Residential Miscellaneous Electric Loads: Energy Consumption Characterization and Savings Potential

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Final Report by TIAX LLC
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TIAX Reference No. D0370

for

Building Technologies Program
Project Managers: Mr. Lew Pratsch
Contract No.: GS-23F-0064L

July 2007

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National Technical Information Service (NTIS)
U.S. Department of Commerce
Springfield, VA 22161
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NTIS Number: PB2007-110017

Acknowledgements

The authors would like to acknowledge the valuable support provided by several others in the preparation of this report. Dr. Detlef Westphalen of TIAX LLC served as the senior reviewer for the project and Ms. Donna Bryan, also of TIAX, helped with the formatting of the final report.

Mr. Lew Pratsch of the U.S. Department of Energy, Building Technologies Program, provided day-to-day oversight of this assignment and helped to shape the approach, execution, and documentation. He also reviewed and constructively critiqued draft versions of the report. Mr. Ed Pollock, also of DOE/BT, provided valuable input on the project scope and direction.

The report also benefited from the review and comments provided by several energy researchers.

- John Cymbalsky, Energy Information Administration (EIA), U.S. Department of Energy (DOE)
- D. Barley, National Renewable Energy Laboratory
- B. Nordman, Lawrence Berkeley National Laboratory
- L. Pratsch, U.S. Department of Energy, Building Technologies Program
- Hans-Paul Siderius, SenterNovem

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1 EXECUTIVE SUMMARY

Miscellaneous electric loads (MELs) appear to account for an increasingly large portion of residential electricity consumption. A study of a wide range of MELs estimated that, in 1995, they accounted for about 25 percent of U.S. residential annual electricity consumption (AEC; Sanchez et al. 1998). The U.S. Department of Energy's Energy Information Administration (DOE/EIA) estimated that "other" electricity consumption, combined with televisions and office equipment, represented about 29 percent of U.S. residential AEC in 2006 and will grow to approximately 38 percent in 2030.

In addition to its general interest in total MEL AEC, the Building Technology Program at DOE (DOE/BT) has a particularly interest in the per household electricity consumed by MELs. Specifically, DOE/BT has a goal of constructing cost-effective net zero-energy homes (ZEH) by the year 2020. To meet the ZEH objective, building researchers expect that the all-electric home designs will use highly efficient envelope and fenestration technologies to greatly reduce space heating and cooling loads, deploy high-efficiency building equipment to serve the reduced building loads, and use solar energy to power the efficient equipment.

To support its strategic planning efforts, DOE/BT contracted TIAX to characterize residential MELs, analyze their unit, household, and annual electricity consumption in 2006, carry out an initial assessment of the energy-saving potential for MELs using best-available devices and practices.

Energy Consumption by Miscellaneous Electric Loads in 2006

The study identified 21 key MELs and 9 secondary MELs and characterized their energy consumption in 2006 (see Table 1-1).

Table 1-1: Miscellaneous Electric Loads Evaluated

Key Equipment Types	Secondary, Common	Secondary, Uncommon
• Ceiling Fan • Coffee Machine • Compact Audio System • Component Stereo • DVD Player • Home Theatre in a Box • Inkjet Printers + MFDs • Lighting, Outdoor • Lighting, Portable • Microwave Oven • Modem, Broadband • Monitors • PC, Desktop • PC, Notebook • Rechargeable Electronics • Security System, home • Set-top Box, Cable • Set-top Box, Satellite • Television, Analog • Television, Digital • VCR (stand-alone)	• Hair Dryer • Iron • Toaster • Toaster Oven • Vacuum Cleaner	• Aquarium • Pool Pump • Portable Electric Spa • Waterbed Heater

Overall, the key and secondary MELs evaluated consumed about 297TWh of electricity and 3.2 quads of primary energy[1] in 2006. Placed in context, this represents about 22 percent and 15 percent of residential electricity and primary energy consumption[2], respectively (see Table 1-2 and Figures 1-1 and 1-2). If portable and outdoor lighting are not counted as MELs, these percentages decrease to 17 and 12 percent. A preliminary assessment of other MELs found that they accounted for about an additional 5 percent of total residential electricity consumption. Placed in a national context, the residential MELs evaluated account for about 8 percent of U.S. electricity consumption and 3.2 percent of U.S. primary energy consumption in 2006 (EIA 2006).

Table 1-2: Miscellaneous Electric Loads in a National Context

Category	Key + Secondary + Uncommon MELs	Key + Secondary + Uncommon MELs *less* Lighting	All MELs Evaluated
Residential Electricity	22%	17%	27%
U.S. Electricity	8%	6.4%	10%
Residential Primary Energy	15%	12%	18%
U.S. Primary Energy	3.2%	2.5%	3.8%

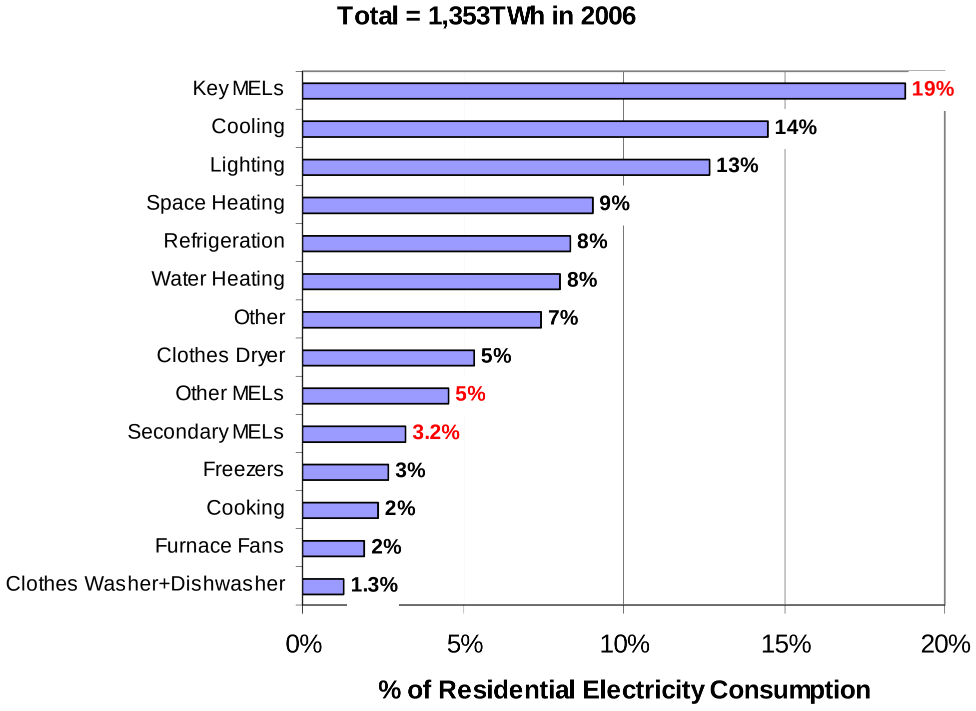

Figure 1-1: Residential Electricity Consumption Breakdown by End Use in 2006 (EIA 2006, Current Study)

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[1] Primary energy, as opposed to site energy, takes into account the energy consumed at electric power plants to generate electricity. In 2006, every kWh of site electricity requires the consumption of an average of 10,831 Btus to generate, transmit, and distribute (EIA 2006). The total shown also includes fuel energy cosumption, i.e., for buildings, most notably natural gas, heating fuel, and propane used for space heating and water heating.

[2] As portable and outdoor lighting electricity and energy consumption values are considered as MELs for the purposes of this study, we subtracted those values from the EIA (2006) estimates for lighting energy consumption.

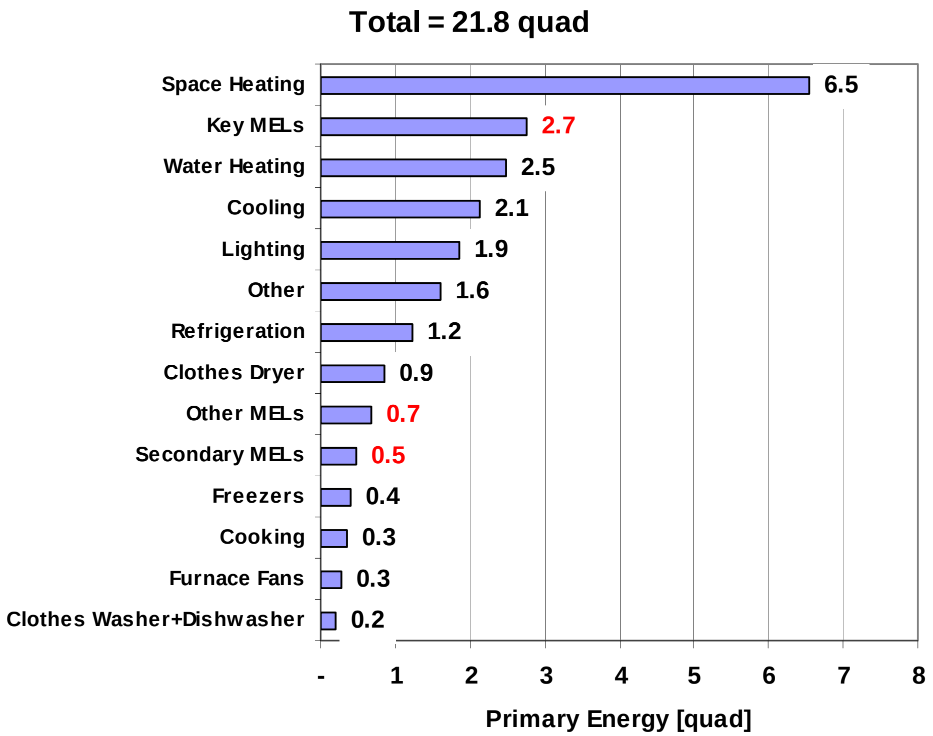

Figure 1-2: Residential Primary Energy Consumption Breakdown by End Use in 2006 (EIA 2006, Current Study)

Even after completing this detailed assessment of MELs, "other"[3] still appears to account for about 7 to 8 percent of residential electricity consumption. Discussions with the U.S. Department of Energy's Energy Information Administration (DOE/EIA) indicated that they derived total electricity (and energy) consumption values for the "other" category by comparing total residential sector electricity (or primary energy consumption) consumption estimates to the sum of bottom-up estimates for the different end uses. All of these estimates have some error and uncertainty associated with them, and DOE/EIA confirmed that statistical error probably accounts for most of the apparent "other" energy consumption that remains (Cymbalsky 2007). That is, most of the "other" energy consumption shown above is *not* real but a statistical artifact.

We evaluated MEL household electricity consumption (HEC) in two ways. First, we calculated the *average* HEC, which equals the total electricity consumption of key and secondary MELs divided by the 115 million U.S. households in 2006. Second, we calculated the *typical* HEC, based on the number of each MEL analyzed in a typical household based on penetration and installed base data. For example, the average value will reflect the energy consumed by 2.4 televisions and 0.03 water beds, while the typical household value will reflect two televisions and zero water beds. The calculated average and typical HEC values for the MELs analyzed are within four percent of each other (see

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[3] EIA (2006) states that other includes small electric devices, heating elements, and motors not included in other end uses. In addition, Cymbalsky (2007) indicates that "other" includes Christmas lights and wine coolers and under-bar refrigerators (the latter two are not included in the refrigeration category).

Figure 1-3). It appears that, for the typical household, incremental HEC increase from several key MELs with high (but less than 100%) penetration in an average household is approximately equal to the fractional contributions of the secondary, uncommon MELs in the average calculation.

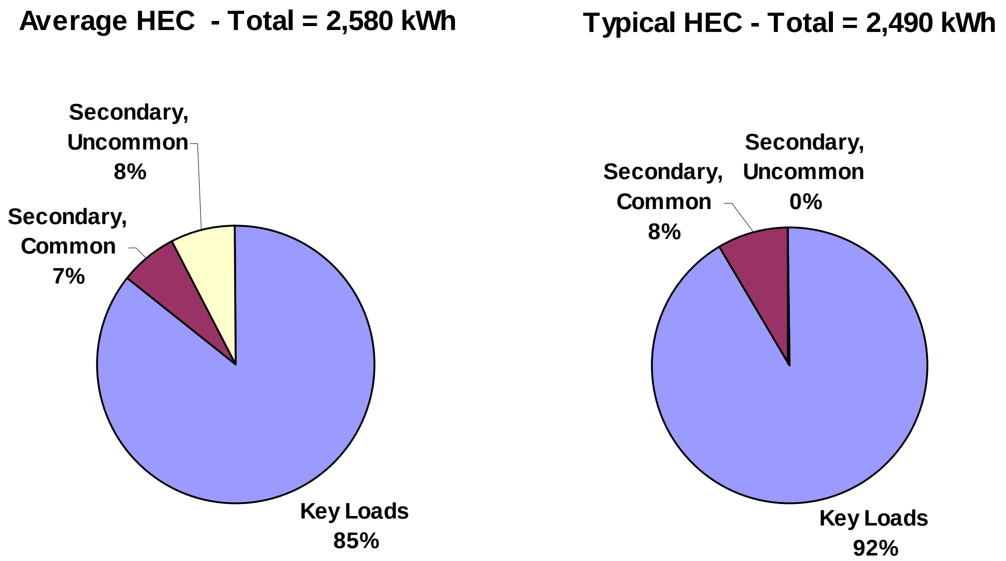

Figure 1-3: Average and Typical Household Electricity Consumption Values

Televisions (23%), portable and outdoor lighting (21%), and PCs (12%, including monitors and peripherals) are the largest contributors to average HEC (see Figure 1-4) and, together, represent more than half of average MEL HEC for the key and secondary loads evaluated.

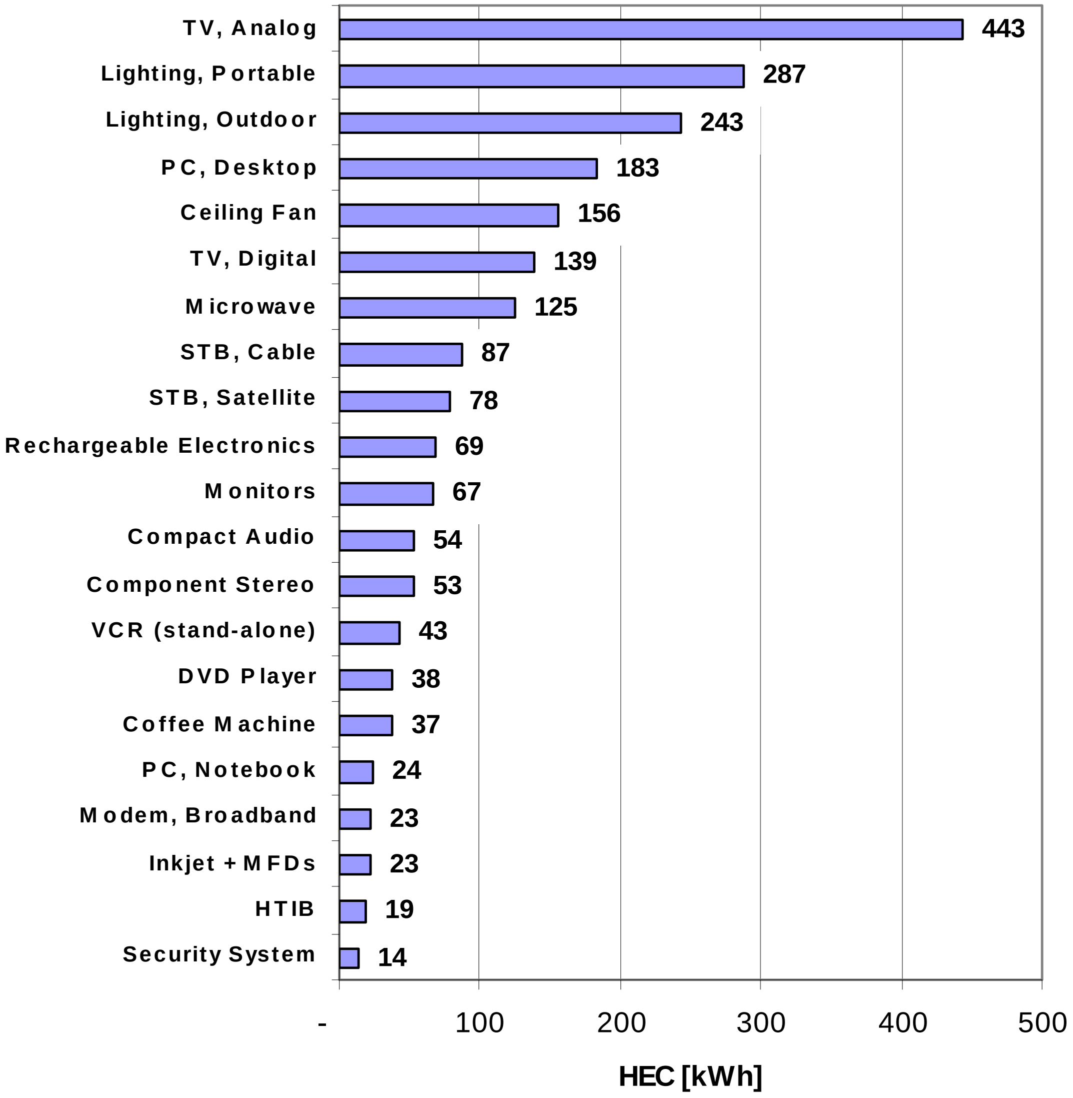

Figure 1-4: Average Household Electricity Consumption for the Key MELs

The average number of devices per household in a household with at least one device varies from one to five (see Figure 1-5).

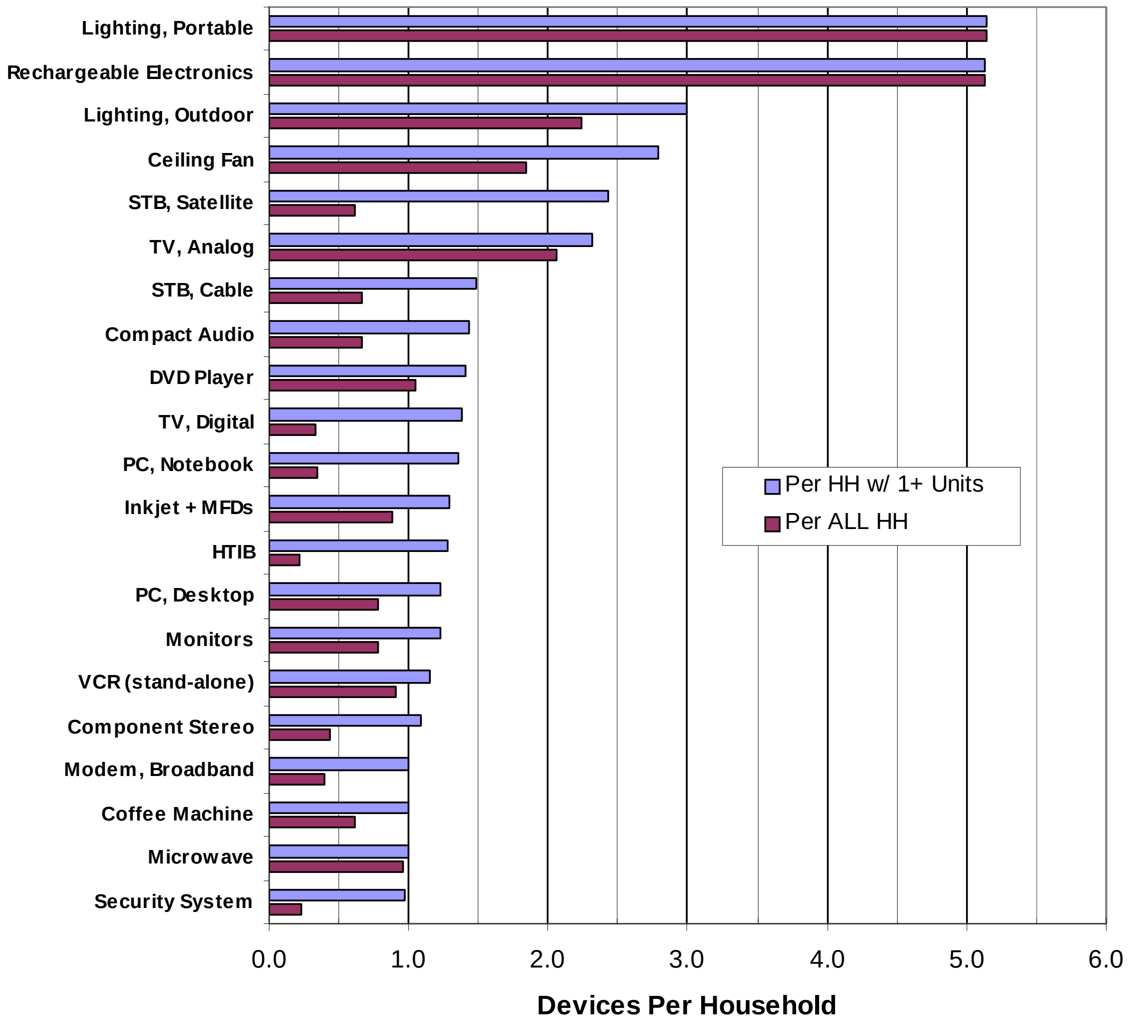

Figure 1-5: Number of Devices per Household in for All Households and Households with at Least One Device

Due to significant differences in the penetration of various MELs, i.e., the percentage of households with at least one or more of a given MEL (see Figure 1-6), the number of devices averaged over ALL households varied greatly (see Figure 1-5). Notably, the uncommon MELs had much smaller penetrations that most of the key and secondary, common MELs.

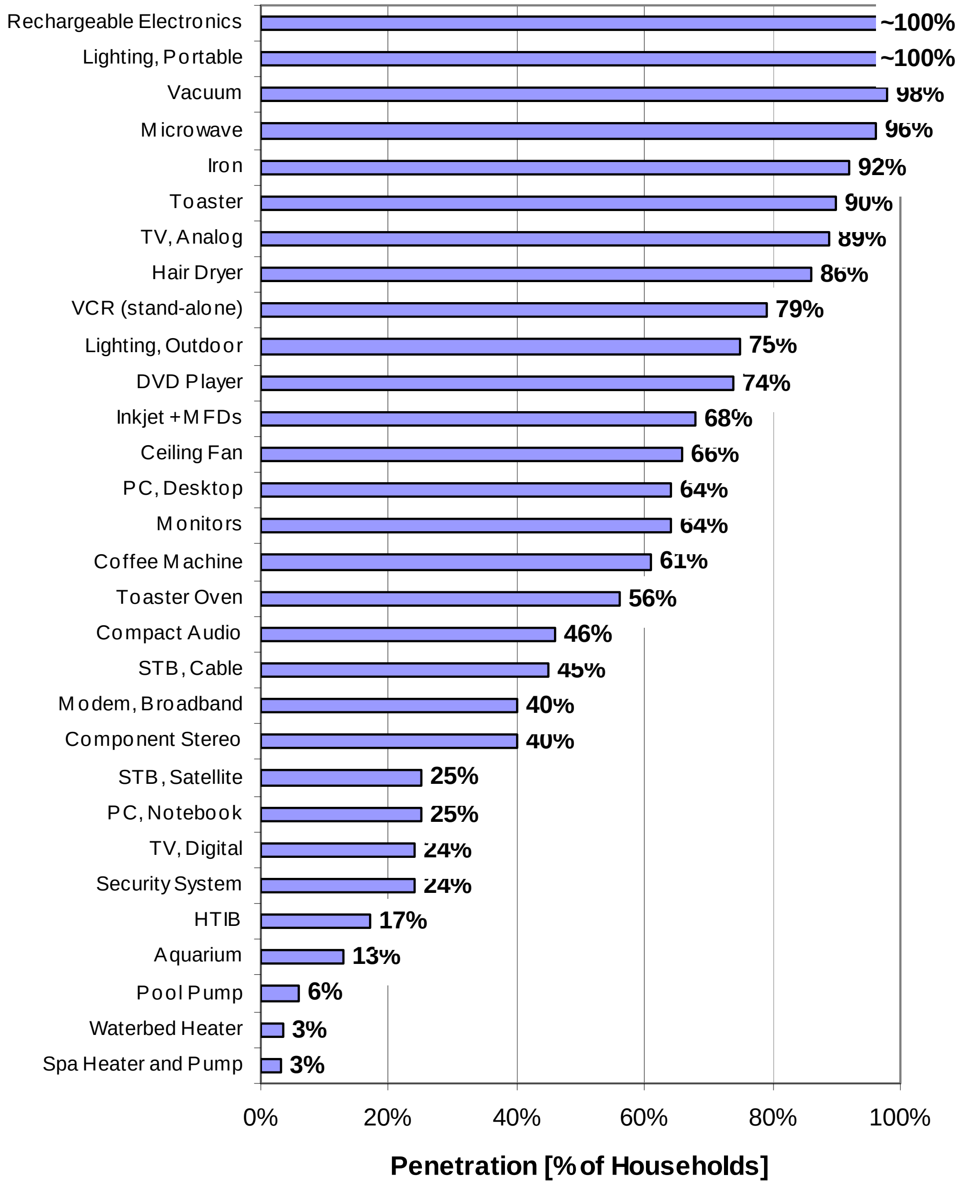

Figure 1-6: Estimated Penetration of MELs Evaluated

The unit electricity consumption (UEC) of the key MELs vary by more than an order of magnitude (see Figure 1-7). Digital televisions have the highest value, followed by desktop PCs and analog TVs. Relative to most key MELs, the secondary, uncommon loads have higher UECs while the secondary, common loads have more moderate UECs.

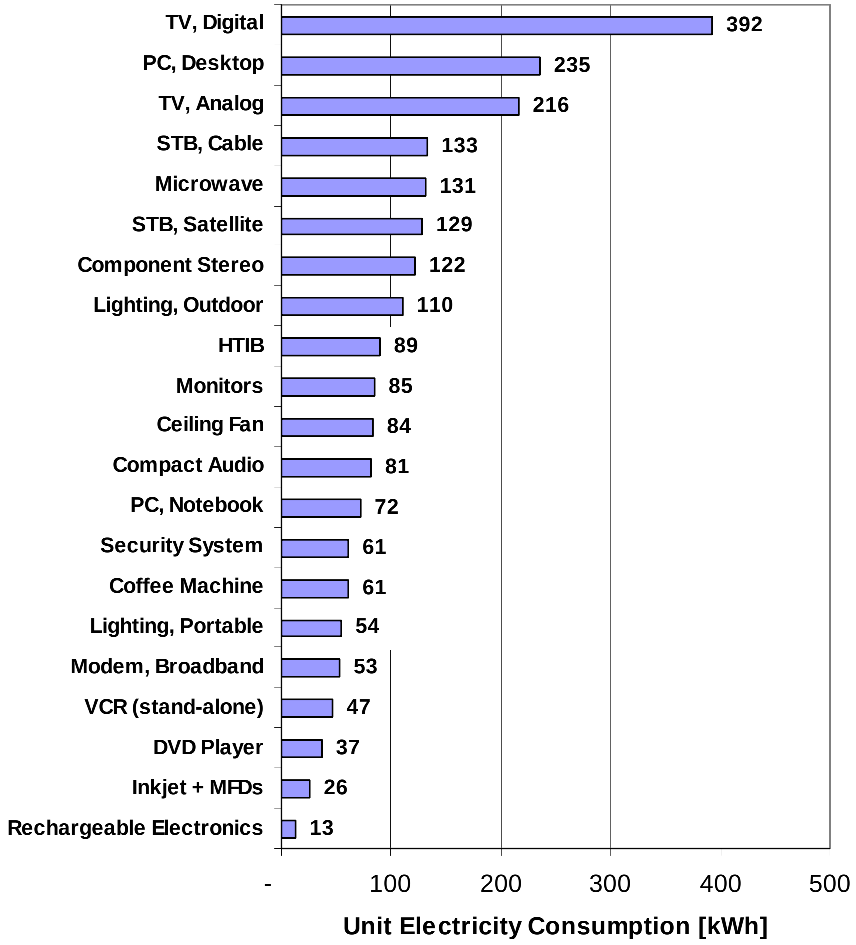

Figure 1-7: Unit Electricity Consumption (UEC) for the 21 Key Miscellaneous Electric Loads

Breaking down HEC by mode for the key and secondary MELs, active mode accounted for about 80 percent of average HEC, with idle, sleep, and off accounting for about 7 percent, 0.1 percent, and 13 percent of HEC, respectively. Different modes account, however, for varying portions of the overall UEC for different MELs. In general, active mode accounts for the largest portion of the MELs with the highest UEC, such as televisions, desktop PCs, while low-power modes account for a significant portion of the UEC of many consumer electronics besides televisions. The active mode accounts for almost all of the UEC of the secondary loads, both common and uncommon loads, with the exception of spa heaters and pumps[4].

In addition to characterizing the electricity consumption of the thirty MELs, we analyzed energy-saving opportunities for each. Energy-saving measures considered included: best-performing (from an energy perspective) products currently or recently available in the

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[4] Idle mode, i.e., heater operation to keep the spa warm and pump operation to filter the water when spas are not in use, accounts for most spa heater and pump UEC. As this is a key function for the device, we do not consider this a low-power mode.

U.S., enabling power management, and using power strips to turn off products. Although not comprehensive, these estimates do provide credible estimates for the general magnitude of energy reductions attainable today.

On average, currently available energy-saving measures can reduce the total electricity consumption of all of the MELs evaluated by approximately 50 percent. The range of energy savings varies greatly between key MELs (see Figure 1-8). For most MELs studied, an available product that drew appreciably less power in one or more modes yielded the greatest energy savings. We did not, however, compare the functionality and features of the products with the best energy performance with those of typical products to understand if the most efficient products were truly comparable with typical products.

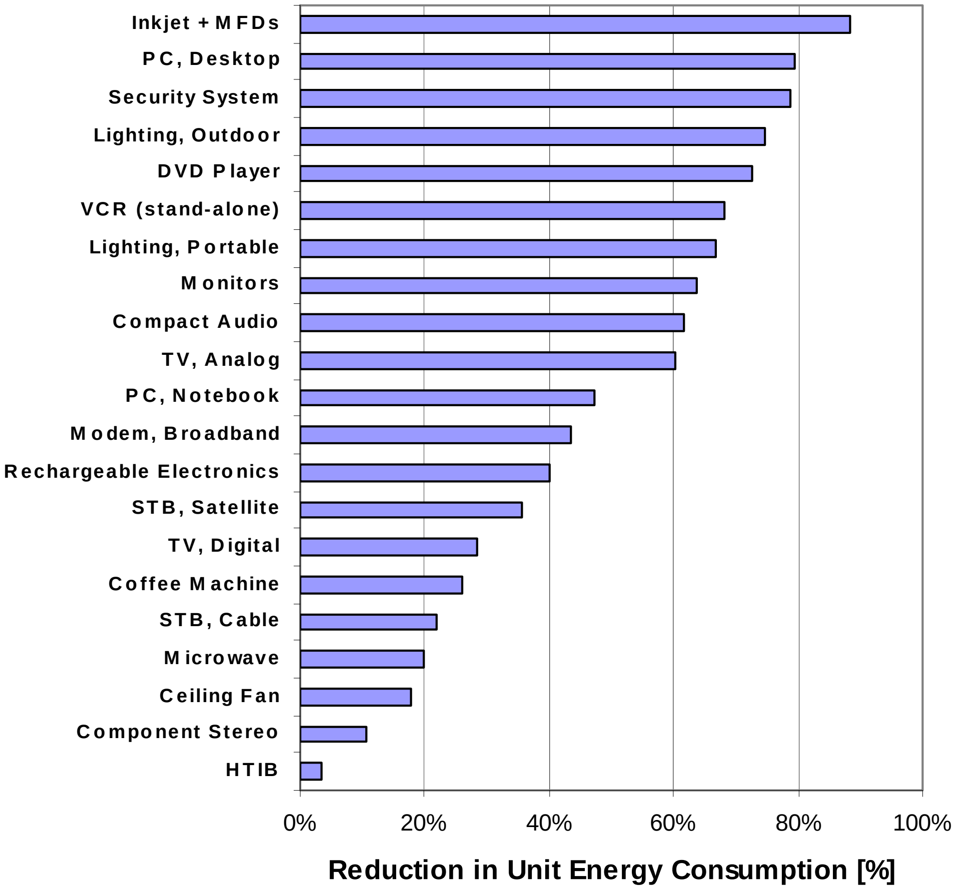

Figure 1-8: Estimated Energy Savings Potential for Key MELs from Available Measures

Recommendations

Based on the insights gained from this characterization of residential MELs, we have two recommendations for further study.

Regular Evaluation of Rapidly Evolving MELs: We recommend performing regular (e.g., every 3-4 years) evaluations of MEL energy consumption to understand how the evolution of MELs are affecting the feasibility of cost-effectively attaining DOE's ZEH goal[5]. This is necessitated by past and continuing rapid and dramatic changes in the residential installed base, usage, functionalities, characteristics, and underlying technologies (and, hence, their power draw by mode) of many MELs, most notably consumer electronics.

More Refined Evaluation and Characterization of MEL Energy-Saving Opportunities: Our initial characterization of energy-saving opportunities for residential MELs primarily focuses on energy savings attainable using existing products and found that, on average, this approach can yield reductions in total MEL HEC of about 50 percent. We recommend that DOE perform a study focused on a thorough characterization of residential MEL energy savings opportunities with an emphasis on a critical assessment of the likelihood that a large portion of real consumers would accept and effectively deploy different measures. Ultimately, this could yield a roadmap for credibly achieving major reductions in MELs that identifies the necessary technologies and policies to achieve those reductions.

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[5] TIAX is currently working on a scenario-based assessment of residential MELs circa 2020 for DOE/BT. Not coincidentally, 2020 is the year that DOE/BT has targeted for achieving large-scale deployment of mortgage-neutral (i.e., annual utility savings equal or exceed the annual incremental cost to finance the ZEH) net zero-energy homes.

2 INTRODUCTION

Miscellaneous electric loads, hereafter referred to as MELs, appear to account for an increasingly large portion of residential electricity consumption. A study of a wide range of MELs estimated that, in 1995, they accounted for about 25 percent of residential electricity consumption (Sanchez et al. 1998).

Several trends appear responsible for this increase, many related to the dramatic increases in connectivity and the performance and concurrent decreases in the cost of consumer electronics over this period. First, the installed base of residential MELs has increased. Most notably, the residential installed base of many consumer electronics (CE), which account for a majority of residential MEL annual electricity consumption (AEC), has dramatically increased since 1995. For example, the installed base of the CE MELs shown in Figure 2-1 has approximately doubled from1995 to 2006 (TIAX 2007).

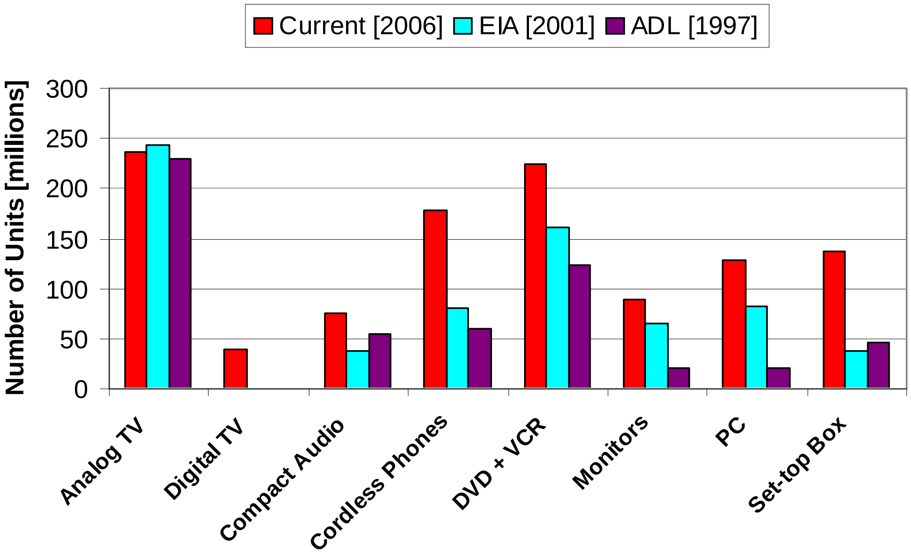

Figure 2-1: Estimates of Residential Installed Base for Selected CE Products (from TIAX 2007)

Second, the number of distinct MELs has grown, often driven by the increased use and penetration of information and communication technologies (ICT). Third, the average on-mode power draw of some more energy-intensive MELs, such as televisions and desktop PCs, has also increased. Finally, it appears that the *usage* of some more energy-intensive MELs has increased, i.e., again TVs and PCs (and monitors).

Moreover, the U.S. Department of Energy's Energy Information Administration (DOE/EIA) estimated that "other" electricity consumption, combined with televisions and office equipment, represented about 29 percent of U.S. residential AEC in 2006 and will grow to approximately 38 percent in 2030 (see Figure 2-2[6]). In fact, they predict that *non*-MEL electricity consumption per household will actually decrease by about 8 percent in 2030 even though floorspace per household is projected to increase by 13 percent (EIA 2006).

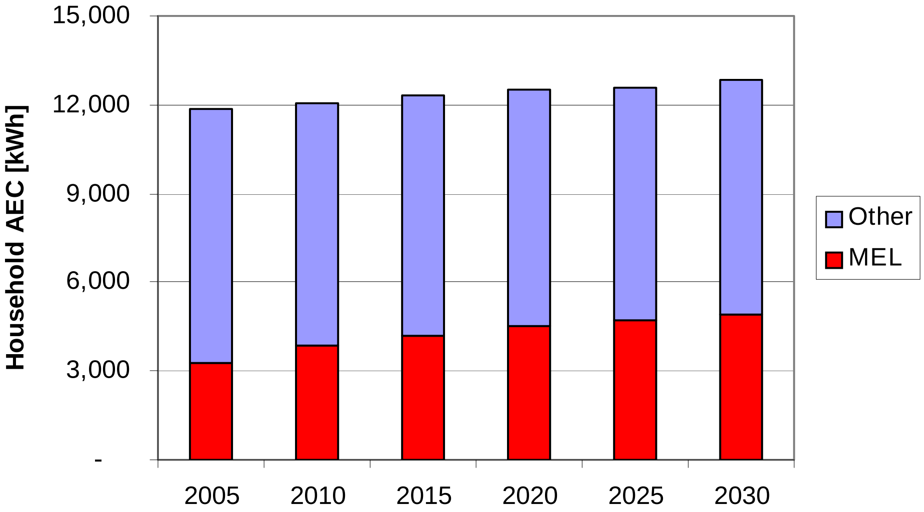

Figure 2-2: Projections of Per-Household Electricity Consumption to 2030 (EIA 2006)

In addition to its general interest in the level of MEL AEC, the Building Technology Program at DOE (DOE/BT) has a particularly interest in the per household electricity consumed by MELs. Specifically, DOE/BT has a goal of constructing cost-effective net zero-energy homes (ZEH) by the year 2020. To meet the ZEH objective, building researchers expect that the all-electric home designs will use highly efficient envelope and fenestration technologies to greatly reduce space heating and cooling loads, deploy high-efficiency building equipment to serve the reduced building loads, and use (at presently, more costly) solar energy[7] to power the efficient equipment (see, for example, Anderson et al. 2004).

Simulations of highly efficient home designs indicate that MELs may pose a major barrier to achieving the cost-effective ZEH goal. As the other building loads shrink, MELs represent an increasingly large portion of overall energy use and make it challenging to achieve large (e.g., 50 percent or more) reductions in home energy consumption. For example, if MELs account for 30% of total energy consumption in a new home built to code and their absolute energy consumption does not change, a home that realizes a 50

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[6] The definition of what products are considered as MELs vary from one study to another. For example, Sanchez et al. (1998) includes Furnace Fans, Torchiere Lamps, Clothes Washer and Dishwasher Motors, whereas EIA breaks out Furnace Fans, Clothes Washers, and Dishwashers separately and includes Torchiere Lamps under lighting. For Figure 2-2, MELs include the following categories from EIA (2006): "Other Uses," Color Televisions, and Personal Computers. Furnace Fans, Clothes Washers, and Dishwashers are considered separate end uses.

[7] Typically photovoltaic [PV] panels to meet electric loads and, potentially, solar thermal collectors to meet some portion of space and/or water heating loads.

percent reduction in total energy consumption requires more than a 70 percent decrease in all of the other loads. To site an actual example, one study estimated that MELs account for about 14 percent of energy consumed in a typical house in the Denver area. Consequently, a low-energy home in Loveland, Colorado that achieved a 54% reduction in total energy consumption had to reduce non-MEL energy consumption by 65%; MELs accounted for 32 percent of the high-efficiency home's energy consumption (Hendron and Eastment 2006).

Although several studies have analyzed one or more individual MELs (e.g., ADL 1998, Amann 2004, Calwell and Horowitz 2001, Ostendorp et al. 2005, Rosen and Meier 1999a, Rosen and Meier 1999b, Rosen et al. 2001, Sanchez et al. 1998; Hendron and Eastment [2006] summarizes findings from several of these – and other – studies), many of their finding studies are dated due to the rapid turnover and evolution of many MELs and reliance on highly uncertain estimates for usage by mode. This study leverages newer studies and information to develop an up-to-date characterization of residential MELs.

2.1 Study Approach

To support its strategic planning efforts, DOE/BT contracted TIAX to characterize residential MELs, analyze their unit, household, and annual electricity consumption in 2006, carry out an initial assessment of the energy-saving potential for MELs using best-available devices and practices. This study:

- Provides up-to-date information on U.S. residential MEL electricity consumption (for BT and EIA)
- Provides up-to-date information on per-household MEL energy consumption to accurately model potential ZEH designs
- Enables accurate assessment of the energy-saving potential of measures to reduce MELs, including initial assessments
- Informs appliance codes and standards activities and potential actions
- Helps to quantify the benefits of voluntary program activities, such as DOE/EPA's EnergyStar®

To realize these goals, TIAX and DOE/BT decided upon the following approach to the project:

1. Develop an extensive list of MELs for potential evaluation and select key and secondary MELs for evaluation
2. Characterize the key and secondary MELs
3. Analyze the unit, household, and national (U.S.) electricity consumption of key and secondary MELs and Discuss future trends and how they will impact MELs
4. Assess the energy savings potential for key MELs from existing products and technologies
5. Characterize secondary MELs and analyze their unit, household, and national (U.S.) electricity consumption and energy savings potential

6. Compose a Final Report to DOE/BT presenting the main findings and clearly explaining the methodology

This report describes the methodology, results, findings, and recommendations of the study.

2.2 Report Organization

This report has the following organization:

Section 3 summarizes the methodology used to assess the electricity consumed by residential MELs.

Section 4 presents the process used to select MELs for evaluation and the analyses and characterizations of the twenty-one key MELs selected for further evaluation.

Section 5 presents the characterizations of nine secondary MELs selected for further evaluation.

Section 6 presents the conclusions of this report and recommendations for further study.

Appendix A summarizes preliminary assessments of other MELs not selected for evaluation.

3 ENERGY CONSUMPTION CALCULATION METHODOLOGY

Figure 3-1 depicts the basic methodology used to develop the annual electricity consumption (AEC) estimates for the miscellaneous electric loads (MELs) evaluated.

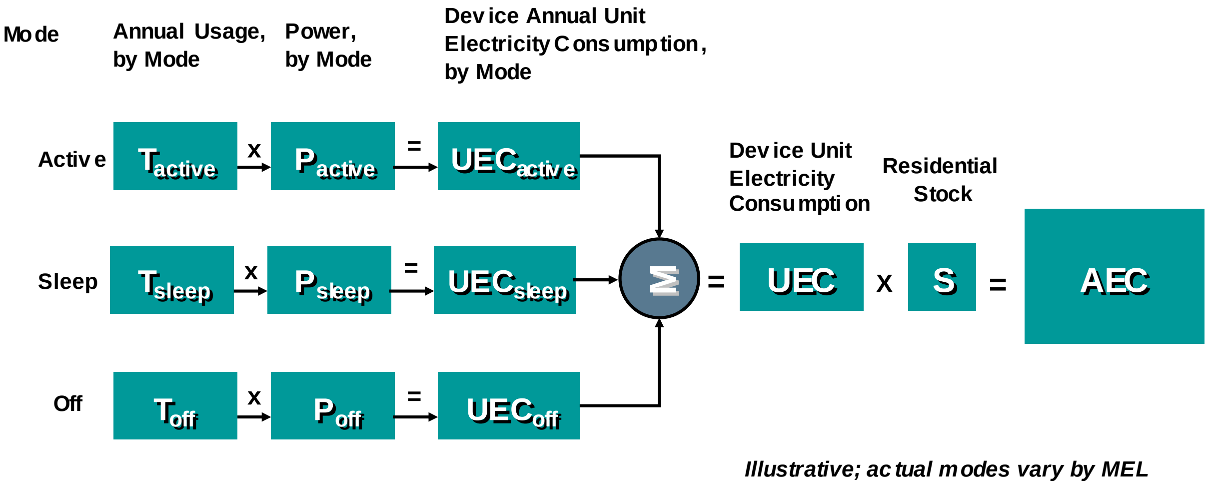

Figure 3-1: Annual Electricity Consumption Methodology

For each MEL, we calculated the average annual unit electricity consumption (UEC, in kWh) of a single device (e.g., a PC monitor) for an entire year. The UEC equals the sum of the products of the approximate number of hours that each device operates in a residential setting in each power mode relevant to that product and the power draw in each mode. The product of the estimated device stock (i.e., installed base) and the device UEC yields the total annual energy consumption (AEC, in TWh) for that equipment type. ADL (2002) describes the calculation methodology in greater detail. The household energy consumption (HEC; not shown in Figure 3-1), equals the product of the UEC and the typical number of units in a household, rounded to the nearest integer[8].

The following sections describe our approach to developing values for the different components of AEC calculations, while Sections 4 and 5 present the specific values used for each device type.

3.1.1 Residential Equipment Stock

Residential building equipment stock simply means the number of devices in use in residential buildings. Stock estimates primarily came from published estimates, such as industry market reports and the EIA Residential Energy Consumption Survey (RECS). Overall, residential stock estimates appear to have the smallest uncertainty of all three components of device AEC calculations.

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[8] For example, the typical household has two televisions (not 2.4 televisions) and one toaster (not 0.9 toasters). In several instances, we also present average HEC, which equals total MEL AEC divided by the number of households (115 million in 2006; EIA 2006).

3.1.2 Usage Patterns

A MEL's usage pattern refers to the number of hours per week that, on average, a device operates in a given mode. Most MELs analyzed in our study have at least two distinct operational modes, i.e., on and off, while many have more. Historically, developing accurate estimates for MEL usage has been very challenging due to the expense of collecting data for a statistically significant and representative sample of U.S. households. Furthermore, several MELs, such as consumer electronics (CE), evolve rapidly, in which case their usage profiles may change appreciably over a period of a few years.

In general, relatively few statistically significant and nationally representative *measurements* of residential MEL usage patterns exist. This study primarily uses usage estimates from prior consumer research studies and, in a limited number of cases, in-house monitoring of MEL usage, to assess annual usage by mode. Most notably, for consumer electronics, we have used usage profiles developed from recent phone surveys of 2,000 demographically-representative U.S. households about the usage, quantity, and characteristics of twelve CE products. TIAX (2006) and TIAX (2007) describe the surveys in more detail. Nonetheless, we expect that device usage patterns typically have the greatest uncertainty of any component of the AEC calculations for most MELs.

3.1.3 Power Draw by Mode

The AEC estimates incorporated power draw data for different MELS for each mode of operation. For each mode, the power draw value represents the best estimate for the average power draw of all of the different devices included in a single MEL. This estimate assumes that annual usage by mode does not vary appreciably with power draw by mode, e.g., that desktop PCs that draw 120W in active mode do not spend appreciably more hours in active mode per year than desktop PCs that draw 50W in active mode. A recent study investigated this effect for televisions, the device where we expected the most significant deviation from this assumption. On average, larger, more powerful TVs were used more, but energy consumption only increased by 5% when accounting for the power/usage correlation (see TIAX 2006). We did not, however, analyze this effect for most other MELs due to the dearth of meaningful data, the difficulty and expense of generating this data, and our perception that the magnitude of the error introduced by this simplification is likely on the order of or less than that of the magnitude of other uncertainties in usage patterns.

For all MELs evaluated, the power draw values for all modes reflect power draw measurements of devices instead of rated power draw values. Rated power draws represent the maximum power that the device's power supply can handle and often exceed typical active power draw values by at least a factor of three. Ideally, the power draw values would come from measurements of a statistically representative sample of products that reflect the installed base of equipment for the entire U.S., i.e., accounting for make, model, and vintage[9]. When this information was available for product categories, this

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[9] For example, the Australia Greenhouse Office has carried out invasive surveys of more than 100 Australian homes where they measured the power draw by mode of all plug loads in the homes (see Energy Efficient Strategies 2006). Assuming that the homes sampled were truly a representative sample of Australian homes, that sample could approach statistical significance.

strategy was employed, but this level of accuracy was not achieved for most MELs. The sources of power draw data for this study vary by product type, but in general, come from a wide range of measurements reported in prior analyses and limited, targeted measurements by TIAX. The MEL-specific sections explain the approach we took and present the data for each MEL. Overall, we concluded that the uncertainty in the average power draw by mode values is probably smaller than uncertainties in annual usage for many MELs.

4 KEY RESIDENTIAL MISCELLANEOUS ELECTRIC LOADS

A wide range of residential miscellaneous electric loads (MELs) exist in 2006. For example, our preliminary screening identified well in excess of 100 different loads, as have earlier studies (e.g., Sanchez et al. 1998, ADL 1998, Nordman and McMahon 2004, Hendron and Eastment 2006). Due to the scope limitations of this study, however, the project team could only model the energy consumption of a limited subset of equipment types. The main criteria for selecting the MELs for evaluation were:

1. Select loads with the greatest per-household energy consumption
2. Select loads with high penetrations, i.e., greater than half of all households
3. Select devices that the occupants choose and that are not installed by the builder – these cannot be controlled directly by construction specifications
4. In general, do not consider devices that fall under EPAct/EPCA (as part of the DOE Appliance Standards process, most have been well characterized)
5. In general, do not consider devices that are part of an existing major end use (they, too, have often been well characterized)

We also carried out less refined analyses for two types of loads: Secondary, Uncommon loads with high unit electricity consumption (UEC) values but low installed base (e.g., aquariums and portable spas) and Secondary, Common devices with moderate UEC values that, in most cases, appear to have a relatively small energy savings potential.

Table 4-1 lists the thirty MELs selected for evaluation.

Table 4-1: Miscellaneous Electric Loads Evaluated

Key Equipment Types (21)	Secondary, Common (5)	Secondary, Uncommon (4)
o Ceiling Fan o Coffee Machine o Compact Audio System o Component Stereo o DVD Player o Home Theatre in a Box o Inkjet Printers + MFDs o Lighting, Outdoor o Lighting, Portable o Microwave Oven o Modem, Broadband o Monitors o PC, Desktop o PC, Notebook o Rechargeable Electronics o Security System, home o Set-top Box, Cable o Set-top Box, Satellite o Television, Analog o Television, Digital o VCR (stand-alone)	o Hair Dryer o Iron o Toaster o Toaster Oven o Vacuum Cleaner	o Aquarium o Pool Pump o Portable Electric Spa o Waterbed Heater

It is important to note that the total annual energy consumption (AEC) figures reported in our study overlap with some traditional end uses. For example, our analysis included outdoor and task lighting, even though these are considered part of the lighting end use. Consequently, any use of this study's findings needs to keep in mind these potential overlaps with other studies to avoid double-counting of energy consumption.

