Miscellaneous Energy Loads in Buildings

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Contents

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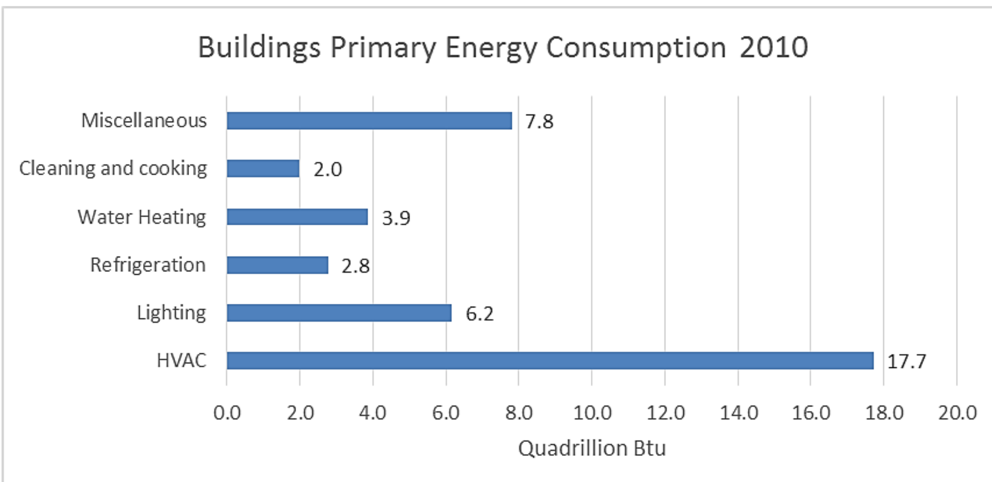
Executive Summary

Introduction

Commercial and residential buildings account for 41% of the total energy consumed in the United States. This amounted to 40.3 out of the 98.2 quadrillion Btu ("quads") of primary energy consumed in 2010. Out of these 40.3 quads, 7.8 quads (or about 20%) can be attributed towards a long and diverse list of appliances and equipment including computers, televisions, ceiling fans, fume hoods, vending machines, escalators and elevators, gas fireplaces, and many others that we term Miscellaneous Energy Loads or MELs. Figure ES-1 shows the primary energy consumption by end-use in residential and commercial buildings combined. After space conditioning (labeled HVAC on the graph for heating, ventilating, and air-conditioning), MELs are the biggest category of energy use in buildings.

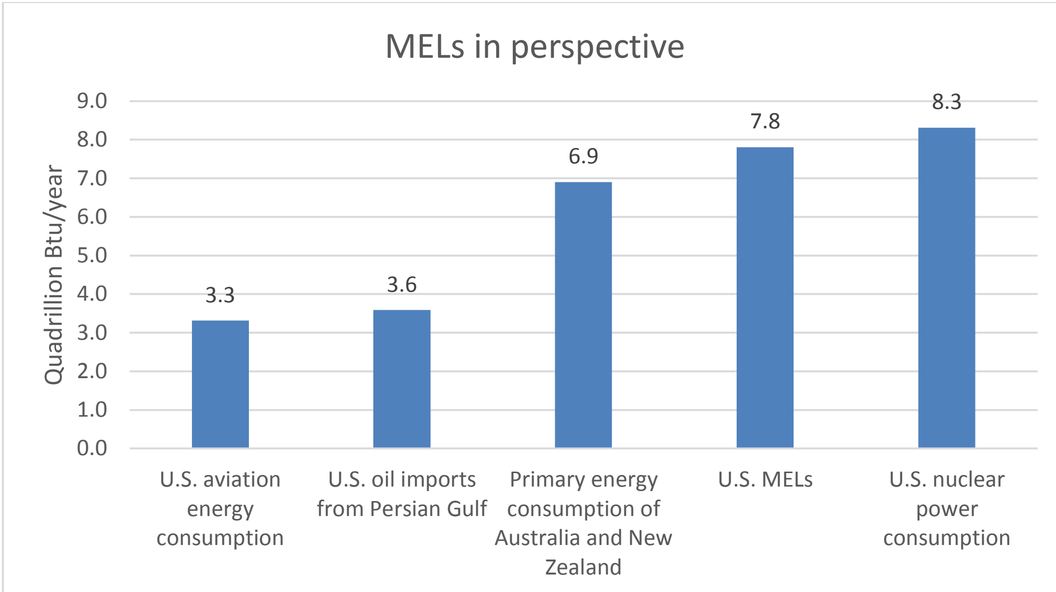
Figure ES-1: Buildings Primary Energy Consumption by End-Use



Source: Buildings Energy Databook 2012
(Adding residential and commercial sectors and distributing State Energy Data Systems adjustment among all end-uses)

We can get a sense of the size of these miscellaneous loads by a rough comparison with other big energy numbers, as in Figure ES-2. For instance, saving 50% of the energy from MELs is approximately equivalent to eliminating U.S. oil imports from the Middle East. We have cited Australia and New Zealand just as illustrations; MELs are bigger than the primary energy consumption of more than 200 countries in the world.

Figure ES-2: Magnitude of Miscellaneous Energy Loads



Source: ACEEE analysis, data from U.S. EIA
Note: Oil imports from Persian Gulf 618 million barrels in 2010

Not only are the miscellaneous loads a significant energy use category today, they are also the fastest growing. In both residential and commercial building sectors, the U.S. Energy Information Administration (EIA), in its *Annual Energy Outlook 2013*, projects miscellaneous end-uses to be the fastest growing energy end-use. Already the total number of miscellaneous products in the nation is over 2 billion and growing every year. The disaggregation and diversity of MELs make them harder to target through conventional equipment replacement or upgrade approaches. Some of these appliances like ceiling fans and commercial gas cooking equipment are covered by federal energy conservation standards and many others comply with voluntary efficiency specifications like ENERGY STAR. However, many others are not and this presents a huge energy savings opportunity. Clearly, it is crucial to improve our understating of what these loads are and how we can manage them in the best possible way.

With this objective, in this report we attempt to define and characterize the energy use of electric and gas miscellaneous loads associated with commercial and residential buildings, identify the biggest among them, and suggest initial strategies for improving the efficiency of energy use.

We have trifurcated our analysis into residential, commercial, and gas end-uses. Even though some devices like computers, televisions, and microwave ovens are common in all types of buildings, we observe that they have different usage patterns and hence different energy profiles. Segregating gas loads is solely based on convenience and we want to underscore the importance of more in-depth study of gas-based end-uses.

Findings

Figure ES-3 shows the top ten residential MELs based on Annual Energy Consumption (AEC) as per our analysis. AEC is calculated by multiplying the installed base of each product (number of units in use in the United States) and the average annual energy consumption per unit. Televisions are the biggest single residential MEL, accounting for 22% of the annual residential MEL load in this study and 4% of the electricity used by households in the United States (DOE 2013). While old TV sets remain in the house, new ones with bigger screens and more features are being added. Along with TVs, set-top boxes are another significant energy load in modern homes, chiefly because they are rarely turned off. In fact, standby or sleep mode is a major cause of high annual energy consumption of several MELs. DVD and Blu-ray players, microwave ovens, and video game consoles are some other devices in this category. Recent research by LBNL (Greenblatt et al. 2013) suggests that microwaves are in standby mode 81% of the time and in active mode for only 40 to 70 hours in a year. Potential savings from these and other MELs are summarized in Table ES-1.

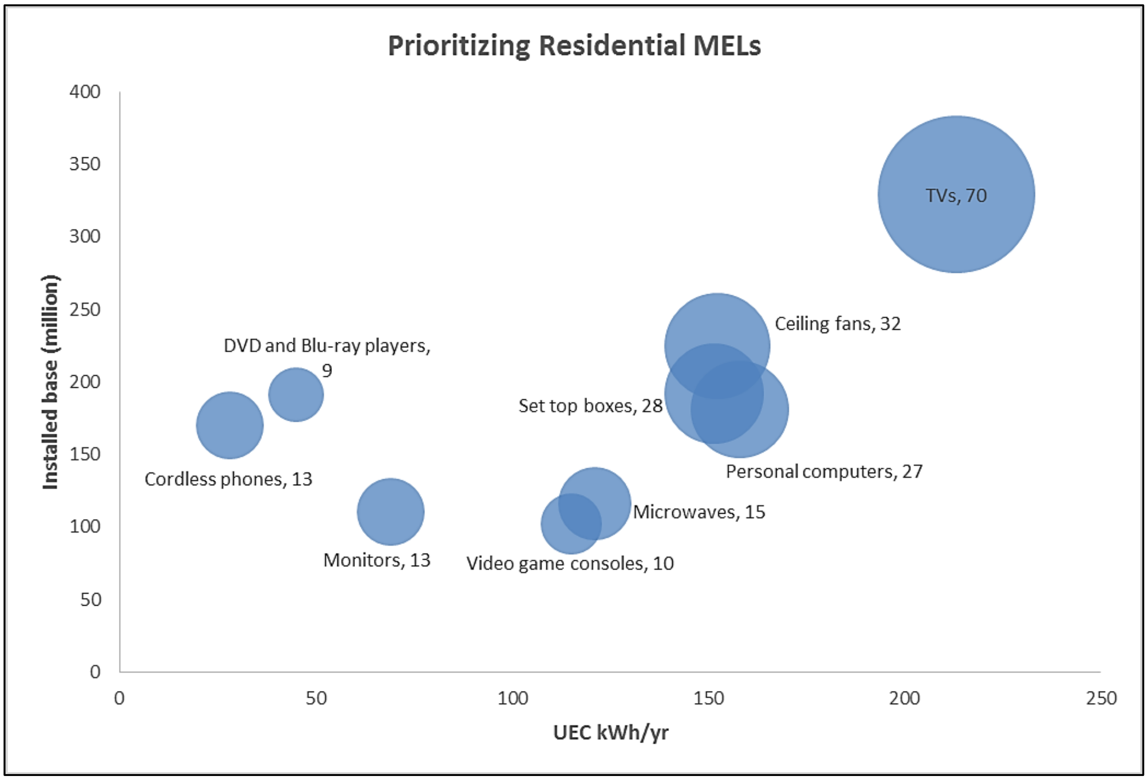
With an installed base of 225 million, ceiling fans are common in U.S. homes and are the second largest residential MEL in terms of annual energy consumption. Energy use for ceiling fans (not including attached lights) is projected to increase through 2030, as newly constructed homes tend to have more ceiling fans installed, and more new homes are built in warmer areas where ceiling fans are used more intensively (EIA 2007).

Computers and monitors make it to the top ten lists in both residential and commercial sectors. Personal computers, either in the form of desktops or notebooks, have an installed base of over 120 million in the commercial sector in addition to 138 million in residences. Significant efficiency potential exists for reducing energy consumption in computers—indeed the leading products in the market use about a tenth of the energy of the existing stock while generally offering higher computing power.

Figure ES-4 shows some of the other large commercial miscellaneous loads. Distribution transformers are devices that transform high voltage electricity (4–35 kilovolts) electricity in utility power distribution lines to lower secondary voltages (120–480 volts) as is needed by the most common electric devices. In this process, some energy is lost as heat during repeated cycles of operation. Federal standards for distribution transformers were revised recently although there is potential for more savings.

There are approximately 150,000 laboratories in the United States and estimates of the installed base of fume hoods range between half to one million. Fume hoods are ventilation chambers used to protect workers from exposure to gases, fumes, and small particles. Due to their large power draw and predominantly 24-hour usage, fume hoods as a class consume about 20.7 billion kWh of energy every year. Estimates suggest that about a third of this can be saved by switching to the most efficient products available in the market.

