substantially higher (91 W) than in active idle (74 W). We therefore conclude that most prior studies measured devices with fewer channels and suggest that power draw measurements should also be carried out at a (to be) specified volume that reflects typical usage, and not just in mute, which might bias the measurement results.

Therefore, we estimate a mean active (active idle and active playing combined) power draw of 44 W for the majority (80%) of speaker systems, but a mean of 85 W for an estimated 20%[6] of systems with multiple channels.

3.3.1.2.2

3.3.1.2.3 Usage

According to CE Usage Survey data, shown in Figure 3-5, AVR systems are used 2.6 hours per day, but 48% of them are not used on typical day. Those systems that are used are typically active for 6.1 hours. Given that they can be used both for audio and video home entertainment and given TV usage, 2.6 hours in active mode seems quite low. For comparison, an in-home measurement campaign by Foster

[6] This estimate has high uncertainty.

Porter et al. (2006)[7] found that AVRs spend 25% of the day in active mode, 75% in standby (idle) mode and 0% in off mode. Given that for the majority of AVR models, *off* mode is not even present, we estimate that AVRs spend the vast majority of time in idle mode and are put in *off* mode only 0% to 5% of the time when the device is not in use. The ENERGY STAR specification version 2.0 for Audio Products that became effective in November 2009 requires qualifying devices to have the default auto power-down setting at two hours maximum, thus the time spent in active standby mode by ENERGY STAR devices might be smaller. We do not, however, have data on the market penetration of ENERGY STAR computer speakers since the specification took effect.

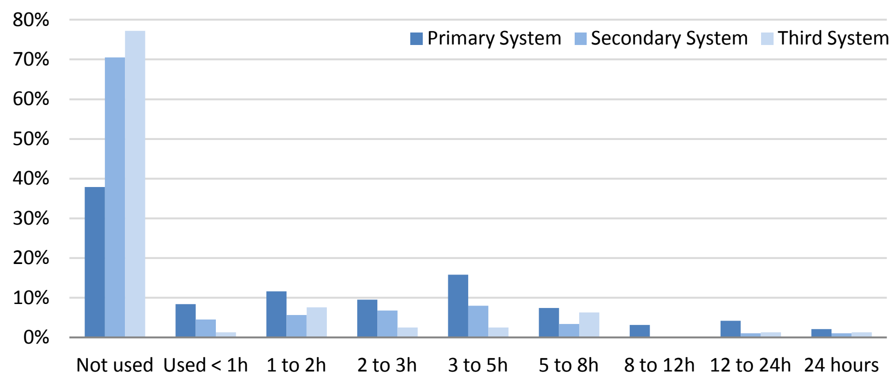

Figure 3-5: Daily usage of audio video receiver systems (CEA phone survey)

Our UEC estimate for audio video receiver systems is 65 kWh/yr, shown in Table 3-4.

Table 3-4: UEC calculation for audio video receivers

	Active	Sleep	Off	Total	Sources
Power [W]	52	2	1	-	Foster Porter et al. 2006, EnergyConsult 2010, NAEEEP 2006, Energy Efficient Strategies 2005, Fraunhofer in-store measurement (2011)
Usage [hr/yr]	950	7,610	200	**8,760**	CE Usage Survey, Foster Porter et al. 2006,
UEC [kWh/yr]	50	15	0.2	**65**	RASS 2009

3.3.1.3 Annual Energy consumption

We estimate that AVRs consumed about 6.4 TWh in 2010, as shown in Table 3-5.

Table 3-5: AEC summary for audio video receivers

UEC [kWh/yr]	Installed Base [millions]	AEC [TWh]
65	99	6.4

[7] Based on a time series measurement campaign in 75 homes, 18 receivers monitored.

3.3.2 Prior Energy Consumption Estimates

The Australian in-store measurement campaign was carried out since 2002, showing that power draw in active and off mode has remained quite stable over this period, whereas sleep-mode power draw has decreased, as shown in Table 3-6. Prior estimates are given in Table 3-7.

Table 3-6: Power measurements of audio video receivers in Australian stores (NAEEP 2006)

	2002	2003	2003-04	2004-05	2005-06	2008-09
Active standby [W]	48	44	39	41	44	43
Sleep [W]	2.1	2.0	1.7	1.3	1.8	0.7
Off [W]	0.2	0.2	0.2	0.2	0.2	NA
Devices measured	26	40	71	51	44	4

Table 3-7: Prior energy consumption estimates for audio video receivers

	Units	Power [W]			Usage [hr/yr]			UEC	AEC	
Year	[millions]	Active	Sleep	Off	Active	Sleep	Off	[kWh/yr]	[TWh/yr]	Source
2010	99	52	2	1	950	7,610	200	55	6.4	Current
-	-	50	3.3	-	2,190	6,570	131	-	-	ECOS 2006
2005	-	35[a]	3.1	0.3	-	-	-	-	-	Energy Efficient Strategies 2006
-	-	44[a]	1.8	0.2	850[a]	4,800	920	-	-	NAEEEP 2006[b]
-	-	35/33[a]	1.8	-	-	-	-	-	-	LBNL 1999

a Active-standby mode.

b Report gives percentage excluding active usage. Hours indicated here account for 25% of active use.

3.3.3 References

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3.4 Blu-ray Disc Players

3.4.1 Current Energy Consumption

This section describes the number of stand-alone or set-top Blu-ray disc players, typical usage patterns, and average power draw estimates in the U.S. in 2010. Computers or video game consoles with the Blu-ray disc playback functionality are covered in a separate section.

3.4.1.1 Installed Base

Since the end of the high-definition optical disc format war between HD-DVD and Blu-ray disc in 2008, this category is growing rapidly. The number of Blu-ray disc players is expected to increase sharply over the next years, with 18% of U.S. households planning to buy a Blu-ray disc player in 2010 alone (CEA 2010a).

According to CEA Market Research, (CEA 2010), the installed base of Blu-ray disc players was 12.3 million units as of May 2010 or a household penetration rate of 9%, compared to 4.4 million units installed in May 2009 (CEA 2009 and CEA 2010); these numbers are based on shipment data, not household survey data. Based on sales data for the first half of the year, we assume an installed base of 13 million units as of July 2010, see Table 3-8. Other sources suggest higher installed base figures and penetration rates, e.g., The Digital Entertainment Group reports 19.4 million homes with Blu-ray disc players as of July 2010, but this includes PC drives and PlayStation 3 consoles.

The CE Usage Survey data suggest ownership rates of 17%. The data discrepancy might be partly due to artificially high self-reported ownership, which is not unusual for newer product categories with limited market penetration. Specifically for Blu-ray disc players, some respondents might count their video-game consoles as Blu-ray disc player – since several models have this functionality, respondents might confuse them with DVD players. In addition, the CE Usage Survey was conducted in October 2010. Given the growth of this product category, the number of households who had a Blu-ray disc player in October may have been somewhat higher than the 11% estimate for earlier in the year.

Table 3-8: Blu-ray disc players installed base

Installed Base [millions]	Penetration	Sources
13	11%	CEA 2009, CEA 2010

3.4.1.2 Unit Energy Consumption

Blu-ray disc players can be characterized by the following three main operating modes:

- *Active*– the device is playing
- *Idle*– the device is on but no motor functions are being performed, the device is paused
- *Sleep* – The device has entered its low power consumption state

Power draw by mode is given in Table 3-9. Active mode consumption for Blu-ray players is higher than for DVD players.

Table 3-9: Power draw by mode for Blu-ray disc players

Power [W]			
Active	Idle	Standby	Sources
30	16	0.5	Cnet 2010, Oeko-Institut 2009

Most Blu-ray players don't have a dedicated button to switch them off entirely. Unless they are unplugged or connected to a power strip that is switched off, which we assume to be rarely the case, they spend most of their time in *sleep* state.

Some Blu-ray disc players have an additional quick-start mode, which results in a higher sleep state consumption of approximately 9 W which increases the UEC of those devices considerably. However, as only some Blu-ray disc players have this feature and as they are not shipped with this mode as the default setting, we assume that the majority of Blu-ray players do not have this setting enabled.

In July 2010, a new ENERGY STAR specification that includes Blu-ray disc players became effective, which specifies requirements for auto power down default values, as well as power consumption limits for active, idle and off mode consumption limits (EPA 2010).

Figure 3-6 summarizes Blu-ray disc player usage responses from the CE Usage Survey (see Appendix A). Based on those responses, we estimated the average usage values in Table 3-10.

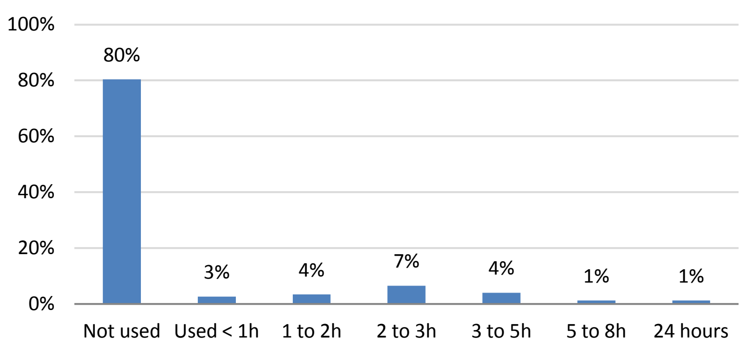

Figure 3-6: Daily usage of Blu-ray disc players, CE Usage Survey

Table 3-10: UEC calculations for Blu-ray disc players

	Active	Idle	Standby	Sources
Power [W]	30	16	0.5	CE Usage Survey 2010,
Usage [hr/yr]	300	30	8,430	Cnet 2010, Oeko-Institut 2009
UEC [kWh/yr]	9.0	0.5	4.2	

3.4.1.3 Annual Energy Consumption

Blu-ray disc players consumed about 0.2 TWh in 2010, as shown in Table 3-11.

Table 3-11: AEC summary for Blu-ray disc players

UEC [kWh/yr]	Installed Base [millions]	AEC [TWh]
13.7	12.3	0.2

3.4.2 Prior Energy Consumption Estimates

As Blu-ray disc players are a recent product category, the number of prior studies is limited, see Table 3-12. For comparison, we included one study from Germany (Oeko-Institut e.V., 2009).

Table 3-12: Prior energy consumption estimates for Blu-ray disc players

	Units	Power [W]			Usage [h/yr]			UEC	AEC	
Year	[millions]	Active	Idle	Off	Active	Idle	Off	[kWh/yr]	[TWh/yr]	Source
2010	12.3	30	16	0.5	300	30	8,430	13.7	0.2	Current
2010	-	35	-	0.5	-	-	-	-	-	Cnet 2010[a]
2010	-	18.5	15.9	0.2	-	-	-	-	-	Sust-it 2010[b]
2009	-	26.3	-	0.5	730	-	8,030	23.6	-	Oeko-Institut 2009

a Average of 8 devices measured.
b Average of 62 devices listed.

3.4.3 References

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3.5 Desktop Computers

3.5.1 Current Energy Consumption

This section covers the energy use of desktop computers. A relatively new subcategory is nettops, or mini desktop computers, which are devices designed for basic tasks that draw less power than standard desktop computers. We have included these in the installed base and consumption estimates of this section. This section also treats all-in-one computers, those with a built in display, (e.g., iMac), as a unique device class, since they must power both the monitor and computer.

3.5.1.1 Installed Base

According to the CE Usage Survey, the installed base of desktop computers is 101 million units, as shown in Table 3-13. The distribution of desktop computers is shown in Figure 3-7: the number of computers per household (left) and the desktop computer usage priority (right). Usage priority refers to the computer's usage rank within the household, (e.g., a primary computer is the most-used computer in a household, and 71% of all desktop computers were primary computers).

Table 3-13: Installed base of desktop computers

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

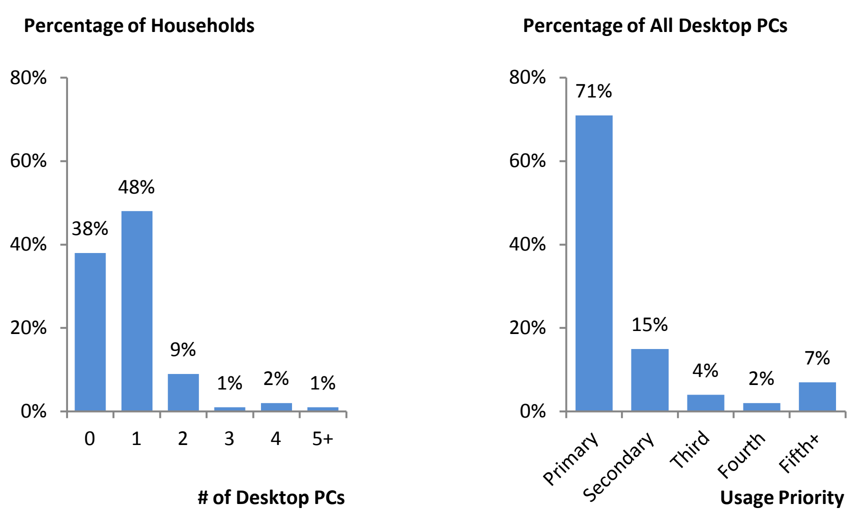

Figure 3-7: Ownership of residential desktop computers (CE Usage Survey)

A CEA market research report from May 2010 (CEA 2010a) estimates a considerably higher installed base of 128 million units. We reason that survey wording is responsible for the difference: whereas the CE Usage Survey (Appendix A) asked about units that were *plugged in* during the past month, the CEA market research report survey asked about all units *owned* by the household, thus including retired devices that are no longer plugged in, which are irrelevant to electricity consumption.

Similarly, (CEA 2010a) finds that 75% of U.S. homes have at least one desktop computer, whereas only 60% of CE Usage Survey respondents report having had at least one plugged in within the past month. Although the average number of desktop computers in households with at least one desktop computer has increased from 1.2 in 2005 to 1.5, the share of desktop computers relative to all (i.e., desktop and portable) computers has declined from 70% to 56%. Considering only plugged-in units, their share has decreased to 43%, while their portion of sales dropped from 54% in 2006 to 24% in 2009 (CEA 2010b).

3.5.1.2 Unit Energy Consumption

Desktop computers can be characterized by three operating modes:

- *Active* – Device is being actively used (active-used) or is not actively being used but remains on and has not entered sleep (active-idle)
- *Sleep* – Device has entered a power saving mode, but had not been turned off
- *Off* – Device is turned off but remains plugged in

The *active* mode power draw values used are more typical for what the ENERGY STAR program refers to as the active-idle mode, i.e., where the PC is on but is not actively being used and has not entered sleep mode. Prior studies suggest that the idle mode accounts for most active mode energy consumption by Computers (e.g., Herb et al. 2006).

3.5.1.2.1 Power Draw

Table 3-14 shows a summary of the average power draw by mode for desktop computers. These values are based on EPA data (EPA 2010a) and several recent studies.

Table 3-14: Power draw by mode of desktop computers

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

* Active-idle mode.

EPA (2010a) includes data for all ENERGY STAR qualified desktop models submitted to EPA as of February 2010, and lists 607 desktop computer models (115 V); their average power draw in active-idle mode is 47 W, in sleep mode 2.3 W and in off mode 1.1 W. According to EPA data (EPA 2010b), 27% of desktop computers shipped in 2009 met the ENERGY STAR specification. These values must be interpreted with care when drawing conclusions about the installed base of desktop computers.

Recent studies on power draw by mode include Bensch et al. (2010), that found an active[8] mode power consumption of 70 W and an off mode power consumption of 2.4 W for desktop computers based on a in-home data collection that included 42 devices. A field study of *office* electronic devices (Meister et al. 2010) reports an average power draw of 79 W in active-used, 46 W in active-idle, 3.2 W in sleep and 2.2

[8] As several of the other studies listed, the report does not distinguish between active-used and active-idle; some reports (e.g. Roth and McKenney 2007) point out that the reported number represents active-idle values.

W in off mode. SELINA (2010) reports a median power consumption of 3.1W in sleep mode and 1.6 W in off mode for 45 models measured in stores. Foster Porter (2006) reports an average power draw of 70 W in active mode, 17 W in sleep mode and 4.4 W in off mode. The European PROSA study (Quack 2007) found 60 W in active mode, 25 W in sleep mode and 4 W in off mode. Roth & McKenney (2007) estimated 75 W for active mode, 4 W for sleep mode and 2 W for off mode.

One prior study found that nettop computers (compact desktop computers) consume an average of 25 W in active-idle mode (PROSA 2010).

3.5.1.2.2 Usage

We developed usage by mode estimates based on the CEA usage survey 2010 and the usage model explained in Appendix B. As with portable computers, we expect that the power draw values are relatively accurate and that the usage by mode estimates have greater uncertainty. Table 3-15 summarizes our estimates for typical usage by mode of desktop computers. Note that these values reflect actual usage (active-used) and not the total time spent in active mode, which includes active-idle time.

Table 3-15: Daily usage (actively-used) of desktop computers (CE Usage Survey)

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

The usage survey indicates that approximately 60% of desktop computers are always or often powered down at night, which is less than for portable computers (70%). The median default time to sleep of ENERGY STAR qualified desktop models submitted to EPA as of February 2010 is 15 minutes (EPA2010a). As with desktop computers, we used the delay time for the computer to respond reported by survey respondents as a proxy for power management settings (see Appendices A and B). This yields the breakdown for desktop computer power management settings shown in Figure 3-8, which are quite similar to portable computers.

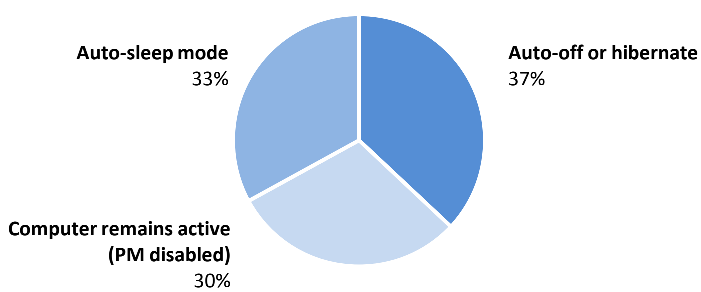

Figure 3-8: Power management settings of desktop computers (CE Usage Survey)

Figure 3-9 compares the calculated time spent by desktop computers in *on* mode to the usage indicated by the survey respondents. On average, 54% of the time spent in on mode is not due to usage, but to the fact that the computer is neither switched off manually, nor disabled by power management, compared to 45% for portable computers. These findings are consistent with previous reports (Roth and McKenney 2007). On average, this additional time spent in *on* mode accounts for about 111 kWh per desktop computer per year.

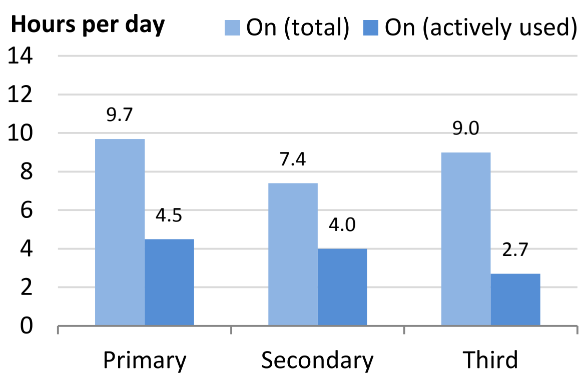

Figure 3-9: Daily usage (actively-used) and total active usage (active-used + active-idle) for desktop computers by usage priority (CE Usage Survey)[9]

Daily desktop computer usage by mode is given in Table 3-16 for weekdays and weekend days, and annual usage is given in Table 3-17 by weighting weekend and weekday usage across all desktop computers. A usage summary is shown in Figure 3-10. Although the sample of third-most used desktop computers was too small to obtain meaningful data (N=27), 93% of desktop computers are used as a primary or secondary computer.

Table 3-16: Time spent in usage modes by desktop computers (CE Usage Survey)

Usage	Primary Computer		Secondary Computer		Weighted
[h/day]	Weekday	Weekend	Weekday	Weekend	Average
Active	9.9	7.3	9.1	7.8	**9.4**
Sleep	5.8	7.3	6.2	5.9	**5.9**
Off	8.3	9.4	8.7	10.3	**8.7**

Table 3-17: Annual usage by mode for desktop computers

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

[9] The high *on* mode time for 3rd computers is based on a small sample size (n=27) and, thus, likely has appreciable uncertainty. On the other hand, primary and secondary computers account for 93% of all desktop computers, so the impact of this uncertainty on the overall AEC of desktop computers is relatively small.

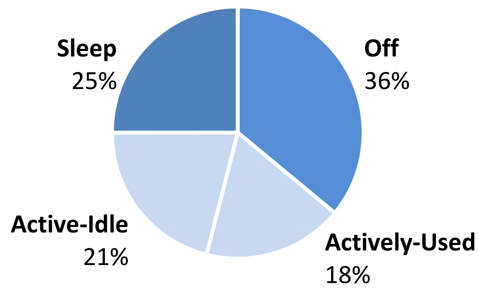

Figure 3-10: Fraction of time spent by power mode for desktop computers (CE Usage Survey)

For comparison, the weighting of operational modes used in the current ENERGY STAR specification (version 5.2, EPA 2010) estimates 55% of the time spent in off mode, 5% in sleep mode and 40% in idle mode for conventional desktop computers, as well as 40% (off), 30% (sleep) and 30% (idle), respectively, for proxy desktop computers that maintain full network connectivity.

3.5.1.3 Unit Energy Consumption

Together, the breakdown of desktop computers installed and their estimated power draw by mode and the time spent in each mode calculated with our computer usage model yield a UEC of 224 kWh/year. Table 3-18 summarizes the UEC calculation.

Table 3-18: UEC calculation for desktop computers

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

The latest ENERGY STAR specification for computers (version 5.2, effective July 2009) has increased the stringency of several values. While maximum active-idle levels for desktop computers in the previous version ranged from 50 to 95 W, these power draw by mode requirements have been replaced with the standardized TEC approach (typical energy consumption; for details on this approach, please refer to EPA 2009b).

3.5.1.4 Annual Energy Consumption

Based on the prior estimates for the installed base, power draw by mode, and annual usage by mode, we calculate that desktop computers consumed about 22 TWh in 2010, as shown in Table 3-19.

Table 3-19: AEC summary for desktop computers

UEC [kWh/yr]	Installed Base [millions]	AEC [TWh]
220	101	22

3.5.2 Prior Energy Consumption Estimates

The current AEC estimate of 22 TWh is somewhat higher than in prior studies, as shown in Table 3-20. A larger installed base of desktop computers is responsible for their increase in AEC, even though sales of portable computers have eclipsed those of desktop computers. The main underlying trends are a shift from desktop to portable computers, a decrease in average power draw by mode, and an increase in active-mode usage.

Table 3-20: Prior energy consumption estimates for desktop computers

	Units	Power [W]			Usage [hr/yr]			PM*	UEC	AEC	
Year	[millions]	Active	Sleep	Off	Active	Sleep	Off	Enabled	[kWh/yr]	[TWh/yr]	Source
2010	101	60	4	2	3,420	2,150	3,190	70%	220	22	Current
2006	90	75	4	2	2,954	1,779	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.

The 2009 REC (EIA 2009) found a considerably lower household penetration rate of 42% for desktop computers. Compared to the most recent studies (e.g., Roth & McKenney 2007), the UEC has decreased moderately, primarily due to a substantial decrease in active-mode power draw that has more than offset an increase in the time spent in on mode.

In spite of increased usage and processing power, UEC has decrease in the past years mainly due to more widespread power management default settings and decreases in active mode power draw. These trends reflect changes in the last two versions of the ENERGY STAR requirements for PCs (see also the Portable Computers section). Table 3-21 summarizes the two most recent ENERGY STAR specifications for computers; these are the most relevant to the current installed base.

Table 3-21: Evolution of the ENERGY STAR specification for desktop computers

Version	Effective Date	Maximum Mode Power Draw and other Specifications	Source and Comments
4.0	20 July 2007	• Active/Idle: ≤ 50/65/95W* • Sleep: ≤4W • Off: ≤ 2W • Internal power supply efficiency > 80% • External power supply meets ENERGY STAR EPS 1.0	ENERGY STAR (2007) • Includes higher active mode power draw levels for more powerful computers • Includes minimum power supply efficiency requirements
5.2	1 July 2009	• Internal power supply efficiency > 82/85/82% • External power supply meets ENERGY STAR EPS 2.0 • TEC < 148/175/209/234kWh	ENERGY STAR (2009c, 2009d) • More restrictive energy allowances

*Classification into 4 categories based on the number of physical cores, system memory and discrete GPU

3.5.3 References

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3.6 Portable Computers

3.6.1 Current Energy Consumption

This category includes notebook/laptop[1] computers, netbooks[2] and tablets. It does not include ebook readers or smart phones.

3.6.1.1 Installed Base

According to the CE Usage Survey data and based on (EIA 2009), the installed base of portable computers is 132 million units, as shown in Table 3-22, a dramatic increase from 39 million units in 2005 (TIAX 2006). The distribution of portable computers is shown in Figure 3-7: the number of portable computers per household (left) and the portable computer usage priority (right). Usage priority refers to the computer's usage rank within the household, (e.g., a primary computer is the most-used computer in a household, and 57% of all portable computers were primary computers).

Table 3-22: Installed base of portable computers

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

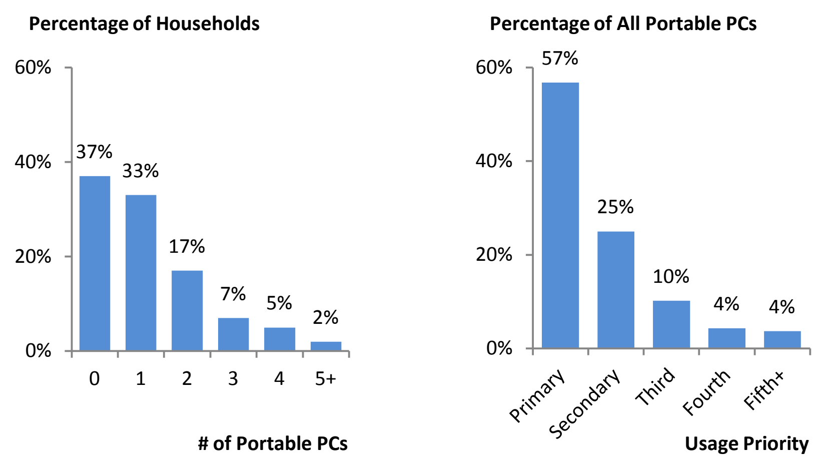

Figure 3-11: Ownership of residential portable computers (CE Usage Survey)

Findings are consistent with the CEA market research estimate (CEA 2010b) of 112 million laptop/notebook computers[10] and 18 million netbooks[11] (no number given for tablets). With an average number of 1.7 notebook computers and 1.3 netbook computers among owner households, respectively, the household penetration rate for notebook computers has risen to 58% from 25% in 2005 (TIAX 2006). As of May 2010, 12% of U.S. households had a netbook computer (CEA 2010a).

[10] Some sources distinguish between laptop and notebook computers, others use the term interchangeably. We'll consider them as one category and refer to them as notebook computers.
[11] As a rule of thumb, netbooks have a screen size between 7 and 10 inches and typically weigh 2.5 to 3.0 pounds. Other factors used for the differentiation are battery life, CPU power, optical drives and price.

In 2007 portable PC sales passed for the first time desktop PC sales (CEA 2010c) and their share continues to increase, representing 76% of computers shipped in 2009, compared to 46% in 2006 (CEA 2010b). In particular, the number of netbooks and tablet computers has risen sharply in 2009 and 2010. According to survey data, nearly 4 million people reported owning a tablet PC as of June 2010 (Rotmann Epps 2010); 2.5 million of these are iPads.

3.6.1.2 Unit Energy Consumption

Portable computers can be characterized by three operating modes:

- *Active* – Device actively used (active used) or not actively used and remains on and has not entered sleep (active-idle)
- *Sleep* – Device is on and has entered a power saving mode
- *Off* – Device is turned off but remains plugged in

The active mode power draw values used are typical of what the ENERGY STAR program refers to as the active-idle mode, i.e., where the PC is on but is not actively being used and has not entered sleep mode. Prior studies suggest that the idle mode accounts for most active mode energy consumption by computers (Herb et al. 2006).

3.6.1.2.1 Power Draw

Table 3-23 shows a summary of the average power draw by mode for portable computers. These values are based on EPA data (EPA 2010a) and several recent studies.

Table 3-23: Power draw by mode of portable computers

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

EPA (2010a) has data for all ENERGY STAR qualified notebook models submitted to EPA as of March 2010. It lists 2,249 notebook computer models in the relevant voltage category; their average power draw in idle mode is 11.7 W, in sleep mode 1.2 W and in off mode 0.6 W. According to EPAdata (EPA 2010b), 74% of portable computers shipped in 2009 met ENERGY STAR requirements. This value must be interpreted with care regarding the installed base of portable computers.

Recent studies on power draw by mode include Bensch et al. (2010), which found an active mode power consumption of 29.7 W and an off mode power consumption of 0.7 W for notebook computers based on a in-home data collection that included 17 devices. SELINA (2010) reports a median power consumption of 0.85 W in sleep mode and 0.55 W in off mode of 261 models measured in stores. Quack et al. (2009) report an active mode power draw of 8 W for netbooks, of 15-25 W for 14-17 inch notebooks and of 25-40 W for notebooks used for high-gaming or as graphic workstation. Foster Porter (2006) reports an average power draw of 21.9 W in on mode, 3.1 W in sleep mode and 1 W in sleep mode, the European PROSA study (Quack 2007) found 21 W in active mode, 6 W in sleep mode and

2.5 W in off mode. Roth and McKenney (2007) reports 25 W for active mode and 2 W for sleep and off modes.

In off mode, we need to distinguish between time when the portable computer and its power supply are not plugged in (power draw of 0 W) and the time when it is. Unfortunately, we do not have reliable data for the fraction of time that portable computers (and their power supplies) spend between these two modes. When the PC and its power supply are plugged in, the PC might be recharging, but we assume that the majority of the time in this mode the average portable computer is in off mode (i.e., drawing approximately 1 W). In our analysis, we do not consider "off but charging" as a separate operation mode, since we assume that the majority of recharging occurs while the computer is, i.e., the power draw for recharging is already part of the on mode power draw value.[12]

3.6.1.2.2 Usage

Table 3-24 shows the reported usage time for portable computers in homes. We developed usage estimates from responses to a phone survey about residential consumer electronics usage. The survey relied upon respondents' recollection of PC usage. Appendix A contains the survey questions, while Appendix B describes the model we used to calculate the usage by mode. Note that these values reflect actual usage (active used) and not the total time spent in active mode, which includes active-idle time. For example, a computer might be actively used by household members for four hours of the day, but may be in active mode 24 hours of the day if its power management is disabled and if it is never switched off manually.

Table 3-24: Daily usage of portable computers (CE Usage Survey)

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

Approximately 70% of portable computers were reported to be always or often powered down at night, which is comparable to the 63% indicated for residential computers in a PC energy report carried out in 2009 (Alliance to Save Energy 2009). The median default time to sleep of ENERGY STAR qualified notebook models submitted to EPA as of March 2010 is 25 minutes (EPA2010a).

[12] Our analysis only considers computers that were plugged in during the past month (Appendix A, Question 1e) to calculate the installed base, excluding computers that are only rarely plugged in. As a rough estimate, we assume that most portable computers and their power supplies remain plugged the majority (75%) of the time spent in off mode. To calculate an upper bound for the UEC impact of this uncertainty, we consider portable computers to be plugged in 100% of the time in off mode. This results in an off mode UEC of 4kWh/yr, for a total UEC of 63kWh/yr. As a lower bound, we assume that the PCs are unplugged whenever off, resulting in zero power draw in off mode and a UEC of 59kWh/year. Assuming portable computers and their power supplies remain plugged in 75% of the time in off mode yields 3kWh/yr in off mode, for a UEC of 62W.

We did not directly ask phone survey respondents about the power management settings since many people are likely not aware of their computer power management settings and/or their responses might be influenced by a social desirability bias.[13] Instead, we asked how long it typically takes the computer to respond after it has not been used for one hour or more (see question M13, Appendix A), and we used the reported delay time as a proxy for power management settings. The survey data show little difference between primary, secondary and third computers; sleep mode is more common for portable computers than desktop computers. The survey responses indicate the breakdown of power management settings for portable computers shown in Figure 3-12.

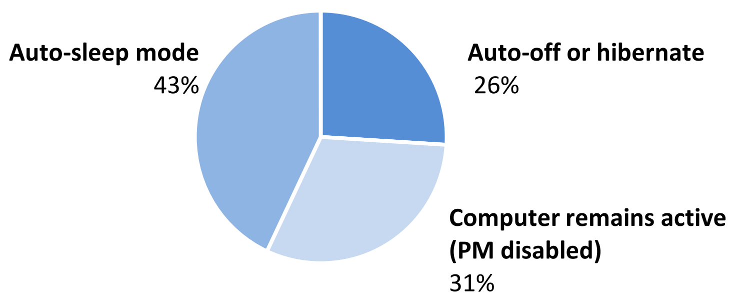

Figure 3-12: Power management settings of portable computers (CE Usage Survey)

These numbers seem reasonable given that more recent operating systems (e.g., Windows 7) have power management enabled by default. This means that 74% of the computers have power management settings enabled, a much higher percentage than what the ENERGY STAR program had set as a goal for its specification 4.0 (40% power management enabling rate by 2010 and 60% by 2012; EPA 2006).