Subsequently, the team analyzed the electricity consumption for each load in 2006. Section 4.1. presents the results for the 2006 analysis. Sections 4.2 through 4.16 show and explains the values used to model IT energy consumption for each of the key loads, while Section 5 presents the analyses for the secondary, common loads and the uncommon, high UEC loads.

4.1 Electricity Consumption in 2006

In 2006, the 30 residential miscellaneous electric loads (MELs) evaluated are estimated to consume about 297TWh, or 22 percent of residential electricity consumption and 8 percent of U.S. electricity consumption (based on EIA 2006; see Figure 4-1). Translated into primary energy, the residential MELs account for about 3.2 quads, or 3.2 percent of U.S. primary energy consumption in 2006[10] (based on EIA 2006).

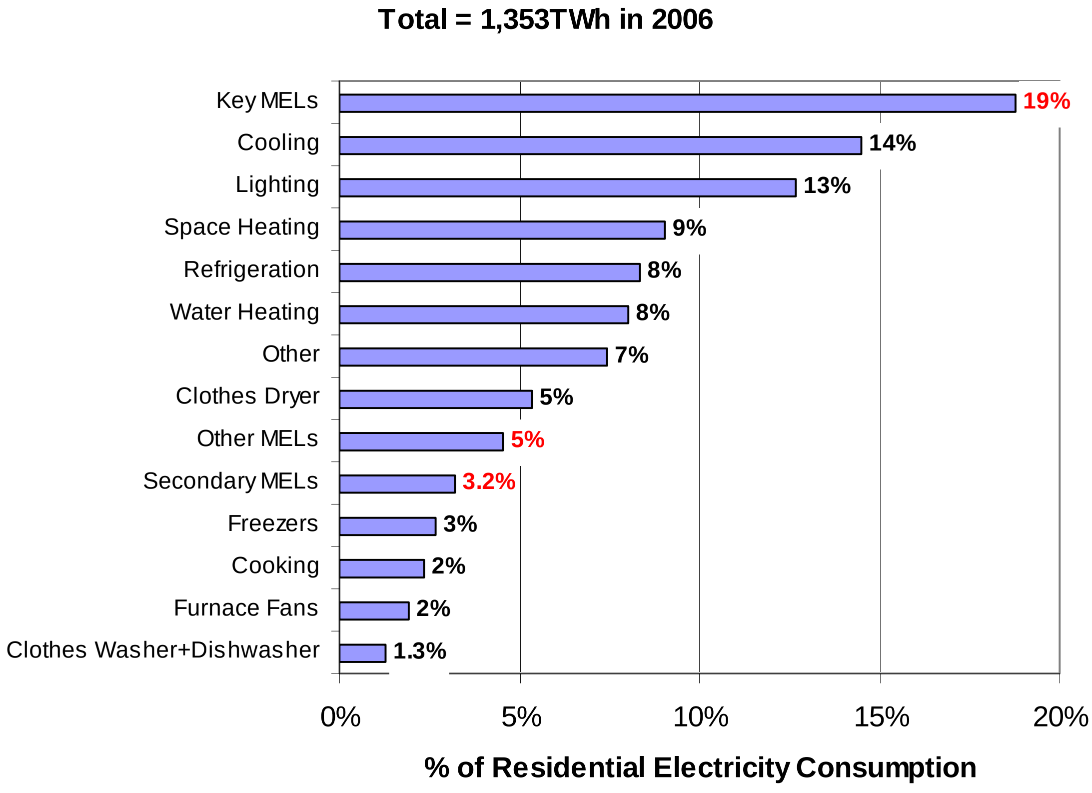

Figure 4-1: Residential Electricity Consumption in 2006 (Current Study, EIA 2006)

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[10] Assuming that each kWh of electricity requires the consumption of 10,831 Btus on average to generate, transmit, and distribute (EIA 2006).

Inclusion of very preliminary estimates for more than 50 other MELs (see Appendix A) increases the total portions of MEL residential electricity and primary energy consumption to about 27 and 18 percent, respectively.

Averaged over the estimated 115 million U.S. households in 2006, the miscellaneous electric loads evaluated consumed almost 2,600 kWh per household (EIA 2006). Together, televisions and set-top boxes (29%), outdoor and portable lighting (21%), and PCs and monitors (12%) accounted for more than half of the annual energy consumption (AEC) of the MELs evaluated (see Figure 4-2).

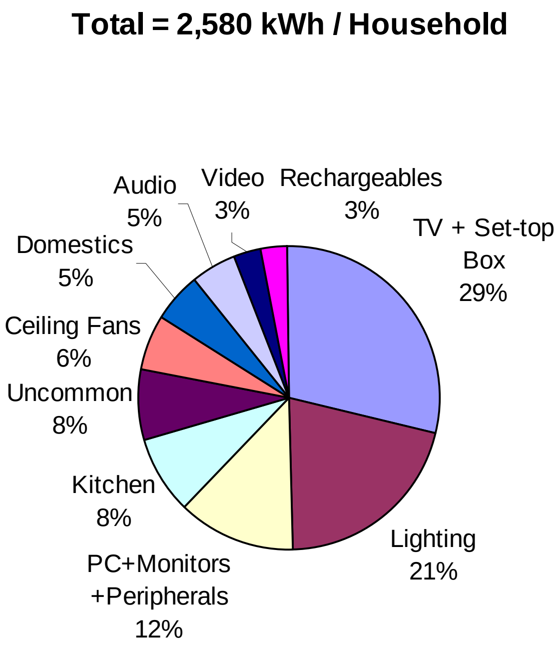

Figure 4-2: Breakdown of the AEC of Key and Secondary Miscellaneous Electric Loads Evaluated[11]

Table 4-2 summarizes the key energy consumption characteristics of the MELs.

Table 4-2: Energy Consumption by the Miscellaneous Electric Loads Evaluated

	Category / Device	Installed Base [millions]	UEC [kWh]	AEC [TWh]
Key	Ceiling Fan	212	84	17.9
	Coffee Machine	70	61	4.3
	Compact Audio	76	81	6.2
	Component Stereo	50	122	6.1
	DVD Player	120	37	4.4
	HTIB	25	89	2.2
	Inkjet + MFDs	101	26	2.6
	Lighting, Outdoor	258	110	28
	Lighting, Portable	592	54	33
	Microwave Oven	110	131	14.4
	Modem, Broadband	46	53	2.6

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[11] "Kitchen" includes: Coffee Machine, Microwave Oven, Toaster, and Toaster Oven; "Domestics" includes: Security System, Hair Dryer, Iron, and Vacuum Cleaner.

	Category / Device	Installed Base [millions]	UEC [kWh]	AEC [TWh]
	Monitors	90	85	7.7
	PC, Desktop	90	235	21
	PC, Notebook	39	72	2.8
	Rechargeable Electronics	590	13	7.9
	Security System	27	61	1.6
	STB, Cable	77	133	10
	STB, Satellite	70	129	9
	TV, Analog	237	216	51
	TV, Digital	38	392	16
	VCR (stand-alone)	105	47	5
	Total	**3,000**	**N/A**	**257**
Secondary	Hair Dryer	99	42	4.2
	Iron	106	53	5.6
	Toaster	104	39	4.1
	Toaster Oven	64	33	2.1
	Vacuum	113	42	4.7
	Total	**490**	**N/A**	**21**
Un-common	Aquarium	14.7	210	3.1
	Pool Pump	7	1,100	7.7
	Spa Heater and Pump	3.5	2,040	7.1
	Waterbed Heater	4.3	1,100	4.6
	Total	**30**	**N/A**	**23**

The following subsections of Section 4 present the characterization of the 15 miscellaneous electric loads evaluated in more detail, while Section 5 contains the analyses for the 11 other loads evaluated.

4.2 Home Audio Products

Table 4-3: Home Audio Summary Table

Characteristic	Compact Audio	Component Audio	HTIB	Portable Audio	Clock Radios	Comments
Installed Base [millions]	76	50	25	40	155	
Market Penetration [% of Households]	44%	40%	17%	30%	90%	
Unit Electricity Consumption [kWh/year]	81	122	89	17	15	
UEC – Best in Class [kWh/year]	31	103	86	9	9	
UEC Savings – Best in Class [kWh/year]	50	19	3	8	6	
Annual Electricity Consumption [TWh/year]	6.2	6.1	2.2	0.7	2.3	
Peak Demand Impact	Low					
Variability in Usage	High				Low	

Characteristic	Compact Audio	Component Audio	HTIB	Portable Audio	Clock Radios	Comments
Notable Regional or Seasonal Variations in Penetration or Use?	None known					
Typical Location(s) in Household	Living room, Bedroom			Multiple	Bedroom	
Potential Ways to Reduce UEC	Automatic shut off, improved active mode power management, continued replacement of older units with new EnergyStar units					
Significant Data Uncertainties	Idle usage					
Key Technology Trends	HTIB replacing component systems, smaller "micro" compact systems are available, tape players are becoming obsolete					

4.2.1 Introduction

The home audio category consists of compact stereo systems, component stereo systems, home theaters in a box (HTIB), portable stereos (boomboxes), and clock radios.

- *Compact stereos* (a.k.a. shelf systems, mini-systems, midi-systems) generally consist of a main center component with one or more audio media players (e.g., CD, tape, radio tuner) and two or more detached speakers. Figure 4-3 illustrates an example of a compact stereo, although there is a large range of sizes and shapes.

Figure 4-3: Compact Audio System Example (Source: JVC)

- *Component stereos* consist of separate stereo modules including CD players and speakers based around an audio receiver or amplifier (see Figure 4-4). When sold as a set, component stereos are known as "rack" audio systems. When connected with a television, the arrangement is called a home theater system.

Figure 4-4: Component Audio System Example (Receiver) (Source: Yamaha)

- *Home Theaters in a Box* (HTIB) are groups of devices that are all packaged together and generally include: an A/V receiver with or without an integrated DVD player, two or more speakers, a subwoofer, and an integrated radio tuner (see Figure 4-5). When connected with a television larger than 27 inches, the combined system is called a home theater system. A relatively new product category, HTIB have shown significant sales since the year 2000 (CEA 2005), and generally serve the same function as a component stereo system.

Figure 4-5: Example of a Home Theater in a Box (HTIB) System (Source: JVC)

- *Portable stereos* , also known as "boom boxes," can be powered by a cord or batteries. They often have a handle and attached side speakers (see Figure 4-6). Personal audio devices are not included in the portable stereo category.

Figure 4-6: Portable Stereo Example (Source: Panasonic)

- *Clock radios* are generally small "bed-side" units that provide clock, radio tuner, and alarm capabilities (see Figure 4-7).

Figure 4-7: Clock Radio Example (Source: RCA)

Table 4-4 summarizes the installed base and household penetration for each home audio product category.

Table 4-4: 2006 Home Audio Installed Base

Device	Installed Base [millions]	Penetration	Comments and Sources
Compact Audio	76	44%	• Average of survey data (TIAX 2007) • 1.5 units per unit home (TIAX 2007)
HTIB	25	17%	• CEA sales data (CEA 2006, CEA 2005) • Average of 1.3 units per unit-home
Component Audio	50	40%	• Rosen and Meier (1999) estimate of 74 million units adjusted to account for increasing HTIB popularity
Portable Stereo	40	30%	• Household penetration from Appliance Magazine (2005) • Units per unit home (1.2) from Rosen and Meier (1999)
Clock Radio	155	90%	• Penetration from appliance Magazine (2005) • Units per unit home (1.5) from Rosen and Meier (1999)

HTIB is a relatively new product category and is generally used for the same purpose as component stereos; home theater systems. The installed base estimate suggests that HTIB are displacing the installed base of component audio systems.

4.2.2 Unit and Household Energy Consumption

Unit Electricity Consumption

Home audio products can be simply characterized by four operating modes as follows:

- *Active* – Cassette tape, CD, or radio is being played or recorded; or TV sound is being played through the stereo
- *Idle* – The system is on, but no audio function is being performed
- *Off* – The power has been turned off, but the system remains plugged in
- *Disconnected* – Primarily relevant only for boomboxes, the system has been unplugged and draws no power from the grid (it may operate on battery power)

There is some variation in active and idle mode power draw depending on what the system is playing or ready to play. For example, the active power draw resulting from playing the radio or television sound through the stereo is generally less than that required to play a CD or tape (Rosen and Meier 1999). The power draw difference between playing a CD and playing the radio or TV sound is an average of 2 to 3 Watts (Nordman and McMahon 2004, Rosen and Meier 1999). On the other hand, because we do not know of data that accounts for the time spent in more specific sub-modes, and because the differences in power draw are rather small (on a percentage basis), we decided to use a single active mode and idle mode to characterize home audio products.

Tables 4-5 through 4-9 summarize the UEC calculations by mode for the five home audio categories.

Table 4-5: UEC for Compact Stereo Systems (CEA 2006)

	Active	Idle	Off	Total	Comments and Sources
Power [W]	23	16	7		• Active mode from CEA (2006) measurements • Idle mode 70% of active mode (CEA 2006) • Off mode from sales model (TIAX 2007)
Usage [hr/yr]	840	730	7,190	8,760	CEA (2006) survey data
UEC [kWh/yr]	19	12	50	81	
% of Total UEC	23%	15%	62%		

The power draw estimates are taken from TIAX (2007). The active mode power draw estimates come from measurements by the CEA of 51 compact audio systems while playing a CD (TIAX 2007). The systems were manufactured from 1991 through 2006, although 37 of the 51 were made in 2005 or 2006. In an attempt to have the power draw data approach the characteristics of the units actually sold and used in 2005 and 2006, the manufacturers that supplied equipment for measuring were identified as manufacturers with major market shares for that product. Furthermore, the equipment request specifically asked manufacturers to provide their better-selling products. Although the units measured were mostly of newer vintage, comparison with older product data (Rosen and Meier 1999) reveals that the average active mode power draw has not changed appreciably.

The CEA measurement data from TIAX (2007) reveals a wide range of active power draw among compact audio systems. This reflects, at least in part, the wide variety of functions and speaker capabilities (i.e., power). The measurement data indicate that there are two main compact audio groups based on active mode power; one centered in the 12 to 14 Watt range, and one in the 28 to 30 Watt range. It is not clear, however, whether or not these two power groupings in the measured sample have equal weighting and the U.S. installed base. Assuming that the sample is statistically representative of the installed base, the overall average active power draw is approximately 23 Watts[12].

The average idle mode is 70% of the average active mode. This comes from an average of measurements taken by Rosen and Meier (1999) and Nordman and McMahon (2004). There is notable uncertainty in this estimate, but more recent measurement data is needed for a confident estimate.

The off mode power draw of compact stereos has dropped significantly in the past decade, and installed base and sales data indicate that older units are still installed. TIAX (2007) developed a model to account for this trend using sales and EnergyStar market penetration data. Power draw estimates for older units come from measurements made by Rosen and Meier (1999), while estimates for newer products were calculated from measurements by

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[12] This value coincides with the 21 to 24 W range of values (for different play modes) estimated by Rosen and Meier (1999).

the CEA (TIAX 2007) and the EnergyStar product list (EPA 2007). The model estimates the overall installed base average off mode power draw to be 7 watts.

CEA survey data (TIAX 2007) affirm that compact audio systems are used an average of 2.3 hours per day, or 840 hours per year. Respondents estimated that 40% of the active usage results from playing television sound through a compact audio system.

Compact audio systems operate in idle mode for an average of two hours per day, or approximately 730 hours per year (TIAX 2007). There is likely significant uncertainty associated with this estimate since many participants likely have a difficult time accurately estimating idle time. Even if they do understand the terminology, which may cause some confusion, survey respondents simply may not be aware of when their devices are in idle mode. Nonetheless, the idle usage data comes from a more reliable source than prior estimates, which rely on anecdotal evidence (Rosen and Meier 1999).

Table 4-6: UEC for Component Stereo Systems

	Mode				
	Active	**Idle**	**Off**	**Total**	**Comments and Sources**
Power [W]	45	43	3		• Active mode is an average of CD/tape play (47 W) and line/tuner play (43 W) from Rosen and Meier (1999) • Idle and off modes from Rosen and Meier (1999)
Usage [hr/yr]	1580	730	6450	8760	TIAX (2007) survey data for HTIB
UEC [kWh/yr]	71	31	19	122	
% of Total UEC	58%	25%	16%		

The power requirements of component stereos are taken from Rosen and Meier (1999). We took the average of the "CD/tape play" power draw and the "line/tuner play" power draw because playing TV sound through the stereo accounts for approximately half of the active usage.

Component stereos were not included in the usage survey conducted for the TIAX (2007) report. We expect, however, that their usage is similar to that of HTIB because both are often used for similar purposes.

Table 4-7: UEC for HTIB (CEA 2006)

	Mode				Comments and Sources
	Active	Idle	Off	Total	
Power [W]	38	34	0.6		- Active and off modes from CEA measurements - Idle mode 4 W less than active mode (Rosen and Meier 1999)
Usage [hr/yr]	1,580	730	6,450	8,760	CEA (2006) survey data
UEC [kWh/yr]	60	25	4	89	
% of Total UEC	67%	28%	4%		

The active mode and off mode power draw estimates come from CEA measurement data for HTIB identified by major HTIB manufacturers as their best-selling units (see TIAX 2007). One system had two speakers and the rest had six, and nine of the 13 systems had an integral DVD player. None of the units measured had a separate external power supply to power the subwoofer. Approximately half of the systems had a known manufacturing date of 2005 or 2006, and we assumed that the others were of similar vintage since all systems were acquired new. The active mode measurements were taken when a CD was playing.

Rosen and Meier (1999) reported that the idle mode power draw for a "receiver based component stereo system", which includes a CD player component, was approximately 4 Watts less than the active mode power draw[13]. We used the same offset in power draw for HTIB since measurement data is not available.

As TIAX (2007) suggests, HTIB spend 4.3 hours per day in active mode, or 1,580 hours per year. Survey respondents estimated that 56% of the active usage results from playing television sound through an HTIB.

Table 4-8: UEC for Portable Stereo Systems

	Active	Idle	Off	Total	Comments and Sources
Power [W]	6	4.9	1.8		Rosen and Meier (1999)
Usage [hr/yr]	526	1,139	4,468	6,132	Estimated to be disconnected for 30% of time (Rosen and Meier 1999)
UEC [kWh/yr]	3.2	5.6	8	17	
% of Total UEC	19%	33%	47%		

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[13] We considered using a percentage increase, but the measurements in Rosen and Meier (1999) indicate that an offset more accurately models the power draw difference.

Table 4-9: UEC for Clock Radios

	Active	Idle	Off	Total	Comments and Sources
Power [W]	2	-	1.7		(Rosen and Meier 1999)
Usage [hr/yr]	88		8672	8760	(Rosen and Meier 1999)
UEC [kWh/yr]	0.2	-	15	15	
% of Total UEC	1%	-	99%		

The UEC estimates for portable stereos and clock radios were modeled from data reported in Rosen and Meier (1999).

Household Energy Consumption:
A typical household could be described as owning one component stereo system or HTIB, one compact audio system, and two clock radios. Given this scenario, and using a weighted average UEC for component audio and HTIB (111 kWh/yr), the estimated HEC is 220 kWh/yr. The average energy per household, calculated by dividing the total AEC of all the home audio equipment and dividing by 115 million households, is 152 kWh per year per household. Because there are many possible household home audio arrangements, it is not surprising that our median household estimate differs from the average calculation.

4.2.3 National Energy Consumption

Home audio equipment consumed around 18 TWh of electricity in 2006, with component and compact audio accounting for about 70% of the total (see Table 4-10).

Table 4-10: AEC for Home Audio Equipment

Home Audio Catagory	Installed Base [millions]	UEC [kWh/yr]	AEC [TWh]	% Total AEC
Compact Audio	76	81	6.2	35%
Component Audio	50	122	6.1	35%
Clock radio	155	15	2.3	13%
HTIB	25	89	2.2	13%
Portable Stereo	40	17	0.7	4%
Total			**18**	

4.2.4 Current Best in Class and Market Trends

The EnergyStar® audio/DVD product list (EPA 2007), ranks eligible home audio products based on off mode power draw. Table 4-11 summarizes the potential energy savings that result from using the lowest reported off mode power requirements from the EnergyStar® product list.

Table 4-11: Home Audio Potential Energy Savings from Best in Class Off Mode Products

Home Audio Category	Best in Class Off Mode Power [W]	Best in Class UEC [kWh/yr]	UEC Savings as a % of Total Original UEC	Best in Class AEC savings [TWh/yr]
Compact Audio	0.1	31	61%	3.8
Component Audio	0.1	103	15%	0.9
Clock radio	1.4	12	17%	0.4
HTIB	0.1	86	3%	0.0
Portable Stereo	0.1[a]	9	44%	0.3
Total				**5.5**

[a] Estimated to be the same as compact audio

The above best in class energy savings do not take credit for any active or idle mode savings. Component stereos and HTIB would benefit the most from more efficient active and idle mode power use, considering active and idle mode account for 84% and 96% of their energy consumption, respectively. However, since there are many different sizes, features, speaker capabilities, and quality levels; a low active power draw may be the result of lower device functionality. Therefore, it is difficult to quantify real potential energy savings from active and idle mode power requirement reductions. Nonetheless, significant relative energy savings potential exists for component stereos and HTIB from improved active and idle mode power management.

Using best in class off mode home audio systems, a typical household as described above (one component stereo or HTIB, one compact stereo, and two clock radios) would have a HEC approximately 150 kWh/yr. This represents an approximate 30% reduction from the original estimate of 220 kWh/yr.

As mentioned above, the average off mode power requirement of compact stereos has dropped significantly over the past seven years. This decrease reflects the sizeable portion of products that have met the EnergyStar® off mode power draw criteria (see Figure 4-8). The first EnergyStar® specification – 3W or less in off mode – came into existence in 1999 and was subsequently reduced to 1W or less in 2003 (EPA 2007 (2)).

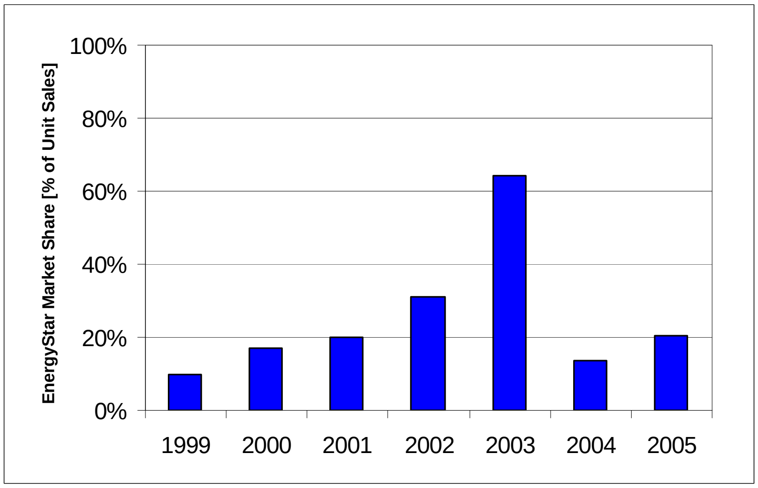

Figure 4-8: Market Penetration of EnergyStar® Compact Audio Systems (EPA 2006)

Many older compact stereos are still installed in households, and generally have higher off mode power requirements. As newer EnergyStar® products replace older vintage models, the overall installed base average off mode power draw will continue to drop and energy savings will be realized.

HTIB have gained popularity, and are replacing component stereos. This trend may yield energy savings since the average HTIB draws less power in each mode than the average component stereo system.

4.2.5 References

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4.3 Ceiling Fans

Table 4-12: Ceiling Fan Summary

Characteristic	Result	Comments
Installed Base [millions]	212	Projected from 2001 RECS
Market Penetration [% of Households]	66%	Based on 2.8 ceiling fans per household with at least one ceiling fan
Unit Electricity Consumption [kWh/year]	84	
UEC – Best in Class [kWh/year]	69	Based on EnergyStar specifications; some fans may have a similar UEC but move much more air (i.e., have a much higher efficacy)
UEC Savings – Best in Class [kWh/year]	15	
Annual Electricity Consumption [TWh/year]	17.9	Majority of energy is consumed in the southern regions of the country
Peak Demand Impact	Moderate	Higher load during evening (RLW 2002)
Variability in Usage	Moderate	Depending on the region of the country; varies from half to full day operation to only a few hours a day.
Notable Regional or Seasonal Variations in Penetration or Use?	High	Higher power draw, usage, and installed base in southern regions and during the cooling season.
Typical Location(s) in Household	Living areas of the home	
Potential Ways to Reduce UEC	• Aerodynamic blades • Brushless DC motor • Advanced controls • Air conditioning energy offset	
Significant Data Uncertainties	Ceiling fan speed setting usage, regional hours of use	
Key Technology Trends	Less efficient decorative fans	

4.3.1 Introduction

According to the 2001 RECS, there were a total of 192.8 million ceiling fans installed in 69.6 million households in the United States. Therefore, nearly two-thirds of households have a ceiling fan, averaging 2.8 ceiling fans per household with at least one ceiling fan (EIA 2001). This is an increase in the number of installed ceiling fans, with 155.6 million ceiling fans installed in 1997 in 61.7 million households, a 24 percent increase in the existing stock (EIA 1997). In 2001, annual sales of ceiling fans equaled about 16.5 million units (Davis Energy Group 2004). Despite a relatively high penetration into households nationwide, large regional and home vintage variations in the distribution of ceiling fans exist. Figure 4-9 presents the regional variation of ceiling fan penetration.

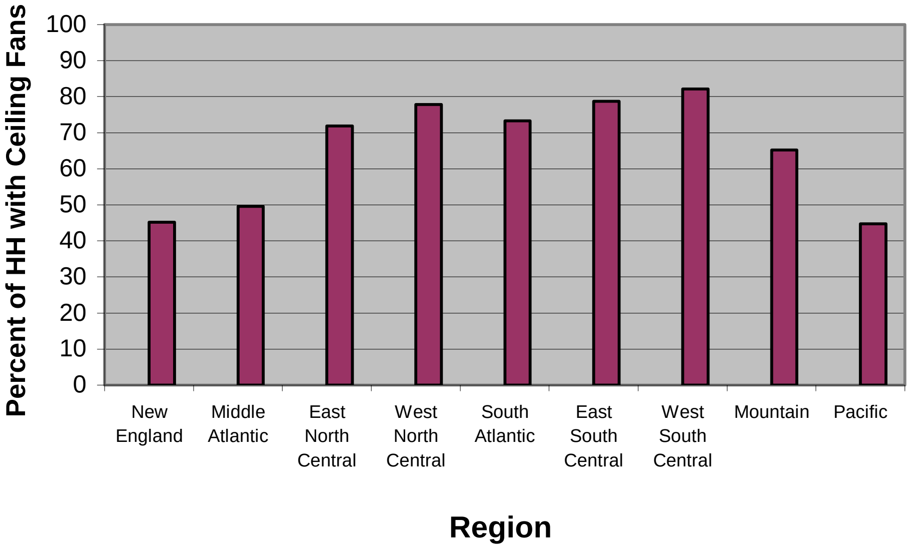

Figure 4-9: Percentage of Households with Ceiling Fans by Region (EIA 2001)

Not surprisingly, the warmer regions of the US have the highest penetration of ceiling fans in households. The regional trend also affects the average number of ceiling fans per household. A survey of 400 "recently" constructed homes in Florida indicated an average of 4.3 ceiling fans per household (James et al. 1996). A California study with access to a statewide database of 472 homes with ceiling fans indicated an average of 2.2 ceiling fans per household (RWL 2002).

In addition to the regional trend in ceiling fans, home vintage also has a strong correlation with penetration of ceiling fans (see Figure 4-10).

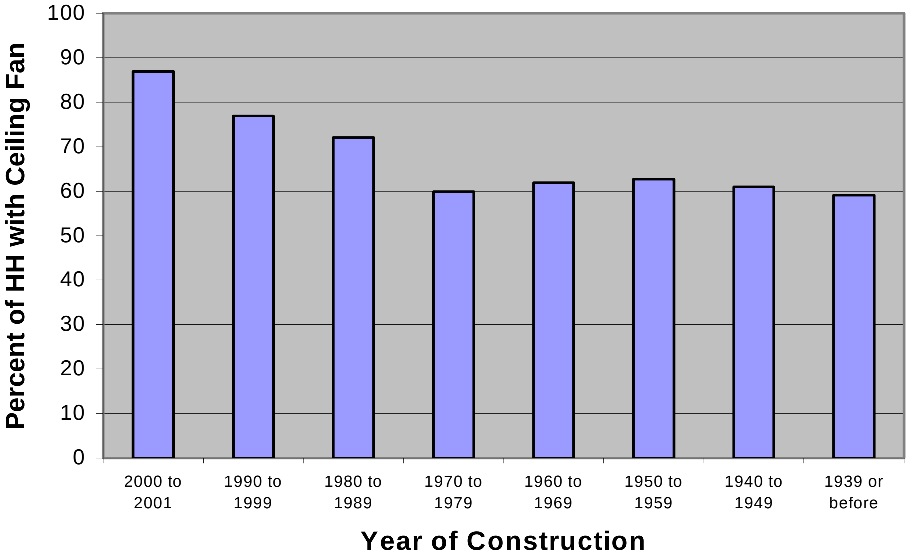

Figure 4-10: Percentage of Households with Ceiling Fans by Home Vintage (EIA 2001)

To estimate the current installed base, the regional and home vintage trends must be taken into account. In 2001, EIA estimated there was about 107 million households in the US, and projected about 115 million households in 2006 (EIA 2001). In order to approximate the number of ceiling fans, the average number of fans per household for homes built between 1999 and 2000 was calculated from the 2001 RECS data. Furthermore, to account for some regions of the US having significantly higher average number of fans per household, the average number of fans per household was calculated per region (see Figure 4-11).

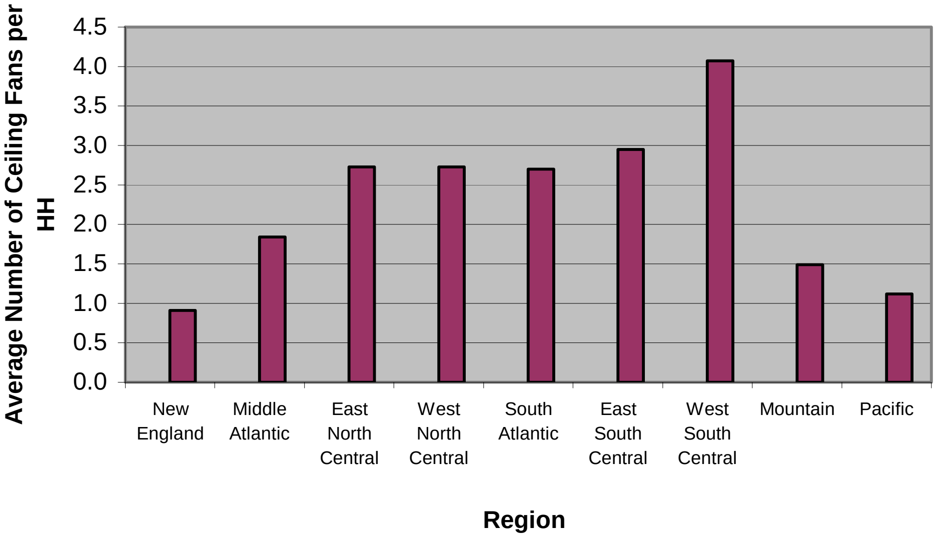

Figure 4-11: Average Number of Ceiling Fans per Household by Region for Homes Built Between 1990 and 2000 (EIA 2001)

Again, the distribution indicates warmer areas of the country have more ceiling fans per home on average, as expected. The average number of ceiling fans per household was then multiplied by the difference in the number of homes between 2001 and the projected values for 2006, by region. The sum over the different regions provides the total number of ceiling fans installed between 2001 and 2006. Adding to the 2001 total gives an estimate of 212 millions ceiling fans in 2006.

Ceiling fan modes relate to the fan speed. While there can be many different fan speeds, units tested for several different studies indicate there are typically three fan speeds: low, medium, and high (Parker 1999, RLW 2002, Davis Energy Group 2004). Additionally, EnergyStar® standards require testing at these three speeds. For the purposes of this study, ceiling fans will be considered to have three speeds, or modes, based on the characteristics of fans tested in the afore mentioned studies and the EnergyStar® standards.

Different modes, or fan speeds, are intended to create a greater flow of air. EnergyStar® standards specify an air flow for each setting; however, the particular design of a fan will cause the actual air flow of each speed to vary. Associated with each increase in air flow is an increase in blade speed, motor speed, and motor power draw.

4.3.2 Unit and Household Energy Consumption

As with the market penetration estimation of ceiling fans in the U.S., the regional trends must also be accounted for when considering the average power draw and typical usage patterns.

The amount of time each mode is used and the power draw of those modes determine the average power draw of a ceiling fan. A ceiling fan set at a higher speed draws more power than at a lower speed, and if a fan runs at a higher speed the majority of the time, its average power draw is greater than if it operated more frequently at a lower speed. While the average power draw for each mode is fairly straightforward, obtaining an approximation for a typical usage pattern of modes is more challenging due to regional trends. Data presented in the Introduction section indicate that ceiling fans are more common in warmer areas of the country. Warmer climates may also bias the operating speeds of ceiling fans installed in those climates towards higher fan speeds to provide residents with the desired level of comfort. Therefore, ceiling fans in warmer regions may have a higher average power draw.

Unfortunately, data are lacking for the distribution of ceiling fan speed usage by region. One California study conducted by the Sacramento Municipal Utility District and RLW Analytics investigated the relationship between ceiling fans and air conditioning usage, and provided the fan speed distribution for 81 ceiling fans monitored in 24 new homes in their service district. The results indicated the “high” speed was used 5 percent of the time, “medium” speed 51 percent of the time, and “low” speed 44 percent of the time (RLW 2002). Additionally, an EnergyStar® cost estimating worksheet for ceiling fans utilizes a 2004 LBNL breakdown of mode usage, with high, medium, and low speed usage percentages equal to 40 percent, 40 percent, and 20 percent of operational time, respectively (EnergyStar 2005).

While not nearly as limited as the data available for operation speed usage distributions, no rigorous studies were found that provide an average power draw by fan speed. Studies were limited in the number of fans tested, only stated the average power draw over all fan speeds, or provided incomplete information, such as only including fan efficacy. The table below summarizes fan power draw estimates from several studies (see Table 4-13). Average power draw values for different fan speeds are provided in the same table as usage-weighted overall power draw estimates.

Table 4-13: Overview of Various Estimate of Ceiling Fan Power Draw

"Low" Speed [W]	"Medium" Speed [W]	"High" Speed [W]	Overall Power [W]	Source	Notes
	30	70	35	EnergyStar (2001)	From comments of manufacturers
15	38	63		Schmidt (1999)	Tested eight "conventional" ceiling fans
			27	RLW (2002)	From a concurrent study by SMUD in Sacramento, CA
			38	RLW (2002)	Survey of 62 homes in CA
15	40	75		Chandra (1985)	For a "typical" ceiling fan
8.6		72.6		Parker (1999)	An average of three different ceiling fan models
22	48	95		Gossamer (2006)	For a "typical" ceiling fan
			35	Davis (2002)	Interpolated from RECS and Calwell & Horwitz
15.2	34.8	72.5		EnergyStar (2005)	Cites LBNL (2004)
12.5	30	80		Home Energy (2001)	Taken as the average of an approximated range of values
18	35	70		Calwell and Horowitz (2004)	Approximated values from a table of fan speeds and power for several Hunter and Hampton Bay ceiling fans.
15	**35**	**75**	**35**	**Values Used in This Study**	

While none of these studies may provide a thorough estimation of ceiling fan power draw at various fan speeds, the combination of all the studies may provide a large enough sampling to estimate power draw. Fortunately, the range over which they vary is relatively small. To obtain average power draw, the average is taken for each mode, which approximately equals 15 W for "low" speed, 35 W for "medium" speed, and 75 W for "high" speed. These values are assumed for the purpose of this study.

As a check on these averages, the two estimates for mode usage previously discussed can be used to compare with overall averages. First, the RLW and SMUD study stated for the given fan speed usage profile of its customers; the average power draw is reported as 27 W (RLW 2002). Weighting the average power draw for low, medium, and high calculated above with the usage profile provided by RLW and SMUD, the overall average power equals 28.2 W, which seems to correlate well with the overall average provided in the report. Additionally, the EnergyStar® usage profile can be used to compare the assumed power draws by fan speed to the overall power draws listed in the table above. The average of the four overall power draws listed in Table 4-13 is about 35 W. Using the EnergyStar usage profile and the assumed power draw by mode, the overall power draw is calculated to be 35 W, matching the average of other reported overall power draws.

Nonetheless, the lack of regional data on mode usage prevents the use of power draw to account for the regional usage trends. Given the difficulty in making a reasonable estimate at these characteristics, regional trends in mode usage can not and will not be taken into account. Using the non-regional EnergyStar® usage profile in conjunction with the assumed power draws by mode yields a single, average power draw of 35 W that is assumed to apply to all regions.

As with projecting the installed base and estimating the average power draw, regional trends affect the number of hours ceiling fans are typically in operation. Many of the same sources cited for power draw also provide information regarding overall usage and highlight the differences in ceiling fan operation across the country.

A Florida survey of 400 homes indicated that fans are in use 13.7 hours per day (weighted average of weekend and weekday use). The study also showed that about one third of ceiling fans were left on 24 hours a day (James et al. 1996). The California survey from RLW Analytics also provided statewide data on ceiling fan operation. From their monitoring of 62 homes, the average ceiling fan was used about 2.5 hours per day, about 80% less than the usage time in Florida. Further highlighting the regional differences in ceiling fan use, a concurrent study to the RLW's statewide study was a survey of 25 homes in and around Sacramento, California indicated an average fan use of 8.3 hours per day, 5.8 hours more than the California average (RLW 2002). The report notes the difference between the statewide survey and the Sacramento utility survey may reflect the significantly higher temperatures in the Sacramento area compared to the statewide average. Furthermore, the study was also conducted between August and September, a period of presumably higher ceiling fan usage, and not year round as the statewide study.

The Florida and California studies provide reliable data for ceiling fan operation, but emphasize the need to make regional adjustments. The EnergyStar® cost estimating worksheet utilizes a regional usage values for ceiling fans, citing an LBNL source. The table below provides the break down by region for the average number of operation for ceiling fans over the course of a year.

Table 4-14: Average Ceiling Fan Hours of Use by Region

New England	Middle Atlantic	South Atlantic	East North Central	East South Central	West North Central	West South Central	Mountain	Pacific
[hrs/day]	[hrs/day]	[hrs/day]	[hrs/day]	[hrs/day]	[hrs/day]	[hrs/day]	[hrs/day]	[hrs/day]
1.6	3.2	9.6	2.8	8.0	4.0	8.8	5.6	2.8

The numbers are based on the number of days where average temperatures are warm enough to use a ceiling fan[15]. While these values are not derived from residential surveys, they do correlate well with the two surveys described above. The South Atlantic has the highest number of operational hours per day, and the Pacific region is relatively close to the California survey's estimation. Therefore, the UEC calculations use these operational hour values.

In order to compute the overall UEC, the UEC is calculated separately for for each region based on the power draw and usage described above. Subsequently, the regional UECs

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[15] A quick review by TIAX suggests that the percentage of days where the average daily temperature exceeds 70°F is a reasonable proxy for the percentage of annual operating hours.

are weighted by the percentage of ceiling fans in each area and summed over the entire U.S. to provide an overall value. Table 4-15 summarizes the UEC and AEC values for ceiling fans.

Table 4-15: Ceiling Fan UEC Calculation

Region	Installed	% of Total	Power	Usage	UEC by Region	Weighted UEC	AEC
	[millions]	[%]	[W]	[hrs/year]	[kWh/yr]	[kWh/yr]	[TWh/yr]
New England	5.3	2.5	35.0	584	20	1	0.1
Middle Atlantic	17.4	8.2	35.0	1168	41	3	0.7
South Atlantic	38.3	18.0	35.0	3504	123	22	4.7
East North Central	17.1	8.1	35.0	1022	36	3	0.6
East South Central	49.9	23.5	35.0	2920	102	24	5.1
West North Central	18.7	8.8	35.0	1460	51	5	1.0
West South Central	38.2	18.0	35.0	3212	112	20	4.3
Mountain	11.6	5.5	35.0	2044	72	4	0.8
Pacific	15.8	7.4	35.0	1022	36	3	0.6
Total	**212**					**84**	**18**

This table clearly shows that ceiling fans have significantly higher UEC values in the southern portions of the U.S. and that these regions account for the bulk (>75%) of ceiling fan AEC. Presently, a significant portion of new construction occurs in these regions and newer homes and these regions have, on average, higher numbers of ceiling fans installed. Taken together, this suggests that ceiling fan AEC will continue to grow, barring a trend (e.g., aesthetic) away from ceiling fans.

4.3.3 Current Best in Class and Market Trends

One current trend in ceiling fans is toward ornamental fans designed for their aesthetic appeal and not for efficiency (EnergyStar 2004). Indeed, the two fans with the lowest efficacy of the 26 tested in one report were described as ornamental (Davis Energy Group 2002). This trend does not, however, necessarily translate directly into increased average power draw per fan. Power draw per speed setting could remain the same, but reduced efficacy may mean a reduced air flow. If an ornamental ceiling fan is not used for increasing comfort, owners may not compensate for lower air flow volumes by increasing fan speed.

EnergyStar® does have a voluntary program for ceiling fans based on air flow and efficacy using measurement at three different speeds. The air flow and efficacy levels translate into a power draw of 8W at “low”, 30W at “medium”, and 67W at “high” (EnergyStar 2006), a 5W to 8W savings over what was estimated at the same fan speeds[16]. If the EnergyStar® minimum performance levels were used for the average power draw, the estimated UEC would be 69 kWh, or about 15 kWh in savings. As of July 2007, there were several hundred ceiling fans that meet the EnergyStar® performance levels

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[16] The power draw values for EnergyStar® products are for specific air flows, and that the typical ceiling fan considered here may not have the same air flow at a specific fan speed.

(EnergyStar 2007). Additionally, there are several states that have programs (such as rebate programs) to encourage buying EnergyStar-compliant ceiling fans (EnergyStar 2004). Furthermore, while some states, e.g., California, have moved forward with regulations for ceiling fans, EPAct 2005 pre-empted state-level standards for ceiling fan motors and gave DOE the authority to regulate ceiling fan energy consumption. However, no timeframe has been set for establishing a standard level.

Beyond the EnergyStar® program, research has been conducted to design more efficient ceiling fans. In particular, two different designs both improve on current industry standards and EnergyStar® efficacies. First, the Florida Solar Energy Center and AeroVironment, Inc. designed a ceiling fan that uses aerodynamic blades to reduce the motor power required to produce a given volume of air flow, decreasing energy consumption by about 40% (DOE 2005). Additionally, it incorporates energy-saving advanced controls, i.e., a motion detector to turn off the fan when no one is in the room and a built-in thermostat to turn on the fan only when needed (Parker et al. 1999, Gossamer 2006). The second research ceiling fan is from Australia, where a more efficient brushless DC motor is utilized along with more aerodynamic fan blades. The power draw of the high efficiency fan is reported as 4.7 W, 16 W, 32 W, at “low”, “medium”, and “high” fan speeds, respectively (Schmidt 1999).

In addition to potential energy savings through the installation of new, higher efficiency ceiling fans, many advocate the use of ceiling fans to offset the use of more energy intensive air conditioning (Calwell and Horowitz 2004, Chandra 1985, Home Energy 2001, CEC 2006). By creating an air flow, it is proposed that residents can be comfortable at a higher thermostat setting, thus reducing air conditioner energy consumption. In a Florida study, simulations showed that using ceiling fans in conjunction with a 2°F increase in the thermostat setting could save about 14% on cooling energy in Florida. However, if the temperature setting is not increased enough, the energy saved from the air conditioner energy is not enough to offset the energy required to run the fans, resulting in negative savings at or below about a 0.5°F increase in thermostat setting. Additionally, the study also completed a survey of homeowners that found that few residents actually turned up the thermostat set point, leaving no opportunity for savings (Park et al. 1996). Finally, the California study conducted by SMUD and RLW Analytics focused on determining the relationship between air conditioning and ceiling fan use, and the thermostat set point. The study concluded that people would set the thermostat higher when operating both fans and air conditioning, but only up to a point. The study was inconclusive as to whether or not the higher set point would actually save any energy (RLW 2002).

4.3.4 References

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4.4 Coffee Makers

Table 4-16: Coffee Makers Summary

Characteristic	Result	Comments
Installed Base [millions]	70	
Market Penetration [% of Households]	61%	
Unit Electricity Consumption [kWh/year]	61	
UEC – Best in Class [kWh/year]	45	Using thermos-based carafe to eliminate power draw in warming mode
UEC Savings – Best in Class [kWh/year]	16	
Annual Electricity Consumption [TWh/year]	4.3	
Peak Demand Impact	Low	Coffee makers are most commonly operated in the morning
Variability in Usage	Moderate	
Notable Regional or Seasonal Variations in Penetration or Use?	None found	Significant variations in coffee consumption between cities known
Typical Location(s) in Household	Kitchen	
Potential Ways to Reduce UEC	Use of thermos-style carafe instead of a glass carafe to decrease power draw in warming ("idle") mode; auto off feature based on time after brewing	
Significant Data Uncertainties	Idle usage (while warming) Number of electric percolating coffee makers	
Key Technology Trends	None	

4.4.1 Introduction

According to the most recent Residential Energy Consumption Survey (RECS) in 2001, 65 million households in the U.S. owned (and used) coffee machines (EIA 2001). This is an effective installed base estimate because the survey only counts coffee machines that are plugged in and used. Projecting this estimate based on household growth yields approximately 70 million coffee machines in 2006 based on 115 million households.

Table 4-17: 2006 Automatic Drip Coffee Maker Installed Base

Installed Base [millions]	Penetration	Comments and Sources
70	61%	Extrapolated from RECS detailed data (EIA 2001)

Appliance magazine lists the penetration of percolating coffee machines in households at 21%. These coffee makers can be electric, but it is assumed that the majority of the installed base are stovetop or camping type percolators. The same source also estimates that as much as 18% of U.S. households have an espresso machine. Annual unit sales of approximately 1 million per year are approximately 1/20th of conventional automatic drip coffee makers (Appliance 2005). Consequently, we concluded that espresso machines have a much lower installed base in U.S. residences than conventional coffee makers, leading us to exclude espresso machines from our analysis.

4.4.2 Unit and Household Energy Consumption

Estimates from various sources put the active, or brewing, power draw of automatic coffee machines between 860 W and 1,500 W (ADL 1998). The most common estimate of 1,100

W was chosen by ADL (1998) as the average active mode power draw. The same selection process was used by ADL (1998) to pinpoint the idle, or warming, power at 70 W.

Many modern coffee machines have a digital clock display that can be used to schedule automatic start times. These machines will have an off mode power draw, but there is little information about how many machine have display features or how much power they require. The average of measurements from two devices yields an off mode power draw of 0.4 W (Nordman and McMahon 2004). There is significant uncertainty in this estimate due to the very limited sample size. However, the energy consumption of coffee makers is dominated by the active and idle modes, and therefore uncertainty in the off mode power draw estimate has little effect on final energy consumption calculations.

Coffee makers are characterized by the following three operating modes:

- *Active* – Coffee maker is in the brewing process
- *Idle* – Device is warming coffee that has already been brewed
- *Off* – The power has been switch off, but the system remains plugged in

Active usage was calculated based on the estimated coffee volume drunk in 2005, and the average brewing rate of coffee machines. Survey data from the National Coffee Association (NCA) show that approximately 290 million cups of coffee were drunk by people 18 years and older in the U.S. in 2005. The average cup of coffee is 9 ounces (Nelson 2001), and the typical coffee machine can brew 48 ounces of coffee in 8 minutes. Based on the estimated installed base, the average coffee machine is in active mode for 6.3 minutes per day or 38 hours per year. The estimated idle usage is taken from detailed RECS data to be approximately 38 minutes per day, or 230 hours per year (EIA 2001)

Given these power and usage estimates, the unit electricity consumption (UEC) for automatic drip coffee machines was estimated to be 61 kWh/yr (see Table 4-18).

Table 4-18: Unit Electricity Consumption of Coffee Makers

	Usage Mode				
	Active	**Idle**	**Off**	**Total**	**Comments and Sources**
Power [W]	1,100	70	0.4		• Active mode from ADL (1998), manufacturer's data • Idle mode power draw from Nordman and McMahon (2004), ADL (1998)
Usage [hr/yr]	38	229	8,493	8,760	• Active usage from NCA (2005) • Idle usage from detailed RECS (EIA 2001)
UEC [kWh/yr]	42	16	3	61	

As the typical household would have one coffee maker, the UEC equals the household energy consumption.

4.4.3 National Energy Consumption

Based on the unit electricity consumption and installed base estimates for 2005, the AEC for automatic drip coffee machines is approximately 4.3 TWh (see Table 4-19).

Table 4-19: AEC Summary for Coffee Makers

UEC [kWh/yr]	Installed Base [millions]	AEC [TWh]
61	70	4.3

4.4.4 Current Best in Class and Market Trends

Coffee consumption in the U.S. is at an all time high, including coffee consumed at home (Food & Drink Weekly 2004). This fact fuels the steady growth of automatic drip coffee machine installations as well as the active and idle usage.

The majority of the power draw comes from heating elements in coffee machines. Little can be done in terms of technology development to replace the simplicity of the electric resistance heater. The use of a less powerful heater would result in lower brewing temperatures and poorer quality coffee. Therefore, little reduction is expected in power draw.

Energy consumption during idle (warming) mode also offers potential for savings. As noted by Siderius (2007), using a thermos-style carafe[17] instead of a conventional carafe would appreciably reduce or, potentially, the heat required to keep the coffee hot. Consequently, use of such carafes could reduce the UEC of coffee machines by up to 26 percent. In addition, some machines are equipped with an automatic shutoff function which prevents machine from being accidentally left on, but it is unclear how much savings this feature might generate. Off mode energy consumption only accounts for a couple percent of the total. If coffee machines with digital displays become ubiquitous, the off mode energy consumption would still likely not exceed 10% of the total energy use.

4.4.5 References

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4.5 Personal Computers (PCs)

Table 4-20: Personal Computers Summary

Characteristic	Desktop	Notebook	Comments
Installed Base [millions]	85	36	Estimated 7:3 desktop : notebook ratio
Market Penetration [% of Households]	64%	25%	7:3 ratio of desktop to notebook PCs based on sales figures[18] (Krazit 2004)
Unit Electricity Consumption [kWh/year]	235	72	
UEC – Best in Class [kWh/year]	48	35	
UEC Savings – Best in Class [kWh/year]	187	37	
Annual Electricity Consumption [TWh/year]	21	2.8	
Peak Demand Impact	Low	Low	Residential devices tend to not be used as much during the day
Variability in Usage	High	High	
Notable Regional or Seasonal Variations in Penetration or Use?	No	No	Unknown
Typical Location(s) in Household	Not clear		Expected to be study room/bedroom/living room, generally in close proximity phone/cable jack.
Potential Ways to Reduce UEC	*Existing*: • Turn off PC when not in use • Enable Power Management *Potential*: • Use more efficient power supplies • Processors with embedded power management used in desktops • More powerful processors could share/take over computational load of graphics card		
Significant Data Uncertainties	Highly variable usage pattern with each household		
Key Technology Trends	Notebooks becoming on par to desktops in terms of processing power and cost and likely to become the dominant PC form factor as demand for wireless and mobility grows		

4.5.1 Introduction

At present, most residential IT devices and their usage patterns revolve around PCs. Being relatively affordable, high in processing power, and the primary means to interface with

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[18] Data from RECS (2001) and ADL (2002) indicate that notebook computers had similar shares of both the residential installed base (~20%) and the overall PC market (~17%).

the Internet, PCs currently cater to a much wider array of applications than traditional word processing, such as digital picture/video editing, graphics-intensive gaming, web-browsing, and other online activities. The importance of PCs as tools to access and manage digital information has made them one of the largest residential IT energy consumers. To a large degree, this reflects their intensive usage, which appears to have grown as the penetration of broadband access enabling perpetual connectivity has increased.