Figure ES-3. Top Residential MELs

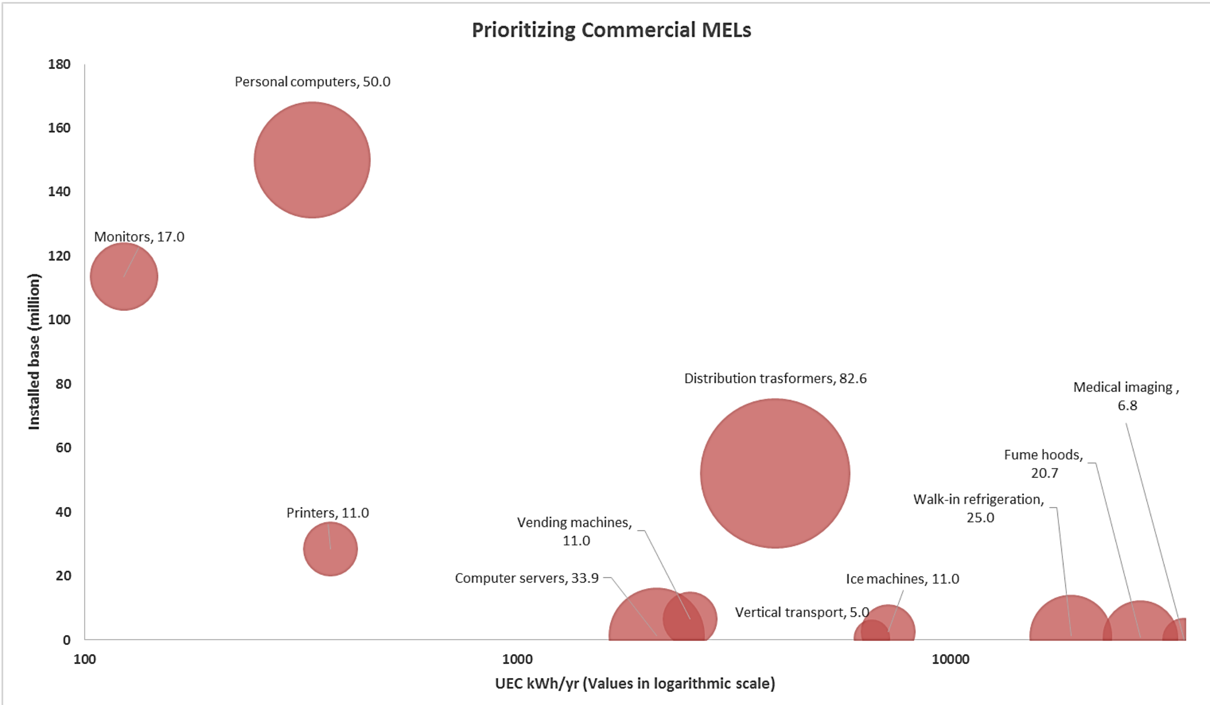


Notes: 1. Size of the bubble represents AEC in TWh/year (as given in the data labels).
2. Portable electric spas (not shown on the chart) have a UEC of 2500 kWh/yr.
Source: ACEEE analysis, data from multiple sources

Walk-in refrigeration refers to large capacity units that are used for short-term storage of perishable goods before shelving or prior to food preparation. There are estimated to be 1.3 million units installed across the nation (McKenney et al. 2010). Walk-ins as an aggregate consume 25 billion kWh of energy annually but there are technologies that can help us save over 60% of this every year.

Servers are computers used to store and process data, and transmit it to other computers connected via a network. While large Information Technology companies have dedicated data centers to house servers, many other companies have their own office 'server room.' Amongst other measures, virtualization of servers offers significant energy saving potential.

Figure ES-4. Top Commercial MELs

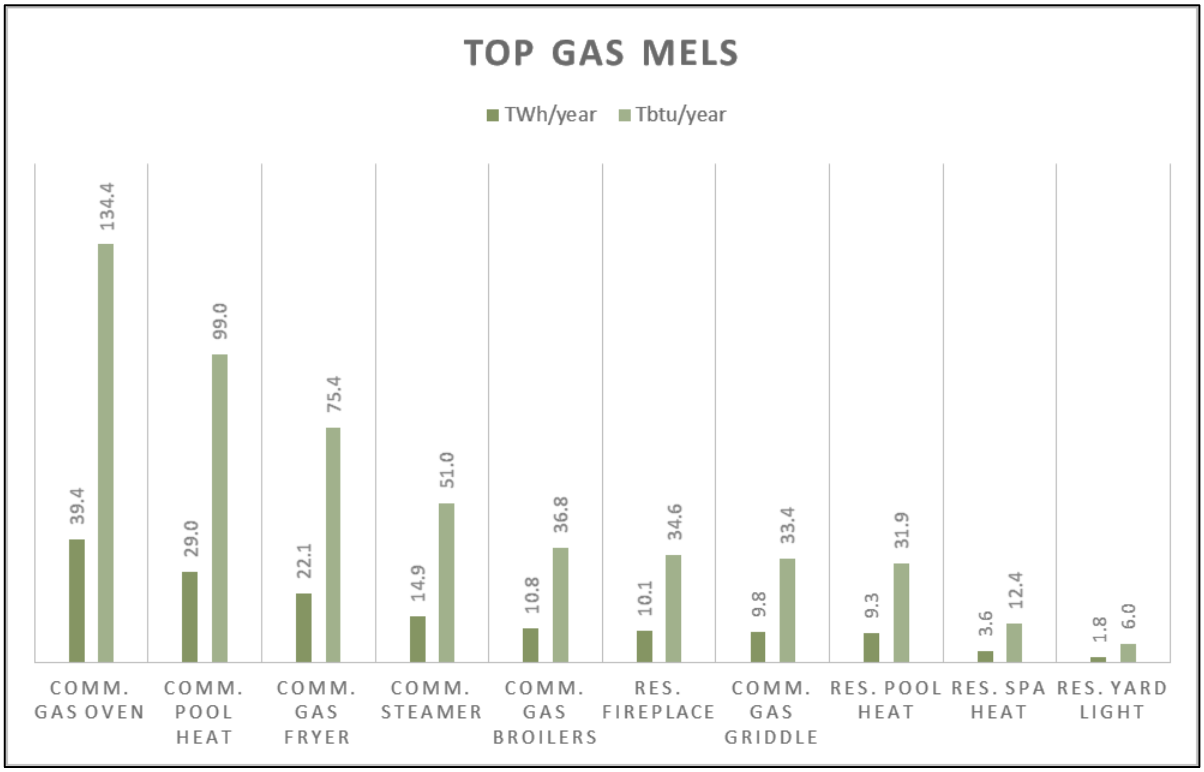


Note: Size of the bubble represents AEC in TWh/year (as given in the data labels)
Source: ACEEE analysis, data from multiple sources

Healthcare facilities are among the most energy-intensive commercial buildings in the United States (Singer and Tschudi 2009) and most medical equipment is not well researched for energy efficiency potential. The energy consumption of MRI and CT equipment has grown considerably as more powerful technology provides better resolution and advanced diagnostics. As a category, medical equipment consumes about 6.8 billion kWh per year. This is more than the energy consumed by the 700,000 elevators and 35,000 escalators installed across the country. There are savings available from MRI and CT equipment and we discuss this in the detailed write-ups in this report.

Commercial multi-load clothes washers and commercial dishwashers are big gas loads. We have, however, focused on other gas loads that fall within the scope of our definition of miscellaneous. Several gas-using commercial cooking appliances make it to our list of top gas MELs (Figure ES-5). Research suggests that there is a considerable difference in the efficiency of the existing cooking equipment and the best models in the market. Other major gas MELs include commercial gas pool heaters, residential pool and spa heaters, gas fireplace equipment, and outdoor gas lighting. Because evaporation is the dominant heat loss mechanism for pools, the least expensive option, pool covers, has the highest energy-saving potential for both commercial and residential pool heaters. Using electronic ignition coupled with timers and sensors are some of the other ways to save energy from gas equipment like lighting and spa heaters.

Figure ES-5. Top Gas MELs



Source: ACEEE analysis

Notes: 1. Gas loads are usually measured in therms or MMBtu; we have converted to TWh in this graph to provide a comparison with other electric MELs discussed before. Conversion: 1Quad = 1 billion MBtu = 293 TWh

2. As discussed in the main report, we have excluded from our analysis commercial multi-load washers and commercial dishwashers.

Savings

Significant savings in annual energy consumption are possible from each of the products that we analyzed. Most often just switching to a more efficient product currently available in the market or adopting an already proven technology is all that is required to achieve these savings. We summarize the savings potential for the top MELs in Table ES-1. Our calculations suggest that electric MELs savings of 285 TWh are possible every year with full application of the highly efficient units and efficiency measures now on the market. This equals 47% of the total annual consumption of the top 20 residential and top 20 commercial MELs that we analyzed. To achieve all of these savings will require the full turnover of the current equipment stock. Hypothetically, if one were to extrapolate the percent savings to the entire base of MELs, 40–50% of the 7.8 quads now used by MELS could be saved, or more than 3 quads every year. We also estimate 203 TBtu per year of savings from some of the gas loads that we analyzed, which equals 43% of the total annual consumption of these loads.

Table ES-1. Estimated Annual Savings from Key MELs

Electric MELs	Res. or Comm.	Current Stock (kWh/yr)	Standards (kWh/yr)	Best Available (kWh/yr)	Max Tech (kWh/yr)	Savings % (Best over Current Stock)	AEC Savings (TWh/yr)
TVs	R	213.3		62.7	24	89%	62.2
Distribution transformers	C	3950		2400	1700	57%	47.1
Personal computers	R,C	336		33.7		90%	45.0
Ceiling fans	R	152.4	109.6	58.5	23.8	84%	23.6
Monitors	R, C	96.2		37.7		61%	18.2
Walk-in refrigeration	C	19,000		7,200		62%	15.5
STB	R	151.5			74.4	51%	14.2
Video game consoles	R	115.1		15.3		87%	9.1
DVD/Blu-ray players	R	45		10		78%	8.1
Microwaves	R	121	94.7		86.1	29%	7.8
Fume hoods	C	27,500		17,500	17500	36%	6.9
Computer servers	C	2,100		1,701		19%	6.4
Ice machines	C	12,966	11,777	9229		29%	4.9
Vending machines	C	2,509		1,800	1505.4	40%	4.4
Printers	C	369.5		238		36%	3.9
Electric spa	R	2,500			1750	30%	2.6
MRI equipment	C	93,000		55,800		40%	2.5

Electric MELs	Res. or Comm.	Current Stock (kWh/yr)	Standards (kWh/yr)	Best Available (kWh/yr)	Max Tech (kWh/yr)	Savings % (Best over Current Stock)	AEC Savings (TWh/yr)
Escalators	C	22,850		17,150		25%	1.3
Elevators	C	7,600		5,700		25%	1.3
					Total Electric Savings	47%	**285.2**

Gas MELs	Current Stock (MMBtu/yr)	Standards	Best Available	Savings % (Best over Current Stock)	AEC Savings (TBtu/yr)
Commercial broilers	174		95	45%	16.7
Commercial fryers	110.9	112.2	40	64%	48.2
Commercial griddles	90.15	106	34	62%	20.8
Commercial ovens	89	74.6	57	36%	48.3
Commercial steamers	153.9	96.1	28	82%	41.7
Commercial pool heater	~2000			45%	45.0
			Total Gas Savings	43%	**220.8**

Recommendations

In the report, we outline three approaches for managing MELs.

1. Encourage manufacturers to upgrade their products so that the best-performing products now on the market become common. This can be done with the use of mandatory and voluntary efficiency standards that affect the manufacture, or assembly, of these products as well as other manufacturer inducements.

2. Undertake a variety of strategies that energy efficiency program administrators can employ to include MELs in their portfolios, including motivating consumers to purchase efficient products as well as affect manufacturer design and end-user decisions on how products are used.

3. Develop and promote behavioral initiatives that can be undertaken by a variety of entities including building owners, conservation groups, program administrators,

facility managers, and building occupants. These initiatives aim to raise awareness and modify service consumption habits to encourage energy conservation through reinforcing messages and sometimes even redesign of environment.

The magnitude of energy consumed by miscellaneous loads makes them impossible to ignore. We are confident in our belief that the technology to make these devices more efficient is ready and available. This report is an effort to highlight some of these options. What we need is an increased focus on implementation.

Introduction

Not only are Miscellaneous Energy Loads (MELs) a significant energy use category today, they are also the fastest growing. In this report, we attempt to define and characterize the energy use of electric and gas miscellaneous loads associated with commercial and residential buildings and suggest initial strategies for improving the efficiency of the most significant MELs.

MELs are exceptional in that they are often defined solely on the basis of exclusion — e.g., as everything *except* space conditioning, lighting, refrigeration, cooking, and laundry (EIA 2012). MELs come in many diverse forms. "Miscellaneous" is a term used to simply bracket a set of items that are considered either uneconomical or unimportant to tackle on their own. Many MELs in this report, as we will find out, have outlived either of those two associations. The letter "E" in the acronym may stand for any one of 'energy,' 'electronic/electricity/electric' (Dirks and Rauch 2012), and even 'end-use.' To indicate the add-on nature of such loads, authors have used 'user dependent electric loads'; alternatively, the term 'plug load' is used instead to bound the set of anything plugged in to an electrical outlet. Other studies, however, just simplistically label these as 'others.' MELs include devices that we find in innumerable offices and homes. Gas fireplaces, coffee machines, televisions, gas grills, data center equipment, ceiling fans, pool heaters, electric pencil sharpeners, and x-ray machines are all MELs, along with hundreds of other devices. The MEL bracket widens even further when evaluating the type of equipment that may be served through a building meter but is not a typical 'building load.' For example, the U.S. Energy Information Administration (EIA), in its *Annual Energy Outlook* (EIA 2012), includes service station equipment, automated teller machines, telecom equipment, and medical equipment in the 'others' category. Another way MELs are described are as business process loads (BPLs), which tie the loads to the function of the business performed by the occupants in the facility (Dirks and Rauch 2012). Walk-in refrigerators, central refrigeration, medical imaging, and fume hoods fall into this category. Defining is the first step in solving a problem and indeed one of the objectives of this study is to come up with a definition of MELs that is consistent and salient.