Figure 3-13 compares the calculated time spent by portable computers in *on* mode to the usage indicated by the survey respondents. On average, we estimate that 45% of the time spent in on mode is not due to usage, but to the fact that the computer is not switched off and power management is disabled. These findings are consistent with previous reports (Roth and McKenney 2007). On average, this additional time spent in *on* mode accounts for nearly 24kWh per portable computer per year.

[13] Survey respondents often tend to reply in a manner that will be viewed favorably by others, leading to over-reporting of "good" behavior or under-reporting of "bad" behavior.

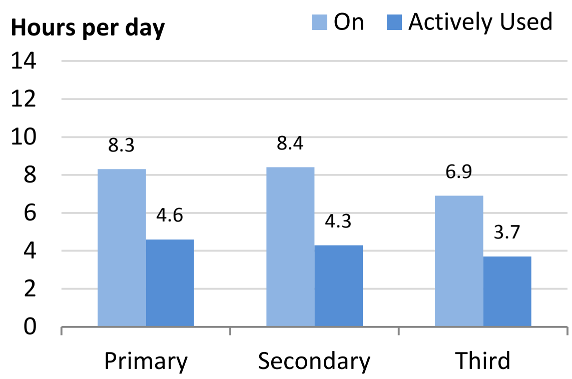

Figure 3-13: Daily usage (active-used) and calculated time in active (active-used + active-idle) modes for portable computers by usage priority (CE Usage Survey)

Table 3-26, and Table 3-27 summarize the time spent in each mode by portable computers on weekdays and weekend days. Including the distinction of weekdays and weekend-days as well as a weighting for primary, secondary and third computers, we obtain annual usage by mode breakdown for portable computers shown in Figure 3-14 and Table 3-27. Note that Table 3-27 reflects the upper bound for the time spent in "off and plugged in" mode.

Table 3-25: Time spent in usage modes for portable computers (CE Usage Survey)

Usage	Primary Computer		Secondary Computer		Weighted
[h/day]	Weekday	Weekend	Weekday	Weekend	Average
On	8.6	7.6	7.3	7.0	**9.4**
Sleep	6.3	5.9	7.3	6.0	**5.9**
Off	9.1	10.5	9.4	11.0	**8.7**

Table 3-26: Time spent in usage modes by portable computers

Usage [h/day]		Primary	Secondary	Third
Active	Weekday	8.6	9.0	6.6
	Weekend	7.6	7.0	7.5
Sleep	Weekday	6.3	6.5	5.5
	Weekend	5.9	6.0	5.4
Off	Weekday	9.1	8.5	11.9
	Weekend	10.5	11.0	11.1

Table 3-27: Annual usage by mode of portable computers

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

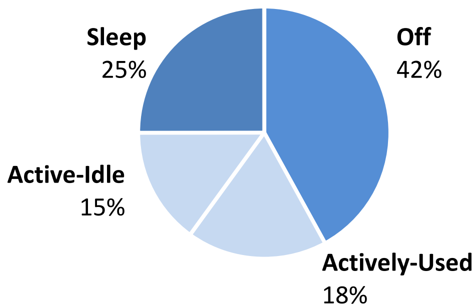

Figure 3-14: Fraction of time spent by power mode for portable computers (CE Usage Survey)

For comparison, the weighting of operational modes used in the current ENERGY STAR specification (EPA 2009b) estimates 60% of the time spent in off mode, 10% in sleep mode and 30% in idle mode for conventional notebook computers, as well as 45% (off), 30% (sleep) and 25% (idle), respectively, for proxy notebook computers that maintain full network connectivity.

3.6.1.2.3 Unit Energy Consumption

Taking into account the breakdown of desktop computers installed, their power draw by mode and the time spent in each mode calculated with our computer usage model, we obtain a UEC of 63 kWh/year. Table 3-28 summarizes the average power draw, usage, and unit energy consumption by mode for portable computers.

Table 3-28: UEC calculation for portable computers

	Active	Sleep	Off	Sources
Power [W]	19	2	1	See above
Usage [hr/yr]	2,915	2,210	2,726[14]	Based on CE Usage Survey (2010)
UEC [kWh/yr]	55	4	3	

In the latest ENERGY STAR specification for computers (version 5.2, effective July 2009), a number of program requirements have been set to stricter values. While maximum idle active idle levels for portable computers in the previous version ranged from 14 to 22 W, these power draw by mode

[14] Under the assumption that portable computers/their power supplies remain plugged in 75% of the time spent in off mode (lower bound=never plugged in when turned off: 0 h/yr, upper bound=always plugged in when turned off: 3,635 h/yr). Given this uncertainty, the lower and upper band for AEC value are 7.8 TWh and 8.3 TWh, respectively.

requirements have been replaced with the standardized TEC approach (typical energy consumption; for details on this approach, please refer to EPA 2009b).

3.6.1.3 Annual Energy Consumption

Portable computers consumed approximately 8.3 TWh in 2010, shown in Table 3-29.

Table 3-29: AEC summary for portable computers

UEC [kWh/yr]	Installed Base [millions]	AEC [TWh]
63	132	8.3

3.6.2 Prior Energy Consumption Estimates

The current AEC estimate of 8.3 TWh is much higher than reported by previous studies, as shown in Table 3-30, with the AEC having increased by over 190% since 2006 primarily due to a nearly three-fold increase in the installed base. In spite of a considerable increase in the usage of portable computers, their UEC has decreased. The average power draw in active and off mode has been reduced.

Table 3-30: Prior energy consumption estimates for portable computers

	Units	Power [W]			Usage [hr/yr]			PM[a]	UEC	AEC	
Year	[millions]	Active	Sleep	Off	Active	Sleep	Off	Enabled	[kWh/yr]	[TWh/yr]	Source
2010	132	19	2	1	2,915	2,210	3,635	70%	63	8.3	Current
2009	76	76	-	-	-	-	-	-	43	3.1	CCAP 2009[b]
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	16.6	-	-	-	-	-	-	77	1.3	RECS 2001
2001	17.3	15	3	0[c]	1,007	651	7,102	-	-	-	LBNL 2004
1999	16	15	3	2	521	261	7,978	100%	9	0.14	LBNL 2001

a Percent of computers with power management enabled.
b Data for office equipment only.
c Disconnected.

Compared to the last study (Roth&McKenney 2007), active mode and especially sleep mode usage have increased considerably for portable computers. We attribute this to a more refined calculation model that reflects habits/ probabilities for switching off the computer as indicated by the phone survey respondents. Besides that, the penetration of high-speed internet access increased from 56% in 2006 (J.D. Power 2006) to 66% as of August 2010 (NTIA 2010; Pew Research Center 2010), which may also contribute to a higher active usage time. The biggest uncertainty in the numbers calculated comes from power management settings and reported likelihood of powering down the computer manually.

Since 2007 the ENERGY STAR program covers allowable active, sleep and off power draw for portable computers, Table 3-31. Allowances for power TEC were further limited and external power supply energy performance requirements increased in 2009. The most crucial change to UEC, however, came from power management settings being enabled by default, which is the case now for most computers. As many users likely never change the default settings, this has certainly contributed to mitigate the effects of an increased usage of portable computers.

Table 3-31: Evolution of the ENERGY STAR specifications for notebook computers

Version	Effective Date	Maximum Mode Power Draw and other Specifications	Source and Comments
4.0	20 July 2007	• Active/Idle: ≤ 22/14W • Sleep: ≤1.7W • Off: ≤ 1.0W • Internal power supply efficiency > 80% • External power supply meets ENERGY STAR EPS 1.0	EPA (2006) • Includes higher active mode power draw levels for more powerful Computers • Includes minimum power supply efficiency requirements
5.0	1 July 2009	• Internal power supply efficiency > 82/85/82% • External power supply meets ENERGY STAR EPS 2.0 • TEC < 40/53/88.5 kWh	EPA (2009c) • More restrictive energy allowances

3.6.3 References

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3.7 Computer Speakers

3.7.1 Current Energy Consumption

Computer speakers, or multimedia speakers, are 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 (NAEEEC 2004). Some smaller systems, especially for portable computers, are powered directly through a USB port. This analysis excludes those devices, as did the CE Usage Survey. A typical computer speaker system configuration includes either two speakers only, 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 according to speaker configuration.

3.7.1.1 Installed Base

According to CE Usage Survey data, 44% of primary computers (i.e., the most-used computer in a household) are connected to a computer speaker system, compared to 23% and 16% of secondary and tertiary computers, respectively. The CE Usage Survey data for computers further indicate that out of the 262 million home computers (see desktop and portable computer sections), 46% are used as primary computer, 27% as secondary and 13% as third computers. This yields an installed base of 74 million computer speaker systems, as shown in Table 3-32.

Table 3-32: Installed base of computer speaker systems (CE Usage Survey)

Computer Usage Priority	Home Computers [millions]	Percentage with External Speakers	Total Speakers [millions]
Primary	121	44%	**53**
Secondary	71	23%	**16**
Third	34	16%	**5**
Fourth+	37	0%*	**0**
Total/Average	**262**	**28%**	**74**

* Assumed to be zero, as the trend is decreasing.

These data suggest a household penetration rate of 47%. Unfortunately, we could not find complementary data for the installed base of computer speaker systems from other sources.

3.7.1.2 Unit Energy Consumption

3.7.2 Power Draw

Computer speaker systems can be characterized by the following three operating modes:

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

We analyzed several studies on computer speaker power draw by mode. A Canadian in-store measurement campaign carried out on 20 different models in 2007 (Hamer et al. 2008) found an average active standby consumption of 4.2 W. The European SELINA project (SELINA 2010) measured 97 computer speaker systems in retail shops. The study reports an average *off* mode consumption of 1.8 W and an *active standby* consumption of 4 W (SELINA 2010). Another measurement campaign carried out in Hungary for the International Standby Power project (APP6 2008a) included 26 devices and considers *passive standby* mode as not relevant, as none of the 26 devices measured had a remote control. For the 26 devices tested, the average off mode power was 1.5 W and the average active mode 2.4 W. A similar study carried out as part of the same program in the Czech republic included 17 devices and reports an average off mode consumption of 2.7 W, an average of 4.8 W for active standby mode (APP 2008b), the passive standby mode was not considered to be applicable. An Australian report (NAEEEC 2004) provides power measurement data for computer speakers from Australia and the U.S. for the years 1993 to 2004 in *off* and *standby* mode. The average power draw for models manufactured in 2003/2004 is 3 W in *off* mode and 4 W in *standby* mode.

Plug load field monitoring reports (Foster Porter et al. 2006; Meister et al. 2011) found an average *active*-mode power draw in the range of 7 to 8 W for computer speakers systems with two speakers only (sample sizes of 12 and 20, respectively), with two outlier systems that comprised multiple speakers and a subwoofer that consumed 78 W. The power draw and installed base of these larger systems warrants further investigation, however the outlier high-power draw systems were not considered in our analysis.

Based on these data, we estimate that the installed base of computer speakers has the average power draw by mode values shown in Table 3-33.

Table 3-33: Power draw by mode for computer speaker systems

Power [W]			Sources
Active	**Active Standby**	**Off**	
8	4	3	SELINA 2010, APP6 2008a, APP6 2008b, NAEEEC 2004, Foster Porter et al. 2006, ECOS 2008, ACEEE 2008

3.7.2.1.1 Usage

Computer speaker usage, see Table 3-34, was determined from the CE Usage Survey. Sixty-one percent of respondents (question M26, see Appendix A) answered that their computer speakers are always on when the computer is used, i.e. 4.5 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 3.6 hours per day. The data suggest that 61% of computer speaker systems are not switched off over night (question M24A-C). During the day when the computer 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 (question M25A-C). Overall, this suggests that the average speaker system spends 15% of the day in active mode, 50% of the time in active standby mode, and 35% of time in *off* mode. For comparison, Foster Porter et al. (2006) collected time-series data in 50 homes for one week and found that the 12 computer speaker systems analyzed spent 22% of the time in active mode and 78% in standby mode. The study did not report any off mode usage for the systems that were monitored nor did it distinguish between active standby and off mode.

Table 3-34: Annual usage by mode of computer speaker systems

Usage [h/year]			Sources
Active	Active standby	Off	
1,314	4,380	3,066	CEA Usage Survey (Appendix A), Foster Porter et al. 2006, ECOS 2008

The ENERGY STAR specification version 2.0 for Audio Products that became effective in November 2009 requires qualifying devices to have the default auto power-down setting at 2 hours maximum, thus the time spent in active standby mode by ENERGY STAR devices might be smaller. We do not, however, have data on the market penetration of ENERGY STAR computer speakers since the specification took effect. In any case, the available data indicate that computer speakers draw similar levels of power draw in off and active standby modes.

3.7.2.1.2 Unit Energy Consumption

Our calculation Computer UEC is 37kWh/year, as shown in Table 3-35.

Table 3-35: UEC calculation for computer speaker systems

	Active	Active Standby	Off	Total
Power [W]	8	4	3	**-**
Usage [hr/yr]	1,314	4,380	3,066	**8,760**
UEC [kWh/yr]	10.5	17.5	9.2	**37**

3.7.2.2 Annual Energy Consumption

Computer speaker systems consumed approximately 2.8 TWh in 2010, as shown in Table 3-36.

Table 3-36: AEC summary for computer speaker systems

UEC [kWh/yr]	Installed Base [millions]	AEC [TWh]
37	74	2.8

3.7.3 Prior Energy Consumption Estimates

The UEC value is comparable to the value found by Meister et al. (2011) of 45kWh in commercial buildings. Roth et al. (2008) did not analyze computers speakers as a separate category, but expected the installed base to grow due to the trend of audio content obtained via the internet and the growing number of computers, especially notebooks and handheld PCs.

3.7.4 References

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3.8 DVD Devices

3.8.1 Current Energy Consumption

This section describes the number of DVD players, DVD recorders and DVD-VCR combos with their typical usage patterns and average power draw estimates in the U.S. in 2010. This category includes stand-alone DVD players, DVD recorders and DVD-VCR combos. It does not include portable DVD players and digital video recorders, which include set-top-boxes with recording facility, portable media players with recording facility, and computer software that allows users to capture and view DVD content on a computer. Blu-ray disc players are covered in a separate section.

3.8.1.1 Installed Base

According to CEA market research, the installed base of DVD players/recorders (any type[15]) was 223 million units as of May 2010, with a household penetration rate of 93% and an average of 2.1 players per owner household (CEA 2010a), see Table 3-37. This represents an increase of 86% in units installed compared to 2006, when the household penetration rate was 74% with an average of 1.4 units per owner household (TIAX 2007). In the CE Usage Survey, 79% of the respondents indicated having such a device plugged in within the past month.

Table 3-37: Installed base of DVD players, recorders, and VCR combos

Installed Base [millions]	Penetration	Sources
223	93%	CEA 2010a

The CE Usage Survey data found the breakdown of product types shown in Figure 3-15 and the ownership distribution shown in Figure 3-16.

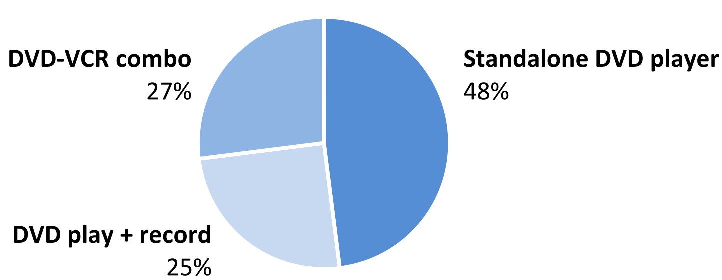

Figure 3-15: Breakdown of stand-alone DVD players, DVD recorders and DVD-VCR combo units

[15] Excluding portable DVD players.

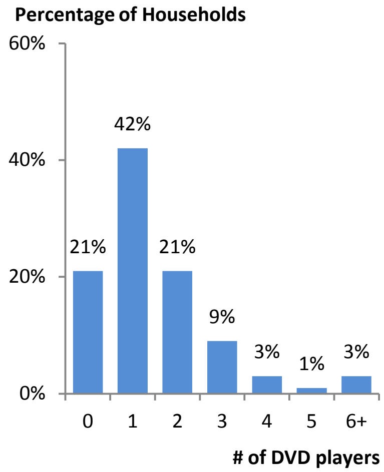

Figure 3-16: Ownership of DVD players, DVD recorders, and DVD-VCR combo units (CE Usage Survey)

3.8.1.2 Unit Energy Consumption

The operating mode distinction of DVD players/recorders is not consistent among different studies. Following the ENERGY STAR terminology for the current specification 2.0 (EPA 2010a), we will distinguish between the following four main operating modes:

- *Active* – the device is playing content or recording
- *Idle*–device is on but no motor functions are being performed: the device is either paused, programmed with a timer or has the "QuickStart" mode activated
- *Sleep* - The device is connected to a power source, produces neither sound nor picture, neither transmits nor receives program information and/or data (excluding data transmitted to change the unit's condition from Sleep Mode to On Mode), and is waiting to be switched to On Mode by a direct or indirect signal from the consumer (e.g., with the remote control)
- *Off* – The device is connected to a power source and cannot be switched into any other mode except by user actuation of a manual power switch

3.8.1.2.1 Power Draw

The energy consumption of DVD players and recorders has decreased over the past years for all operational modes. A growing number of devices now include an auto power down functionality, as required by ENERGY STAR version 2.0, which switches the device from *on* mode to *sleep* mode after a predetermined period of time, just as a device that is switched off with a remote control. Unfortunately, we do not have data on what fraction of devices is manually switched off by the users, which puts the device into *off* mode. However, we assume that the majority of devices are not switched off with a manual power switch and many models do not have a real *off* mode (Oeko-Institut 2009; APP 2010; Fraunhofer IZM 2009). Besides, as sleep mode power consumption has fallen below a level that was considered as off mode in previous studies (e.g., TIAX 2007), we will aggregate *sleep* and *off* mode power consumption.

As Figure 3-17 shows for *active* mode, power draw values of DVD players have decreased substantially over the last years. Note that the TIAX 2007 data are based on values from the ENERGY STAR product databases, measurement from Rosen and Meier (1999), and measurement carried out by CEA for 2005/2006 models. The Australian and Canadian data are average values from in-store measurements (AP6 2011).

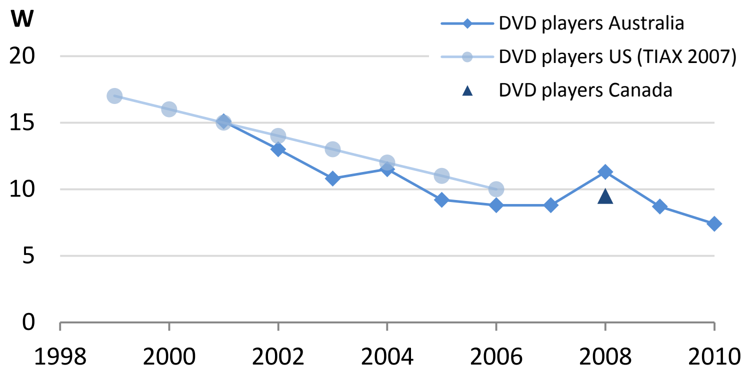

Figure 3-17: Active mode power draw of DVD players (TIAX 2007, AP6 2011)

Since January 2003, DVD players, recorders and combo were covered by the ENERGY STAR consumer audio and DVD products category, which became effective in 2003 (Phase II). It limits sleep mode power consumption to 1.0 W. After a dramatic decrease in the years 1999-2006 (TIAX 2007), power consumption of DVD players in *sleep* mode seems to have stabilized at 0.6 W for ENERGY STAR devices, the average *sleep* mode consumption of current ENERGY STAR models still being 0.54 W (EPA 2011). As the penetration rate of ENERGY STAR devices has increased, overall sleep consumption has decreased, resulting in a decrease of average *sleep* mode consumption, see Table 3-38.

Table 3-38: ENERGY STAR penetration rate and sleep mode power draw for DVD players (EPA 2010c)

	DVD units, all [millions]	Percentage ENERGY STAR	Sleep Mode Power [W]			
			ENERGY STAR Allowance	ENERGY STAR Estimate	Non-ENERGY STAR Estimate	Average
2009	23.5	80%	1	0.6[a]	2.0[b]	**0.9**
2008	20.9	44%	1	0.6[a]	2.0[b]	**1.4**
2007	23.3	26%	1	0.6[a]	2.0[b]	**1.6**
2006	26.4	8%	1	0.6[a]	2.0[b]	**1.8**
2005	20.5	32%	1	0.6	2.5	**1.9**

a Interpolation of EPA data.

b Estimates based on prior development (TIAX 2007).

There is a scarcity of off-mode DVD power data, which is unfortunate since the majority of time is spent in this mode. Values reported by recent studies range between 0.4 W (Bensch et al. 2010) and 2.2 W (AP6 2008; ECOS 2006; Oeko-Institut 2009). Time series from Australia show a similar yet less pronounced trend for sleep mode consumption of in-store measurements, falling from 2.0 W in 2005 to 1.5 W in 2010 and the data are also consistent with U.S./Canadian data of store measurements published by the SELINA project (Selina 2010).

In July 2010, a new ENERGY STAR specification (version 2.0) for audio/video became effective with limits for the power consumption in active mode, idle mode, sleep mode, as well as auto power down default settings. Table 3-39 summarizes the requirements of the new ENERGY STAR specification for DVD players as well as the average of 38 ENERGY STAR DVD players (EPA 2011).

Table 3-39: EnergStar requirements and average values of qualified products (EPA 2011)

Requirement	ENERGY STAR Allowance	Average of Qualified Products
Default time auto power down	<30 min (no idle mode requirements) or <2hours	23 minutes
Active – playback	6 W (SD/audio source) 15 W (HD)	5.5 W
Active – record	16 W (SD/audio source) /25 W (HD)	-
Idle	5 W	3.5 W
Sleep	1 W	0.5 W

DVD recorders consume more power in all operational modes than devices that only have playback functionality. Many newer devices come with an auto-power down functionality. However, as their current *sleep* mode consumption exceeds the ENERGY STAR limits, the ENERGY STAR market penetration is still close to 0%. Unfortunately, U.S. data on these devices are very scarce. Measurements carried out in Germany (Oeko-nstitut 2009) and Denmark (Savingtrust 2008) both report average standby of approximately 3 W, which would be a decrease compared to 2006 consumption values (TIAX 2007) of 4.5 W.

Power draw values of DVD-VCR combo units have decreased only slightly (Bensch et al. 2010, TIAX 2007), as the majority are legacy units; only a few models are still offered in shops.

Given sales data (CEA 2010b) and installed base data of DVD players, recorders and DVD/VHS combo units, we assume that 2007/2008 values are most representative of the current installed base. Apart from the studies mentioned above, we also included data of models that were used to develop ENERGY STAR specification version 2.0 (EPA 2009) as well as in-house measurement data from a study carried out by the Energy Center of Wisconsin (ECW 2010) for the current development of the power draw by mode estimates.

Based on these data, Table 3-40 shows our estimates for power draw across device categories.

Table 3-40: Power consumption by mode of DVD players, recorders, and DVD-VCR combo units

	Power [W]			Sources
	Active	Idle	Sleep	
DVD player	9	5	1.5	EPA 2009, Bensch et al. (2010),
DVD recorder	18	14	3	AP 6 2011, Oeko-Institut 2009, TIAX
DVD-VCR combo	12	8	3	2007, ECOS 2006, Savingtrust 2008

3.8.1.2.2 Usage

Based on CE Usage Survey responses, we developed an estimate of DVD player, recorder and combo unit usage, shown in Table 3-41. Figure 3-18 shows the reported usage for primary and secondary DVD players (data aggregated for players, recorders and DVD-VCR combos). We found that the reported usage of DVD recorders is nearly twice as high as for devices that only have DVD playback functionality. This seems reasonable, as for once, these devices spend additional time in on mode when they are recording; besides, they are often used as a household's the primary DVD device, which also explains the higher usage. Compared to previous studies, we assume that the idle time for DVD players has decreased, as several units incorporate an auto power down functionality required by the new ENERGY STAR specification version 2.0. Data are lacking on the fraction of DVD players with this functionality. In a small dataset that was used for the development of the ENERGY STAR specification, 5 out of 8 DVD players had this functionality (EPA 2009).

Table 3-41: Annual usage by mode of DVD players, recorders, and DVD-VCR combo units

	Usage [h/year]			
	Active	**Idle**	**Sleep**	**Total**
DVD player	210	700	7,850	**8,760**
DVD recorder	410	900	7,450	**8,760**
DVD-VCR combo	300	900	7,560	**8,760**

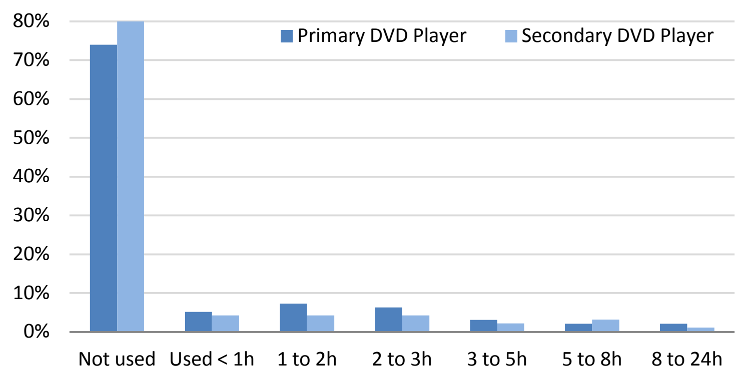

Figure 3-18: Daily usage of DVD players, recorders, and DVD-VCR combo units (CE Usage Survey)

Table 3-42 presents the energy consumption by mode for DVD players, recorders, and DVD-VCR combo units.

Table 3-42: UEC calculations for DVD players, recorders, and DVD-VCR combos

	Power [W]			Usage [h/year]			UEC [kWh/year]			
	Active	Idle	Sleep	Active	Idle	Sleep	Active	Idle	Sleep	Total
DVD player	9	5	1.5	210	700	7,850	1.9	4.5	11.3	**17.7**
DVD recorder	18	14	3	410	900	7,450	7.4	12.6	22.4	**42.4**
DVD-VCR combo	12	8	3	300	900	7,560	3.6	7.2	22.7	**33.5**
Wt. Average	**12**	**8**	**2**	**284**	**804**	**7,672**	**3.7**	**7.3**	**17.2**	**28.2**

3.8.1.3 Annual Energy Consumption

DVD players, recorders and DVD-VCR combos consumed about 6.3 TWh in 2010 as shown in Table 3-43.

Table 3-43: AEC summary for DVD devices

UEC [kWh/yr]	Installed Base [millions]	AEC [TWh]
28	223	6.3

3.8.2 Prior Energy Consumption Estimates

Compared with a prior estimate (TIAX 2008), the current calculations yield a lower UEC, prompted by a decrease in power consumption, along with a higher AEC, due to growth in the installed base, as shown in Table 3-44. There are few U.S. power draw values for DVD recorders. For sleep mode consumption, we mostly had to rely on European and Australian values, which may be conservative due to stricter consumption regulations in these countries.

Table 3-44: Prior energy consumption estimates for DVD devices

Year	Units [millions]	Power [W] Active	Power [W] Idle	Power [W] Sleep	Usage [hr/yr] Active	Usage [hr/yr] Idle	Usage [hr/yr] Sleep	UEC [kWh/yr]	AEC [TWh/yr]	Source
All DVD										
2010	233	12	8	2	284	804	7,672	28	6.3	Current
2007	120	14	11	2	283	900	7,577	33	4.4	TIAX 2008
DVD-only										
2010	107	9	5	1.5	210	700	7,850	18	1.9	Current
2009	-	10	3.3	1.6	730	-	8,030	20	-	Oeko-Institut 2009
2007	75	13	10	2	270	900	7,590	30	2.3	TIAX 2008
2005	-	11	5.3	1	964	88	7,709	19	-	ECOS 2006
DVD-VCR										
2010	60	12	8	3	300	900	7,560	33.5	2.0	Current
2007	35	15	11	2.3	270	900	7,590	34	1.8	TIAX 2008
2005	-	12	6	2	175	526	8,059	29	-	ECOS 2006
DVD-Recorder										
2010	56	18	14	3	410	900	7,450	42.4	2.4	Current
2009	-	27	11.5	2.7	730	-	8,030	41	-	Oeko-Institut 2009
2007	10	20	15	4.5	425	900	7,435	50	0.3	TIAX 2008
2005	-	18	-	3	2,365	-	6,395	55	-	ECOS 2006

It is important to note that mode definitions among prior studies are not consistent, which is partially due to a change in technology: the quick start mode is a relatively new feature in some newer models. The reported power draw of this mode is 11.5 W (Oeko-Institut 2009), thus higher than passive standby, but lower than active mode. However, the same is true for DVD players with a programmed timer (3.3 W). All these features and modes could be listed separately, for the sake of simplicity, we distinguish between 3 power states and indicate the hours reported for these states. Also note that the power draw values indicated by the ECOS study were from vintage models that were measured in households, whereas the Oeko-Institut study values are based on models that were for sale in 2009.

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3.9 Monitors

3.9.1 Current Energy Consumption

The computer monitors category includes displays that must be plugged in, 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.

3.9.1.1 Installed Base

We estimate an installed base of 131 million monitors in 2010, see Table 3-45, based on the CE Usage Survey (Appendix A). Phone survey participants were asked how many monitors were used with each of (up to) three most-used computers, producing the distributions in Figure 3-19. At least 55% of all households had at least one monitor (68% per computer-household).

Table 3-45: Installed base of monitors

	Computers [millions]	Monitors per computer	Monitors [millions]
Desktop	101	0.96	**96**
Portable	132	0.26	**35**
Total/Average	**233**	**0.56**	**131**

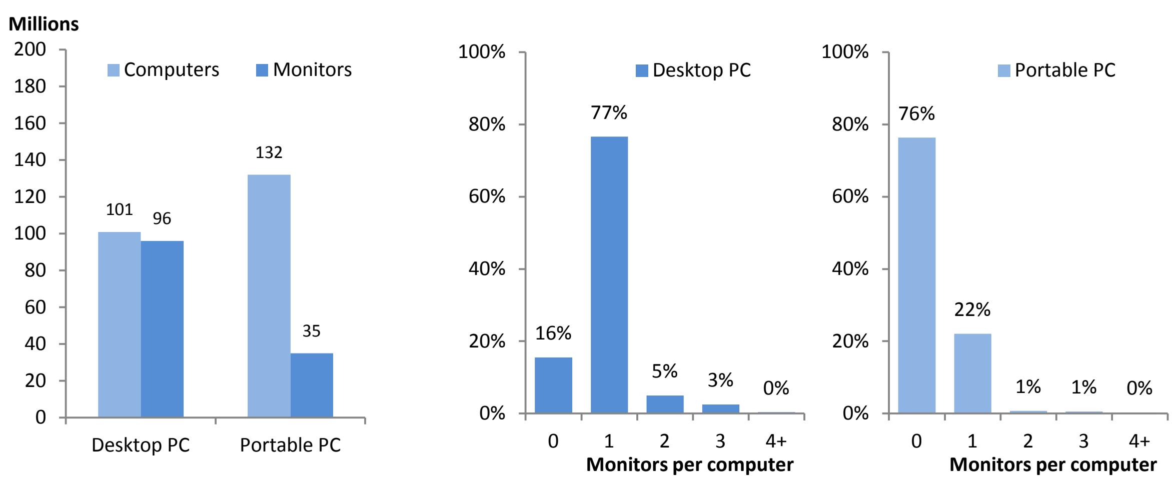

Figure 3-19: Installed base of monitors and computers (left), and distribution of monitors per computer (right)

The survey revealed that that 73% of monitors were used with desktop computers and 27% with portable computers, including laptops, notebooks, netbooks, or tablet PCs. Prior analyses assumed that every desktop computer had exactly one external monitor and portable PCs did not have any (TIAX 2007, 2008). Surprisingly, desktop PCs now average slightly less than one monitor per computer, with 16% having none at all. This unexpected result is at least partly due to the prevalence of all-in-one PCs, i.e., those with integrated displays, as their cumulative sales[16] numbered about 7 million from 2007 to mid-2010 (Display Search 2011), or about 7% of all desktop computers.

[16] We did not find estimates for the fraction of all-in-one PCs sold to consumers.

3.9.1.2 Unit Energy Consumption

3.9.1.2.1 Power Draw

Monitors have three primary power modes, including active, sleep, and off. Active mode occurs whenever the monitor is on and displays an image. Sleep mode is a temporary low-power state entered after a period of inactivity, typically 20 minutes (Bensch et al. 2010) when power management is enabled. User input from a keyboard or mouse brings a sleeping monitor back to active mode. Off mode is the lowest power mode and is reached when the user powers down the monitor by manually switching it off. Monitor active-mode power draw depends most strongly on display technology, screen size, and year of manufacture.