PCs come in two main form factors, desktop and notebook (also known as laptop). Both have similar basic hardware (motherboard, processor, hard drive, graphics card and power supply) and run similar operating systems. Notebooks, including their LCD screens, consume significantly less power than desktops due their needs for long battery life when not plugged in. Notebooks tend to cost more and have less processing power than desktops due to their smaller size, but this gap has shrunk. The market share of notebooks has increased over time, as their price has decreased while their performance, battery life, and screen size have all increased. As a result, a major IT market research firm projects that notebooks may have outsold desktops in the residential sector in 2005[19] and predict that notebooks will outsell desktops in 2007 (Kanellos 2006[20]). Due to the three- to four-year average product lifetime of desktop and notebook PCs (Appliance 2005, September, ADL 2002), it will take a few more years for the installed base of notebooks to equal that of desktops.

According to a survey conducted in the fourth quarter of 2005 found a penetration of 71% (Parks Associates 2006). Assuming that the number of PCs per household with at least one PC did not change appreciably from the TIAX Survey value of 1.6 in 2005 (TIAX 2006), U.S. homes have a total of 129 million PCs in use. As Figure 4-12 indicates, single PC households are most common.

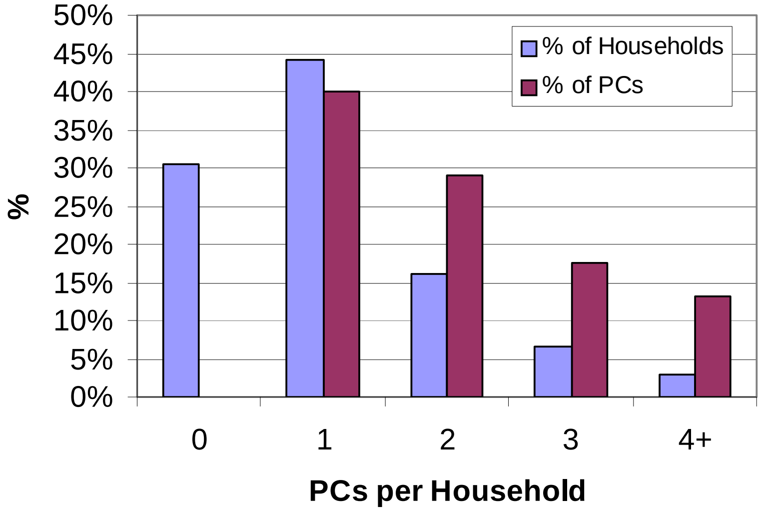

Figure 4-12: Distribution of Residential PCs (TIAX 2006)

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[19] Notebooks had higher retail unit sales than desktops in 2005 (51% to 49%), but this does not include residential sales through other outlets (Kanellos 2006, quoting IDC data).

[20] Quoting research carried out by IDC.

Approximately 70% of home PCs are desktop PCs, with laptop/notebook devices accounting for 30% (TIAX 2007). Consequently, the current analysis assumes that the median household has one desktop PC and no notebook PCs.

Table 4-21: PC Installed Base

PC	Installed Base [millions]	Penetration [%]	Comments and Sources
Desktop	90	64	• Average number of PCs per household that has one or more PC increased from 1.4 (EIA 2001) to 1.6 (TIAX Survey) • 7:3 ratio of desktop to notebook PCs based on recent sales figures[21] (Krazit 2004) • TIAX (2007) explains the penetration estimates
Notebook	39	25	

4.5.2 Unit and Household Energy Consumption

PCs share the same basic hardware, but are relatively easy to customize, in particular desktops where major hardware components such as additional hard drives, CD-ROM/DVD drivers/burners, better performing graphics cards and sound cards can be added/replaced via ISA, PCI and USB bus interfaces. It is harder to replace existing hardware internal to notebooks; however, additional hardware interfacing with USB or PCMCIA can be easily added. In general, these aforementioned hardware additions (with the exception of graphics card) do not significantly affect the overall energy consumption of PCs. This report does not directly take in account the potential range of hardware variability among PCs and their effects on power draw outside of the basic PC hardware makeup, i.e., motherboard, processor, one hard drive, external memory drives (e.g. CD-ROM/ floppy disk drive), basic graphics card and power supply.

Table 4-22 summarizes the average power draw, usage, and unit electricity consumption by mode for desktop and notebook PCs. The active mode power draw values used are more typical for what the EnergyStar® 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 PCs (e.g., Herb et al. 2006).

Table 4-22: PC Power Draw by Mode

		Active	Sleep	Off	Comments and Sources
Desktop	**Power [W]**	75	4	2	• Power draw values from EPA EnergyStar (2005b), Roberson et al. (2002) • Usage based on TIAX Survey (TIAX 2006), modified to account for increase in broadband internet access
	Usage [hr/yr]	2,968	333	5,457	
	UEC [kWh/yr]	223	1	11	
Notebook	**Power [W]**	25	2	2	
	Usage [hr/yr]	2,383	918	5,458	
	UEC [kWh/yr]	60	2	11	

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[21] Data from RECS (2001) and ADL (2002) indicate that , historically, notebook computers generally had similar shares of both the residential installed base (~20%) and the overall PC market (~17%).

Power draw values by mode were primarily based of EPA EnergyStar (2005b[22]) and Roberson et al. (2002); both sources yielded similar average power draw values by mode. Due to limited prior data about PC usage patterns and the large contribution that PCs make to residential IT energy consumption, TIAX commissioned a phone survey in a prior study (TIAX 2006) to develop a more up-to-date estimate of PC usage by mode. The survey was based on 1,000 demographically-representative households of residential PC and monitor usage patterns. One of the major challenges was to infer a reasonable estimate for power management (PM) enable rates. When power management is enabled, a PC will typically enter a low-powered sleep mode (or, in some cases, an even lower power hibernate mode), which reduces PC UEC for PCs left on for extended periods unused. Although, the vast majority of PCs have the capability to enter a lower power sleep mode, most do not. For example, one source estimated that 20% and 40% of desktop and notebook PCs, respectively, have PM enabled (CCAP 2005). The TIAX survey found similar values, but they possess an appreciable degree of uncertainty due to the challenges of posing meaningful (from the respondents' perspectives) questions to ascertain whether or not a given PC has PM enabled.

Based on the responses received, the Survey estimated that a typical PC spends an average of more than eight hours per day in active mode. Interestingly, no one is using the PC during more than half of this time spent in active mode, likely because approximately 20% of PCs remain on throughout the night and only a small percentage of these have PM enabled (TIAX 2006). This large quantity of active-unused time, which appears to account for more than half of desktop PC UEC (see Figure 4-13), represents a significant energy savings opportunity.

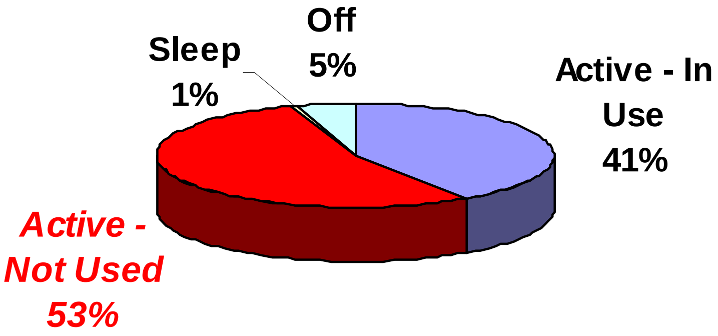

Figure 4-13: Approximate Breakdown of Desktop PC UEC by Mode (based on TIAX 2006)

Because TIAX (2006) found that high-speed internet access increased PC active mode usage by about 25%, we adjusted the usage estimate to reflect the continued growth in high-speed access. In 2006, the penetration of high-speed internet access increased from approximately 50% in 2005 (TIAX 2006) to 56% (J.D. Power 2006).

4.5.3 National Energy Consumption

Desktop PCs account for more than 85 percent of PC AEC (see Table 4-23).

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[22] EPA EnergyStar (2005b) provided power data for more than 100 different PCs, including models from most major PC manufacturers.

Table 4-23: AEC Summary for PCs

	UEC [kWh/yr]	Installed Base [millions]	AEC [TWh]
Desktop	235	90	21
Notebook	72	39	2.8

Several factors influence the usage pattern of PCs, which can vary greatly among households. The growing penetration of broadband access and home offices has encouraged users to leave their PCs on and use them more often for longer durations. This is particular true of desktops where, unlike notebooks, battery life conservation is not an issue. The time to reboot PCs is another factor that leads users to keep their PCs on. In addition, broadband usage and home offices, coupled with the short product life cycle and affordability of PCs along with their associated hardware and software, strongly correlates with higher number of PCs in each residence as well as increased usage. For instance, the TIAX Survey found that PCs in households with broadband connectivity spent about 25% more time in active mode per year than PCs in households with dial-up connectivity.

How often and, in turn, the amount of time PCs assume sleep mode depends on the configuration of power management. Under an industry standard specification called Advanced Configuration and Power Interface (ACPI), current operating systems provide interfaces for users to configure when and under what condition(s) their PCs would go into a lower power mode or even disable power management altogether. Such conditions could be, for example, an arbitrary amount of time of inactivity, a certain key sequence, or, in the case of notebooks, if the LCD monitor is closed. Even though almost all PCs possess power management, some users, especially those who own desktops, are either unaware of it or have disabled it to avoid the lag time for their PCs to awake up from sleep mode. Korn et al. (2004) notes several reasons why users have disabled PM in the commercial sector that appear to be relevant to the residential sector, including prior problems with PM reliability, software incompatibility, a lack of awareness of PM, and prior myths about PM that decreased its use. In the future, greater use of in-home networks may also pose another barrier to PM enabling. Christensen et al. (2004) notes that PCs often lose network connectivity when they enter a low-power mode. Many users may not accept the inconvenience of losing connectivity and, thus, disable power management to avoid this problem. As a greater percentage of households use data networks, this can increase the scale of this PM-related problem. Moreover, a faster network connectivity tends to increase network interface power draw, as faster data rates usually require processors embedded on network interface connections to operate at faster clock frequencies. For example, circa 2004, increases in connectivity speeds to 1GB/s and 10GB/s from speeds of about 10MB/s added approximately 3 and 18W of extra power (Nordman and Brown 2004). Over time, network speeds for routers have increased dramatically without, however, correspondingly large increases in power draw. That is, it is not clear that network interface connection power draw would increase anywhere that much in future devices if they became widespread.

Notebook owners however, tend to see more value in power management because it can play a vital role in prolonging battery life, as well as alleviating the potential for overheating, especially in fanless PCs.

4.5.4 Current Best in Class and Market Trends

Turning PCs off when they are not actively used and ensuring that power management is enabled can achieve dramatic reductions in the average UEC of PCs. Indeed, the draft version of a new EnergyStar® specification for PCs[23] (in development) acknowledges this issue and includes a requirement for default PM enabling and maximum times to enter low-power modes. Currently, most PCs meet the EnergyStar® specifications depicted in Table 4-24 (from EnergyStar® 2006).

Table 4-24 Key Product Criteria for EnergyStar® Qualified Computers

Computer Model Ship Date	Guideline	Power Draw	
Before July 1, 2000	• Shall enter a sleep mode within 30 minutes of inactivity • If shipped with network capability, shall sleep on networks and respond to wake events	Power Supply	Watts (W) in Sleep Mode
		< 200W	< 30W
		> 200W	< 15% of power supply's maximum continuous output rating
On & After July 1, 2000	• Shall enter a sleep mode within 30 minutes of inactivity • If shipped with network capability, shall sleep on networks and respond to wake events	**Guideline A:**	
		< 200W	< 15W
		> 200W < 300W	< 20W
		> 300W < 350W	< 25W
		> 350W < 400W	< 30W
		> 400W	< 10% of power supply's maximum continuous output rating
		Guideline B	< 15% of power supply's maximum continuous output rating

Using the values for PCs with the lowest power draw values in all three modes from an EPA Energy Star (2005) database of mesaurements yields about an 80% reduction in UEC for desktops and almost a 50% reduction for notebooks (see Table 4-25). These values are, however, represent an upper bound in potential reductions because they use the lowest power draw values found for *each* mode, i.e., no machine exists that realizes all of these power draw values. Furthermore, we did not investigate the mix of features in these units and compare them to those typically found in desktop and notebook PCs. Nonetheless, these values provide insight into the general magnitude of savings available. Looking at energy savings from a power management standpoint, the TIAX Survey data indicate that a power management-enabled rate of 100% increases the amount of time spent in sleep mode by almost five- and two-fold for desktop and notebook PCs, respectively (see Table 4-25). This translates into a 44% and 28% reduction in UEC.

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[23] See: http://www.energystar.gov/ia/partners/prod_development/revisions/downloads/Computer_SpecDraft3.pdf .

Table 4-25 UEC Summary for Best in Class PCs

Mode	Usage [hr]	Usage w/ 100% PM-enabled Rate [hr]	Best in class Power Draw [W]	Original UEC [kWh]	100% PM-enabled UEC [kWh]	Best in Class UEC [kWh]
Desktop						
Active	2,954	1,523	14.9	223	114	44
Sleep	350	1,779	1.5	1	7	0
Off	5,456*	5,458*	0.6	11	11	3
			Total UEC	235	132	48
Notebooks						
Active	2,368	1,523	14	60	38	33
Sleep	935	1,779	1.1	2	4	1
Off	5,457*	5,458*	0.7	11	11	4
			Total UEC	72	52	38

*Small differences in off mode time reflect rounding differences in the calculations.
Note: Sums may not equal totals due to rounding of summed values.

Microprocessor and PC manufacturers and operating system developers can play a role by ensuring that PCs, in particular desktops, are equipped with processors embedded with a chip-level voltage and clock frequency scaling technology[24]. To date, this technology has primarily been used for notebook PCs but major manufacturers envision greater use in desktops (Fisher and Brady 2006), where they could reduce UEC by approximately 15 percent (TIAX 2004). Looking forward, measures that reduce the amount of time PCs take to reboot and awaken from sleep mode, such as non-volatile RAM (see, for example, Magnetic Random Access Memory discussed in TIAX 2004), could also overcome help to overcome these barriers to users turning off PCs and enabling PM. Beyond power management, more efficient power supplies can reduce PC power draw (see TIAX 2004) and the aforementioned draft version of a new EnergyStar® specification for PCs also includes minimum power supply efficiencies for both internal and external ac-dc power supplies.

It appears that PCs will continue to be the backbone of residential IT in the future. Driven by the Internet and continued growth in broadband access and home offices, PCs' usage patterns and installed base will likely continue to grow. In addition, PCs' processing power will continue to grow to support more computationally intensive online and multimedia applications; indeed, the PCs processor to share or even take over the computational role of function-specific hardware such as graphics or video card, which can draw a lot of energy, i.e., as much as 20% to 40% of peak power energy consumption or 60W to over 100W power draw in idle state depending on the performance rating of the card according to (Calwell and Foster 2005). At present, current PCs come with adequate graphics cards for general multimedia applications such as playing movies and gaming. However, certain graphics-intensive PC games require a separate higher-performing graphics card to be installed.

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[24] Microprocessor manufacturers are equipping their processors, particular those in notebooks, with a technology that significantly reduces the energy consumption of PCs by controlling the operating voltage and/or clock frequency in response to computational load obtained from the operating system. Major chip manufacturers such as Intel, AMD and Transmeta market their power management technology as SpeedStep™, PowerNow™ and LongRun™ respectively, each work primarily in the same manner, but differ in the number of discrete steps in which voltage and clock frequency can be adjusted as well as algorithm heuristic (TIAX 2004).

The continuing growth in notebook market share relative to desktop PCs also will likely have a major impact on total PC energy consumption. Specifically, a desktop PC plus a monitor has a UEC about five times greater than a notebook PC. Consequently, if the growth of the installed base of PCs slows and notebooks displace a portion of desktop PCs, this could lead to an appreciable decrease in the total energy consumed by PCs and monitors[25]. As noted earlier (in Section 4.5.1), a major IT market research firm projects that notebooks may have outsold desktops in the residential sector in 2005 and predict that notebooks will outsell desktops in 2007 (Kanellos 2006). Due to the three- to four-year average product lifetime of desktop and notebook PCs (Appliance 2005, September, ADL 2002), it will take a few more years for the installed base of notebooks to equal that of desktops.

If the much-discussed “Media Center PC” concept catches on, using the ubiquitous PC architecture as the hub of home entertainment, this could have major impacts on PC energy consumption. Notably, the need to be always on would tend to increase time spent in active mode and, thus, UEC. In addition, media PCs tend to use larger quantities of memory (HD and RAM) and may use more powerful graphics cards and/or processors to serve their target applications. These features can, in turn, increase active mode power draw as well.

Lastly, PCs have the potential to serve as distributed and 24-hour computing resource, whose down time could be shared/leased with other machines to enable unfathomably-large calculations realized only by supercomputers before. Some high visibility examples include SETI at Home[26], the Globus Project[27], and Human Genome Project[28].

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[25] Not considering the potential energy impact of pervasive non-traditional (e.g., hung on walls) displays.

[26] See: http://setiathome.ssl.berkeley.edu/ .

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4.6 Microwave Ovens

Table 4-26: Summary Table for Microwaves

Characteristic	Result	Comments
Installed Base [millions]	110	
Market Penetration [% of Households]	96%	
Unit Electricity Consumption [kWh/year]	131	
UEC – Best in Class [kWh/year]	105	For units with hard off switches (appear to be a very small portion of units, features not known)
UEC Savings – Best in Class [kWh/year]	26	
Annual Electricity Consumption [TWh/year]	14.4	Active mode usage accounts for approximately 80% of energy consumption
Peak Demand Impact	Low	Usage presumed higher around breakfast and dinner times
Variability in Usage	High	
Notable Regional or Seasonal Variations in Penetration or Use?	None	
Typical Location(s) in Household	Kitchen	
Potential Ways to Reduce UEC	Off mode power draw reduction using low-power features, such as LED displays, or hard off switches	
Significant Data Uncertainties	Active usa	
Key Technology Trends	None	

4.6.1 Introduction

Microwaves have become ubiquitous as a U.S. household appliance. According to Appliance Magazine saturation data, microwaves have been hovering between 95% and 96% household penetration since 2000 (Appliance Magazine 2005). Making the assumption owner households have only one microwave, we can calculate the installed base to be 110 million units, given 115 million total households (as shown in Table 4-27).

Table 4-27: 2006 Installed Base Estimate for Microwaves

U.S. Households (millions)	Market Penetration	Microwaves Installed (millions)	Comments and Sources
115	96%	110	Appliance Magazine (2005)

4.6.2 Unit and Household Energy Consumption

Microwaves ovens' energy consumption can be characterized by two operating modes: active mode (when the microwave is performing its cooking operation), and off mode (when the microwave is not cooking). We will not take into account the various power level options that many microwaves offer. Generally these appliance continues to draw power in off mode to power a clock display. Table 4-28 offers average values for power draw in each operating mode.

Table 4-28: Microwave Power Draw by Operating Mode

Appliance	Active [W]	Off [W]	Comments and Sources
Microwave	1,500	3	Foster Porter et al. (2006), CEC (1997) cited in ADL (1998)

Microwave oven components that consume energy include the power supply, fan, clock display, light, tray spinning motor, and magnetron. By improving these components and oven reflective surfaces, microwaves can be made more energy efficient. The power draw in on mode may not be reduced because manufacturers may opt to instead reduce the on time necessary for cooking. Nonetheless, the overall energy consumption would be reduced. Currently, however, there is not a minimum microwave efficiency standard.

Usage data for microwave ovens are limited. The Central Maine Power Company (CMPC) reports that a microwave is used for approximately 6 hours per month or just under 12 minutes per day (see Table 4-29). ADL (1998) used the CMPCO estimate in 1998 and the estimate remains unchanged on the CMPC website. Although the time in active mode is relatively small, because of the high power draw, active mode energy consumption accounts for approximately 80% of microwave energy consumption.

Table 4-29: Microwave Usage by Power Mode

Appliance	On time [hrs]	Off Time [hrs]	Comments and Sources
Microwave	70	8,690	CMPCO (2005)

Because there is significant uncertainty about the usage data, we compared our calculation of UEC with other sources. Although power and usage data are limited for microwaves, several sources report estimates for UEC. Table 4-30 lists several estimates and most are consistent with the current estimate.

Table 4-30: UEC Estimates and Sources

UEC [kWh]	Sources and Comments
110	2005 forecasted value from ADL (1998)
133	CEC (2004)
143	DOE (1996), from DOE (2005) DOE (1996) also reports that certain design options can reduce the UEC to 132 kWh
132	Wenzel et al. (1997)
131	**Current Estimate**

4.6.3 National Energy Consumption

Overall, microwaves consumed about 14TWh of electricity in 2006 (see Table 4-31).

Table 4-31: 2006 Microwave Oven Energy Consumption

Ave On Power [W]	Ave Off Power [W]	On Usage [hr]	Standby Usage [hr]	Annual UEC [KWh]	Annual Energy [TWh]
1,500	3	70	8,690	131	14.4

4.6.4 *Current Best in Class and Market Trends*

Power draw and usage have remained fairly unchanged, and since the market is saturated, the total annual energy consumption of microwaves is only expected to grow with the number of households.

LBNL (1998) discusses several approaches to increase the active mode efficiency of microwave ovens from just under 56% to about 60%. In addition, the potential to reduce the off mode power draw exists, e.g., by reducing the power draw of the display. Few data exist that characterize the range of off mode power draw values for microwaves in the U.S. In-home surveys in Australia found that a small minority (<3%) of microwave ovens had a hard off switch and, thus, drew zero watts when off (Energy Efficient Strategies 2006). Similarly, in-store measurements of off mode power draw of microwave ovens for sale in Australia in 2004 found that 1 out 44 units sampled drew less than one Watt (but >0.05W) when off (AGO 2004). The feature(s) of this unit were not detailed. If the off mode power draw decreases to 0 or 1 watts, this translates into a 13 and 20 percent decrease in UEC, respectively (see Table 4-32).

Table 4-32: Theoretical Energy Saving Scenarios for Microwave Ovens

Scenario	UEC	AEC	% Reduction
Baseline	131	14.4	0%
Off power = 1 W	114	12.5	13%
Off Power = 0 W	105	11.5	20%

4.6.5 *References*

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4.7 Broadband Access Devices (Cable Modem, DSL)

Table 4-33: Broadband Access Devices Summary

Characteristic	Result	Comments
Installed Base [millions]	46	
Market Penetration [% of Households]	40	Assumes one access device per household with broadband access
Unit Electricity Consumption [kWh/year]	53	
UEC – Best in Class [kWh/year]	30	Based on data from (Nordman and McMahon 2004)
UEC Savings – Best in Class [kWh/year]	23	
Annual Electricity Consumption [TWh/year]	2.6	
Peak Demand Impact	Low	Devices draw similar power around the clock
Variability in Usage	High	Small energy impact because power draw does not vary appreciably with usage
Notable Regional or Seasonal Variations in Penetration or Use?	None known	
Typical Location(s) in Household	Known	Living room, study room or bedroom, i.e., in close proximity to cable jacks
Potential Ways to Reduce UEC	*Existing*: • Turn off device when not in use. *Potential*: • More efficient distribution of broadband access (e.g., shared access) • Implement device sleep mode • EnergyStar® coverage	
Significant Data Uncertainties	Appreciable degree of uncertainty in active mode power draw due to differences among cable/DSL, hardware, and product models and limited measurements	
Key Technology Trends	New higher speed access technologies including: Very high Bit-rate DSL (VDSL), Fiber to the home (FTTH), and Wireless broadband access technologies (e.g., WiMAX)	

The Internet has introduced and affected the usage patterns of an array of technologies and devices that impact residential energy consumption. As Web content become increasingly sophisticated to include more complex server-side applications to support activities such as online banking, ecommerce and streaming multimedia, the demand for greater bandwidth to access information and data over the Internet at higher speed than conventional dialup has noticeably increased. This demand has fueled the growth of broadband Internet access and associated broadband access devices to the extent that approximately 42% (about 46 million; Pew Internet, 2006) of households in 2006 and about 56% of all homes with Internet access had a high-speed broadband connection (J.D.

Power 2006).

Currently, there are two main competing technologies for broadband access, cable modem and digital subscriber lines (DSL), which are delivered to the home via cable TV network and traditional phone network, respectively. Both technologies exploit the extra, unused capacity in terms of range of frequencies in their respective network to transmit and receive data to and from the Internet. This is why one is able be watch cable TV (in the case of cable modem) or talk on the phone (in the case of DSL) while simultaneously connected to the Internet. Data transfer rates vary for cable modem and DSL depending on circumstances and there is not a clear winner on which technology is better or faster. Both can deliver speeds of up to 1.5Mbps or more, particularly cable. Cable is, however, based on shared bandwidth and thus its performance depends on the number of subscribers on the local area network. With DSL, each subscriber has a dedicated connection but, unlike cable, performance and signal quality deteriorates as the distance from the subscriber to the provider's central office increases.

Table 4-34: Broadband Access Device Installed Base

Installed Base [millions]	Penetration [%]	Cable Modem : DSL	Sources
46	40	Approximately 4 : 3	J.D. Power (2006), EIA (2006)

4.7.1 Unit and Household Energy Consumption

Data shown in Figure 4-14 indicate that broadband access device power draw does not vary appreciably with data transfer rates once a device is turned on and ready for data transfer. For example, a powered-up DSL modem that is ready to transfer data that is disconnected from a PC (0kb data transfer) draws 7.3W, whereas it draws incrementally more power (7.6W) when it is ready and connected to a PC (and, presumably, transferring some data).

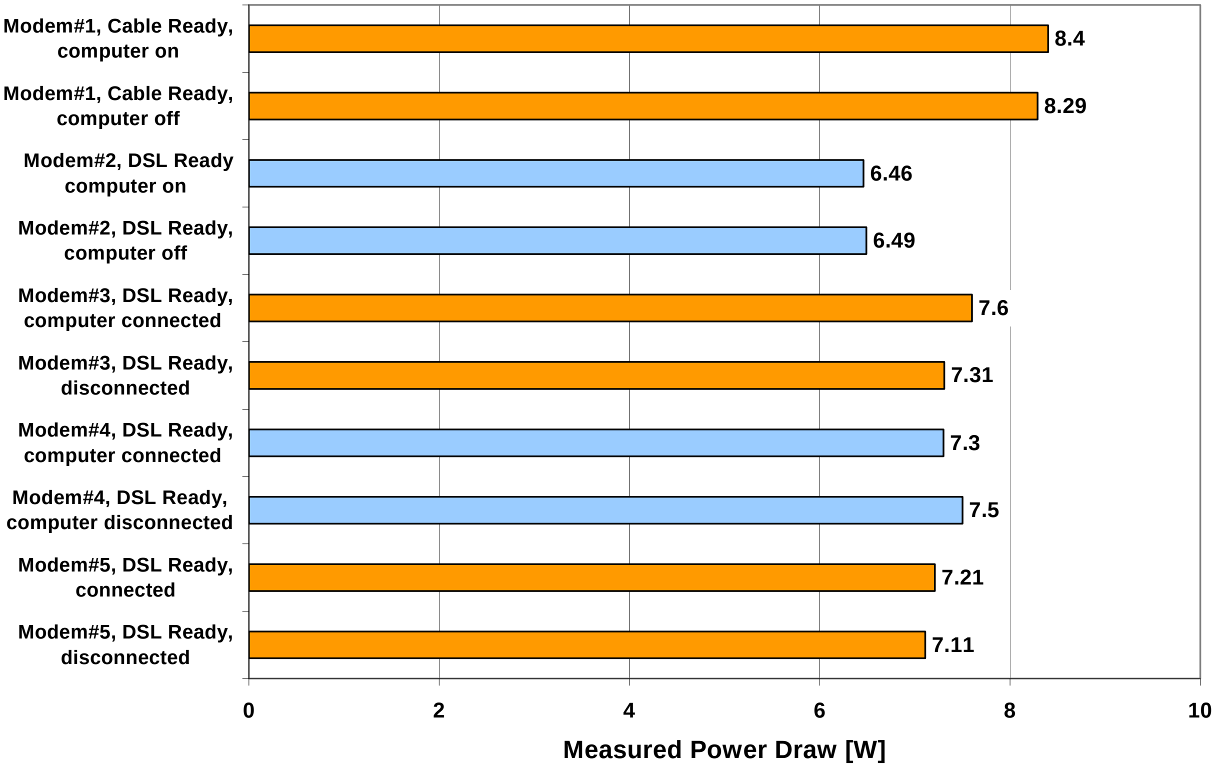

Figure 4-14: Power Draw Measurements of Cable and DSL Modems by Mode (Nordman and McMahon 2004)

Due to the lack of concrete data that suggests otherwise, it is assumed that broadband access devices are rarely turned off or undergo sleep mode. The estimate for broadband access devices active mode power draw has an appreciable degree of uncertainty because a range of different cable and DSL modems models (with corresponding variations in power draw) need to be taken into account. Unfortunately, a representative set of data was not found.

Table 4-35: Broadband Access Device Power Draw by Mode

	Active	Sleep	Off	Comments and Sources
Power [W]	6	N/A	N/A	• Power draw from Nordman and McMahon (2004), Foster Porter et al. (2006) • Assumed to be “always on” with no lower power mode
Usage [hr/yr]	8,760	0	0	
UEC [kWh/yr]	53	N/A	N/A	

4.7.2 National Energy Consumption

Cable and DSL modems consumed about 2.6TWh of electricity in 2006 (see Table 4-36).

Table 4-36: AEC Summary for Broadband Access Devices

UEC [kWh/yr]	Installed Base [millions]	AEC [TWh]	Comments and Sources
53	46	2.6	Assumed to be "always on" with no lower power mode

It is safe to assume that broadband access devices are always left on, i.e., in Active mode primarily due to convenience. Most users enjoy the immediate connectivity that broadband provides such as the ability to check email and browse the web at any given time without having to wait to "boot up" to establish connection; this attribute has led some dialup users to switch to broadband. Furthermore, most broadband access devices lack sophisticated embedded power management algorithms[29] comparable to those found in PCs for it to effectively switch to a lower, power-drawing (sleep) mode. A device's sleep mode is implemented and enabled in its embedded processor and is a common feature of most microprocessors and microcontrollers used in electronic devices to significantly reduce power draw when appropriate, for example during low computational load. Data from Nordman and McMahon (2004) suggest that current broadband access devices in the market do not to the full extent, if at all, leverage the sleep mode feature of its embedded processors since power draw is relatively constant regardless on whether or not data is being transferred (see Figure 4-14).

Although the installed base of broadband access devices will undoubtedly increase, it is worthwhile to mention that a substantial portion of households still use dialup modems to access the Internet. Some portion of these users live in areas that do not receive cable or DSL service and will not be able to choose high-speed access until the deployment of other high-speed connectivity solutions.

The speed, robustness, security[30], and ease of connectivity that broadband access provides has facilitated the growing trend for people to work remotely from their homes and to set-up home offices and computer networks, directly influencing the number of PCs and devices (such as printers and MFDs) in the home. This trend perpetuates the need for broadband access devices to be actively on for longer durations and also encourages increased use of other devices connected to the home network, such as PCs, printers and MFDs. Notably, the TIAX survey suggests that PCs with a broadband connection spend about 25% more time per year in active mode than those with dial-up connections. Consequently, broadband appears to indirectly increase overall residential IT electricity consumption.

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[29] Examples of PC power manage algorithms are SpeedStep™ from Intel, PowerNow™ from AMD and LongRun™ from Transmetta (see TIAX 2004).

[30] Security features and settings associated with broadband connection such as firewalls are integrated in the system utilities of most popular operating systems such as Windows and Linux, giving users greater flexibility and ease to configure security settings of their broadband connection as well as limit unauthorized users/programs to access to their computer via the Internet or other computer networks.

4.7.3 Current Best in Class and Market Trends

An easy way to reduce energy consumption attributed from broadband access devices is to turn it off when it is not in use. This is, however, seemingly, impractical due to the inconvenience of rebooting[31], the potential to inconvenience and irritate other household members in households with multiple PCs, and challenges accessing the broadband devices in some households (e.g., when using a wireless router).

Another means to moderate energy consumption is to distribute broadband access in a more efficient manner. It is less efficient from bandwidth, energy, and cost of service standpoints to have a broadband access device for every PC or even for every household considering that a single broadband access channel from most providers could easily accommodate and connect several computers to the Internet through the use of routers without much loss in speed and performance. Residences with multiple PCs already take advantage of routers, both regular and wireless, to distribute their broadband access. If this notion can be implemented on a larger scale, for example one broadband access device for every floor in an apartment complex or area in a neighborhood, it would substantially impact the overall energy consumption attributed from broadband access devices. There is, however, a commercial barrier in that providers currently charge on a per-channel basis for broadband access and unless that were to change, providers would likely oppose such a means of distributing broadband access.

Currently, EnergyStar® does not yet cover these products, but such a program would promote the use of more energy-efficient broadband access devices in residences as it has with other products. Using the best in class broadband access device derived from a limited data set produced in 2004 (sample size of 10 measurements; Nordman and McMahon 2004) would have an UEC of about 30 kWh. This represents more than a 40% reduction relative to the current estimate of 53 kWh.

Broadband internet access has grown aggressively, attaining 2008 penetration projections developed in 2005 by TIA (2005) within a year. Competitive pricing of bundled services by providers, e.g., the “triple play” of Internet access, cable TV, and VoIP-based phone service, has played an important role in the increased the demand for broadband. Sending data over the Internet through broadband has proven to be fast, reliable and inexpensive, clearing the path for contents other than Web content, such as video on demand, television and voice to be transmitted by this method, known as Internet Protocol (IP). Systems and services that deliver data using the Internet Protocol such as Voice over IP (VoIP), Audio Video on Demand (AVOD) over IP, and IP Television (IPTV) have begun to make their way into the home.

In countries with the highest broadband penetration, such as the Nordic countries and South Korea, high-speed Internet access is becoming an integral part of many citizens’

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[31] TIAX measured the time for a PC to regain cable modem-based Internet access via a wireless router after turning off the cable modem and subsequently turning it back on. Once the cable modem was turned on, it took approximately one minute for the PC to regain Internet access for a web browser. The time would likely be shorter for a cable modem alone, as the time for the router to broadcast the wireless network and for the PC’s network interface card (NIC) to locate, authenticate and reestablish connection to the wireless network increases the connection time.

lives, providing and integrating telecommunications, IT, and multimedia within the home. To keep up with consumers' demands, broadband data transfer rates will increase in the future by using data transfer media with higher potential throughputs (e.g., higher bandwidth cabling), more efficient use of bandwidth (e.g., more efficient data transfer protocols), and faster microprocessors in networking equipment and broadband access devices. Examples of the next generation broadband access devices and their associated technologies include:

- *Fiber to the home (FTTH)* refers to the movement of replacing traditional telecommunication copper cables with fiber optic cables, a much faster, data-transporting medium offering data rates of up to 100Mbps (Wilkinson and Nakano 2003), all the way to the home. Although FTTH has become available in some communities, it will take several years before FTTH achieves significant residential market share due to the cost of infrastructure upgrades, comprised of optical transmitters, receivers, regenerators and other associated hardware (all of which will consume energy).
- *Very high Bit-rate DSL (VDSL)* is another DSL technology that provides tremendous bandwidth of up to 52Mbps (Smart Computing 2006). Deployment of VDSL requires some infrastructure changes, including installation of enabling hardware and upgrading access to fiber-optic cables. Consequently, it will likely take at least several years until VDSL becomes widely available. The increased bandwidth could encourage the use more computationally intensive, web-based application in the home, but may not necessarily directly increase energy consumption because VDSL and similar technologies will use bandwidth more efficiently.
- *WiMAX* refers to broadband wireless networks based on the IEEE 802.16 standard, which ensures compatibility and interoperability between broadband wireless access equipment. In a typical radius deployment of a few miles, WiMAX Forum Certified™ systems can be expected to deliver capacity of up to 40 Mbps per channel (Wimaxforum 2006). WiMAX is a promising means to more efficiently distribute broadband access without the need for expensive large scale civil infrastructure, change such as laying physical cables. With WiMAX, broadband access devices could migrate from the home to become a technology associated with the neighborhood or even city scale, where a single direct broadband access point provides connectivity for an entire community. The time for WiMAX to have a market impact will depend on the effort required to ensure robustness and security, issues generally of greater concern for wireless networks than wired networks.

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4.8 Monitors

Table 4-37: Monitor Summary

Characteristic	Result	Comments
Installed Base [millions]	90	
Market Penetration [% of Households]	64%	Equal to the penetration of desktop PCs
Unit Electricity Consumption [kWh/year]	85	
UEC – Best in Class [kWh/year]	31	17-inch LCD with power management (PM) enabled
UEC Savings – Best in Class [kWh/year]	54	32kWh relative to an average 17-inch LCD
Annual Electricity Consumption [TWh/year]	7.7	

Characteristic	Result	Comments
Peak Demand Impact	Likely Low	Usage in the evening likely most common
Variability in Usage	Medium	
Notable Regional or Seasonal Variations in Penetration or Use?	None known	Usage model assumes most common use between 7 and 10pm
Typical Location(s) in Household	Home office, family room, bedroom	TIAX estimate
Potential Ways to Reduce UEC	*Existing*: Enabling power management, LCD *Potential / Future*: improved LCD backing light efficiency, OLED-based displays	
Significant Data Uncertainties		
Key Technology Trends	LCDs are displacing CRT-based displays	

There were approximately 129 million PCs in the U.S. in 2006, 70% of which were desktop PCs. The monitor installed base estimate of 90 million monitors assumes that there is one monitor for every desktop PC (see Table 4-38). Assuming an equivalent penetration to desktop PCs, about 64% of U.S. households have at least one monitor

Table 4-38: 2006 Monitor Installed Base

Installed Base [millions]	Penetration	Comments and Sources
90	64%	Assumes one monitor for every desktop PC

4.8.1 Unit and Household Energy Consumption

The average power for monitors comes from TIAX (2007) and was calculated using a weighted average of the four key monitor categories based on installed base and shipment estimates for each monitor type from iSuppli (2005) and power draw values from Roberson et al. (2002) and data from EPA Energy Star (EnergyStar 2006) (see Table 4-39).

Table 4-39: Monitor Power Draw Values (from TIAX 2007, iSuppli 2005)

Monitor Size	Installed Base [%]	Power Draw [W]		
		Active	Sleep	Off
CRT - 17-inch	40%	61	2	1
LCD - 15-inch	15%	20	1	1
LCD - 17-inch	35%	31	1	1
LCD – 19-inch	10%	35	1	1
Average	100%	42	1	1

The average usage by mode for monitors comes from models developed by TIAX with slight modifications to take into account the increase in broadband internet access. The models use survey data to create monitor daily weekday and weekend usage patterns (see TIAX 2006 for details of the survey). In addition, the survey results suggest that monitors associated with PCs that have high-speed internet access spend slightly more time (~6%)

in active mode than those associated with PCs with dial-up access[32]. As data indicate that high-speed internet access grew from approximately 50% in the 2005 TIAX Survey[33] to 56% in 2006 (J.D. Power 2006), we adjusted all usage values to reflect this increase.

Table 4-40 summarizes the power draw, usage, and UEC by usage mode. A typical household has one monitor and therefore the UEC equals the typical household energy consumption.

Table 4-40: Monitor Average Power Draw and Usage by Mode

	Active [W]	Sleep [W]	Off [W]	Comments and Sources
Power Draw [W]	42	1	1	EnergyStar (2006) and Roberson et al. (2002) for power draws
Usage [hrs/yr]	1,861	869	6,029	TIAX (2006) values modified to reflect increase in active usage from greater broadband access
UEC [kWh/yr]	78	1	6	

4.8.2 National Energy Consumption

With an AEC of 7.6 TWh, monitors are the second largest energy consumer among residential IT products after desktop PCs.

Table 4-41: 2006 AEC Summary for Monitors

UEC [kWh/yr]	Installed Base [millions]	AEC [TWh]
85	90	7.7

4.8.3 Current Best in Class and Market Trends

Once dominated by CRT displays, the monitor market has transitioned to liquid crystal displays (LCDs). On average, a 17-inch LCD monitors draws about 40% less power than CRT monitors in active mode with a potential for even higher energy savings through improvements in LCD backlight efficiency or the use of reflective (rather than transmissive) displays (see below). Notably, the backlights in an LCD monitors account for approximately 80% of the active power draw and only about one percent of the electricity flowing into the backlights comes out the front of the display, i.e., a system efficiency of around 1%[34] (TIAX 2004).

Power management (PM)-enabled rates also have a substantial impact on monitor UEC and AEC. A survey conducted by TIAX (2006) found monitor PM-enabled rates generally consistent with the 60% to 70% estimated in prior studies (Nordman and Meier 2004, ADL 2002). Although significantly higher than the PM-enabling rates for PCs, an appreciable energy savings potential remains for the sizeable minority of monitors that do not have PM enabled.

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[32] In contrast, PCs with broadband access spend approximately 25% more time in active mode; see Section 5.8.1.2.

[33] The 2005 J.D. Power & Associates survey estimated high-speed internet access penetration at 44% (J.D. Power 2006).

[34] On the order of 4% of the backlight comes out the front of the screen (TIAX 2004).

Monitors are also showing a shift towards larger screen sizes. Larger screen monitors draw more power than small screen monitors of the same display technology. For example, the active mode power draws for average Energy Star®-rated 17-inch, 19-inch, and 21-inch LCD monitors are 31 W, 35 W, and 40 W respectively. However, in the near term, the average monitor UEC is likely to drop overall because of the technology shift from CRT displays to LCDs, and because of energy conservation programs like Energy Star®.

95% of all monitors sold in 2004 met the 2004 Energy Star® power requirements for sleep and off mode power draw. Starting in 2005, an active mode power requirement was implemented based on monitor resolution along with sleep and off mode requirements of less than 4 and 2 watts respectively (EPA 2006.) The requirements for each operating mode again tightened at the start of 2006. An Energy Star® qualified monitor with a typical resolution of 1.31 megapixels will have an active mode power draw of less than 80 W and 37 W in 2005 and 2006, respectively (EPA 2006).

Table 4-42 lists the power draw by mode and the UEC for best in class monitors according to data gathered by EnergyStar (2005). If the entire monitor installed base was replaced by the best in class for a given size and technology, the AEC would decrease by approximately 40%.

Table 4-42: Best in Class UEC from Energy Star Monitors Product List (EPA 2005)

	Active [W]	Sleep [W]	Off [W]	UEC [kWh] (Assuming Avg. Usage)	Brand and Model
CRT – 17 Inch	37	2	1	77	Lanix LN710S
LCD – 15 Inch	14	0.7	0.5	30	NEC AccuSync LCD52V Mitsubishi DiamondPoint V51LCD Philips 150B6
LCD – 17 Inch	15	2	1	36	Lanix 700P Lanix AL170
LCD – 19 Inch	23	0.9	0.7	49	AccuSync LCD92V Mitsubishi DiamondPoint V91LCD

Emerging monitor technologies also could offer significant energy savings over both CRT and LCD monitors in the future (TIAX 2004). Organic light-emitting diodes (OLED)-based monitors potentially could offer energy savings of 50% over LCD monitors. Companies are racing to develop OLED-based monitors for potential manufacturing cost savings and small profile advantages along with the energy savings benefits. High-volume manufacturing issues may prove to be one of the largest barriers to widespread OLED monitor adoption (Mentley 2002). In addition, OLED life may be a substantial barrier to commercialization due to material instability issues. Currently OLEDS fall significantly short of the 20,000-hour required lifetime estimated for monitor applications.

Table 4-43 compares the energy consumption of several monitor technology and usage scenarios. UEC calculations show that significant energy savings are possible by using current available best in class LCD monitors with power management. The estimated 31 kWh/yr offers a reduction of approximately 58% over the estimated average monitor. The bulk of the energy savings comes from lower active mode power draw. Future technologies such as LCDs with high efficiency backlights and OLED displays could offer further significant reductions in unit electricity consumption.

Table 4-43: Monitor Unit Electricity Consumption Scenarios

Monitor Energy Consumption Scenario		Active [W]	Sleep [W]	Off [W]	UEC [kWh]
Current Avg. 17-inch CRT with average usage	Power	61	2	1	122
	Usage	1,861	869	6,029	
Current Avg. 17-inch LCD with average usage	Power	31	1	0.8	63
	Usage	1,861	869	6,029	
Current Avg. 17-inch LCD with 100% PM-enabled rate	Power	31	1	0.8	51
	Usage	1,464	1,295	6,029	
Best-in-Class 17-inch LCD, 100% PM-enabled rate	Power[a]	15	2	1	31
	Usage[b]	1,464	1,295	6,029	
Potential High-Efficiency Backlight, 17-inch LCD, 100% PM-enabled rate	Power[c]	10	1	0.5	19
	Usage	1,464	1,295	6,029	
Potential 17-inch OLED, 100% PM-enabled rate	Power[d]	8	1	0.5	16
	Usage	1,464	1,295	6,029	

One projection of residential monitor power draw in 2010 suggests that the average active mode power draw will decrease to around 33W (TIAX 2006).

As the market share of laptops in the residential computer market continues to increase in the future, this will tend to reduce the AEC of monitors by decreasing their installed base. Notably, laptop computers are expected to be the majority of residential sales circa 2007 (Kanellos 2006[35]); some households may, however, continue to use monitors with laptops and docking stations.

Looking further into the future, some researchers project a significant increase in the number of non-traditional displays deployed throughout the house to provide information or ambient art, networked to other devices via wireless networks (Nordman and Brown 2004). The development of inexpensive and flexible flat-panel displays (e.g., polymer OLED displays; see TIAX 2004 for a discussion) would be a key driver become. If this did occur, many of these displays could remain on for extended periods of time, increasing the energy consumed by household displays.

4.8.4 References

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4.9 Inkjet Printers and Multi-Function Devices (MFDs)

Table 4-44: Inkjet Printer and Multi-Function Device Summary

Characteristic	Result	Comments
Installed Base [millions]	101	Approximately 75% inkjet printers and 25% multi-function devices
Market Penetration [% of Households]	68%	For either an inkjet printer or MFD
Unit Electricity Consumption [kWh/year]	16 / 57	For inkjet printers / MFDs; significant uncertainty in usage by mode
UEC – Best in Class [kWh/year]	1.6 / 7.5	For inkjet printer / MFD; based on EnergyStar® (2006)
UEC Savings – Best in Class [kWh/year]	14 / 50	
Annual Electricity Consumption [TWh/year]	2.6	About 45% inkjet printer, 55% MFD
Peak Demand Impact	Low	Peak printer usage periods likely do not coincide with peak electric demand periods
Variability in Usage	High	Variable usage patterns, particularly for households with home offices and for households that leave on printers
Notable Regional or Seasonal Variations in Penetration or Use?	None known	
Typical Location(s) in Household	See PCs	Typically in close proximity to PC

Characteristic	Result	Comments
Potential Ways to Reduce UEC	*Existing*: - Connect to power strip to decrease off mode power draw (~0.1W when strip off, ~0.6W when strip on; Nordman and McMahon 2004) - High-performance EnergyStar® devices	
Significant Data Uncertainties	Highly variable usage pattern with each household	
Key Technology Trends	- MFDs may continue to gain market share - Greater usage of PCs may increase on time - Potential for more printers per household, e.g., dedicated color photo printers	

4.9.1 Introduction

As the name implies, inkjet printers create an image by spraying tiny jets of ink onto the paper. Multi-function devices (MFDs), also known as all-in-one printers, incorporate printing, copying, and faxing capabilities and most units also use inkjet printing. Together, inkjet printers and MFDs are the predominant residential IT imaging device. Relative to black and white laser printers, they are favored due to their lower cost, greatly improved and acceptable printing resolution and color capability. The increased use of the Internet, home offices and more recently, the growing popularity of digital photography, have driven the market penetration of inkjet devices and likely affected their usage patterns.

Our estimate for the total installed base of inkjet devices involves some complexity. CEA (2006) found that 96% of households with a PC had at least one color computer printer. This study estimates that 71% of all households have a PC, which yields a penetration 68% of households for inkjet devices, or 79 million households. Subsequently, we multiplied that by the CEA (2005) estimate that each household with one or more color printer has 1.3 color printers, assuming that almost all color printers in residences are inkjet devices[36]. This yields a total of 103 million inkjet devices, a quantity equal to approximately 5 years of computer printer sales (CEA 2006).

To develop a breakdown between MFDs and inkjet printers, we compared sales to dealers for all computer printers from CEA (2006) with unit shipments for inkjet printers[37] from Appliance (2006). These data indicate that approximately 75% of inkjet devices are stand-alone printers and 25% MFDs (see Table 4-45), yielding an installed base of 76 and 25 million stand-alone and MFD inkjet devices, respectively (see Table 4-46).

Table 4-45: Inkjet Printer and MFD Shipments Year (millions; CEA 2006, Appliance 2006)

Type	2001	2002	2003	2004	2005	Total	%
Inkjet	17.0	16.8	13.0	13.8	14.5	75	75%
MFD	1.8	3.5	8.5	5.8	5.5	25	25%

Table 4-46: Inkjet Printer Installed Base

Inkjet Device	Installed Base	Penetration

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[36] Nordman and Meier (2004) estimated that there were 3 million residential laser printers circa 2001, most of which were, presumably, black and white devices.

[37] Appliance Magazine clarified that unit shipment data for inkjet printers did exclude MFDs.

	[millions]	[%]
Printer (stand-alone)	76	68%
MFD	25	

Unfortunately, we were not able to develop an estimate for the installed base of dedicated photo printers. For purposes of this study, we assumed that they have usage and power draw characteristics similar to inkjet printers.

4.9.2 Unit and Household Energy Consumption

The hours of operation under the various modes present an appreciable gap in the estimation due to the highly variable usage pattern of inkjet printers among households. We used data developed during week-long measurements of a total of 31 inkjet devices located in California homes reported in Foster Porter et al. (2006). Although the usage measurements were limited and have some odd results, notably that inkjet printers never appear to enter the ready mode, they represent an improvement over past informed estimates for inkjet printer usage. In addition, the power draw estimates came from the same study (see Tables 4-47 and 4-48).

Table 4-47: Inkjet Device Usage by Mode (Foster Porter et al. 2006)

Device Type	Active	Ready	Off
Inkjet Printer	88	-	8,672
MFD*	283	659	7,818
*MFD usage was adjusted by eliminating the usage data for one MFD that was disconnected throughout the week-long monitoring period.			

Table 4-48: Inkjet Device Power Draw by Mode Values (Foster Porter et al. 2006)

Device Type	Active	Ready	Off	Source	Number of Measurements
Inkjet Printer	8.9	3.2	1.7	Foster Porter et al. (2006)	18
MFD	15.2	9.1	6.2		13

Combined together, the usage and power draw valuesyield the UEC values shown in Table 4-49. In general, MFDs appear to have a much higher UEC that reflects both higher power draw values in all modes, most importantly off mode.

Table 4-49: UEC Values for Inkjet Printers and MFDs

Device Type	UEC [kWh/yr]
Inkjet Printer	16
MFD	59

The typical household would have one inkjet printer and no MFDs, which translates into an HEC of 16 kWh.