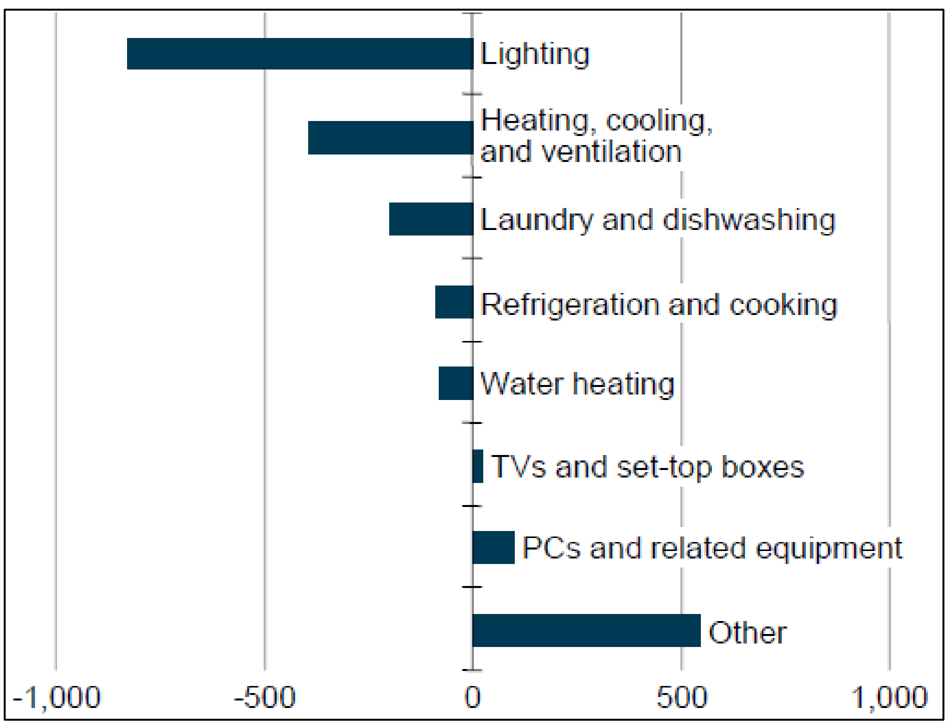
The significance of studying MELs cannot be overstated. In both commercial and residential buildings, MELs are bigger than any other major end-use category (EIA 2012). According to one recent study (Reeves et al. 2012), taking together both residential and commercial buildings, there is an installed base of 2.14 billion miscellaneous electric products in the United States. Many of these products consume very little energy as a unit, but multiplied by the installed base and aggregated over a year, the collective energy consumption of these devices is significant. In a study for DOE, TIAX LLC ((McKenney et al. 2010) selected 28 key commercial MELs and estimated the energy consumption as equivalent to the output of more than eleven 1 GW power plants.

Energy use by miscellaneous devices is growing faster than any other category. Figures 1 and 2 show EIA projections for residential and commercial energy end-uses, respectively. In both sectors, projected change in the 'other' category is the highest. According to EIA projections, electricity use by "other household electrical devices" will increase by 1.8 percent annually and account for nearly one-fourth of total residential electricity consumption in 2035 (EIA 2012). Commercial sector projections are similar: EIA projects electricity consumption for 'other' electrical end-uses—including video displays and medical devices—to increase by an average of 2.2 percent per year and in 2035 account for 38 percent of total commercial electricity consumption.

Energy consumption for 'other' office equipment—including servers and mainframe computers—is projected to increase by 2.3 percent per year from 2010 to 2035, as demand for high-speed networks and internet connectivity continues to grow (EIA 2012).[1] Overall, for purchased electricity, the miscellaneous load is projected to increase 47% in magnitude from 2012 to 2035, growing to over half of the total U.S. electricity load in 2035 (Dirks and Rauch 2012). Moreover, this increase is not univariate — MELs are increasing in numbers and diversity, and many of them are increasing in unit energy consumption as well (Roth et al. 2008). .

At the same time, there have been significant efficiency gains in other major building components and systems like building envelope, windows, HVAC, lighting, refrigeration, water heating, cooking, and laundry. As many of the plugged-in MELs are within a building, making them more efficient also results in less heat generation, further reducing energy consumption required for cooling. EIA estimates show that energy intensity (for commercial buildings) and electricity consumption (for the residential sector) by major end-use has been declining and is expected to continue to trend in that direction (Figures 1 and 2). This means the MELs are likely to be the biggest impediment to achieving high efficiency/net zero energy buildings.

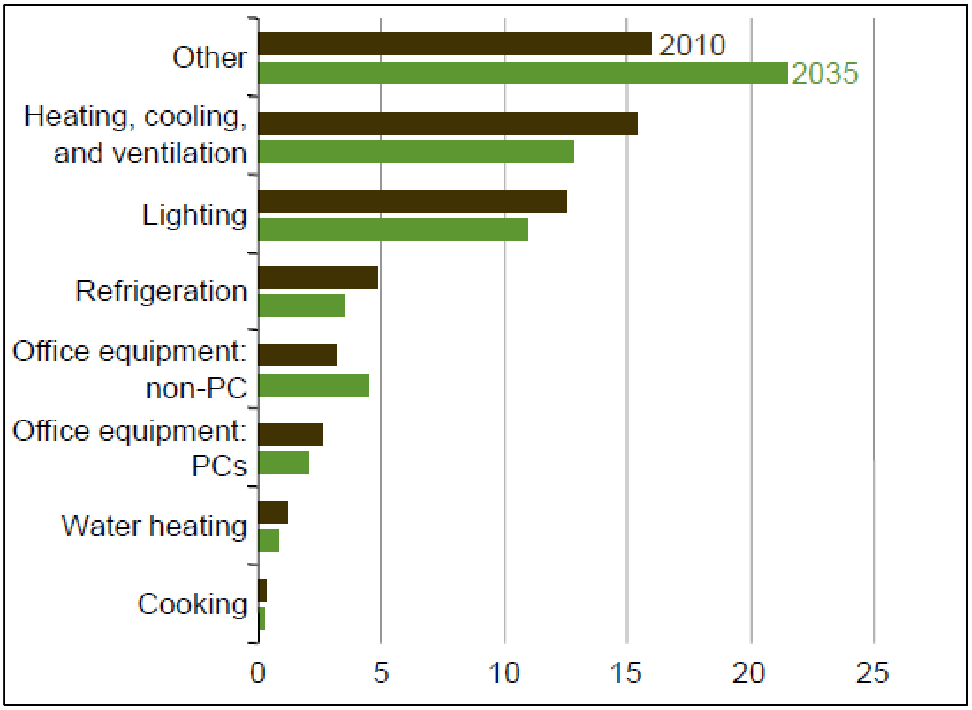
Figure 1. Projected Change in Residential Electricity Consumption for Selected End-uses 2010-2035 (kWh per Household)



Source; EIA 2012

[1] Note: EIA has projected lower growth estimates for commercial sector other office equipment in the *Annual Energy Outlook 2013* Reference case that came out in December 2012; however, the overall growth in the 'others' category is still higher than in any other end-use.

Figure 2. Projected Energy Intensity of Selected Commercial Electric End-Uses, 2010 and 2035 (kBtu per sf)



Source: EIA 2012

This study is an analysis of existing data with the objective of identifying key electric and gas miscellaneous loads that merit further attention. Most studies on this topic have focused on electric end-uses only, even our analysis of gas loads is preliminary and we believe further research is required on this topic. Within commercial buildings, we covered all building types as defined in the *Commercial Buildings Energy Consumption Survey,* or CBECS (EIA 2003) and, consequently, some of the MELs that rise up as big energy consumers, such as walk-in refrigeration and medical imaging equipment, may be associated with specific building types. While we considered non-building MELs, like wastewater treatment and mobile phone towers, a detailed discussion of these is suited to more targeted studies. We have also excluded other larger end-uses like refrigeration, laundry, and dishwashing since they are relatively well studied.

Methodology

We started with the list of appliances surveyed in the *Residential Energy Consumption Survey* (RECS) (EIA 2009) and CBECS as a base and then added more items to this list based on information available from other studies. Even though some MELs like coffee machines, televisions, and computers are common to both, we maintained these on separate lists for residential and commercial categories. Often the same device serves similar but not the same needs and hence can have different features and usage. For example, due to differences in usage patterns and settings, the annual energy consumed by a TV in a home can be very different from that in an office or in a stadium. Generalizing assumptions regarding usage patterns between the residential and commercial sectors for devices common to both sectors can have large implications on energy consumption estimates for the devices in questions and even the sector as a whole.

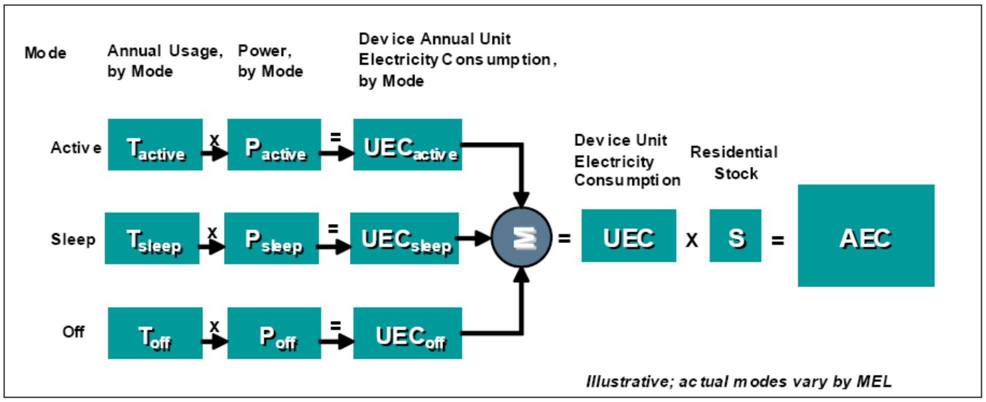
Not all sources of information refer to the same year and there are significant temporal variations for high growth categories like consumer electronics. We have attempted to reduce this variability in two ways: by averaging the data from multiple sources; and by using projected values for older data. TIAX, for example, provides both 2005 data and 2010 projections. For high growth items, we have used TIAX projections for 2010 after corroborating with other recent studies. Finally, a fair amount of uncertainty accompanies information aggregated at this scale. We have indicated the uncertainty around the results using three levels of agreement. The agreement level is low where only one source is available and is higher where more sources provide information about the same item, particularly where these multiple sources are largely consistent with each other.

Calculations of the **energy use** of MELs have been consistent across the literature; we have followed the same methodology. A brief description of the key parameters is as below.

- Unit energy consumption (UEC) is the product of energy consumed by a product in each mode of operation and the time spent in each of those modes.
- Installed base is the total stock of the device across the nation but specific to the residential or commercial sector.
- Annual energy consumption[2] is UEC multiplied by the installed base
- 'Penetration' is the weighted ratio of the sampled households that have or use that item to the total number of households (as per the RECS 2009 data). In other words, it is the percentage of households that have at least one such device.
- Saturation is the ratio of the total installed base of the product and the number of households that own at least one unit. For example, although there are 2.4 TVs per household in the United States, not all households have one. While 99% of households have at least one TV, some of them have multiple. Therefore, 'penetration' of TVs is 99% and 'saturation' is 2.4.

[2] Note: Other similar matrices include Total Energy Consumption and Typical Energy Consumption; Household Energy Consumption (HEC) is sometimes used to aggregate energy consumption for devices that have a saturation of more than 1.

Figure 3. Annual Energy Consumption Methodology



Source: Roth et al. 2008

There are a number of ways to estimate the potential **energy savings** from improving MELs. One extreme option, at least for some devices, can be to calculate the theoretical possible efficiency and hence estimate the potential savings that can be achieved by reaching this maximum efficiency level. Another approach is to evaluate the bar set by the minimum efficiency standards or voluntary ratings and the savings that can accrue if the entire stock conforms to these standards and ratings. A third approach, somewhere between the two, is to look at the efficiency of the best-in-class devices available today and project savings by replacement of the current stock with best-in-class products. We believe the last approach gives a more pragmatic approximation of the savings that are possible in the short term. For most products discussed in detail, we have compared the average UEC of the existing stock, as calculated by the methodology discussed above, with the best available products and best available technology.

LITERATURE REVIEW

Although miscellaneous energy use has seen an increasing interest from researchers, recent comprehensive data on measured energy consumption by various products are still limited. For gas-based end-uses, data are even sparser. Some of the early efforts towards characterization and quantification of miscellaneous home energy loads date back to the 1980s. Box 1 provides a brief overview of select studies on miscellaneous energy use.