The CE Usage Survey (see Appendix A) shows growing LCD dominance with a breakdown[17] of 84% LCD and 16% CRT, compared with 78% LCD in 2009 (EIA 2009), and 60% LCD in 2006 (TIAX 2007). Only 3% of monitors sold between 2006 to mid 2010 were CRTs (Display Search 2011). Displays have also been getting larger, with an average diagonal viewable screen size of 18 inches in 2010, compared with 17 inches in 2006 (TIAX 2007). LCD monitors sold between 2006 and 2010 averaged 19 inches (Display Search 2011). Figure 3-20 shows the estimated size distribution of LCDs.

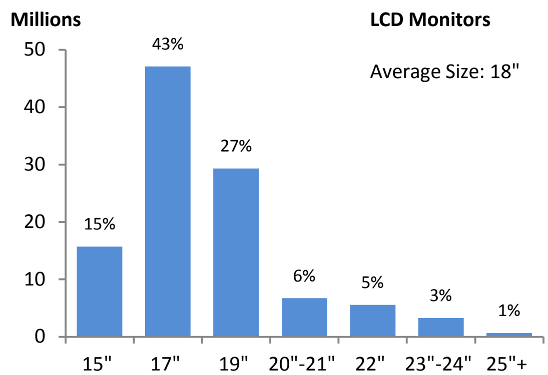

Figure 3-20: Diagonal viewable screen size of the 2010 installed base of LCD monitors

We divide the installed base into pre- and post-2006 models according to available power draw data. Adjusted[18] industry sales data (Display Search 2011) show that 58 million displays made their way to U.S. consumers between 2006 to mid-2010. This means that more than half of all displays are over five years old; annual residential sales of about 13 million units imply a mean product lifetime of about 10 years.

For all CRT monitors and pre-2006 LCDs, we use power draw characteristics from (TIAX 2007). For post-2006 LCDs, we used measurements of 133 displays (EPA 2008) to produce correlations with screen area (A) in inches, shown in Figure 3-21. Sleep and off mode power draw average 1.2 and 0.8 W, respectively,

[17] Since monitor responses were given only for up to three computers, we assumed the proportions of LCD and CRTs were the same for lesser-used computers. In the limiting case where all monitors on computers four and beyond were CRTs, the split would shift to 73% LCD and 27% CRT.

[18] We scaled the total North American unit shipment data (commercial and consumer) by the U.S. population fraction (90%) – based on 34 million people in Canada (Statistics Canada 2010) and 308 in the U.S. (EIA 2010) – and by the average consumer fraction (38%), given by Display Search for 2009 and 2010.

and do not vary appreciably with screen area. To estimate LCD power draw, we converted screen size into area by assuming 16:9 aspect ratio and applied the screen area-power correlations. On average, post-2006 LCDs draw 33 W in active mode, compared with 29 W for pre-2006 models. Table 3-46 shows our power draw estimates by display type and screen size.

Table 3-46: Power draw estimates for monitors

	Year	Screen Size [inches]	Units [millions]	Power [W]		
				Active	Sleep	Off
LCD	2006-2010	15	2.6	15	0.8	0.5
	2006-2010	17	16.6	23	0.8	0.6
	2006-2010	19	20.6	32	0.9	0.6
	2006-2010	20-21	6.7	39	0.9	0.6
	2006-2010	22	5.6	46	1.0	0.6
	2006-2010	23-24	3.3	55	1.1	0.7
	2006-2010	25+	0.6	96	1.4	0.8
	Subtotal/Avg.	**19.1**	**56.0**	**33**	**0.9**	**0.6**
LCD	pre-2006	15	13	20	1.0	1.0
	pre-2006	17	30	31	1.0	1.0
	pre-2006	19	9	35	1.0	1.0
	Subtotal/Avg.	**16.8**	**52.3**	**29**	**1.0**	**1.0**
LCD	**Wt. Avg.**	**18**	**108.3**	**31**	**1.0**	**0.8**
CRT	**Wt. Avg.**	**17**	**23.1**	**61**	**2.0**	**1.0**
Total/Avg.	**-**	**17.7**	**131.4**	**36**	**1.1**	**0.8**

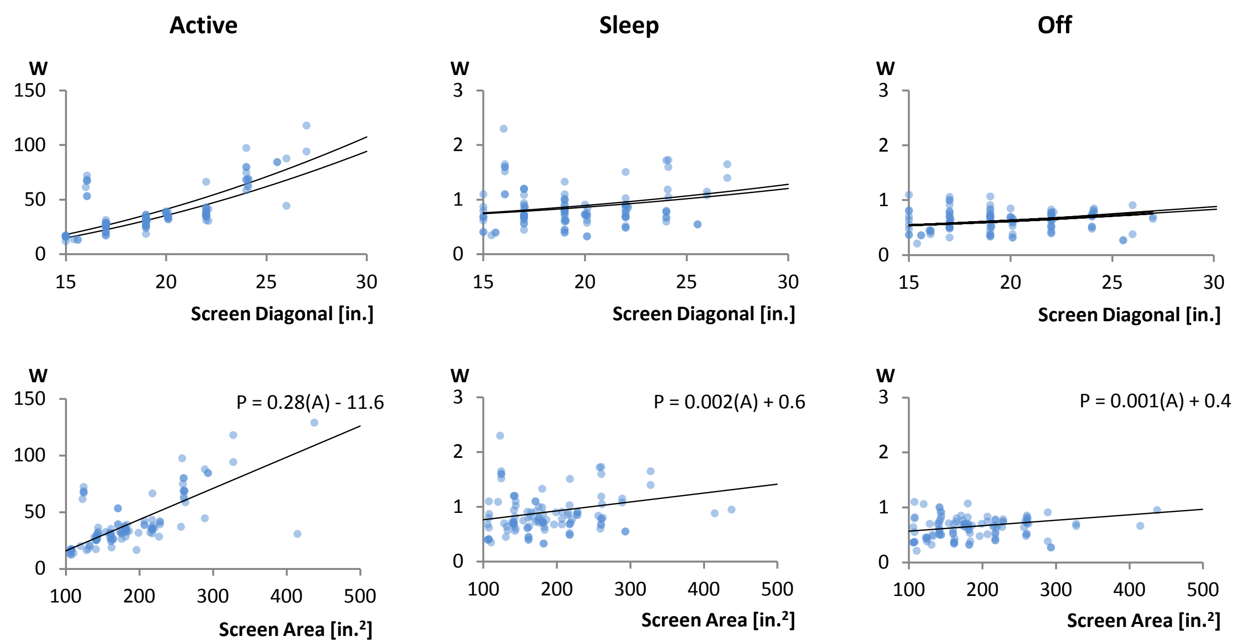

Figure 3-21: Power draw measurements for post-2006 LCD monitors (EPA 2008) versus diagonal screen size and area, N=133. Linear regressions are based on area. Upper and lower curves on size plots represent 4:3 and 16:9 aspect ratios, respectively.

Some monitors have different aspect ratios. Compared to monitors with a 16:9 ratio, those with 16:10 are 5% larger and those with 4:3 are 12% larger by area. One manufacturer indicated that 16:9 monitors represent 75% of their offerings, while 16:10 make up 25% and 4:3 only 10%. The overall impact of this 16:9 simplification translates to a potential underestimation of on-mode power draw and energy consumption of about 2.5%. Lacking a more detailed understanding of monitor sales by aspect ratio, we maintain our initial assumption.

The ENERGY STAR program published version 5.1 of its standard for displays in January 2010 (EPA 2010), specifying active mode power draw limits for displays based on diagonal screen size (d) in inches, viewable screen area (A) in square inches, and resolution (r) in megapixels, with requirements shown in Table 3-47. Maximum sleep and off mode power draw are now 2.0 and 1.0 W, respectively, for all displays. About 90% of LCD monitors below 30 inches met the ENERGY STAR criteria in 2009 (EPA 2011). Lacking installed base distributions for screen resolution, these criteria could not be applied to our model. Our power draw estimates are shown in Table 3-46.

Table 3-47: ENERGY STAR requirements for displays

		Display		Maximum Power [W] by Mode		
Version	**Effective**	**Size [inches]**	**Resolution [MP]**	**Active (*A* [in.^{2}], *r* [MP])**	**Sleep**	**Off**
5.1	Jan. 2010	$30.0 \leq d \leq 60.0$	$r = any$	$8.0 + (0.27 \times A)$	2.0	1.0
	Oct. 2009	$d < 30.0$	$r \leq 1.1$	$3.0 + (0.05 \times A) + (6.0 \times r)$	2.0	1.0
	Oct. 2009	$d < 30.0$	$r > 1.1$	$3.0 + (0.05 \times A) + (9.0 \times r)$	2.0	1.0
4.1	Jan. 2006	$d = any$	$r \leq 1.0$	$0.0 + (28.0 \times r)$	2.0	1.0
	Jan. 2006	$d = any$	$r > 1.0$	23.0	2.0	1.0
	Jan. 2005	$d = any$	$r = any$	$30.0 + (38.0 \times r)$	4.0	2.0

3.9.1.2.2 Usage

On average, monitors spend 6.9 hours per day in active mode, 9.7 in sleep mode, and 7.4 in off mode. We determined these usage patterns by extending the survey-based computer usage model with additional responses about power management settings and user habits. These we applied to 12 data subdivisions: 2(weekday/weekend) × 2(portable/desktop) × 3(primary/secondary/third computer) to arrive at the typical usage shown in Table 3-48.

Table 3-48: Daily usage of monitors by mode

	Fraction of	Monitor Usage [h/day]		
	Monitors	**Active**	**Sleep**	**Off**
Desktop	73%	6.4	9.9	7.7
Laptop	27%	8.8	8.8	6.4
Total/Avg.	**100%**	**6.9**	**9.7**	**7.4**

In calculating the usage estimates, we made the following assumptions:

- Any time the computer is actively used, the monitor is in active mode
- Any time the monitor is manually turned off, it is in off mode

- Any time the computer is in off mode, the monitor is in sleep mode (unless it is off)
- After a session of computer activity is completed:
  - If power management is enabled, the monitor remains on for 20 minutes before going into sleep mode (unless it is off)
  - If power management is disabled the monitor will remain on (unless it is off)

To infer power management settings we asked[19] about the state of monitors upon the first use of the day. If a monitor displayed an image or a screensaver in the morning, we assumed it was on overnight (8 hours). We also asked whether users had to manually turn on the monitor in the morning (indicating off mode) or not (indicating sleep mode). This analysis find that power management for displays is enabled in 68% of computer stations. We found, for desktop (laptop) monitors: 15% (10%) are on all night; 36% (40%) are switched off at night, and 49% (50%) are in sleep mode at night.

To determine the daytime (16 hours) modes, we apply users' power management settings and night-time behavior to their daytime computer usage[20] between active sessions according to the procedure in Figure 3-21. For example, suppose a user has three one-hour daytime sessions, has power management enabled, and does not manually turn off her computer. The model calculates 4 hours in active mode (3 hours of usage plus 1 hour [3 sessions x 20 minutes] of inactivity before power management engages), and standby mode would then make up the remaining 12 daytime hours. Power management settings as inferred from the CE Usage Survey are described in Figure 3-23.

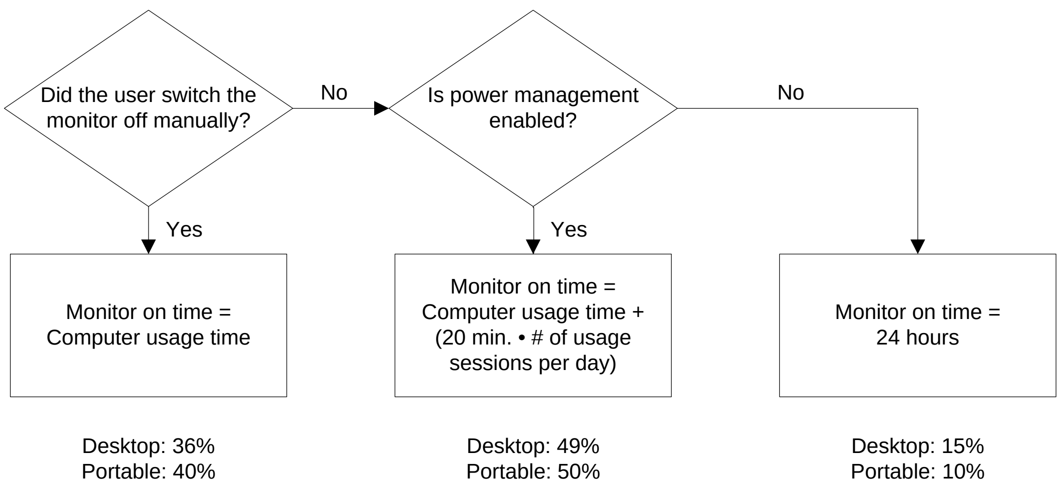

Figure 3-22: Decision tree for calculating daytime monitor time by mode

This procedure may underestimate on-mode usage during the daytime for users who manually turn off monitors more frequently at night than during the day. The potential underestimation for monitors with power management enabled is 20 minutes for each computer session, and for monitors without power management it is the time between multiple daytime sessions.

[19] We asked this question only of people who were the first to use their computer that day (N=248, or 32% of the survey respondents who reported having a computer).

[20] The method for calculating computer usage is described in the computers section.

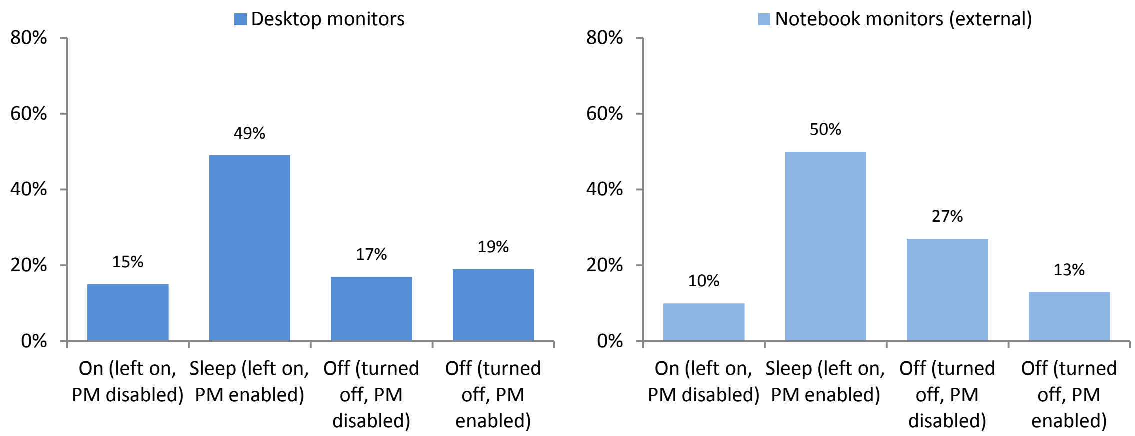

Figure 3-23: Power mode of monitor while computer is not actively used (CE Usage Survey)

Responses for manual power switching and power management settings were similar among primary, secondary, and third computers. Of the limited respondents who indicated the morning status of secondary and third computer monitors, most were consistent with the primary computer. Therefore, we applied the average user-behavior to all computers (primary, secondary, and third) to generate our usage estimates.

Monitor UEC averages 97 kWh/yr. On average LCD monitors consume 83 kWh/yr, about half as much as CRTs (163 kWh/yr).

3.9.1.3 Annual Energy Consumption

The total AEC equals 12.7 TWh/yr, with LCDs accounting for 71% of the total (82 % of the installed base). Nearly all (94%) monitor energy consumption occurs in active mode, due to the very low average power draw in both off and standby modes. Table 3-49 shows UEC and AEC breakdowns by display technology and screen size, and Figure 3-24 summarizes the AEC by mode.

Table 3-49: UEC and AEC estimates of monitors; daily usage is 6.8h on, 9.7h sleep, and 7.4h off

	Year	Screen Size [inches]	Units [millions]	UEC [kWh/yr] Active	Sleep	Off	*Total*	AEC [TWh/yr]
LCD	2006-2010	15	2.6	39	2.8	1.5	*43*	0.1
	2006-2010	17	16.6	58	3.0	1.5	*62*	1.0
	2006-2010	19	20.6	79	3.2	1.6	*84*	1.7
	2006-2010	20-21	6.7	97	3.4	1.7	*102*	0.7
	2006-2010	22	5.6	116	3.5	1.8	*122*	0.7
	2006-2010	23-24	3.3	137	3.8	1.8	*142*	0.5
	2006-2010	25+	0.6	241	4.8	2.2	*248*	0.2
Subtotal/Wt. Avg.		**19.1**	**56.0**	**82**	**3.2**	**1.6**	***87***	**4.9**
LCD	pre-2006	15	13	50	3.5	2.7	*56*	0.7
	pre-2006	17	30	78	3.5	2.7	*84*	2.6
	pre-2006	19	9	88	3.5	2.7	*94*	0.8
Subtotal/Wt. Avg.		**16.8**	**52.3**	**73**	**3.5**	**2.7**	***79***	**4.1**
LCD	**Wt. Avg.**	**18**	**108.3**	**77**	**3.4**	**2.2**	***83***	**9.0**
CRT	**Wt. Avg.**	**17**	**23.1**	**153**	**7.1**	**2.7**	***163***	**3.8**
Total/Avg.	**-**	**17.7**	**131.4**	**91**	**4.0**	**2.3**	***97***	**12.7**

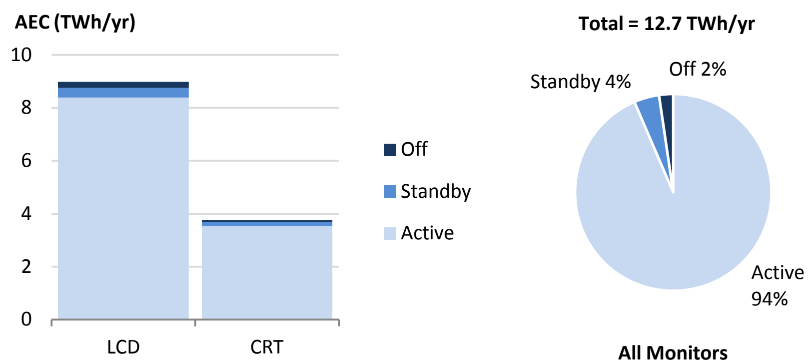

Figure 3-24: AEC in active and off mode by monitor display technology

3.9.2 Prior Energy Consumption Estimates

Our estimates for UEC (97 kWh/yr) and AEC (12.7 TWh/yr) are both higher than in 2006, even as average active mode power draw decreased by 8% over the same period. This reflects a 35% increase in the active mode usage estimate relative to TIAX (2006) and an installed base increase of 62 million monitors; the 27% of the installed base associated with portable computers were not included in prior studies. Prior estimates and projections of the installed base of monitors are given in Table 3-50.

Table 3-50: Prior energy consumption estimates for monitors

Year	Units [millions]	Power [W] Active	Power [W] Low	Power [W] Off	Usage [h/yr] Active	Usage [h/yr] Low	Usage [h/yr] Off	UEC [kWh/yr]	AEC [TWh/yr]	Source
2010	152	38.8	1.2	0.9	2,519	3,541	2,701	97	12.7	Current
2010	-	43.3	1.2	-	1,935	6,825	-	84	-	Bensch et al. 2010
2008-CRT	-	70.6	45.9	2.6	-	-	-	-	-	ECOS 2011
2008-LCD	-	34.2	6.2	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
2005	-	64	3.4	1.3	1,442	894	6,424	-	-	CCAP 2005
2001	68	85	5	0.5	1,170	488	7,102	105	7.2	LBNL 2004
2001	54.5	85	5	0.5	626	104	8,130	57	3.1	LBNL 2001

Sales trends, indicated in Figure 3-25 and Figure 3-26, show the disappearance of CRTs from the market by 2008. These figures also show the recent decline in annual monitor sales, precipitated by the rise of portable PCs that do not require an external display. Although monitors have grown in size, their power draw has not due to improvements in the efficiency of display technologies.

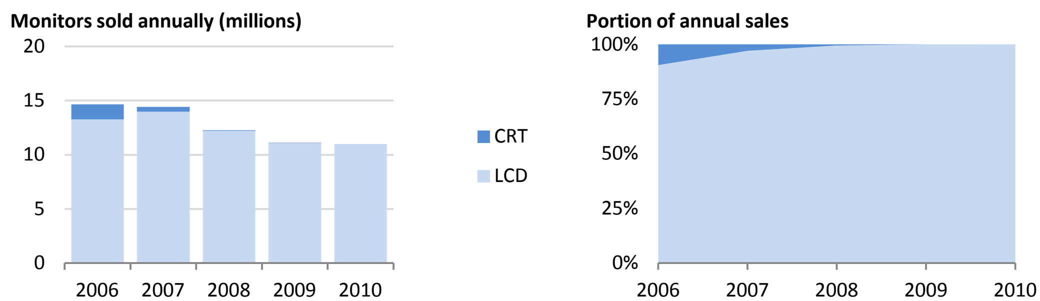

Figure 3-25: Annual monitor sales to dealers by display technology (DisplaySearch 2011)

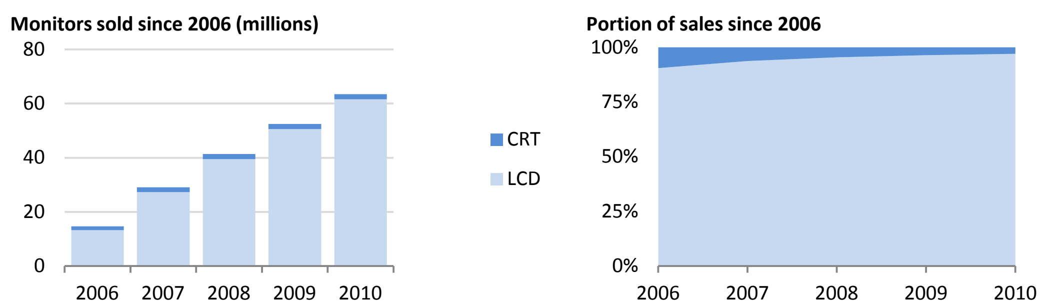

Figure 3-26: Cumulative monitor sales to dealers by display technology since 2006 (DisplaySearch 2011)

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3.10 Network Equipment

3.10.1 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)**; 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). In our installed base estimates we include cable, digital subscriber loop (DSL), fiber optic, and satellite modems among the broadband modem and IAD categories. Less common modems, including stationary WiMAX and 4G modems, are included among the routers and other devices category.

Routers and other devices include routers, hubs, switches, and other less common devices. These are used to establish one or more local area networks (LANs) for communication between household consumer electronic devices. Routers, the most common and feature-rich, can manage data transfer between multiple computer networks and can provide security, internet connection sharing, and other advanced features, whereas hubs and switches provide only simple wired LAN communication.

3.10.1.1 Installed Base

Broadband subscription penetration in 2010 was 67% according to the CE Usage Survey[21], and this agrees with independent survey-based estimates: 69% in 2010 (CEA 2010b), 66% in 2010 (Pew 2010), 65% in 2009 (FCC 2010), and 60% in 2008 (Strategy Analytics 2009). Growth in broadband penetration has recently slowed, while growth in home network penetration appears steady, as in Figure 3-27. In 2010, 40-54% of homes had local networks (CEA 2010a-b), and the diverging curves in Figure 3-27 indicate that IADs were likely included in the upper estimate and not the lower.

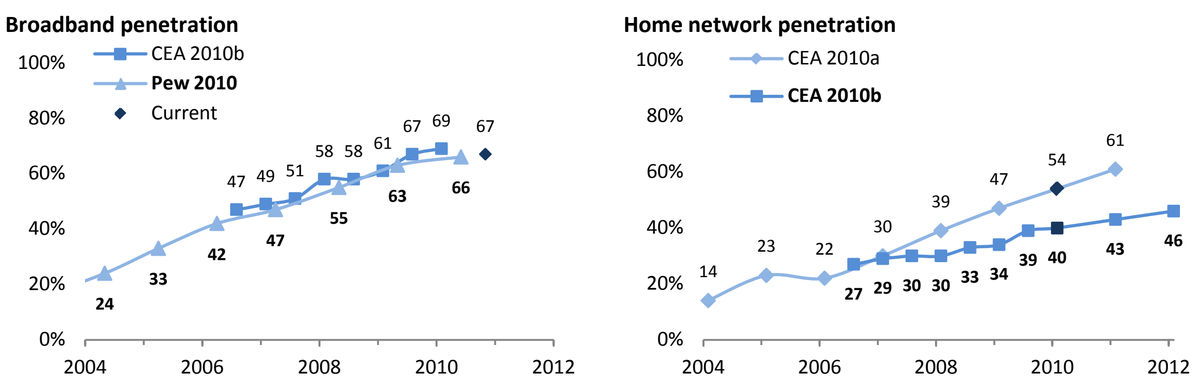

Figure 3-27: Household penetration of broadband internet subscribers and home networks

Among the 136.8 million network devices installed as of 2010, 45.4 million were modem-only, 42.0 IAD, and 49.5 router and other (LBNL 2010), shown in Figure 3-28. Of the 87.4 million broadband modems

[21] Based on 82% of computer households having high speed internet access, and 82% of households having at least one computer, the product of these yields 67% penetration.

and IADs, 46.1 million were cable, 35.9 DSL, and 5.4 fiber. Satellite home internet subscribers number about 0.9 million[22], however, these were counted by LBNL among the routers and other devices category.

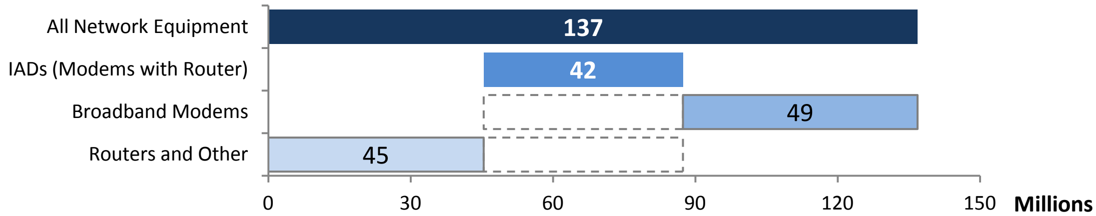

Figure 3-28: Installed base of network equipment by category for 2010 (LBNL 2010)

In Table 3-51, we adjust the installed base from LBNL to include satellite modems in the broadband modem category. Household penetration is calculated based on LBNL installed base estimates (LBNL 2010), ownership per household figures (CEA 2009), and 116 million households in 2010 (EIA 2009). Broadband subscriber penetration (modem and IAD) of 69.2% is consistent with the 66-69% range indicated above. Home network penetration (router and other devices + IADs) of 67.8%, while higher than the 54% reported by CEA respondents, is still reasonable; and the discrepancy could be attributed to IAD owners who do not use integrated LAN capabilities.

Table 3-51: Installed base of network equipment

	Household penetration	Households [millions]	Units/owner household	Installed base [millions]
Broadband Modems	36.3%		1.1	46.3
IADs (Modem with Router)	32.9%	116	1.1	42.0
Routers and Other	34.9%		1.2	48.6
Totals	-	-	-	**136.8**

Note: Values differ from Figure 3-27; satellite modems are counted as modems here.
Sources: households (EPA 2009), Units per hhousehold (CEA 2009), Installed base (LBNL 2010).

Network device power consumption depends on features – routers, for example, have more features and use more power than hubs or switches – so we subdivide the main categories to provide better energy consumption estimates. The detailed installed base estimates given in Figure 3-29 and Table 3-52 indicate broadband subscribers numbering 46.1, 35.9, and 5.4 million for cable, DSL, and fiber, respectively (LBNL 2010). These figures correspond well with the 42, 34, and 8 million subscribers calculated based on other survey data (Pew 2010). LBNL estimates indicate that 95% of routers and other devices include wireless functionality, and while high, this agrees with other estimates. Of networked households in 2005, 52% were using wireless technology according to Parks Associates (CNET 2005), and the fraction of networked households using wireless technology increased by 24% from 2008 to 2010 (Nielsen 2010a). Assuming a consistent growth rate from 2006 to 2010 would mean at least 80% of home network devices have wireless capabilities.

[22] Based on 2009 estimates from two of the four major satellite Internet providers, one of which indicated that residential subscribers make up about 94% of their subscribers (de Selding 2010).

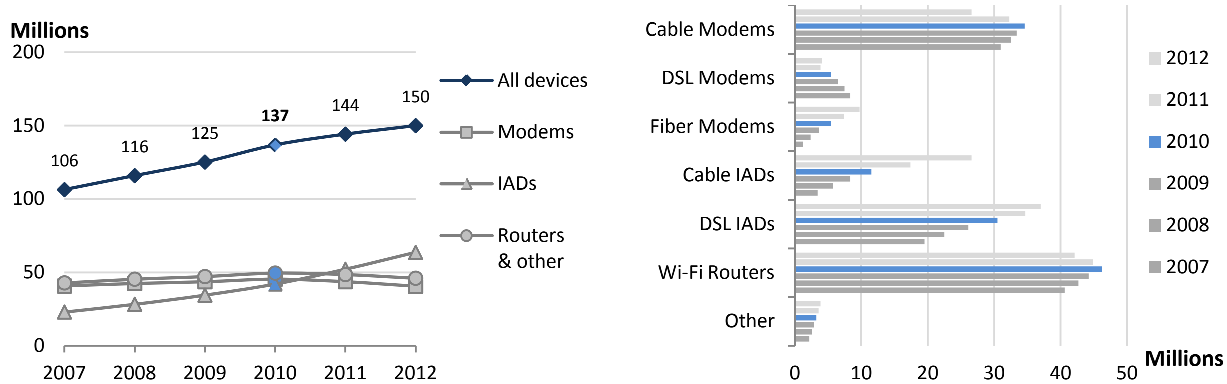

Figure 3-29: Installed base of home network equipment (LBNL 2010)

3.10.1.2 Unit Energy Consumption

3.10.1.2.1 Power Draw

Network product specifications do not normally provide detailed power draw attributes[23], so we rely instead on measured data from laboratory testing (LBNL 2010,11) and home monitoring (LBNL 2008, Bensch et al. 2010). Table 3-52 includes active mode power draw values from these sources. The EWC study found that the average[24] active mode power draw for network equipment was 5W, while no device drew more than 8W (Bensch et al. 2010). Prior estimates placed active mode power draw at 6W for broadband modems (TIAX 2006), substantially the same as the average 5.8W for all residential network equipment.

Table 3-52: UEC and AEC calculations for network equipment; usage is 7,826h active and 934h standby

	Devices [millions]	Category %	*Overall %*	Power [W] Active	Power [W] Standby	UEC [kWh/yr] Active	UEC [kWh/yr] Standby	UEC [kWh/yr] *Total*	AEC [TWh/yr]
Modem-only									
Cable modem	34.6	75%	*25%*	5.2	0.1	40.7	0.1	*40.8*	1.4
DSL modem	5.4	12%	*4%*	4.7	0.1	36.8	0.1	*36.9*	0.2
Fiber modem (all)	5.4	12%	*4%*	8.0	0.1	62.6	0.1	*62.7*	0.3
Satellite modem	1.0	2%	*1%*	9.5	0.1	74.3	0.1	*74.4*	0.1
Subtotal/Wt. Avg.	**46.4**	**100%**	***34%***	**5.6**	**0.1**	**43.5**	**0.1**	***43.6***	**2.0**
IAD (Modem + Router)									
Cable IAD	11.5	27%	*8%*	7.0	1.5	54.8	1.4	*56.2*	0.6
DSL IAD	30.5	73%	*22%*	6.5	1.5	50.9	1.4	*52.3*	1.6
Subtotal/Wt. Avg.	**42.0**	**100%**	***31%***	**6.6**	**1.5**	**51.9**	**1.4**	***53.3***	**2.2**
Router and Other									
Wireless router	46.2	95%	*34%*	5.2	1.8	40.7	1.7	*42.4*	2.0
Wired-only router / other	1.7	3%	*1%*	10.0	0.0	78.3	0.0	*78.3*	0.1
Hub or switch	0.6	1%	*0%*	3.8	0.0	29.7	0.0	*29.7*	0.0
Subtotal/Wt. Avg.	**48.5**	**100%**	***35%***	**5.4**	**1.7**	**41.9**	**1.6**	***43.5***	**2.1**
Total/ Weighted Average	***136.8***	-	***100%***	***5.8***	***1.1***	***45.5***	***1.0***	***46.0***	**6.4**

Data for standby or idle mode power draw is limited. Since prior studies assumed that network devices were always on, standby or off power was not necessary to determine energy usage. Standby power

[23] DC power supply rated power is sometimes available; however, average power draw is a fraction of rated power.
[24] Based on the measurements of 34 devices.

measurements indicate 0.1W for DSL modems (n=5), 1.5W for modems (n=12), and 1.8W for wireless routers (n=5) (Bensch et al. 2010). We tested a basic four port switch for idle mode power draw and via continuous monitoring, determined power usage to be much less than 0.1W. Based on these limited data, we populate Table 3-52 with standby power draw estimates. Uncertainty about standby power draw does not significantly impact energy usage estimates, since network devices are nearly always on. An ENERGY STAR standard for small network equipment is under development at the time of this writing, and the resultant power measurements will likely offer more information about network device power draw (EPA 2011).