4.9.3 National Energy Consumption

All together, residential inkjet printers and MFDs consume about 2.6 TWh of electricity in 2006. Despite having an installed base one-third that of inkjet printers, MFDs consume more energy than inkjet printers because their UEC is about four times greater (see Table 4-50).

Table 4-50: AEC Calculations for Inkjet Printers and Multi-Function Devices

Device Type	UEC [kWh/yr]	Installed Base [millions]	AEC [TWh]
Inkjet Printer	16	76	1.2
MFD	59	25	1.5

In recent years, digital cameras have become increasingly popular due to their competitive price and ability to produce quality images, immediately delete unsuccessful photo shots and electronically store and edit images. As a result, one of the main uses for inkjet printers is to conveniently print digital photographs taken from digital cameras at home. Many newer inkjet printer models seamlessly integrate with image processing software programs that run on PCs through a fast USB connection and some can directly connect to digital cameras, i.e., serving as a docking station, and are solely dedicated to printing digital photographs at a touch of a button. There are, of course, other alternatives to printing digital photographs at home with inkjet printers.

Another popular option is to use web-based digital photo sharing/printing services, where users can upload and store their photos into online albums as well as order prints of varying size. Such an alternative might deter the pool of people looking to obtain inkjet printers solely to print digital photographs, slightly reducing the penetration of inkjet printers in that market. Nonetheless, as the penetration of digital cameras continues to grow, so, too, will the installed base of inkjet printers. Indeed, digital cameras have outsold traditional film cameras in the U.S. since 2003 (Dobbin 2005) and approximately 45% of households had one or more digital cameras in 2005 (CEA 2005). Furthermore, many cell phones now can take (and store) digital pictures of increasing quality.

Broadband access has facilitated the growing trend for people to work remotely from their homes and to set-up home offices, directly increasing the usage of inkjet printers and thus their time spent in active mode. Due to other common imaging needs in home offices such as copying, scanning and faxing, MFDs continue to gain a larger portion of the residential imaging device market by offering more versatility and space optimization for an incremental cost. In addition, retail printing chains offers a means to mitigate some of the printing demands of home offices by offering greater, high-volume printing speed and other customization options such as paper quality/size, binding etc. Despites these factors, the number of home offices, estimated to be as many as 40 million depending on the definition (Lonier 2006), have undoubtedly influenced the residential usage pattern and penetration of inkjet printers and will likely continue to do so in the future.

4.9.4 Current Best in Class and Market Trends

All printer products, including inkjet printers, are covered under the voluntary EnergyStar® program. Most inkjet printers do not, however, have a distinct low power mode (different from a "ready" mode) that they enter after a predetermined period of inactivity. Nonetheless, almost all inkjet printers draw less power than the maximum EnergyStar® specification in ready mode[38] (CCAP 2005).

Consequently, the greatest savings for inkjet printers comes from selecting devices that have the lowest power draw in ready and off modes and from turning the printers off when they are not in use. Using the best in class inkjet printer based sleep and off mode values (1W and 0.04W) from a recent data base of printers[39] (EnergyStar 2006) would have an UEC of 1.6 kWh, about a 90% decrease relative to the baseline unit. Similarly, the MFD with the lowest energy consumption (2.5W and 0.2W), would also decrease UEC by close to 90%.

For a typical device (i.e., with the power draw and usage characteristics shown in Tables 4-48 and 4-49), turning off MFDs when not in use would reduce its UEC by only few percent, while printers would realize no energy savings at all. This clearly shows how off mode power draw dominates MFD and inkjet printer UEC. In contrasts, using a generic power strip to turn off power flow to the printer when it is off reduces power draw for all connected devices further achieves very dramatic reductions for both inkjet printers and MFDs, reducing their respective UECs by approximately 90 and 80 percent. This reflects the much lower off mode power draw for the power strip, i.e., approximately 0.1 W[40].

Alternately, advanced power strips exist that automatically turn on and off peripherals (inkjet printers, monitors, scanners, etc.) connected to the power strips depending on whether the master PC is in a high-power or low-power state (OneClick 2006) or if someone is in a room is detected by an occupancy sensor integrated into the power strip (Watt Stopper 2006). Both of these approaches have significant implementation challenges. Notably, a device that turns on and off peripherals in response to the PC operational status could actually increase printer time in ready/sleep mode if the PC is left on without power management enabled. Indeed, data from a recent study of residential IT energy consumption (TIAX 2006) indicate that PCs spend much more time in active mode than do printers (based on Foster Porter et al. 2006), in which case the device would increase inkjet printer energy consumption. In addition, an occupancy sensor-based device suffers from the same challenges as occupancy sensors used for lighting controls in buildings, i.e., the potential for false negatives when the sensor does not detect occupancy (e.g., due to poor sensor placement) and false positives when the sensor detects extraneous motion that does not correlate with occupation (e.g., pets, paper movement induced by airflows). Furthermore, the one device found (Watt Stopper 2006) draws 6W before any devices are plugged in, i.e., it would have a higher power draw than an average inkjet printer that wasn't turned off and a similar value to a MFD in off mode.

Looking to the future, the continued growth in Internet and broadband access will continue to be the main driver for the increased usage of PCs in the home and facilitating

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[38] 10W for a 0-10ppm device and 20W for an 11-20ppm device (EnergyStar 2006).

[39] Active=13.8W; Sleep=1W; Off=0.04W; 14ppm.

[40] Based on a power draw of 0.1W for a basic power strip for all time spent in ready and off modes and ready only, respectively (Nordman and McMahon 2004); using a strip with surge protection (0.5W, Nordman and McMahon 2004), would result UECs of about 5 and 14kWh for inkjet printers and MFDs, respectively.

the trend for people to setup home offices. This trend indirectly increases the usage of inkjet printers capable of printing at higher speeds and resolution. Higher speed inkjet printers will, in turn, ultimately require blowing and heating to remove the water from the ink and prevent image streaking during paper handling. This increases active mode power draw dramatically, e.g., to around 700W in the case of one business inkjet printer, and consumes approximately 1W-h per image (TIAX 2004). On the other hand, active mode will typically not account for the bulk of residential printer UEC in most applications and, because inkjet printers do not have a fuser roll to keep warm (unlike electrophotographic devices), higher printing speeds would not necessarily translate into higher ready/sleep or off mode power draw. In sum, higher speeds would not likely substantially increase the average inkjet printer UEC unless print volumes increased dramatically (i.e., to several thousand pages per year).

Second, the use of inkjet printers for picture printing may continue to grow, due to increasing popularity of digital photography and the penetration of digital cameras. It would not be surprising to see the increased adoption of dedicated camera-integrated units[41] that produce only high-quality digital pictures. If these printers achieved widespread acceptance, it would increase the number of households with multiple printers and inkjet printer household energy consumption.

Finally, color laser printers could pose a challenge to inkjet printers in the future. Currently, color laser printers cost significantly more than inkjet printers, have similar per-page printing costs, and cannot print on glossy photographic paper (Consumer Reports 2007). Consequently, inkjet printers dominate the residential printer market. If the first and per-page printing cost of color laser printers decreased appreciably, however, they might gain appreciable market share. This could increase residential imaging energy consumption because laser printers consume additional energy in ready and printing modes to heat the fuser roll (e.g., Nordman and Meier 2004).

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4.10 Exterior Lighting

Table 4-51: Exterior Lighting Summary

Characteristic	Result	Comments
Installed Base (fixtures) [millions]	258	75% household penetration, 3 fixtures per unit household
Market Penetration [% of Households]	75%	Many multi-family homes typically do not have individual outdoor lighting
Unit Electricity Consumption [kWh/year]	110	
UEC – Best in Class [kWh/year]	37	66% UEC reduction[42]
UEC Savings – Best in Class [kWh/year]	66%	
Annual Electricity Consumption [TWh/year]	28	

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[42] EnergyStar® claims an average of 66% energy reduction when exchanging incandescent lamps with CFLs.

Characteristic	Result	Comments
Peak Demand Impact	Low	Used after dark
Variability in Usage	High	
Notable Regional or Seasonal Variations in Penetration or Use?	Seasonal	Typically light use is inversely proportional to daylight hours
Typical Location(s) in Household	Front yard, front porch, back yard, driveway	
Potential Ways to Reduce UEC	Lamp technology (CFLs, HID lamps, LED lamps, solar lamps), motion detectors, and photocells	
Significant Data Uncertainties	Usage estimate, installed base	
Key Technology Trends	95% of residential exterior lamps are incandescent, although the market penetration of CFLs for exterior use is growing	

4.10.1 Introduction

The outdoor, or exterior, light fixture category is made up of porch lights, pathway lights, spotlights, landscape lights, post-mounted lights, or other fixtures located outside households. Each outdoor fixture may hold multiple lamps (also known as bulbs). Outdoor lighting is ubiquitous in single family homes, but the lack of exterior lighting outside multifamily homes causes the penetration of outdoor lighting to fall to 75% (Navigant Consulting 2002).

Navigant Consulting (2002) estimated that there were 4.6 billion total residential lamps in 2001 based on 107 million households, 319 million of which were outdoor lamps. Extrapolating this installed base estimate to 115 million households in 2006 gives 344 million outdoor lamps out of a total 5 billion. Additionally, the Heschong Mahone Group (HMG) (1999) estimated that there was an average of 1.33 lamps per outdoor fixture in California in 1997. Assuming that the national average mirrors this California estimate, and that the number of outdoor lamps per home has not appreciably changed, this source yields an estimated 258 million outdoor light fixtures in the U. S. in 2006 (see Figure 4-52).

Table 4-52: 2006 Outdoor Lamp Fixtures Installed Base

Installed Base [millions]	Penetration	Comments and Sources
258	75%	Navigant Consulting 2002, HMG 1999

Incandescent lamps constitute the lion's share of outdoor lamps, i.e., 98% of outdoor lamps were incandescent as of 2002 (Navigant 2002). 62% of all outdoor lights used standard incandescent lamps, 32% (of all outdoor lights) used reflector type incandescent bulbs, and 4% used halogen incandescent bulbs (Navigant 2002). The remaining 2% of outdoor fixtures is made up of screw base compact fluorescent lamps (CFLs) and high intensity discharge (HID) lamps.

The penetration of CFLs in residential lighting in general has grown (see portable lighting). For example, the 2004 RASS indicates that about 16% of exterior fixtures in California are CFL fixtures, while the 2005 California Satewide Lighing and Appliance Saturation Study (CLASS) estimated that 15% of porch lights in California are CFLs. However, California typically has had a higher rate of CFLs than the rest of the U.S. due to heavy promotion of their use. Furthermore, standard CFLs do not perform well in temperatures below 20°F without special cold weather ballasts. California would not be greatly affected by this limitation, where as colder climate customers may be wary of installing CFLs. Cold weather CFLs are rated for about 0°F operating conditions, although some have been tested successfully in temperatures down to -24°F (Home Energy 1995)

It is likely that the current distribution of lamps by technology mirrors the Navigant survey results, with a slight modification to increase the percentage of CFLs from 1% to 4%. The vast majority (95%) of installed lamps remain incandescent (see Figure 4-53). There is uncertainty related to the CFL and HID lamp installed base, but the energy consumption of outdoor lights is not significantly affected because these lamp types still make up a relatively low percentage of the total installed base.

Table 4-53: Installed Base of Outdoor Lamps by Lamp Type

Lamp Type	Installed Base [%]
Standard Incandescent	60%
Reflector Incandescent	31%
Halogen Incandescent	4%
CFL	4%
Mercury Vapor HID	1%

4.10.2 Unit and Household Energy Consumption

The average lamp power was calculated using a weighted average of different lamp types based on the installed base of each (see Table 4-54). Reflector incandescent and halogen incandescent are listed separately because they generally draw more power. HID lamps are more efficient than incandescent, but are typically also higher power lamps used for outdoor flood lights. The average outdoor lamp draws 80W which, combined with an average of 1.33 lamps per outdoor lighting fixture (HMG 1999), yields an estimated power draw per fixture of 107 W (see Figure 4-54).

Table 4-54: Outdoor Lamp Power Draw by Lamp Technology (Navigant Consulting 2002)

Lamp Type	Installed Base [%]	Avg. Power [W]
Standard Incandescent	61%	63
Reflector Incandescent	31%	102
Halogen Incandescent	4%	200
CFL	3%	18
HID	1%	179

Average per Lamp	100%	80
Average per Fixture	100%	107

The average household outdoor lighting fixture usage was calculated using a weighted average of usage by lamp type based on the percent of outdoor fixtures found in the respective household types (Navigant 2002). As show in Table 4-55, this calculation yields an average annual outdoor fixture usage of 1,020 hours per year, or about 2.8 hours per day. This is consistent with the estimate of just under three hours per day per outdoor fixture from HMG (1999).

Table 4-55: Outdoor Fixture Usage by Household Type (Navigant Consulting 2002)

Household Type	% of Total Fixtures	Active Usage [hrs/yr]
Mobile Home	8%	981
Single Family, Detached	80%	1,027
Single Family, Attached	12%	989
Multifamily	0%	0
Weighted Average	100%	1,020

The use of motion detectors, photo sensors, and timers make the off mode power draw of light fixtures nonzero. According to the California Residential Appliance Saturation Study (RASS) (2004), about 14% of households have at least one exterior light timer, 16% have one or more exterior photo sensor, and 25% have one or more exterior motion detector. It is unclear from the survey how many of these sensors are used in combination on single fixtures; a preliminary estimate is that approximately one quarter of exterior light fixtures have some sort of sensor or combination of sensors. One study presented power draw measurements for a sample of these sensors that indicate that motion detectors and photosensors draw around 1W (Ecos Consulting 2006). Given these standby mode power draw estimates, lighting sensors account for less than 2% of exterior lighting energy use.

The average unit electricity consumption of an outdoor light fixture is calculated to be 111 kWh/yr (see Table 4-56).

Table 4-56: Outdoor Light Fixture Average Power Draw and Usage by Mode

	Active	Off	Comments and Sources
Power Draw [W]	107	0.25	• Average of 80 W per lamp • Average of 1.33 lamps per fixture (HMG 1999) • 25% of fixtures use sensor control
Usage [hrs/yr]	1,020	7,740	Takes into account proportion of lamps with a sensor that continuously draws power
UEC [kWh/yr]	109	2	
HEC [kWh/yr]	334	6	Three outdoor fixtures per single family household (Navigant Consulting 2002)

The average energy use per household for exterior lighting is calculated to be 250kWh/yr, but this mean is lowered by multifamily homes that do not have outdoor lights. Detached single family homes make up 60% of households, and we estimate they have 3 outdoor fixtures (four outdoor lamps) (Navigant Consulting 2002), consuming 334 kWh per year. On average, exterior lighting accounts for 15% of the energy consumed by lighting in households that have exterior lights (Navigant Consulting 2002).

4.10.3 National Energy Consumption

The total annual energy consumption of outdoor lighting in the U.S. is estimated to be 29TWh (see Figure 4-57). Extrapolating NCI's estimate of total residential lighting energy consumption in 2001 based on the increase in households, 29 TWh equals approximately 13% of the total energy consumed by residential lighting.

Table 4-57: AEC Summary for Outdoor Lights

UEC [kWh/yr]	Installed Base [millions]	AEC [TWh]
111	258	29

4.10.4 Current Best in Class and Market Trends

Current CFLs could replace incandescent bulbs and provide immediate energy savings. Energy Star reports that an average EnergyStar® CFL will provide 66% energy savings relative to a comparable incandescent lamp (EnergyStar 2007). Efficacies for fluorescent lamps range from about 60 lumens/watt up to 100 lumens/watt compared to the standard incandescent lamp efficacy of about 12-18 lumens/watt; thus, a 20 to 25W CFL can supply the same light as a 100W incandescent lamp. However, up front costs and lack of consumer awareness has led to slow implementation of these technologies in outdoor applications (as well as indoor applications). Also, special CFLs are required for use in cold weather. Standard CFLs do not work well below 20°F, making them unattractive for outside lighting in colder climates. Cold weather ballasts can be used to improve the operating temperature, and some lamps have been tested successfully down to -24°F (Home Energy, 1995).

Motion detectors, photocell sensors, and timers can be used to reduce usage of exterior lights if applied to lamps that would otherwise remain active. However, applying only one sensor type to a light fixture may have detrimental effects on energy consumption. For example, a photocell sensor applied to a lamp would cause the lamp to remain on throughout the night, and therefore may or may not provide energy savings. A light fixture equipped with both a motion detector and a timer or a motion detector and a photocell sensor would provide the greatest energy savings for a lamp normally left on by minimizing the lamp usage. As mentioned previously, the 2004 RASS results indicate that about 14% of California households have one or more exterior light timer, 16% have at least one exterior photo sensor, and 25% have an exterior motion detector, although it is unclear how many of these sensors are used together on a single fixture. It is estimated that 25% of outdoor light fixtures have some sort of light sensor or sensor combination, so these controls devices have the potential to increase their market share. An important note, however, is that lighting controls will only conserve energy when used on a light fixture that is normally left on when not in use. For example, if a driveway lamp is normally left on all night, a photo sensor and a motion sensor may significantly reduce energy consumption. A flood light that is normally only turned on when in use may consume more energy if fitted with lighting controls.

The overall impact of controls on exterior lighting energy consumption is unclear. A secondary impact of using lighting controls is that they may restrict energy savings by deterring consumers from using fluorescent lamps. Many CFLs are not specified for use with motion detectors because frequent on/off switching shortens the CFL life. Photocell sensors must be chosen which are compatible with CFLs. Finally, CFLs with electronic ballasts may have problems with electronic timers (Oikos 2007).

HID lamps typically have not been used in a residential setting, but are commonly used in warehouses, arenas, and street lights. HID lamps generally take some time to warm up, an undesirable characteristic in residential lighting, particularly for lamps that switch on and off more frequently. However, lower power (35-100 W) metal halide (MH) HID lamps with electronic ballasts are becoming more common in residential environments (Advanced Buildings 2006). Pulse-start electronic ballasts offer quicker start and restart times, although still on the order of minutes. HID lamps can be several times more efficient than comparable incandescent lamps, but energy savings would only be realized if they were used for an application that requires high light output. HID lamps will likely continue to play a minor role in exterior residential lighting.

Solar power landscape lights are also currently available to consumers. These lamps charge during the day, and come on during the night hours. They produce relatively little light, and can be used for pathway or landscape lighting. They offer extremely easy installation, and obviously consume zero electric grid energy. However, the energy savings potential of outdoor solar lighting is unclear.

4.10.5 References

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4.11 Portable Lighting

Table 4-58: Portable Lighting Summary

Characteristic	Result	Comments
Installed Base [millions]	592	Number of portable fixtures
Market Penetration [% of Households]	Close to 100%	83% for table fixtures, 47% for floor fixtures, and 29% for torchiere fixtures (RLW 2005)
Unit Electricity Consumption [kWh/year]	54	
UEC – Best in Class [kWh/year]	18	66% average energy savings by replacing incandescent lamps with CFLs
UEC Savings – Best in Class [kWh/year]	66%	
Annual Electricity Consumption [TWh/year]	33	
Peak Demand Impact	Low	Peak residential lighting demand occurs ~7-8 pm
Variability in Usage	High	
Notable Regional or Seasonal Variations in Penetration or Use?	Seasonal Variation	Usage higher in winter due to shorter daylight and fewer outdoor activities
Typical Location(s) in Household	Bedroom, living room	48% of fixtures in bedrooms, 40% in living rooms (HMG 1999)
Potential Ways to Reduce UEC	Compact Fluorescent Lamps (CFL), dimmers, step switches, occupancy sensors	
Significant Data Uncertainties	Percentage of CFLs installed in portable fixtures	
Key Technology Trends	Incandescent lamps still dominate installed base, but CFL installations are climbing	

4.11.1 Introduction

Residential portable lighting consists of interior table and floor fixtures that are plugged into an electrical outlet (rather than hardwired) in a household. Portable light fixtures have a single plug, but may have multiple lamps (aka. bulbs) installed. Undercabinet fixtures are not counted although they may have plugs. Heschong Mahone Group (HMG) (1999) indicates that undercabinet lights make up less than 2% of residential light fixtures and less than 1% of residential lighting energy use.

The California Statewide Lighting and Appliance Saturation Study (CLASS) (RLW Analytics 2005) reported that there are 41 lamps per California home, up from 34 lamps per household in 2000, and that the ratio of lamps to light fixtures is approximately 1.8. NCI (2002) estimates a slightly higher number of lamps per household, i.e., 43 lamps per household. To arrive at a 2006 national estimate for light fixtures, the NCI total installed lamp estimate was scaled based on an increase in total residential floor space from 2001 to 2006, a scale factor of approximately 1.11[43] (AEO 2006). This calculation yields 5 billion lamps and 2.8 billion fixtures (using 1.8 lamps per fixture) in U.S. residences in 2005. According to the CLASS report, portable light fixtures accounted for approximately 21%

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[43] This scale factor is slightly greater than the ratio of households during the same period.

of all light fixtures in California homes. Applying this percentage to the entire U.S. gives an estimated 592 million portable light fixtures in 2006 (see Table 4-59). The CLASS further reports that of the total residential installed base, table lamps make up 15% of fixtures, floor lamps constitute 3.6%, and torchiere fixtures compose 2%. Torchiere fixtures are a type of floor fixture, but are broken into a separate category because they commonly use halogen lamps and typically have higher power draws than other indoor fixtures.

In general, lamps (portable and hardwired) installed in households are predominately incandescent, making up approximately 85% of all lamps, with fluorescent lamps accounting for the majority of the remaining lamps[44]. Portable light fixtures are also predominately populated with incandescent bulbs. However, compact fluorescent lamps (CFLs), a subset of the fluorescent category, are growing in popularity and screw-in CFLs accounted for approximately 10% of combined sales of filament and CFL lamps in 2006, up from around 5% only a year earlier (U.S. DOC 2006, Sanchez 2007). Notably, CFLs use appears to be greater in portable fixtures, likely because of the ease of replacing lamps and the significant, predictable, and cost-effective energy savings potential. Table 4-60 shows the penetration growth of CFLs in portable fixtures in California as estimated by RLW Analytics (2005). California had particular rapid growth of installed CFLs during the 2001 California energy crisis. We estimate that the national rate of CFL installations equals approximately half that of California based on estimated variation in sales penetration from PNNL (2006).

Table 4-59: Percentages of CFLs in Portable Fixtures

Fixture Type	California, 2000[45]	California, 2005[46]	TIAX Estimate for U.S.
Table	1.2%	15%	8%
Floor	1%	16%	8%
Torchiere	1.5%	10%	5%

Table 4-60 gives the installed base of different lamp technologies for different portable light fixtures, as well as the calculated totals. Halogen lamps, a subset of incandescent lamps, are relatively common in torchiere floor fixtures and tracked independently.

Table 4-60: Portable Lighting Fixture Installed Base Break Down

Fixture Type	Standard Incandescent [millions]	Halogen Incandescent [millions]	CFL [millions]	Total Portable Fixtures [millions]	% of Portable fixtures
Table	396	2	35	432	73%
Floor	90	4	8	102	17%
Torchiere	30	24	3	57	10%
Total Portable	516	30	46	592	
% of Portable	87%	5%	8%		

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[44] Less than 0.1% of installed lamps were high intensity discharge (NCI, 2002)
[45] From the 2000 CLASS (RLW Analytic 2000)
[46] From the 2005 CLASS (RLW Analytic 2005)

4.11.2 *Unit and Household Energy Consumption*

Table 4-61 displays the average power per fixture type reported in the CLASS, inclusive of the number of lamps found in the fixtures (RLW Analytic 2005). Torchiere fixtures have, on average, the highest wattage of any residential fixture. An adjustment was made to take into account that the U.S as a whole has a lower CFL penetration rate than California; his adjustment proved to have a minor impact on overall UEC and HEC.

Table 4-61: Portable Lamp UEC Values

Fixture Type	California Avg. Power per Fixture (CLASS 2005)	U.S. Avg. Power per Fixture (TIAX adjusted)	Avg. Lamps per Fixture (CLASS 2005)	Avg. Lamp Power (TIAX adjusted)
Table	67	68	1.1	60
Floor	90	91	1.5	61
Torchiere	165	172	1.1	153
Avg. Portable	80	82	1.2	69

Table 4-62 presents typical wattages for the relevant lamp technologies; they are household averages, and not specific to portable fixtures alone.

Table 4-62: Average Power Draw by Lamp Type (NCI 2002)

	Standard Incandescent	Halogen Incandescent	CFL
Average Power	63	200	14

Light dimmer switches and step switches would affect the average power draw of a portable fixture. The RASS (2004) results indicate that 4.5% of California fixtures inside homes have dimmer switches. However, data about step switches, data specific to portable fixtures, and data pertaining to how these switches are used are unavailable. Therefore, the affects of such switches are not included in these calculations.

Portable fixture usage was calculated by averaging the typical fixture usage for each room in a home based on the installed base of portable fixtures in each room (see Table 4-63). Torchiere lamps are assumed to have the same usage patterns as floor lamps. Based on this data, the average table and floor lamps operate 1.7 and 2.1 hours per day respectively. The overall weighted usage estimate for portable fixtures equals 1.8 hours per day, or 660 hours per year.

Table 4-63: Usage of Different Lamps by Location

Room	Usage per Day [hours][a]	% of Table Fixtures[b]	% of Floor Fixtures[b]	% of Portable Fixtures
Living Room	2.5	35%	61%	40%
Bedroom	1.1	52%	27%	48%
Den	1.7	6%	8%	7%
Kitchen / Dining Room	2.8	2%	2%	2%
Utility Closet	2	1%	0%	1%
Garage	1.5	1%	0%	0%
Porch	2.1	0%	1%	1%
Hall / Entry	1.5	1%	0%	0%
Bathroom	1.8	1%	0%	1%

[a] NCI (2002)
[b] HMG (1999)

The unit electricity consumption (UEC) for portable fixtures was calculated based on average usage and power estimates to be 54 kWh/yr (see Table 4-64). The UEC of floor fixtures is 70 kWh/yr (not including torchieres), 132 kWh/yr for torchieres, and 42 kWh/yr for table fixtures. Floor fixtures are more likely to use higher wattage bulbs, are more likely to house multiple lamps, and are most commonly found in the living room where usage is relatively high.

Table 4-64: Portable Lighting Average Power Draw and Usage by Mode

	Active	Off [W]
Power Draw [W]	82	0[47]
Usage [hrs/yr]	660	8100
UEC [kWh/yr]	54	0
HEC [kWh/yr]	238	0

Based on 592 million portable light fixtures and 115 million households in 2006, the round number of portable fixtures per household is 5, likely 4 table fixtures and 1 non-torchiere floor fixture. Therefore, the typical household energy consumption (HEC) for portable lights is 238 kWh/yr. Torchiere lamps are only in 29% of households according to the 2005 CLASS (RLW 2005). If a home has a torchiere fixture rather than a standard floor fixture, the HEC would jump by approximately 25%, to 300 kWh/yr.

4.11.3 National Energy Consumption

Table 4-65 summarizes the AEC calculation for portable lamps.

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[47] Timers and occupancy sensors could contribute an off mode power draw to a light fixture. The RASS (2004) results indicate that approximately 1% of indoor light fixtures have timers and another 1% have occupancy sensors, although it is unclear if these percentages also apply to portable lighting. Nevertheless, at present, the limited installed base of lighting controls has a negligible effect on portable lighting energy consumption.

Table 4-65: AEC Summary for Portable Lights

UEC [kWh/yr]	Installed Base [millions]	AEC [TWh]
54	592	32

4.11.4 Current Best in Class and Market Trends

Standard incandescent lights remain the dominant lighting technology in the residential sector. Compact fluorescent lights (CFL) have been available for 25 years and offer significant energy savings over incandescent bulbs, i.e., CFLs can draw an average of 67% less power than comparable incandescent lamps (Energy Star 2007). They are, however, still slow to penetrate the residential lighting market for reasons related to lamp performance, customer knowledge and perception, and initial lamp costs. Historically, customers have been unsatisfied with CFL problems such as hum, flicker, and poor light quality. Although many of these problems have been solved, customer perception has been slow to change. Homeowners are also deterred by the initial cost of CFL bulbs, even though increased lamp life (approximately 10 times longer than incandescent lamps; PNNL 2006) and energy savings make CFLs more cost effective than incandescent lamps.

CFL technology has improved, solving many of the earlier problems with CFLs, and retail prices have dropped significantly for several reasons (see PNNL 2006) Also, utilities have promoted the use of CFLs (particularly in the West and Northwest during the energy crisis in 2001), and EnergyStar® has a program for residential lighting to promote the use of high efficacy lamps as well as dimmers and step switches. Sales of CFL lamps have responded to these positive trends, increasing from 0.5% of light bulbs in 2000 to over 2% in 2002 (PNNL 2006). The installed base of CFLs is likely growing faster than the sales growth because CFLs last much longer than conventional incandescent lamps. As noted earlier, portable lamps have seen the most rapid growth of installed CFLs, likely because portable fixtures are very easy to retrofit with CFLs.

A significant potential for energy saving in residential portable lamps remains via the implementation of existing CFL technology. Multiple studies have concluded that residential lighting represents the largest achievable and economically sound energy savings opportunity in homes (e.g., Northwest Power and Conservation Council 2005, KEMA-XENERGY 2003, et al.). As consumer knowledge awareness improves about newer CFL technology, and as prices further drop, additional potential lighting energy savings will be realized.

Solid state lighting technologies such as light emitting diodes (LEDs) and organic light emitting diodes (OLEDs) show promise for future lighting energy savings. These semiconductor devices may offer efficacies 10 to 15 times that of incandescent bulbs as well as longer life (Brodrick 2004). However, significant technical improvements are still required to reach theoretical efficacies and bring costs down. Currently, LED lamps exist that are marketed as replacements for incandescent lamps. These LED "bulbs" come at a much higher price than the comparable incandescent and often do not perform as well (PNNL 2006).

Lighting controls such as dimmer switches and step switches can be used with portable light fixtures to save energy by allowing consumers to adjust the amount of light needed or, in the case of automated photosensor-based lighting controls, automatically adjusting electric light output to achieve a minimum acceptable indoor illuminance. In addition, occupancy sensors can be used to limit the light energy use in unoccupied (see, for example, TIAX [2005] for an assessment of automated occupancy- and photosensor-based lighting control systems as applied to commercial buildings). On the other hand, special CFLs are needed for dimmer and step switches. Also, CFLs are generally not specified for use with occupancy sensors because frequent on/off switching can reduce lamp life[48]. Finally, automated lighting controls often have longer payback periods in many commercial building spaces and are likely to face similar economic challenges in residences.

Task lighting is another tactic that can be employed in an effort to reduce overall household lighting energy. This strategy uses more fixtures with lower power lamps so that homeowners can better adjust the light to their needs. While this tactic may reduce overall household lighting energy consumption, it may increase the installed base and usage of portable lamps.

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[48] As described in TIAX (2005), the impact on lamp life depends on the ballast technology and switching time delay (i.e., the minimum time duration during which the sensor must not detect occupancy before switching off the circuit.

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4.12 Rechargeable Electronics

Table 4-66: Rechargeable Electronics Summary

Characteristic	Result	Comments
Installed Base [millions]	590	Total for products considered in this analysis; see Table 4-69
Market Penetration [% of Households]	>95%	Approximate estimate
Unit Electricity Consumption [kWh/year]	Varies by Device	
UEC – Best in Class [kWh/year]		
UEC Savings – Best in Class [kWh/year]		
Annual Electricity Consumption [TWh/year]	7.9	For all devices
Peak Demand Impact	Low	McAllister and Farrell (2004) survey data suggest that "the bulk of actual battery charging is accomplished in evening and early morning, typically off peak periods"
Variability in Usage	Not known	
Notable Regional or Seasonal Variations in Penetration or Use?	None known	
Typical Location(s) in Household	None	
Potential Ways to Reduce UEC	*Existing*: • Disconnect charger from mains when not in use • Use power strip with easily accessible on/off switch • Recharge device only when batteries are almost empty to maximize time chargers spent in *no-load* mode *Potential*: • Use of power-conscious integrated circuits such as the MSP430 to regulate power draw within chargers	
Significant Data Uncertainties		
Key Technology Trends	• Increase penetration of lithium ion batteries in rechargeable electronics	

4.12.1 Introduction

Rechargeable electronics run off of rechargeable batteries that are charged using mains power. The benefit of portability (light weight, operation anywhere without an outlet or plug) and convenience of not having to routinely replace batteries have made cordless rechargeable electronics popular in a wide range of products (see Table 4-67). Due to constraints on battery energy capacities relative to the size of products' form factors and power demands, however, most rechargeable electronics cannot produce relatively high levels of electrical power for prolonged periods of time. This limits the types of applications they can effectively serve. Notably, most are relatively small and light and their batteries are often fixed in place or can remain inside the device while charging. For example, many rechargeable electronics can be quickly docked and removed from their chargers for ease of accessibility. In addition, a considerable number of electronics run off of standard form factor (e.g. AA, AAA) NiCd or NiMH batteries that are removed from the device and recharge in stand-alone chargers. For such cases, the stand-alone charger is considered the rechargeable electronic device because it is the device where the power flows from the grid into the batteries. Many rechargeable electronics use an external power supply to convert AC mains power to DC power that provides power to the device and the battery charger unit. In some products, such as cell phones, PDAs and cordless power tools, that is sometimes integrated with the charger unit.

Due to the vast variety of rechargeable electronics, this report organizes and discusses them in three main functional categories: Information, Communication & Entertainment (ICE), Personal Care, and Home Appliances & Tools. Table 4-68 presents installed base estimates for different rechargeable electronics.

Table 4-67 Categories of Rechargeable Electronics and Examples

Information, Communication, & Entertainment (ICE)	Personal Care	Home Appliances & Tools
• Cordless Phone • Cordless Phone with Telephone Answering Device (TAD) • Cell Phone • Camcorder • Digital Camera • MP3 Player • PDA • Two-way Radio • Walkie-Talkie/Two-way radio • Rechargeable Toys	• Rechargeable Toothbrush • Cordless Shaver • Beard Trimmer • Cordless Hairdryer/styler • Cordless Massager	• Cordless Vacuum • Cordless Power tool • Cordless Handheld blender • Stand-alone Charger • Rechargeable Lawnmower

Table 4-68: Rechargeable Electronics Installed Base

	Device	Installed Base [millions]	Penetration [%]	Sources and Comments
ICE	Cordless Phone	122	83	CEA (2005), Bates (2006); Overall penetration of 83% for all cordless phones
	Cordless Phone w/ TAD	57		
	Cell Phone	200	71	CTIA (2006), CEA (2005a)
	Camcorder	64	57	CEA (2005)
	Digital Camera	3.7	<4%	CCAP (2005); applies to only rechargeable digital cameras
	PDA	21	14	CEA (2005)
	Rechargeable Toy	0.2	<1%	CCAP (2005)
	Two-way radio	23	20	CEA (2005)
	MP3 Player	23	15	CEA (2005)
	ICE subtotal:	464		
Personal Care	Rechargeable Toothbrush	9	6	CCAP (2005); units per household from McAllister and Farrell (2004)
	Shaver	28	25	CCAP (2005); includes products for men and women
	Trimmer/Clipper	7.7	7	CCAP (2005)
	Personal Care Subtotal:	45		
Home Appliances and Tools	Cordless Power Tools	51	45	EPA (2006) and Darnell (2005); estimate has significant uncertainty
	Standalone Battery Charger	8.6	7.5	CCAP (2005)
	Cordless Vacuum	21	18.5	CCAP (2005), based on stated seven-year life
	Rechargeable Lawnmower	0.005	0.004	CCAP (2005)
	Home Appliances and Tools Subtotal:	81		
	Grand Total	**590**		

4.12.2 Unit and Household Energy Consumption

When plugged into mains, rechargeable electronics primarily operate in one of four operational modes:

> *Disconnected*: The power supply and charger are disconnected from mains power
> *No-load*: The power supply is plugged in but the chargeable device is not connected to the charger
> *Charge Maintenance*: The chargeable devices is connected to the charger and the battery(s) are fully charged
> *Charging*: The charger is recharging partially-full or empty batteries.

It is important to note that cordless phone has an extra *active mode*, which is defined as when the handset is in use and communication with the charger base; in this case, the *no-load* mode is when the handset is not in use and removed from the base. The majority of rechargeable electronics spend, however, most of their time in charge maintenance or no-load mode due to the relative short amount of time spent recharging batteries.

Tables 4-69 and 4-70 present, respectively, estimates for power draw and annual usage by mode for many different types of rechargeable electronics. Most of the usage patterns for different devices, particularly for the most common and energy-intensive devices, came from McAllister and Farrell (2004). They carried out in-person interviews of the occupants of 34 randomly selected households in the Pacific Gas & Electric service area to develop information to model device weekday and weekend usage patterns for a population of 286 rechargeable devices. The profiles were aggregated by device category and by household to determine overall usage patterns. The study discovered that most of the devices are typically in *charging* mode during off peak periods, i.e., evening or early morning. Alternately, if survey-informed usage estimates from McAllister and Farrell (2004) were not available, informed estimates from CCAP (2005) were used.

Many of the power draw by mode estimates also come from measurements made by McAllister and Farrell (2004) in the same households where they performed the usage surveys. Due to small sample sizes (ranging from 2 to 12 units for each type of device), the power draw estimate have an appreciable degree of uncertainty. In general, the authors of the current study invested more effort in developing power draw and usage estimates for devices that appear to consume more energy, notably cordless phones and power tools.

Table 4-69: Rechargeable Electronics Power Draw by Mode

Device		No-Load [W]	Charge Maintenance [W]	Charging [W]	Sources
ICE	Cordless Phone	2.3	3.1	4.0	TIAX (2007)
	Cordless Phone w/ TAD	2.8	3.8	4.4	TIAX (2007)
	Cell Phone	0.3	0.52	2.6	Foster Porter et al. (2006b)
	Camcorder	0.37	0.39	9.6	McAllister & Farrell(2004)
	Digital Camera	0.4	0.4	3	McAllister & Farrell(2004), Foster Porter et al. (2006a)
	PDA	0.58	0.61	4.7	McAllister & Farrell(2004)
	Rechargeable Toy	1.0	4.9	6.0	CCAP (2005), Foster Porter et al. (2006a)
	MP3 Player	0.26	0.62	3.7	McAllister & Farrell(2004)
Personal Care	Rechargeable Toothbrush	1.7	1.6[49]	1.7	McAllister & Farrell(2004)
	Shaver	0.3	0.68	2.3	McAllister & Farrell(2004), Foster Porter et al. (2006a)
	Trimmer/ Clipper	0.3	0.68	2.3	Assumed to be similar to shavers
Home Appliances and	Cordless Power Tools	0.9	3.6	15.9	McAllister & Farrell(2004)[50]
	Standalone Battery Charger	1.1	3.1	11.8	McAllister & Farrell(2004), Foster Porter et al. (2006a)
	Cordless Vacuum	0.8	3.7	4.7	McAllister & Farrell(2004)
	Rechargeable Lawnmower	10	6.5	40	CCAP (2005)

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[49] The difference between charging and charge maintenance modes may not appear to be real.

[50] Foster Porter et al. (2006) has a significantly higher value for no-load mode (2.5W versus 0.9W).

Table 4-70 Rechargeable Electronics Power Usage Pattern

Device		Usage				
		No-Load [hrs/yr]	Charge Maintenance [hrs/yr]	Charging [hrs/yr]	Source/ Comments	UEC [kWh/yr]
ICE	Cordless Phone	2,015	5,694	701	Rosen et al. (2001); UEC value includes active mode (350 hours)	26
	Cordless Phone w/ TAD					31
	Cell Phone	175	7,446	438	Ostendorp et al. (2004); an additional 701 hours disconnected	3.5
	Camcorder	**	**	**	McAllister & Farrell (2004)	2.3
	Digital Camera	**	**	**	McAllister & Farrell (2004)	7.2
	PDA	**	**	**	McAllister & Farrell (2004)	6.1
	Rechargeable Toy*	1,351	1,351	803	CCAP (2005)	13
	MP3 Player	**	**	**	McAllister & Farrell (2004)	5.6
Personal Care	Rechargeable Toothbrush	**	**	**	McAllister & Farrell (2004)	11.5
	Shaver	**	**	**	McAllister & Farrell (2004)	1.0
	Trimmer/ Clipper*	**	**	**	Assumed to be similar to shavers	1.0
Home Appliances and Tools	Cordless Power Tools	**	**	**	McAllister & Farrell (2004)	16
	Standalone Battery Charger	**	**	**	McAllister & Farrell (2004)	1.3
	Cordless Vacuum	**	**	**	McAllister & Farrell (2004)	41
	Rechargeable Lawnmower	1,241	7,373	146	CCAP (2005)	66
	* Hours do not sum to 8,760 due to rounding and do not take into account the time spent disconnected **UEC and usage pattern based on 24 hours load curve for common chargers from McAllister & Farrell (2004) fig 2. p.11-113					

In general, ICE products tend to spend more time in *no-load* mode than personal care and home appliances and tools categories; for those devices, the *charge maintenance* mode is more predominant. This likely reflects that ICE devices, such as cell phones, MP3 players, and PDAs, are used more and often accompany their owners when they leave the home. As a result, ICE devices tend to be used more outside the home and additional charging may occur at work or in cars.

Assuming 113 million households, the estimated installed bases translate to about 1.1 cordless phones, 0.5 cordless phones with answering machine, 1.8 cell phones, and, in total, 5.2 rechargeable electronics ownership per household. This is broadly comparable to the values from McAllister and Farrell (2004) who estimated about 6.6 rechargeable electronics of similar type[51] per household, with 1.6 cordless phones and 1.7 cell phones.

4.12.3 National Energy Consumption

Table 4-71 summarizes the AEC calculations for the rechargeable electronic devices analyzed.

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[51] McAllister and Farrell (2004) includes devices that are addressed in different sections of the report, such as notebook PCs, security systems, emergency/utility light and other rechargeable devices (e.g. toys, digital comm. Personal transport power systems, safety equipment and a variety of other uncommon devices).

Table 4-71 AEC Summary for Rechargeable Electronics

Device Category		UEC [kWh/yr]	Installed Base [millions]	AEC [TWh]
ICE	Cordless Phone	26	122	3.2
	Cordless Phone w/ TAD	31	57	1.8
	Cell Phone	3.5	200	0.7
	Camcorder	2.3	59	0.1
	Digital Camera	14[52]	3.7[53]	0.06
	PDA	6.1	21	0.1
	Rechargeable Toy	12.4	0.2	0.003
	MP3 Player	5.6	3	0.02
			Subtotal:	6.0
Personal Care	Rechargeable Toothbrush	11.5	9	0.1
	Shaver	1.0	28	0.03
	Trimmer/ Clipper	1.0	7.7	0.008
			Subtotal:	0.14
Home Appliances and Tools	Cordless Power Tools	16.1	51	0.8
	Standalone Battery Charger	1.3	8.6	0.01
	Cordless Vacuum	40.6	21	0.9
	Rechargeable Lawnmower	66.2	0.005	0.0003
			Subtotal:	1.7
			Total:	**7.9**

It can be seen that cordless phone account for about a third of the total AEC of rechargeable electronics.

Overall, it is probably that the overall installed base of rechargeable electronics will increase in the future due to continued growth in existing rechargeable electronics (e.g., cell phones, flashlights) and the development of new cordless products (e.g., kitchen appliances). In contrast, the installed base of the rechargeable electronics category accounting for the largest portion of energy consumed, cordless phones, could begin to decrease as the number of landlines continues to decrease.

4.12.4 Current Best in Class and Market Trends

Table 4-72 summarizes the approximate energy savings from best-in-class products for a few representative rechargeable electronics products. These estimates are based on limited data and typically take into account the power draw in only a single mode. Thus, devices that consume less energy very likely exist.

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[52] Estimated to be roughly double the UEC calculated by McAllister and Farrell (2004), as the power draw in no-load and maintenance modes used is double their values and these two modes are assumed to account for most energy consumption.

[53] Units with integral rechargeable battery.

Table 4-72 Best in Class UEC for Selected Rechargeable Electronics

Device	Best in Class power draw and UEC				Original UEC [kWh/yr]	Energy Savings [%]	Source/ Comments
	No-Load [W]	Charge Maintenance [W]	Charging [W]	UEC [kWh/yr]			
Cordless Phone	2.3*	3.3	4.0*	27	26	-4%	EnergyStar® (2006b) minimum; analog
Cordless Phone	2.3*	1.3	4.0*	16	26	39%	Lowest no-load from EnergyStar® dataset[54]
Cordless Phone w/ TAD	2.8*	4.0	4.4*	33	32	-4%	EnergyStar® (2006b) minimum; analog
Cordless Phone w/ TAD	2.8*	1.5	4.4*	19	32	41%	Lowest no-load from EnergyStar® dataset[55]
Cell Phone	0**	0**	2.6	2.4	1.1	67%	Lowest no-load from Ostendorp et al. (2004)
Cell Phone	0.3	0.52	2.6	2.3	3.5	32%	Half of time in maintenance mode unplugged
Power Tools	0.9	3.6	15.9	11[56]	16	32%	Lowest no-load from Foster Porter et al. (2006a)

*Assumed same as typical device
**Value of 0 shown; actual value may be greater than zero but not resolved in measurements

Interestingly, cordless phones meeting the EnergyStar® minimum performance threshold for maintenance mode do not appear to realize savings relative to an average device in the installed base. On the other hand, the EnergyStar® database shows that the products with the lowest power draw in maintenance mode can realize energy savings of approximately 40% relative to the installed base.

The energy consumption characteristics of battery chargers intended for the same applications can vary significantly with the model of the charger (Foster Porter et al. 2006a). To address this efficiency opportunity, the voluntary EnergyStar® program includes a specification for battery chargers. Quoting EnergyStar®, “to be eligible for ENERGY STAR qualification, a battery charging system must not exceed a maximum Nonactive Energy Ratio, which is based on the nominal battery voltage (V_b). The maximum allowed Nonactive Energy Ratios are provided below for select battery voltages.” The Nonactive Energy Ratio (ER) equals the ratio of the accumulated nonactive energy (E_a), which is the energy in watt-hours consumed by the battery charger in *charge maintenance* mode over a 36-hour period plus energy consumed by the battery charger in *no-load* mode over a 12-hour period, divided by the battery energy (E_b). The Nominal

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[54] See: http://www.energystar.gov/index.cfm?fuseaction=find_a_product.showProductGroup&pgw_code=CL .
[55] See: http://www.energystar.gov/index.cfm?fuseaction=find_a_product.showProductGroup&pgw_code=CL .
[56] Based on an approximate usage profile of 65% of time spend in no-load mode and 35% spent in maintenance mode estimated from a plot shown in McAllister and Farrell (2004).

Battery Voltage (V_b) is industry standard cell voltage multiplied by the number of cells in the battery pack, normally listed on battery packaging. For intermediate voltages, the battery charging system must not exceed the maximum Energy Ratio associated with the next highest voltage represented in the Table 4-73 (EnergyStar 2006a). Although a rigorous savings potential is difficult to estimate, the program estimates savings of approximately 35% for compliant devices[57].

Table 4-73 Energy Performance Criteria for Common Battery Voltages taken from EnergyStar® (2006a)

V_b	**1.2**	**2.4**	**3.6**	**4.8**	**6.0**	**7.2**	**8.4**	**9.6**	**10.8**	**12.0**
ER	20.0	16.9	13.7	11.6	9.6	7.5	7.0	6.5	6.1	5.6
V_b	**13.2**	**14.4**	**15.6**	**16.8**	**18.0**	**19.2**	**20.4**	**21.6**	**22.8**	**≥ 24.0**
ER	5.1	4.5	4.3	4.2	3.8	3.6	3.5	3.3	3.2	3.0

A simple way to reduce energy consumption attributed from rechargeable electronics is to unplug the charger from mains when not recharging the devices, which is physically impractical and not an option for devices such as cordless phones. However, connecting some chargers to power stripes with an easily accessible on/off switch could to a certain extent facilitate this. Another possibility is to incorporate low-power integrated circuits such as the TI MSP430 to power up and down the electronics within the charger depending on whether a devices is connected to the charger. Taking the case of cell phone whereby if a typical user disconnects the charger when s/he is away from the home (assuming 8 hours/day or 2,920 hours/year less time in *no-load* mode) would decrease the UEC by about 20%.

Another energy-saving strategy is to capitalize on the fact that rechargeable electronics tend to consume the least amount of power during *no-load* mode. Therefore, any means to maximize the amount of time spent in *no-load* mode and, in turn, minimize the amount in *charge maintenance* and *charging* mode, both of which consumes the most amount of power, will translate into energy savings. One example could be to include battery capacity indicators on rechargeable electronics which will facilitate users to recharge their devices only when their batteries are almost empty. Such battery capacity indicators are already prevalent in devices under the ICE category (albeit with limited accuracy of resolution), but less so in devices in the other categories.

Increasing the efficiencies of external power supplies would help to reduce rechargeable electronics energy consumption. In general, quantifying the baseline energy performance of external power supplies has proven challenging due to the wide variety of products using EPSs, the rapid turnover of many ICE products, and the ongoing migration[58] from (typically) less efficient linear EPSs to (typically) more efficient switchmode EPSs. Nonetheless, opportunities for savings exist. Furthermore, reducing the no-load (i.e., plugged in but not connected to a load) power draw of most EPSs to the California levels

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[57] See: http://www.energystar.gov/index.cfm?c=battery_chargers.pr_battery_chargers .

[58] For example, Darnell (2005) estimates that the unit-based market share of switchmode EPSs has increased from 54% in 2000 to 75% in 2005, and is projected to increase to 84% circa 2010.

of 0.5W of 0.75W[59] will result in savings for some portion of the installed base of rechargeable electronics.

There are four common electrochemical systems used in rechargeable batteries: lead-acid, nickel metal hydride (NiMH), nickel-cadmium (NiCd) and lithium ion. The market share of lithium ion batteries continues to increase due to their higher energy-to-weight ratio. Lithium ion also has advantages from an energy saving standpoint. Firstly, it has an extremely slow self-discharge rate (i.e., the gradually lost of charge that occurs even when batteries are not used) compared to NiMH and NiCd, which require trickle charging to maintain full capacity. Secondly, being more sensitive to overcharging, over discharging and other environmental factors (e.g., heat and pressure), Li-ion cells requires safety devices that can also save energy, most notably controls for smart charging and discharging. The controls shut down the charging circuit when the battery is charged above or discharged below a predefined threshold. Overcharging will cause a lithium ion cell to become chemically unstable and over discharging can render the battery unserviceable and recharging on a regular charger will no longer be possible. Smart charging and discharging could also be implemented in NiNH and NiCd batteries, but since those types of batteries are less sensitive to overcharging, such safety precautions are not necessary and are often omitted to avoid their cost.

With the advantages of lithium ion technology, it is foreseeable that more devices would use lithium ion batteries. For example, cordless phones (which primarily use NiMH), might begin to adopt to use lithium ion batteries to take advantage of their very slow self-discharge rate to prolong operational times when users leave the handset off their bases for a prolonged period.

4.12.5 References

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[59] 0.5W for EPSs with a rated output power draw of 10W or less and 0.75W for other devices. In 2008, most EPSs sold in California must draw 0.5W or less in no-load mode.