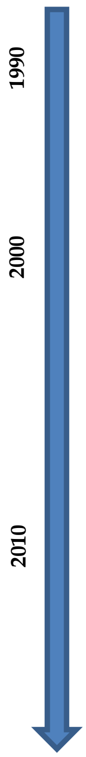
Box 1 Select list of literature reviewed

EIA National Surveys

Residential Energy Consumption Survey (RECS): Administered to a nationally representative sample of housing units, provides housing characteristics and appliance ownership data; most recent data are available for 2009

Commercial Buildings Energy Consumption Survey (CBECS): End use estimates for commercial buildings based on statistical regression from utility bills of a representative sample of buildings; most recent comprehensive CBECS data are available for 2003; next version for 2012 expected to be released in 2014

Reports



(Meier et al 1987, 91): Estimated energy use for residential electric appliances on the basis of measurements and engineering calculations

(Sanchez et al. 1997): Bottom-up calculation of total energy for 90 residential miscellaneous electric appliances and growth projections till 2010

(KEMA-XENERGY et al. 2004): California's Residential Appliance Saturation Survey (RASS) covering about 22,000 customers over a period of two years; data include information on all appliances, general usage habits and UEC values for all individually metered customers

(Roth et al 2008): Energy consumption and savings potential of residential MELs with base year as 2006 and projections for 2020

(Zogg et al. 2009): Energy use characteristics of gas and electric appliances in commercial buildings based on technical literature and industry interviews

(McKenney et al 2010): An overview of energy consumption of 28 key commercial MELs by building type, prepared by TIAX LLC

(Urban et al. 2011): Commissioned by the Consumer Electronics Association as a bottom-up approach to characterize energy consumption for residential consumer electronics

(Dirks and Rauch 2012): DOE multi-lab metering study for different commercial buildings measuring energy consumed by miscellaneous electric loads

Other resources

EIA Annual Energy Outlook: Estimate of energy use and projections till 2040 by end use
http://www.eia.gov/forecasts/aeo/er/index.cfm

EIA: Overview of residential and commercial miscellaneous electric loads
http://www.eia.gov/oiaf/aeo/otheranalysis/mesbs.html

Food Service Technology Center: Administered by Pacific Gas and Electric Company; useful for commercial gas cooking appliances; http://www.fishnick.com/

Metropolitan Utilities District: Annual gas use by appliance
http://www.mudomaha.com/service/pdfs/gasappliancecosts.pdf

DEFINITION AND TAXONOMY

The definition of MELs is an evolving one. The EIA hasn't specifically defined MELs. As per the Annual Energy Outlook 2012, the EIA considers residential lighting, space conditioning, refrigeration and cooking, laundry and dishwashing, TV and set-top boxes and computers and related equipment as major end-uses. Everything else falls into the 'others' category[3]. For commercial office buildings, the EIA treats 'office equipment' and 'computers and related equipment' as distinct categories and not as 'others' while non-building loads like distribution transformers, water treatment and supply, and mobile phone towers are included in the 'others' category.

The definition used by an ongoing DOE multi-lab study (Dirks and Rauch 2012) is any electric load that is not in the main building service (HVAC, lighting, or water heating) as defined by the ANSI/ASHRAE/IESNA 90.1 building codes. Thus, products such as space heaters and dehumidifiers would be categorized MELs although they are being used for space conditioning. The same study defines exterior lighting, extra task lighting, signage, or process lighting (e.g., a photo studio), as MELs because these lighting applications are usually not included in design calculations of lighting power density. The list of types of MEL equipment is hundreds of lines long and even longer if we factor in different designs for the same equipment (Dirks and Rauch 2012).

Most of these definitions do not address natural gas (and propane and liquefied petroleum gas) explicitly and cover only those products that run on electricity. Gas based products have a significant end-use share in some miscellaneous categories. Examples include pool heaters, exterior gas lighting, and commercial cooking equipment. Some miscellaneous gas uses could be categorized into traditional end-uses like HVAC or cooking.

In the current study, we suggest heuristics that help in distinguishing between a major energy use and an MEL. We begin by defining critical building functions — providing shelter, habitable conditions like heating, cooling, ventilation, hot water and lighting. Juxtaposed with the critical building functions are another set of tasks that we call — 'principal building activity'. These activities directly serve the primary purpose of the building. The primary purpose of a bank is to provide financial service, for a restaurant is to provide food, for a home is to provide shelter and sustenance. Any other energy services that the users introduce, primarily, but not always, through plugged-in devices, to augment or modify their atmospherics (air temperature, air quality, scent, noise, lighting etc.) or to perform subordinate tasks like brewing coffee, shredding paper and so forth, are most often ideal to classify as MELs. For example, in the residential context, the stove does not serve a critical building function but cooking food is one of the principal activities in a home. Thus, a cooking stove is not miscellaneous, but the microwave oven, toaster oven, and coffee maker all provide supplementary cooking services and can be classified as MELs. Similarly, commercial washers and dryers perform the principal building activity in a laundry and hence are not included in our analysis. Walk-in refrigeration in food sales buildings is included since the principal activity of the building is not refrigeration but stocking and display of food products. Our definition

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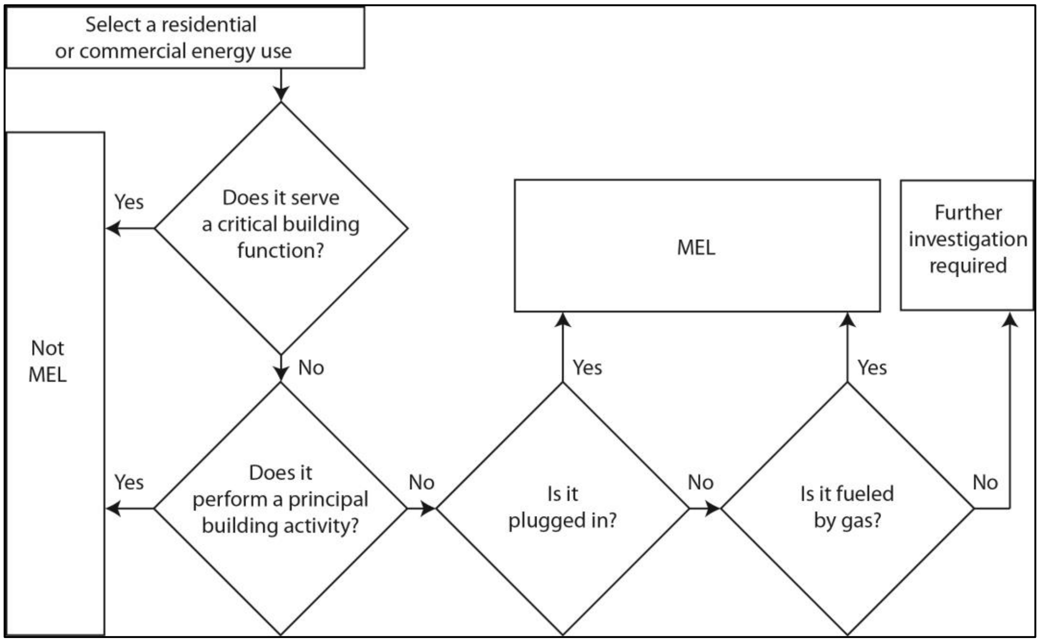
[3] As per EIA, the "Other" category of end-use services includes those end-uses that are either not explicitly modeled but still account for non-major end-use consumption, or are modeled in lesser detail than major end-use equipment.

leaves room for new products that have not yet been incorporated into conventional end-use categories. Figure 4 illustrates this classification process.

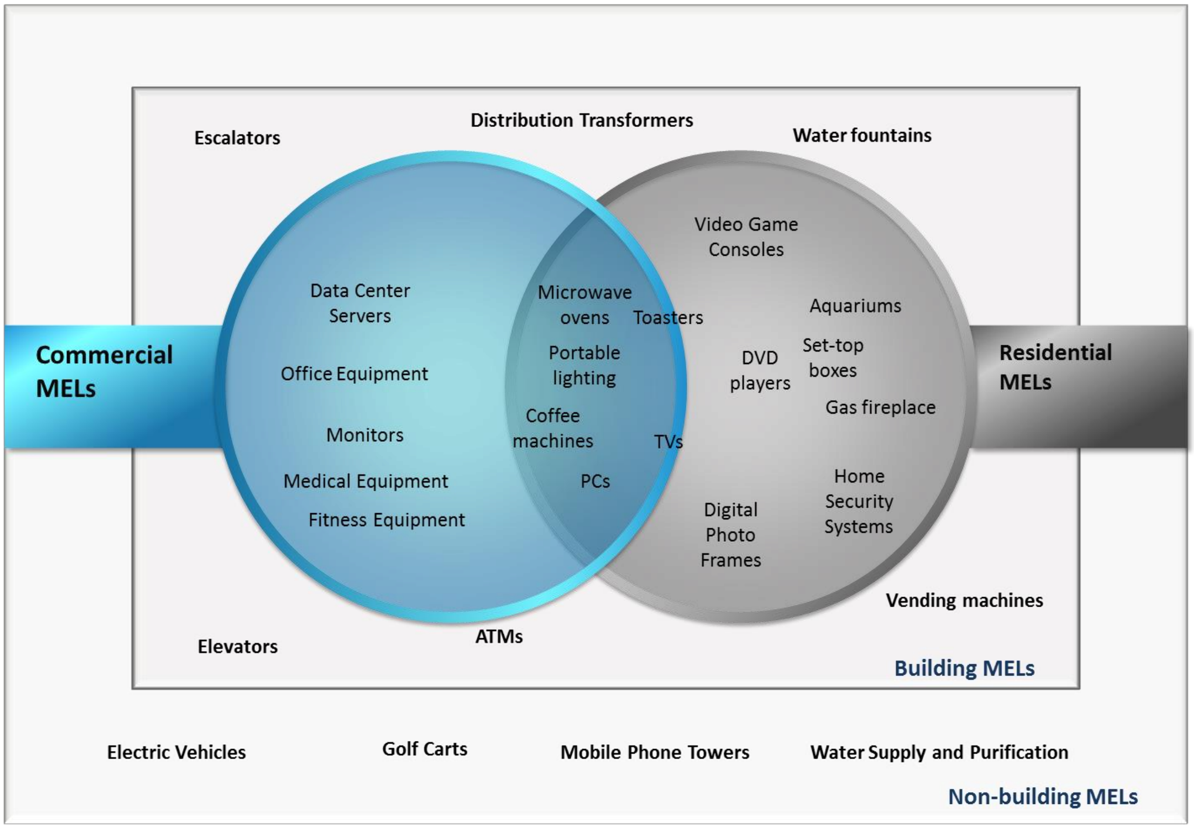
Figure 4. A Heuristic to Define MELs



Source: ACEEE

At the top level, MELs are further bifurcated into residential and commercial. These two categories are not mutually exclusive and there are some overlapping items between the two. Figure 5 shows a sample of MELs that fall into either category. Some MELs are not plugged in (e.g., elevators) and some are not used in buildings at all (e.g., mobile phone towers) but some of the latter may have building-related energy use for instance golf carts maybe charged in buildings. Since the scope of this study is to identify all major end-uses that are not traditionally covered, we have drawn wide boundaries for the items that we analyzed. We have chosen to evaluate items individually or in small groups that are amenable to policy action. For example, most rechargeable electronics benefit from improved battery chargers. At the same time, microwaves and coffee machines have very different characteristics and need individual attention.

Figure 5. Classifying MELs



Source: ACEEE

Findings

In the following sections, we present the key findings from our analysis of miscellaneous loads in residential and commercial buildings. Natural gas MELs are discussed in a separate section.

RESIDENTIAL SECTOR (ELECTRIC)

The composition of MELs in the residential sector is different from that of the commercial sector due to the heterogeneity of activity found in residences, including cooking, cleaning, and bathing functions, as well as due to the presence of more specialized equipment devoted to relaxation and entertainment. Televisions, video game consoles, and portable spas make their way into the top energy consumers in residential buildings. At the same time, with increasing telecommuting, many devices formerly reserved for the office have found their way into the home. The Census Bureau's Survey of Income and Program Participation finds about 9.4 million Americans, or 6.6% of workers, worked exclusively from home on their primary job in 2010, up from 4.8% in 1997 (Wessel 2012) and one estimate gives the number of people working at least one day from home as high as 44 million (Telework 2013). Thus, it is not uncommon to see computers, printers, scanners, fax machines, and paper shredders in modern homes although their energy use varies considerably when found in residential settings.

Consumption of energy is also different in homes. Except in the case of 'all inclusive' rental units, residents have a direct incentive to conserve energy and save money. Domestic consumption of energy is often bound up with routine and habit (Shove 2002) rather than rules and protocol. These differences are apparent when we look at the data for instance, the average UEC of personal computers is 158 kWh/year for residential use[4], but increases to 336 kWh/year when used in a commercial establishment. Similarly, for microwaves, the residential UEC at 121 kWh/year is much less than that for commercial at 447 kWh/year. When considering peak load impacts, the residential and commercial sector complement each other to an extent with commercial use highest during peak mid-day and afternoon hours, whereas most residential energy use occurs during off-peak hours (e.g., evenings and weekends). We believe residential MELs may be harder to tackle as households are harder to reach collectively and the consumption habits are driven by culture and tradition.

It is important to note that national level averages for MELs may understate the differences in MEL ownership by housing characteristics and by region. Program design to tackle MELs would benefit from understanding the variations such as those highlighted here.

In new homes that are built to the latest building energy codes, we find that miscellaneous uses account for over 50% of total energy use. There are significant differences if we analyze the penetration of specific products as illustrated in Table 1. For example, we are twice as likely to find a home theater system in a new house as in a pre-1950 house; and the converse is true for portable electric heaters.

Table 1. Illustrating the Differences in Penetration with the Age of House

Product	Old Houses (pre-1950)	New Houses (post-2000)
Rechargeable tools and appliances	80%	98%
Computer	75%	88%
Home theater system	10%	25%
Portable electric heaters	21%	11%
Air conditioning equipment	73%	93%

Source: ACEEE analysis based on RECS 2009

In another example, data shows that while 18% of single-family detached homes have a dehumidifier, only 3% of multi-family apartments have one (Table 2).