3.10.1.2.2 Usage

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. Prior studies assumed (TIAX 2006, LBNL 2010) or found (LBNL 2008) that internet modems and home network devices were typically never in the off or disconnected mode. The more recent Energy Center of Wisconsin (ECW) study found that network devices were turned on for 20 hours per day on average (Bensch et al. 2010). As part of this study's phone survey of 1,000 representative households, we asked broadband internet users about their modem's power settings. Surprisingly, 12% reported their modems were switched off when not in use, 86% reported always on and 2% didn't know. To account for this behavior, we estimate each modem is used actively for 2.7 hours per day[25]. If 12% of users always turn off their modems when not in use, as reported, this would amount to an average modem on-time of 21.4 hours per day, or 7826 hours per year. This is close to the ECW finding of 20 hours per day. We did not ask the same question about routers, however, it is reasonable to assume a similar response, especially given the growing number of integrated devices.

Since 2008 some manufacturers have introduced new power management features for networking equipment. Active port sensing can eliminate power wasted on unused ports, while cable length sensing can help reduce excess transmission power for wired equipment, with rough estimates for savings amounting to 0.6W per typical port (LBNL 2011). Future devices could be designed to scale power almost linearly with data throughput, with corresponding energy gains of up to 60% feasible (Bolla et al. 2010). With recent trends favoring wireless device communication in the home, and with more Ethernet ports going vacant, the savings potential for data throughput scaling is less important than the simple deactivation of unused ports. User controlled energy-saving features are also relatively new. These include manual off- or standby- buttons, and programmable schedules that disable certain features during user-specified times. Although these options could save energy, adoption is likely to be low due to setup complexity, inconvenience, and small energy cost savings potential.

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[25] Nielsen estimates the average monthly per-person internet usage at 25.4 hours, or 305.2 hours per year, based on the 294 million people over 2 years of age (Nielsen 2010b). Assuming non-concurrent usage and using 116 million households in 2010 (EIA 2009), this amounts to 774 hours per year of usage per household. This usage figure includes all households, not just those with modems, so we adjust consider usage only among modem households (66% according to Pew 2010), or 1172 hours/year per modem household. Dividing by the average of 1.2 modems per owner household (CEA 2009) yields an average annual internet usage of 977 hours per modem. Applying the 88% always on and 12% off when not in use criteria, the average modem is on for 7826 hours per year, or 21.4 hours per day.

3.10.1.3 Annual Energy Consumption

Network equipment consumes 6.4 TWh per year: 2.0 TWh from modems, 2.2 from IADs, and 2.1 from routers, as shown in Table 3-52.

3.10.2 Prior Energy Consumption Estimates

Prior estimates of AEC for broadband modems and network devices are given in Table 3-53 and Table 3-54. Current estimates are lower than the LBNL estimate for 2010 mainly because of the inclusion of off or standby-mode hours. Differences from prior estimates are due to the increasing installed base and the shift from stand-alone routers to modem-integrated routers. In general power draw estimates have not changed much over the years. Unless network devices become capable of switching to a low power mode while inactive, usage patterns among network devices are also unlikely to deviate much from the current “always on” paradigm.

Table 3-53: Prior energy consumption estimates for broadband access devices (modems and IADs)

	Units	Power [W]			Usage [h/yr]			UEC	AEC	
Year	[millions]	Active	Low	Off	Active	Low	Off	[kWh/yr]	[TWh/yr]	Source
2010	88.4	6.1	-	0.8	7,826	-	934	48.2	4.3	Current
2010p	87.4	6.0	-	-	8,670	-	0	52.8	4.6	LBNL 2010
2008	70.6	5.8	-	-	8,760	-	0	50.8	3.6	LBNL 2010
2007	63.6	5.7	-	-	8,760	-	0	49.8	3.2	LBNL 2010
2006	46	6.0	-	-	8,760	-	0	53.0	2.4	TIAX 2007
2005	32	6.0	-	-	8,760	-	0	53.0	2.6	TIAX 2006

Table 3-54: Prior energy consumption estimates for routers and other devices (non-modem)

	Units	Power [W]			Usage [h/yr]			UEC	AEC	
Year	[millions]	Active	Low	Off	Active	Low	Off	[kWh/yr]	[TWh/yr]	Source
2010	48.5	5.4	-	1.7	7,826	-	934	43.5	2.1	Current
2010p	49.5	5.5	-	-	8,760	-	0	48.3	2.4	LBNL 2010
2008	45.3	5.5	-	-	8,760	-	0	48.0	2.2	LBNL 2010
2007	42.8	5.4	-	-	8,760	-	0	47.7	2.0	LBNL 2010
2005	15	6.0	-	-	8,760	-	0	53.0	0.8	TIAX 2006

A higher installed base is the primary reason for today’s higher AEC. With 2010 household broadband penetration at 66-69%, and router or hub ownership at 43-61%, saturation is approaching and growth rates have already begun to decline (Pew 2010). Routers and other network devices have increased fourfold since 2005, reaching 65% of computer households. Meanwhile, the number of computer households is high but still growing, with computer adoption at 84% in 2009, 86% in 2010, and 89% projected for 2011 (CEA 2009, 2010a).

Following DSL provider tendencies, cable internet providers indicate that most new cable modems will be IADs and not stand-alone modems, and thus will displace routers in the coming years (LBNL 2010). This trend is reflected in the LBNL device projections, shown in Figure 3-29 and Figure 3-30. Since existing modems are typically replaced only when a hardware failure occurs or when a subscriber switches providers, the transition will take years. Modem sales to dealers (including IADs) reached 20.3 million in 2010 (CEA 2010b), representing 23% of the existing modem stock and suggesting a product lifetime of about 4 years. In the LBNL analysis a 5 year product lifetime was assumed for enterprise network equipment, though no value was given for residential equipment (LBNL 2010).

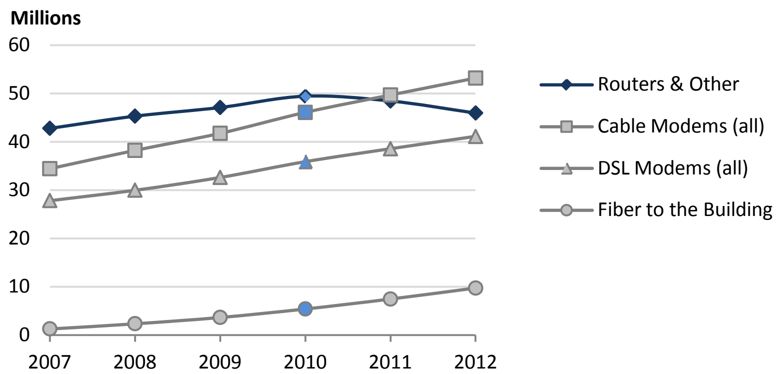

Figure 3-30: Residential broadband access equipment, including broadband modems and IADs (LBNL 2010)

Power draw among network equipment has remained fairly consistent. For both modems and network devices power draw varies weakly with device type, so even if usage shifts from one broadband or network technology to another, the effect on energy use estimates would remain small. Recently, cellular-based broadband access (e.g., 4G, WiMAX) has shown rapid growth, though only about 6% of subscribers connect with a fixed outlet-powered network device (Maravedis 2010). Instead, most wireless subscribers rely on handsets, USB dongles, and PCMCIA cards for their connection. Cellular broadband subscribers numbered 650,000 in 2010 (WiMax.com 2010).

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3.11 Printers and Multi-Function Devices

3.11.1 Current Energy Consumption

This category includes stand-alone printers and multi-function devices (MFDs), i.e., devices also called all-in-one printers that perform multiple core functions of a printer, scanner, copier, or fax machine (EPA 2010c). Nearly all current home printers use inkjet or laser marking technology. Other printing technologies that don't have a substantial market share in the residential market yet but might become relevant in the future are dye-sublimation (in photo printers) and LED printers; the latter are based on a electrophotographic marking process just as laser printers (Digitaltrends 2010). Photo printers are not considered here, they are analyzed separately in the other-devices category, as most data sources distinguish by printing technology and not dedicated functions.

Inkjet printers create an image by spraying jets of ink onto the paper via a series of nozzles. Most manufacturers of consumer desktop printers use thermal inkjet technology, where drops are formed by rapidly heating a resistive element in the ink container. The temperature of the resistive element causes a thin film of ink above the heater to vaporize into a rapidly expanding bubble, creating a pressure pulse that forces a drop of ink through the nozzle (Xennia 2011). Laser printers interpret electronic signals representing an image to trigger a laser beam. The laser projects light on certain areas of an electrically charged rotating drum, removing charge from the areas exposed to light. The drum's charged areas pick up dry ink particles that hot fuser rolls bond to paper by direct contact and heat from hot fuser rolls. Unlike inkjet printers, which use low-temperature technology, this process results in higher power consumption in order to keep the fuser rolls at high temperature, both while printing, but also in ready mode to keep the drum mechanism warm to facilitate short recovery times for future printing. As of 2010, most laser printers were monochrome printers; color laser printers are, however, expected to be a major trend over the next years, as their prices have fallen dramatically (Digitaltrends 2011). MFDs incorporate multiple core functions of printing, scanning, photocopying, sending faxes and emails. Just as single-function printers, most models used in the residential market are based on either inkjet or laser printing technology. Compact photo printers are typically inkjet printers that can print pictures of digital cameras without a computer as intermediate device.

3.11.1.1 Installed Base

According to CEA market research (CEA 2010b), 98 million MFDs are installed in U.S. homes and 66% of homes have at least one MFD. In the CEA Usage Survey (Appendix A), 71% of respondents reported ownership of a printer (including MFDs), with an average of 1.4 devices per owner household. The installed base is shown in Table 3-55.

Table 3-55: Installed base of printers and multi-function devices

	Installed Base [millions]	Penetration	Sources
Printers – single function	15	-	CE Usage Survey (Appendix A), CEA 2010b
Printers – multi function	98	66%	CEA 2010b
Total	**113**	**71%**	CE Usage Survey (Appendix A)

Recently, the market for home printers has evolved considerably, as shown by the shipping trends among device types in Figure 3-31. Prices of MFDs have fallen dramatically and are now comparable to single-function inkjet printers. In prior years the vast majority of home printers were standard-size single-function inkjet printers (Roth and McKenney 2007). Today, however, MFDs now account for approximately 85% of installed home printers (CEA 2010a), compared to 25% in 2006 (Roth et al. 2008). Laser printer prices have also fallen significantly, which has increased their use in homes. The California Statewide Residential Appliance Saturation Study (RASS 2010) found a household penetration rate of 44% for inkjet printers and 15% for laser printers. Based on these findings and current sales data[26], we estimate that approximately 10% of home printers are laser printers. By the end of 2010, 84% of laser printers sold were monochrome and 16% were color laser printers (residential and commercial sector combined; Eddy 2010).

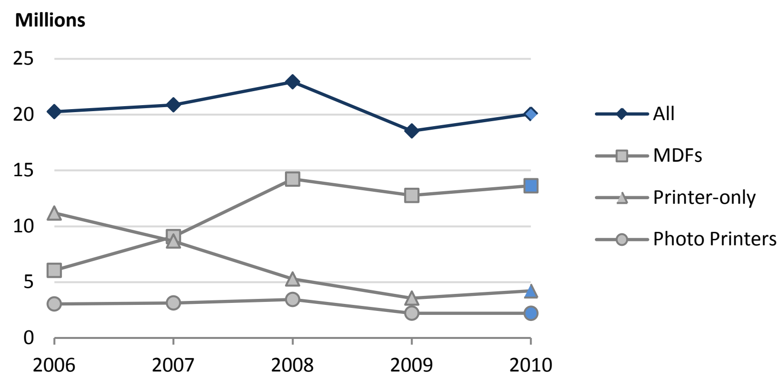

Figure 3-31: Shipments of printers to U.S. dealers by type (CEA 2011)

3.11.1.2 Unit Energy Consumption

Printers can be characterized by the following four operating modes (based on EPA 2010c, shortened):

- *Active* – Device is actively producing output or performing any of its other primary functions
- *Ready* – Device is not producing output, has reached operating conditions, has not yet entered into any lower-power modes, and can enter Active mode with minimal delay
- *Sleep* – The reduced power state that the product enters automatically after a period of inactivity
- *Off* – Device is turned off but remains plugged in

Note that this study distinguishes between 4 power modes instead of 3 as in (Roth et al. 2008), which allows a more accurate depiction of the operating modes defined by ENERGY STAR (EPA 2010c).

Figure 3-32 shows inkjet printer off mode consumption data of 6 countries from in-store measurements (APP 2008a). Australian time series show the decline of off mode power consumption for in-store MFDs from 6.8 W in 2003/04 to 1.1 W in 2009/10 (APP 2010). European in-store measurements (SELINA 2010)

[26] Among the 50 best-selling printers on Amazon.com in March, 2011, 16% are laser printers.

on the other hand found an off-mode power draw of 0.3 W for inkjet printers and of 2.5 W for MFDs. Several other studies from different countries find similar values for MFDs of 1.7 W (APP 2008b) and 3.2 W (EuP 2007), respectively. Manufacturers on the other hand report lower values for current models of 0.4 W approximately (HP 2011).

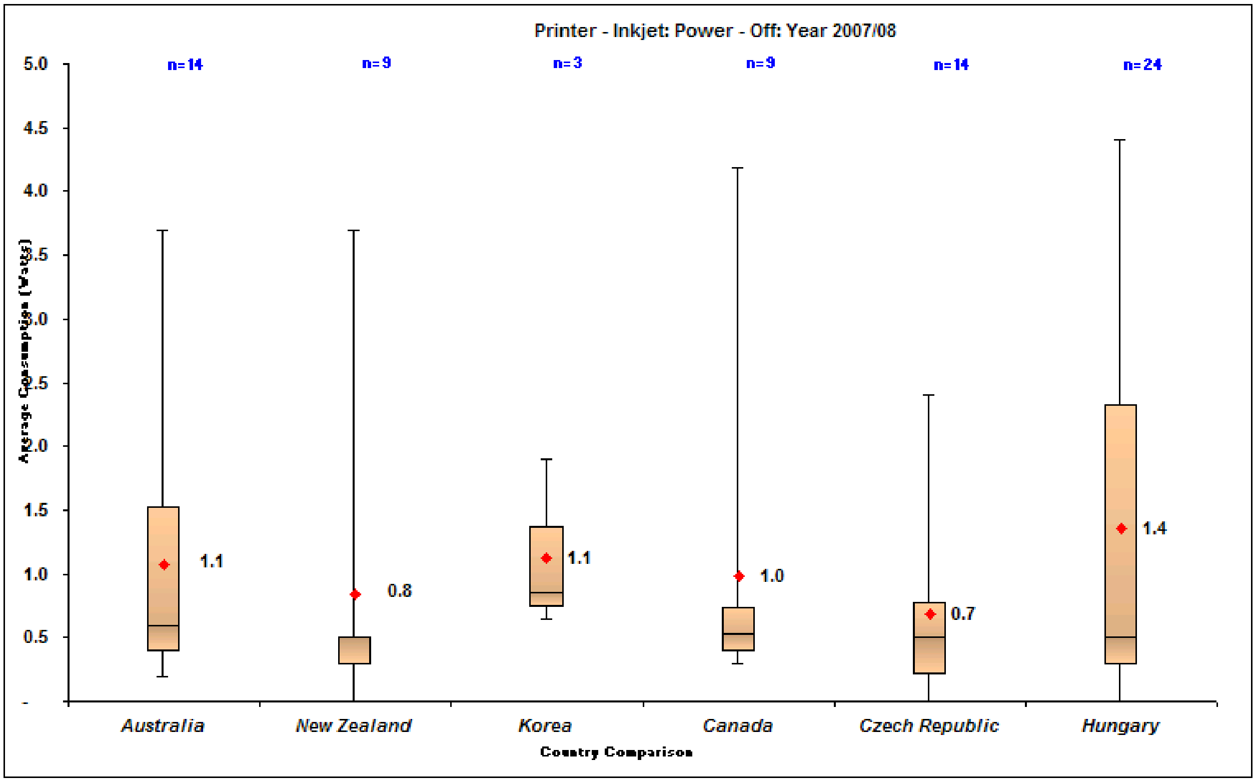

Figure 3-32: Power draw in off mode of in-store inkjet printer models (APP6 2008a)

The estimates presented in Table 3-56 are based on data from manufacturers (HP 2010), in-store measurement data (SELINA 2010; International Standby Power Data Project of the Asia-Pacific Partnership on Clean Development and Climate (APP 2008)), and data of the EuP preparatory studies (EuP 2007c).

Table 3-56: Power draw by mode of printers and MFDs

Device Type	Power [W]				Sources
	Active	Ready	Sleep	Off	
Inkjet single-function	17	6	2	1.0	EPA 2011a, EPA 2011b, EPA 2008, HP 2011, APP 2008, SELINA 2010, EnergyConsult 2008
Inkjet MFD	22	7	4	0.7	
Laser single-function	400	11	7	0.4	
Laser MFD	420	12	8	0.4	

Printers spend a very small fraction of time in *active* mode (as defined by EPA). We also assume that most modern printers and MFDs enter a lower power state after a certain period (default time to sleep). The EuP preparatiory study (EuP 2007b) estimates personal printers to spend 0.3% in *active* mode, 2% in *ready* mode, 14% in sleep mode, 67% in *off* mode with losses and 17% in *off* mode without losses (hard switch off). We used CE Usage Survey data to determine active and ready mode usage, and attributed the remaining time to sleep and off mode using the ratio from the EuP study.

Current ENERGY STAR printers are shipped with much shorter default time to sleep delay times than previous models (EuP 2007b). The median delay time is 5 minutes for inkjet (single function) printers, 30 minutes for inkjet MFDs, 45 minutes for laser printers and 60 minutes for laser MFDs, which reduces the time spent in *ready* mode considerably (EuP 2007b). The biggest uncertainty arises from the time spent in *sleep* vs. *off* mode; at least in the case of laser printers, the difference in power draw between these two states is considerable. MFDs draw more power while printing or copying than when scanning or faxing. (Brown 2011).

We assume that printing time is the same for both MFDs and single-function devices, and we assume MFDs spend an additional two hours in active mode at 15 W for the UEC calculation. We base this estimate on the assumption that printing demand is similar for MFDs. The contribution of scanning and faxing to the total UEC is based on the assumption that the power consumption of MFDs while scanning/faxing is comparable to stand-alone scanners (10 W in active mode) and fax devices (32 W in active mode) (ECOS 2006). The added usage time of 2 hours is based on an uninformed conservative guess; however, the lack of precision of these figures does not have a relevant impact on the UEC calculation, given that the UEC contribution of *printing* is 0.11 kWh for inkjet MFDs and 4.2 kWh for laser MFDs, compared to an estimated UEC contribution of 0.03 kWh for *scanning/faxing*.

Our usage estimates are summarized in Table 3-57.

Table 3-57: Annual usage of printers and MFDs by mode

	Usage [h/year]				**Sources**
	Active	**Ready**	**Sleep**	**Off**	
Inkjet single-function	5	35	1,220	7,500	EPA 2010, EuP 2007b,
Inkjet MFD	7	105	1,211	7,437	Schlomann et al. 2005, CE
Laser single-function	10	280	1,186	7,284	Usage Survey (Appendix A)
Laser MFD	12	352	1,175	7,221	

Combining power draw by mode and usage estimates, we obtain the UEC values in Table 3-58.

Table 3-58: UEC calculation for printers and MFDs

	Energy Consumption [kWh/yr]				
	Active	**Ready**	**Sleep**	**Off**	**UEC**
Inkjet single-function	0.2	0.2	2.4	7.5	**10**
Inkjet MFD	0.1	0.7	4.8	5.2	**11**
Laser single-function	4.0	3.1	8.3	2.9	**18**
Laser MFD	4.2	4.2	9.4	2.9	**22**

The energy consumption estimates for printers contain several uncertainties. First, power draw by mode of both of inkjet and laser printers varies over a wide range for different products and manufacturers don't have consistent power mode definitions (see EuP 2007b for an overview of intermediate operational modes). For instance, many HP products now have a power-save mode; the printer automatically leaves this mode when a print job is sent. However, as the power draw of the power-save mode is only slightly lower than in sleep mode, see specification documents (HP 2011), we consider both as sleep mode. The factor with the greatest uncertainty, however, is the time spent in the individual modes and values from prior studies show wide variability. In part, this may be due to different definitions of operational modes. For instance, *ready* mode is considered as *active* mode in some studies, whereas others treat it separately or include it in what they call *standby*.

3.11.1.3 Annual Electricity Consumption

Printers and multi-function devices consume approximately 1.3 TWh per year, as shown in Table 3-59.

Table 3-59: AEC calculations for inkjet printers, laser printers, and MFDs

	UEC [kWh/yr]	Installed Base [millions]	AEC [TWh]
Inkjet Printer	10	10	0.1
Inkjet MFD	11	92	1.0
Laser Printer	18	5*	0.1
Laser MFD	21	6*	0.1
All Printers	**12**	**113**	**1.3**

* The breakdown between laser printers and laser MFDs is based on sales data for the residential and commercial sector combined (Eddy 2010), and needs further evaluation.

3.11.2 Prior Energy Consumption Estimates

The energy consumption of single-function printers and especially MFDs has decreased considerably since the earlier residential CE energy consumption study. Today's MFDs use only slightly more energy than single-function models; the difference in power draw between inkjet and laser printers is much more prominent. For most devices, s*leep* and *off* mode now account for a lower fraction of total printer energy consumption than in previous studies (e.g., TIAX 2006), although newer devices tend to spend more time in these modes due to shorter default delay to sleep times.

Table 3-60: Prior energy consumption estimates for printers and MFDs

Year	Units [millions]	Power [W] Active	Ready	Sleep	Off	Usage [h/yr] Active	Ready	Sleep	Off	UEC [kWh/yr]	AEC [TWh/yr]	Source
Inkjet												
2010-SFD*	15	17	6	2	1	5	35	1,220	7,500	10	0.1	Current
2010-MFD	98	22	7	4	2.5	7	105	1,211	7,437	24	1.2	Current
2010-ALL	113	-	-	-	-	-	-	-	-	-	2.3	Current
2007-ALL	-	16.5	7.7	4.4	3.2	25	183	1,252	7,300	-	-	EuP Prep 2007
2005-ALL	85	13	5	-	2	52	1,606	-	7,102	23	1.7	TIAX 2006
2005-SFD	-	9	3	1.7	1.9	88	-	8,672	-	15	-	ECOS 2006
2005-MFD	-	15	9	6.2	5.3	7,884	-	613	263	55	-	ECOS 2006
Laser												
2010-SF	-	400	11	7	0.4	10	280	1,186	7,284	18	0.1	Current
2010-MFD	-	420	12	8	0.4	12	352	1,175	7,221	22	0.1	Current
2010-ALL	11	-	-	-	-	-	-	-	-	-	0.2	Current
Inkjet or Laser												
2006-SFD	76	8.9	3.2	-	1.7	88	-	-	8,672	16	1.2	TIAX 2008
2006-MFD	25	15.2	9.1	-	6.2	283	-	659	7,818	59	1.5	TIAX 2008
2006-ALL	101	-	-	-	-	-	-	-	-	-	2.7	TIAX 2008

* SFD = single function device, MFD = multi-function device, ALL = both.

Over the past years, printer manufacturers have introduced several modifications to their products to reduce power consumption of imaging equipment. These include various techniques to shorten fuser warm-up times, and novel toner materials requiring lower fuser temperatures (EuP 2007d). Devices that meet stricter ENERGY STAR requirements have certainly contributed to a lower UEC. The ENERGY STAR specification for imaging equipment that became effective in June of 2009 distinguishes between different printer types and speeds. It specifies sleep-mode power draw, external power supply performance, the default delay time to sleep (for low-temperature technologies such as inkjet printers), and a maximum total energy consumption (TEC) allowance for high-temperature imaging technology (e.g., laser printers).

3.11.3 References

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3.12 Set-top Boxes

3.12.1 Current Energy Consumption

Set-Top Boxes (STBs) receive and decode signals for playback on televisions. They may offer services and applications that vary by service provider and STB, including high definition (HD) programming, video-on-demand, digital video recording (DVR) capabilities, multiple tuners, format conversion, home networking, and a variety of additional applications. Digital-to-Analog Adapters[27] (DTAs), decode digital signals for TV viewing. These exist in two forms: (1) Cable-DTAs that may decode digitally encrypted Cable signals for viewing on subscriber TVs, and (2) Over-the-Air (OTA)-DTAs that decode unencrypted digital signals transmitted via antenna for older TVs that lack a digital tuner.

We divide STBs into two major categories: Pay-TV STBs and Stand-Alone STBs. Pay-TV STBs are generally leased to consumers by Cable, Satellite, and Telco[28] TV service providers to provide a variety of services and features. Stand-Alone STBs may be purchased independently, and generally provide alternative services to those of Pay-TV STBs. Stand-Alone STBs include OTA-DTAs, stand-alone DVRs, and digital media adapters (DMAs). DMAs stream digital media from computer servers or the Internet to a television or audio system. We evaluated stand-alone DVRs and DMAs in less detail than the other categories.

3.12.1.1 Installed Base

3.12.1.1.1 Pay-TV Set-top Boxes

There were almost 180 million pay-TV STBs as of mid-2010, with the breakdown by subscriber shown Table 3-61. We drew upon three sources to estimate the installed base of pay-TV STBs: the CE Usage Survey, market research data, and consultation with industry experts. The estimates were built upon market research data (SNL Kagan 2010, 2011) that gave subscriber count and STB installed base by provider type. In response to data provided by industry sources (Langille 2011), we reduced the SNL Kagan estimate for Satellite STBs per household from 2.8 to 2.3. The total installed base as given by Table 3-61 agrees with our CE Usage Survey to within 3%. Additional installed base estimates are presented in the final portion of this section.

Table 3-61: Installed base of subscription STBs by service

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

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

Cable subscribers have the fewest STBs per household, since not all Cable subscribers require STBs to receive the basic unencrypted level of service, while Satellite and Telco subscribers require STBs to receive any level of service. Some Cable providers use digital signals for basic service, which may also

[27] Also called digital terminal adapters, digital transport adapters, and digital television adapters.
[28] Other studies have referred to Telco TV as IPTV, but Telco TV includes subscription TV services that are not provide via IP, most notably Verizon FiOS. It does not include the streaming of video over an internet connection.

require a Cable-DTA for viewing digitally-encrypted channels or for viewing digital channels on analog televisions. Cable DTAs numbered 14 million by mid-2010 (SNL Kagan 2011), and their number is increasing as more providers switch to digital programming.

In our phone survey, participants indicated the number of TVs in the household, TV subscriptions, and for up to three most-used TVs, the presence of any STBs and the service they provide. For households with more than three TVs, we assumed that their 4^{th}-10^{th} TVs did not have an STB[29]. When calculating STBs per subscriber household by service type, we excluded the potentially confused Satellite or Telco service respondents who indicated zero STBs, since these services require at least one STB.

3.12.1.1.2 Stand-alone Set-top Boxes

Over-the-Air Digital-to-Analog Adapters (OTA-DTAs) are stand-alone devices that enable analog TVs to view digital broadcasts. By June 2009, all antenna-based TV broadcasts were switched to digital-only transmissions, as required by the Digital Television Transition (FCC 2010). To facilitate the transition the U.S. government issued a consumer coupon program for OTA-DTAs, and by the program's end 34.9 million coupons had been redeemed (DTV.gov 2010). About 51 million OTA-DTAs were sold to U.S. dealers from 2006 to mid 2010 (CEA 2010b).

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

Stand-alone DVRs, those obtained independently of TV service providers, are few in number since most DVRs are now integrated with subscription STBs (see the summary in Table 3-62). Only 5% of DVR households had a stand-alone DVR as of March 2009 (Nielsen 2009), suggesting about 3 million in service. Provider data support this estimate, as in January 2010 the dominant stand-alone DVR manufacturer had 1.5 million stand-alone customers (Gorman 2010). DMA sales totaled 8.9 million from 2006 to mid-2010 (CEA 2010a).

Table 3-62: Installed base of stand-alone STBs

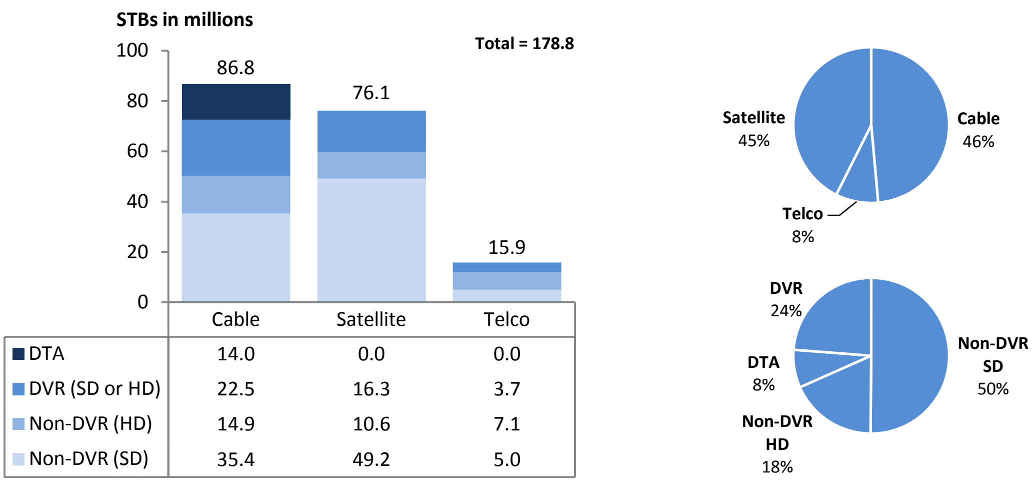
Device	Units [millions]
OTA-DTA	33.0
DMA	8.9
DVR	3.0
Total	**45**

[29] For households with more than 3 TVs, we analyzed the survey data in two ways to obtain lower and upper bound estimates on subscription STBs. Assuming a household's 4^{th}-10^{th} TVs had zero STBs gives 173 million STBs, whereas applying the STB:TV ratio of their 1^{st} three TVs yields 223 million STBs.

3.12.1.2 Unit Energy Consumption

3.12.1.2.1 Features

The power draw of a set-top box depends on the kind of subscription service and its features. Based on available segmentation and power data, we split subscription STBs into three feature categories: (1) DVR-enabled with any tuner; (2) non-DVR with Standard Definition (SD) tuner, and (3) non-DVR with High Definition (HD) tuner. Within these categories there may be variations in features and functionality that affect power draw, such as number of tuners, processing power, multi-room playback, and home networking capabilities. This breakdown, shown in Figure 3-33 for mid-2010, is based on SNL Kagan (2011), and we used these values to evaluate AEC.



	Cable	Satellite	Telco
DTA	14.0	0.0	0.0
DVR (SD or HD)	22.5	16.3	3.7
Non-DVR (HD)	14.9	10.6	7.1
Non-DVR (SD)	35.4	49.2	5.0

Figure 3-33: Installed base of subscription STBs by service provider and select capabilities for mid-2010 (SNL Kagan 2011). Percentages are based on installed devices and not number of subscribers.

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. We do not consider thin-clients in our estimates since they appeared to have a low installed base circa mid-2010.

We also present other estimates of DVR penetration for comparison with the SNL Kagan data. Household DVR penetration reached 33% in 2009 growing to 39% in 2010, with 1.4 DVRs per owner household (CEA 2010a), and 36% of TV households had DVRs at the start of 2010 (Nielsen 2010b). Both estimates indicate about 58 million DVRs, 20% more than our estimate of 46 million. Up to 24% of Comcast and 35% of Time Warner Cable subscribers had DVR service by mid-2010, though penetration was lower for other Cable operators such as Mediacom at 16% (RBR.com 2010). Projecting from prior shipments estimates (LBNL 2010), DVR STBs would comprise 18% of Cable STBs, compared with 31% in the SNL Kagan estimate. Of Satellite subscribers 47% had at least one DVR by 2010 (RBR.com 2010, LBNL 2010), though only 22% of the installed base included DVR (SNL Kagan 2011). Of Telco STBs, 35%

shipped with DVR capability in 2008 (LBNL 2010), more than the 23% reported in the SNL Kagan installed base.

3.12.1.2.2 Power Draw

Subscription STBs have two primary power modes: (1) on- or active-mode and (2) off-standby mode. Even when manually "turned off" most STBs continue communicating with the service provider, so the two modes have similar power draw, making the energy analysis less sensitive to user behavior than for other devices. We expect that the use of power strips to completely turn off STBs is uncommon, since interrupting power can provoke a disruptive automatic reprogramming period.

Measurements of on- and standby-power for 64 devices (EPA 2010) are shown in Figure 3-34 according to subscription type and selected features (SD=standard definition, HD=high definition, DVR=digital video recorder). The slight difference between on- and standby-mode power draw for most subscription STBs is apparent, with average values for all features and categories summarized in Table 3-63 and Table 3-64 (later in this section). Average on- and (standby-) mode power draw values were 17.7 W (16.6) for Cable, 13.5 W (12.1) for Satellite, and 14.0 W (12.1) for Telco, with overall average values of 15.6 W (14.3). Most measured devices were introduced between 2007 and 2010, and since average service life is nearly 6 years, based on sales of 30 million units per year (CEA 2010a), the older units may be under-represented. Even though the sample size is limited, there are not many major STB manufacturers so results may still be representative.