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4.13 Home Security Systems

Table 4-74: Home Security System Summary

Characteristic	Result	Comments
Installed Base [millions]	27	Estimate primarily based on Parks and Mikelk (2005)
Market Penetration [% of Households]	24	
Unit Electricity Consumption [kWh/year]	61	Has high uncertainty
UEC – Best in Class [kWh/year]	13	Has high uncertainty
UEC Savings – Best in Class [kWh/year]	48	
Annual Electricity Consumption [TWh/year]	1.6	
Peak Demand Impact	Low	Approximately constant load throughout day
Variability in Usage	Very Low	
Notable Regional or Seasonal Variations in Penetration or Use?	Yes	Home security system are much more common in single-family homes than multi-family units
Typical Location(s) in Household	Yes	Control unit and keypad are usually situated inside near the front or rear door where home owner can easily arm the system prior exiting his/her home; sensors typically located around windows and doors

Characteristic	Result	Comments
Potential Ways to Reduce UEC	*Existing*: - Maximize usage of passive sensor versus active sensors *Potential*: - Reduce energy consumption of home security system components, such as: more efficient power, more power-conscious electronics and microcontrollers within control units	
Significant Data Uncertainties	Lack of data from actual measurements of current hard-wired security systems	
Key Technology Trends	- Web-enabled and remote access of home security systems - Potential integration with other home control systems such as lighting, HVAC, and entertainment	

4.13.1 Introduction

Many commercial buildings have security systems and they are becoming increasingly common in residences. Typically, home security systems consist of a central control unit with a keypad, a network of sensors to detect intrusion, audible and/or visual alarms, backup battery, and an external power supply (for those not connected to mains power). Motion sensing is the main method of detection of intruders for most home security systems using passive infrared (PIR) sensors; they detect rapid changes of infrared energy within their field of view. In order to mitigate false positives, e.g., due to the movement of wild animals and pets, the electronics associated with these sensors can be programmed with heuristics that hone into physical characteristics specific to an adult intruder, for example height, weight, body temperature, rapid movements (Stealth Labs 2006). Furthermore, dual tech sensors, which are PIR sensors incorporated and/or supplemented with one or more other types of sensors such as microwave, ultrasonic, infrasonic, volumetric, audio, proximity, geophonic, piezoelectric and vibration (Beletich and Ellis 2004) increase the sensitivity of home security systems while decreasing false positives.

In addition to the basic components, there are numerous devices and accessories that can augment home security systems, making them highly customizable and configurable. Examples include cameras, remote monitors, smoke detectors, glass break detectors, panic buttons, pressure mats, and alarm screens for windows that incorporate a wire woven in their mesh that activates an alarm when cut or removed (City of Scottsdale 2006). In addition, most include a connection to a remote monitoring central office that notifies the home owner and the police of a security breach (Home Security Systems 2006).

Home security systems use either mains power or power from a 12-26DC external power supply (Australian Government 2005). The former is usually and more easily installed in new construction while the latter is commonly retrofitted into existing homes.

Table 4-75: Home Security System Installed Base

Installed Base [millions]	Penetration [%]	Comments and Sources
27	24%	Parks and Mikelk (2005)

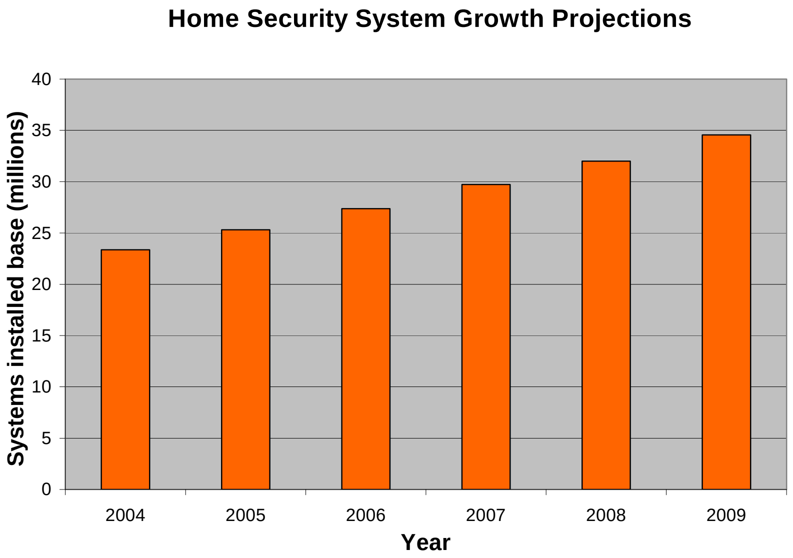

Figure 4-15: Home Security System Growth Projections (from Park and Mikelk 2005)

4.13.2 Unit and Household Energy Consumption

Table 4-76: Home Security System Power Draw by Mode

	On	Active-Standby	Passive-Standby	Comments and Sources
Power [W]	N/A	7	7	Power draw data from McAllister and Farrell (2004), Australian Government (2005), Nordman and McMahon (2004), and Parker (2006), as well as analytical estimates using component current draw of several home security system products (see Tables 4-77 and 4-78); usage estimate from Huber (1997)
Usage [hr/yr]	0	4,990	3,770	
UEC [kWh/yr]	0	35	26	

Home security systems have three modes of operations: *on* (when alarm is sounding), *active standby* (when system is armed ready to detect an intrusion) and *passive standby* (when system is disarmed)[60]. Often, systems draw about the same level of power in the two standby modes due their similar system functionalities (Australian Government 2005). For the most part, it is assumed that home security systems usually operate in a standby mode, armed (active standby), when the home owner is asleep or out of his/her home or disarmed (passive standby) when the home owner is at home during the day. The amount of time within a year in which the alarm goes off, i.e., when the home security system is in on mode, is assumed to be negligible from an energy consumption standpoint.

The power draw estimate of home security systems in standby mode has an appreciable degree of uncertainty due to wide range of components, number of sensors, additional accessories/devices, configurations and functionalities that can make up a system. More importantly, there is a lack of data from actual measurements of current home security

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[60] Security systems tend to not have an off mode.

systems. One source sites a household survey that includes measurements for four hard-wired systems with an average power draw of 5.3W (Australian Government, 2005, from NAEEC 2001). In addition, measurements of three home security systems with battery chargers yielded an average power draw of 4.7W during battery maintenance mode[61] from McAllister and Farrell (2004) measurement of 3 home security system battery chargers, which primarily charges the control units and keypads.

Both of these values are similar to the values estimated by adding up the power draw of the various components of home security systems, as shown in Table 4-77 (5.9W) and Table 4-78 (5.10W-7.65W). Overall, the control unit and keypad consume the most power compared the other basic component of home security systems.

Table 4-77: Estimated Alarm System Power Draw (from Australian Government 2005)

Component	Standby Power (W)	No. Per system	Subtotal Standby Power (W)	Comments
Control Panel+ Keypad (battery fully charged)	4.0	1.0	4.0	Power draw data for PIR and dual tech sensors was taken from a sample of manufacturer specification sheets. The average power draw is calculated for each model by weighting the quiescent and 'with motion' power draw by 90% and 10% respectively. Across al models, the average power for PIR sensors was 0.13W and for dual tech sensor was 0.2W
Power Supply	1.4	1.0	1.4	
PIR Sensor	0.13	3.0	0.4	
Dual Tech Sensor	0.20	0.2	0.04	
Total Power			***5.9***	

Table 4-78: System Component Amperages and Power Draw from a Major Security System Manufacturer

	System 1	System 2	System 3	System 4	System 5	# Components	Comments
Controller [Amps]	0.135	0.135	0.105	0.275	0.275	1	12V DC external power supply, and 80% external power supply efficiency[62]
Console [Amps]	0.035	0.035	0.035	0.035	0.035	1	
Expansion Enclosure [Amps]	0.08	0.08	0.08	0.08	0.08	0	
Serial Interface [Amps]	0.04	0.04	0.04	0.04	0.04	1	
Touch Screen [Amps]	0.3	0.3	0.3	0.3	0.3	0	
Per Trigger Relay Module [Amps]	0.04	0.04	0.04	0.04	0.04	4	
TOTAL [Amps]	0.37	0.37	0.34	0.51	0.51		
TOTAL Watts, w/o External Power Supply (EPS)	4.44	4.44	4.08	6.12	6.12		
TOTAL Watt, with EPS	***5.55***	***5.55***	***5.10***	***7.65***	***7.65***		

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[61] According to (McAllister and Farrell, 2004), "maintenance mode I when the charger is plugged in, battery inserted in the charger, battery fully charged. A continuous small charge may be applied to the batter whenever in place. This mode dominates in devices that are plugged in 24 hours". For all of the standby mode values in this report, it is assumed that home security systems are always in battery maintenance mode from a power draw stand point.

[62] Data shown in Table 4-78 (from Australian Government 2005) suggest an external power supply efficiency of 76%.

Currently, EnergyStar® does not yet cover home security systems, but it does cover some components that makeup home security systems, including battery chargers and external power supplies, as do the recently approved California regulations for external power supply efficiency. Both will tend to reduce the power draw of home security systems, as would an EnergyStar® specification specifically for home security systems.

4.13.3 National Energy Consumption

Table 4-79 AEC Summary for Home Security Systems

UEC [kWh/yr]	Installed Base [millions]	AEC [TWh]	Comments and Sources
61	23	1.4	

Park and Mikelk (2005) projects that the installed base of home security system will grow by close to 50% from 2004 to 2009 (see Figure 4-15). Factors influencing the configuration and particularly the installed based of security systems include dwelling type, square footage and income of the household. For example, a statewide survey in California found that the penetration of home security systems in single-family homes is almost twice that in town houses, duplexes, and row homes, and approximately six times greater than in apartments. Similarly, the prevalence of security systems increases dramatically with both income and home square footage (CEC 2004).

4.13.4 Current Best in Class and Market Trends

Using the best in class home security system drawing 1.5W of power derived from a limited data set produced in 2001 for Australia (sample size of 5 measurements, from NAEEC 2001) would have an UEC of about 13 kWh. This represents more than an 80% reduction relative to the current estimate of 61 kWh. It is not clear, however, if this unit is available in the U.S.; consequently, this best-in-class value has significant uncertainty.

It is possible to reduce the energy consumption of components used in security systems, particularly those that consume the most energy, i.e., control units/keypads and power supplies. This can be done by using more efficient power supplies. For example, an 85% efficient external power supply would reduce home security system power draw by approximately 10%. In the case of control unit and keypads, increased use of low-power electronics and microcontrollers such as the MSP430 whose current draw is less than 2µA (TI 2005) a little over 6.5µW in terms of power draw in sleep mode (assuming running off of a 3.3V system). Replacing microcontrollers in the control panels, which typically draw about 10-20mA (~0.2W in a 12V system) with integrated circuits such as the MSP430 could translate to about 1-2% in energy savings for a typical home security system unit. The LCD screens of control units would probably consume the most power (~3.5W for the touchscreen in Table 4-78, roughly at least half of unit power draw), but have the potential to be intelligently turned off or put in a low-power mode when its associated electronics are tied to microcontrollers such as the MSP40. Given that occupants do not interact with the LCD screen most of the time, such an approach would have a significant energy savings potential in units with lit displays. Additionally, writing more power-conscious programs embedded in microcontroller using the following techniques can reduce computational load and could reduce power draw by about 0.05-0.1W, potentially 1% in energy savings: minimizing sampling rates; taking advantage of hardware interrupts to flag events rather than using a software flag variable, avoided nested software subroutine calls; perform calculations using lookup tables versus conventional operators such division, trigonometry etc.; maximize the duty cycle in which the microcontroller is in sleep mode; turn off pins and peripherals when they are not in use.

Another area where there are energy saving potential is in the sensors. Active sensors, even though tend to be more sensitive and accurate, usually draw more power because they emit some sort of energy, be it light/sound, into the environment to make detection possible. Consequently, maximizing the use of passive sensors where possible would reduce the overall energy consumption of home security systems. The energy saved would be the power draw of the active sensors (at least a couple of watts) being eliminated. Because passive components account for most home security systems sensors, this would likely not result in significant energy savings.

There is a lot of room for advancement for home security systems in the future. The penetration of broadband access as well as the convergence of consumer electronics with the PCs (Park and Mikelk 2005), has established the infrastructure for home security systems and their associated accessories, most notably cameras, to become web-enabled and integrated with computer systems. This functionality allows home owners to remotely monitor, access real-time information, and control the systems from their PCs or wirelessly from cellphones, PDAs and notebook PCs. Furthermore, there has long been a slow movement towards a whole home control system, where home security would be integrated with other systems such as lighting, HVAC and entertainment (Steen 2005). Such a notion, however, has not yet been fully embraced by the mass market due to lack of awareness, installation expenses (Steen 2005), and technical and user interface complexities (Park and Mikelk 2005) when unifying multiple home control systems. This same functionality could also be extended to enable occupants to monitor and control home energy-consuming equipment if that equipment (notably air conditioners, furnaces or heat pumps, and water heaters) became networked. There might be beneficial implications for energy consumption that a unified home control system might bring through more efficient allocation and distribution of resources. For instance, enabling/arming the home security system can automatically disable the entertainment system) as well as reducing redundant interfaces (e.g., one shared control panel for whole home control system).

4.13.5 References

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4.14 Set-Top Boxes (STBs)

Table 4-80: Summary Table for Set-top Boxes

Characteristic	Cable	Satellite	Stand-alone PVR	Comments
Installed Base [millions]	77	70	1.5	
Market Penetration [% of Households]	45%	25%	1%	
Unit Electricity Consumption [kWh/year]	133	129	237	
UEC – Best in Class [kWh/year]	104	83	57	
UEC Savings – Best in Class [kWh/year]	29	46	180	
Annual Electricity Consumption [TWh/year]	10	9	0.4	
Peak Demand Impact	Low			
Variability in Usage	High			
Notable Regional or Seasonal Variations in Penetration or Use?	n/a			
Typical Location(s) in Household	Living room, Bedroom			
Potential Ways to Reduce UEC	Automatic low-power or sleep mode			
Significant Data Uncertainties	Best in class power requirements			
Key Technology Trends	• Digital STBs to replace all analog devices • Increasing installed base of cable, satellite, and stand-alone PVRs			

4.14.1 Introduction

There is a growing demand for set-top boxes (STBs) in the United States, including cable boxes, satellite receivers/tuners, and stand alone personal video recorders (PVRs) (a.k.a. digital video recorders (DVRs)). The Federal Communications Commission (FCC) has mandated that all broadcast television switch from analog to digital by 2009. When this switch occurs, every analog TV in the U.S. will need a STB of some sort. Analog cable boxes are the one STB that will not see sales growth; instead, they will become obsolete. The number of installed STB will see a sudden surge during the analog to digital switch as consumers purchase digital to analog converters (DTAs, a.k.a., digital television converters (DTCs)) for their analog TVs.

Approximately 86% of households subscribe to a multichannel video programming distributor (MPVD) (e.g., cable, satellite, etc.; FCC 2006) Cable subscriptions make up the largest portion of these MPVD offerings, accounting for 69% of MPVD subscriptions. However, most TVs are equipped to receive standard analog cable signal without a STB (i.e., the cable is connected directly to the TV). Premium cable services often require a STB, which is generally leased by the service provider. Digital cable subscription also require a STB, and the number of digital subscribers is growing due to the additional offerings provided by digital cable as well as the narrowing gap in cost. Digital TVs with point of deployment (POD) slots can use POD modules (such as CableCARD) rather than a digital STB, but relatively few installed TVs currently offer this technology.

Digital Broadcast Satellite (DBS) TV subscribers each have a wireless receiver/tuner STB to accompany their satellite dish. All satellite programming is transmitted digitally, and the receiver/tuner unscrambles the signal, and then converts it to analog or tunes it for high-definition viewing depending on the type of TV the customer owns. Non-cable multichannel video programming distributor subscriptions grew 13% from 2004 to 2005, with DBS subscriptions making up the majority of that growth (FCC 2006).

PVRs are STBs that allow users to digitally record, organize, and store recordings of TV programs on an internal hard disk. These STBs offer a new level of control over TV viewing, allowing users to watch recorded programs at a later time, as well as pause, fast forward, and rewind as they please. Both cable and satellite service providers offer STBs with PVR functionality, which are generally leased to customers. Stand-alone PVR products such as TiVo are also available for consumers to buy, but are less common than the cable and satellite provider PVRs.

We did not analyze other STBs because their current market penetration will not significantly affect the overall STB energy consumption. DTAs are likely to see rapid installed base growth in 2009 when the broadcast TV signal goes digital. Internet protocol (IP) STBs are required to receive broadband telephony service such as video-over-DSL, but their installed base in the U.S. is still relatively low.

We used prior research and sales data were used to generate the estimate of STB installed base and the breakdown of STB sub-categories in TIAX (2007). Table 4-81 displays the installed base estimates.

Table 4-81: STBs Installed in the U.S. (in millions)

	Cable	Satellite	Stand Alone	Total
Analog STB	28	n/a	n/a	28
Digital STB	42	61	n/a	102
HD Digital STB	1.0	1.4	n/a	2
PVR Digital STB	4	6	1.5	12
HD PVR Digital STB	1.0	1.4	n/a	2
Total	77	70	2	148

Amann (2004) estimated that there were 30 million analog STBs in 2003. Kagan Research, LLC (2004) projected that less than 2 million subscribers would convert from analog to digital STBs from 2004 to 2006, which equates to just over 2 million STB units. Therefore, we estimate an installed base of approximately 28 million analog STBs. Kagan Research (2004) also projected that there would be approximately 48 million digital cable STBs, and approximately 1.5 units per subscriber household. Limited shipment data indicate that from 2001 to 2006 approximately 11% of STBs shipped had PVR capability

(CEA 2006). The same source suggests that 4% of STBs offered HD[63]. We also applied these percentages to digital cable STBs to arrive at the breakdowns in Table 4-81.

In 2006, there were approximately 29 million digital broadcast satellite (DBS) subscribers based on an extrapolation of the Federal Communication Commission's estimate of 26 million in 2005 (FCC 2006). According to an industry representative, each subscriber has an average of 2.4 STBs per DBS household, yielding 70 million total DBS STBs. As with the cable STBs, we estimate that 11% of the units provide DVR capability, and 4% are estimated to be HD compatible.

Stand-alone PVR STBs (dominated by TiVo products) account for approximately 1.5 million of the installed PVRs (Kagan Research 2004).

4.14.2 Unit and Household Energy Consumption

STBs can be characterized by two operating modes:

- *Active*: The STB is plugged in and performs functions for the user, such as video signal processing, PVR recording or playing, and providing signals to multiple TVs
- *Off-Ready:* The STB is plugged in and switched off by the user. However, it continues to receive data from and/or send data to the service provider.

An additional Off-Sleep mode could be used to define a lower power mode when a STB is plugged in but neither provides user functionality nor exchanges data with the service provider. Typically, today's cable and satellite STBs do not have such a mode, but some stand-alone PVRs do (TIAX 2007).

Motorola and Scientific Atlanta dominate the U.S. cable STB market, accounting for approximately 55% and 40% of the market, respectively (Kagan Research 2004). Kagan Research describes the more popular STBs based on functionality. The power draw values taken from TIAX (2007) are from measurement data for the most popular cable STBs. This analysis strategy should provide a more accurate estimate than a straight average of all measurement data, even though measurements for all the popular STB models were not available. The two largest DBS service providers are DIRECTV and EchoStar (DISH Network). Measurement data for approximately 20 units were used to estimate the average power draw for DBS STBs (TIAX 2007).

Table 4-82 summarizes the average STB power draw by operating mode and STB functionality. Because STBs are constantly receiving, transmit, and/or recording service provider signals, they draw nearly the same power in off mode as they do in active mode. The stand-alone PVR category is dominated by TiVo products and, therefore, power draw estimates come from measurements of TiVo PVR systems[64].

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[63] Lacking data, we assumed that 50% of the HD units have PVR capability

[64] Other stand-alone PVR products are available and measurements by CEA indicate that they drew an average of 26W in "delayed watch" mode, 23W in "record + watch" mode, and 10W in "sleep" mode (TIAX 2007).

Table 4-82: Power Draw Summary for STBs

		Cable		Satellite		Stand-alone DVR	
Operating Mode		Active	Off	Active	Off	Active	Off
Power Draw by Functionality and Operating Mode [W]	Analog STB	16	16	n/a	n/a	n/a	n/a
	Digital STB	14	14	13	13	n/a	n/a
	HD STB	22	21	21	18	n/a	n/a
	PVR STB	26	21	25	25	27	27
	HD DVR STB	29	24	42	40	n/a	n/a
	Weighted Avg.	16	15	15	14	27	27

The usage estimates come from the survey results reported by TIAX (2007) (see Table 4-83). There are questions about survey participants' ability to accurately estimate STB on time, since some users may not turn off their STBs with their TVs. In particular, one might question why the stand-alone PVR on time is significantly lower than cable or satellite STB on time. In practice, because there is so little difference between on power and off power for most STBs[65], any errors in usage by mode estimates do not significantly affect the energy consumption calculations.

Table 4-83: STB Usage by Mode

	Cable		Satellite		Stand-alone PVR	
Active Usage	Active	Off	Active	Off	Active	Off
Off Usage	2,730	6,030	3,240	5,520	2,080	6,680

Table 4-84 summarizes the unit electricity consumption (UEC) for STBs using average power and usage estimates. Off mode energy consumption accounts for 68%, 62%, and 76% of the UEC for cable STBs, satellite STBs, and stand-alone PVRs, respectively.

Table 4-84: UEC Summary for STBs

		Cable			Satellite			Stand-alone PVR		
		Active	Off	Total	Active	Off	Total	Active	Off	Total
UEC by STB Type and Operating Mode [kWh/yr]	Analog STB	44	93	138						
	Digital STB	38	84	123	43	70	113			
	HD STB	59	124	182	69	100	169			
	PVR STB	71	127	198	82	139	222	56	180	237
	HD DVR STB	79	145	224	137	223	360			
	Weighted Avg.	43	90	133	49	80	129	56	180	237

We estimate a typical household to own two standard digital cable STBs, which would consume approximately 250 kWh per year. A household owning two standard DBS STBs

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[65] We found two exceptions. When units with a PVR are off, the PVR appears to stop spinning and power draw decreases by about 5W. In addition, measurements by CEA of three stand-alone PVR units that are not subscription based revealed that all drew substantially less (32, 44, and 91% less) power in a low-power mode than in active (watch + record) mode.

would consume approximately the same energy (less than 10% lower based on model estimate).

4.14.3 *National Energy Consumption*

Table 4-85 displays the annual energy consumption (AEC) for each STB category based on the estimated installed base and average UEC. Cable and satellite STBs each account for approximately half of the 20 TWh consumed by STBs annually.

Table 4-85: Annual Energy Consumption of Set-Top Boxes (TWh/yr)

	Cable	Satellite	Stand Alone	Total
Analog STB	4	n/a	n/a	4
Digital STB	5	7	n/a	12
HD Digital STB	0	0	n/a	0.4
PVR Digital STB	1	1	0.4	3
HD DVR Digital STB	0	1	n/a	1
Total	10	9	0.4	**20**

4.14.4 *Current Best in Class and Market Trends*

The energy savings potential for STBs is not well understood. Even when examining STBs that fit within one of the general categories that we have defined (ie., digital cable, HD digital cable, etc.), there may be multiple levels of functionality. Therefore, “best in class” energy savings may really be a result of a decrease in product functionality. Furthermore, most STBs are not purchased by customers, but rather are leased by service provides. For this reason, customers are not given the opportunity to select energy saving products.

The off mode power draw of STBs is generally nearly as high as the active mode draw because STBs continuously receive data from service providers, even when the STBs are switched off by the user. The EPA has been unable to define an EnergyStar® off mode standard for STBs that does not restrict their functionality. The European Commission Code of Conduct specifies a set of maximum power draw targets for STB “standby active” and “standby passive” operating modes. (European Commission 2003) The Code of Conduct provides power allowances for added functionality. Because of the clear potential for energy savings, such a standard is of interest in the U. S., and continues to be addressed.

To estimate energy savings from best in class STB products, we used available measurement data to select the lowest power units for each of our STB categories. Again, it is unknown whether the energy savings are a result of a more efficient product or from a loss of functionality. Furthermore, the measurement data does not cover all available STB products. Tables 4-86, 4-87, and 4-88 display the minimum power draw data selected, the resulting UEC and energy savings, and the AEC with annual energy savings, respectively.

Table 4-86: Best in Class Power Draw Values for STBs

		Cable		Satellite		Stand-alone DVR	
Operating Mode		Active	Off	Active	Off	Active	Off
Power Draw by Functionality and Operating Mode [W]	Analog STB	10	10	n/a	n/a	n/a	n/a
	Digital STB	12	12	8	8	n/a	n/a
	HD STB	13	13	21	15	n/a	n/a
	PVR STB	26	21	17	16	21	2
	HD DVR STB	21	20	37	37	n/a	n/a
	Weighted Avg.	12	12	10	9	21	2

Table 4-87: UEC and Energy Savings of Best in Class STBs

		Cable			Satellilte			Stand-alone DVR		
		Active	Off	Total	Active	Off	Total	Active	Off	Total
UEC by Functionality and Operating Mode [kWh/yr]	Analog STB	27	60	88	n/a	n/a				
	Digital STB	33	72	105	26	44	70			
	HD STB	35	78	114	69	83	152			
	PVR STB	71	127	198	55	88	143	44	13	57
	HD DVR STB	57	121	178	120	204	324			
	Weighted Avg.	33	71	104	31	52	83	44	13	57
	% Energy Savings	23%	22%	22%	36%	35%	35%	22%	93%	76%

Table 4-88: AEC and Energy Savings of Best in Class STBs

		Cable	Satellite	Stand Alone	Total
AEC by Functionality [TWh/yr]	Analog STB	2	n/a	n/a	2
	Digital STB	4	4	n/a	9
	HD Digital STB	0	0	n/a	0.3
	PVR Digital STB	1	1	0	2
	HD DVR Digital STB	0	0	n/a	1
	Total	8	6	0.1	14
	AEC Savings	2	3	0.3	6
	% Energy Savings	22%	35%	76%	29%

In terms of household energy consumption, our typical household with two standard digital cable STBs would consume 210 kWh per year, saving 15% as compared to the standard HEC. On the other hand, a household with two best in class standard satellite STBs might save nearly 40% compared to a household with two average power DBS STBs. The best in class DBS STB home would have an HEC of 140 kWh per year.

The installed base of PVR STBs is growing rapidly in the U.S. TIAX (2006) predicts that there will be 55 to 70 million units with PVR capability installed in the U.S. in 2010. Growth in this STB category in particular will have a significant impact on overall STB energy consumption.

The number of total cable subscriptions has grown rather slowly the past couple years, but from 2003 to 2005, digital cable subscriptions grew over 10% per year (FCC 2006). While standard analog cable subscriptions don't require a STB, most digital cable television subscribers will need a digital STB. Even digital TVs may not be digital cable ready. Many DTVs have been sold as digital television *ready* or *compatible*, meaning they require an external tuner to display digital television programming. However, the FCC has mandated that all new TV sets include a digital tuner as of 2007. Nonetheless, unless a TV has a POD slot, it often requires a STB.

POD devices have the potential to slow the growth of STBs, although the energy consumption of TVs would increase as a result. However, current POD cards only offer "one-way" functionality, so services like Video On Demand and Pay-per-view are not available. Also, if PVR functionality is desired, a STB would be required anyway.

After the conversion to digital broadcast television, digital to analog TV converter boxes (DTAs) will be required by all standard analog TVs that receive broadcast (terrestrial) signal. The converter will convert the digital broadcast signal to analog NTSC format that analog TVs can display. DTVs and HDTVs will be able to directly display a broadcasted digital signal, but they will need a tuner if one is not integrated in the TV. Currently there isn't a market for DTA, but during the analog to digital switch there will likely be a spike in sales. The installed base of DTA's will then fade out with analog televisions.

4.14.5 References

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4.15 Televisions (TVs)

Table 4-89: Televisions Summary

Characteristic	Result		Comments
	Analog	Digital	
Installed Base [millions]	237	38	Sum of analog and digital
Market Penetration [% of Households]	89%	24%	99% of households own at least one TV
Unit Electricity Consumption [kWh/year]	216	392	
UEC – Best in Class [kWh/year]	86	280	Analog – Average using lowest active power device for each size range. Assume 0.1 W in off mode. Digital – Assume using lowest active mode devices for each technology. Assume 0.1 W in off mode.
UEC Savings – Best in Class [kWh/year]	130	112	
Annual Electricity Consumption [TWh/year]	51	16	
Peak Demand Impact	Low		Peak TV viewing occurs between 8pm and 11pm
Variability in Usage	High		
Notable Regional or Seasonal Variations in Penetration or Use?	Seasonal Variation		Highest usage during winter, lowest during summer
Typical Location(s) in Household	Living room, Bedroom, Family room		
Potential Ways to Reduce UEC	Active mode power management		
Significant Data Uncertainties	Active mode usage, DTV size distribution, Off mode power draw		
Key Technology Trends	Larger, high definition, digital TVs are becoming more common		

4.15.1 Introduction

Televisions are ubiquitous in the United Sates, i.e., 99% of all homes in the U.S. have at least one TV, and the average national household owns 2.4 TVs. While the number of TV-households[66] grows with the number of total households, the number of TVs per household can also increase. Figure 4-16 shows the estimated distribution of televisions among homes for 2006, based on 2001 RECS data (EIA 2002) that we adjusted to match our estimate of 275 million installed TVs in 2006. (TIAX 2007)

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[66] A TV-household is a household that owns at least one TV.

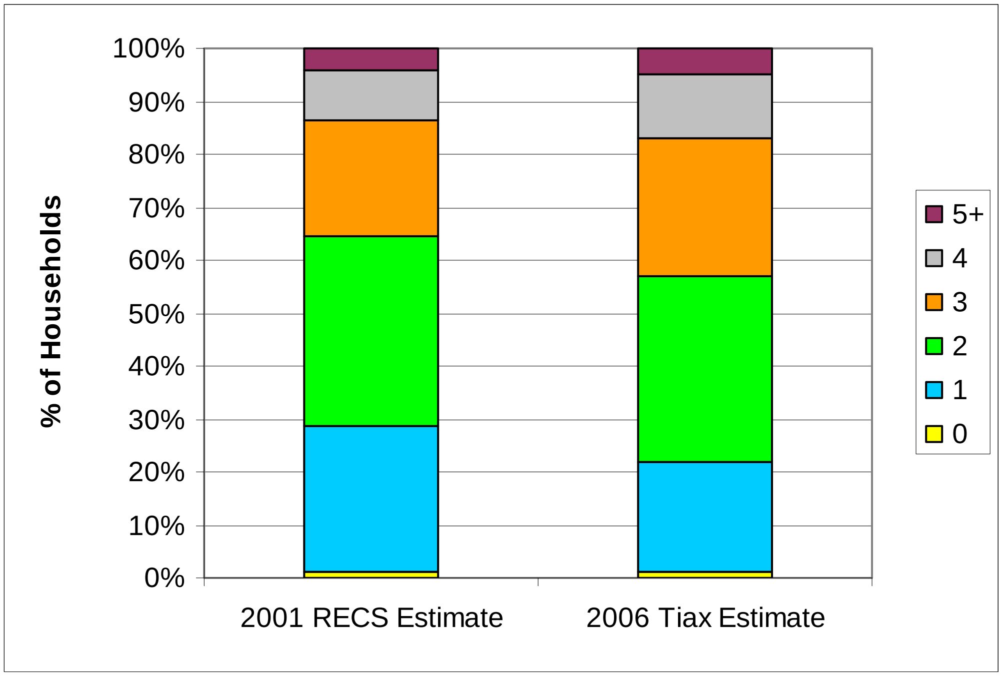

Figure 4-16: Distribution of Televisions Among Households

According to survey results from TIAX (2007), there are approximately 237 million analog TVs installed, or approximately 86% of all installed TVs. Figure 4-17 plots the distribution of the number of TVs per household for analog displays.

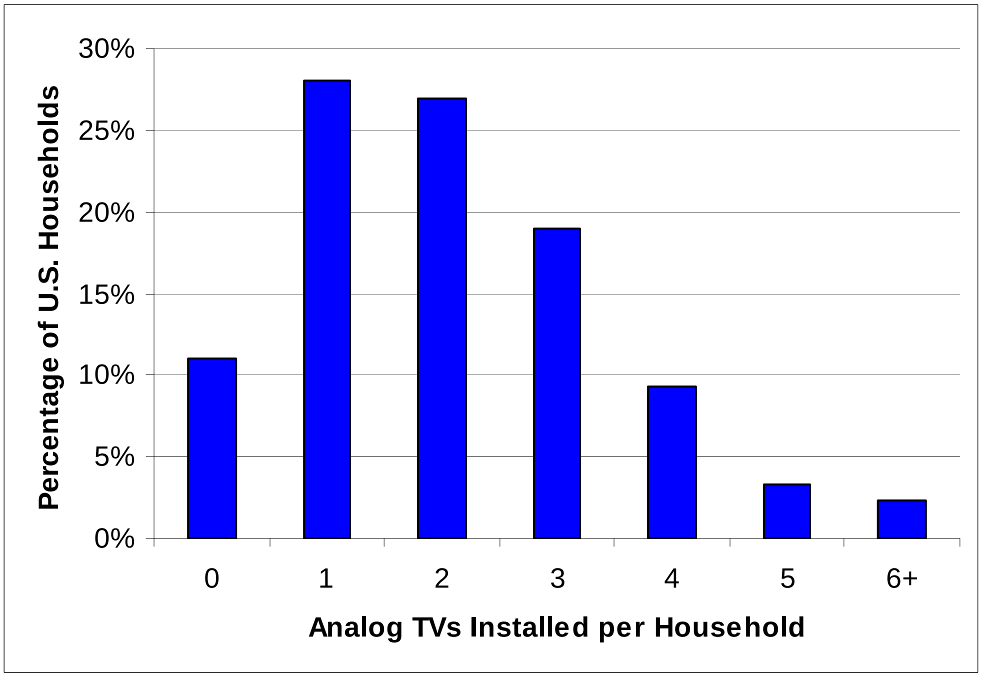

Figure 4-17: Distribution of Number of TVs per Household for Analog TVs

Subtracting the 237 million analog TVs from the total leaves 38 million digital TVs installed in the U.S. We do not have data to plot the distribution of digital TVs per household, but it is likely that the majority of owner-households have one digital TV. The CEA Ownership Study (2005) reports that 21% of households own at least one digital TV in 2005. The household penetration likely increased to over 25% in 2006. The current analysis assumes that nearly all digital TVs are high definition (HD) displays. As DTV becomes more commonplace, a percentage of the installed base may be standard definition (SD) or extended definition (ED).

Television energy consumption can be characterized by two operating modes: active mode (when the TV displays an image), and off mode (when the screen is off). TVs, like many other electronics, continue to draw power while they are “off”. Typically, televisions draw power while in off mode so they can respond to a signal from a remote. Memory and time-keeping functions also require power while the TV is off. Although active mode power draw increases with screen size, screen size does not have an impact on off mode power draw. Digital TVs may have cooling fans that remain on for some period after the TV has been switched off. This intermediate power draw and it’s energy impact are not well understood, but at this time likely does not have a significant impact on overall TV energy consumption.

4.15.2 Unit and Household Energy Consumption

The majority of households own multiple television sets, which are likely to be of varying screen size and, thus, have different power draw values. Figure 4-18 shows the size distribution of analog TVs from CEA survey data (TIAX 2007), based on the size categories selected for the survey.

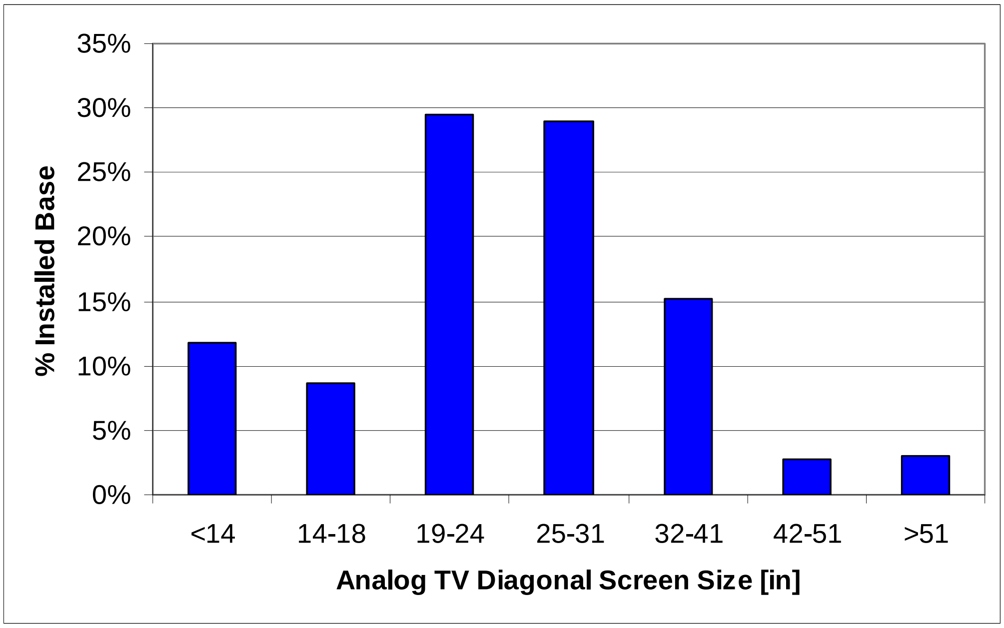

Figure 4-18: Analog TV Screen Size Distribution Based on Survey Results

Furthermore, survey results included in TIAX (2007) showed that larger TVs tend to be the primary televisions and, thus, are used more than other household TVs. To capture the effect of this fact on energy consumption, we analyzed the usage of each TV group (i.e., primary TV, secondary TV, etc.) separately, and calculated the AEC using the estimated installed base of TVs for each usage group. The results are summarized for analog TVs in Table 4-90.

Table 4-90: Energy Consumption Summary for Analog TVs

Usage Group	% of Installed Base	Average Active Usage [hrs/day]	Average Screen Size [in]	Average Active Power [W]*	Average Off Power [W]**	UEC [kWh/yr]	AEC [TWh/yr]
Primary	43%	7.1	30	110	4	310	32
Second	29%	4.2	24	92	4	171	12
Third	16%	3.3	21	79	4	124	5
Fourth	7%	3.2	21	77	4	122	2
Fifth	3%	2.0	18	67	4	81	0.5
Sixth	1%	1.2	18	67	4	62	0.2
Total							53

*Calculated using measurement data from Rosen and Meier (1999) and TV size data from TIAX (2007)
**Average from measurement data from Rosen and Meier (1999) with estimated modification for recent EnergyStar® products

The analog TV active mode power draw was estimated from measurement data from 370 analog TVs (Rosen and Meier 1999). Although all the measured TVs were manufactured before 1999, analog CRT television is a mature technology and, therefore, we assumed that active mode power draw has not changed appreciably since the mid 1990s. Based on the number and average size of each usage priority TV (i.e., primary, secondary, etc), we calculated an average active power draw for each TV in an average household (TIAX 2007). All analog TVs over 40 inches are projection televisions. Table 4-91summarizes the this calculation process.

Table 4-91: Calculation of Average TV Size and Active Power Draw for Each TV in an Average Household

		Percentage of Installed TV Within Size Range							Avg. Screen Diagonal (in)	Average Active Power (W)
Size Range (in)		<13	14-18	19-24	25-31	32-41	42-51	52+		
Avg. diagonal (in)		10	16	21.5	28	36.5	46.5	60		
TV Priority	Primary	4%	4%	22%	35%	24%	4%	6%	30	110
	Secondary	10%	10%	35%	30%	11%	2%	1%	24	92
	Third	23%	14%	35%	21%	6%	1%	0%	21	79
	Fourth	28%	11%	35%	18%	4%	3%	1%	21	77
	Fifth	34%	19%	30%	16%	1%	0%	0%	18	67

	Percentage of Installed TV Within Size Range							Avg. Screen Diagonal (in)	Average Active Power (W)
Size Range (in)	<13	14-18	19-24	25-31	32-41	42-51	52+		
Avg. diagonal (in)	10	16	21.5	28	36.5	46.5	60		
Sixth	34%	19%	30%	16%	1%	0%	0%	18	67
# of Installed Analog TVs in Size Range	28	21	70	69	36	7	7		
% of Total Installed Analog TVs	12%	9%	29%	29%	15%	3%	3%		
Avg. Acitve Mode Power Density (W/in^2)	0.66	0.55	0.39	0.28	0.21	0.15	0.10		
Active Mode Power (W)	32	68	86	106	133	156	173		

In contrast to TV active mode power draw, which generally increases with screen size (assuming the same display technology), TV off mode power draw does not depend on screen size (see Figure 4-19). The overall average of the aforementioned 370 units measured was approximately 5 W (Rosen and Meier 1999). This average would not, however, account for any effect that the EnergyStar® program, which established a maximum off mode power draw threshold in 1999, has had on off mode power draw. Therefore, we used the 4 W estimate of Ostendorp et al. (2005) for both analog and DTV off mode power draw. The active mode dominates (~90% on average) TV UEC; therefore, a more complex approach to estimate the off mode power draw estimate would not significantly affect the overall energy consumption[67].

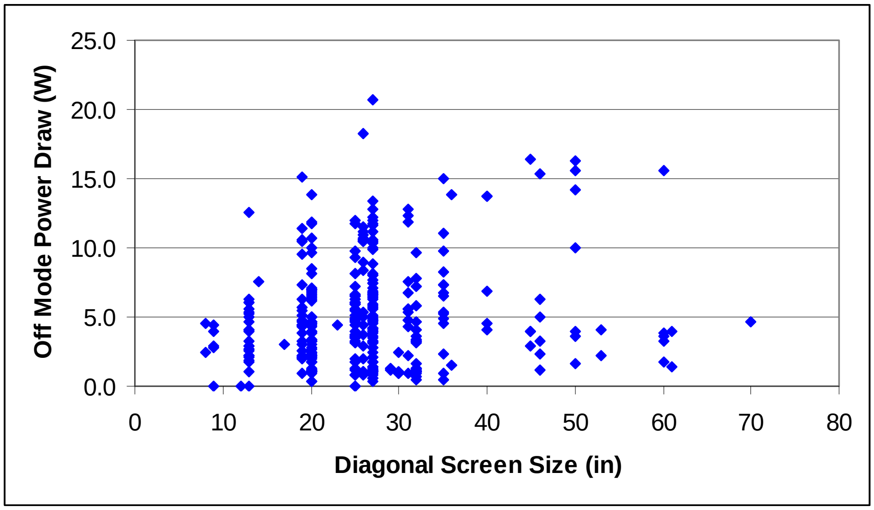

Figure 4-19: Analog TV Off Mode Power Draw as a Function of Screen Size (Rosen and Meier 1999)

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[67] In addition, very few data were available for TV-VCR and TV-DVD power draw by mode.

We used the data from (TIAX 2007) to estimate analog TV usage. Survey participants were asked how long each household TV was turned on the prior day, and the survey was conducted over multiple days. This captures the time the TV was used to watch broadcast television, as well as home video and time when TVs were on "in the background" with no one actively watching. The survey data enables resolution of usage for each TV usage group (i.e., primary, secondary, etc).

The results clearly indicate that the average primary household TV is larger, draws more power in active mode, and used significantly more often than other TVs in households. As a result, in general, the larger the TV in a household, the more time it spends in active mode. Capturing this trend in the energy consumption calculations increased the AEC for analog TVs by 5% relative to the assumption that average usage does not vary with screen size. More importantly, employing usage groups enabled an accurate representation of the variation in power draw among installed TVs.

There are an average of 2.4 TVs per household in the U.S., and since digital TVs still have a relatively low installed base, a "typical" household owns two analog TVs. Combining the UEC of a primary and secondary TV yields an estimated household energy consumption (HEC) of 496 kWh/yr.

A more simple model was employed to calculate the energy consumption of digital TVs due to the lack of data supporting the screen size distribution and usage trends. Ostendorp (2005) estimated that 50% of installed digital TVs are over 40 inches. CEA (2006) sales data seem to confirm this approximation assuming taking that digital projection and plasma TVs are generally over 40 inches. Assuming a normal distribution, we estimated the average diagonal screen size for digital TVs to be 40 inches as well. Lacking usage data specific to digital TVs, we used average analog TV usage calculated from the above analog data as the usage estimate for digital TVs.

Table 4-92: Energy Consumption Summary for Digital TVs

	Usage Mode		Total	Comments
	Active	Off		
Power [W]	192	4		Avg. 40 in TV based on power draw densities of direct display and projection display TVs and their installed base
Usage [hr/yr]	1,900	6,860		Avg. analog TV usage
UEC [kWh/yr]	364	27	392	
% UEC	93%	7%		

The digital TV power draw estimates are taken from power draw measurements by Ostendorp et al. (2005) and CNET (2006). Direct display digital TVs do not show a decrease in power draw density (watts per screen area) with an increase in screen size as do analog TVs. Figure 4-20 plots raw measurement data for various technology displays. Although the sample size is small, for each technology there is a range of power densities (due to manufacturer variation and power management variation), but the average power density is relatively constant with screen size. Furthermore, the average power density for any direct display technology does not vary from the overall average by more than 5%. It is important to note that a standard test method for TV active mode power draw does not yet exist that accurately characterized the power draw of televisions.[68] Because the existing data do not reveal a significant variation among direct display technologies, and because there isn't a standard test procedure, we used an average of 0.36 watts per square inch to represent the power density for all direct display digital TVs.

Digital projection displays show an expectedly low power density, as shown in Figure 4-20. The available measurement data show less of a power density range for projection displays, with the average falling at 0.15 watts per square inch.

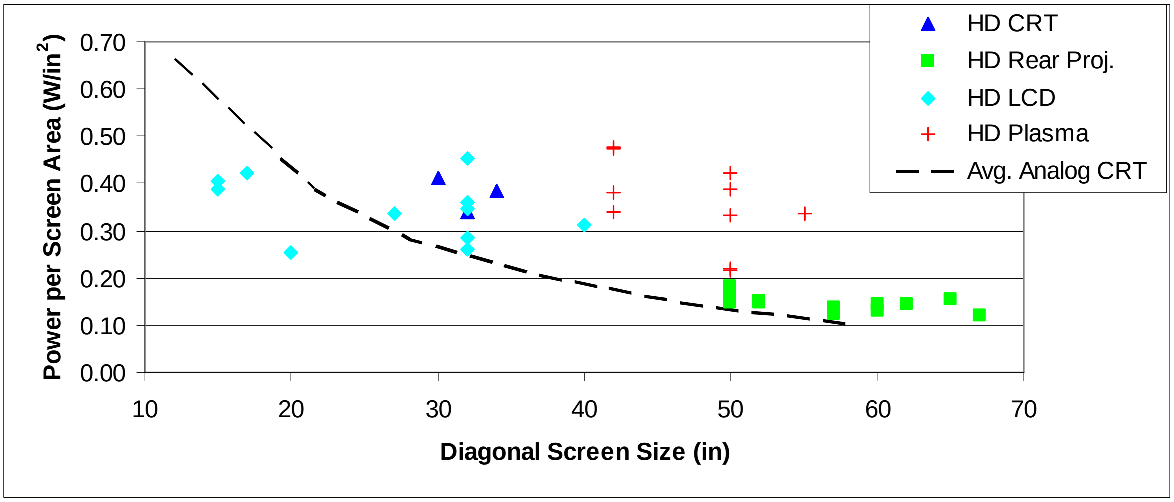

Figure 4-20: Power Requirement for Various Display Technologies Normalized for Screen Area (Ostendorp et al. 2005, CNET 2006)

Using the raw measurement data to calculate the average power density values for TVs within the same size buckets used for analog TVs, the average power per screen size can be plotted for analog and digital TVs as shown in Figure 4-21.

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[68] Ostendorp et al. (2005) measured TV power draw televisions while playing a standard test clip when possible. Otherwise the televisions were tuned to an in-store signal. In both cases, the reported power draw is based on TV operation over a two-minute period. They made no attempt to calibrate the televisions for brightness and contrast and left the settings at in-store levels (typically factory settings). In general, factory settings are exceedingly bright to attract customers; consequently, in-store power measurements may over-estimate active mode power draw levels. On the other hand, Ostendorp et al. (2005) reported that most people don't change the brightness and contrast settings when they purchase a TV. In this case, the measurements would accurately capture residential TV power draw. An international effort is currently underway to develop a standard TV test procedure for active mode power draw; this procedure is expected to be finalized in 2007.

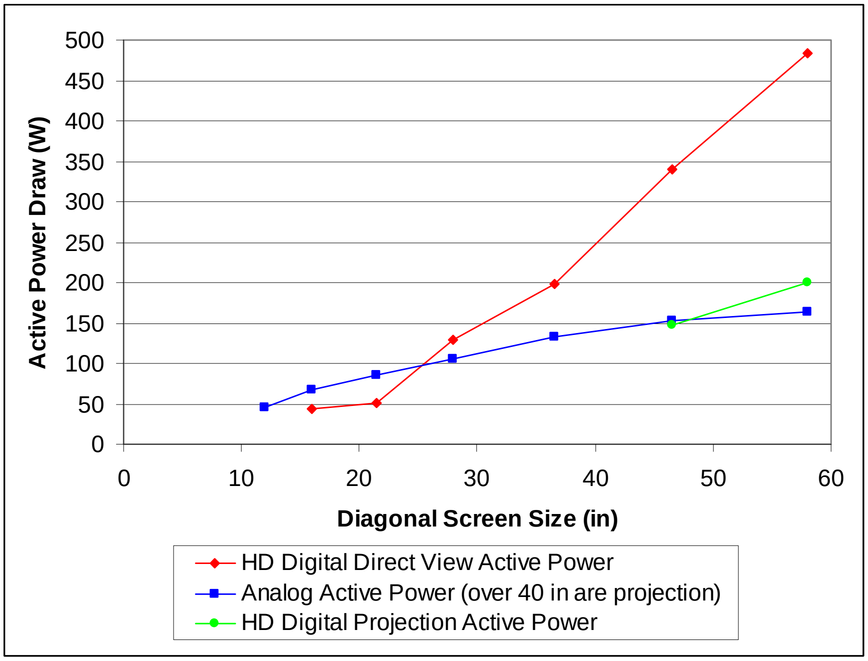

Figure 4-21: Active Mode Power Draw by Screen Size (based on measurement data from Rosen and Meier (1999), Ostendorp et al. (2005), and CNET (2006))[69]

Using the average power densities calculated for digital direct view and projection TVs and digital TV sales data (CEA 2006), we estimated the overall average power draw of a 40 inch digital TV. Table 4-93 summarizes the average power draw calculation.

Table 4-93: Average Digital TV Power Draw Calculation

	% Projection	Avg. Power Density (W/in^2)	Average Power (W)
> 40 in.	80%	0.19	
< 40 in.	0%	0.36	
Total	40%	0.28	192

We estimated the average off mode power draw for digital TVs to equal that of analog TVs due to the lack of measurement data specifically for digital TVs. There is clearly uncertainty in this estimate, but because active mode dominates energy consumption, more accurate data will unlikely significantly effect the energy consumption estimate.

To vet our usage estimate, we calculated the total TV usage from its components by summing the time watching television from Nielsen Media and the time watching home video and playing video game systems from the current survey. Figure 4-22 plots the increase of broadcast television viewing by households over the past two decades (Nielsen Media Research 2005) and indicates that households watched an average of 8.2 hours of broadcast television per day in 2005. As Rosen and Meier (1999) noted, this result does

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[69] Note that the DTVs measured have a screen aspect ratio of 16:9, while the analog TVs measured have an ratio of 4:3. Therefore the analog TVs have approximately 12% more screen area than digital TVs of the same diagonal screen size.

not include time spent watching home video, time spent playing video games, or time when multiple TVs are on simultaneously in a single home.