[4] Desktop computers used in residences for commercial purposes likely have higher than the average UEC for residential computers

Table 2. Illustrating the Differences in Penetration with Type of Housing

Product	Multifamily Apartment	Single-Family Detached
Outdoor grill	18%	75%
Coffee maker	46%	69%
Cordless telephone	41%	72%
Humidifier	9%	18%
Dehumidifier	3%	18%

Source: ACEEE analysis based on RECS 2009

As shown in Table 3, some products show a higher regional variation some of which can be attributed to differences in climate zones. We note that regional variations for coffee makers and cordless phones are smaller than for other climate-driven products such as humidifiers and dehumidifiers.

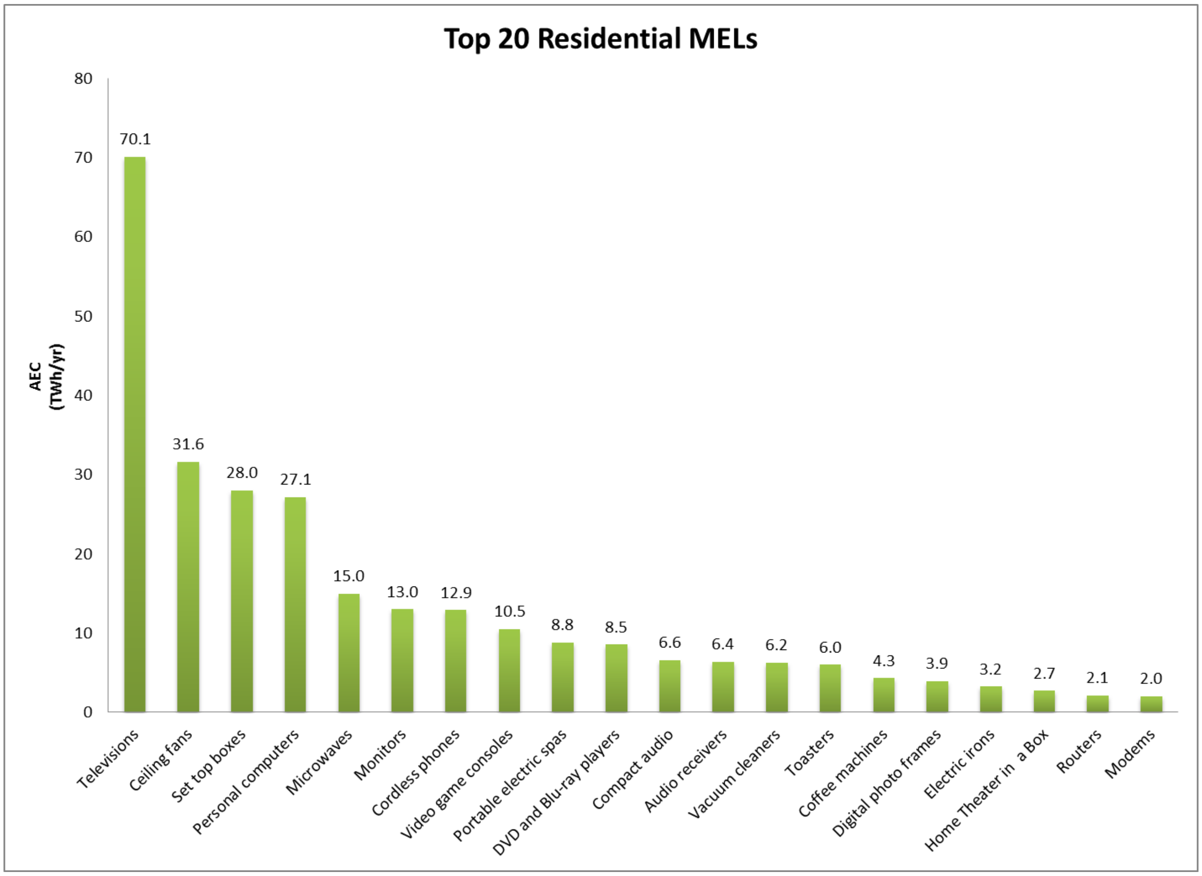
Table 3. Illustrating Regional Differences in MEL Penetration

Product	Northeast	Midwest	South	West
Outdoor grill	56%	69%	59%	60%
Coffee maker	64%	67%	64%	59%
Cordless telephone	70%	63%	60%	64%
Humidifier	16%	27%	10%	11%
Dehumidifier	25%	25%	7%	2%

These variations illustrate that building characteristics, demographics and climate variables are intertwined in determining the energy use profile for products in the miscellaneous category. More research will help us tease them apart and will be valuable in designing effective program strategies around reducing MEL energy use.

Figure 6 provides the AEC for the **top twenty residential MELs.** As discussed in the Methodology, we have calculated AEC as the product of unit energy consumption and total installed base. (See Table A-1 for detailed AEC, UEC and installed base data for residential MELs).

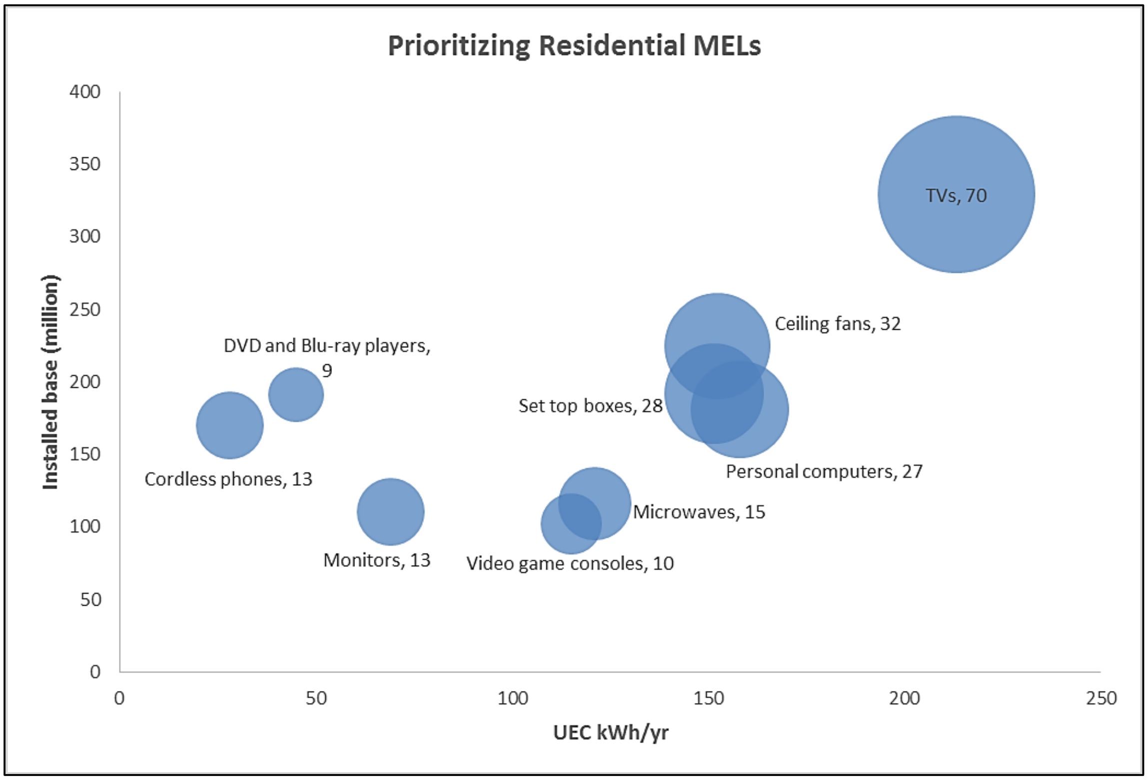
Figure 6. Residential MELs by Annual Energy Consumption



Source: ACEEE analysis

For the highest energy consuming MELs, we depict the three dimensions of unit energy, annual energy and installed base graphically in Figure 7. The size of the bubble represents AEC in TWh/year. Although there are more DVD players (~200 million) in U.S. homes than microwave ovens, the latter consume much more energy on a unit basis and may offer greater energy saving potential. We discuss the top ten products in detail in the subsequent section.

Figure 7. Key Measures of Residential MELs



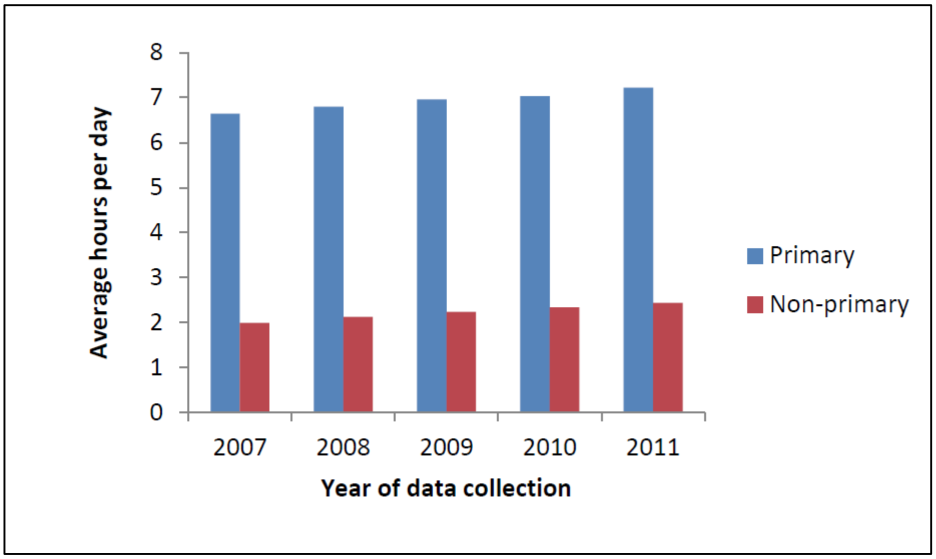
Note: 1. Size of the bubble represents AEC in TWh/year (as given in the data labels)
2. Portable electric spas (not shown on the chart) have a UEC of 2500 kWh/yr
Source: ACEEE analysis, data from multiple sources

Televisions

Televisions are the biggest single residential MEL accounting for 22% of the annual residential MEL load in this study and 4% of the electricity used by households in the United States (DOE 2013). Almost 99% of U.S. households own a TV (EIA 2012), and the installed base of over 320 million TVs outnumbers the U.S. population. More than half of households own three or more TVs. The biggest impact on the annual energy consumption of TVs is that of usage hours. Estimates of active use of TVs center around 3.8 hours per day per TV (Urban et al. 2011) or 9.5 hours per day per household (Roth et al. 2008). In recent years, low power Liquid Crystal Display (LCD) and Light-emitting diode (LED) TVs have been gaining market share although they are yet to overtake the installed base of the older technology cathode ray tubes (CRTs). Some of the efficiency gains in power draw are offset by the increase in size of display — primary TVs, the ones that are used most in a household, are also bigger than before with average screen size of 38 inches (Urban et al. 2011).

ENERGY STAR specifications have played an important role in driving down energy consumption in non-active modes and the current specification limits off-mode power to 1.0 W for all TVs (EPA 2010). As a result, the UEC is relatively insensitive to off-mode power and active mode is responsible for over 85% of UEC (Roth et al. 2008). TV use in active mode has been increasing gradually but steadily in recent years as shown in Figure 8. Active mode power draw could increase more rapidly in the future if much larger HDTVs become more common. The EIA projects very little growth in energy consumption from televisions. With the increasing options for watching traditional television programming on computers, tablets and smart phones — there is an increasing number of 'no TV' modern households.

Figure 8. Television Usage Trends



Source: DOE 2012

STANDARDS

Federal Standards	Not covered	DOE initiated rulemaking regarding test procedures for televisions in March 2013
ENERGY STAR	Version 5.3 since September 2011	Version 6.0 currently under development
Other	California standards Tier 2 in effect from 2013	

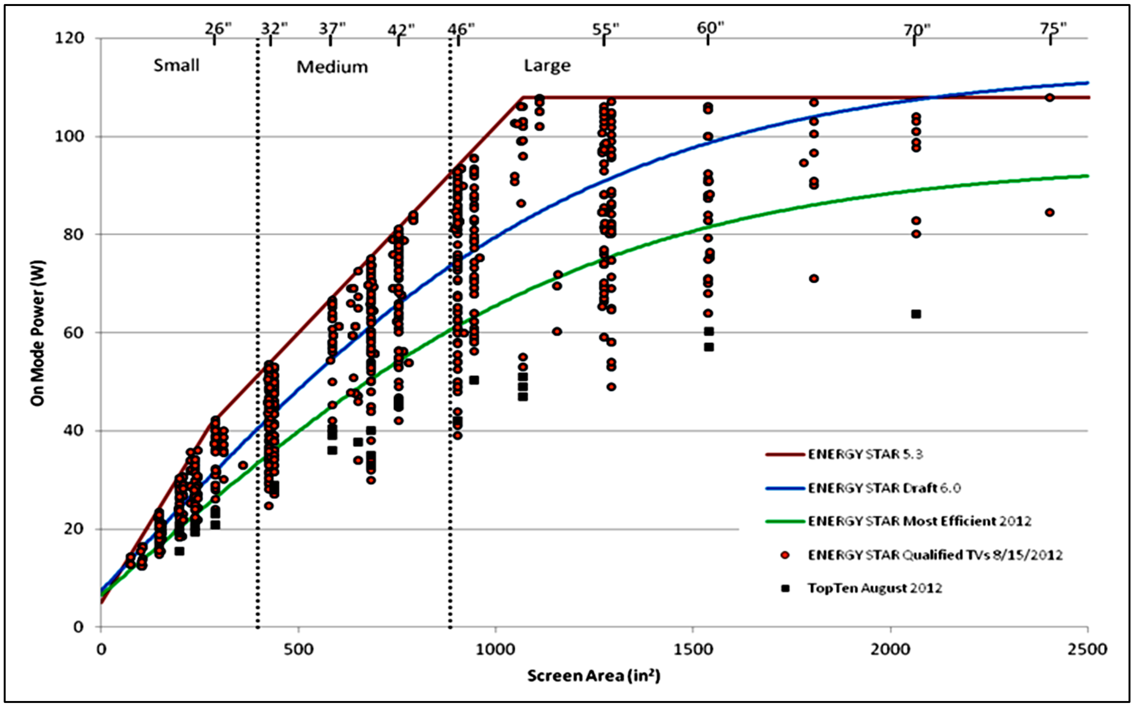
As of 2012, there are over 1,200 ENERGY STAR qualified products available in the market.[5] Approximately 95% of all TV models are reported to be compliant with ENERGY STAR specifications (EPA 2011) and, as a result, EPA is developing a new specification for ENERGY STAR qualified TVs. ENERGY STAR specifications have proven effective in promoting efficiency gains from TVs, especially in larger size models. A comparison with the best in class models on energy efficiency as determined by ENERGY STAR Most Efficient[6] and Top Ten

[5] http://www.energystar.gov/ia/partners/prod_development/revisions/downloads/television/ES_Televisions_Draft_2_V6_Webinar.pdf?5136-4c6f

[6] ENERGY STAR Most Efficient designation recognizes the most efficient products among those that qualify for the ENERGY STAR

USA[7] suggests that still greater reductions in energy consumption are possible. Figure 9 shows how ENERGY STAR version upgrades have helped in bringing down power draw in active mode, and highlights the best in class efficiency.