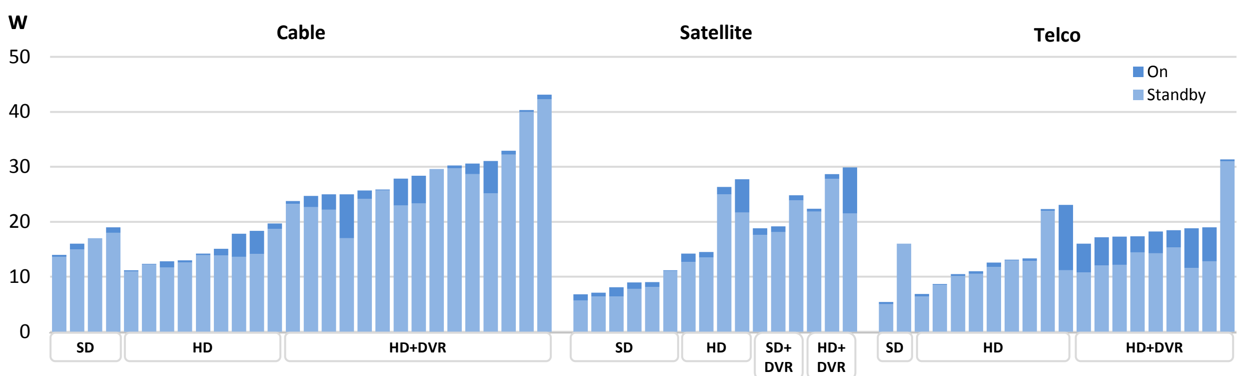


Figure 3-34: Power draw of subscription set-top boxes by technology, N=64 (EPA 2010)

DTA power measurements for 10 (EPA 2010, 2011) and 14 (LBNL 2011) units are shown in Figure 3-35. All of the labeled EPA data were Cable-DTAs. Of the 14 devices measured by LBNL, two were Cable-DTAs and the remainder were OTA-DTAs. The ENERGY STAR specifications for STBs do not require automatic power down for DTAs; however, to be eligible for the government coupon program, OTA-DTAs must power down within four hours by default and have a maximum standby power of 2 W. All but one measured by LBNL had automatic power down. Furthermore, 13 coupon-eligible devices made up 90% of the 2009 sales according to an industry representative (LBNL 2011). As of mid-2010 the average Cable DTA draws 4.4 W (Glist 2011), and we assumed these were on all the time since most lack an off button or power switch. The average OTA-DTA draws 6.5 W in on mode and 0.8 W in standby mode.

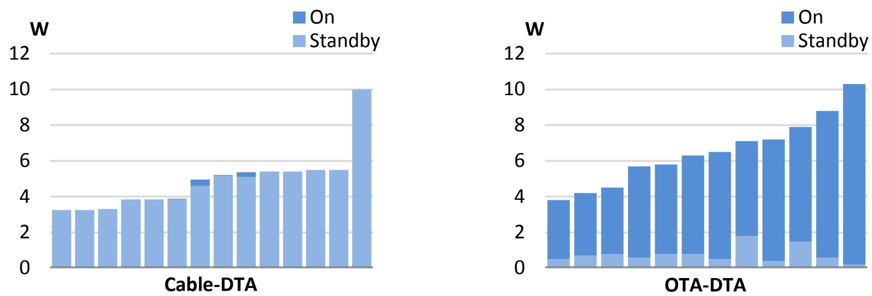


Figure 3-35: Power draw of Cable-DTA and OTA-DTA devices (EPA 2008, 2010 and LBNL 2011)

Limited data for stand-alone DVRs and DMAs were available. Users reported measuring power draw between 27 and 40 W for popular models of DVRs – the higher values for newer models – with standby-mode power consuming 3 W less than active-mode (TiVo 2008). This is consistent with prior estimates of 27 W (TIAX 2007), and a single measurement of 27.4 W (Bensch et al. 2010). DMA power draw ranges from 4 to 10 W based on several sources (CNET 2010, Apple 2011, Roku 2011, WD 2011). These values make sense based on DMA functionality, which is similar to network equipment. We assume average active (standby) power draw of 33 (30) W for DVRs and 8 (6) W for DMAs.

3.12.1.2.3 Usage and Consumer Behavior

Most STB energy consumption depends weakly on time spent in each mode, yet if lower power standby modes become more prevalent, a deeper understanding of consumer habits and mode times may prove useful. We used data from the CE Usage Survey to estimate the hours spent in on- and standby-modes for the first three subscription STBs per household. Participants answered questions about their (up to) 3 most used TVs and corresponding STBs. They were asked to indicate if their STBs were left on when the TV was not in use (daytime power state), and if they had to turn on their STB when first using their TV (nighttime power state). Figure 3-36 shows their responses.

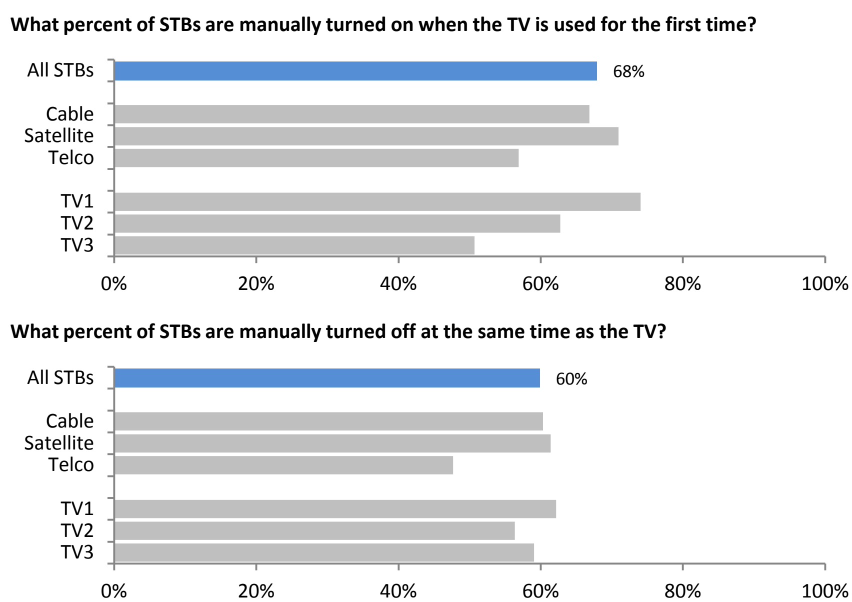


Figure 3-36: Frequency STBs were manually turned on before use and off after use, N=1,258 (CE Usage Survey)

We calculated usage estimates for each set-top box according to the following procedure. We split each day into (up to) 3 parts: (1) TV usage time, (2) TV inactive time at night, and (3) TV inactive time during the day. First, we assumed that each set-top box was always on while the corresponding TV was in use. Next, we inferred night time usage based on whether or not the participant had to manually turn on the STB during the first use of the day. We assumed that night time lasted up to 8 hours. Finally, we determined usage during the remaining time (if any) by asking participants if they turn off STBs while not watching TV.

Although TV usage time varied strongly among the top three most used TVs, STB usage did not. Average on-mode usage was about 11.5 hours per day. This estimate is between the 7 and 14 hours of daily on-time prescribed by the ENERGY STAR energy budget calculations[30] (EPA 2011a). Survey participants indicated that 68% of STBs had to be switched on for the first use of the day (i.e., most were off during the night), while 60% of STBs were said to be switched off with the TV.[31]

OTA-DTA usage was determined similarly, as users were asked how often they had to turn on the DTA when using it to watch OTA-TV. Responses representing 111 DTAs among 77 households were limited to never (0%), occasionally (25%), about half the time (50%), often (75%), and always (100%) and are shown in Figure 3-37. On average users had to turn on their OTA-DTA 70% of the time.

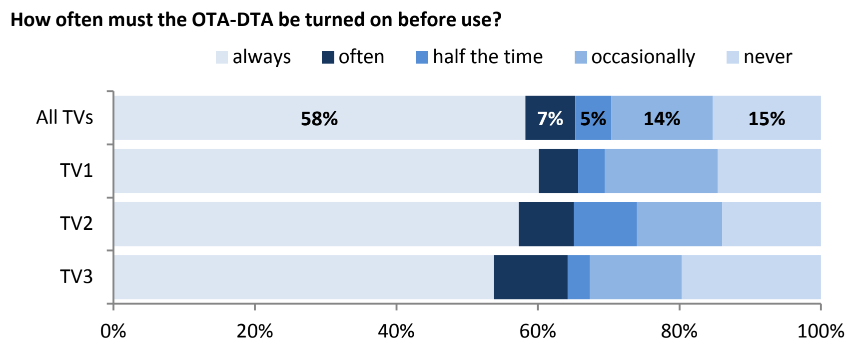


Figure 3-37: Frequency that OTA-DTAs were manually turned on before use, N=111 (CE Usage Survey)

We obtained total average OTA-DTA on-time of 10.8 h/day by calculating usage for each DTA represented in the survey, assuming DTAs were on while the TV was active and applying[32] the user-reported "already-on" frequencies. The dependence of OTA-DTA usage on TV priority is weak, at 70% (TV1), 71% (TV2), and 66% (TV3). Figure 3-38 shows the results with variation by TV priority. As one may expect of older TVs, OTA-DTA TVs were used 23% less than the average television. Because Cable-DTAs lack an auto-off feature and are meant to stay on all the time, we place their usage at 24 hours per day, though this has no bearing on energy use since power draw is virtually identical for both modes.

[30] ENERGY STAR assumes 7 hours of daily on-time for devices with auto-power down and 14 hours for those without.
[31] Units featuring auto-power down made up 14% of ENERGY STAR qualified STBs that were on the market as of June 2010 (EPA 2011b). This may explain why more people had to turn on their STBs than claimed to turn them off.
[32] Users can reach off-mode through auto-power down or through manual switching. We assume that off mode is reached by both ways equally, and use the default 4-hour auto-power down in the calculations. Assuming auto-off only yields 12.5 h/day, manual-off only yields 9.1 h/day, and an even mix yields 10.8 h/day.

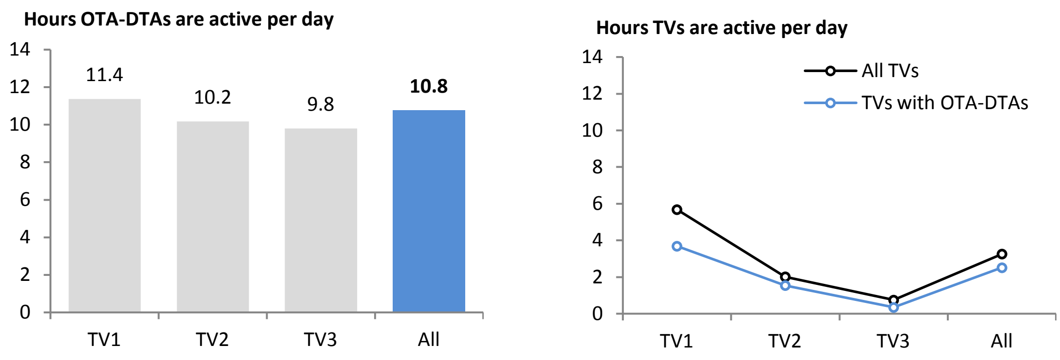


Figure 3-38: Average active-mode usage of OTA-DTAs and TVs (CE Usage Survey)

As with many subscription DVRs, stand-alone DVRs are typically always recording, hence their on and off modes draw about the same amount of power. We assume DVRs are on 11.5 h/day (the same as subscription STBs) and DMAs are on 21.6 h/day (the same as network equipment).

3.12.1.2.4 Unit Energy Consumption

On average Cable units used the most energy per device, at 150 kWh/yr, compared with 112 and 115 for Satellite and Telco services. DVR-enabled STBs, at 24% of the installed base, were responsible for 41% of the energy consumption. This is because DVR-enabled STBs consumed on average 222 kWh/yr, roughly twice as much as non-DVRs (109 kWh/yr). Due to differences in features, the UEC for OTA-DTAs (29 kWh/yr) and Digital Media Adapters (68 kWh/yr) were both much lower than subscription STBs (131 kWh/yr), while stand-alone DVRs (275 kWh/yr) were comparable to DVR-enabled STBs (222 kWh/yr).

3.12.1.3 Annual Energy Consumption

Figure 3-39, Table 3-63, and Table 3-64 summarize energy consumption estimates for set-top boxes, with a total AEC of 26.6 TWh/yr. We found about 91% of the usage was due to subscription STBs (25 TWh/yr), while the remaining 9% was split between OTA-DTAs (1.0 TWh/yr), DVRs (0.8 TWh/yr), and DMAs (0.6 TWh/yr). Most STBs spend about the same time in on- and off-modes, yet unlike most other consumer electronics, power draw is relatively mode-independent.

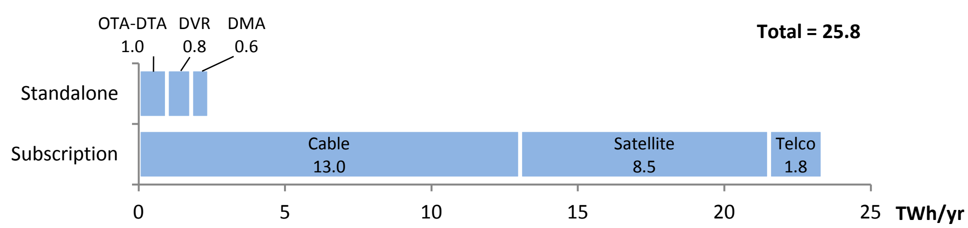


Figure 3-39: Set-top box AEC by type

Table 3-63: UEC and AEC calculations for subscription STBs

	Units [millions]	Type %	*All %*	Usage [h/day]	Power [W]		UEC [kWh/yr]			AEC [TWh/yr]
					Active	Off	Active	Off	*Total*	
Cable										
Cable DTA	14.0	16%	*8%*	24.0	4.4	4.4	39	0	*39*	0.5
Non-DVR (SD)	35.4	41%	*20%*	12.1	16.5	15.9	73	69	*142*	5.0
Non-DVR (HD)	14.9	17%	*8%*	12.1	14.9	13.5	66	59	*125*	1.9
DVR (SD or HD)	22.5	26%	*13%*	12.1	29.6	27.3	130	119	*249*	5.6
Subtotal/Wt. Avg.	**86.8**	**100%**	***49%***	**12.6**	**17.7**	**16.6**	**81**	**69**	***150***	**13.0**
Satellite										
Non-DVR (SD)	49.2	65%	*28%*	10.8	8.5	7.6	34	37	*70*	3.5
Non-DVR (HD)	10.6	14%	*6%*	10.8	20.7	18.2	82	88	*169*	1.8
DVR (SD or HD)	16.3	21%	*9%*	10.8	24.0	21.8	94	105	*199*	3.3
Subtotal/Wt. Avg.	**76.1**	**100%**	***43%***	**10.8**	**13.5**	**12.1**	**53**	**58**	***112***	**8.5**
Telco										
Non-DVR (SD)	5.0	32%	*3%*	13.2	10.7	10.5	52	41	*93*	0.5
Non-DVR (HD)	7.1	45%	*4%*	13.2	13.5	11.8	65	46	*112*	0.8
DVR (SD or HD)	3.7	23%	*2%*	13.2	19.3	14.9	93	59	*152*	0.6
Subtotal/Wt. Avg.	**15.9**	**100%**	***9%***	**13.2**	**14.0**	**12.1**	**68**	**48**	***115***	**1.8**
Total/Weighted Avg.	***178.8***	***-***	***100%***	***11.9***	***15.6***	***14.3***	***68***	***63***	***131***	**23.4**

Table 3-64: UEC and AEC calculations for stand-alone STBs

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

* Estimates for usage and power draw for starred categories are based on limited data and carry greater uncertainty.

3.12.2 Prior Energy Consumption Estimates

Our subscription STB energy use estimate of 23.4 TWh/yr is reasonably close to the 27 TWh/yr estimate by NRDC (2011) for 2010, and although their estimate did not include Cable-DTAs, the impact is small at about 0.5 TWh/yr. Other estimates for subscription and stand-alone STBs are given in Table 3-65 and Table 3-66. Cable STB power draw has increased, due to the adoption of new features, such as HD and DVR. Satellite STBs, however, draw slightly less power than in 2006. OTA-DTA consumption has likely reached its peak, as all new TVs must have digital tuners. Likewise, stand-alone DVRs are few in number, owing to the popularity of integrated DVRs.

Table 3-65: 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								
2010	87	18	17	4,526	4,234	150	13.0	Current
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	-	-	Davis Energy Group 2004
2003	65	23	22	-	-	-	-	ACEEE 2004
2000	49	13	11	-	-	103	5.0	LBNL 2001
Satellite								
2010	76	14	12	3,941	4,819	112	8.5	Current
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	-	-	Davis Energy Group 2004
2003	32	18	17	-	-	-	-	ACEEE 2004
2000	13	17	16	-	-	140	1.9	LBNL 2001
Telco								
2010	16	14	12	4,834	3,926	115	1.8	Current
2008	3	-	-	-	-	164	0.5	LBNL 2010

Table 3-66: Prior energy consumption estimates for OTA-DTA and standalone DVRs

Year	Units [millions]	Power [W] Active	Power [W] Off	Usage [h/yr] Active	Usage [h/yr] Off	UEC [kWh/yr]	AEC [TWh/yr]	Source
OTA-DTA								
2010	33	6.5	0.8	4,165	4,595	29	1.0	Current
2008	35	6.5	0.8	4,745	4,015	27	0.9	LBNL 2011
DVR								
2010	3.0	33	30	4,198	4,562	275	0.8	Current
2006	1.5	27	27	2,080	6,680	237	0.4	TIAX 2007
2003	-	24	24	-	-	-	-	NRDC 2005

We prepared several installed base estimates for subscription STBs, shown in Table 3-67, before settling on the ones used in this study. First, our CE Usage survey indicated there are 173 million STBs based on household reporting. Next, we considered SNL Kagan industry data, which indicated 190.5 million STBs (SNL Kagan 2011) across a subscriber base of 93.6 million (The Bridge 2010), notably higher than suggested by the CE survey. The major difference in the number of STBs per Satellite subscriber was confirmed by a Satellite industry representative: the two major providers had 2.8 and 1.7 STBs per subscriber (Langille 2011). We thus modified the SNL Kagan value from 2.7 to 2.3 STBs per Satellite subscriber, bringing the two estimates into alignment: the totals agree to within 3%. This modified SNL Kagan estimate is the one we ultimately used in the study. The NRDC estimated 160 million STBs installed (NRDC 2011), not counting the approximately 14 million Cable DTAs. Ultimately, these models show good agreement.

Table 3-67: Other estimates of subscription STB installed base

Source	Subscribers [millions]			STBs per subscriber			STBs [millions]			
	Cable	Satellite	Telco	Cable	Satellite	Telco	Cable	Satellite	Telco	Total
CE Survey	63.1	36.5	6.6	1.4	2.0	2.2	85.8	73.3	14.2	173.3
SNL Kagan-raw	54.8	33.1	5.7	1.6	2.7	2.8	86.8	87.9	15.9	190.5
SNL Kagan-mod	54.8	33.1	5.7	1.6	2.3	2.8	86.8	76.1	15.9	178.8
NRDC	-	-	-	-	-	-	-	-	-	174.0
Others*	57.9	30.0	5.2	1.0	2.8	3.0	60.3	84.0	15.5	159.8

* Less accurate, built from less robust data sources.

For another source of comparison, we constructed the “others” estimate based on various, perhaps less-consistent sources, amounting to 160 million STBs. This estimate was clearly too low, due to an unrealistically low Cable subscriber estimate. Satellite and Telco estimates were in line. About 98% or 114.9 million U.S. households had at least one TV, as of January 2010 (Nielsen 2010a). Of those, 90% had at least one TV subscription service, while 9% received only antenna broadcasts, 29% had Satellite service (Nielsen 2010a), 5.2% had fiber (Point Topic 2010), and assuming no household service overlap, the remaining 55.8% had Cable.

Values for 2008 are lower. One report suggests 0.8, 1.7, and 3.0 STBs per subscriber household for Cable, Satellite, and Telco subscribers, with 48% of Cable subscribers having no STBs (LBNL 2010). The increase in Cable STBs since 2008 is primarily due to the adoption of digital service and to the rise of DVRs. Cable DTAs appear to be on the rise, as they numbered approximately 1 million by Q4 2008, 9 million by Q4 2009, 15.3 million by Q2 2010, and 20 million by Q2 2011 (Baumgartner 2009; Comcast 2009, 2010; IHS 2011). Finally, we present annual and cumulative STB sales since 2005 in Figure 3-40 and Figure 3-41 to illustrate the recent rise in Cable STBs, due in part to HD and DVR deployment, and the introduction and growth of Telco STBs.

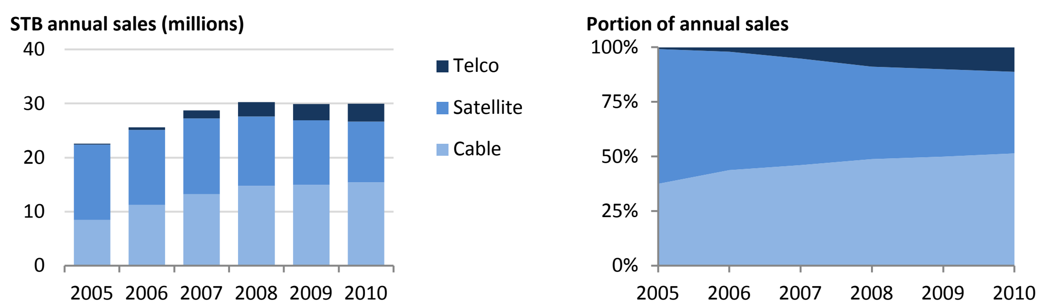


Figure 3-40: Annual STB sales to dealers by display technology (CEA 2010a)

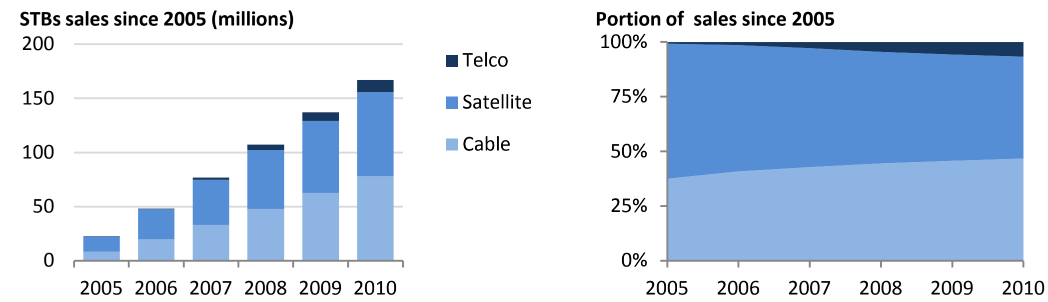


Figure 3-41: Cumulative STB sales to dealers by display technology since 2005 (CEA 2010a)

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3.13 Televisions

3.13.1 Current Energy Consumption

Televisions are the most widely owned consumer electronic device in the U.S. at 95-99% household penetration in 2010 (CEA 2010a; CE Usage Survey, Appendix A). TV energy consumption varies with display type, screen size, and year of manufacture. The recent widespread adoption of energy efficient flat panel displays and the subsequent disappearance of the cathode ray tube (CRT) from the marketplace are largely responsible for the changes TV energy consumption patterns.

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

3.13.1.1 Installed Base

Televisions outnumber people in U.S. homes with 353 million in 2010 and 342 million in 2009, Table 3-68. Our 2010 estimate is based on the October 2010 phone survey data. Due to its wording[33], the August 2009 survey produced low values for TV penetration (95.8%) and TVs per owner household (2.44) so we did not use these directly. Nielsen's 2009 penetration rate (99.2%) was a suitable substitute, since their 2010 value (99.1%) agreed with our October 2010 survey (Nielsen 2010b). Nielsen's ownership estimates of 2.93 and 2.86 TV sets per household in 2009 and 2010, respectively, however, were slightly lower than our survey suggested. To arrive at 2.99 TVs per owner household for 2009, we reduced our 2010 estimate of 3.07 by the 2.4% change reported by Nielsen. Other installed base estimates of 324.9 in 2010 and 338.6 in 2009 (CEA 2010a, 2009) indicate some uncertainty associated with ownership surveys. CEA market research estimated a somewhat lower installed base in 2011 (331 million); the main difference appears to be in estimates for the installed base of the least-used TVs, predominantly CRTs (Koenig 2011). The distribution of TVs per household for 2010 is shown in Figure 3-42.

Table 3-68: Installed base estimates for TVs in 2009 and 2010

Year	Household penetration	Households [millions]	Units/owner household	Installed Base [millions]	Sources
2010	99.0%	116.0	3.07	352.6	CE Usage Survey; DOE/EIA 2009,
2009	99.2%	115.4	2.99	342.1	Nielsen 2010b

[33] The October 2010 survey asked about all TVs that were plugged into an electrical outlet during the past month, while the August 2009 survey asked only about TVs that were used to watch television at least once in the past week. Furthermore, the 2009 survey recorded values only up to "6 or more," whereas the 2010 survey recorded values up to "10 or more." Thus, the 2010 survey more accurately represents the number of TVs installed.

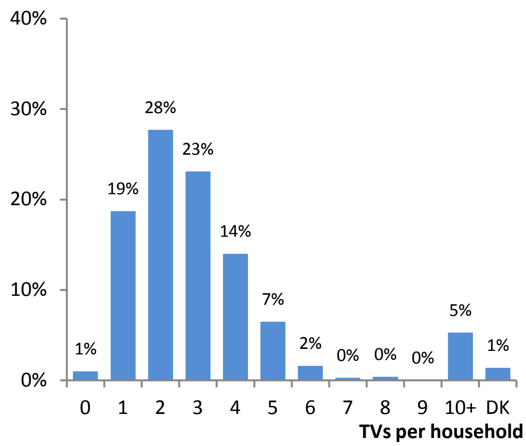


Figure 3-42: Ownership of TVs, DK="don't know" (CE Usage Survey)

We used the display technology distributions shown in Figure 3-43 (labeled "2010 model") in our energy analysis, which are based on survey data (August 2009) and sales data (CEA 2010b). Even though LCD and plasma displays have held top market shares since 2006, they have not yet overtaken the installed base of CRTs. Consumers reported owning more plasma TVs than were sold during the 11 year period, indicating potential confusion. In our 2009 model, we used survey results directly, despite the discrepancy. An attempted re-classifying of excess plasma TVs as LCD TVs, had only a minor effect on energy consumption since their power draw characteristics are similar and because the penetration of plasmas is relatively low.

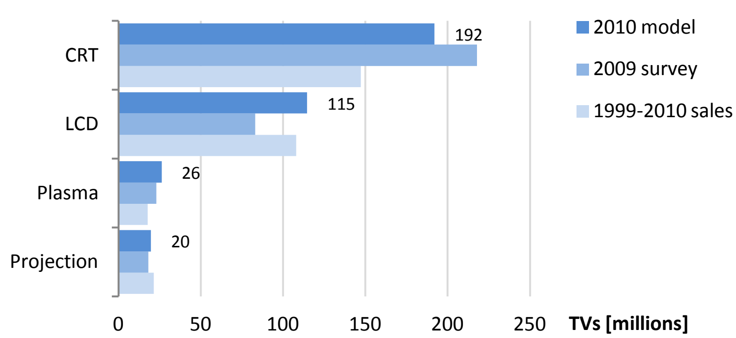


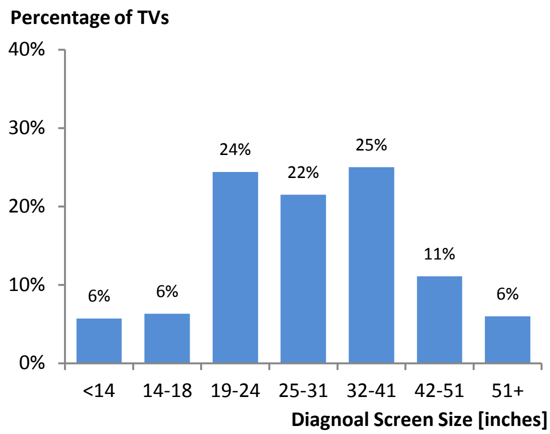
Figure 3-43: Installed base estimates of TVs by display technology

Table 3-69 compares raw survey data for 2009, modeled data for 2010, and independent CEA consumer survey results (CEA 2010a). The CEA survey indicated a higher portion of CRTs than our model, however, it also indicated nearly twice the number of plasma TVs, which agrees even less with reported sales data. Since we assume that only CRT TVs are retired from the installed base, our 2010 model reflects a lower bound estimate on their total number.

Table 3-69: Distribution of TVs by display type, three estimates

	August 2009 survey	2010 CEA survey	2010 model
CRT	62%	62%	54%
LCD	25%	21%	33%
Plasma	7%	13%	7%
Projection	5%	5%	6%

TV screen sizes have increased to an average diagonal screen size[34] of 29.1 inches, up from 25.5 in 2006[35] (TIAX 2007). In Figure 3-44 we show the distribution of screen size and age according to the August 2009 survey. Primary TVs, those used most in a household, are substantially larger at about 38 inches. TVs on average are about 6.2 years old[36] according to consumer reporting.



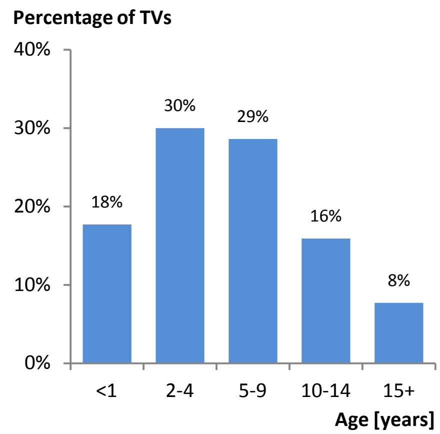


Figure 3-44: TVs by display technology and age (August 2009 survey). Bin ranges not of equal size.

Usage patterns greatly affect TV energy consumption estimates. Newer, larger TVs, for instance, are used more frequently than older, smaller ones. We accounted for usage patterns by assigning TVs to a "usage priority group" where TV1 is the most used TV in a household, TV2 is the second most used, and so on. The assignments, based on survey responses, are indicated in Figure 3-45.

[34] Average size is approximate, since we asked only about discrete size ranges.
[35] TIAX figures included only analog TVs, which made up the vast majority of displays in 2006.
[36] 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.

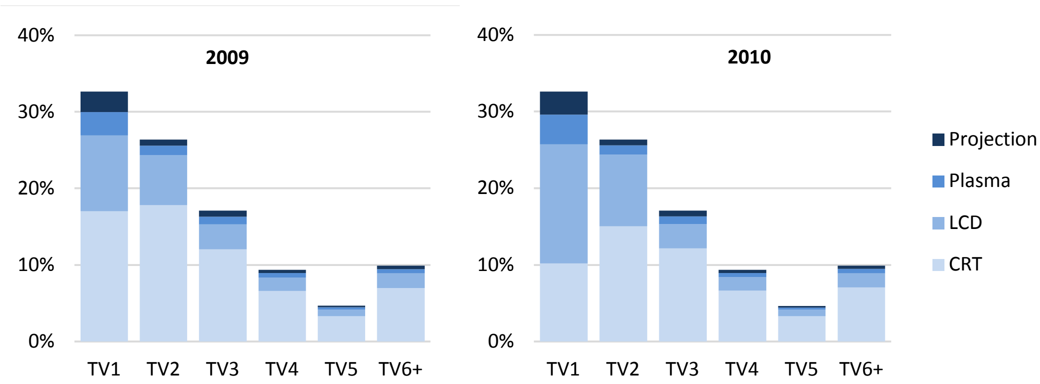


Figure 3-45: Distribution of TVs by display technology and usage priority

3.13.1.2 Unit Energy Consumption

3.13.1.2.1 Power Draw

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

We asked TV manufacturers and retailers to provide measured power draw values for their top selling models in various screen sizes, display technologies, and years of manufacture. Responders provided data for 385 models (320 LCD and 65 plasma) produced between 2008 and 2010, shown in Figure 3-46. We used these data to compute linear regressions for active-mode power draw for units by display technology and year of production. ENERGY STAR data were used to generate regressions for older LCD, plasma, and projection TVs. Active mode power regressions are shown in Figure 3-47 and Table 3-70.

CRT power draw was modeled using the values in TIAX (2007), appropriate since CRT sales diminished rapidly after that study. Off-mode power draw for LCD and plasma TVs averaged 0.41W independent of screen size between 2008 and 2010. For TVs made prior to 2008, we assume 4W for off-mode power draw (TIAX 2008).

Table 3-70: Active mode power regressions by TV screen area, display, and production year

		$P[W]=C_1+C_2*A[in^2]$				
Display	**Year**	C_1	C_2	R^2	**N**	**Source**
LCD	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	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

* Regressions used in the energy models.

** CRT data points are summary values for the 2006 installed base, not measurements; the regression is included for comparison only.