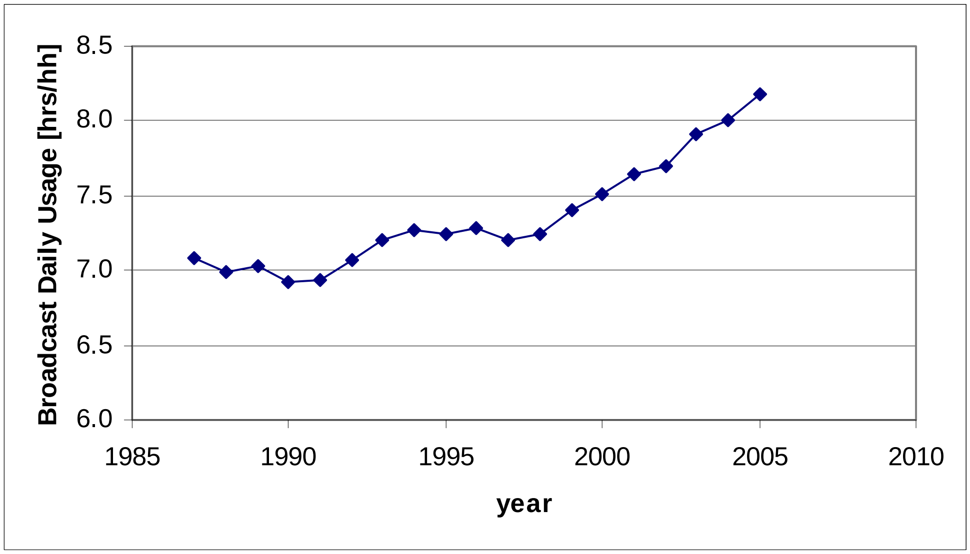

Figure 4-22: Nielsen Media Research (2005) Broadcast Television View Estimates per Household

Adding home video and video game usage to television usage, Table 4-94 presents the results of this alternative usage analysis.

Table 4-94: Secondary TV Usage Model

	Daily Usage per Unit [hours/day]	Units per TV (analog and digital)	% of TV Households w/ Multiple TVs[70]	Analog TV Active Usage	Comments
Television Viewing (analog + digital)	3.4	-	80%	3.7	8.2 hrs/hh broadcast TV viewing (Nielsen Media 2005) divided by 2.4 TVs/hh (analog and digital) from current survey
Simultaneous Viewing	3.8				Households with multiple TVs have 2 TVs on simultaneously 12% of the time (Rosen and Meier 1999, from Media Dynamics 1998)
DVD viewing	0.7	0.51		0.35	DVD usage, DVD units, and total TVs from survey results
VCR viewing	0.4	0.38		0.15	VCR usage and units, and total TVs from survey results
Video game viewing	1.2	0.23		0.28	Video game system usage and units, and total TVs from survey results
Total				4.5	Sum of television, home video, and video game systems

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[70] That is, percent of TVs capable of simultaneous viewing.

There is significant uncertainty associated with the estimate of time television is being viewed on multiple TVs in a household simultaneously. Lacking newer data, we used the 12% value from the 1998 source cited in Rosen and Meier (1999), which yields a total estimate of 4.5 hours per TV per day. This is 15% lower than the survey average result of 5.2 hours per day, but 4.5 hours per day, or 1,640 hours per year, exceeds the estimates of Ostendorp et al. (2005) and Rosen and Meier (1999) by about 14 and 28 percent, respectively.

4.15.3 National Energy Consumption

Overall, televisions consumed about 67 TWh in 2006, with analog TVs accounting for 77% of the total (see Table 4-95). Televisions consume the most energy of the miscellaneous electric loads evaluated, representing about 23% of the total.

Table 4-95: Annual Energy Consumption of Televisions

TV Category	Installed Base [millions]	UEC [kWh/yr]	AEC [TWh/yr]	% of Total AEC
Analog	237	216	51	77%
Digital	38	392	16	23%
Total			67	

4.15.4 Current Best in Class and Market Trends

Active mode accounts for approximately 90% of total TV AEC. As shown above, TV active mode power draw generally increases with screen area and also increases with resolution (Ostendorp et al. 2005). Figure 4-23 shows the average TV screen size as a function of time since 1991 (TIAX 2007). Increasing sales of high definition digital TVs (HDTVs) will likely continue this trend.

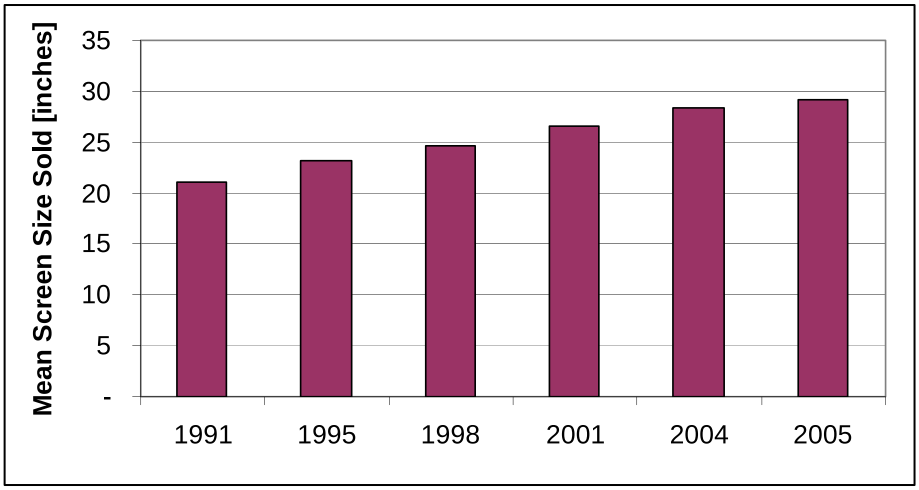

Figure 4-23: Evolution of Mean Television Size from 1991 to 2005 (from TIAX 2007)

Consequently, a straightforward way to reduce TV AEC would be to reduce the screen size and resolution or reduce screen brightness. In practice, all three are desirable product attributes that consumers clearly value. Consequently, we analyze neither as an energy-saving opportunity.

Beyond TV screen area and resolution, display technology may have an impact on active mode power draw for a TV of a given screen area and resolution. Unfortunately, limited measurement data and the absence of a fair standard test method prevent accurately comparing different display technologies. Figure 4-21 presents the limited active mode power draw measurements from Ostendorp et al. (2005) and CNET (2006) for various display technologies, normalized based on screen area. The plot exhibits a wide range of power densities for each major type of digital direct display technology. This may be a consequence of design differences between manufacturers, display resolution, and display brightness levels. Digital projection TVs appears to have a smaller power density range and generally draw less power than similarly sized direct view displays. In general, the power draw of direct view non-CRT TVs[71] should scale approximately linearly with screen area as the light source dominates display energy consumption at the scale of most TVs.

Figure 4-21 also shows that HD LCDs can have appreciably lower power draw than CRTs for screens smaller than 25 inches. LCD power draw increases, however, more precipitously with screen area than does CRT power draw and the two become equivalent at a screen size slightly larger than thirty inches (Itoh and Tanaka 2002).

To estimate the energy savings potential from best in class products, we used the energy models developed above, but replaced the average power per size range with the minimum power per size range from the same available data sets. Figure 4-24 plots the power draw for the analog TV drawing the least power in each size range. The lowest power TV in each size group draws 20% to 60% less power than the average for that group. This translates to overall energy savings of 50%.

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[71] The active mode power draw of CRTs may also increase linearly with screen size, but the *slope* of the increase appears to be appreciably less than that for LCDs and Plasma TVs (Siderius and Harrison 2007).

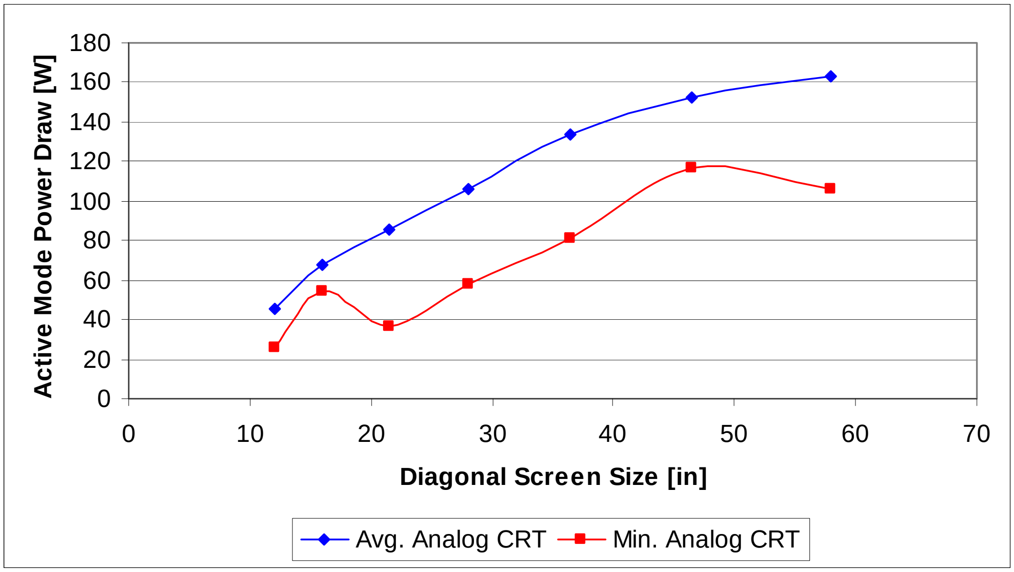

Figure 4-24: Average and Minimum TV Power Draw per Screen Size for Analog TVs

Using minimum power digital TV data, we estimated the best in class average power draw to be 144 W, approximately 25% lower than the standard average. This translates to approximately 25% energy savings based on our simple model.

In addition, opportunities exist to reduce TV consumption in off mode. The EPA Energy Star product list (EnergyStar 2007) reports an LCD display with an off mode power draw of 0.04 W and a plasma display with an off mode draw of 0.06 W. If the average TV off mode power draw was 1 Watt (i.e., the current EnergyStar® threshold) rather than the estimated 4 W, the AEC of analog and digital TVs would decrease by 10% and 5% respectively. Similarly, an average off mode power draw of 0.1 W would correspond to energy savings of 12% and 7% for analog and digital TVs, respectively. Combining the 0.1W off mode power draw with the minimum active mode power reduction, the overall TV AEC would drop by 55% to approximately 30 TWh per year. The energy savings results are summarized in Tables 4-96 and 4-97.

Table 4-96: Energy Savings Potential for Analog TVs – AEC

Scenario	AEC (TWh)	Energy Savings (TWh)	% Energy Savings
Baseline	51	-	-
Off Power - 1W	46	5	10%
Off Power – 0.1W	45	6	12%
Minimum Active Power	25	26	50%
Minimum Active Power and Off Power 0.1 W	19	32	63%

Table 4-97: Energy Savings Potential for Digital TVs - AEC

Scenario	AEC (TWh)	Energy Savings (TWh)	% Energy Savings
Baseline	15.7	-	-
Off Power - 1W	14.9	0.8	5%
Off Power – 0.1W	14.6	1.1	7%
Minimum Active Power	12	3.7	24%
Minimum Active Power and Off Power 0.1 W	10.9	4.8	31%

The television market is extremely dynamic as digital television and new display technologies rapidly displace older analog cathode ray tube (CRT) TVs. The FCC mandate to switch from analog to digital broadcast TV by 2009 drives this trend. Newer digital display technologies include direct-view technologies, such as plasma (PDP) and liquid crystal display (LCD), as well as projection technologies, e.g., liquid crystal on silicon (LCOS), Digital Direct Drive Image Light Amplifier (D-ILA), and Digital Light Processing (DLP).

CEA (2006) sales data through 2006 indicate that approximately 55% of all direct view digital displays sold are LCDs. Sales of direct view LCD screens doubled from 2005 to 2006, from 4 million to projected sales of approximately 8 million. Direct view LCDs are generally under 40 inches. Plasma displays account for slightly less than 20% of direct view displays, and are generally over 40 inches. Digital projection technologies account for approximately 80% of TVs over 40 inches.

4.15.5 References

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4.16 Home Video – VCRs and DVD Players and Recorders

Table 4-98: Home Video Summary

Characteristic	Result		Comments
	VCR	DVD and DVD/VCR	
Installed Base [millions]	105	120	
Market Penetration [% of Households]	79%	74%	
Unit Electricity Consumption [kWh/year]	47	36	
UEC – Best in Class [kWh/year]	15	10	DVD value is a weighted average of DVD players, DVD recorders, and DVD/VCR combo units based on installed base
UEC Savings – Best in Class [kWh/year]	32	26	
Annual Electricity Consumption [TWh/year]	5	4.4	
Peak Demand Impact	Low		
Variability in Usage	High		
Notable Regional or Seasonal Variations in Penetration or Use?	n/a		
Typical Location(s) in Household	Living room, Bedroom, Family room		
Potential Ways to Reduce UEC	Active mode power management, Automatic shut off to reduce idle usage		
Significant Data Uncertainties	Idle mode usage		
Key Technology Trends	DVD players are currently co-existing with VCRs, but VCRs will fade as DVD recorders become more popular		

4.16.1 Introduction

The home video analysis includes all stand-alone DVD players and recorders, as well as DVD/VCR combination units, and stand-alone VCRs. Portable DVD players, and DVD players or VCRs integrated with home computers, televisions, or home theatres in-a-box (HTIB) are excluded from this study.

Sales data from 1999 to present indicate that there are approximately 120 million DVD players installed in households. According to survey data from TIAX (2007), 74% of U.S. households owned at least one DVD player, and therefore households with DVD players owned an average of 1.4 units based on 115 million households (see Table 4-99). CEA sales data indicate that approximately 10 million installed DVD players have recording capability. Additionally, approximately 35 million of the installed DVD players are DVD/VCR combination units (TIAX 2007).

Table 4-99: DVD Player Installed Base

Type	Installed Base [millions]	Penetration [% HH]	Comments and Sources
Stand-alone DVD player	75	74%	Installed base from sales data (CEA 2006, Appliance 2005)
DVD recorder	10		
DVD/VCR combo	35		
Stand-alone VCR	105	78%	CEA Survey, less number of DVD-VCR combo units
TOTAL	225		Penetration from CEA Survey

VCRs have recently passed their market penetration peak. Appliance Magazine saturation statistics indicate that 94% of all U.S. households owned at least one VCR from 2000-2002 (Appliance Magazine 2005b). Since then the market penetration has dropped and TIAX (2007) suggests that VCRs were installed in 78% of homes in 2006. Survey data from TIAX (2007) also estimates that households with VCRs owned an average of 1.6 units, which translates to approximately 141 million VCRs in the U.S. in 2006 based on 115 million households (EIA 2006). This total includes, however, the 35 million DVD/VCR combination units for which have already been accounted. Consequently, approximately 105 million stand-alone VCR units remain.

Home video products can be characterized by 3 operating modes as described by Rosen and Meier (1999):

- *Play/Record* – Disk or tape is being played or recorded
- *Idle* – The system is on but no motor functions are being performed
- *Off* – The power has been switch off by the user, but the system remains plugged in.

A separate "record" mode could be added for DVD players capable of recording to a disk or internal hard drive. However, according to recent CEA measurements, the average recording power draw was only 1 W higher (5%) than the average active mode power draw of devices capable of recording, and therefore the record mode was lumped together with the active mode (TIAX 2007).

4.16.2 Unit and Household Energy Consumption

Unit Electricity Consumption by Mode:
The power draw estimates for VCRs come from models developed in TIAX (2007). Older power draw estimates come from measurements made by Rosen and Meier (1999), while

estimates for newer products were derived from extrapolation of historical trends, as well as EnergyStar® market share data. The overall average is weighted based on annual sales data going back to 1996[72] (CEA 2006). Using this method, the average active mode and off mode power draws were calculated to be 16 Watts and 4.5 Watts respectively. Based on the values reported in Rosen and Meier (1999) and Nordman and McMahon, the average VCR idle mode power draw was taken to be approximately 75% of the active mode draw, or 12 Watts.

Survey data from TIAX (2007) indicate that VCRs are used an average of 156 hours per year, or approximately 3 hours per week. Survey participants also responded that their VCR players sit in idle mode an average of 15 hours per week, or 10% of the time not in active mode. The estimate of the time VCRs are left in idle mode is critical to the calculation of energy consumption. A VCR could be in idle mode while the TV is active because the user has the TV cable running through the VCR. Alternately, the VCR could be set to record a TV program, and therefore sits in idle while not recording. In addition, a VCR could be in idle mode because the user forgot or didn't bother to turn the unit off. Although idle usage data comes from a more reliable source than prior estimates, there is likely still significant uncertainty associated with this estimate. Many participants may have a difficult time accurately estimating idle time because they simply may not be aware of when their devices are in idle mode.

Table 4-100 summarizes the UEC calculations by mode for VCRs. 75% of the energy consumption occurs while in off mode, idle mode energy consumption accounts 20% of the UEC, while only 5% of the UEC occurs in active mode.

Table 4-100: UEC for VCRs

	VCR Usage Mode			
	On	**Idle**	**Off**	**Total**
Power [W]	16	12	4.5	
Usage [hr/yr]	156	793	7,811	8,760
UEC [kWh/yr]	2.5	10	35	47

Similar modeling was done by TIAX (2007) to estimate the average power draw by mode of the installed base of DVD players and DVD/VCR combination units. The models calculate the overall installed base average active mode power draw using available measurements and sales data. Overall average off mode power was estimated in a similar fashion, only with the addition of EnergyStar® market share data (from EnergyStar 2006), as the EnergyStar® program uses a maximum off mode power draw criterion for DVD players[73]. Idle mode was again estimated to be 75% of the active mode draw.

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[72] The sum of the stand-alone VCRs over this period approximately equals the installed base estimate for these devices. We decided not to employ a more complex retirement model to describe the installed base, as we believed that this refinement would lead to a marginal increase in the accuracy of the AEC calculation.

[73] DVD products launched after 1 January 2003 must draw <=1W standby for EnergyStar®, while products launched before 1 January 2003 that drew <=3W may continue as EnergyStar® products while they remain on the market.

DVD recorders form a recent product category, and the bulk of the installed base are assumed to be of newer vintage. Therefore, we used recent power draw measurements to estimate the average active and off mode power draw.

Usage estimates by mode come from survey data from TIAX (2007). The average DVD player was used for 270 hours per year, or about 5 hours per week. Since a demographically representative sample of households was surveyed, the usage estimate represents a weighted average of DVD players and DVD recorders. On one hand, it is likely that DVD recorders spend more time in active and idle modes than DVD players due to the extra functionality. On the other, the relatively small installed base of DVD recorders limits the impact of using a weighted average for usage on the total AEC estimate. We estimated the usage for combination DVD/VCR units by summing the usage of the average DVD player and VCR, yielding 425 hours per year.

Table 4-101 shows the energy consumption by mode for DVD products. Only 12% of the energy consumption of the average DVD player comes from the active use of the device, while 27% of the energy is consumed in idle mode. The remaining 61% of energy is consumed when DVD products are off.

Table 4-101: UEC for DVD Products

		Usage Mode				
		Active	**Idle**	**Off**	**Total**	**Comments and Sources**
Power Draw [W]	Stand-alone DVD players	13	10	2.3		• DVD and DVD/VCR combo active and off mode from sales and EnergyStar® market share (TIAX 2007) • DVD recorder active and off mode from measurements (TIAX 2007) • Idle mode power draw 75% of active mode based on Nordman and McMahon (2004)
	DVD recorders	20	15	2		
	DVD/VCR combos	15	11	4.5		
Usage [hr/yr]	Stand-alone DVD players	270	900	7,590	8,760	Survey data (TIAX 2007)
	DVD recorders	270	900	7,590	8,760	
	DVD/VCR combos	425	900	7,435	8,760	
UEC [kWh/yr]	Stand-alone DVD players	3.5	8.8	17.5	30	
	DVD recorders	5.4	14	15	34	
	DVD/VCR combos	6.4	10.1	33.5	50	
	Weighted Average	4.5	9.6	22	36	

Household Energy Consumption by Mode:

Based on market saturation data, the most common household contains two home video units, i.e., one VCR and one DVD player. Household energy consumption (HEC) for a typical two-unit home is given in Table 4-102.

Table 4-102: Typical HEC for a Two-unit Home

		Usage Mode			Total
		On	Idle	Off	
HEC [kWh/yr]	VCR	2.5	10	35	47
	DVD	3.5	8.8	17.5	30
Total	DVD & VCR	6	19	53	77

4.16.3 National Energy Consumption

Table 4-103 summarizes the total annual energy consumption of all analyzed home video products.

Table 4-103: AEC Summary for DVD Players

DVD Type	UEC [kWh/yr]	Installed Base [millions]	AEC [TWh]
Stand-alone DVD player	30	75	2.3
Stand-alone DVD player w/ record	34	10	0.3
DVD/VCR combo	50	35	1.8
Stand-alone VCR	47	105	5.0
TOTAL	42	225	9.4

4.16.4 Current Best in Class and Market Trends

To examine potential energy savings, we repeated the UEC and AEC calculations using “best in class” power draw values for active and idle modes from recent measurement data and estimates (TIAX 2007), as well as off mode measurement data from EnergyStar® product lists (EnergyStar 2007). Different products may represent the best in class for different operating modes.

Table 4-104 summarizes the UEC calculations for home video products with “best in class” power draw levels, while Table 4-106 presents the resulting AEC and energy savings for each home video product category using best in class UEC estimates.

Table 4-104: Home Video Best in Class UEC

		Usage Mode				
		Active	**Idle**	**Off**	**Total**	**Comments and Sources**
Power [W]	Stand-alone DVD	5	4	0.05		- Active and off modes from CEA measurements (TIAX 2007) - Idle mode 75% of active
	DVD w/ record	14	11	0.7		
	Combo DVD/VCR	12	9	0.6		- Active and off modes from average estimate for new units (TIAX 2007) - Off mode from EnergyStar® product list (EnergyStar 2007) - Idle mode 75% of active
	Stand-alone VCR	12	9	0.8		
Usage [hr/yr]	Stand-alone DVD	270	900	7,590	8,760	Same usage estimates
	DVD w/ record	270	900	7,590	8,760	
	Combo DVD/VCR	425	900	7,440	8,760	
	Stand-alone VCR	156	793	7811	8760	
UEC [kWh/yr]	Stand-alone DVD	1.4	3.4	0.4	5	
	DVD w/ record	3.8	9	5	19	
	Combo DVD/VCR	5.1	8.1	4.5	18	
	Stand-alone VCR	1.9	7.1	6.2	15	

Table 4-105: Home Video Best in Class AEC and Energy Savings

DVD Type	Best In Class UEC (kWh/yr)	Installed Base (millions)	Best in Class AEC (TWh)	% Energy Savings
Stand-alone DVD player	5	75	0.4	84%
Stand-alone DVD player w/ record	19	10	0.2	37%
DVD/VCR combo	18	35	0.6	65%
Stand-alone VCR	15	105	1.6	69%
TOTAL		225	2.8	71%

If a household owned one best in class VCR and one best in class DVD player, the household energy consumption would decrease by about 74% to 20 kWh/yr.

The current estimated AEC of home video products is dominated by off mode energy consumption (61% for DVD products and 75% for VCRs). There are two orders of magnitude difference between the off mode power draw of older vintage home video products and newer units. This is the main reason for the high potential energy savings offered by best in class products. The EnergyStar® voluntary labeling program for home video products is largely responsible for the recent off mode power requirement reduction in home video products. Measurements of "best selling" 2006 model DVD players were reported in TIAX (2007) and are shown in Figure 4-25. Approximately 40% of the units measured drew less than 0.5 watts in off mode and 70% of the units drew less than 1 Watt. The percentage of units drawing less than 1 W broadly agrees with recent EnergyStar® market share data (see Figure 4-25), as 1 W is the current maximum power draw value for EnergyStar® DVD players.

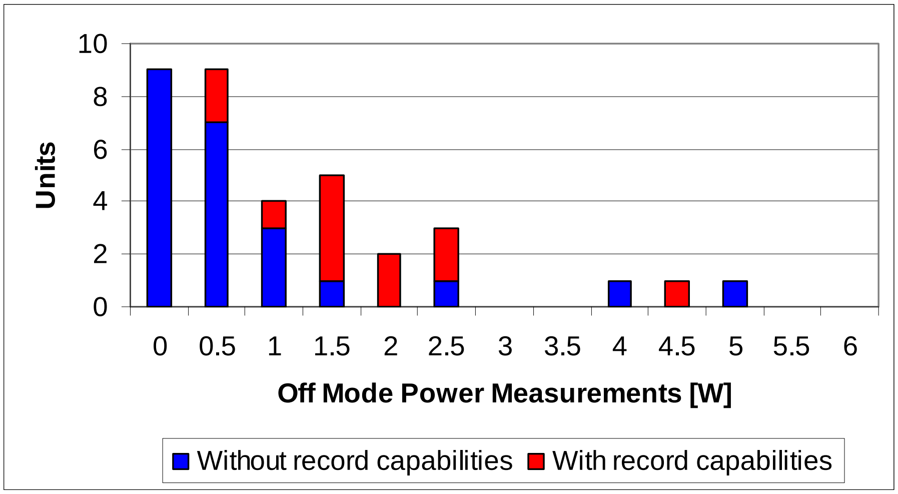

Figure 4-25: Distribution of Off Mode Power Draw Measurements of Recent Vintage DVD Players (TIAX 2007)

Figure 4-26 plots historical EnergyStar® unit sales as a percentage of total sales for home video products. It is unclear why the EnergyStar® market share is reported to be approximately 30%, while measurements of "best selling" units by CEA revealed that 70% of the units drew less than 1 watt in off mode. (TIAX 2007).

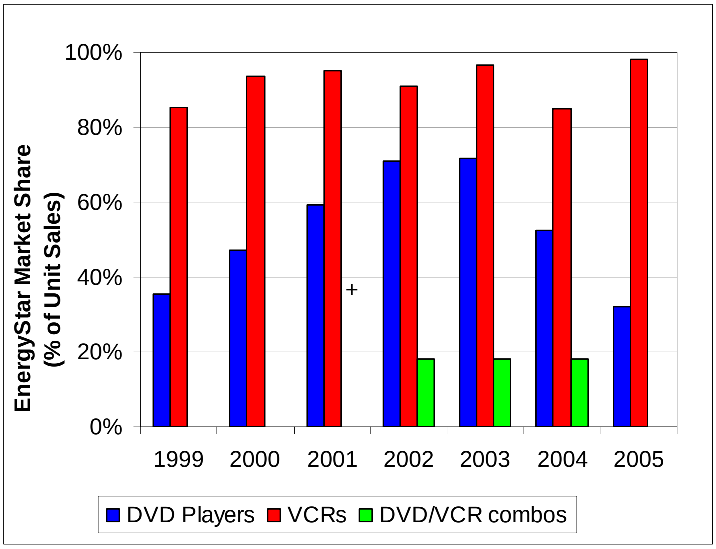

Figure 4-26: EnergyStar® Market Penetration for Home Video Products (EnergyStar 2006)

The power draw in active and idle modes has also generally decreased in home video products (TIAX 2007). This is likely a result of gradual technology improvements and an increased focus on power management by manufacturers.

VCRs now co-exist with DVD players because most installed DVD players lack recording capability. DVD recorders will likely continue to gain popularity and will displace VCRs. High resolution Blu-ray DVD players and HD DVD players are also available as high end DVD products. The installed base of these products is currently very low, but the active mode power draw is likely higher than standard DVD players due to the added data processing requirements.

Other technologies such as video-on-demand, internet protocol television (IPTV), and fiber to the home (FTTH) can offer home video over a broadband connection. The mass acceptance of these offerings could potentially reduce home video product usage.

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5 SECONDARY MISCELLANEOUS ELECTRIC LOADS

In addition to the key loads presented in Section 4, we also analyzed a more limited number of secondary MELs. These fell into two categories: 1) Uncommon loads with high unit electricity consumption (UEC) values but low installed base (e.g., aquariums and portable electric spas), and 2) Common devices with moderate UEC values that, in most cases, appear to have a relatively small energy savings potential (such as hair dryers and irons). In general, prior analyses have analyzed these MELs to a lesser extent than the key MELs and, as with the current analyses, most have large uncertainties in annual usage by mode that results in large uncertainties in both UEC and AEC.

Overall, the secondary MELs evaluated accounted for about 15 percent of the AEC of all the MELs analyzed (see Figure 5-1).

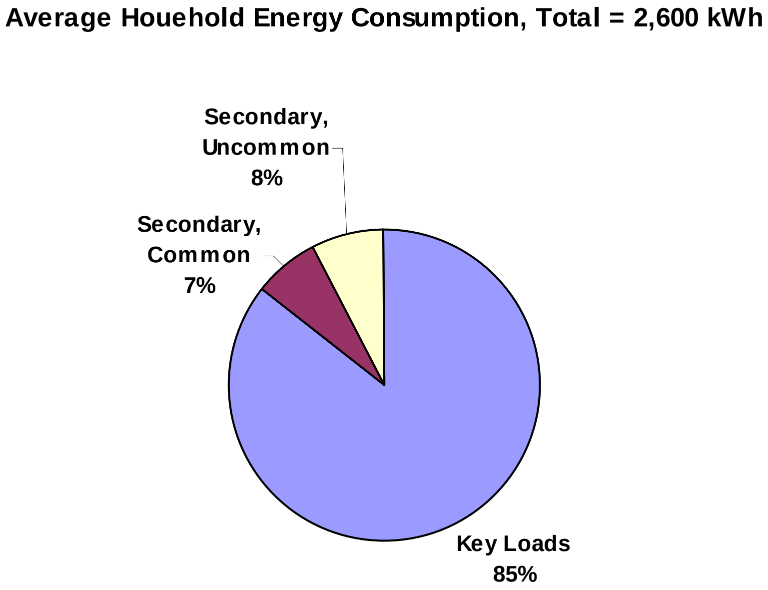

Figure 5-1: Breakdown of Average Household Energy Consumption (HEC) of MELs Evaluated by Load Categories

As shown in Figure 5-2, most of the common, secondary MELs have similar average HEC values (i.e., AEC divided by 115 million households in 2006). With the exception of toaster ovens, the HEC and UEC values of common, secondary MELs are similar due to their high penetration.

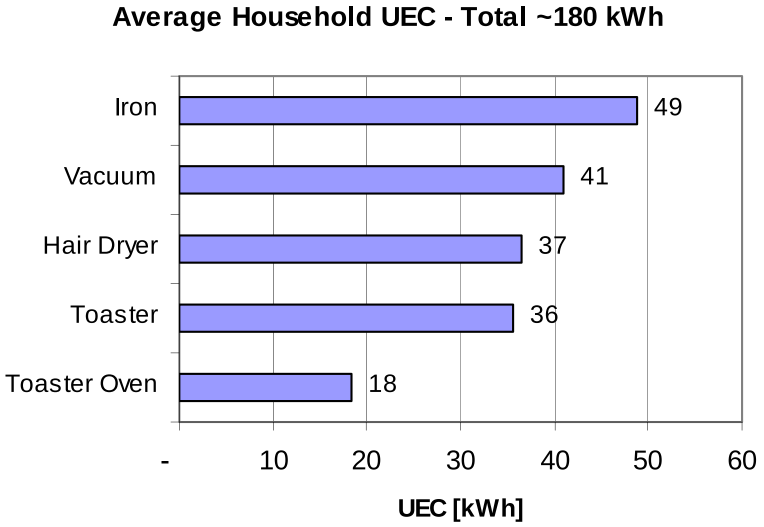

Figure 5-2: Average Household Energy Consumption (HEC) of Common, Secondary MELs

In contrast, the HEC of the uncommon, secondary MELs is much lower than their UEC because of the low saturations. When present in a home, uncommon, secondary MELs can appreciably increase total MEL HEC (see Figure 5-3).

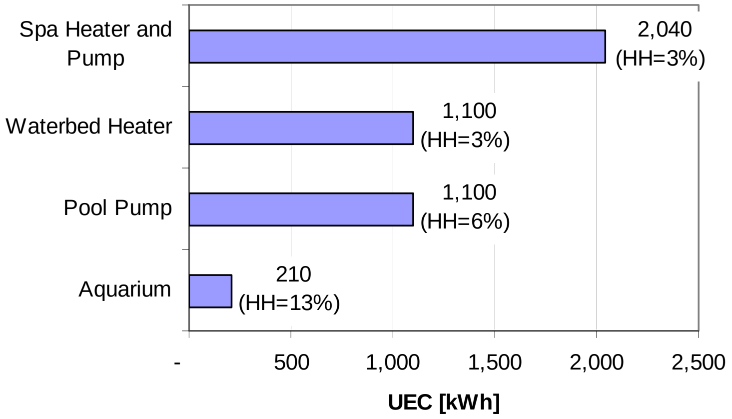

Figure 5-3: Unit Electricity Consumption of Uncommon, Secondary MELs

The following sections presented the analyses for all of the secondary MELs analyzed.

5.1 Aquariums

Table 5-1: Aquarium Device Summary

Characteristic	Result	Comments
Installed Base [millions]	14.7	
Market Penetration [% of Households]	13%	The number of households with an aquarium has nearly doubled in the past 15 years
Unit Electricity Consumption [kWh/year]	210	Large variations in UEC with tank size and features used (notably heaters)
UEC – Best in Class [kWh/year]		
UEC Savings – Best in Class [kWh/year]		
Annual Electricity Consumption [TWh/year]	3.1	
Peak Demand Impact	Low	Heaters (which draw the most power out of all aquarium devices) would run most frequently when the indoor ambient temperature is lowest, likely at night.
Variability in Usage	High	A large portion of tanks do not have heaters; water pumps and aerators run continuously, however heater and light only operate about a quarter of the time.
Notable Regional or Seasonal Variations in Penetration or Use?	Seasonal/ Regional	Heating loads primarily depend upon indoor and tank temperatures RECS (2001) suggests that larger (20+ gallon) heated aquaria are much less common in New England (~1% vs. 4% for U.S.)
Typical Location(s) in Household	Known	Living room, bedroom
Potential Ways to Reduce UEC	*Existing*: • Maintaining other organisms to maintain tank water quality • High efficiency lighting	
Significant Data Uncertainties	Uncertainties in the heater duty cycle, lighting duty cycle, types of filters (aerators or water pumps) typically used with different sizes of tanks, and heater rating by tank	
Key Technology Trends	None known	

5.1.1 Introduction

The most reliable source of information regarding the number of fish tanks in residential homes is provided by the Pet Owners Survey. This survey is conducted by the American Pet Products Manufacturers Association and directly questions pet owners on a wide variety of pet related topics. The 2005/2006 survey reported a total of 13.9 million households with freshwater fish and 0.8 million households with salt water fish (Pet Owners Survey 2006). Translating this information into an installed base estimate required some assumptions.

This study only considers fish tanks that draw power, yet not all of the aquariums in households reported in the survey draw power. Notably, certain types of fish (such as beta and gold fish) do not require common energy-consuming devices. Based on a qualitative survey of aquarium retailers, however, it is considered a valid assumption that the majority of fish tanks are associated with a combination of electrical accessories. Though it is acknowledged that some do not consume any power, discussions with retailers in these tanks tend to be smaller (less than 5 gallons) tanks that consume the least amount of energy when they do consume energy. Consequently, their omission would likely have a small impact on the average aquarium energy consumption. Additionally, although it is conceivable for households to have more than a single aquarium, it is not unreasonable to assume that the vast majority of households would have a single tank. Finally, the number of households with aquariums is separated into fresh and salt water tanks. Retailers indicated that fresh and salt water fish have similar needs, therefore share the same common accessories. Assuming there is no power draw bias in fresh or salt water aquariums, the values can are combined to provide a single population of aquarium.

Therefore, it assumed that there is an installed base of 14.7 million energy-consuming aquaria. Trends over the past decade and a half indicate that aquarium ownership is on the rise (see Figure 5-4).

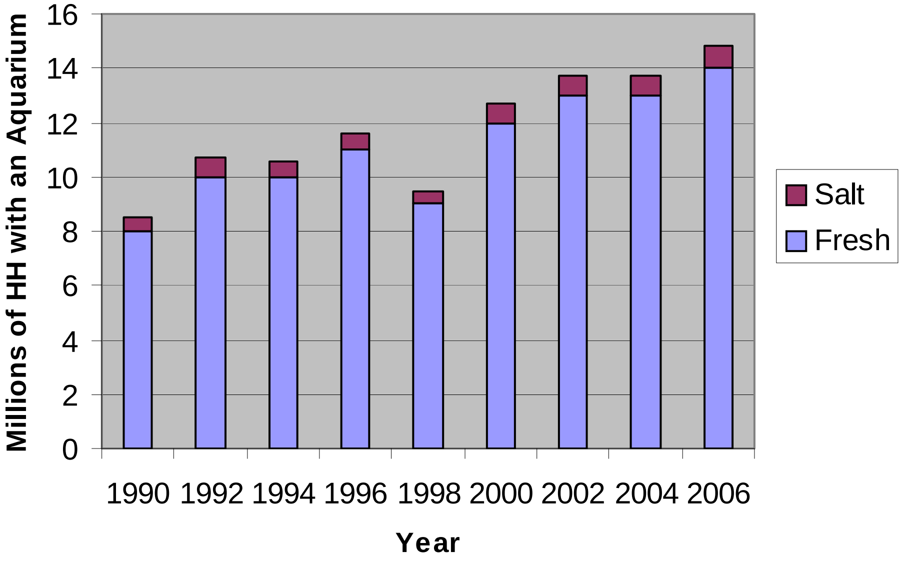

Figure 5-4: Number of Households with Salt and Fresh Water Aquariums Compiled from Past National Pet Owners Surveys (infoplease 2006)

There are four widely utilized accessories that are considered here: heaters, aerators, water pumps, and lights. Each has its own purpose, application, and modes of operation.

Heaters are used for tanks containing fish that require a water temperature above the ambient temperature. According to retailers, this can be as high as 88 degrees for some tropical fish, but is typically around 78 degrees. Heaters are generally set to maintain a set temperature within a few degrees. Therefore, the heater does not run continuously. Its duty cycle primarily depends on heating capacity, tank size, and the difference between the set point and ambient temperature. Thus, heaters have two modes of operation, on and off. In the on mode, it draws somewhere close to its rated power draw and in the off mode it does not draw any power.

Aerators and water pumps filter and circulate the water. Aerators pump air and, in decades past, were the primary means of performing these necessary operations. They are, however, less effective than other methods and their popularity has decreased. The advantage of aerators is their relatively small size and they are typically used for filtration and circulation in smaller (5 gallons or less) tanks. Additionally, aerators may serve a decorative purpose to operate other aquatic devices, such as bubble walls, air stones, or décor (treasure chests, sunken ships, etc.). Water pumps, on the other hand, have become common in larger tanks because they provide superior water circulation for filtration and aeration. Most aquariums typically have at least an aerator or a water pump, though some can have multiple devices per tank, especially for larger tanks. Both accessories have a single mode where they operate continuously.

Aquaria of all sizes typically use a light to illuminate the fish, though some high-power bulbs may also provide light for aquatic plants. However, it is difficult to maintain these plants and the plants would not be included as part of the average aquarium. Therefore, the typical light would have two modes, on and off, with power draw approximately equal to the rated power of the light bulb when on, and no power draw when off.

5.1.2 Unit and Household Energy Consumption

To obtain an estimation of aquarium unit electricity consumption and household energy consumption, it is useful to consider different sizes of tanks as accessories vary with aquarium size. An approximate break down of tank sizes is taken from an online survey at Pet Products News (see Table 5-2).

Table 5-2: Percentage of Aquarium Sales by Size in the Past Six Months (Pet Products News 2006)

5 gallon or less	7.7%
10 to 20 gallon	53.9%
25 to 50 gallon	23.0%
50 to 75 gallon	11.5%
More than 75 gallon	3.8%

Although these percentages come from sales data, it is assumed that these data also generally reflect the tank distribution for the installed base. Furthermore, the dominance of 10 to 20 gallon tanks in the table correlates well with qualitative feedback from retailers.

Accessory Penetration
To account for the variation of accessories by size of tank, the analysis takes into account the penetration of each aforementioned device for the different tank sizes listed above. The penetration of heaters can be obtained from the 2001 Residential Energy Consumption Survey and from the distribution of tank sizes. The 2001 RECS indicated that there were 4.5 million large, heated tanks nationwide (EIA 2001). The survey defined large tanks as 20 gallons or bigger. Interpolation from Figure 5-4 yields an estimate of approximately 13.2 million aquaria in 2001. Assuming 35% of those are less than 20 gallon (all of 5 gallon or less and half of 10 to 20 gallon tanks, 8.5 million are 20 gallon or larger. Therefore, about 50 percent of all tanks in 2001 had heaters and the analysis assumes that the same value holds for 2006.

As discussed above, aerators are used for circulation and filtration almost exclusively with smaller tanks. Therefore, tanks of 5 gallons or less will be considered to have an aerator. Aerators are use also used as decoration in larger tanks and an average of 0.5 aerators will be considered for tanks larger than 5 gallons, based on discussions with retailers.

Water pumps are generally not used with the smaller tanks, as aerators provide means of filtration and circulation. Therefore, only tanks larger than 5 gallons will be considered to have a water pump. The range of water pump capacities goes up to 70 gallons, necessitating a single pump for larger tanks up to 70 gallons. Aquaria 75 gallons and larger will be considered to use two 40-gallon water pumps.

A survey of aquarium products and discussions with retailers indicates nearly all aquariums are sold with lights. This includes smaller, starter kits up to the largest displays. Therefore, all aquariums will be considered to have a light.

Power Rating
Heaters, aerators, and water pumps are all rated for use with certain size aquariums. In order to estimate the power draw of these devices, several products were surveyed over the range of rated capacities from two major pet suppliers (Petco and Petsmart). The average of all devices was taken for a particular size of tank for each of the three accessories. Field measurements of several different aerators suggest that the power draw of aerators equals about 90% of the rated power.

While this approach works well for aerators and water pumps[74], heater selection depends on tank size as well as the temperature set point. Based on recommendations by the aquatics manager for a major chain of pet stores, the analysis assumes a typical set point of 78°F and uses heater power ratings for specific aquarium sizes[75] shown in Table 5-3.

In contrast, lighting is not rated for use with a particular size of tank. An in-store survey of aquariums with lighting indicated larger tanks generally have larger bulbs and greater power

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[74] For these products, manufacturers explicitly state the intended tank size for products.

[75] Proper heater sizing is important. An oversized heater may not effectively dissipate heat quickly enough and could harm the fish, while an undersized heater may not be able to maintain the set point temperature.

draw. Data was gathered from a major chain pet store, looking at the rated power of the lighting attached with tanks of various sizes. The results indicate lighting power draw generally increases with the size of tank. Similar to the other accessories, the average power draw for each tank size range will be taken and used for calculating the unit's energy consumption.

Usage

As mentioned in the previous section, the aerators and water pumps operate continuously, i.e., 8,760 hours of operation per year. As noted earlier, heater usage duty cycle depends on several factors; however, because the heaters have been selected for particular sizes, there are fewer variables. Therefore, the temperature of the ambient air is the largest variance in the heater usage time, which can vary with time of day, time of year, and region of the country. Yet, with a home's conditioned environment, it can be assumed that homes are, on average, maintained at 72 degrees (Emerson 2004) and aquarium heaters are set to maintain 78°F, the correct heater capacity based on tank size have duty cycle of approximately 25% (Algone 2006), or 2,190 hours per year[76].

The light usage time depends on the times the user may be viewing the aquarium. In order to estimate the usage time of an aquarium light, it is assumed the light would only be used during typical times owners would be viewing their aquarium, which may be considered to be evenings and weekends. For any given week, the weighting factor and usage time during each period are estimated based on a typical work schedule. Evenings have a 5/7 weighting with an operating period of approximately 4 hours per day, while weekends have a 2/7 weighting and an estimated operational time of approximately 8 hours a day. Assuming the number of people who leave their lights on all the time approximately cancel people who do not turn their aquarium lighting on, the average duty cycle would be about 5 hours a day. Therefore, the light's estimated usage time equals 1,825 hours per year. Table 5-3 presents the data used for the UEC calculations.

Table 5-3: UEC for Aquaria, by Tank Size

Size of Tank [gal]	<= 5	10-20	25-50	55-75	>75
Accessories per Tank					
Heaters	0.5	0.5	0.5	0.5	0.5
Aerators	1.0	0.5	0.5	0.5	0.5
Water Pumps	0.0	1.0	1.0	1.0	2.0
Light	1.0	1.0	1.0	1.0	1.0
Power Draw					
Heaters [W]	25	50	100	200	250
Aerators [W]	2	2	4	4	7
Water Pumps [W]	5	5	10	12	10
Light [W]	15	15	27	30	40
Usage					
Heaters [hrs/year]	2190	2190	2190	2190	2190
Aerators [hrs/year]	8760	8760	8760	8760	8760
Water Pumps [hrs/year]	8760	8760	8760	8760	8760
Light [hrs/year]	1825	1825	1825	1825	1825

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[76] An employee of a major pet retailer estimated a similar duty cycle.

Size of Tank [gal]	<= 5	10-20	25-50	55-75	>75
Energy Consumption					
Heaters [kWh]	28	57	114	228	285
Aerators [kWh]	18	9	18	18	31
Water Pumps [kWh]	0.0	44	88	105	175
Light [kWh]	27	27	49	55	73
UEC by Size [kWh]	75	135	270	405	565

Heaters account for the largest portion of aquarium UEC and, for all but the smallest tanks, water pumps consume the second largest portion of energy. Despite a continuous active mode, aerators comprise relatively little of the UEC (at most 25% for the smallest tanks, around 5% for larger tanks). To derive an average UEC for all aquaria, the individual UEC's estimated in Table 5-4 were weighted by the percentages given in Table 5-2 and summed.

Table 5-4: Weighted Average UEC by Size of Tank and Overall Average UEC for Aquariums

Size of Tank [gal]	**<= 5**	**10-20**	**25-50**	**55-75**	**>75**
UEC (by size)	75	135	270	405	565
Weighting [% of Total]	7.7%	53.9%	23.0%	11.5%	3.8%
Weighted UEC [kWh]	6	74	62	47	21
Average UEC [kWh]	**210**				

Studies of varying degrees of rigor have also provided estimates of aquarium energy consumption. A Pacific Gas and Electric study indicated a 20 gallon tank maintained at 78 degrees consumed about 730 kWh per year in 70^{o}F ambient air. The accessories used nor the test procedure are not, however, specified (Energy Magazine Online 1994). LBNL's study of energy consumption in by the residential sector estimates the UEC of aquariums to be 548 kWh per year (Wenzel 1997), and in a separate LBNL report on miscellaneous electricity use states the range of UEC's for 90% of tanks to be 150 to 400 kWh per year (Sanchez 1998). Algone, an aquarium chemical manufacturer, published on their website an estimation of 150 to 200 kWh per year for a 30 gallon tank at 72^{o}F (Algone 2006)

5.1.3 Current Best in Class and Market Trends

Discussions with two major national pet store chains and two manufacturers of aquariums and aquarium accessories (Hagen and Tetra) found that no aerators or water pumps are currently marketed as energy efficient. While the motors for both of these devices could be made more efficient, with the lack of existing models, the magnitude of the savings is not well understood. Nearly no energy can be saved from the heaters, as they are immersed in the tank and would be extremely efficient at transferring energy. Hoods are useful to reduce heat loss through the top of the tank, though they are already standard equipment on most aquariums. Some advances in lighting do provide some possible savings. The majority of light bulbs are fluorescent, though smaller tanks typically have incandescent bulbs. Lighting is, however, typically the second lowest power draw component in a typical aquarium and limits possible savings.

Overall, retailers from Petco indicate trends in the market are toward more accessories. The most prevalent accessories not included in the UEC are biowheels, protein skimmers (which supplement or replace standard filters), and pump heads. All of these devices have power ratings comparable to water pumps.

5.1.4 References

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5.2 Hair Dryers

Table 5-5 Hair Dryer Summary

Characteristic	Result	Comments
Installed Base [millions]	99	Based on 2004 (Appliance 2005b)
Market Penetration [% of Households]	86	
Unit Electricity Consumption [kWh/year]	42	
UEC – Best in Class [kWh/year]	42	
UEC Savings – Best in Class [kWh/year]	Negligible	
Annual Electricity Consumption [TWh/year]	4.2	
Peak Demand Impact	Low	Likely used most in the morning
Variability in Usage	Unknown	
Notable Regional or Seasonal Variations in Penetration or Use?	Low	
Typical Location(s) in Household	Bathroom	
Potential Ways to Reduce UEC	Unclear	
Significant Data Uncertainties	Usage by mode, power draw by mode	
Key Technology Trends	Newer models have higher rated power	

5.2.1 Introduction

RECS includes hair dryers under “residual” energy consumption and does not provide any information about their installed base. Appliance Magazine estimated that 86 percent of households have at least one hair dryer in 2004 (Appliance 2005b). With 115 million households projected by the EIA’s AEO in 2006, it is estimated there are 99 million households with a hair dryer, assuming the percentage of households is maintained (EIA 2006).

Hair dryers can have multiple modes. An in-store survey of hair dryers at a major retailer of available hair dryers indicated typical options include different drying speeds and fan only. Two existing stock hair dryers were tested with a watt meter to identify the differences between the modes. The results indicated significant differences between the settings, which will be discussed in more detail below. For the purpose of this analysis, hair dryers will be considered to have a high and low setting.

5.2.2 Unit and Household Energy Consumption

Few data exist about hair dryer energy consumption. To overcome the data gaps, the in-store survey of irons described in the previous section also included collecting the rated power of the available hair dryers. In all, 20 hair dryer models were surveyed, including five different manufactures. Surprisingly, all of the models had the same power rating of 1,875 W[77]. Using the in-store data as the reference for power rating has the downside of not accounting for market share and being biased toward newer models. Accounting for the market share for each model requires data that are not readily available and is noted as a source of uncertainty.

Unfortunately, ignoring the bias towards newer models can not be neglected, as an informal survey of existing units indicates the rated power of older models is significantly less. Four existing hair dryers, including two different manufactures (both of which were represented in the in-store survey), all had a rated power of 1,600W. This very limited data sample suggests that the maximum power draw of hair dryers may have increased over time. Hair dryers are a less expensive appliance, thus it is possible that newer devices may account for a large percentage of the installed base. Therefore, it is assumed that approximately 50 percent of the installed base is of the higher, 1,875 W rating, and 50 percent are of the existing stock, 1,600 W rating. Therefore, the reference average power rating is assumed to equal 1,750 W.

Since the rated power often is much larger than the actual power draw, the actual power draw of two models was measured using a wattage meter. On the high setting, both hair dryers drew about 85 percent of their rated power. Therefore, the high speed mode’s estimated power draw is assumed to equal 85 percent of the reference power rating, or 1,500 W. The reference power rating does not, however, help to estimate the power draw for the lower power mode. Therefore, the power draw of both hair dryers was measured at the

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[77] This suggests that hair dryers draw the maximum current allowable for a 15 amp circuit.

lower speed; for both models, it equaled about 375 W and this value will be used for the low power mode.

There is a dearth of information about hair dryer usage. One utility company's appliance data sheet did include an estimated usage. The Bangor Hydro-Electric Company estimated 15 minutes of use per day (BHEC 2006). After several conversations with hair dryer users, however, it appears that this estimate may be high. Therefore, from these discussions with users, it is estimated that each uses average 10 minutes, 5 days a week, for a total of about 45 hours per year; this compares favorably with the estimate of 50 hours of operation[78] per year by Sanchez et al. (1998). Additionally, conversations with users indicated an approximate split on modal usage. Therefore, it is approximated that 50 percent of the time is used on low and 50 percent on high. For comparison, Sanchez et al. (1998) uses an average power draw value of 710W based on a 1991 measurement of one hair dryer set on "medium speed".