Figure 9. Television Active Mode Power by Specification and Comparison with Best in Class Models



Source: Analysis by Katherine Dayem, ECOVA

ENERGY SAVINGS

An ASAP/ACEEE report, *The Efficiency Boom* (Lowenberger et al. 2012), estimates that a DOE standard modeled on ENERGY STAR 5.3 can lead to potential savings of 10 TWh in 2035 with a present value of $8.3 billion. Many recent technological advancements offer the potential to make TVs ever more efficient.

- Automatic Brightness Control (ABC), if available and enabled, adjusts the picture brightness dynamically in response to changing ambient light levels consequently decreasing power draw by up to a third (Pigg et al. 2010).
- Auto powering down when idle and using a smart power strip[8] (useful for peripherals, too) are some of the other options for reducing the energy footprint of televisions.

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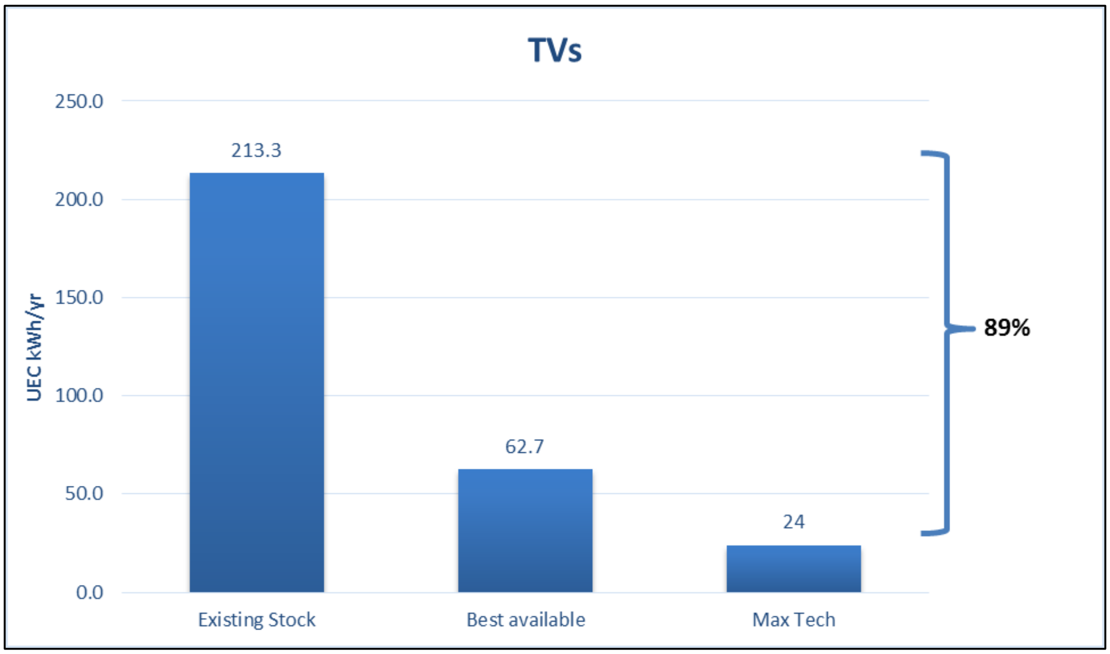
[7] TopTen USA (www.toptenusa.org) evaluates consumer products like computers, TVs, refrigerators and identifies the most efficient products available in the market

[8] "Smart" power strips have multiple sockets for plugging in a primary device, such as a TV, and peripherals that are used with the primary device like a DVD player. When the smart power strip senses that the primary device is turned off, it automatically switches off the power to the peripherals, thereby eliminating whatever standby power those devices might otherwise draw

- Future display technologies, such as carbon nanotube and organic LED (OLED) may use significantly less power than today's technologies (EIA 2007).
- Behavioral change (like collective viewing, switching off, and reduction in use) can potentially save more energy without requiring any technological change.
  Figure 10 shows that there is an energy saving potential of 89% of annual UEC by replacing the existing stock with the best products in the market and further by adopting the most advanced current technology.

Figure 10: Energy Saving Potential



Data Source
Best available: Average of medium size models (http://www.toptenusa.org/)
Max Tech : (Desroches and Garbesi 2011)

Ceiling Fans

Energy use by ceiling fans varies highly with seasons as well as regions. TIAX (2008) estimates an average annual usage of 2300 hours. Electricity use for ceiling fans (not including attached lights) is projected to increase through 2030, as newly constructed homes tend to have more ceiling fans installed, and more new homes are built in warmer areas where ceiling fans are used more intensively (EIA 2007). Performance of a ceiling fan is measured in terms of airflow per unit of energy and is dependent on the electric motor and the blade design amongst other things. Most residential ceiling fans (and all ENERGY STAR qualified fans) feature the ability to reverse the motor and airflow direction, allowing year-round operation of the fan.

STANDARDS

Federal Standards	In effect since January 2007	DOE initiated revision of standards for ceiling fans and ceiling fan light kits in March 2013
ENERGY	ENERGY STAR V 3.0 in effect since April 2012	

STAR	
Other	No state standards

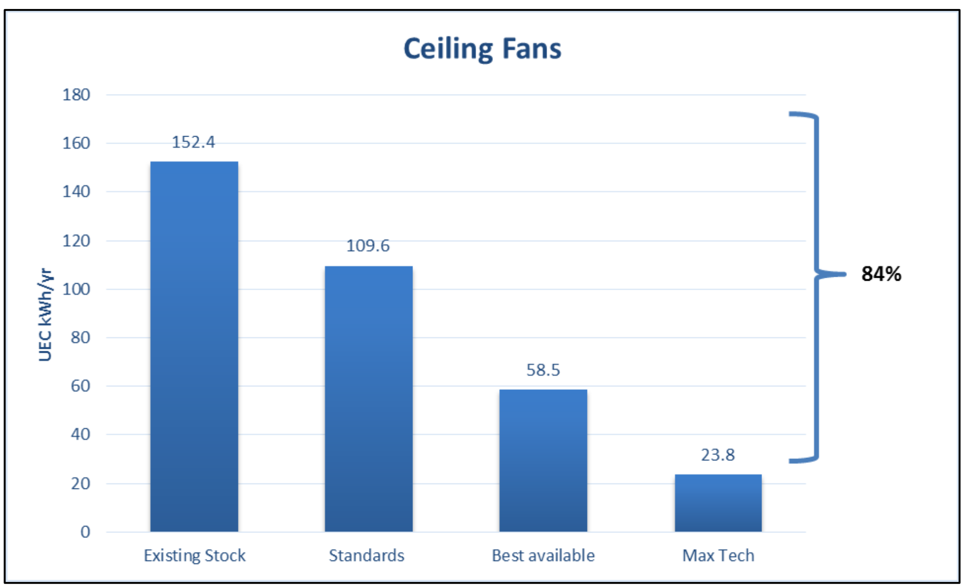
Federal standards require that ceiling fans have more than one speed, which can be controlled separately from lights, and have a switch to reverse action of the fan blades (to match differing air circulation requirements for the heating and cooling seasons).

ENERGY SAVINGS

- While the ENERGY STAR specifications require an average airflow efficiency of 122 cfm/W (at 2,300 cfm)[9], the current stock of ceiling fans is estimated to have an airflow efficiency of only 70 cfm/W (ASAP 2012). The most efficient fan on the market achieves 680 cfm/W (Desroches and Garbesi 2011) much above that of the current stock.
- Older ceiling fans incorporate a standard shaded pole motor, which typically consumes 35 watts (W). Current ENERGY STAR-compliant models gain roughly 15% efficiency for the motor (30 W). The best available units on the market use a DC motor, improved fan blade design with proper balance, and sealed bearings reducing motor power to just 10 W (Desroches and Garbesi 2011).
- Thus, there are gains to be had from 1) increasing the penetration of ENERGY STAR ceiling fans and 2) making ENERGY STAR specifications even more stringent.

Quantitatively, in terms of annual unit energy consumption, these different options stack up as shown in Figure 11 below. Energy savings of 84% are possible by replacing the current stock with the best available technology.

Figure 11: Energy Saving Potential



Data Source: Desroches and Garbesi 2011

[9] This is an average of efficiency requirements at three different fan speeds low, medium and high

Set-Top Boxes

More than 190 million set-top boxes are used to deliver pay-television services to TVs in more than 80% of U.S. homes. On average, set-top boxes use 152 kWh per year, but energy use varies widely depending on the service provider and the type and vintage of the set-top box. The majority of energy used by set-top boxes is consumed when the box is not in use (i.e., the viewer is not watching or recording content) because most boxes rarely go into a low-power standby mode and, even if they did, most use only a few watts less in standby than when fully active. As more and more pay-tv subscribers have migrated toward boxes incorporating digital video recorders (DVRs) and other features, set-top box energy use has increased. Improvements in power supply and other component efficiencies have been offset by the higher power demands of these advanced features. Overall, the current stock of installed boxes uses approximately 28 TWh of electricity each year. Rapid evolution in the pay-tv industry and in the options available to consumers for streaming content directly to TVs, computers, tablets and other devices make it difficult to predict the future market and use of set-top boxes.

STANDARDS

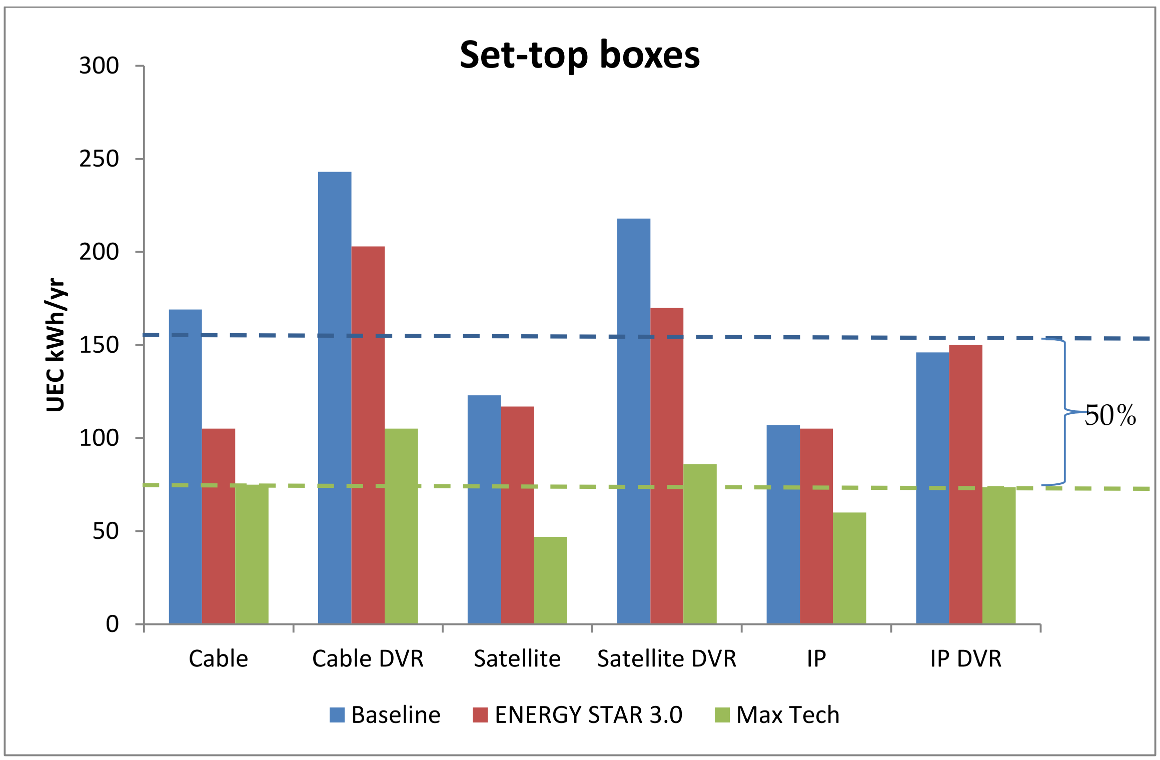
Federal Standards	Currently not covered	DOE initiated a rulemaking regarding test procedures for set-top boxes in January 2013
ENERGY STAR	Version 3.0 September 2011	Version 4.1 currently under development
Other	California has announced that they will be considering standards, labeling and other efficiency measures for computers along with several other consumer electronics products as part of their 2013 appliance efficiency proceedings	

Unlike other consumer electronics that are sold directly to consumers through conventional retail outlets, set-top boxes are purchased by pay-tv service providers (i.e., cable and satellite system operators) and deployed in subscriber homes. Consumers choose their service provider and level of service (e.g., HD, DVR), but do not select the model of the set-top boxes installed in their home. Service providers also work closely with manufacturers to tailor set-top box models to their unique system needs and service offerings. As a result, ENERGY STAR has requirements for manufacturers and service providers that call on service providers to purchase and deploy a certain percentage of qualified boxes to participate in the program.