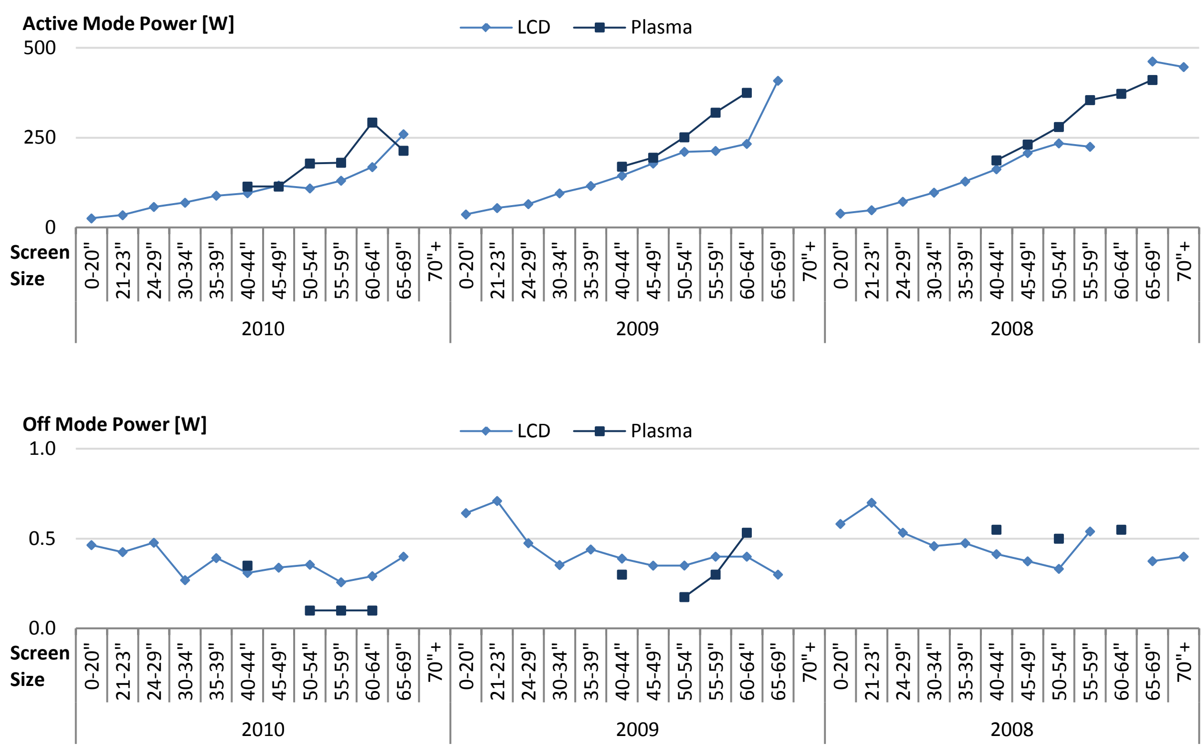


Figure 3-46: Average active and off mode power draw versus TV screen size, display technology, and year of manufacture (Fraunhofer 2010). Bin ranges not of equal size.

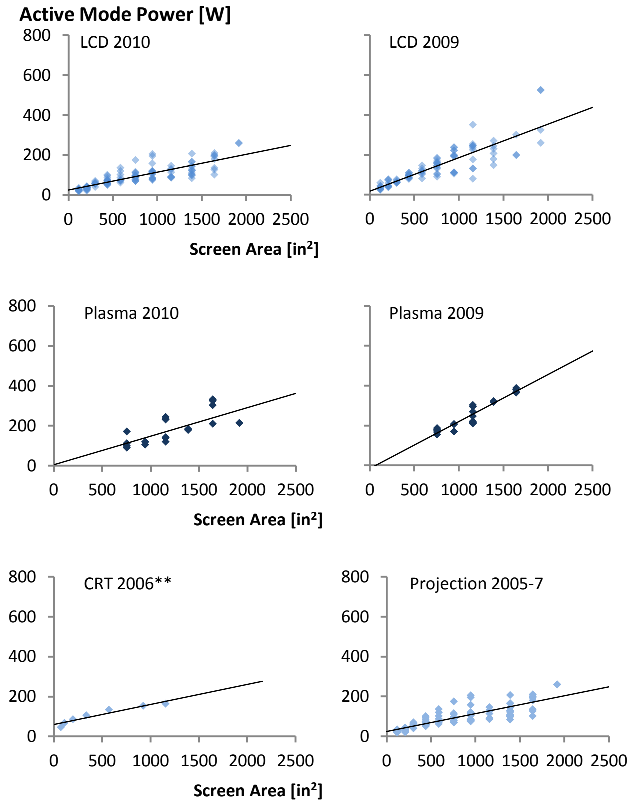


Figure 3-47: Selected active mode power draw regressions based on TV screen area, display technology, and year of manufacture (2008-10: CEA partner questionnaire; 2005-7: EPA 2007)

3.13.1.2.2 Usage

Average TV usage, determined from the August 2009 survey, equals about 3.8 h/day (1,392 h/yr) per TV, with primary TV usage much higher at 6.5 h/day (2,373 h/yr). Participants in this survey were asked about "TV on time," or total time spent in the on mode for all uses (viewing TV, DVD, game consoles, etc.) and included times when the TV was left on but unused. In contrast, the October 2010 survey asked about "TV usage time" and yielded lower estimates of 3.1 h/day (1,123 h/yr), presumably because responders may not have included time their TVs were left on but unused. The 2009 survey, then, provides the best estimates for actual on mode usage. Our surveys asked for hourly usage of only the three most used televisions. To obtain usage estimates for lesser used televisions, we proportionally scaled our TV3 usage data with prior study data for TVs 3-6 in TIAX (2007), and the results are shown in Table 3-71 and Table 3-72.

TV usage for watching television in 2010 amounts to 1,723 h/yr per person (Nielsen 2010a), or at most 1,506 h/yr per TV assuming no collective viewing. Reducing this value by one third to adjust for collective viewing (arbitrarily) and adding to this the active usage calculated for other uses including DVD/Blu-ray (360 h/yr per TV) and gaming consoles (180 h/yr per TV) yields 1,690 h/yr per TV. This is nearly 20% higher than our estimate. Usage remains a source of uncertainty in the model.

3.13.1.2.3 Unit Energy Consumption

To calculate UEC and AEC for TVs, we prepared estimates for both 2009 and 2010. The 2009 estimates were largely based on the August 2009 phone survey results, in which participants provided estimates for TV display type, screen size, age, and usage for the three most used TVs per household. To this dataset we applied the energy usage regressions from Figure 3-47 to determine power and energy usage characteristics for each TV usage group, subdivided by display technology. We then used the October 2010 survey results to determine the portion of TVs in each usage group, and applied our 2009 installed base estimate of 342.1 million TVs to obtain the AEC estimates.

To obtain results for 2010, we began with the 2009 model and introduced 36.3 million new TVs based on CEA sales and screen size data for Q2-4 of 2009 and Q1-2 2010, applying the 2010 power draw regressions. We introduced most of these new TVs (25.7 million) into the primary usage group; however, to preserve the average primary LCD TV screen size, 34% of new LCD TVs (10.6 million, all with screen sizes below 29") were introduced into the TV2 usage slot. Next, we assumed that each usage group would retain the same proportion of TVs in 2010 as 2009, so we "demoted" CRT TVs to a lower usage group to maintain the balance. For example, 25.7 million new TVs were introduced into the TV1 usage slot, and nearly the same amount of CRT TV1s were demoted to TV2s, which then bumped some CRT TV2s to TV3s, and so on, with 25.8 million CRT TVs being retired from the lowest usage categories.

Table 3-71: UEC and AEC calculations for TVs for 2010

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

Table 3-72: UEC and AEC calculations for TVs for 2009

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	113	33%	6.5	36	5.3	136	3.2	342	38.2	59%
TV2	89	26%	3.2	29	6.2	107	3.4	155	14.0	22%
TV3	58	17%	2.6	21	6.5	78	3.4	102	5.9	9%
TV4	31	9%	2.5	21	6.5	78	3.4	100	3.2	5%
TV5	17	5%	1.6	21	6.5	78	3.4	73	1.2	2%
TV6+	34	10%	0.9	21	6.5	78	3.4	56	1.9	3%
Avg./Total:	**342**	**100%**	**3.8**	**28**	**6.1**	**105**	**3.3**	**188**	**64.3**	**100%**

Estimates based on EPA data, CE Usage Survey, October 2009 Survey, CEA partner surveys, and CEA 2010 sales data.

We estimate unit energy consumption for TVs at 183 kWh/yr in 2010 and 188 in 2009; the difference is due mainly to the adoption of lower power LCD displays and the presumed retirement of older CRT TVs.

Although results were mostly consistent, a few sources of error are worth mentioning. First, we recognize that survey based reporting has limitations. Participants reported 9% more LCD TVs and 58%

more plasma TVs than were sold during the prior 11 years according to CEA sales tracking. This overestimation likely occurs predominantly in lower usage TVs where the impact on energy estimates is small. For instance, the average screen size of plasma TVs among the TV3 usage group was reportedly 14.9" – clearly indicating an improper classification since plasma displays are not manufactured in such small sizes. To assess the associated error, we re-allocated low-usage LCD and plasma TVs as CRT displays, and found only a very slight change in AEC. Since the off-mode power dominates in smaller, lower-usage TVs, this was expected. Second, we recognize that in modeling the transition from 2009 to 2010, some non-CRT TVs will be retired and others will be shifted among usage categories. Finally, the allocation of TVs among usage groups has a strong impact on total energy consumption. Initial attempts to use the 2009 survey data for this allocation met with inconsistent results, indicating more primary TVs than households. This was due to question wording, as participants were asked to report on TVs used for watching television during the past week, thus omitting infrequently used TVs and skewing the TV distribution. The 2010 survey asked about all TVs that were plugged in during the past month, giving the distribution we used for both 2009 and 2010 allocations.

3.13.1.3 Annual Energy Consumption

We estimate that TVs consume 64.3 and 64.7 TWh/yr, with primary household TVs responsible for 59% of the total annual energy consumption, as summarized in Table 3-71 and Table 3-72.

3.13.2 Prior Energy Consumption Estimates

Prior estimates of television AEC are given in Table 3-73 together with our estimates of 64.3 and 64.7 for 2009 and 2010. Despite significant growth in the total number of installed TVs, estimates for AEC appear relatively stable. Even though per person TV viewing has reached all time high levels, our estimates for per-TV active-mode usage are lower than prior estimates. This is consistent, since the number of new TVs is outpacing the rate of TV retirement, and it supports the idea that many older, smaller TVs are being displaced by newer TVs and are used infrequently. Furthermore, average active-mode power draw has reached a plateau, even while average screen size has increased, owing to the greater efficiency of newer displays.

Table 3-73: Prior energy consumption estimates for TVs

Year	Units [millions]	Power [W]			Usage [h/yr]			UEC [kWh/yr]	AEC [TWh/yr]	Source
		Active	Low	Off	Active	Low	Off			
2010	353	104	-	3.0	1,392	-	7,368	183	64.7	Current
2009	342	105	-	3.3	1,392	-	7,368	188	64.3	Current
2006	275	111	-	4	1,882	-	6,878	244	67	TIAX 2008
2006*	237	98	-	4	1,882	-	6,878	222	53	TIAX 2007
2004*	234	100	-	3.9	1,278	-	7,483	156	36.6	NRDC 2005
1998*	212	75	-	4.5	1,443	-	7,317	150	31.0	LBNL 1999
1997*	229	60	-	4	1,460	-	7,300	117	27	ADL 1998
1995*	191	77	-	4	1,498	-	7,262	141	26.0	LBNL 1998

* Analog TVs only.

A major shift is taking place as older CRTs are replaced with newer, more efficient digital flat panel TVs, as indicated by Figure 3-48 and Figure 3-49. At least 75% of the more than 35 million TVs sold per year are flat panel LCD displays, and these should overtake CRTs as the most prevalent display technology in the coming years.

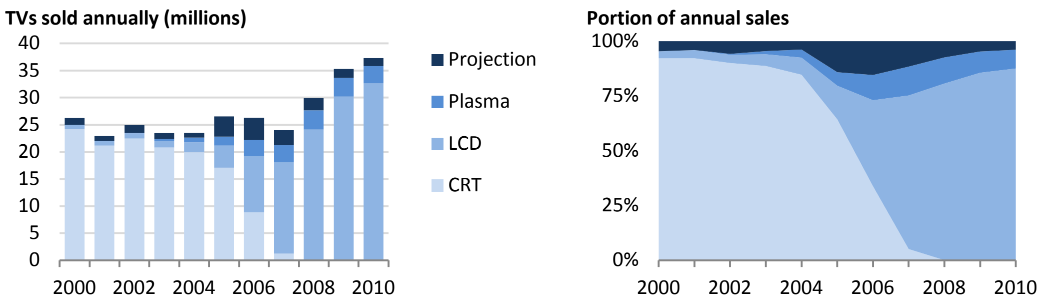


Figure 3-48: Annual TV sales to dealers by display technology (CEA 2010)

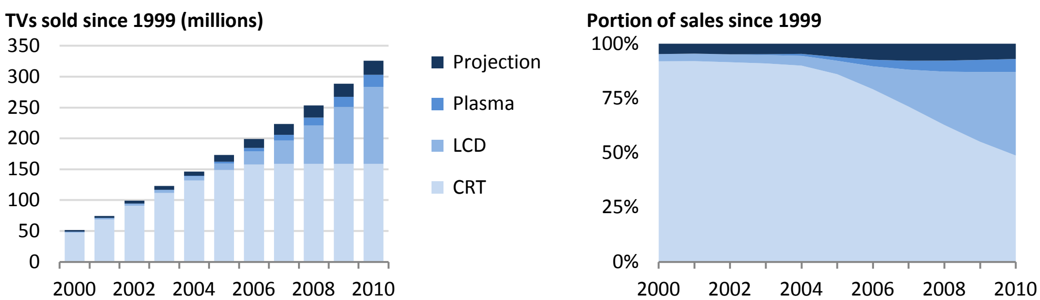


Figure 3-49: Cumulative TV sales to dealers by display technology since 1999 (CEA 2010)

Finally, about 88% of TV energy usage is due to active mode use, while the remaining 12% is due to off mode consumption. Figure 3-50 shows this breakdown. Naturally, a TV's priority has a major influence: 95% of TV1 energy usage is from active mode, compared to about 50% for TVs 6 and beyond.

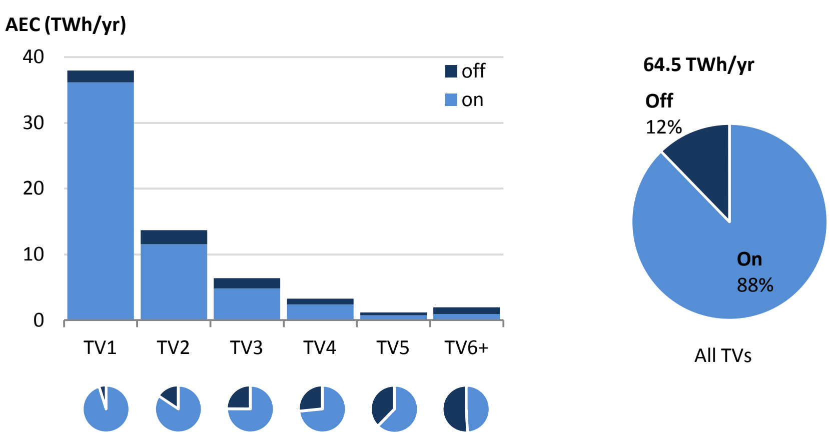


Figure 3-50: Active and off mode AEC by TV priority in 2010, pies indicate mode fraction for each TV

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3.14 Video Game Systems

3.14.1 Current Energy Consumption

The video game systems described in this section refer to video game consoles, such as the Sony Playstation, Nintendo Wii, or Microsoft Xbox 360. Handheld devices, such as the Sony Playstation Portable and the Nintendo DS are not covered in this report.

3.14.1.1 Installed Base

According to CEA market research (CEA 2010a), the installed base of video game systems (excluding portable devices) is 109.4 million units, as shown in Table 3-74, an increase of 70% compared to the estimate 64 million units in the previous study (Roth& McKenney 2007). The average owner household has 1.7 game consoles installed (CEA 2010a).

Table 3-74: Installed base of video game systems

Installed Base [millions]	Penetration	Sources
109	48%	CEA 2010a

Three companies dominate the video game system industry: Sony, Nintendo, and Microsoft. Models of the so-called 7th generation, i.e. the newer models Nintendo Wii, Sony PlayStation 3 and Microsoft Xbox360, all released since 2005, together account for 57% of the installed units. In the CEA gaming survey, these three models together accounted for 94% of the primary systems (CEA 2010b). Sales data (NDP 2010, Gruener 2010, Pvc museum 2010), previous breakdowns of installed models (NRDC 2010, TIAX 2006) and assumptions made on the replacement of vintage models yield the breakdown of installed models shown in Figure 3-51.

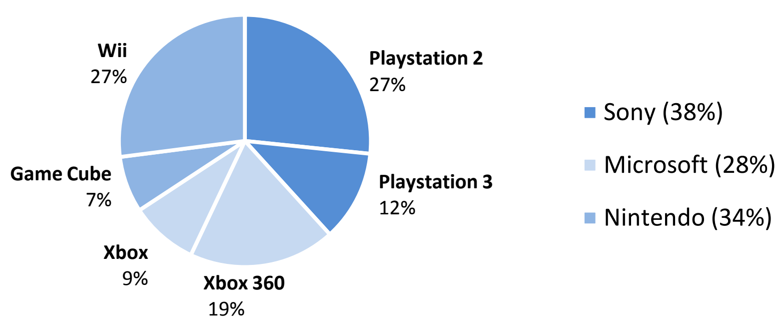

Figure 3-51: Fraction of video game systems installed in U.S. homes by platform

3.14.1.2 Unit Energy Consumption

Video game consoles can be characterized by four main operating modes.

- *Active: gaming* – The system is on and a game is being played
- *Active: other* (video replay and other usage) – The system is on and a video is being played or a similar non-gaming functionality is used (depending on the model, power draw is 0 and 30% higher than in active, gaming mode)

- *Navigation* – The console is on and being used to manage the game or menu (selection, starting, pausing, stopping), but no game or video is being played. Most video game systems consume about the same power in this mode as in active mode
- *Off* – The power has been switched off by the user, but the system remains plugged in.

3.14.1.2.1 Power Draw

Power draw of video game systems by console, release date, and mode are given in Table 3-75.

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

	Release	Installed Base		Power [W]			
		[millions]	[%]	Active	Video	Navigation	Off
Nintendo Wii	2006	30	27%	16	16[a]	11	0.1[b]
Microsoft Xbox 360	2005	21	19%	185	126	162	2
	2007			120	110/85[c]	118	3
Sony PlayStation 3	2006	13	12%	220	180	180	1
PlayStation 3 Slim	2007			150	148/129[d]	153	1
	2009			105	78	77	1
	2010			80		-	1
Sony PlayStation 2	2000	30	27%	35	24	17	2
Microsoft Xbox (excl. Xbox 360)	2001	10	9%	68	-	60	2
Nintendo GameCube	2001	8	7%	21	-	20	1
Total/Wt. Avg.	**-**	**109**	**100%**	**89**	**76**	**75**	**2**

a No DVD playback.
b 1W if connect24 disabled, 10W if enabled.[37]
c 110W for HD-DVD, 85W for regular DVD.
d 148W for Blu-ray DVD, 129W for regular DVD.
Sources: NRDC (2010), Moskovciak (2009), PlaystationPro2 (2011), Sony (2011), Miller (2009), Katzmaier & Moskovciak (2010).

3.14.1.2.2 Usage

The CEA Gaming and Energy Study found that systems are actively used 3.1hours/day and on (active or navigation mode) for 4.0 hours/day.[38] This is slightly higher, yet comparable to the average 10% of active usage time found in (Nielsen, 2009) and also consistent with the behavior reported by survey respondents for pausing their systems, with the average system paused / in navigation mode for approximately one hour per day.

Power management features are not easily accessible and often disabled by default, and many users are not aware of the existence of power management settings and their impact on the annual electricity

[37] The Wii consumes 9W in off mode with its contact24 (ability to receive updates and messages) setting activated and 1W if it is switched off. The survey data suggest that most Wii users are not aware of the color-coded status indicator LED on the console and that only 30% of users have the contact24 function turned off.

[38] 66% of the console usage is for gaming; other uses include watching DVD /Blu-ray/HD-DVD movies, streaming videos, listening to music and surfing the Internet.

consumption (NRDC 2008). In a CEA 2010 Gaming Survey, only 14% of the survey respondents reported that they were aware of the power management feature of their system and using it, see Figure 3-52.[39]

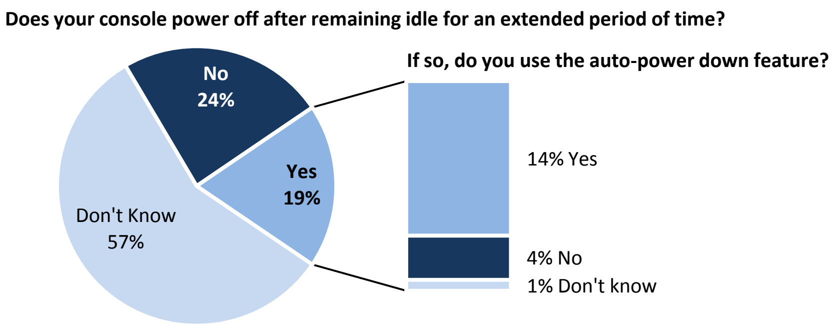

Figure 3-52: State of video game systems after longer period of user inactivity

Nielsen (2009) found that system use varied with system type, with Playstation 3 and Microsoft Xbox 360 falling into the heavy-use category as compared to other systems, with average active usage of 18.5 hours per week as compared to 11 hours for the Nintendo Wii. The CEA Gaming Survey found similar usage values for the Playstation 3 and the Microsoft Xbox 360 (both approximately 19 hours/week), but higher usage values for the Nintendo Wii (17 hours/week). A field study (Bensch et al. 2010) measured much lower usage values (4.9 hours/week for Playstation 2, 8.4hours/week for Nintendo Wii and 3.5 hours/week for Microsoft Xbox 360). For this study, we did not use different usage by mode values for different system types.

3.14.1.2.3 Unit Energy Consumption

Our calculation of video game system UEC is summarized in Table 3-76.

Table 3-76: UEC calculation for video game systems

	Active-game	Active-other	Navigation	Off	Total
Power [W]	89	76	75	2	-
Usage [hr/yr]	750	370	330	7,310	**8,760**
UEC [kWh/yr]	67	28	25	15	**135**

3.14.1.3 Annual Energy Consumption

Video game systems consumed about 14.7 TWh in 2010, as shown in Table 3-77.

[39] The Xbox 360 features power management settings, but it is disabled when shipped. Previous versions of the Sony Playstation3 did not provide native power-down settings; in 2008, a firmware update for existing consoles was released that includes a power saving feature that powers the console down after 6 hours of inactivity – it is disabled by default. In early 2010, a firmware update (version 3.4) enabled the Auto-off function by default. All PlayStation 3 consoles now ship from the factory with the System Auto-off function enabled (personal communication, Sony).

Table 3-77: AEC summary for video game systems

UEC [kWh/yr]	Installed Base [million]	AEC [TWh]
135	109	14.7

3.14.2 Prior Energy Consumption Estimates

Prior energy consumption estimates for video game systems are given in Table 3-78.

Table 3-78: Prior energy consumption estimates for video game systems

Year	Units [millions]	Power [W]			Usage [h/yr]			UEC [kWh/yr]	AEC [TWh/yr]	Source
		Active	Navigation	Off	Active	Navigation	Off			
2010	109	85[a]	75	2	1,120	330	7,310	135	14.7	Current
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.

All three components of the AEC calculations have changed appreciably since 2006. First, the installed base of video game systems has grown by about 70% since 2006. Compared to prior studies, the reported active use is substantially higher. One potential explanation for this finding could be that today's game systems are used for other functions and entertainment features in addition to gaming, such as watching movies on DVDs/Blu-ray discs, streaming videos, browsing the internet. The estimated time in navigation mode is substantially lower than in NRDC (2008), which assumed that 50% of users leave on their device continuously. Our estimate is based on CEA gaming survey data (2010), in which 10% of the respondents reported leaving their system on all of the time.

Figure 3-53 shows the history of active mode power draw for systems of the three main manufacturers Sony, Microsoft, and Nintendo, over time (Katzmaier and Moskovciak 2010, Miller 2009, Moskovciak 2009, NRDC 2008, Roth and McKenney 2007, Sony 2011). In general, power draw increased until around 2005/2006, peaking with the release of the first Playstation 3 and Xbox 360 models. Since then, both of these models have been replaced by versions that draw less power (PlayStation 3 slim, released in September 2009 and Xbox360 S, released in June 2010).

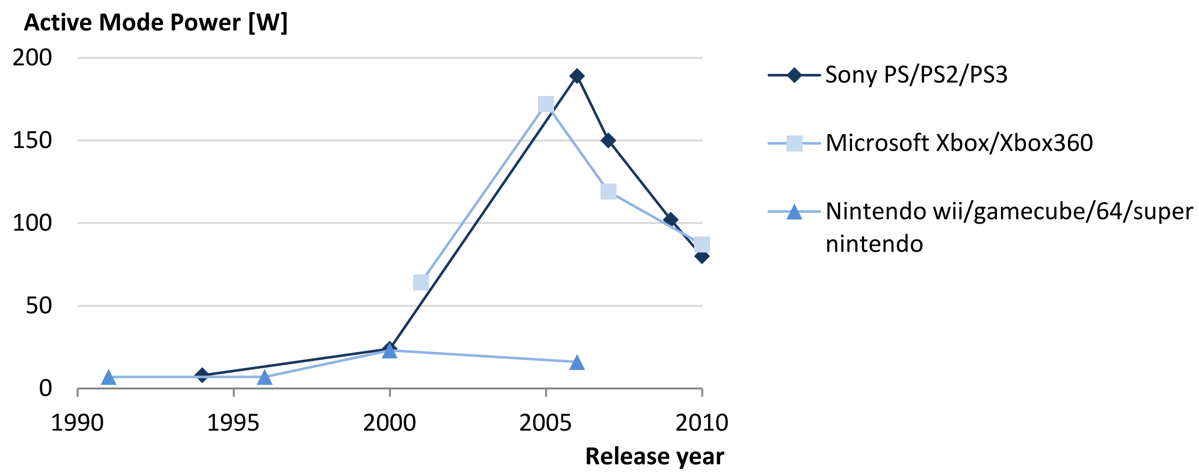

Figure 3-53: Historical active mode power draw values for video game systems

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3.15 Other Devices

We estimate that other CE devices consumed 21 TWh of electricity in 2010, an amount equal to 11% of total residential CE AEC. Table 3-79 through Table 3-84 and Figure 3-54 summarize AEC estimates and the data used to calculate the AEC of CE products not selected in detail. In general, these estimates have a higher degree of uncertainty than the estimates for CE products analyzed in greater detail.

Table 3-79: UEC and installed base estimates for other products

Product	UEC [kWh]	Installed Base [millions]	AEC [TWh]
Camcorder	2.3	62	0.1
Compact Audio	105	63	6.6
Copy Machine - Stand-alone	13.5	9	0.1
Cordless Phone	15.8	137	2.2
Digital Camera	0.3	164	0.05
Digital Picture Frame	14.8	33	0.5
Fax Machine - Stand-alone	46	10	0.5
External Storage Device	10.5	80	0.8
Home Theater in a Box (HTIB)	91	30	2.7
Mobile Phone	2.2	233	0.5
MP3 Player Docking Station	25	48	1.2
Portable Audio	5.6	120	0.7
Projector	97	4	0.4
Radio	15.7	81	1.3
Scanner - Stand-alone	18.7	9	0.2
Telephone Answering Device - Stand-alone	17.5	19	0.3
Video Cassette Recorder (VCR)	47	57	2.7
Voice-over IP Adaptor - Stand alone	36	4.7	0.2
Total/Average	**18.1**	**1,159**	**21**

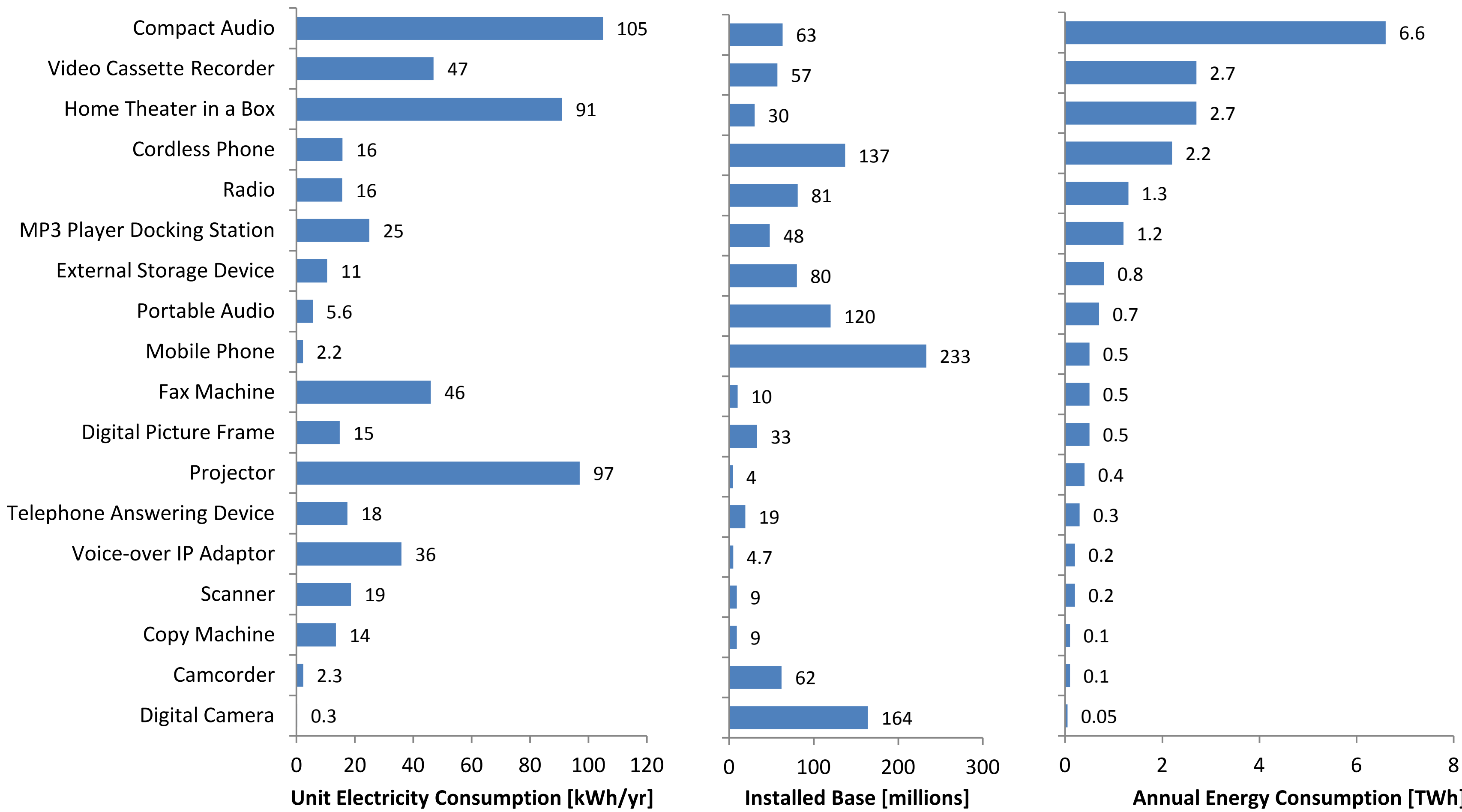

Figure 3-54: UEC, installed base, and AEC of other CE devices evaluated in less detail

Table 3-80: Average power draw by mode estimates for other products

Product	Power [W]		
	Active/Recharging	Sleep/Idle	Off
Camcorder	NA / 9.6	0.4	0.4
Compact Audio	31.6	NA	4.3
Copy Machine - Stand-alone	9.6	NA	1.5
Cordless Phone	2	1	NA
Digital Camera	NA / 4.0	NA	0.3
Digital Picture Frame	3.1	NA	0
Fax Machine - Stand-alone	6.2	5.2	NA
External Storage Device	1.2	NA	NA
Home Theater in a Box (HTIB)	37	33	1.3
Mobile Phone	4	2.2	0.2
MP3 Player Docking Station	10[a]	3[a]	NA
Portable Audio	5	3	1.7
Projector	182	9.8	4.7
Radio	4.3	NA	1.6
Scanner - Stand-alone	10	NA	2.0
Telephone Answering Device - Stand-alone	2	NA	NA
Video Cassette Recorder (VCR)	16	12	4.5
Voice-over IP Adaptor - Stand alone	6	4	NA

a Notably high uncertainty for this value.