Table 5-6 summarizes the UEC and AEC calculations for hair dryers.

Table 5-6: UEC and AEC of Hair Dryers

Installed Base [millions]	Mode	Power Draw [W]	Usage [hrs/yr]	UEC [kWh]	AEC [TWh]
99	High	1,500	22	42	4.2
	Low	375	22		

As a check on the calculated values, LBNL's energy data sourcebook estimates the UEC to be 35 kWh and the AEC to be 3.0 TWh in 1995 (Wenzel 1997). Additionally, Sanchez et al. (1998) projected the AEC of hair dryers to equal 3.5 TWh in 2010, lower than the current estimate. This value appears not have projected the apparent increase in rated power draw of newer hair dryers.

This prior analysis only considered energy consumed in active mode. As Nordman and McMahon (2004) notes, some hair dryers have ground fault circuit interrupters (GFCI) incorporated into their plugs, in which case they do draw some additional power when still plugged in. The three hair dryers with low-power modes measured by Nordman and McMahon (2004) drew an average of less than 0.1W (when the GFCI was untripped or tripped). Given that hair dryers appear to draw very low levels of power when plugged in and not in use and that many units do not remained plugged in when not in use, we neglected the impact of low-power modes from our UEC analysis.

5.2.3 Current Best in Class and Market Trends

The energy savings for hair dryers is limited, as energy inefficiencies lost in the motor in the form of heat contribute to the drying process. Earlier, it was observed that the rated power draw of hair dryers may be increasing. Ultimately, however, air temperatures (cannot harm the user) and circuit power draw limitations (e.g., 15-amp circuits) in older homes limit the maximum power draw of hair dryers.

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[78] Citing Ohio Edison, based on 10 minutes per day for 300 days per year.

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5.3 Clothes Iron

Table 5-7 Clothes Iron Summary

Characteristic	Result	Comments
Installed Base [millions]	106	Assumes one iron primarily used per household
Market Penetration [% of Households]	92	
Unit Electricity Consumption [kWh/year]	53	
UEC – Best in Class [kWh/year]	Negligible	Appears to have little energy savings potential
UEC Savings – Best in Class [kWh/year]		
Annual Electricity Consumption [TWh/year]	5.6	
Peak Demand Impact	Unclear	
Variability in Usage	Likely high	
Notable Regional or Seasonal Variations in Penetration or Use?	None known	Very high penetration
Typical Location(s) in Household	Laundry room, bedroom (estimated)	
Potential Ways to Reduce UEC	None known	
Significant Data Uncertainties	Annual usage	
Key Technology Trends	None known	

5.3.1 Introduction

In 2005, Appliance Magazine estimated that 92 percent of all households had an iron (Appliance 2005) and. Combined with an estimate of 115 million households in 2006 (EIA 2006), about 106 million households have at least one iron. While households may have more than a one iron, multiple units per household would probably not, on average, affect the energy consumed by irons per household, i.e., more irons would probably decrease the average usage per iron. Therefore, the number of irons used is estimated to also be 106 million units.

Typical irons come with a variety of features, but few effect the energy consumption of the device. An in-store survey at a major retailer[79] of available clothes irons indicated the vast majority include adjustable settings for different types of material, which require varying temperatures. These settings may be discrete or continuous.

In order to investigate the differences in settings, two irons were tested using a commercially available watt meter at different settings under actual ironing conditions. Both irons controlled the temperature by turning the device on and off, heating it when it became too cool and turning it off once it has reached the desired temperature.

While the different settings could be considered different modes, no data were available about the frequency and duration of usage in different modes. Additionally, while the duty cycle differs with the different settings, the power draw when heating does not. Therefore, the simplified model assumes that irons have a single "on" mode, with the differential duty cycles accounted for in the usage. Some irons do draw power when turned off and still plugged in. For example, Nordman and McMahon (2004) reports that two irons drew an average of 1.6W in off mode and that one of those units incorporated an auto-off feature that turned off the iron after a period of non-use. In general, irons are typically unplugged after being used and, thus, do not draw power. Consequently, the active mode likely accounts for the vast bulk of iron energy consumption and this analysis focused upon active mode energy consumption.

5.3.2 Unit and Household Energy Consumption

Although there appears to be a dearth of data about iron energy consumption, several sources do provide estimates of irons' power draw (see Table 5-8). Two of these estimates are large ranges and the other two are the lower end of those ranges.

Table 5-8: Clothes Iron Estimated Power Draws

Estimated Power [Watts]	Source
1,000 – 1,800	EcoVillage (2006)
1,000 – 1,800	MSU (2006)
1,000	BHEC (2006)
1,000	OTPC (2006)

To gain more data about iron power draw, the in-store survey of irons described in the previous section also recorded the rated power of the available irons. Table 5-9 summarizes the rated power draw and manufacturer of the 13 irons surveyed.

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[79] Target.

Table 5-9: In-Store Survey of Irons' Rated Power

Rated Power [Watts]	Manufacturer
1,700	Rowenta #1
1,600	Rowenta #2
1,300	Hamilton Beach #1
1,700	Shark #1
1,500	Black & Decker #1
1,500	Shark #2
1,200	Panasonic
1,500	Black & Decker #2
1,500	Rowenta #3
1,600	Shark #3
1,200	Sunbeam #1
1,200	Sunbeam #2
1,300	Hamilton Beach #2
1,350	**Average**

Averaging the in-store data to use as the reference for typical rated power does not necessarily provide the most accurate information. By using the in-store data, the average is biased towards any trends in newer models that may not accurately represent the installed base. Additionally, the survey does not take into account the market share for each model, nor is it guaranteed the majority of models and manufacturers are represented. Unfortunately, taking into account market share of different models and weight their associated power rating lay outside the scope of the current project. With the noted data gap for power draw and the relatively small range of values, the average in-store power rating of 1,350 W is used to represent the typical iron.

As with all devices, the rated power does not necessarily represent the actual power draw of irons. Therefore, the actual power draw values were measured for the two irons tested for modal operation. One unit rated at 1,000 W drew 975 W, while the other, rated at 1,100 W, actually drew 1,060 W. On average, the actual power draw equaled about 97 percent of the rated power; consequently, the rated power was used to approximate the actual power draw.

The greatest information gap was in the typical usage. No rigorous survey was found that adequately described the ironing usage pattern in the U.S. The Bangor Hydro-Electric Company's energy efficiency guide does offer an estimate for usage, equal to five hours per month (BHEC 2006). Unfortunately, this is only an estimate and not a result of actual data. A promotional survey conducted by iron manufacturer, Rowenta, did interview 4,000 people in 14 major cities, categorizing people's ironing habits (Rowenta 2005). The survey indicated the majority of people use their iron approximately once a week. While the information gathered is biased towards those in urban settings, it does provide a reasonable check. If households average one session of ironing per week, and assuming the BHEC value of 5 hours per month, each use of the iron would last approximately 1.25 hours. Lacking additional information, the energy consumption model uses an approximate active usage time of 1.25 hour per week.

On the other hand, the testing found that irons control the temperature by turning the iron on and off. In order to determine the actual "on" time with respect to usage, both irons were monitored while ironing clothes. While set on an approximately medium-high setting, both irons had a duty cycle of approximately 60 percent. Therefore, with an hour and a half of weekly usage, the actual time of drawing power equals 0.75 hours.

Table 5-10 summarizes the UEC and AEC calculations for irons.

Table 5-10: UEC and AEC of Irons

Installed Base [millions]	Power Draw [W]	Usage [hrs/yr]	UEC [kWh]	AEC [TWh]
106	1350	39	53	5.6

As a check on the calculated values, several sources provide estimates of iron's UEC and AEC. Clark Public Utilities' energy use fact sheet estimates that an iron has a UEC of 96 kWh (CPU 2004). Additionally, LBNL's energy data sourcebook estimates the UEC to be 53 kWh and the AEC to be 4.5 TWh in 1995 (Wenzel 1997).

5.3.3 Current Best in Class and Market Trends

The energy savings potential for irons appearsto be very limited. With resistive heating at the ironing surface, irons are relatively efficient. Since they are thermostatically controlled, lower power ratings would most likely mean a higher duty cycle. Future changes in the AEC may have less technology influence, and greater cultural dependence. For example, trends towards more business casual dress in the office environment and increased use of professional laundry services, could decrease iron usage.

5.3.4 References

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5.4 Pool Pumps and Heaters

Table 5-11: Pool Pump Summary

Characteristic	Result	Comments
Installed Base [millions]	7.0	Based on 2001 RECS and assuming no change in market penetration
Market Penetration [% of Households]	6	
Unit Electricity Consumption [kWh/year]	1,100	
UEC – Best in Class [kWh/year]	420	Based on estimated savings of 62%
UEC Savings – Best in Class [kWh/year]	680	
Annual Electricity Consumption [TWh/year]	7.7	
Peak Demand Impact	Variable	Cleaning schedule can be set to avoid peak demand periods
Variability in Usage	Low	User would set regular cleaning schedule
Notable Regional or Seasonal Variations in Penetration or Use?	Seasonal and Regional	• Higher use during warmer times of the year • Greater use and installed base in warmer regions
Typical Location(s) in Household	Outdoors	
Potential Ways to Reduce UEC	Higher efficiency motor, lower flow rates, oversized pipes and filters	
Significant Data Uncertainties	National average usage, pump power	
Key Technology Trends	Two-speed motors with controls	

5.4.1 Introduction

The 2001 RECS estimates that there were about 6.5 million swimming pools installed in the United States (EIA 2001). Assuming one swimming pool per household, and with 106 million households estimated in 2001 (EIA 2001), about six percent of all households had a pool in 2001. If the penetration of swimming pools remains constant, the projected number of installed units in 2006 can be readily estimated. On the other hand, the penetration of swimming pools exhibits significant regional variance, i.e., warmer regions tend to have more pools than cooler regions. Table 5-12 takes into account these variations and multiplies the regional penetration rates by the number of households per region in 2006 to project the number of installed pools by region in 2006. This implicitly assumes that the penetration of pools did not change appreciably between 2001 and 2006. This yields an installed base of approximately 7.0 million swimming pools in 2006.

Table 5-12: Projection of Swimming Pools by Region (based on EIA 2001, EIA 2006)

Region	Penetration [%]	HH in 2006 [millions]	Installed Units [millions]
New England	8	5.6	0.45
Mid Atlantic	6	15.3	0.92
East North Central	6	18.0	1.08
West North Central	2	8.0	0.16
South Atlantic	9	22.8	2.05
East South Central	6	7.2	0.43
West South Central	5	12.7	0.64
Mountain	5	7.6	0.38
West	5	17.7	0.89
TOTAL	**6**	**115**	**7.0**

With water filtration such an integral component of maintaining a pool's cleanliness, all installed pools are considered to include a pump, i.e., the installed base of pumps also equals 7.0 million. In contrast, pool heaters are not nearly as widespread as pools themselves. Additionally, they use many different power sources, where as pumps consume electricity. Fortuitously, the 2001 RECS included survey questions regarding the number of heated pools and the type of fuel source. According to the survey, about 1.2 million pools are heated. Of those, only approximately 50,000 use electric heat while the majority of heaters use solar energy and natural gas. Because of the small number of electrically heated pools, the remainder of the energy consumption analysis only considers pool pumps.

As noted above, pool pumps circulate water through a filter to maintain the quality of the water. Thus, they only consume energy when the pump runs. Pool pumps typically use either a one-speed or a two-speed motor. While a two-speed motor would offer two operating modes, pump power draw is provided as an average power draw in the Davis report and no additional information was found on the installed base or usage of two-speed pumps. Therefore, pumps will be considered to have a single operational mode.

5.4.2 Unit and Household Energy Consumption

The power draw of pool pumps varies with the particular pump. Typical motors sizes range from a half horsepower to three horsepower (Davis Energy 2004). Pumps are selected according to the size of pool and the corresponding flow rate required for water circulation. A Davis Energy Group study on swimming pool pumps for Pacific Gas & Electric cites an ADM Associates survey of 4,900 swimming pools that estimated the average power draw of pool pumps by comparing the actual power draw versus the rated power. That study indicated that the average pool pump had a 1.28 hp pump that drew approximately 1.36 kW. Unfortunately, the Davis study was directed at regulations in California and only presented data in certain in-state utility service districts. Therefore, any regional trends in pool size, and consequently pump size, would bias the results. However, no additional data on pool size by region were found during the course of this analysis to rebut or confirm any concerns regarding regional bias for average power draw. With no additional information, the ADM results are used as an estimate for the national average (Davis 2004).

For pool pump usage, one study indicates the operating hours vary based on seasonal temperatures. Therefore, regional differences in climate also play a part in determining the usage. The report also indicates the amount of daily time a pool owner runs their pump can vary greatly. While a well-designed pool should have a pump adequately sized to allow for the water to be filtered with four to six hours of operation per day during time when the pool is in use, it stated the hours can vary from 4 hours a day to 12 hours a day. With a large number of sources considered, the current analysis uses the estimate of 6.5 hours of use per day for summer usage (ADL 1998).

Additionally, the analysis takes into account regional climates by taking the number of days the average daily high temperature equals 80°F or above in each region[80]. To do so, the average temperature of one major city in each region is used to estimate the number of days the pool pump is used[81] (see Table 5-13).

Table 5-13: Estimated Annual Pool Pump Usage by Region

Region	Days of Usage [days/year]	Daily Operation [hours/day]	Annual Operation [hours/year]
New England	54	6.5	351
Mid Atlantic	113	6.5	735
East North Central	103	6.5	670
West North Central	113	6.5	735
South Atlantic	134	6.5	871
East South Central	121	6.5	787
West South Central	168	6.5	1,092
Mountain	92	6.5	598
West	161	6.5	1,047

Combining the Davis (2004) average pool pump power draw with the usage time and installed base enables calculation of the UEC for each region. Subsequently, the AEC is calculated for each region using the regional UEC and installed base for each region and summed to obtain the national AEC for swimming pool pumps (see Table 5-14).

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[80] Using the RECS definitions for regions. See http://www.eia.doe.gov/emeu/reps/maps/us_census.html for definitions of each region.

[81] In practice, several other factors affect use, including whether or not the pool has a heater, users' lifestyles, and local insolation levels.

Table 5-14: UEC and AEC of Pool Pumps

Region	Installed Base [million]	[% of Total]	Power Draw [kW]	Usage [hours]	Regional UEC [kWh/yr]	Weighted UEC [kWh/yr]	Regional AEC [TWh/yr]
New England	0.45	6%	1.36	351	477	30	0.21
Mid Atlantic	0.92	13%	1.36	735	999	131	0.92
East North Central	1.08	15%	1.36	670	911	141	0.98
West North Central	0.16	2%	1.36	735	999	23	0.16
South Atlantic	2.05	29%	1.36	871	1,185	347	2.4
East South Central	0.43	6%	1.36	787	1,070	66	0.46
West South Central	0.64	9%	1.36	1,092	1,485	135	0.95
Mountain	0.38	5%	1.36	598	813	44	0.31
West	0.89	13%	1.36	1,047	1,423	180	1.3
Total	**7.0**					**1,100**	**7.7**

Not surprisingly, the South Atlantic accounts for the largest portion of the AEC of any region, as it has the largest number of installed units and a relatively long period of use. ADL (1998) provides a check on the national values for the UEC and AEC of pool pumps; it estimated that the average pool pump UEC was 792 kWh and the AEC was 4 TWh. The difference in UEC can be accounted for by the lower ADL power draw estimate. The lower AEC reflects both a lower overall UEC and the smaller installed base at that point in time. An LBNL report estimates the AEC in 1995 to be 6.4 TWh and projects the AEC in 2010 to be 9.6 (Sanchez et al .1998). Linear interpolation between these two data points would yield an AEC of about 8.5 TWh, slightly above the value in Table 5-14.

5.4.3 Current Best in Class and Market Trends

The energy saving potential of swimming pool pumps has been evaluated by both Davis and PG&E for standards setting in California. The research focused on energy savings from pump motors, pump sizing, pipe design, and filter sizing.

The efficiency of pool pump motors varies. PG&E recommended eliminating less efficient motors in their report for the 2008 California Building Energy Efficiency Standards. The standard recommendation suggests that by banning capacitor-start/induction-run and split phase motors, PG&E estimates 10 percent savings in energy use (PG&E 2006).

Another California study cites significant amounts of energy can be saved by sizing and selecting an appropriate pump. Because the pressure drop of piping networks tends to scale with the square of the flow velocity, operating the pumps at a lower speed can result in a large decrease in total pump energy consumption. For example, halving the flow rate and doubling the run time reduces the pump energy consumption by approximately 75 percent[82]. Consequently, systems with a two-speed pump with the low speed sized for filtration operation (most common mode) and the high speed sized for occasional periods that

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[82] This assumes that the motor and pump would have similar operational efficiencies at both loadings. In practice, two-speed motors tend to have a bit (5-10%, absolute) lower efficiencies than single-speed motors (ADL 1999).

demand more intense cleaning can result in significant energy savings. A joint report by Davis and PG&E estimates a two-speed pump could reduce pool pump energy consumption by 53 percent on energy consumption (Davis Energy 2006).

Modification to the pipes and fittings[83] can also reduce the friction loses and, hence, pump energy consumption. This can be achieved by increasing pipe diameters to reduce flow velocities and decrease the system pressure drop. In addition, removing hard turns in the pipe and replacing them with sweeping bends, the losses can be reduced. The total savings of pipes and fittings yields savings of 1 to 15 percent (Davis 2006, PG&E 2006).

Applying all of these energy-saving design modifications can save 1,600 kWh relative to a baseline average UEC of 2,600 kWh, or about 62 percent (PG&E 2006).

5.4.4 References

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[83] Data from Davis Energy (2006) indicate that modifications to the filters have a minimal impact on energy consumption (e.g., ~0.5%), suggesting that the piping system dominates overall pressure drop and, hence, pump energy consumption.

5.5 Portable Electric Spas

Table 5-15 Portable Electric Spas Summary

Characteristic	Result	Comments
Installed Base [millions]	3.5	
Market Penetration [% of Households]	3	
Unit Electricity Consumption [kWh/year]	2,040	
UEC – Best in Class [kWh/year]	1,470	Better insulation and lower idle temperature set point account for most savings; based on modeling
UEC Savings – Best in Class [kWh/year]	570	
Annual Electricity Consumption [TWh/year]	7.1	
Peak Demand Impact	variable	Depending on filtration schedule
Variability in Usage	Intermediate	Use may vary from every day to a few times a month (ADL 2001)
Notable Regional or Seasonal Variations in Penetration or Use?	Intermediate	Less use in warmer seasons, increasing use in West and Mountain regions
Typical Location(s) in Household	Outdoors	
Potential Ways to Reduce UEC	Better insulating cover, lower set temperature	
Significant Data Uncertainties	Usage	
Key Technology Trends	Trends toward larger tubs	

5.5.1 Introduction

The 2001 RECS estimated that approximately 3 percent of households in the U.S. had an electric spa. Similarly, according to a report by Davis Energy Group to Pacific Gas and Electric, the Association of Pool and Spa Professionals (APSP, formerly National Spa and Pool Institute) estimated that there were 3.4 million residential spas in 2000 (Davis 2004). Assuming that the market penetration of spas did not appreciably change by 2006, the EIA estimate of 115 million households in 2006 yields an installed base estimate of 3.5 million spas in 2006.

Several spa components affect its energy consumption, including filtration pumping, jets, shell insulation, and cover. The size of the spa also has a major impact on the UEC, with energy consumption typically increasing with spas size. The Davis report indicates that installed spas can be as large as 500 gallons, but most are in the range of 210 to 380 gallons (Davis 2004). A report by ADL in 2001 for the APSP on spa energy consumption includes a survey of manufactures that indicates the vast majority of new hot tubs are in the size range of 340 to 381 gallons (ADL 2001).

Spas are characterized by two modes: idle and in-use. The operations considered for each mode are based largely on the definitions provided in the ADL report mentioned above. During idle mode the spa has the insulating cover on and only the circulation pump operating. Additionally, the spa is assumed to maintain temperature during idle mode due to the large amount of time required to heat the spa relative to the amount of time spent utilizing it. When the spa is in-use, it is assumed that the cover is removed, the spa is occupied, and high flow rate jets are on.

5.5.2 Unit and Household Energy Consumption

The power draw, usage, UEC, and AEC are based on the ADL work for the APSP. The report involved simulating the annual usage of two different models accounting for differences in new and old vintage spas. The energy consumption of the two prototypical spas was assessed in three different climate regions.

The energy consumption is based on the differences between the newer and older prototypical spas and effects of the simulated climates. It is assumed in the ADL study that the two models are of similar in size and insulation levels[84], while the power draw of the pumps and auxiliary devices in the two modes varies. Table 5-16 summarizes the estimated power draw of the pumps by mode. The pump is responsible for circulating the water through filters in idle mode and operates the high flow jets when the spa is in active mode. The auxiliary devices include lighting and a control panel.

Table 5-16: Power Draw by Mode of Pumps and Auxiliary Devices (from ADL 2001)

Model	In-Use Pump [W]	Idle Pump [W, average]	In-Use Auxiliary [W]	Idle Auxiliary [W]
Vintage	1,107	101	0	0
Prototypical	3,375	93	127	25

The power draw of spas varies with the heating requirement, which depends on the outdoor conditions and the water temperature set point. The ADL report estimates an average temperature set point of 102°F based on a survey by the APSP (ADL 2001). All of the spa models incorporate this assumption. To account for the heating requirement of the simulated spas, the ADL study simulates the heat loss based on several factors. These include the outdoor temperature in three major cities (Los Angels, San Francisco, and New York City), water loss due to splashing, and the use of a cover. The model calculates the heat transfer for each hour of a simulated year, which equals the heat load required to maintain the water temperature at the set point. In addition, it takes into account the pump power draw using the values shown in Table 5-16, and estimates the efficiency of the pump motor to be 70 percent. A subsequent refinement to the model includes the heating effect of the pump energy, i.e., it assumes that the pump work dissipates in the water and offsets the heating requirement.

The spas are assumed to operate 6.25 times per month[85] based on recent survey data for two different times of year for the state of California (CEC 2004) for an average time of 20 minutes (ADL 2001). This yields an average operating time of approximately 0.1 hour per day.

The simulation results for each climate are provided in Table 5-17.

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[84] While the size and insulation are assumed similar between older and newer vintages, the ADL report notes that this is an approximation, as newer spas tend to have more insulation and are larger in size. The energy impact of these trends is assumed to approximately offset each other.

[85] The two reports discussed developed significantly different estimates for spa usage. The 1999 market research survey (PK Data 1999) estimated that users use their spas an average of 16.4 times per month, which is much higher than the estimate cited above from California's RASS. The current UEC estimate uses the RASS data because the PK Data source may have a bias toward more avid spa users.

Table 5-17: Summary Usage Modeling by Spa Type and Climate Zone

Climate/Spa Model	In-Use Power [W]	Idle Power [W]
Los Angels		
Vintage	3,310	222
Prototypical New	2,570	200
New York City		
Vintage	3,490	249
Prototypical New	2,750	226
San Francisco		
Vintage	3,430	237
Prototypical New	2,690	214

To obtain an overall power draw by mode, the results for the two different spa models are averaged based on their estimated installed based. The ADL study estimates vintage and prototypical new each account for half of the installed base (ADL 2001). Therefore, the average power draw by region is the simple average of the two models for both the in-use and idle power. Additionally, the installed base in the three climates are assumed to be approximately equal, making the overall in-use and idle power draws to be equal to the average for the different cities. As noted earlier, the energy consumption model was refined to include the heating effect of the pump energy, which results in the lower UEC value shown in Table 5-18 than that reported in the 2001 study.

Table 5-18: UEC and AEC for Portable Electric Spas

Installed base	Power Draw		Annual Usage		UEC	AEC
	In-Use	Idle	In-Use	Idle		
[millions]	[W]	[W]	[hr/yr]	[hr/yr]	[kWh/yr]	[TWh/yr]
3.5	3,039	225	25	8,735	2,040	7.1

Though the in-use power draw of spas is significantly higher than in idle mode, the idle mode accounts for most of the UEC because most residential spas operate for relatively few hours per year. For comparison, an LBNL study on the energy usage of residential devices projected the AEC of spas and hot tubs to be 4.9 TWh in 2005 (Sanchez *et al* 1998).

5.5.3 Current Best in Class and Market Trends

Because the idle mode accounts for most spa energy consumption, the majority of potential energy savings comes from reducing the idle power draw. One analysis explored technologies and design changes to current spas that would reduce their energy consumption. According to the Davis Energy report on spas, covers can have a major impact on spa energy consumption. The report indicates that the majority of spas are sold with covers of lower insulating value than the rest of the spa and without effective means of sealing the cover to the spa (Davis 2004). However, the cover is easily replaced, as is often required over the life of the spa, and existing stock could be retrofitted to reduce spa energy consumption.

Standby temperature control is another possible way to decrease the energy requirement. Currently, few spas have the ability to set the temperature automatically when the spa is not in use. The Davis Energy Group report estimates the heating requirement could be reduced by 5 to 10% by allowing the user to schedule the spa to maintain a lower temperature during periods of non-use (Davis 2004). Similarly, the ADL model indicates reducing the set point by 2 to 4°F can reduce the idle power draw by approximately three to eight percent (ADL 2001).

According to the Davis report, spas have a wide range of pump configurations to push water through the filters and provide water circulation, as well as to operate jets while the spa is in use. A design with two pumps, one high-speed and one low-speed, can decrease the power draw over a single pump design by using the lower speed pump for filtering at a reduced flow rate, but still sufficiently maintaining the water. However, as noted in the energy consumption analysis, the pump work offsets some of the heating requirement. Indeed, the refined ADL model indicates that increasing the pump efficiency has little benefit because the pump energy is usually less than the heating load in the idle mode and displaces resistance heating. On the other hand, increasing the pump motor efficiency does result in savings because most the heat dissipated from the motor is assumed to be lost to the surrounding environment. Assuming that a motor with an efficiency of 85%[86] supplants the typical low-speed motor efficiency (73%), this would reduce the UEC by only about 2%.

The ADL report included a survey of spa manufactures and current retail spa models. This data indicated that spa sales have trended towards larger tubs with more jets and better insulation. Larger tubs require more heating power to maintain temperature and their greater thermal mass increases the energy required to recover from setting back the set point temperature, while more jets also tend to increase energy consumption. On the other hand, improvements in insulation and shell materials help to offset some of the heating requirements.

To estimate the best in class electric spa, the prototypical new model from the ADL study is considered. However, to estimate the best potential energy savings using current technology, the highest R-values estimated by ADL were used. Additionally, the set temperature for idle use was reduced from 102°F to 98°F and the motor efficiency was increased to 85 percent. Other than these changes, the models were the same as used for the average power draw. Table 5-19 provides the estimated power draws for each city using the increased insulating values and idle temperature set back and the average in-use and idle mode power draw values are used to calculate the best-in-class UEC (see Table 5-20). The model predicts that the best-in-class electric spa reduces UEC by approximately 28%.

Table 5-19: Energy Modeling Results by Climate Zone for Best-in-Class Spas

Climate	In-Use Power [W]	Idle Power [W]
Los Angels	2,870	155
New York City	3,040	170
San Francisco	2,980	160
Average	**2,960**	**160**

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[86] Based on ADL (1999), assuming that the low-speed motor has close to a 1 horsepower rating.

Table 5-20: UEC and AEC for Best-in-Class Portable Electric Spas

Installed base	Power Draw		Annual Usage		UEC	AEC
	In-Use	Idle	In-Use	Idle		
[millions]	[W]	[W]	[hr/yr]	[hr/yr]	[kWh/yr]	[TWh/yr]
3.5	2,960	160	25	8,735	1,470	5.1

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5.6 Toasters and Toaster Ovens

Table 5-21 Toasters and Toaster Oven Summary

Characteristic	Result	Comments
Installed Base [millions]	104 64	For all entries, data for Toasters are first, toaster ovens second
Market Penetration [% of Households]	90% 56%	
Unit Electricity Consumption [kWh/year]	39 33	
UEC – Best in Class [kWh/year]	31 (toaster)	
UEC Savings – Best in Class [kWh/year]	8 (toaster)	
Annual Electricity Consumption [TWh/year]	4.1 2.1	
Peak Demand Impact	Low	Often used for breakfast (prior to peak demand period)
Variability in Usage	Intermediate	Some day to day variance in usage
Notable Regional or Seasonal Variations in Penetration or Use?	None	Toasters have a very high penetration
Typical Location(s) in Household	Kitchen	
Potential Ways to Reduce UEC	Better insulation, higher radiant efficiency	
Significant Data Uncertainties	Usage	
Key Technology Trends	Use of high efficiency heating elements	

5.6.1 Introduction

According to AHAM in 2005, 90 percent of households contained a toaster. This penetration has remained relatively steady since 1997 (Appliance 2005b). This is not surprising considering toasters are mature and widely used appliances. With 115 million households projected in 2006 (EIA 2006) and assuming one toaster per household[87], there were approximately 104 million toasters in the U.S. in 2006.

The 2001 RECS included survey questions regarding toaster ovens. The results indicated there were 36.1 million households in the U.S. with a toaster oven, or about 33 percent of all households (EIA 2001). Making the same assumption as for toasters, i.e., one toaster oven per household, yields 38 million installed units in 2006. In contrast, Appliance (2005b) estimated the market penetration for toaster ovens at 56 percent, or 64 million households in 2006, an increase from 44 percent in 1997 (Appliance 2005b). This discrepancy between the two surveys likely reflects a difference in the methodology in the two surveys. Specifically, Appliance (2005b) appears to inquire about ownership while the RECS asks the respondent if they "*use* any electric toaster ovens" (RECS 2001). Consequently, the current analysis uses the Appliance (2005b) estimate for toaster oven installed base.

Toasters and toaster ovens may be considered to have several power modes. Both appliances typically allow for several settings, often continuous, to adjust the degree of toasting. It is assumed here that these settings only affect the usage time and not the power draw of the appliance. Additionally, both toasters and toaster oven designs may include several options. Toasters may provide for a bagel setting, in which only one side of the toaster heating elements are energized. Another feature is the ability to toast up to four slices of bread, where the heating of the additional slots is controlled by the user in some units, while others heat all slots regardless of the number of slices of bread in the toaster. More exotic features may include specialized hot dog bun toasting slots or a separate heating element designed for frying an egg. Toaster ovens may include multi-rack cooking, convection heating, or a broil setting.

With the wide range of possible modes, many toasters come with some combination of the features described above. In an in-store survey of available toasters and toaster ovens at two retailers[88], all of the 11 toasters sold had adjustable toaster settings and five had at least one of the other modes of operation described above. For the seven toaster ovens surveyed, again all had adjustable settings and three had one of the other modes described above. This suggests that multiple modes are common for newer toasters and toaster ovens. However, these modes depend on the features included in the design, features that may or may not affect the power draw or usage time. The survey also does not take into account the market share for the models with more features, as these models can cost up to twice as much as toasters or toaster ovens without the features.

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[87] Though households may contain more than a single toaster, it is unlikely additional toasters would affect the energy consumption per household.

[88] Target and Best Buy

In addition to operating modes, a standby mode may also by possible. One study provided measured values for several appliances in low, or off, power modes. A single toaster was found to draw power while not toasting and it drew less than 1W (Nordman and McMahon 2004). This power draw may be the result of a feature such as a status light indicating its inactivity. On the other hand, most toasters do not appear to draw power in off mode and toasters and toaster ovens are considered to have two modes, active and off and, because Nordman and McMahon (2004) estimated that the average toaster draws only about 0.03W when off but plugged in, we excluded that mode from our analysis.

5.6.2 Unit and Household Energy Consumption

The limiting assumptions discussed for the modes of toasters and toaster ovens simplify estimating the power draw and usage. As mentioned before, the UEC calculations for toasters and toaster ovens will be done separately.

In order to obtain an average value for the power draw of toasters and toaster ovens, TIAX conducted an in-store survey of two retailers (see the prior subsection) and recorded the rated powers for the available models. Tables 5-22 and 5-23 present the rated power draw of these devices, as well as the manufacturer and unit features.

Table 5-22: Toaster Rated Power Draw

Manufacturer	Rated Power [W]	Notes
Hamilton Beach #1	1,300	Combo toaster and toaster oven, uses same elements
Back to Basics	1,300	Additional heating element for single egg
Delonghi	1,000	Includes standby light, two slots
Oster #1	1,500	Four slots, not independently controlled
Oster #2	800	Two slots
T-Fal	950	Two slots, defrost option
Hamilton Beach #2	900	Two slots
Black & Decker #1	1,400	Four slots, independent control for two pairs
Black & Decker #2	850	Two slots
Oster #3	750	Two slots, bagel option
Toastmaster	750	Two slots
Average	**1,050**	

Table 5-23: Toaster Oven Rated Power Draw

Manufacturer	Rated Power [W]	Notes
Delonghi	1,400	Conventional
Europro #1	1,200	Convection oven, large cooking chamber
Black & Decker #1	1,200	Conventional
Oster	1,500	Conventional
Black & Decker #2	1,350	Multi-rack cooking
Europro #2	1,200	Conventional
Black & Decker #3	1,200	Conventional
Average	**1,300**	

Taking the average power for both toasters and toaster ovens provides an estimate of power draw. It is noted that by surveying current market appliances, the data would be biased towards any recent trends in toaster or toaster oven design. Due to the general lack of dependable, historical data, it is difficult to determine the degree of any bias.

In addition, devices usually do not draw their rated power. Therefore, a brief test was conducted to determine if a substantial difference exists between the rated and actual power draw. A toaster with a rated power draw of 800W was tested and drew around 790 W when on, nearly the same as its rated power draw. Subsequently, tests of a toaster oven found that it drew approximately 1,525W when operating relative to its rated power of 1,550 W. In sum, the actual operational power draw nearly equaled the rated power draw for both devices and, therefore, the average rated power draw values will be assumed to equal the on mode power draw.

Information regarding toasters and toaster ovens' operational time is, not surprisingly, lacking. Both appliances typically have low duty cycles and operational profiles may vary greatly depending on individual's cooling habits. One source estimates an average toaster use of six minutes of use per day and four minutes of use for toaster ovens, or a total of 37 hours and 25 hours of use per year, respectively (Sanchez et al. 1998). A toaster technology assessment conducted by TIAX indicates the average toasting time is about two minutes (TIAX 2003), meaning the earlier estimate average three uses per day, which seems to be qualitatively on the higher end of usage. Yet, lacking comprehensive estimates for toaster and toaster oven usage, the UEC analysis will use the estimate of six active mode minutes per day. Overall toasters and toaster ovens have UEC values of approximately 39 and 33kWh, respectively (see Table 5-24).

Table 5-24: Toaster and Toaster Oven AEC Calculations

Appliance	Installed Base [millions]	Power Draw [W]	Active Usage [hours/year]	UEC [kWh]	AEC [TWh]
Toaster	104	1,050	37	39	4.1
Toaster Oven	64	1,300	25	33	2.1

5.6.3 Current Best in Class and Market Trends

The aforementioned TIAX toaster study identified several factors that effect energy consumption, as well as ways to increase the efficiency of toasters. These include: covering the toasting slots, increasing the radiant efficiency of the heating elements, and the modifying the internal geometry of the toaster (TIAX 2003). While certain alterations to a toaster may increase its efficiency, they also may affect the quality of the toast, and therefore certain energy saving methods would not be acceptable to consumers or manufactures. One promising measure is to increase the radiant efficiency of the heater elements and, thus, decrease the energy required to heat the toaster elements. The TIAX study indicated significant amounts of energy can go into heating the elements and other toaster components. Infrared heating elements offer the ability to reduce amount of energy required to heat the elements and are also very efficient radiators. While the study was conducted specific to toasters, many of the same principles apply to toaster ovens as well, and toaster ovens with IR heating elements are commercially available from Panasonic (Home Appliance 2006).

Of the toasters tested by TIAX, the quickest time required to achieve a standard toasted quality as 98 seconds (TIAX 2003). If the LBNL usage estimates and the average toasting time from TIAX are assumed, the average toaster is used three times a day. Therefore, the best performing toaster tested would have an annual usage of about 30 hours, reducing the UEC and AEC by about 20 percent.

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5.7 Vacuum Cleaners

Table 5-25 Vacuum Cleaner Summary

Characteristic	Result	Comments
Installed Base [millions]	113	Based on one vacuum per household
Market Penetration [% of Households]	98%	
Unit Electricity Consumption [kWh/year]	42	
UEC – Best in Class [kWh/year]	30	
UEC Savings – Best in Class [kWh/year]	12	
Annual Electricity Consumption [TWh/year]	4.7	
Peak Demand Impact	Low	Usage would vary with time of day
Variability in Usage	Poorly understood	Likely high
Notable Regional or Seasonal Variations in Penetration or Use?	None	Market penetration very high
Typical Location(s) in Household	Usage throughout households	
Potential Ways to Reduce UEC	Closed air circuit	
Significant Data Uncertainties	Vacuum active mode usage	
Key Technology Trends	Larger motors, more central vacuum cleaners, automated "robot" units, electronic controls, closed air circuits	

5.7.1 Introduction

According to Appliance magazine in 2005, 98% of households have at least one vacuum cleaner (Appliance 2005b). It is assumed that each household contains only a single vacuum cleaner; in addition, approximately 20% of households also have a smaller, battery-powered cordless hand vacuum cleaner. The current analysis does not consider these battery-powered devices; they energy consumption is, however, analyzed in the Rechargeable Electronics section (see Section 4-12). If a household does contain multiple vacuum cleaners, it is not clear that the quantity of vacuuming performed would not necessarily increase. Therefore, although the assumption of a single vacuum cleaner per household may under-estimate the installed base, it is not clear that it under-estimates the *per household* energy consumption. Based on the EIA estimate that the U.S. had 115 million households in 2006 (AEO 2006) and applying the 98% penetration and the assumption each household contains only a single vacuum cleaner, U.S. residences had an installed base of approximately 113 million vacuum cleaners in 2006.

Vacuum cleaners have several possible operational modes that reflect different power settings (such as low, medium, and high power) and, in turn, correlate with operational power draw. According to some retailers, the purpose of lower power settings is to clean delicate surfaces or to reduce operational noise. Additionally, some units have different settings for cleaning various types of surfaces, such as hardwood flooring and carpet. Some vacuum cleaners (typically upright style cleaners), having “power heads”, which comprise a rotating brush heads that agitate the carpet to enhance dirt removal from carpets. Power heads may run on a separate, secondary motor or may be belted off from the suction motor. Alternatively, “turbo heads” are also rotating brush heads that derive their power from suction air (AchooAllergy 2006). Power and turbo heads may typically be switched off for hard flooring, as an agitator may damage the surface. Turning off a turbo head, or a power head with no secondary motor, may have little effect on the overall power draw of the vacuum cleaner, and only effect the suction power. However, this would reduce the overall power draw for a vacuum with a power head driven by a secondary motor.

While multiple settings may be available on vacuum cleaners, it is reasonable to assume that the vast majority of operation is at its maximum setting. Some may use the lower settings to clean curtains or delicate rugs, but this may be considered a rare use and only the highest power setting will be considered for operational modes.

It is noted above that only power heads with a secondary motor may change the overall power draw of the vacuum. Only a fraction of vacuums have, however, a secondary motor for a power head. Additionally, power head motors may also have little effect on unit active mode power draw. For example, specifications for one Kenmore vacuum cleaner with a secondary power head motor reveal that the suction motor has a rated current draw of 12 amps while the secondary motor has a rated current draw of 0.5 amps (Kenmore 2006), i.e., less than 5% of the total current draw. Therefore, vacuum cleaners are considered to have two primary operation modes, on and off, with on representing the full power of the suction motor and off the no power draw[89].

5.7.2 Unit and Household Energy Consumption

The power draw for a vacuum cleaner depends on the features of a particular model. As mentioned above, vacuum cleaners can use different methods to agitate a surface and may incorporate features, such as self propulsion. Self propulsion appears to be, however, to be uncommon and a brush motor (if present) draws much less power than the suction motor. Therefore, the current analysis only considers the suction motor power draw.

In order to estimate the power draw, the rated power draws of various vacuum cleaners were surveyed online from several major retailers[90]. The survey included leading manufactures, such as Kenmore, Bissell, Eureka, Electrolux, Hoover, Dirt Devil and relatively new comer, Dyson, and spanned the range of upright and canister vacuums. A total of 64 different vacuum cleaner models were included. The results indicate the most common power range falls between 1,200 and 1,400 Watts, with an average rated power draw of about 1,290 Watts[91].

By surveying vacuum cleaner power draws of current models, the average power draw would be biased toward newer vacuums. A 1999 report by ADL estimates the power draw of vacuum cleaners to be 370 W to 1,500 W. This is a wider and generally lower range than the current survey provided; indicating vacuum cleaners from 1999 may have a typically lower rated power draw. The study also cited the annual sales of vacuum cleaners from Appliance magazine as 15.7 million (ADL 1999). Using that sales number and the current number of units, the installed base would be turned over on the order of seven years. With the estimated turn over rate and the power draw range from 1999, an average power rating will be taken from the lower end of the current survey's range, 1200 W, will be used to calculate the UEC.

Understanding that devices do not necessarily draw their rated power, TIAX carried out targeted field tests to understand the relationship between operational and rated power draw. Nine models of various makes with power ratings between 480 and 1,320W were tested at a vacuum cleaner retailer. The results indicated that vacuums drew, on average, about 90% of their rated power. Therefore, power draw for vacuum cleaners is assumed to equal 90% of the average rated power draw, or approximately 1,080 Watts.

Vacuum cleaners tend to be used sporadically and accurate data for vacuum cleaner usage are not easy to find. A survey in the U.S. found that people spent 3.9% of their day (not including an average of eight hours sleeping) on general house cleaning (Dong et al. 2004), or about 37 minutes per day. In addition, a UK study of vacuum cleaners energy consumption a UK survey that found people clean their residence for an average of 24

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[89] Vacuum cleaners are assumed to have negligible "standby" power draw because, typically, they are not plugged in when stored.

[90] The survey included Sears, Target, and Wal-Mart.

[91] This value is not weighted to take into account unit sales or market shares.

minutes a day. The study concludes from the survey that it is reasonable to consider people vacuum for an hour a week (Market Transformation Programme 2006). While the U.S. estimate is larger (possibly due to different definitions of "general house cleaning"), it is similar to the UK estimate, and does not contradict the estimate of one hour per week. Additionally, the aforementioned ADL study estimated a weekly active usage time of 40 minutes. Based on these two usage estimates and the general house hold cleaning surveys, the current analysis estimated 0.75 hours per week, or 39 hours per year.

Table 5-26 presents the UEC and AEC calculations for vacuum cleaners in the U.S.

Table 5-26: UEC and AEC of Vacuum Cleaners

Installed Base [millions]	Active Power Draw [W]	Usage [hrs/yr]	UEC [kWh]	AEC [TWh]
113	1,080	39	42	4.7

For vacuum cleaners, the UEC equals the household energy consumption due to the assumption that most households have a single vacuum cleaner.

5.7.3 Current Best in Class and Market Trends

The current trends in the market are toward more powerful motors (Market Transformation Programme 2006), primarily driven by marketing concerns. Many consumer websites warn that greater power draw does not necessarily equate to better suction (Ristenbatt Vacuum 2006, AbtElectronics 2006). More vacuum cleaners are also integrating electronic controls that enable monitoring and adjustment of suction pressure. (freescale 2006). In addition, central vacuum cleaners have become more common, increasing their market penetration from approximately 5% circa 1997 to 11.5% in 2004 (Appliance 2005b)

Automated vacuum cleaners have appeared in the market in the form of self-propelled, self-guided robots. These self-propelled vacuum cleaners are cordless and would not fall under the current definition of a vacuum cleaner; they are, however, intended to replace the primary vacuum cleaner in the household and may warrant analysis in future studies (irobot 2006).

New technologies offer the potential to reduce operational power draw. One prototype vacuum cleaner utilizes a closed air circuit to reduce the suction motor power requirement while maintaining similar vacuuming abilities (Edginton 2006). A prototype of the vacuum, called the Captive Air-Flow Cleaner, was tested against conventional vacuum cleaners at various power settings. At 350 to 600 Watts, the Captive Air-Flow Cleaner preformed similarly to a 1,400 Watt vacuum cleaner (Market Transformation Programme 2006). If the high end of the Captive Air-Flow Cleaner tested power draw is used as the average power draw of vacuum cleaners, the active mode power draw and, hence, UEC of vacuum cleaners would decrease by almost 50% relative to the current estimate. This technology also has the added benefit of reducing the air recirculated into the room, cutting down on fugitive dust and particles. However, the Market Transformation Programme report notes that the lack of major manufacturer interest may be an indication of the technology's inability to transition into the open market. This may reflect that consumers often perceive more powerful vacuum cleaners to be better units and an ignorance of device energy consumption.

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5.8 Waterbed Heaters

Table 5-27: Waterbed Heater Summary

Characteristic	Result	Comments
Installed Base [millions]	4.3 million	
Market Penetration [% of Households]	3.4%	Household penetration has declined steadily
Unit Electricity Consumption [kWh/year]	1,100	
UEC – Best in Class [kWh/year]		
UEC Savings – Best in Class [kWh/year]		
Annual Electricity Consumption [TWh/year]	4.6	
Peak Demand Impact	Low	Devices draw similar power around the clock
Variability in Usage	Medium	Usage varies with climate, bed size, and insulation (including covers)
Notable Regional or Seasonal Variations in Penetration or Use?	Regional	2001 RECS show regional variations from 2.4% in the Pacific Region to 10.4% in the W-N Central Region.
Typical Location(s) in Household	Bedroom	
Potential Ways to Reduce UEC	Insulation improvements	
Significant Data Uncertainties	Active usage	
Key Technology Trends	Waterbeds showing declining installed base	

All waterbeds are equipped with a heating system in order to maintain the water temperature at a comfortable level, or approximately 85°F. The heating system generally consists of a heating pad and a thermostat. The thermostat requires power continuously, while the heater draws power intermittently to maintain the set temperature.

The California Statewide Residential Appliance Saturation Study (RASS 2004) shows the percentage of households with waterbed heaters in California to be approximately 1.6%, while the EIA Residential Energy Consumption Survey estimated a percentage of 2.4% in the Pacific Region in 2001. Assuming that California is representative of the Pacific Region, the waterbed heater installed base dropped by approximately 33% from 2001 to 2004, or 10% per year. A similar reduction was applied to the RECS national installed base estimate to arrive at an estimated 3.4 million waterbed heaters in the U.S. in 2006.

Table 5-28: 2006 Waterbed Heater Installed Base

2006 Installed Base [millions]	Penetration [%]	Comments and Sources
3.4	2.8%	• 2001 RECS reduced by 10% per year • Estimated 1.07 waterbed per unit-household per RASS (2004)

5.8.1 Unit and Household Energy Consumption

We found few measurements of waterbed heater power draw and used power draw and usage estimates come from ADL (1998). It appears that power draw values have not changed not significantly changed since the late 1990s (see Table 5-29).

Table 5-29: Waterbed Heater Unit Electricity Consumption

	Active	Idle	Off	Total	Comments and Sources
Power [W]	350	2	0		• Power and usage from ADL (1998), estimated by Central Maine Power Company. • 325 W on sale on Waterbed.com (2006) • CEC (2004) estimated UEC in California to be ~800 kWh/yr
Usage [hr/yr]	3,100	5,660	0	8,760	
UEC [kWh/yr]	1,085	11	0	1,096	
% UEC	99%	1%			

The idle mode power is drawn by the thermostat to monitor the waterbed temperature. This power requirement is low, and accounts for only 1% of the overall energy consumption. It is possible that a guestroom waterbed heater is switched off or unplugged, but we don't have data to analyze this effect.

There is appreciable uncertainty related to the usage estimate for waterbed heaters. Heater on time can vary with bed size, insulation (including whether the bed is made up or not), and climate.

5.8.2 National Energy Consumption

National waterbed heater energy consumption has dropped significantly over the last 10 years because of the decline in installed base.

Table 5-30: National Energy Consumption Characteristics for Waterbeds

UEC [kWh/yr]	Installed Base [millions]	AEC [TWh]
1,096	3.4	3.7

5.8.3 Current Best in Class and Market Trends

Although it is not clear that the efficiency of waterbed heaters can readily be improved, increased insulation (i.e., covers) can reduce the heating load of the beds.

The installed base of waterbeds and heaters shows a clear downward trend. Arthur D. Little (ADL 1998) estimated the installed base of waterbed heaters to be approximately 15 million units in 1997. For cultural or energy conservation reasons, the installed base of waterbeds is expected to continue to decline.

5.8.4 References

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6 CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusions

A wide range of residential miscellaneous electric loads (MELs) exist in 2006. For example, our preliminary screening identified well in excess of 100 different loads, as have earlier studies. Of these, we selected twenty-one key MELs for further analysis. In addition, we chose nine secondary loads for additional but less refined evaluation (see Table 6-1).

Table 6-1: Miscellaneous Electric Loads Selected for Evaluation

Key Equipment Types (21)	Secondary, Common (5)	Secondary, Uncommon (4)
• Ceiling Fan • Coffee Machine • Compact Audio System • Component Stereo • DVD Player • Home Theatre in a Box • Inkjet Printers + MFDs • Lighting, Outdoor • Lighting, Portable • Microwave Oven • Modem, Broadband • Monitors • PC, Desktop • PC, Notebook • Rechargeable Electronics • Security System, home • Set-top Box, Cable • Set-top Box, Satellite • Television, Analog • Television, Digital • VCR (stand-alone)	• Hair Dryer • Iron • Toaster • Toaster Oven • Vacuum Cleaner	• Aquarium • Pool Pump • Portable Electric Spa • Waterbed Heater

For all thirty of these loads, we characterized their:

- Unit energy consumption (typical usage patterns and power draw by mode)
- Household energy consumption (penetration and number of devices per household)
- National (U.S.) energy consumption
- Energy savings potential (based on best-in-class devices available and other efficiency measures, e.g., enabling power management)
- Key future trends over the next several years and their expected impact on each MEL's energy consumption
- Other attributes (main data uncertainties, coincidence with peak electric demand periods, typical locations in households, geographic variations in usage)

The following sections discuss the key findings of our study.

Unit Electricity Consumption (UEC)

The unit electricity consumption (UEC) of the key MELs vary by more than an order of magnitude (see Figure 6-1). Digital televisions have the highest value, followed by desktop PCs and analog TVs.