ENERGY SAVINGS

One of the best opportunities for reducing set-top box energy consumption hinges on lowering sleep mode power requirements and incorporating auto power down to ensure that boxes power down to a deep sleep mode when not in use. Many existing boxes as well as new models entering the market consume over 20W in sleep mode (although many boxes are rarely, if ever, turned off or put into sleep mode). Cable and satellite providers are beginning to introduce models that are more efficient and, based on models now available in Europe, there is room for further gains and the potential to bring sleep mode levels to 10W or less. Newly deployed boxes are also incorporating auto power down so that the set-top box enters a deep sleep mode after several hours of inactivity and the capability to go back into sleep mode after recording a program or receiving a system download. Cable operators are beginning to push software upgrades to existing boxes to enable power management features to capture the limited savings available in previous generation boxes. At the household level, the introduction of improved "whole-home" systems can eliminate the need for more than one DVR or other fully featured box. One primary DVR server relays programming to thin-client boxes with much lower power requirements cutting household level set-top box energy use by as much as 70% (NRDC 2011). Figure 12 shows the difference in energy consumption between various configurations of STBs. On an average, there is a potential to cut down the annual energy use by about 50% if the entire stock is replaced by the best technology currently available.

Figure 12: Energy Saving Potential



Source: US DOE, ENERGY STAR

Personal Computers

The existing stock of desktop computers in American homes is approximately 138 million. This includes personal computers that are designed to be used in a single location (i.e., not designed for portability) with an external display, keyboard and mouse. All-in-one (AIO) systems with computer and display in a single housing are included in this category. In addition, Consumer Electronics Association market research (Urban et al. 2011) estimates another 130 million portable computers including laptops, netbooks and tablets. In recent years, sales of portable computers have outpaced those of desktop units for home computing and this trend is expected to continue. On average, personal computers in residences use 158 kWh per year, bringing total annual energy consumption for these products to 27 TWh. Effective use of computer power management settings has a significant impact on energy use; recent studies estimate average energy use in active mode is 60W, while sleep and off-mode power are dramatically lower at

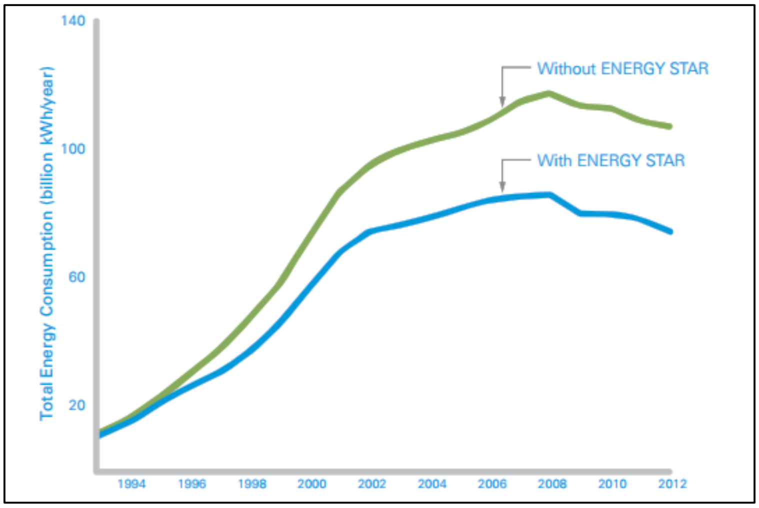
4W and 3W, respectively (Urban et al. 2011). As these numbers attest, early efforts to improve sleep and off-mode efficiency have paid off.

STANDARDS

Federal Standards	Currently not covered
ENERGY STAR	The current specification for desktop computers (Version 5.0, effective July 2009), establishes maximum annual energy use criteria as well as requirements for power supply efficiency and power management features and settings. The Version 6.0 criteria are under development; publication of the final specification is expected in the first half of 2013.
Other	California has announced that they will be considering standards, labeling and other efficiency measures for computers along with several other consumer electronics products as part of their 2013 appliance efficiency proceedings. Other major environmental footprint reduction programs, such as EPEAT, are applicable to computers and base the energy portion of their rating criteria on ENERGY STAR standards (Zogg et al. 2009).

As shown in Figure 13, ENERGY STAR specifications have played a big role in reducing energy consumption by computers and EPA estimates a saving of about 30% of total energy consumption that can be attributed to ENERGY STAR compliance.

Figure 13: ENERGY STAR Impact on Personal Computer?



Source: EPA 2012

ENERGY SAVINGS

Typical household computers consume more than 90% of their annual energy use in active mode even though they spend less than 40% of the time this mode (Urban et al. 2011). Efforts to reduce the energy consumed by personal computers in U.S. homes must focus first on reducing active mode power, then on effective power management strategies that get computers to enter sleep mode faster and to stay in sleep mode longer when the unit is not in active use. A range of emerging technical opportunities will yield active mode energy savings. The most promising improvements include discrete graphics processing units (GPUs) with improved power management and reduced power demand when switching from active to idle mode, solid-state drives to replace traditional spinning hard disk drives, and high-efficiency internal power supplies that help save energy throughout the system. The gap between energy consumed by portable computers (notebooks, tablets etc.) and desktop computers is substantial. With a premium on battery life, cutting-edge technology is adopted rapidly in case of portable computers. Similar technological potential exists for reducing energy consumption in desktop units, indeed the leading products in the market are already much more efficient than the current stock.

Microwave Ovens

With a household penetration of 96% (EIA 2009), microwaves are almost as common in U.S. households as televisions. However, the saturation for microwaves is much less than that of TVs as most households do not have more than one unit. A major part of microwave-oven energy is consumed by the magnetron to provide heat to the cooking chamber; some energy is used in standby mode to power a processer that holds preset cooking times, power the display and for other features (Zogg et al. 2009). A survey by LBNL (Williams et al. 2012) estimates that for microwave-only cooking the average cycle length is 2.63 minutes. Projections of total time of operation range from 45 hours per annum (Williams et al. 2012) to 70 hours per annum (Roth et al. 2008). For 81% of their time, microwaves are in standby mode (Greenblatt et al. 2013) as they are rarely unplugged or switched off. As a result, standby power draw from residential microwaves is as high as 3 TWh annually or about 25% of the total annual energy consumption (DOE 2013). The growth in energy consumption by microwaves is expected to follow the increase in the number of households (Roth et al. 2008).

STANDARDS

Federal Standards	Currently not covered	DOE published energy conservation standard covering **standby and off mode** in May 2013 In January 2013, DOE published a proposed test procedure for microwave **active mode** energy consumption. The final rule is expected in December 2014
ENERGY STAR	Currently not covered	
Other	No state standards	

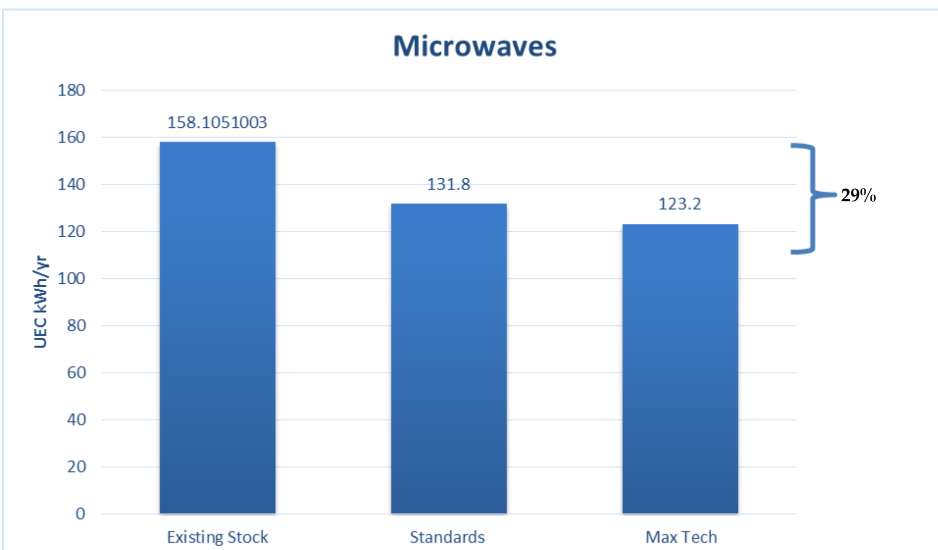
The recently published DOE standards[10] for microwaves, limit standby power to below 1W. In January this year, DOE also proposed a test procedure for measuring the active mode energy use for microwaves.[11]

ENERGY SAVINGS

- Estimated average standby power draw of microwaves is 3W (Roth et al. 2008). DOE identified four technology options that could reduce electricity consumption in standby mode: 1) lower-power display options; 2) cooking sensors with no standby power requirement; 3) improved power supply and control board options; and, 4) automatic power-down.
- Low-power display technologies like liquid crystal display (LCD) or light-emitting diode (LED) displays alone can achieve close to 1W savings.
- Adding an automatic power-down element, which turns off most power-consuming components after a certain period of inactivity, could achieve standby power levels of less than 1 W(ASAP 2012). Thus, the proposed standards can potentially save 2TWh per annum by cutting down on the standby loss by two thirds.

Energy savings of 29% or more are possible by replacing the current stock with the best available technology (Figure 14).

Figure 14: Energy Saving Potential



Data Source: DOE Technical Support Document to the rulemaking

[10] http://www1.eere.energy.gov/buildings/appliance_standards/rulemaking.aspx/ruleid/37
[11] http://www1.eere.energy.gov/buildings/appliance_standards/pdfs/mwo_tp_nopr.pdf

Monitors

We have considered computer monitors as those displays that need to be plugged-in, such as external or stand-alone monitors. Not all desktop computers have a monitor (there are some all-in-one (AIO) PCs), some computers have more than one and some laptop and notebook computers use an external monitor (Urban et al. 2011). In fact increasing number of manufacturers are producing AIO computers following the model of Apple's iMac (Peters et al. 2010). The total number of monitors installed in residences was estimated at 131 million in 2010 (Urban et al. 2011). Over the last decade, small CRT monitors have given way to larger, but more efficient, LCD monitors (Comstock and Jarzomski 2012). Energy Star recognizes three operational modes for monitors– on (or active), sleep and off. When power management is enabled, the device enters a low power sleep mode automatically after a set period of inactivity and exits sleep mode on receiving a signal. Active mode dominates the UEC of monitors especially due to the success of the ENERGY STAR criteria that require sleep mode and off mode power draw of less than 2W and 1W, respectively, for all displays. On average, monitors spend 6.9 hours daily in active mode (Urban et al. 2011). While the active mode power draw in 2010 has decreased by 8% over 2006, the usage has increased by 35% over the same period (Urban et al. 2011).