Table 3-81: References for power draw by mode estimates for other products

Product	Sources
Camcorder	McAllister and Farrell (2004)
Compact Audio	Bensch et al. (2010)
Copy Machine - Stand-alone	LBNL (2008)
Cordless Phone	Bensch et al. (2010), LBNL (2008)
Digital Camera	McAllister and Farrell (2004), Foster Porter et al. (2006), Wood (2011)
Digital Picture Frame	Bensch et al. (2010)
Fax Machine - Stand-alone	Bensch et al. (2010), LBNL (2008)
External Storage Device	Bensch et al. (2010)
Home Theater in a Box (HTIB)	Roth and McKenney (2007)
Mobile Phone	Bensch et al. (2010), LBNL (2008)
MP3 Player Docking Station	Mean of 5 products best-selling Amazon.com products
Portable Audio	Bensch et al. (2010), SELINA (2010)
Projector	SELINA (2010), Meister et al. (2011)
Radio	Bensch et al. (2010)
Scanner - Stand-alone	Bensch et al. (2010)
Telephone Answering Device - Stand-alone	Bensch et al. (2010)
Video Cassette Recorder (VCR)	Roth and McKenney (2007)
Voice-over IP Adaptor - Stand alone	YouSustain (2009), Ooma (2009), Roth et al. (2006)

Table 3-82: Annual usage by mode estimates for other products

Product	Active/Recharging	Sleep/Idle	Off
Camcorder	[a]	[a]	[a]
Compact Audio	2,482	NA	6,278
Copy Machine - Stand-alone	50[b]	NA	8,710[b]
Cordless Phone	7,045	1,715	NA
Digital Camera	13[c]	NA	8,752[c]
Digital Picture Frame	4,782	NA	3,978
Fax Machine - Stand-alone	146	NA	8,614
External Storage Device	8,760	NA	NA
Home Theater in a Box (HTIB)	1,580	730	6,450
Mobile Phone	110	NA	8,650
MP3 Player Docking Station	800[b]	100[b]	7,860[b]
Portable Audio	[a]	[a]	[a]
Projector	312[b]	100[b]	8,348[b]
Radio	620	NA	8,140
Scanner - Stand-alone	146	NA	8,614
Telephone Answering Device - Stand-alone	8,760	NA	NA
Video Cassette Recorder (VCR)	156	793	7,811
Voice-over IP Adaptor - Stand alone	365	8,395	0

a Not shown in McAllister and Farrell (2004)

b Notably high uncertainty for this value.

c Based on estimates of 2,000 images per year for a typical user and 150 images/charge, yielding about 13 hours/year charging (Wood 2011); we also assume (under high uncertainty) that 10% of the chargers remain plugged in.

Table 3-83: References for annual usage by mode estimates for other products

Product	Sources
Camcorder	NA
Compact Audio	Roth and McKenney(2007)
Copy Machine - Stand-alone	NA
Cordless Phone	Bensch et al. (2010), Selina (2010)
Digital Camera	Roth and McKenney(2007)
Digital Picture Frame	Bensch et al. (2010)
Fax Machine - Stand-alone	Bensch et al. (2010)
External Storage Device	Bensch et al. (2010)
Home Theater in a Box (HTIB)	Roth and McKenney (2007)
Mobile Phone	Bensch et al. (2010)
MP3 Player Docking Station	NA
Portable Audio	NA
Projector	NA
Radio	Bensch et al. (2010)
Scanner - Stand-alone	Bensch et al. (2010)
Telephone Answering Device - Stand-alone	Bensch et al. (2010)
Video Cassette Recorder (VCR)	Roth and McKenney (2007)
Voice-over IP Adaptor - Stand alone	Roth et al. (2006)

Table 3-84: References for installed base estimates for other products

Product	Sources
Camcorder	CEA 2010, Koenig (2011)
Compact Audio	Bensch et al. (2010)
Copy Machine - Stand-alone	DOE/EIA RECS (2009), RASS (2009), RASS (2010)
Cordless Phone	Bensch et al. (2010)
Digital Camera	CEA (2010)
Digital Picture Frame	CEA (2010)
Fax Machine - Stand-alone	DOE/EIA RECS (2009)
External Storage Device	Koenig (2011)
Home Theater in a Box (HTIB)	CEA (2010), Roth and McKenney (2007)
Mobile Phone	CEA (2010)
MP3 Player Docking Station	CEA (2010), Koenig (2011)
Portable Audio	CEA (2010)
Projector	Extrapolated to U.S. from German data (Statistica 2011)
Radio	Bensch et al. (2010)
Scanner - Stand-alone	RASS (2009)
Telephone Answering Device - Stand-alone	DOE/EIA RECS (2009)
Video Cassette Recorder (VCR)	Bensch et al. (2010)
Voice-over IP Adaptor - Stand alone	FCC (2011)

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4 Conclusions

We used a bottom-up approach to characterize U.S. residential consumer electronics (CE) energy consumption in 2010. Our effort focused on 17 priority products, see Table 4-1. In addition, we developed preliminary estimates for 17 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**	
Audio Video Receivers	Set Top Boxes	Desktop PCs	Networking Equipment
Blu-ray Player	Cable	Portable PCs	Integrated Access Device
DVD Devices	Satellite	Computer Speakers	Modem
Televisions	Telco	Monitors	Router
Video Game Consoles	Stand-alone	Printers + MFDs	

We estimate that residential CE consumed about 193 TWh of electricity in 2010, an amount equal to 13.2% of residential electricity consumption and 9.3% of residential primary[40] energy consumption, shown in Figure 4-1 and Figure 4-2.

As in the 2006 study of residential CE energy consumption (Roth and McKenney 2007), a few CE categories accounted for the majority of CE electricity consumption, shown in Figure 4-3. Notably, televisions accounted for 34% of residential CE electricity consumption, PCs 16%, and set-top boxes 13%.

Altogether, we estimate that there are almost 2.9 billion CE devices in U.S. households, an average of about 25 devices per household.[41]

The average unit electricity consumption (UEC) of the categories evaluated in detail varies greatly among categories, shown in Figure 4-4.

Looking at AEC by mode, the active mode accounts for 76% of the total AEC of all the categories evaluated in more detail, shown in Figure 4-5. This masks large differences in the distribution of UEC by mode among different CE, Figure 4-6.

[40] 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 3.4 kWh of primary energy (DOE 2011).

[41] Based on an estimated 114.7 million U.S. households in 2010 (DOE 2011).

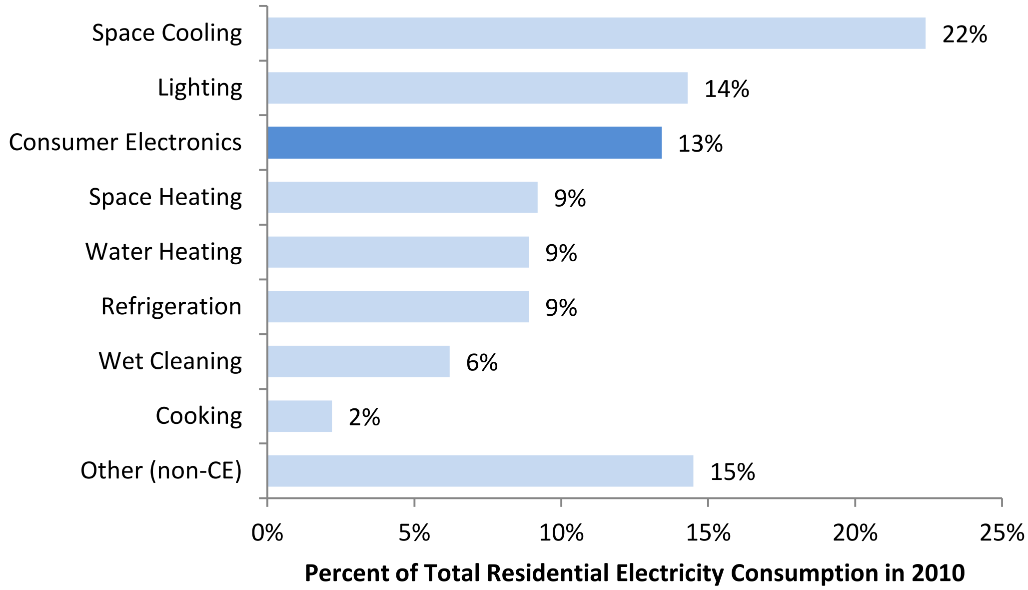

Figure 4-1: Residential electricity consumption in 2010 by major end uses (DOE 2011, Current Study)

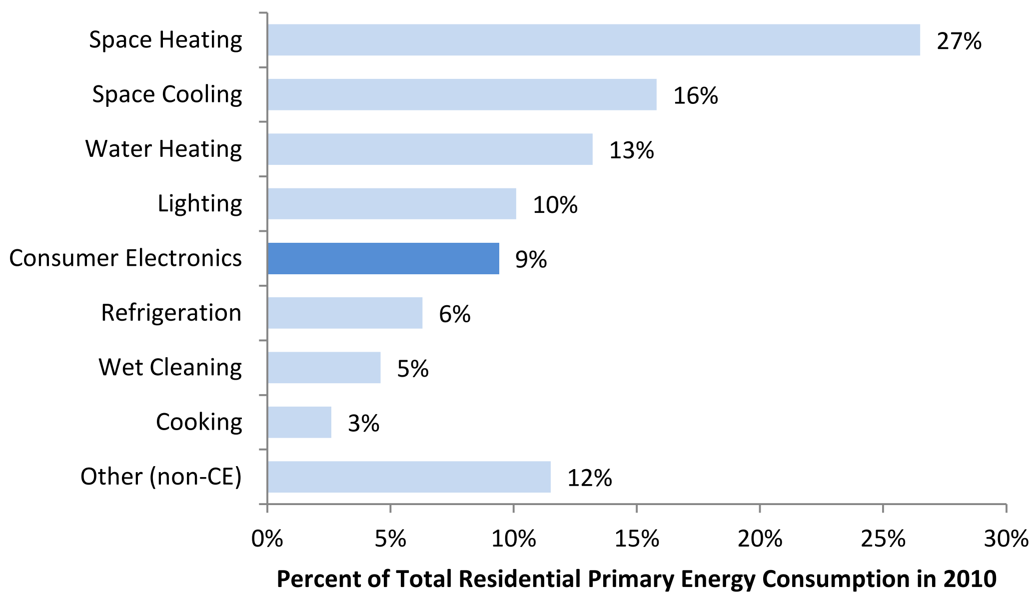

Figure 4-2: Residential primary energy consumption in 2010 by major end uses (DOE 2011, Current Study)

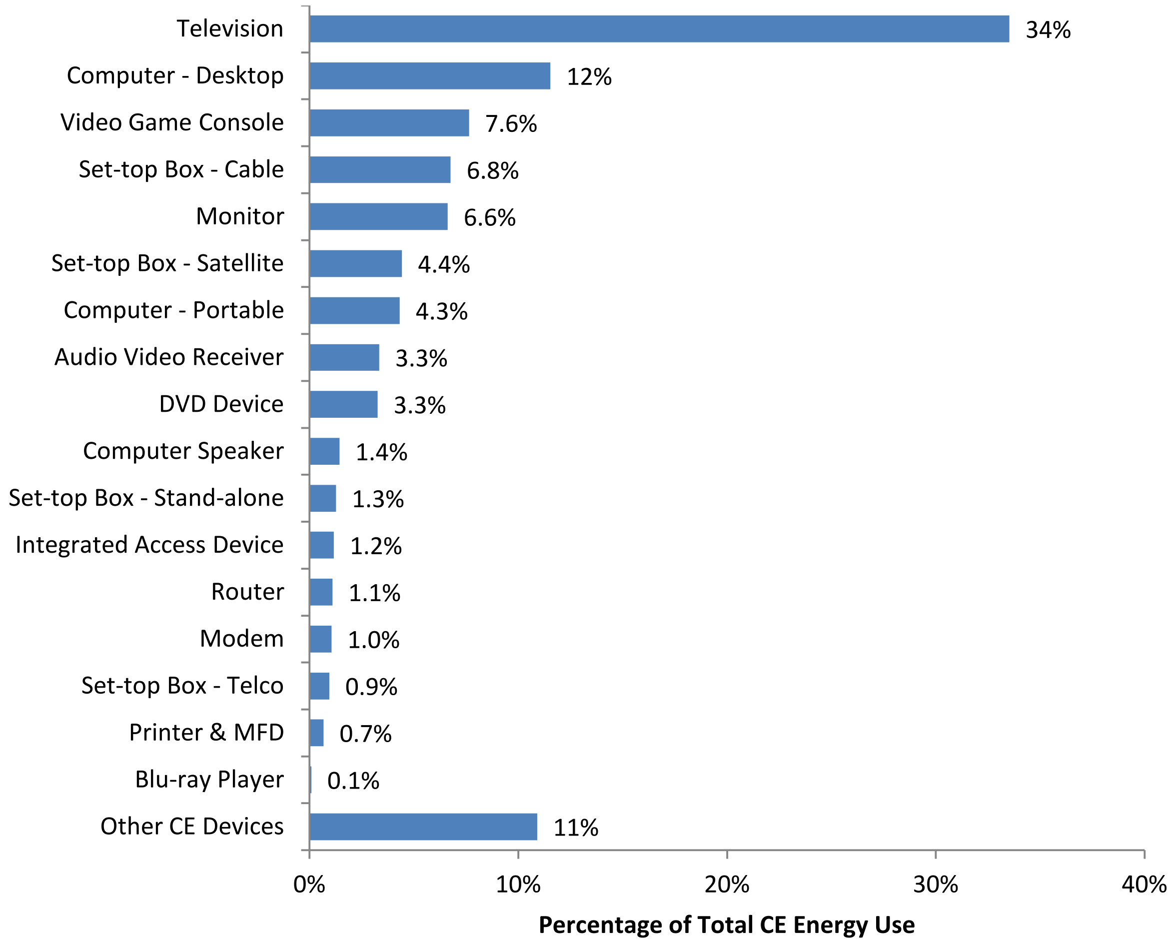

Figure 4-3: Residential CE electricity consumption by category

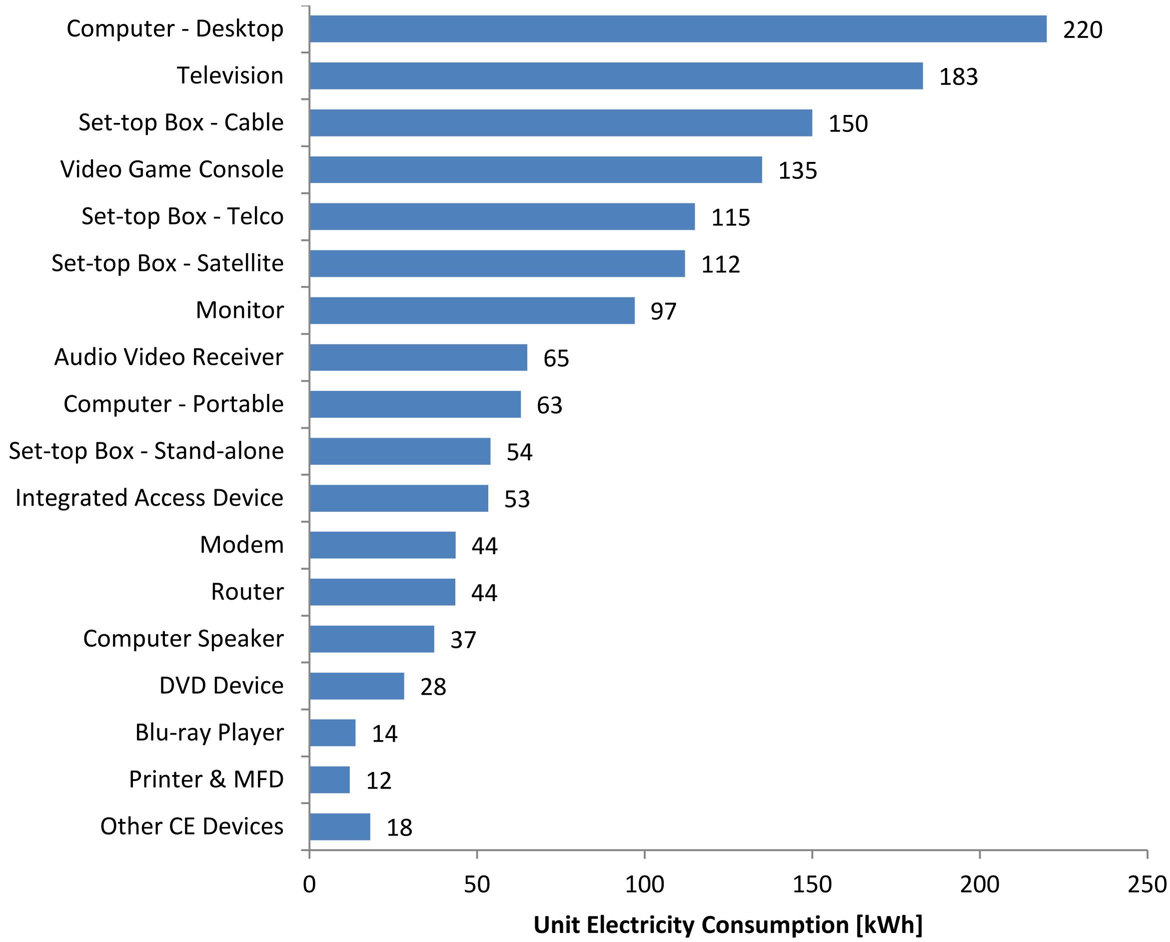

Figure 4-4: Unit electricity consumption for the CE categories evaluated in detail

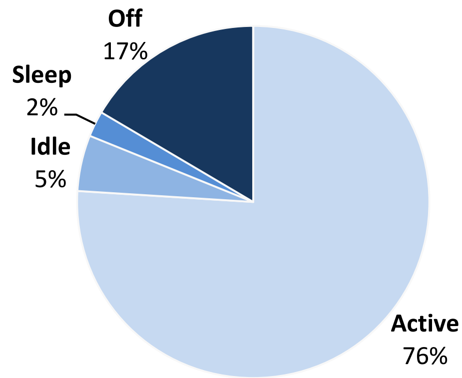

Figure 4-5: AEC by operational mode for the categories evaluated in detail

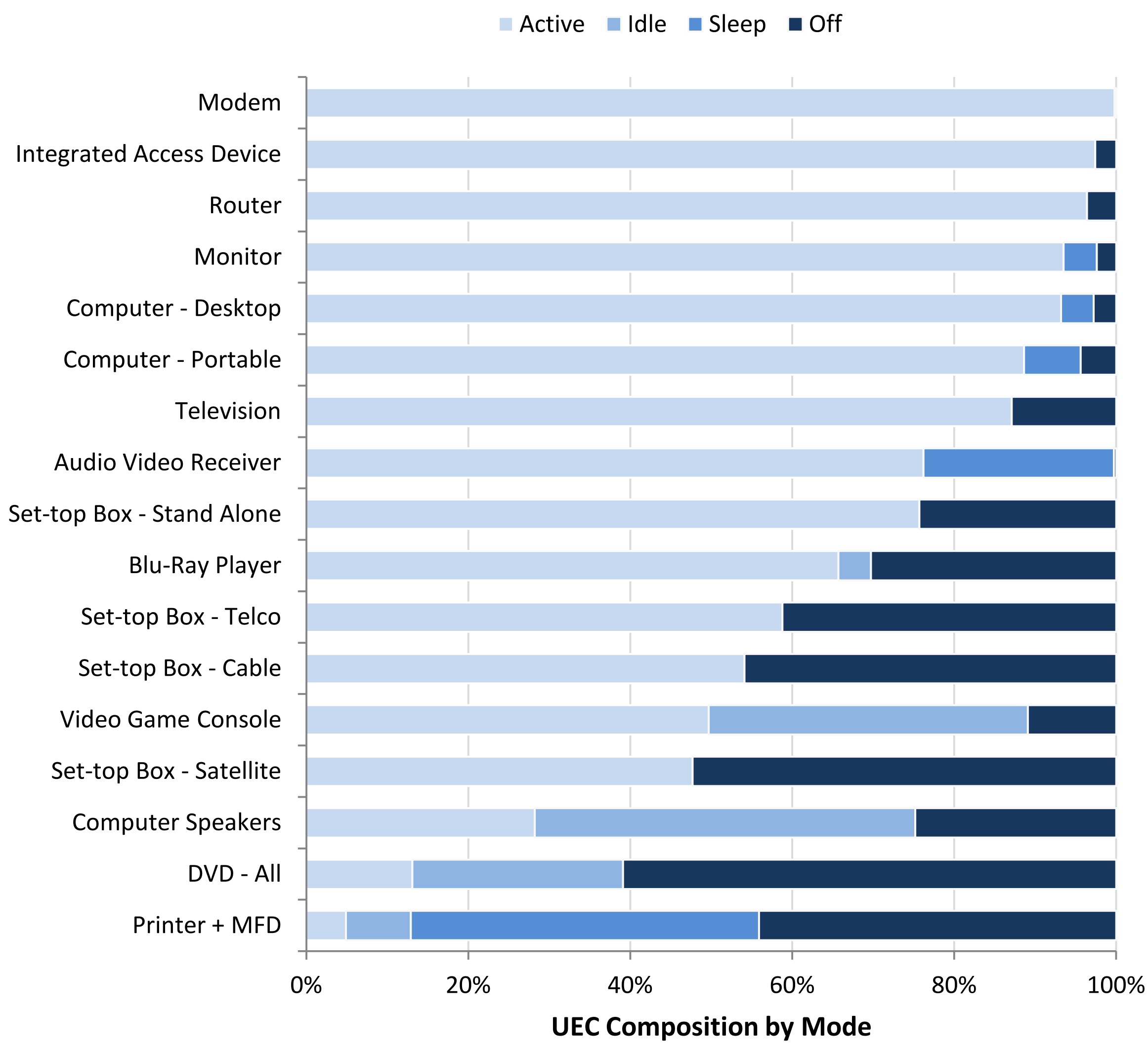

Figure 4-6: Breakdown of UEC by operational modes for the categories evaluated in detail

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Appendix A – CE Usage Survey

As part of this study, the CEA funded a phone survey of 1,000 demographically representative U.S. households. The survey asks 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. 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 script used by the company that performed the survey in October 2010 follows.

The CE Usage Survey

[READ] We will begin this survey by reading a list of household electronic devices.

1. How many of each of the following products were PLUGGED INTO an electrical outlet in your home at some point during the PAST MONTH? **[READ. RECORD NUMBER FROM 0-10 FOR EACH, -1 FOR DON'T KNOW/NOT SURE]**

   Home Entertainment
   a. Televisions
   b. Amplifier or speaker systems, such as external speakers for a TV or a stereo system. Do not include portable stereos or speakers used with computers.
   c. Blu-ray disc players, not including video game consoles that play Blu-ray discs.
   d. DVD players, DVD recorders, and combination DVD-VCR players. Do not include regular VCRs, Blu-ray disc players, video game consoles, or digital video recorders such as TiVo.
   Computer/IT-related
   e. Portable Personal Computers. These include laptops, notebooks, netbooks, and tablet PCs.
   f. Desktop Personal Computers.
   g. Computer printers, including those that also scan and copy, such as all-in-one Printers.

2. Please think all the different TVs in your household and the ways in which you receive television programming, such as cable, satellite, fiber to the home or an antenna that may mount on your roof or an antenna that sits on or near the TV. Thinking of all the televisions that are in your house, which of the following describes how your household receives its television signals?

   [READ LIST. RANDOMIZE. RECORD AS MANY AS APPLY. WAIT FOR YES, NO or Don't Know FOR EACH]

   01 Cable TV Service
   02 Satellite TV service
   03 Fiber to the home service, such as for Verizon Fios or AT&T Uverse
   04 Antenna TV service

Televisions & Subscription TV

[SKIP Q3-7, IF Q1a=0]
[ASK Q2-7 FOR UP TO 3 TVs IN ORDER OF MOST- TO LEAST- WATCHED]
[INSERT VALUES FOR Q3-8]

a. Primary
b. Secondary
c. Third

The next questions are about TELEVISIONS in your household, starting with the PRIMARY, or most-watched TV.

3. How long was the [INSERT] television in your home used yesterday by you or anyone else in your household? If you are not sure, please use your best estimate. [DO NOT READ LIST. PROBE WITH ANSWER LIST BEFORE ACCEPTING DON'T KNOW]

    01 Not used
    02 Less than 1 hour
    03 1 hour to less than 2 hours
    04 2 hours to less than 3 hours
    05 3 hours to less than 5 hours
    06 5 hours to less than 8 hours
    07 8 hours to less than 12 hours
    08 12 hours to less than 24 hours
    09 24 hours
    99 Don't know

4. Which of the following devices, if any, are connected to your [INSERT] television? [READ LIST. RECORD AS MANY AS APPLY. WAIT FOR YES, NO, DON'T KNOW, FOR EACH]

    01 A cable set-top box
    02 A satellite set-top box
    03 A fiber to the home set-top box, such as for Verizon Fios or AT&T Uverse

5. [FILTER BY Q4: EXAMPLE IF Q4_01 = YES, ASK Q4_01. ELSE IF ALL Q4 = NO, SKIP TO Q7] Now we would like you to think of the most recent day when you were the FIRST person in your household to TURN ON the [INSERT] television for the purpose of watching television programming and NOT to watch DVDs, Blu-ray discs or playing video games. Did you ALSO TURN ON any of the following devices?
[READ LIST. RANDOMIZE IN SAME ORDER AS Q4. WAIT FOR YES, NO, DON'T KNOW, FOR EACH]

    01 A satellite set-top box
    02 A cable set-top box
    03 A fiber to the home set-top box, such as for Verizon Fios or AT&T Uverse

6. [FILTER BY Q5: EXAMPLE IF Q5_01 = YES, ASK Q6_01] Thinking of the most recent instance where you TURNED OFF the [INSERT] television during the DAYTIME for the purposes of watching television programming. When you TURNED OFF the TV, did you ALSO manually TURN OFF any of the following devices? [READ LIST. RANDOMIZE IN SAME ORDER AS Q4. RECORD AS MANY AS APPLY. WAIT FOR YES, NO, DON'T KNOW, FOR EACH)

   01 A satellite set-top box
   02 A cable set-top box
   03 A fiber to the home set-top box, such as for Verizon Fios or AT&T Uverse

7. In order to watch television broadcasts using an antenna on older TVs without built-in digital tuners you need a digital-to-analog TV converter box – a separate unit with its own remote control.
   a. Does your [INSERT] television have a digital to analog TV converter box connected to it? [WAIT FOR YES, NO, DON'T KNOW]
   b. [ASK IF Q 7_a=YES, otherwise skip] When you start to watch TV programming using the DIGITAL CONVERTER BOX, how often do you need to TURN ON the DIGITAL to ANALOG TV CONVERTER BOX?, [READ LIST]

      01 Never - the DIGITAL CONVERTER BOX is always ON
      02 Occasionally
      03 About half the time
      04 Often
      05 Always
      99 DON'T KNOW - VOLUNTEERED

Computers & IT Equipment

[SKIP Q8-21 IF Q1e AND Q1f BOTH =0]

[ASK ALL QUESTIONS IN THIS SECTION for each Desktop or Portable computer (up to 3, in order of most-used to least used)]

[INSERT VALUES FOR Q8-21]

a. Primary
b. Secondary
c. Third

[READ] The next questions are about computers in your household, including those used in home offices, [READ IF (Q1e+Q1f)>1] starting with the PRIMARY or MOST USED computer.

8. [SKIP IF Q1e=0 or Q1f=0] Is the [INSERT] computer in your household a…? [READ LIST]

   01 Portable Computer, like a laptop, notebook, netbook, or tablet PC
   02 Desktop Computer
   99 DON'T KNOW – VOLUNTEERED

Computer & IT Usage Questions

[READ] Now I'd like to ask you about how long each computer is used in a TYPICAL DAY by your or others in your household. By use, I mean time spent on activities such as sending or reading email, searching the Internet, watching video clips or movies, playing games, downloading files or playing music. Please include times when the computer is doing some of these activities even if no one is at the computer.

9. How long is the [INSERT] computer used …? [DO NOT READ LIST. PROBE WITH ANSWER LIST BEFORE ACCEPTING DON'T KNOW]

   01 0 minutes (Not used)
   02 Less than 15 minutes
   03 15 minutes to less than 30 minutes
   04 30 minutes to less than 1 hour
   05 1 hour to less than 1hour and 30 minutes
   06 1 hour and 30 minutes to less than 2 hours
   07 2 hours to less than 3 hours
   08 3 hours to less than 5 hours
   09 5 hours to less than 8 hours
   10 8 hours to 12 hours
   11 more than 12 to less than 24 hours **- USE THIS OPTION FOR PARTS A,E, and F ONLY**
   12 24 hours **- USE THIS OPTION FOR PARTS A,E, and F ONLY**
   99 DON'T KNOW

   A. On a TYPICAL WEEKDAY, that is Monday through Friday
   B. BEFORE NOON on a TYPICAL WEEKDAY
   C. In ONE SITTING, that is, one instance of use, on a typical WEEKDAY BEFORE NOON
   D. In ONE SITTING on a typical WEEKDAY AFTER NOON
   E. On a TYPICAL WEEKEND DAY, that is, a Saturday or Sunday
   F. In ONE SITTING on a typical WEEKEND DAY

10. How often is the [INSERT] computer TURNED OFF "OVERNIGHT"? Would you say [READ LIST]. . .

   01 Always
   02 Often
   03 About half of the time
   04 Occasionally
   05 Never
   99 DON'T KNOW - **VOLUNTEERED**

11. Thinking about the LAST TIME you finished using the [INSERT] computer during the DAYTIME, did you: [READ LIST]

   01 "SHUT DOWN" or "TURN OFF" the computer?
   02 Put the computer into "STANDBY" or "SLEEP" mode?
   03 Leave the computer ON?
   99 DON'T KNOW - **VOLUNTEERED**

12. When you or someone else in your household stop using the [INSERT] computer for 30 minutes or longer during the DAYTIME, how often is the computer manually TURNED OFF or completely SHUT DOWN? [READ LIST]

    01 Always
    02 Often
    03 About half of the time
    04 Occasionally
    05 Never
    99 DON'T KNOW - **VOLUNTEERED**

13. If you or someone in your household LEAVE the [INSERT] COMPUTER ON and do not use it for one or more hours, about how long does it take for the computer to respond to moving the mouse or typing on the keyboard? [READ LIST, RECORD]

    01 Instantly – the computer is ON and ready to use right away.
    02 After a few seconds
    03 After about 15 seconds or longer
    99 DON'T KNOW - **VOLUNTEERED**

[READ] The next few questions are about the computer's MONITOR or DISPLAY.

14.

a. How many external monitors or displays does the [INSERT] computer have connected to it? Do not count displays that are built-in to the computer, such as the screen on a laptop or netbook. [RECORD]

    00 NONE
    01 One
    02 Two
    03 Three
    04 Four or more
    99 DON'T KNOW

b. [IF part a = 1 OR MORE] What type of monitor is the [IF part a=2 or more, READ: "MOST USED"] external monitor? Is it a: [READ AND RECORD]

    01 Flat panel display, like an LCD monitor
    02 Other display, like a CRT monitor
    04 DON'T KNOW - VOLUNTEERED

15. [IF Q14a=01, 02, 03, or 04]

    a. How often is the MONITOR of the [INSERT] computer turned off during the day when the computer is not in use? Would you say. . . [READ LIST; IF RESPONDANT SAYS MONITOR GOES INTO "STANDBY/SLEEP", RECORD AS NEVER]

        01 Always
        02 Often
        03 About half of the time
        04 Occasionally
        05 Never
        99 DON'T KNOW - **VOLUNTEERED**

    b. If the monitor is left ON, after one hour or more of not being used, does it continue to display the same image, display a screensaver, or turn itself off? [READ LIST; IF RESPONDENT SAYS THE MONITOR FIRST DISPLAYS SCREENSAVER, AND THEN SHUTS OFF, RECORD AS 03.

        01 It displays the same image
        02 It displays a screensaver
        03 It displays an image for a while, and then turns off by itself or becomes completely dark
        99 DON'T KNOW **- VOLUNTEERED**

16. a. Were you the first person in your household to use the [INSERT] computer TODAY? [RECORD]

        01 Yes
        02 No
        99 Don't know

[IF NO 16a = 02 or 99, skip to 17] Please think about the FIRST TIME you used this computer TODAY.

    b. When you first saw the computer, the MONITOR or DISPLAY was… [READ LIST, RECORD]

        01 Completely dark or black
        02 Displayed an image or screen saver
        99 DON'T KNOW **– VOLUNTEERED**

    c. Which statement best describes your actions before you first started using this computer TODAY? [READ LIST]

        01 I TURNED ON the MONITOR by pressing the power button on the DISPLAY.
        02 I did not press the power button on the MONITOR, since it "TURNS ON" automatically when the computer turns on.
        99 DON'T KNOW **– VOLUNTEERED**

d. Which statement best describes this COMPUTER's condition when you first used it TODAY? [READ LIST]

01 The computer was already ON. I pressed a key or moved the mouse, and INSTANTLY the computer was READY.

02 I pressed a key, moved the mouse, or pressed a POWER button, and after a FEW SECONDS the computer was ready to use.

03 I pressed the POWER BUTTON on the computer, and WAITED more than 15 seconds until it was ready to use.

99 DON'T KNOW **- VOLUNTEERED**

17. [ASK IF Q14a=01, 02, 03, or 04] The LAST TIME you finished using the [INSERT] computer, did you: [READ LIST]

01 Leave the external monitor ON?

02 Turn the external monitor OFF by pressing the power button ON THE MONITOR?

99 DON'T KNOW **- VOLUNTEERED**

[READ] The next few questions are about computer speakers.