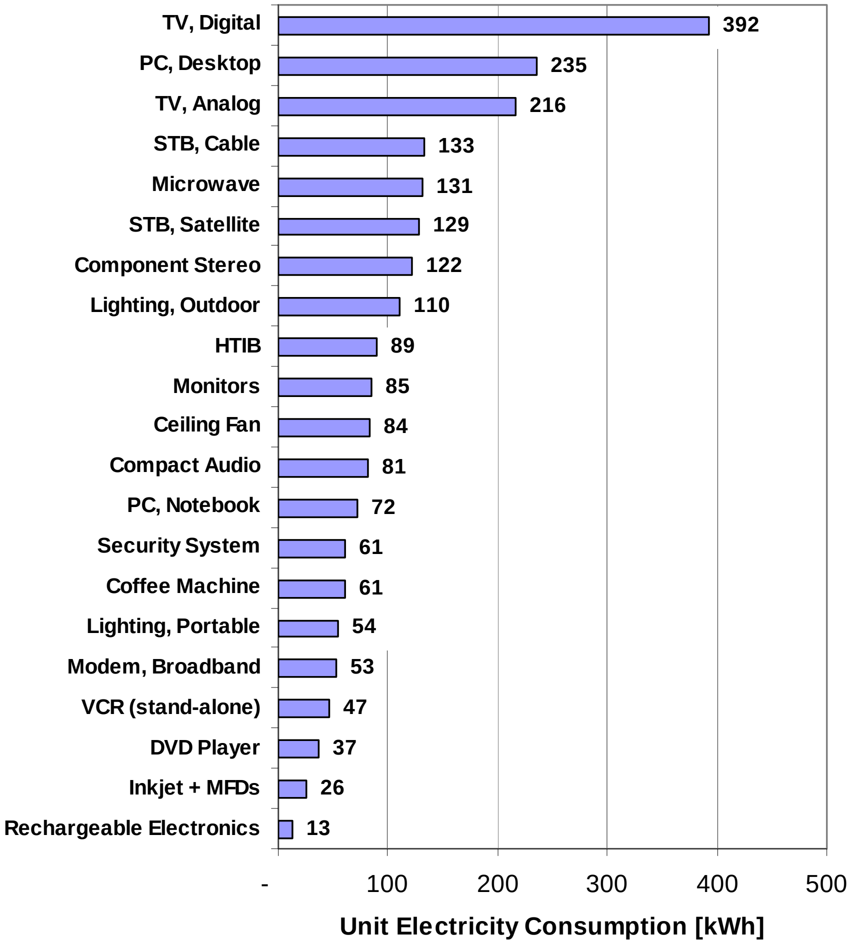

Figure 6-1: Unit Electricity Consumption (UEC) for the 21 Key Miscellaneous Electric Loads

The secondary, uncommon loads have UECs higher than most of the key MELs, while the secondary, common loads have more moderate UECs (see Figure 6-2).

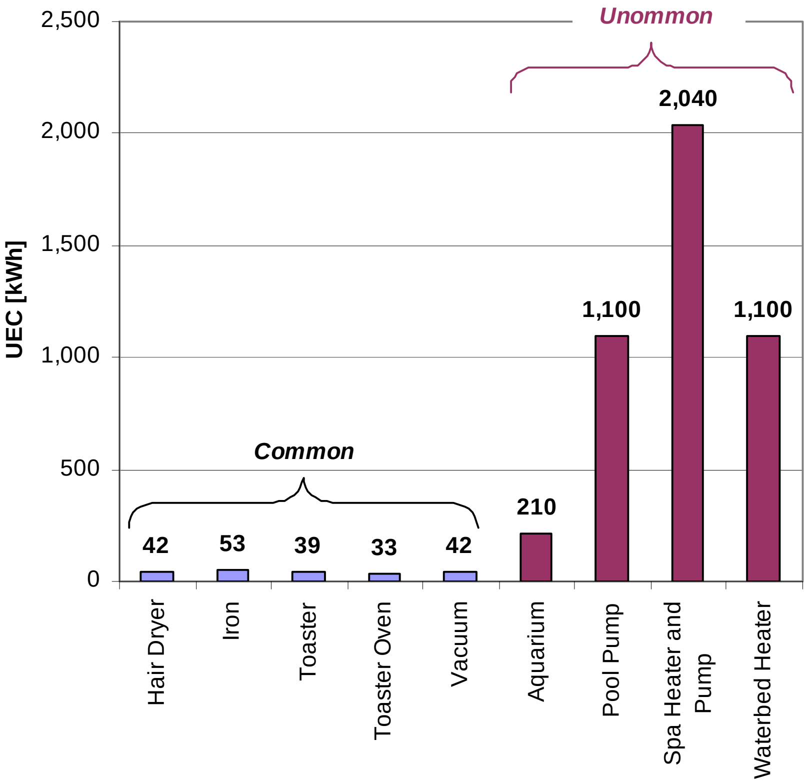

Figure 6-2: UEC of Secondary Common and Uncommon MELs

Different modes account for varying portions of the overall UEC for different MELs (see Figures 6-3). In general, active mode accounts for the largest portion of the MELs with the highest UEC, such as televisions, desktop PCs, while low-power modes account for a significant portion of the UEC of many consumer electronics besides televisions. The active mode accounts for almost all of the UEC of the secondary loads, both common and uncommon loads, with the exception of spa heaters and pumps[92].

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[92] Idle mode, i.e., heater operation to keep the spa warm and pump operation to filter the water when spas are not in use, accounts for most spa heater and pump UEC. As this is a key function for the device, we do not consider this a low-power mode.

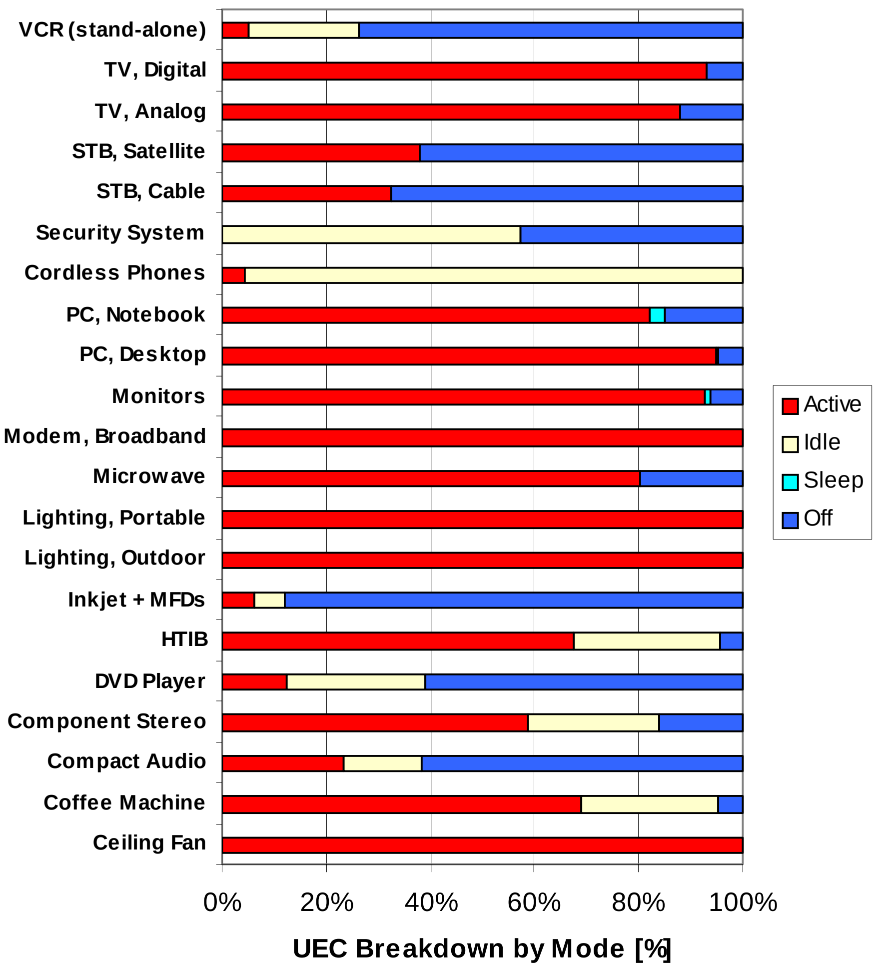

Figure 6-3: UEC Breakdown by Mode for Key MELs

Household Electricity Consumption (HEC)

We evaluated household electricity consumption (HEC) in two ways. First, we evaluated the *average* HEC, which equals the total electricity consumption of MELs divided by the 115 million U.S. households in 2006. Second, we calculated the *typical* HEC, based on the number of each MEL analyzed per household based on penetration and installed base data. For example, the average value will reflect the energy consumed by 2.4 televisions and 0.03 water beds, while the typical household value will reflect two televisions and zero water beds. In general, the penetration of MELs, i.e., the percentage of households with at least one or more of a given MEL, varied greatly between the key and secondary, common MELs and the secondary, uncommon MELs (see Figure 6-4).

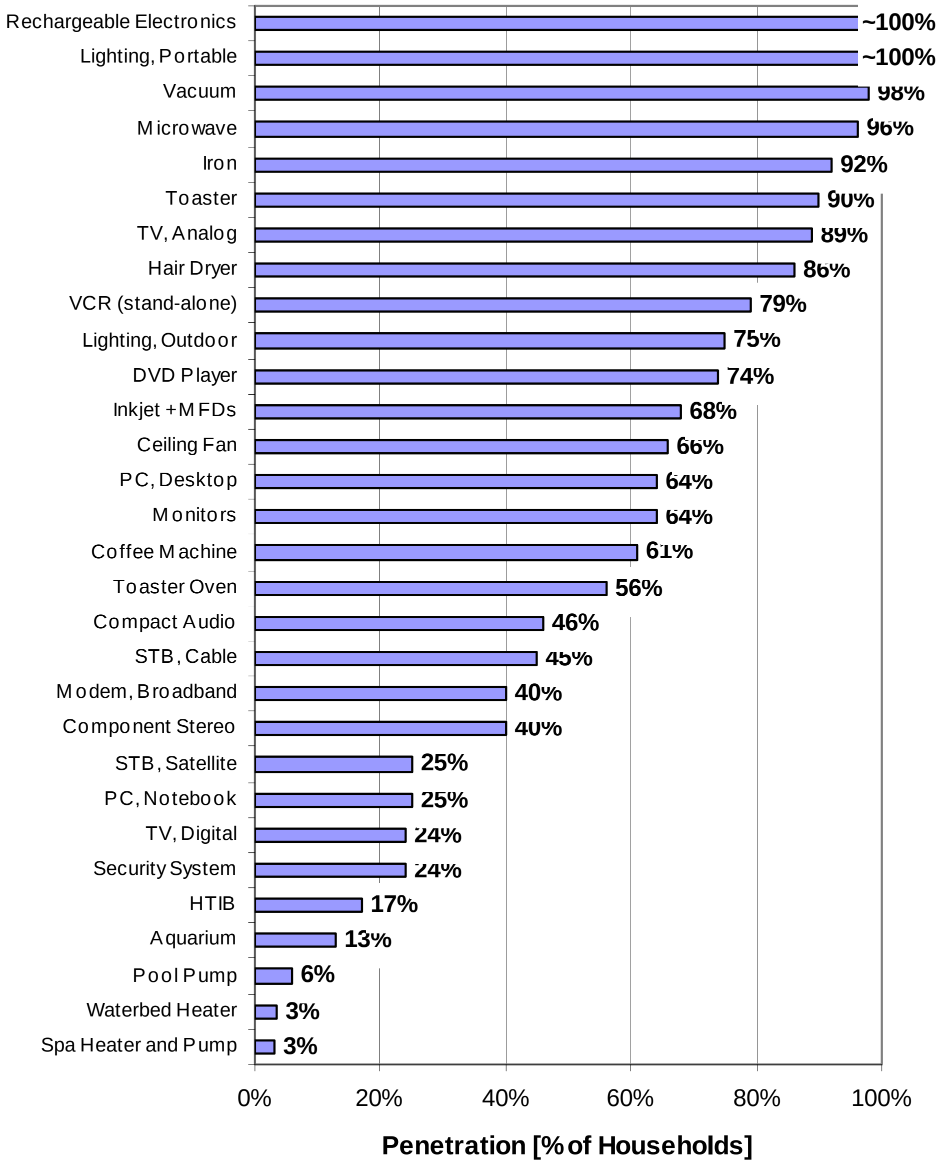

Figure 6-4: Estimated Penetration of MELs Evaluated

Similarly, the average number of devices per household in a household with at least one device varies from one to five (see Figure 6-5). Due to this variable and variations in penetration, the number of MELs averaged overall all households exhibited significant spread. In general, we assumed that the saturation of the secondary MELs equaled unity.

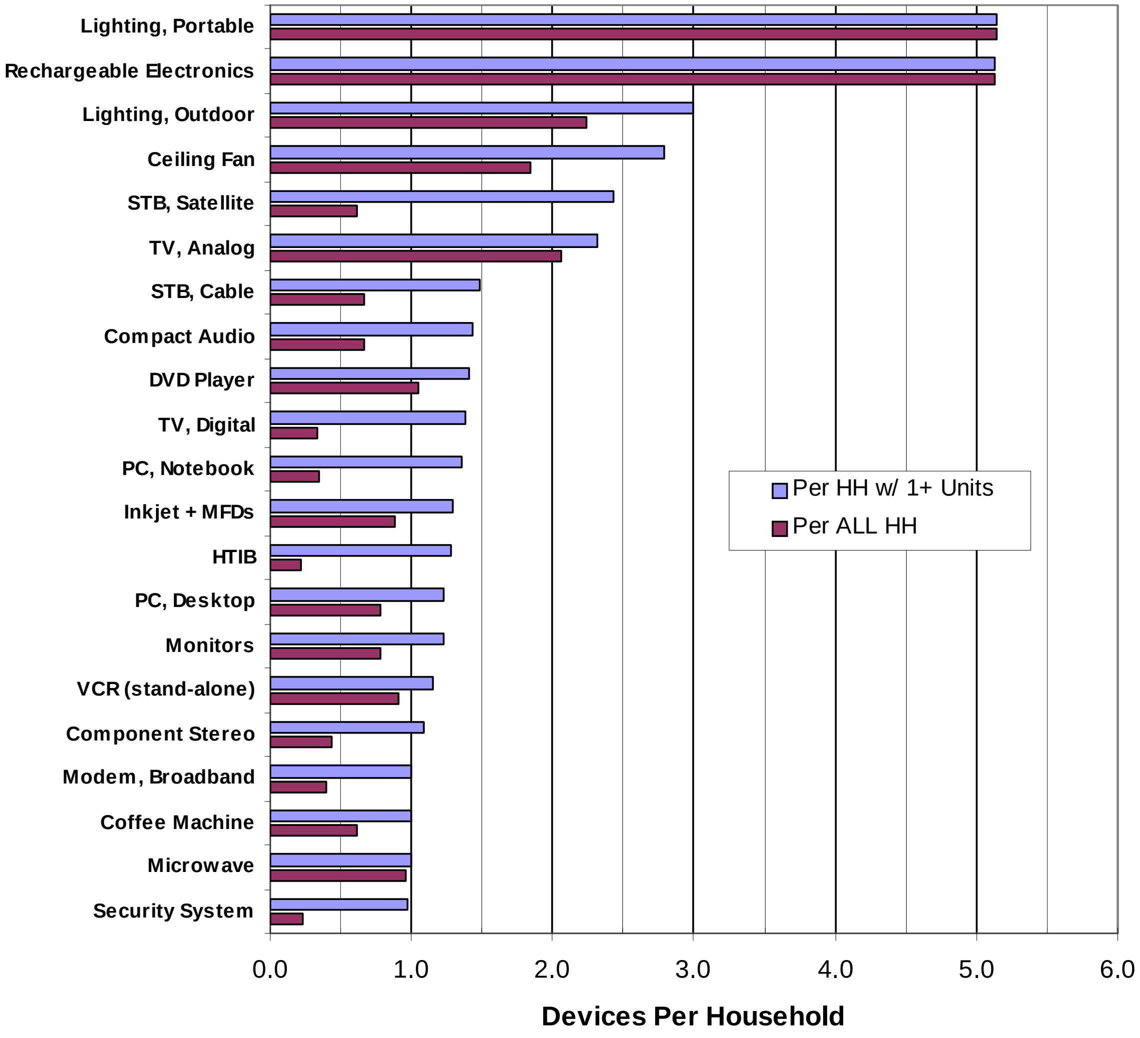

Figure 6-5: Number of Devices per Household in for All Households and Households with at Least One Device

Interestingly, the calculated average and typical HEC values for the MELs analyzed are within four percent of each other (see Figure 6-4). It appears that, for the typical household, incremental HEC increase from several key MELs with high (but less than 100%) penetration in an average household is approximately equal to the fractional contributions of the secondary, uncommon MELs in the average calculation.

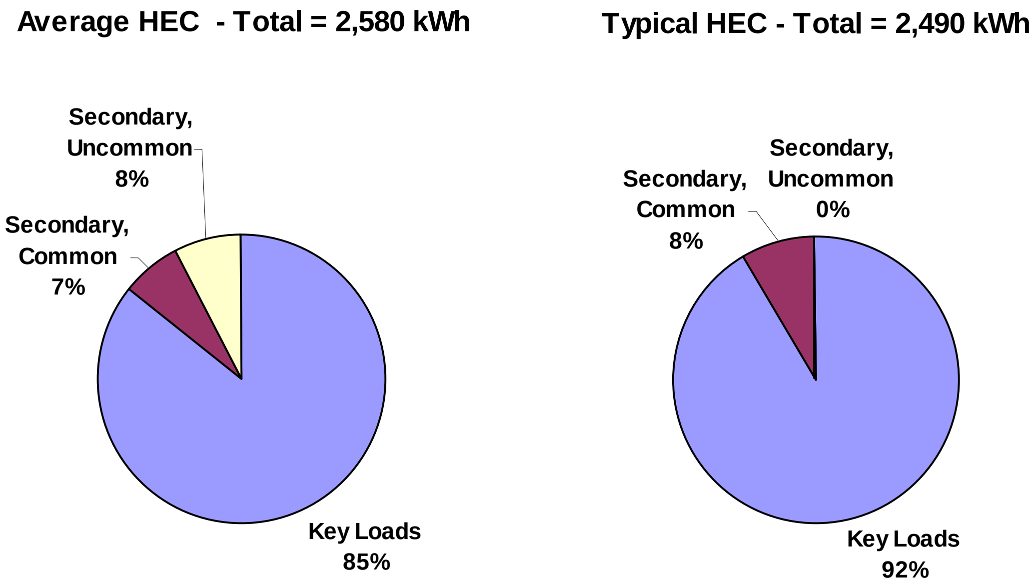

Figure 6-6: Average and Typical Household Electricity Consumption Values

Televisions (23%), portable and outdoor lighting (21%), and PCs (12%, including monitors and peripherals) are the largest contributors to average HEC (see Figure 6-7) and, together, represent more than half of average MEL HEC for the loads evaluated.

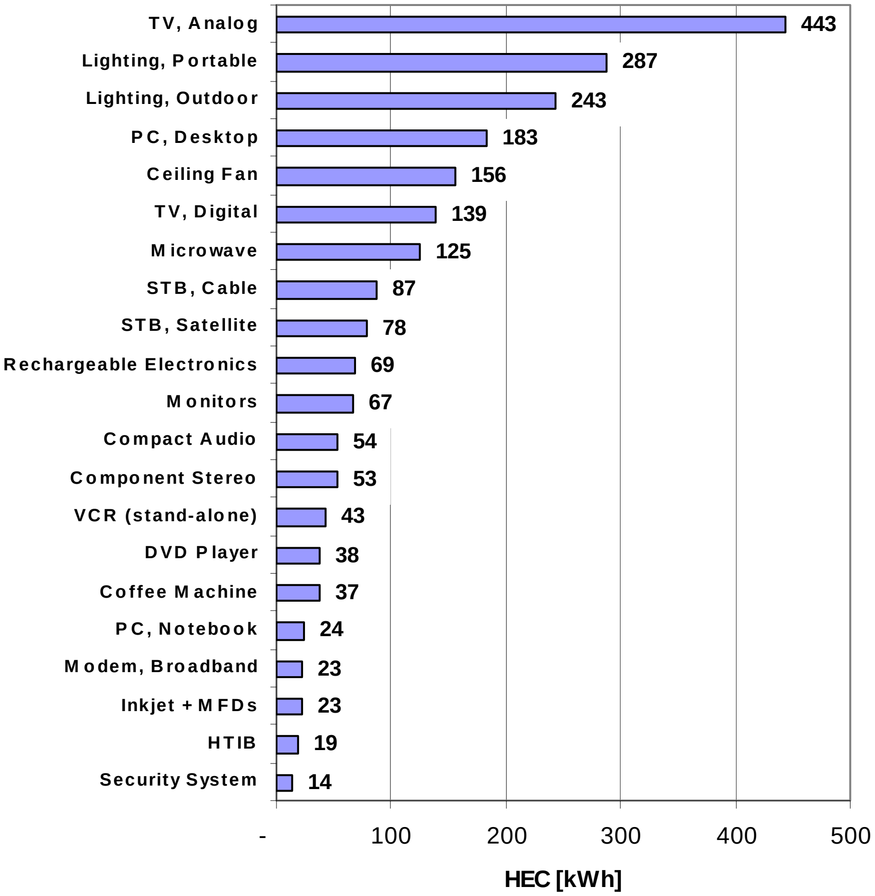

Figure 6-7: Average Household Electricity Consumption for the Key MELs

For the key and secondary MELs, active mode accounted for about 80 percent of average HEC, with idle, sleep, and off accounting for about 7 percent, 0.1 percent, and 13 percent of HEC, respectively.

From a national (U.S.) perspective, the key and secondary MELs evaluated consumed about 297TWh of electricity and 3.2 quads of primary energy[93] in 2006. Placed in context, this represents about 22 percent and 15[94] percent of residential electricity and primary energy consumption[95], respectively (see Figure 6-8 and 6-9). Inclusion of very preliminary estimates for more than 50 other MELs (see Appendix A) increases the total portions of MEL residential electricity and primary energy consumption to about 27 and 18 percent, respectively.

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[93] Primary energy, as opposed to site energy, takes into account the energy consumed at electric power plants to generate electricity. In 2006, every kWh of site electricity requires the consumption of an average of 10,831 Btus to generate, transmit, and distribute (EIA 2006).

[94] If portable and outdoor lighting are not counted as MELs, these percentages decrease to 17 and 12 percent.

[95] As portable and outdoor lighting electricity and energy consumption values are considered as MELs for the purposes of this study, we subtracted those values from the EIA (2006) estimates for lighting energy consumption.

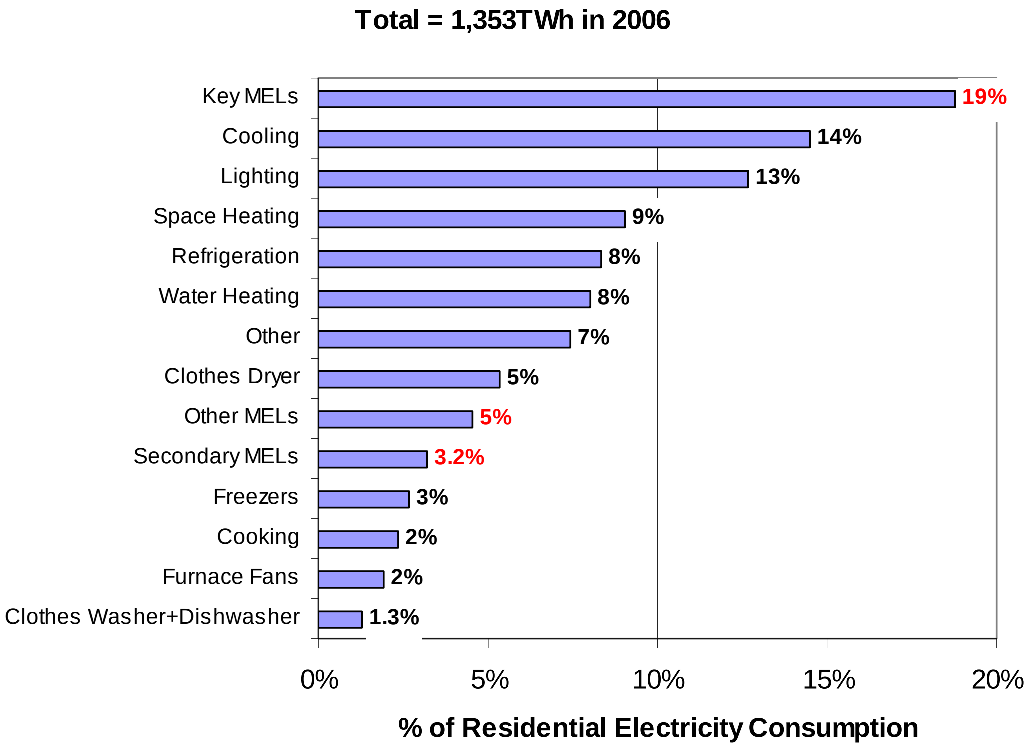

Figure 6-8: Residential Electricity Consumption Breakdown by End Use in 2006 (EIA 2006, Current Study)

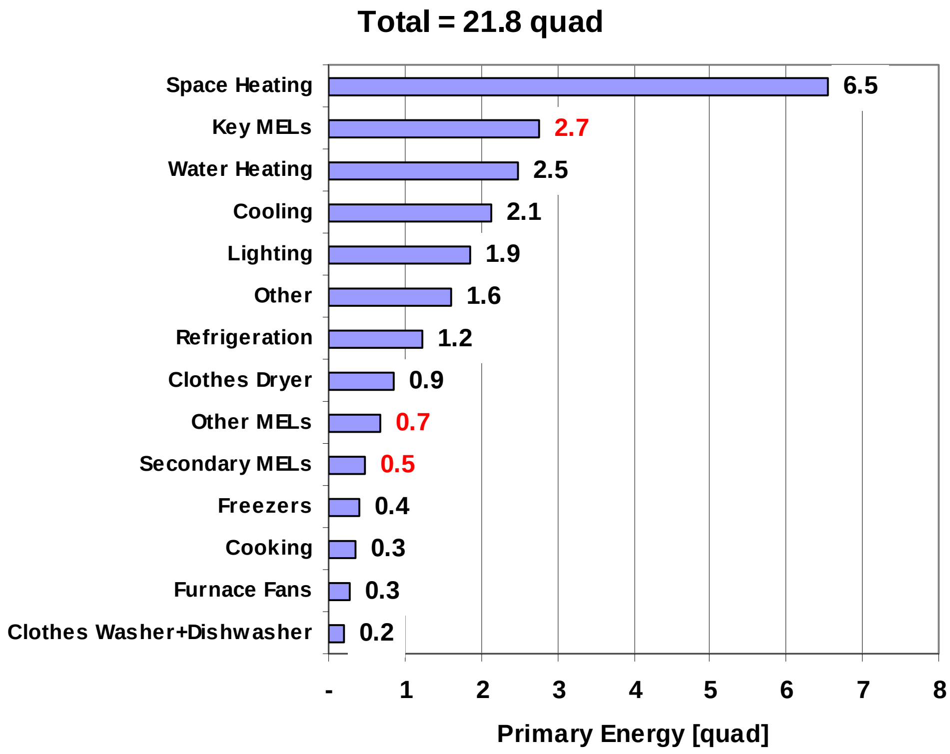

Figure 6-9: Residential Primary Energy Consumption Breakdown by End Use in 2006 (EIA 2006, Current Study)

Even after completing this detailed assessment of MEL electricity consumption, "other"[96] appears to account for about 7 to 8 percent of residential electricity consumption. Discussions with the U.S. Department of Energy's Energy Information Administration (DOE/EIA) indicated that they derived total electricity (and energy) consumption values for the "other" category by comparing total residential sector electricity (or primary energy consumption) consumption estimates to the sum of bottom-up estimates for the different end uses. All of these estimates have some error and uncertainty associated with them, and DOE/EIA confirmed that statistical error probably accounts for most of the apparent "other" energy consumption that remains (Cymbalsky 2007). That is, most of the "other" energy consumption shown above is *not* real but a statistical artifact.

National (U.S.) Annual Electricity Consumption (AEC)

Placed in a national context, the residential MELs evaluated account for about 8 percent of U.S. electricity consumption and 3.2 percent of U.S. primary energy consumption in 2006 (see Figures 6-10 and 6-11).

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[96] EIA (2006) states that other includes small electric devices, heating elements, and motors not included in other end uses. In addition, Cymbalsky (2007) indicates that "other" includes Christmas lights and wine coolers and under-bar refrigerators (the latter two are not included in the refrigeration category).

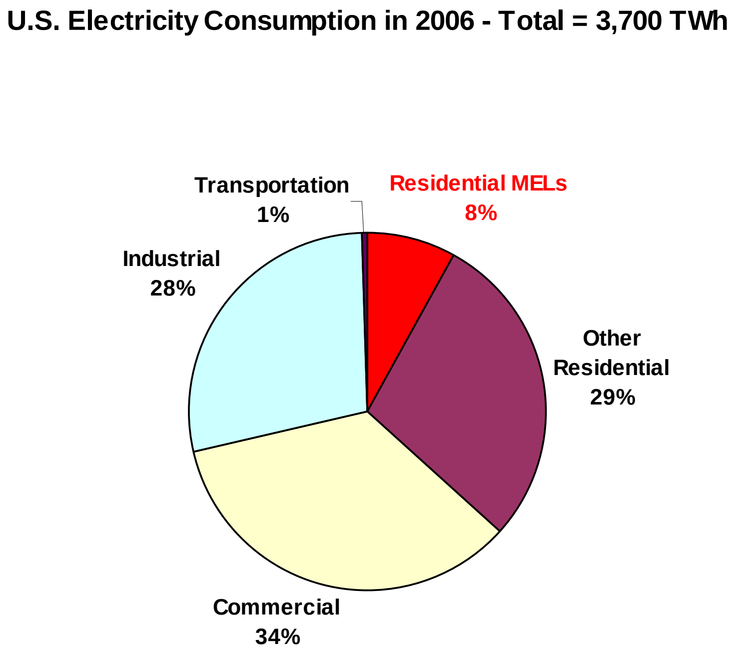

Figure 6-10: U.S. Electricity Consumption in 2006

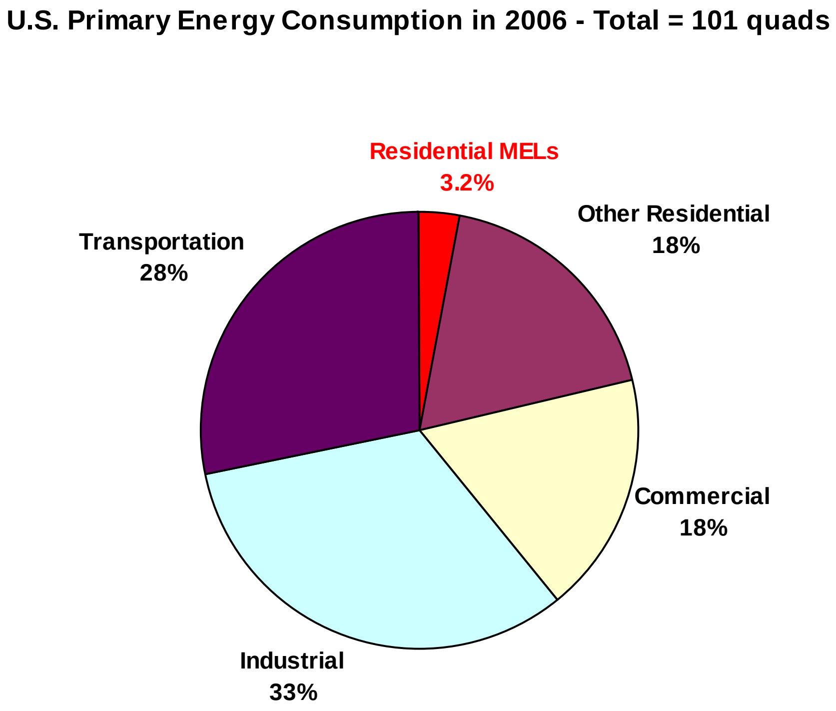

Figure 6-11: U.S. Primary Energy Consumption in 2006 (EIA 2006, Current Study)

Energy Savings Potential

In addition to characterizing the electricity consumption of thirty MELs, we also analyzed energy-saving opportunities for each. Energy-saving measures considered included: best-performing (from an energy perspective) products currently or recently available in the U.S., enabling power management, and using power strips to turn off products. On one hand, the energy savings assessments are not comprehensive, i.e., they were one of several aspects of the study; consequently, the energy savings estimates may not reflect the greatest savings attainable today. On the other hand, the estimates do provide credible estimates for the general magnitude of energy reductions attainable today.

On average, currently available energy-saving measures can reduce the total electricity consumption of all of the MELs evaluated by approximately 50 percent. The range of energy savings varies greatly between key MELs (see Figure 6-12). Four of the five secondary, common MELs had negligible energy savings potential because they consume all of their energy in the active mode and use electric resistance heating to perform their intended purpose. Two of the secondary, uncommon MELs, aquaria and waterbed heaters, also had negligible energy savings potential, while portable electric spas and pool pumps both had significant energy savings potentials.

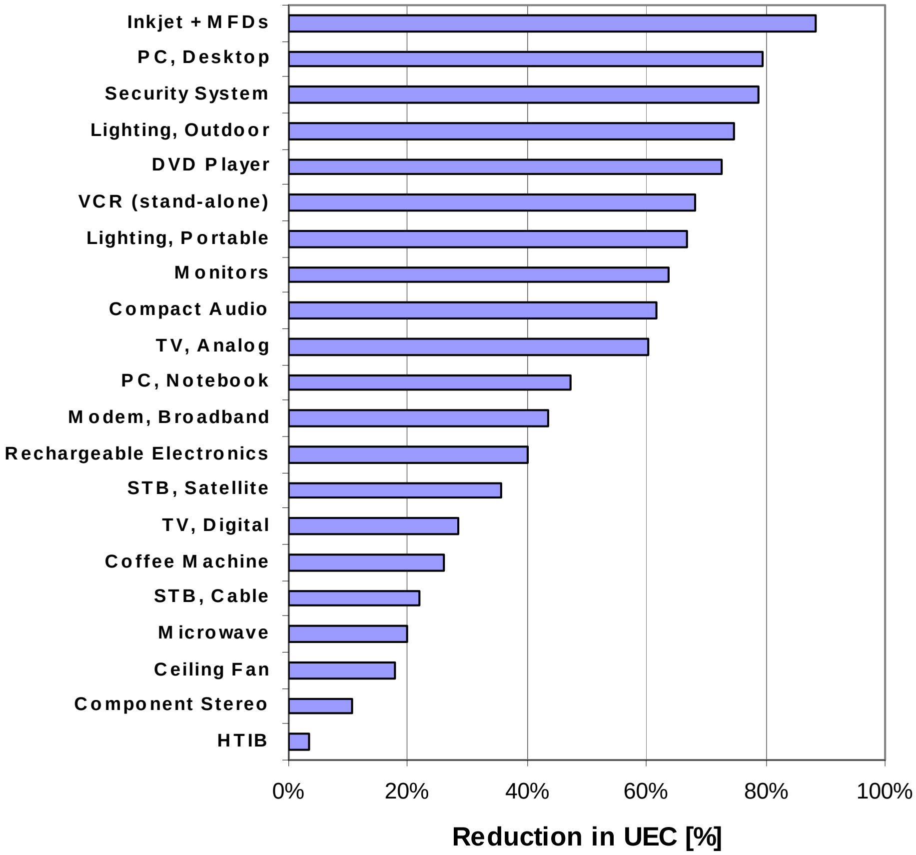

Figure 6-12: Estimated Energy Savings Potential for Key MELs from Available Measures

For most MELs studied, an available product that drew appreciably less power in one or modes yielded the greatest energy savings. We did not, however, compare the functionality and features of the products with the best energy performance with those of typical products to understand if the most efficient products were truly comparable with typical products. In the case of some consumer electronics, connecting the device to a power strip resulted in incremental, additional savings. Enabling power management is an important energy-saving strategy for PCs and, to a lesser degree, monitors.

6.2 Recommendations for Further Study

The insights gained from this characterization of residential MELs point to several recommendations for further study. Each one is discussed separately in the following subsections.

***Regular Evaluation of Rapidly Evolving MELs*:** A significant portion of the devices evaluated have – and, in many cases, continue to – undergone dramatic changes in their residential installed base, their usage, and their functionalities, characteristics, and underlying technologies (and, hence, their power draw by mode). This is particularly true of consumer electronics, which have changed dramatically over the last couple of decades and tend to have much shorter average product lifetimes (i.e., on the order of a few years compared to 10 or more for white goods), but also true of some other products as well (e.g., the increased penetration of ceiling fans and home security systems). In all cases, it has significant ramifications for DOE’s goal of net zero-energy homes (ZEH) in the future. Consequently, we recommend performing regular (e.g., every 3-4 years) evaluations of MEL energy consumption to understand how the evolution of MELs are affecting the feasibility of cost-effectively attaining DOE’s ZEH goal[97].

***More Refined Evaluation and Characterization of MEL Energy-Saving Opportunities*:** Our initial characterization of energy-saving opportunities for residential MELs primarily focuses on energy savings attainable using existing products. Although we found that this approach can yield overall reductions in MEL HEC of about 50 percent, it probably is not realistic to rely on a large portion of the 115 million U.S. households to purchase such “best-in-class” devices to realize large-scale savings. Furthermore, it is often very challenging to reduce the HEC of many MELs via other pathways (e.g., automated controls) due to the low annual energy cost savings potential for most MELs and peoples’ disdain for measures that adversely affect device utility or usability. We recommend that DOE perform a study focused on a thorough characterization of residential MEL energy savings opportunities with an emphasis on a critical assessment of the likelihood that a large portion of real consumers would accept and effectively deploy different measures. Ultimately, this could be used to develop a roadmap for credibly achieving major (e.g., 50 percent) reductions in MELs that identifies the technologies and policies needed to reach realize those reductions.

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[97] TIAX is currently working on a scenario-based assessment of residential MELs circa 2020 for DOE/BT. Not coincidentally, 2020 is the year that DOE/BT has targeted for achieving large-scale deployment of mortgage-neutral (i.e., annual utility savings equal or exceed the annual incremental cost to finance the ZEH) net zero-energy homes.

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APPENDIX A – UEC AND AEC ESTIMATES FOR OTHER RESIDENTIAL MISCELLANEOUS ELECTRIC LOADS

In addition to developing UEC and AEC estimates for the key and secondary MELs, we also developed initial estimates for a wide range of MELs. The estimates rely heavily upon prior studies, particularly the Sanchez et al. (1998) study with adjustments to reflect the increased number of households in 2006 relative to 1995[98]. It is likely that the installed base of many MELs have changed appreciably since 1995 and did not simply increase in proportion to the number of households, but a more detailed assessment lay beyond the scope of this effort. Furthermore, many of the UEC estimates from this and other sources have large uncertainties that reflect limited power draw data and very little information about usage by mode. In sum, most of the UEC and AEC estimates presented in Table A-1 have a high degree of uncertainty.

The MELs listed in Table A-1 have a combined AEC of approximately 62TWh, a quantity equal to 4.6% of residential electricity consumption. Relative to the key and secondary MELs evaluated in Sections 4 and 5, these "other" MELs consume about 5 times less electricity.

This is not, by any means, a comprehensive list of MELs, as a wide and ever-growing variety of products create a truly long tail of MELs found in households[99].

Table A-1: Preliminary Characterizations of Other MELs Not Evaluated Further

MEL	Installed Base [millions]	UEC [kWh]	AEC [TWh]	Sources and Comments
Air Cleaner, un-mounted	6.7	55	0.37	CEC (2004), Sanchez et al. (1998), FSEC (2005)
Air Corn Popper	20	6	0.12	Sanchez et al. (1998); assumed same installed base as 1995
Answering Machine, Stand-Alone	25	35	0.88	TIAX (2007)
Auto Engine Heater	2.3	250	0.57	Sanchez et al. (1998)
Automatic Griddles	31	5	0.17	Sanchez et al. (1998)
Baby Monitor	11.5	18	0.21	NREL (2005)
Battery Charger	8.6	1.3	0.01	McAllister and Farrell (2004), CCAP (2005)
Blender	93	7	0.68	Sanchez et al. (1998)
Boom Box	95	17	1.62	Current Study (Section 5.2)
Bottled Water Dispenser	1.1	300	0.34	Sanchez et al. (1998)
Can Opener	66	3	0.22	Sanchez et al. (1998); assumed same installed base as 1995
Central Vacuum	1.0	24	0.02	Sanchez et al. (1998)
Clock	110	26	2.86	NREL (2005)
Clock/Small Radio	145	15	2.18	Current Study (Section 5.2)
CO2 Detector	30	18	0.52	NREL (2005)
Compactor	1.6	50	0.08	Sanchez et al. (1998)
Copy Machine	0.11	340	0.04	Nordman and Meier (2004), adjusted from number of households in 2001

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[98] 115.0 in 2006 (EIA 2006) versus 99.06 million in 1995 (Sanchez et al. 1998).

[99] For example, Cooney (2007) lists 15 "USB Geek Gadgets" that represent, presumably just the tip of the iceberg for that product category.

MEL	Installed Base [millions]	UEC [kWh]	AEC [TWh]	Sources and Comments
Crankcase Heater	34	200	6.79	Sanchez et al. (1998)
Curling Iron	63	1	0.06	Sanchez et al. (1998)
Dehumidifier	14	653	9.0	DOE (2006)
Desk Fan	37	8	0.30	Sanchez et al. (1998)
Doorbell	79	18	1.4	Sanchez et al. (1998); note: NREL (2005) cites 44kWh/unit from Wenzel et al. (1997)
Dot Matrix Printer	3.5	115	0.40	NREL (2005); penetration seems high
Electric Blanket	29	120	3.5	Sanchez et al. (1998); assume installed base same
Electric Grill	0.8	180	0.15	Sanchez et al. (1998)
Electric Kettle	1.3	75	0.10	Sanchez et al. (1998)
Electric Knife	44	1	0.03	Sanchez et al. (1998)
Electric Lawn Mower	7.4	100	0.7	Sanchez et al. (1998)
Exhaust Fan	42	15	0.6	Sanchez et al. (1998)
Facsimile Machine	6	70	0.44	Nordman and Meier (2004)
Floor Fan	42	8	0.34	Sanchez et al. (1998)
Food Slicer	49	1	0.04	Sanchez et al. (1998)
Garage Door Opener	32	30	0.9	Sanchez et al. (1998)
Garbage Disposer	48	10	0.48	Sanchez et al. (1998)
Ground Fault Circuit Interrupter (GFCI)	115	24	2.8	NREL (2005); note - installed base assumes this number for ALL households, likely quite high
Grow Lights	0.6	800	0.45	Sanchez et al. (1998)
Hair Setter	31	10	0.32	Sanchez et al. (1998)
Hand Held Massager	14	0	0.00	Sanchez et al. (1998)
Hand Mixers	103	2	0.15	Sanchez et al. (1998)
Heat Lamp	1.2	13	0.01	NREL (2005)
Heat Tape	3.4	100	0.34	Sanchez et al. (1998)
Heating Pads	79	3	0.27	Sanchez et al. (1998)
Home Medical Equipment	0.6	400	0.23	Sanchez et al. (1998)
Home Router	15	53	0.8	TIAX (2006)
Hot Oil Corn Popper	5.3	2	0.01	Sanchez et al. (1998); assumed half installed base of 1995
Hot Plate	28	30	0.8	Sanchez et al. (1998)
Humidifier	14.6	100	1.5	FSEC (2005)
HVAC Controls	115	20	2.3	NREL (2005)
Irrigation Timer	5.8	45	0.26	NREL (2005)
Juicer	5.2	0	0.00	Sanchez et al. (1998)
Kiln	2.3	50	0.12	NREL (2005); penetration seems high, UEC low
Laser Printer	6.8	45.3	0.31	Nordman and Meier (2004), adjusted from number of households in 2001
Lighting Timer	32	20	0.64	NREL (2005)
Mounted Air Cleaner	5.9	500	2.9	Sanchez et al. (1998)
Pager	14	3.5	0.05	TIAX (2007)
Pipe and Gutter Heaters	1.2	53	0.06	NREL (2005)
Power Strip	113	3	0.30	Sanchez et al. (1998)
Scanner	21	138	2.9	Nordman and Meier (2004); as they note, the UEC seems very high
Shop Tools	15	26	0.40	NREL (2005)
Slow Cooker	59	16	0.9	Sanchez et al. (1998); assumed same installed base as 1995
Smoke Detector	97	0	-	NREL (2005)
Stand Fan	33	8	0.27	Sanchez et al. (1998)

MEL	Installed Base [millions]	UEC [kWh]	AEC [TWh]	Sources and Comments
Stand Mixer	26	1	0.03	Sanchez et al. (1998)
Stand-Alone PVR/DVR	1.5	237	0.36	TIAX (2007)
Sump Pump	11.3	40	0.45	Sanchez et al. (1998)
UPS	8.6	61	0.53	TIAX (2006), adjusted to 2006 number of households
Video Games	64	36	2.3	TIAX (2007)
VoIP Adaptor	4.0	36	0.14	TIAX (2006), adjusted to 2006 estimated installed base
Waffle Iron/Sandwich Grill	38	25	1.0	Sanchez et al. (1998)
Well Pump	16	83	1.4	ADL (1998)
Window Fan	17	20	0.35	Sanchez et al. (1998)

APPENDIX B – SUPPLEMENTAL TELEVISION USAGE DATA

This Appendix presents additional data that we found for hourly television usage as a function of both time of day, weekday or weekend, and time of year. Building America team members have expressed interest in this level of detail for their evaluations of the overall impact of MELs on whole home energy consumption.

Nielson February and July data give an idea about the seasonal variation in television use (see Figure B-1).

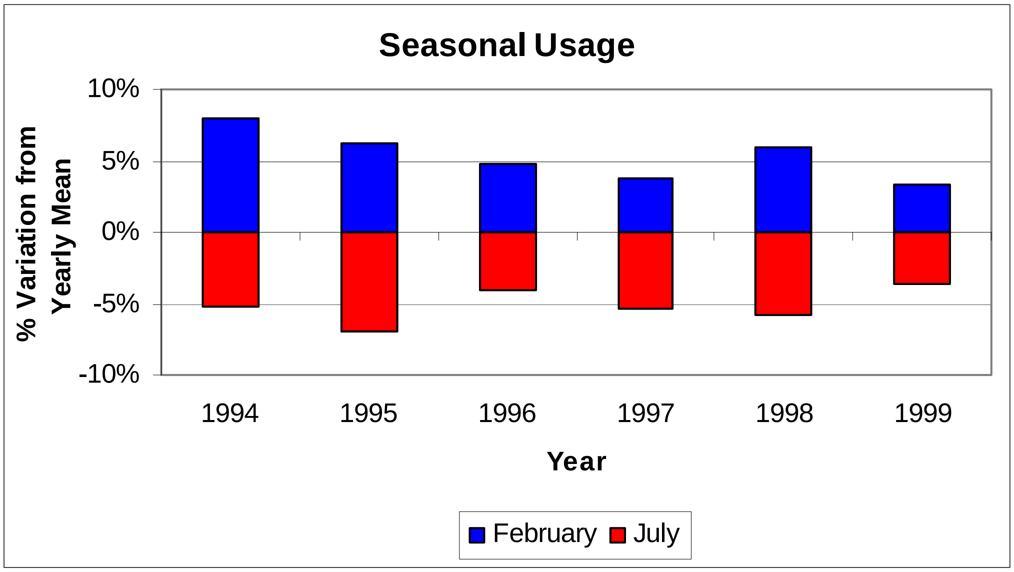

Figure B-1: Variation from the Mean Daily Broadcast TV Viewing Based on February and July Data (Nielsen 2000)

According to Nielsen Media Research (2000), the average person watched 28 hours and 13 minutes per week (4.0 hrs/day) of broadcast television in 1999. Figure B-2 shows the percentage of that time that was spent watching broadcast TV during certain target viewing periods.

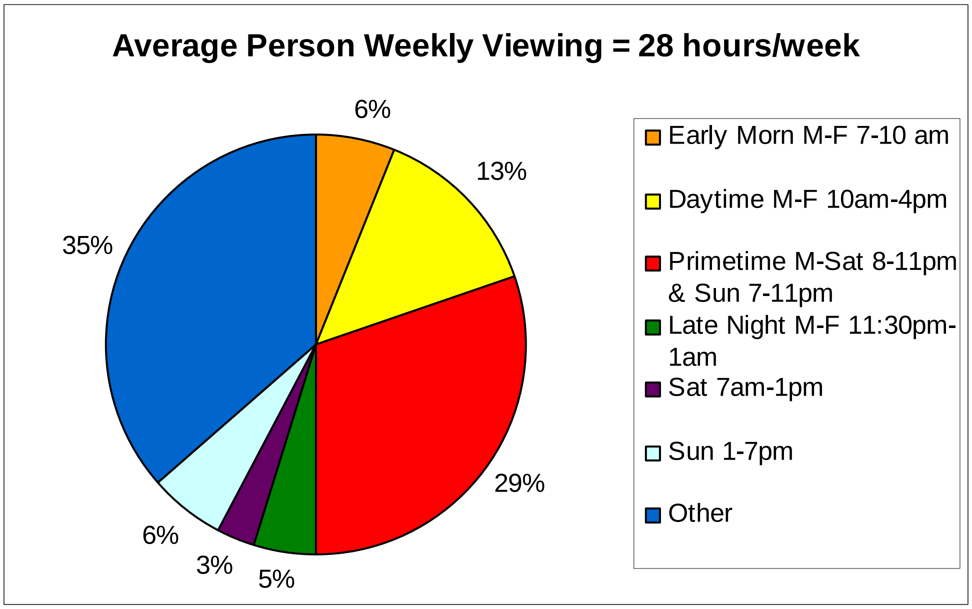

Figure B-2: Average Weekly Viewing Per Viewing Period (Nielsen 2000)

Using Nielsen's raw data from Figure B-2, we plotted the amount of broadcast TV watched during a particular viewing period as a percentage of the total time in the viewing period in Figure B-3.

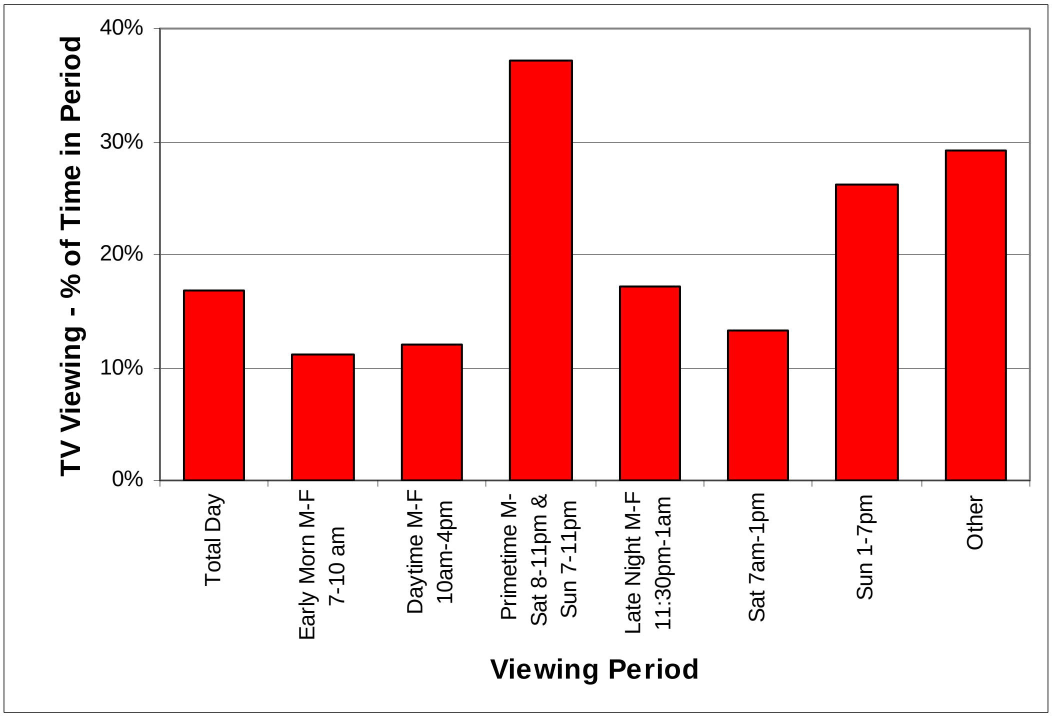

Figure B-3: TV Viewing as a Percentage of the Time in the Period