18. Does the [INSERT] computer have external speakers connected to it? Do not count speakers that are built in to the computer or monitor or speakers powered by a USB cable or by batteries. [OPEN END, RECORD]

01 YES

02 NO

99 DON'T KNOW

19. [ASK IF Q18=01] Think of the most recent time you used the [INSERT] computer for the FIRST TIME that day. Were your computer speakers ALREADY ON? [OPEN END, RECORD]

01 YES

02 NO

99 DON'T KNOW

20. [ASK IF Q18=01] When you start to use the [INSERT] computer DURING the EVENING, how often are the speakers OFF and you need to turn ON the speakers? [READ LIST]

01 Always

02 Often

03 About half of the time

04 Occasionally

05 Never

99 DON'T KNOW - VOLUNTEERED

21. [ASK IF Q18=01] When the [INSERT] computer is "IN USE", how often are the computer speakers ON? [READ LIST]
    - 01 Always
    - 02 Often
    - 03 About half of the time
    - 04 Occasionally
    - 05 Never
    - 99 DON'T KNOW - VOLUNTEERED

Broadband & Home Network Equipment

[READ] This question is about high speed Internet modems, which are small boxes with blinking lights that computers use to connect to a high-speed Internet service.

22. [IF Q1e+Q1f > 0] In the last month, have any computers in your household connected to the Internet with a high speed connection, such as DSL, Cable, Satellite, or Fiber optic? [OPEN END, RECORD]
    - 01 YES
    - 02 NO
    - 99. DON'T KNOW

23. [IF Q22 = 01, ASK. IF NOT, SKIP]. Which statement best describes your household's high speed Internet modem? [READ LIST and RECORD]
    - 01 THE MODEM IS ALWAYS ON and ready to use
    - 02 THE MODEM IS TURNED OFF when NOT IN USE – people need to TURN ON the MODEM to connect to the Internet.
    - 99 DON'T KNOW - VOLUNTEERED

Printers, Including Devices that can also Scan, Copy, or Fax documents

[IF Q1g=0, SKIP Q24-25]

[INSERT VALUES FOR Q24-25]

a. [READ IF Q1g>1] Primary
b. Secondary
c. Third

[READ] The next questions are about printers including those that scan, copy, or fax; [READ IF Q1g>1].

24. Think of the most recent   you printed, scanned, copied, or faxed a document from the [INSERT] printer.
    a. Did you need to turn ON the printer by pressing the printer's power button when you first began printing that day? [RECORD]
        - 01 No
        - 02 Yes
        - 99 DON'T KNOW

b. After using the printer, did you? [READ LIST]

01 Turn OFF the printer soon after you finished printing
02 Turn off the printer when you finished using the computer
03 Leave the printer on
99 DON'T KNOW **- VOLUNTEERED**

25. During a TYPICAL WEEK, how many days is the [INSERT] printer used by you or anyone else in your household? [RECORD INTEGER from 0 to 7, RECORD 99 for "DON'T KNOW"]

Amplifiers (Home Speaker Systems)

[SKIP Q26-27 if Q1b=0]
[ASK QUESTIONS FOR UP TO 3 HOME SPEAKER SYSTEMS from Q1b]
[INSERT VALUES for Q26-27]

a. Primary
b. Secondary
c. Third

[READ] The next questions are about HOME SPEAKER SYSTEMS, [READ IF Q1b>1] starting with the PRIMARY, or most-used HOME SPEAKER SYSTEM.
HOME SPEAKER SYSTEMS include speakers that are used with TVs, "Home Theater Systems," amplifiers, or stereo systems. They do NOT include portable stereos or speakers used with computers.

26. Thinking 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? [OPEN END, RECORD RESPONSE]

01 YES
02 NO
99 DON'T KNOW

27. How long was the [INSERT] speaker system used yesterday, by you or anyone else in your household? [OPEN END, RECORD]

01 Not used
02 Less than 1 hour
03 1 hour to less than 2 hours
04 2 hours to less than 3 hours
05 3 hours to less than 5 hours
06 5 hours to less than 8 hours
07 8 hours to less than 12 hours
08 12 hours to less than 24 hours
09 24 hours
99 DON'T KNOW

DVD player, recorder and DVD-VCR combo

[SKIP Q28-30 if Q1d=0]
[ASK QUESTIONS FOR UP TO 2 DVD PLAYERS from Q1d]
[INSERT VALUES for Q27-29]

a. Primary
b. Secondary

[READ]: The next questions are about DVD Players, [READ IF Q1d>1] starting with the primary, or most frequently used DVD Player.

28. Is the [INSERT] DVD player that you own…?[READ LIST, RECORD]

    01 Capable of recording TV shows
    02 A DVD-VCR combination that can play both DVDs and Video-cassettes
    99 DON'T KNOW – VOLUNTEERED

29. How long was the [INSERT] DVD player used yesterday by you or anyone else in your household, to watch movies or record TV shows? [OPEN END, RECORD HOURS]

    01 Not used
    02 Less than 1 hour
    03 1 hour to less than 2 hours
    04 2 hours to less than 3 hours
    05 3 hours to less than 5 hours
    06 5 hours to less than 8 hours
    07 8 hours to less than 12 hours
    08 12 hours to less than 24 hours
    09 24 hours
    99 DON'T KNOW

30. Think of the last time you used the [INSERT] DVD player. Was it: [READ LIST, RECORD]

    01 ALREADY ON
    02 OFF
    99 DON'T KNOW - VOLUNTEERED

Blu-ray Disc Player

[SKIP Q31 IF Q1c>1]

31. Thinking of your primary or most used Blu-ray disc player, how long was it used yesterday by you or anyone else in your household, to watch movies? [OPEN END, RECORD]

01 Not used
02 Less than 1 hour
03 1 hour to less than 2 hours
04 2 hours to less than 3 hours
05 3 hours to less than 5 hours
06 5 hours to less than 8 hours
07 8 hours to less than 12 hours
08 12 hours to less than 24 hours
09 24 hours
99 Don't know

Appendix B – Computer and Monitor Usage Models

B.1 Computer Usage Model

The team developed a model to translate the survey responses into residential PC daily weekday and weekend usage patterns. Based on survey data and model-specific assumptions, the model calculates the hours per each PC spends active-used, active-unused, sleeping, and off per week.

We developed a more refined model (e.g., than TIAX 2006), especially for time spent in power modes when the computer is not actively used. This mainly depends on power management settings and user habits (e.g., probability of switching the computer off versus leaving it on after usage). As this "not actively used"-time accounts for the majority of a typical day (an average of 19 hours per day) and typical power draw values vary greatly between modes, e.g., between 2W (off) and 62W (on) for desktop PCs (see Sections 3.5 and 3.6), these estimates have a dramatic impact on the UEC and AEC estimates for computers.

Table B-1 summarizes how we used different survey questions (Appendix A) to develop different types of information.

Table B-1: Information obtained from the telephone survey and corresponding survey questions

Information	Survey question(s)
Active usage time per weekday/weekend day	M9A, M9E
Usage before noon/ in the afternoon and length of a typical session to determine the number of sessions over the day	M9B, M9C, M9D, M9F
Power management settings	M13
Likelihood of manually switching off the computer or putting it to standby at the end of a typical session during the day and before nighttime	M10, M11, M12

Our model divides the day into nighttime (12AM-8AM), morning (8AM-12PM) and afternoon/evening (12PM-12AM). We analyzed ATUS (American Time of Use Survey) data to determine typical time of day usage patterns for computers (ATUS 2010). As Figure B-1 shows, usage during daytime (8AM-12AM) has moderate peaks around 8-9AM and 8-10PM, and very few computers start to be used between 12AM-8AM.

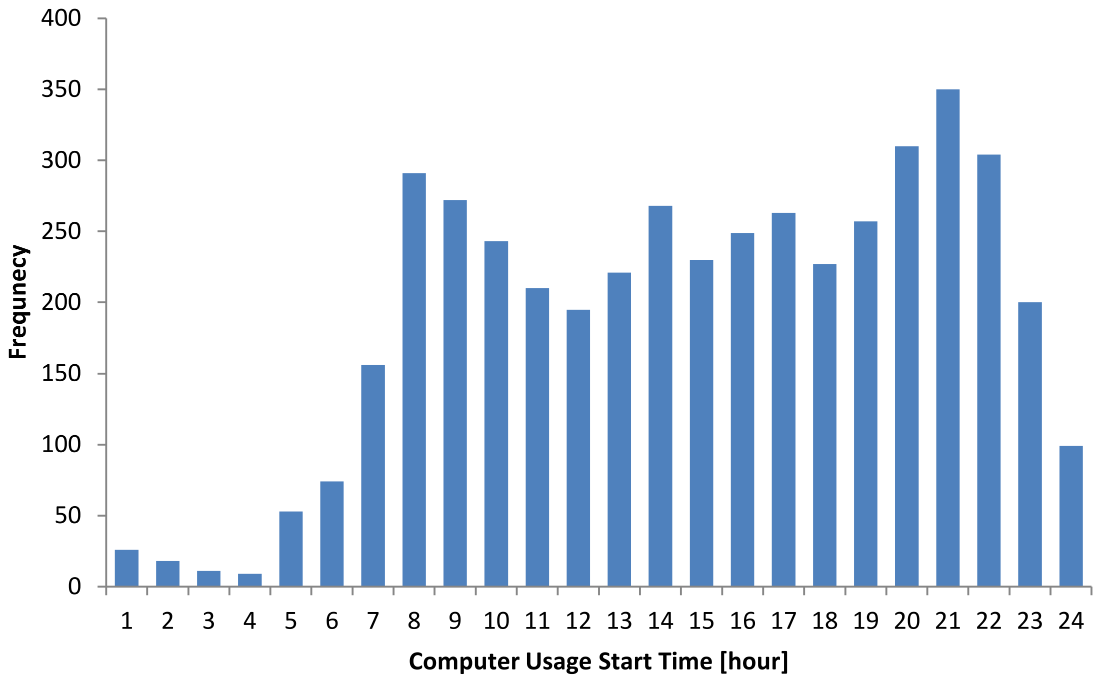

Figure B-1: Probability distribution of computer usage start time over the day (data from ATUS 2010)

The model calculates the time in *on* mode based on several factors:

- Active use reported (A_1 and A_2; see Figure B-2)
- Nighttime if the computer is not switched off manually and power management is disabled (B_1)
- 30 minutes after each session before power management kicks in unless the computer is switched off manually (B_2)
- The remaining time between sessions during daytime (8AM-12AM) if the computer is not switched off manually and if power management is disabled (B_3)

We calculate time in *sleep* mode based on:

- Night time if the computer is not switched off manually and if power management is enabled to sleep mode (B_1)
- The remaining time between sessions during daytime (8AM-12AM) if the computer is not switched off manually and if power management is enabled to *sleep* mode (B_3)

Time in *off* mode is calculated based on:

- Night time if the computer is switched off manually (B_1)
- Night time if the computer is not switched off manually and if power management is enabled to *off* mode (B_1)
- The remaining time between sessions during daytime (8AM-12AM) if the computer is switched off manually (B_3)
- The remaining time between sessions during daytime (8AM-12AM) if the computer is not switched OFF manually but if power management is enabled to *off* mode (B_3)

Both the survey and usage model evaluate usage on weekdays and weekend separately in the survey.

Survey respondents were asked how frequently the computer is switched off manually at night (Question 10) and when the computer has not been actively used for more than 30 minutes (Question 12). Depending on how often the computer is reported to be switched off manually, we allocated the time between active use sessions and nighttime to different power draw modes using the following weights:

- *Always* – Computer in *off* mode 100% of the time between sessions/ at nighttime
- *Often* – Computer in *off* mode 75% of the time between sessions/ at nighttime; the remaining 25% are assigned to *on/sleep/off* mode according to the power management setting reported (30 minutes after each session assigned to *on* mode for power management [PM] delay)
- *About half of the time* – Computer in *off* mode 50% of the time; the remaining 50% according to power management settings (30 minutes after each session assigned to *on* mode for PM delay)
- *Sometimes* - computer in *off* mode 25% of the time; the remaining 50% according to power management settings (30 minutes after each session assigned to *on* mode for PM delay)
- *Never* – 100% according to power management settings (30 minutes after each session assigned to *on* mode for PM delay)

The model calculates separately the time spent in *on, sleep* and *off* mode for each survey respondent, both for weekdays and weekend days, and separately for primary, secondary and tertiary computers. The values thus obtained for each computer are weighted for demographic normalization.

The following example illustrates how we translated the survey responses into the number of hours each PC spends in different power draw mode. In this case, the survey respondent's answers were:

- 6.5 hours of computer usage during the day, of which 1 hour occurs in the morning
- Typical session length in the morning: 30 minutes
- Typical session length in the afternoon: 2 hours
- The computer is never (0%) manually shut down during the day, but always (100%) at night
- Power management setting is enabled (sleep mode)

This translates into the following usage pattern in the model (see Figure B-2): two morning sessions (A_1) and three sessions after noon (A_2) occur. In this case, the computer is left on during the day also after a session ends, and has power management settings set to *sleep* mode; therefore 30 minutes after each session are assigned to *on* mode (time until power management kicks in, B_2), the remaining time between 8AM and 12AM (B_3) is assigned to *sleep* mode.

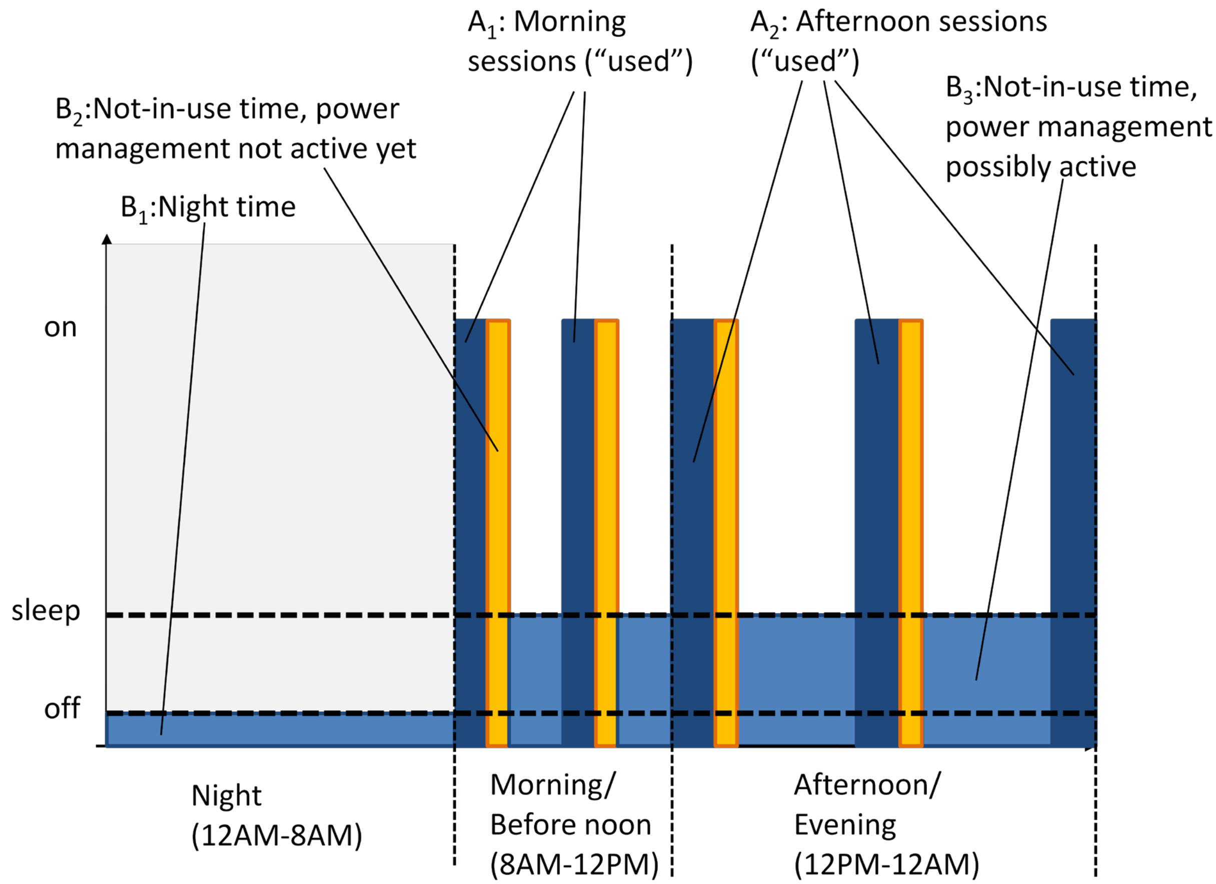

Figure B-2: Example of how survey responses are taken into account in the model to calculate the time spent in different power draw modes

B.1.1 Results

We analyzed the data separately for desktop and portable computers; the results can be found in the corresponding sections. For comparison purposes with other studies, we also analyzed some of the data without differentiating between the two product categories. Specifically, we compared our findings with those of the Massachusetts Residential Appliance Saturation Survey data (RASS 2009) and the Residential Energy Consumption Survey of the DoE Energy Information Administration (EIA RECS 2009a).

Figure B-3 shows the aggregated data for power management settings according to CE Usage Survey data. Based on these data, we find that power management is disabled for 32% of residential computers, 39% enter sleep mode, and 29% turn off or hibernate.

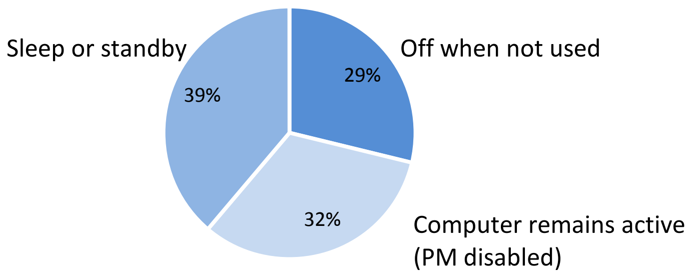

Figure B-3: Power management settings of residential computers based on CE Usage Survey data.

In the survey, 48% of the respondent report switching off their computer manually never or only occasionally between usage sessions. 36% of these do not have power management enabled, thus an estimated 17% of computers remain on all the time during the day. For comparison, the DOE/EIA RECS (2009a) survey found only 4% of computers to remain on when not used, compared to 59% that enter off mode and 37% that enter sleep mode. However, survey respondents were asked directly of the computer is "usually turned off" when it is not in use (EIA RECS 2009b) and answers might be skewed by social desirability bias. To avoid that issue, we asked about the state of the computer after longer periods of inactivity, which we consider as more reliable, and included detailed questions on usage patterns (see Appendix A). The fraction of computers that enter sleep mode in DOE/EIA RECS (2009b) is consistent with our findings.

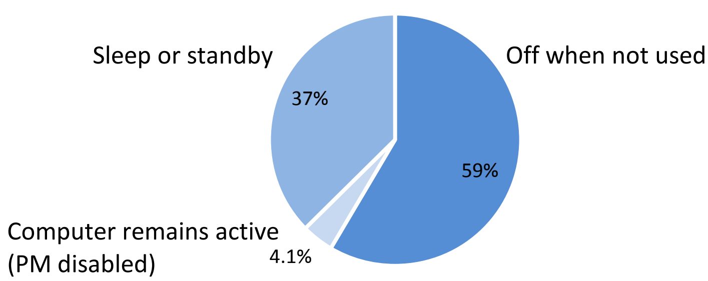

Figure B-4: State of computer when not used, from DOE/EIA RECS (2009)

Based on the CE Usage Survey data on power management settings (question M13), reported usage patterns (questions M9A-F,M11,M12), and weight factors, we calculated the time spent in off, off and sleep mode for desktop and portable computers (see corresponding sections). Figure B-5 shows the weighted results for both product categories combined:

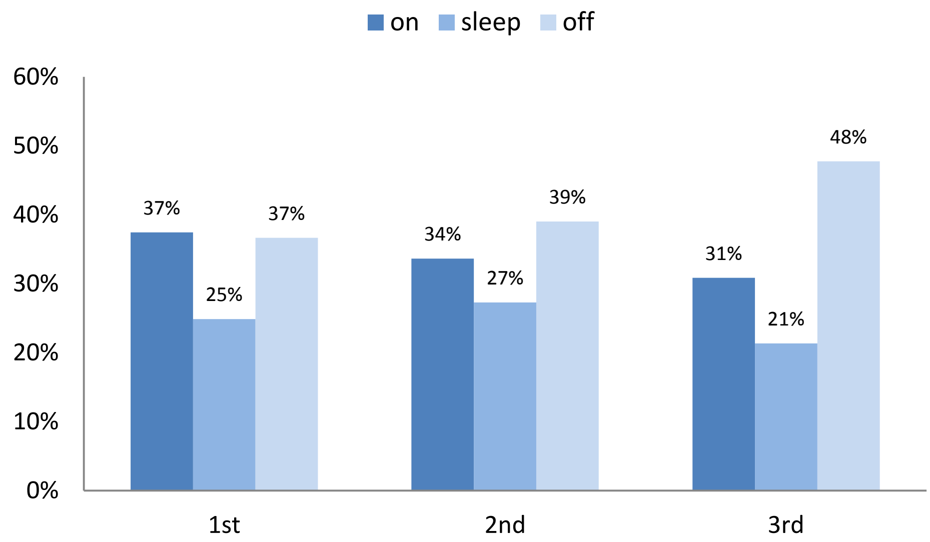

Figure B-5: Usage of primary, secondary and tertiary computers based on our model

In RASS 2009, survey respondents were asked directly for the percentage of time left on/ in sleep mode/off for their first, second and third computer (without the separation between desktop and portable computers though; see Figure B-6). We find a higher fraction of time spent in on mode and less time in off mode, which we attribute to the fact that our refined model includes the time to sleep spent in on mode for computers with power management enabled, as well as questions that we believe are less subject to social desirability bias. Furthermore, we expect that many people have problems directly estimating the time their computer spends in on, sleep or off mode when they are not using it.

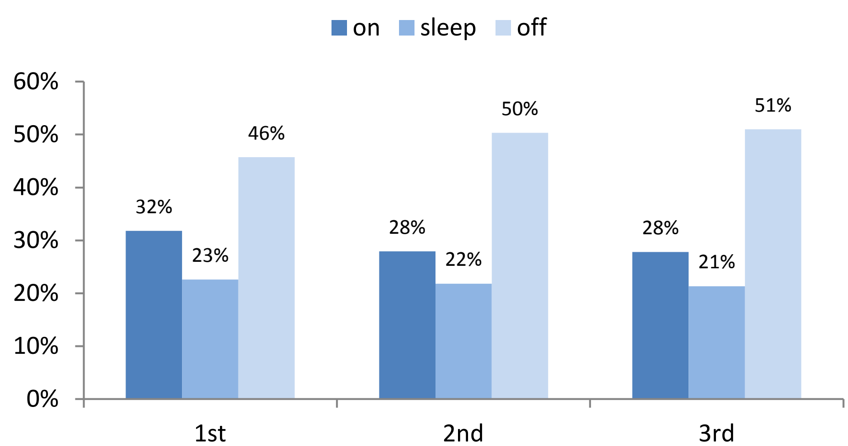

Figure B-6: Usage by mode of primary, secondary and tertiary computer according to Massachusetts RASS

B.1.2 Model Uncertainties and Inconsistencies

The model likely overestimates the energy consumption of some computers that are switched off manually during night time *and* are not switched off between sessions during daytime, as it assigns the start of the first session to 8AM and the end of the last session to 12AM. For other cases, it is not relevant when the usage sessions occur, as the not-in-use-time remains the same and power management settings apply regardless of the time of the day. Comparing the reported likelihoods of manually switching off the computer at night and between daytime sessions, 64% of survey respondents report the same switching off-habits for both nighttime and in between sessions during the day; 14% switch off the computer slightly more often at night (25% difference) and only 23% are likely to switch off their computer much more often at night than between sessions. Among these, only computers with power management settings disabled (34%) will have considerably different energy consumption estimates (due to the very small difference between power draw in sleep and off modes). Thus, the model may significantly overestimate the energy consumption in about 8% of all cases. A calculation of the approximate magnitude of error on the AEC for both desktop and portable computers is 1.3TWh for desktop PCs and 0.3TWh for portable computers.[42]

Another issue that arose was that, in several cases, survey respondents gave inconsistent answers. For example, one respondent reported that a computer was typically used for 1 hour over the whole day, but 3 hours on a typical morning alone. Our algorithms checks for such inconsistencies and, in some cases, we decided to exclude their responses. All together, such inconsistencies or lack of information provided resulted in the exclusion of 10% of all respondents.

In other cases, our algorithm modified the usage profile in light of inconsistencies. For example, one respondent reported that on a typical day, the computer is not used in the morning, but that the length of a typical morning session is 1 hour. In that case, we assume that the computer is rarely used in the morning, but if it is, then for an average of 1 hour. The algorithm counts this as "not used in the morning of a typical day" and assigns the usage hours reported for the entire day entirely to the afternoon/evening time window.

Out of 1,010 survey respondents, 789 reported having a desktop or portable computer plugged in, of which 73 of the 789 were not able to provide the information needed to determine their power management settings (Appendix A, question M13). However, the large majority (80%) of these respondents reports always or often switching their computer off at night, as well as during the day when it is not used for 30 minutes or more (66%), compared to 60% (nighttime) and 40% (>=30 minutes unused), respectively, among all survey respondents. As this population is not representative for the overall sample, simply excluding them would bias the results towards a higher on mode usage. Instead, we randomly assigned them power management settings according to the overall distribution from the other survey respondents (24% on mode, 30% sleep mode, 46% off mode).

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[42] This affects about 8% of computers, and the difference in power draw between on and off mode equals 60W for desktop computers and 18W for portable computers. If we assume that they were only switched on at 4PM (likely a low-bound estimate that overestimates the error) instead of 8AM, this yields a 40% overestimation of UEC for the affected computers, which translates into an AEC overestimation of 1.3TWh and 0.3TWh for the entire population of residential desktop and portable computers, respectively.

B.1.3 References

ATUS. 2010. "American Time Use Survey - 2009." U.S. Department of Labor, Bureau of Labor Statistics. Data downloaded from http://www.bls.gov/tus/.

CE Usage Survey. 2010. October.

EIA RECS. 2009a. "2009 Residential Energy Consumption Survey: Computers and Other Electronics." U.S. Department of Energy, Energy Information Administration. http://www.eia.gov/consumption/residential/data/2009/#undefined .

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RASS. 2009. "Massachusetts Residential Appliance Saturation Survey (RASS) – Volume 1: Summary Results and Analysis." Prepared by Opinion Dynamics Corporation for Cape Light Compact, National Grid, Nstar Electric, Unitil, Western Massachusetts Electric Company. www.env.state.ma.us/dpu/docs/electric/09-64/12409nstrd2af.pdf. April.

B.2 Monitor Usage Model

Our monitor usage by mode model is an extension of the computer usage model to determine the fraction of time a monitor spends in the three states on, sleep and off. Several questions in the CE Usage Survey helped to develop the monitor usage estimate (see Appendix A).

We calculated results separately for desktop and portable computers, weekend and weekdays, primary/secondary/tertiary computers, and also account for the weight factor of the individual respondents in the survey.

B.2.1 Power Management Settings

According to the survey data (question 17, Appendix A), 68% of desktop monitors have power management enabled and 68% of external notebook monitors; the remaining 32% remain on when not turned off manually.

B.2.2 State of the monitor when the computer is not used

Only people who were the first users of the computer the day of the survey were asked questions about the state of the monitor in the morning (248 persons or 32% of the survey respondents who reported having a computer). They were asked if the computer displayed the same image or a screensaver in the morning (question 19), which indicates that the monitor remained on all night. They were also asked (question 20) whether they had to press a button on the monitor in the morning to activate the monitor (off mode).

Based on these data, we estimate that 15% of desktop computer monitors and 10% of external notebook monitors are on all night based on survey question 19, 36% of desktop computer monitors and 40% of external notebook monitors are switched off manually at night (question 20), and 49% (desktop) and 50% (notebook) of the monitors spend the night in sleep mode.

We apply these values to daytime usage between computer usage sessions. This probably underestimates the fraction of monitors in on mode during daytime, as we expect that people are probably more likely to turn off the monitor manually at night than during the day between usage sessions. For monitors with power management enabled, the potential error is 20 minutes after each computer session (average time to sleep); for monitors with power management disabled, the error is the time between multiple daytime sessions. We still believe that our estimate is still a fairly good approximation as a) power management settings remain unchanged and b) we assume consistency in peoples' habits of switching off the monitor manually.

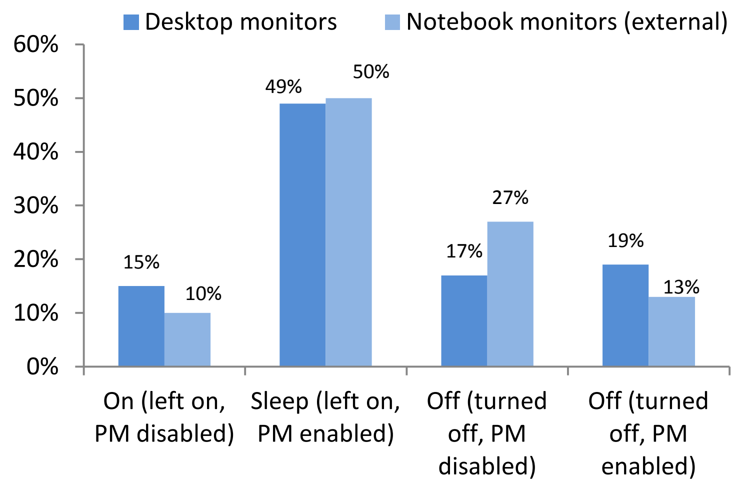

Figure B-5: State of monitors while computer is not actively used, based on CE Usage Survey. PM=power management.

Responses in terms of switching off behavior/ power management settings were quite consistent among devices used as primary, secondary and tertiary computers. Only a limited number of respondents indicated the morning status of the monitor for secondary and tertiary computers. As most of these were consistent with the responses for their primary computers, we assumed that the same percentage of monitors were switched off manually and stayed on all the time for all computers (primary, secondary and tertiary), as well as both for weekend and weekdays. However, we applied the different computer usage times and number of computer sessions we found in the computer usage model and calculated the resulting monitor usage based on 12 different datasets (i.e., 12 = 2 (portable/desktop)* 2 (weekday/weekend) * 3 (primary/secondary/third computer)).

B.2.3 Time in on mode

Figure B-6 depicts how we calculated time in on mode for three cases:

a) Monitors left on all day without power management enabled

b) For all other computers the computer usage time (from the computer usage model)

c) For monitors that are not switched off manually (question 16, Appendix A), but have power management enabled (question 17): the number of computer sessions per day times 20 minutes (until power management powers down the computer).

It also indicates the fraction of monitors attached to desktop/portable computers that fall into these categories based on the survey questions (on the right).

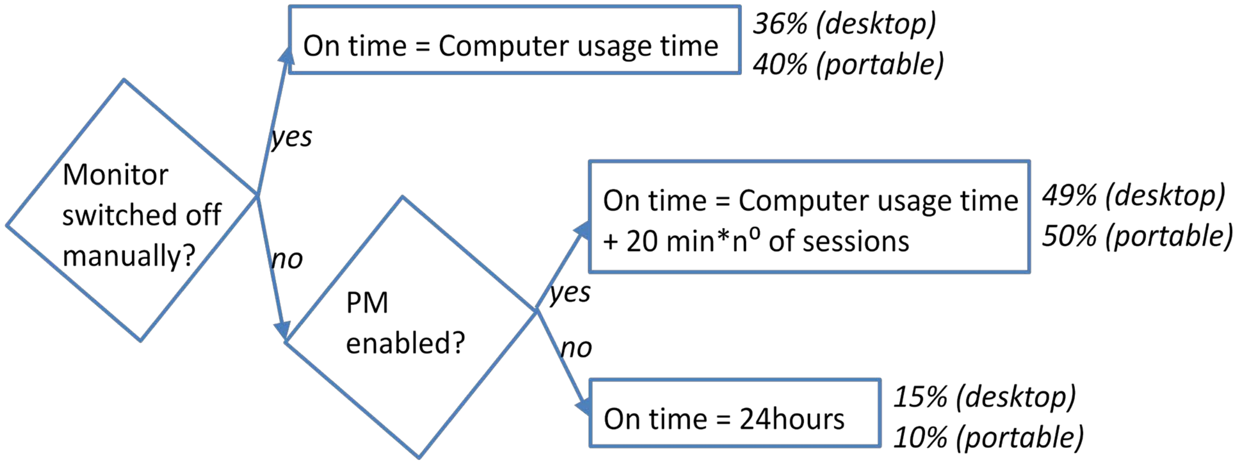

Figure B-6: Monitor model decision tree for usage by mode estimates

B.2.4 Time in sleep and off mode

We calculate the time in sleep/ off mode from the remaining time according to the responses to the night state of the monitor (question 20).

B.2.5 Results summary

Based on these data, we calculate the average usage of monitors shown in Table B-2.

Table B-2: Usage by mode of computer monitors, weighted averages based on CE Usage Survey

Computer Type	Usage [h/yr]		
	On	Sleep	Off
Portable Computer	6.4	9.9	7.7
Desktop computer	8.8	8.8	6.4