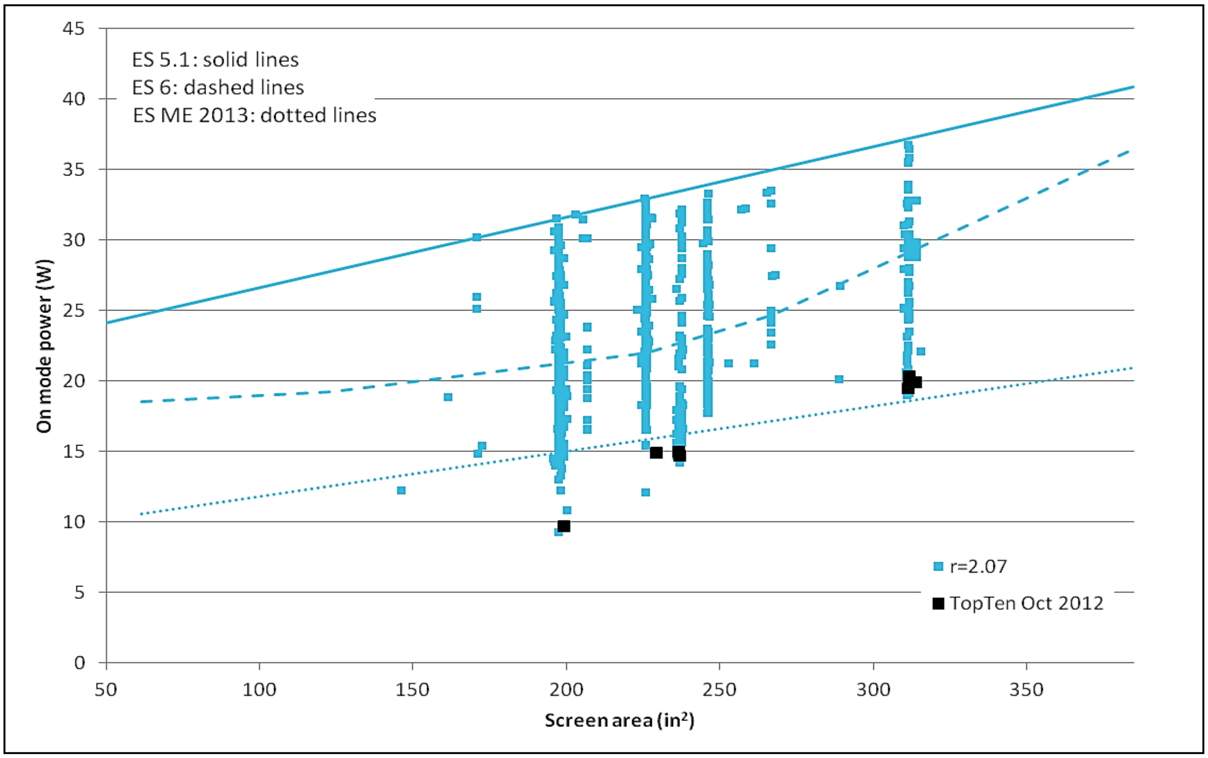
STANDARDS

Federal Standards	Currently not covered
ENERGY STAR	Version 5.1 came into effect in January 2013
Other	EPEAT standards for overall environmental impact

Currently, there are no federal standards for monitors[12]. The Version 5.1 ENERGY STAR displays specification covers computer monitors, digital picture frames, and professional signage and has been in effect since 2009. In 2009, about 90% of all LCD displays below 30 inches were ENERGY STAR-qualified (Urban et al. 2011). Figure 15 shows how ENERGY STAR version upgrades have helped in bringing down power draw in active mode. Clearly, there is a significant potential to improve further to the level of most efficient models.

[12] DOE issued a request for information in January 2012 regarding miscellaneous residential and commercial electrical equipment which includes desktops and monitors amongst other devices

Figure 15. Displays: Active Mode Power by Specification and Comparison with Best in Class Models



Source: Analysis by Katherine Dayem, ECOVA

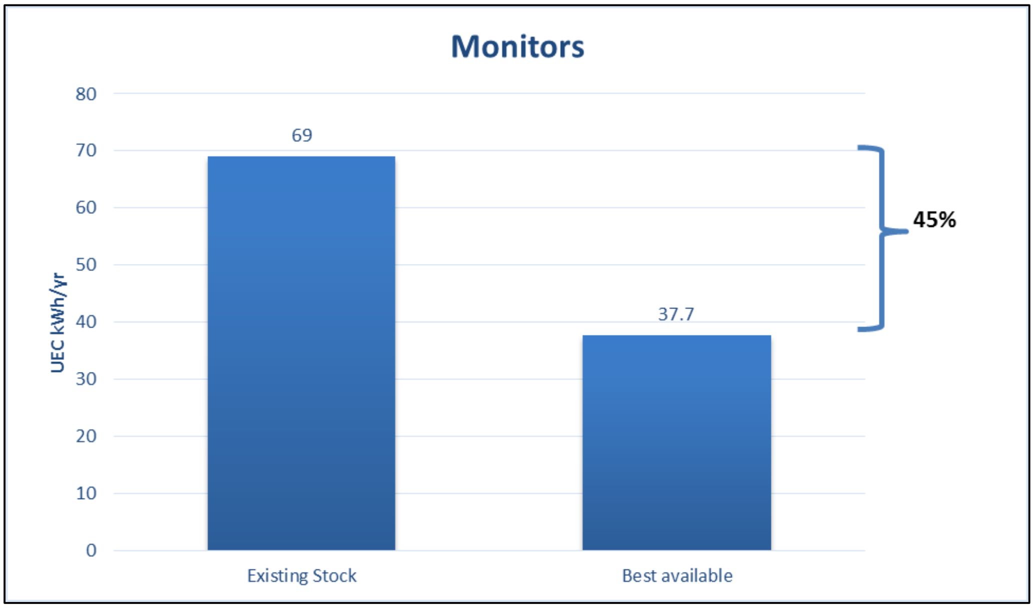
ENERGY SAVINGS

According to estimates (Urban et al. 2011), 15% -20% of monitors are left on overnight and do not enter sleep mode as power management is disabled. A techno-behavioral field assessment by the Energy Center of Wisconsin (Pigg et al. 2010) revealed a high degree of interest among households in enabling power management, which suggests that lack of awareness may be the main barrier.

- Ideally, power management on the monitor should be aligned with the computer so that the turned off monitor does not lead to the false assumption that the computer is off as well.
- Smart power strips are also an effective option for computer peripherals.
- Simple measures may also include plugging a monitor's power cord directly into a desktop computer, which can turn off the monitor as the computer goes to sleep/off mode (Desroches and Garbesi 2011).
- Orientation of the monitor can also have an impact on brightness and energy use. Facing screens away from the source of light and reflections improves performance and reduces glare (NBI 2012).

Most efficient monitors available in the market consume about half the annual energy of the existing stock of monitors (Figure 16) underscoring the great potential to save energy by stock replacement.

Figure 16: Energy Saving Potential



Data Source: Best available from TopTen USA (http://www.toptenusa.org/)

Rechargeable Electronics

Rechargeable electronics is a vast category of products including cordless and cellular phones, cordless vacuums, stand-alone battery chargers, cordless electric shavers, electric toothbrushes, rechargeable digital still cameras, handheld power tools etc. Most of these products use battery chargers (BC) and/or external power supplies (EPS) that are used to convert household electric current into DC current or lower-voltage AC current at which these devices operate. Reeves et al. (2012) estimate that there are more than four rechargeable electronic products per person in the U.S. Out of these, cordless phones account for almost half the energy consumption by rechargeable electronics in residences. There are more cellular phones today than cordless phones and the gap between the two is expected to increase in future. Still the rate of decline of cordless phones is only marginal and TIAX projects 140 million cordless phones still in use in 2030 down from about 170 million today (Roth et al. 2008). Unlike the rapid demise of the VCR due to incompatibility with modern formats, landline phones are still very much functional. However, higher penetration of mobile phones and use of Voice over Internet Protocol (VOIP) may increase the rate of decay for cordless phones (Roth et al. 2008). At the same time, many VOIP service providers for residential customers allow customers to use their existing phone system with the addition of a VOIP router. This may keep a fair number of these systems in use while adding the energy use of the VOIP router.

Rechargeable electronics products, overall, are projected to increase as a percentage of residential MELs.

STANDARDS

Federal Standards	Battery Chargers not currently covered; EPS standards in effect since 2008	DOE has proposed to amend the EPS standards and establish new standards for battery chargers
ENERGY STAR	Version 1.1 came into effect in January 2006	
Other	California adopted standards for battery chargers in 2012	

Most EPSs (with output power ≤250 W) are subject to national standards since 2008, which specify minimum acceptable active mode efficiency and limit the maximum standby power consumption to 0.5 W. California adopted standards for battery chargers in 2012, which, once fully complied with, are expected to save 2.2 TWh per year.[13] At the national level, DOE has proposed to amend the EPS standards and establish new standards for battery chargers[14].

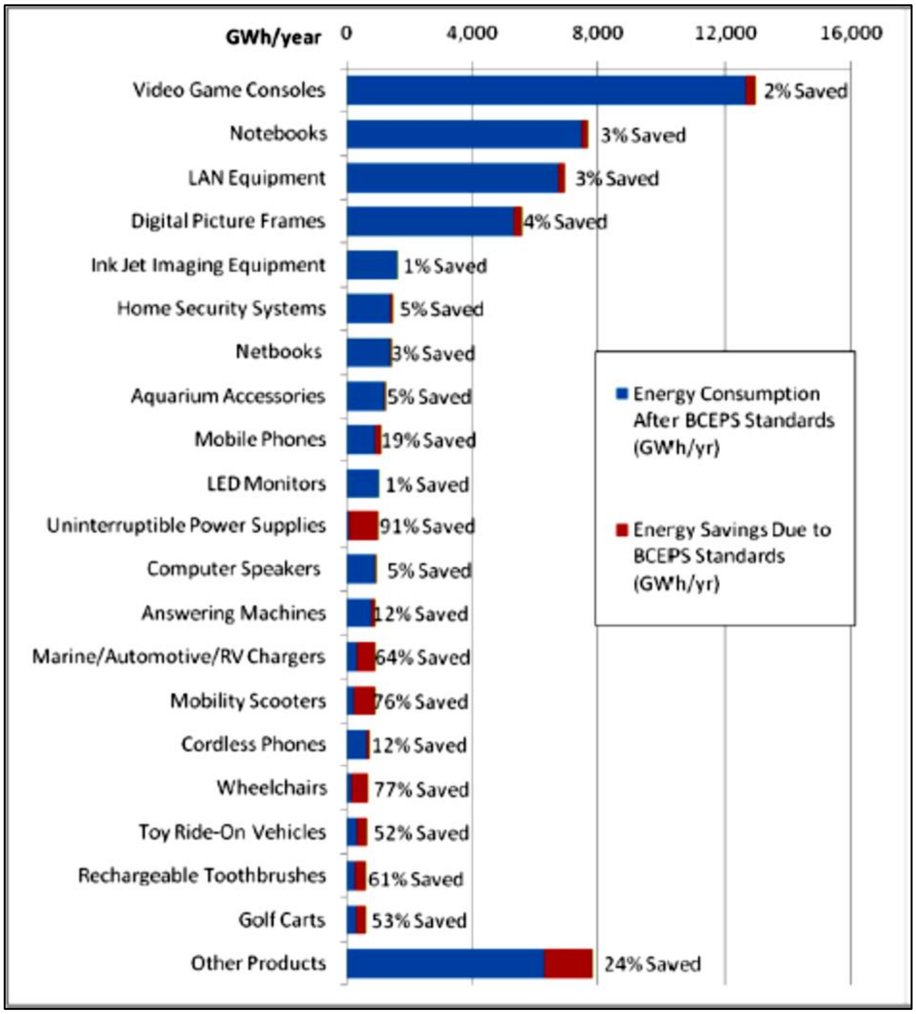
ENERGY SAVINGS

- Products that incorporate ENERGY STAR certified battery charging systems use about 30% less energy than standard equipment.
- Technology options for improving the efficiency of EPSs include improved transformers, low-power integrated circuits, and low-loss transistors[15].
- Behavioral changes like unplugging fully charged devices and unplugging battery chargers that are often left *in situ* can further bring down energy consumption. Smart power strips can often augment the efforts to switch off when not in use.

The energy "consumed" by the battery chargers and EPSs — that is, the energy lost during conversion from line power and in battery charging, can be as high as a third to half of the total energy consumed for some devices.[16] However, for many others devices, including cordless phones, the savings from BCs and EPSs are marginal. Of most relevance to policy makers will be those products that continue to consume relatively large amounts of energy, even after standards are taken into account, as these may provide the greatest remaining potential for energy savings. For many high energy consumption products as shown in Figure 17, energy savings from BCEPS standards represents only a small portion of total AEC (Reeves et al. 2012). For example for cordless phones, efficient battery chargers can help in reducing annual energy use by 12%, further efficiency gains have to come from the device itself.

[13] http://www.energy.ca.gov/releases/2012_releases/2012-01-12_battery_chargers_nr.html
[14] http://www1.eere.energy.gov/buildings/appliance_standards/rulemaking.aspx/ruleid/28
[15] http://www.appliance-standards.org/product/external-power-supplies
[16] http://www.energystar.gov/index.cfm?c=archives.power_supplies

Figure 17. BCEPS Standards Are Crucial but not Enough for these Products



Source: Reeves et al. 2012

Video Game Consoles

The popularity of video games has increased as manufacturers have introduced ever-more sophisticated gaming systems allowing for a much wider diversity of game types and activities. An estimated 98.5 million video game consoles are found in U.S. homes. With average electricity consumption of 135 kWh per year, the annual electricity use for video game consoles at the national level totals 13.6 TWh. Newer game consoles are much more powerful than earlier generations, can connect to the Internet, and incorporate media playback capability (i.e., DVD or Blu-ray disc player, internet streaming etc.). Major gaming system manufacturers have improved the energy efficiency of their consoles in recent years as shown in Figure 18 and the best available models today use a fraction of the power of the older models. Still, among these systems significant differences remain in the power required for game playing, navigation, and media playback. However, all of the systems now use less than 1W in standby mode.

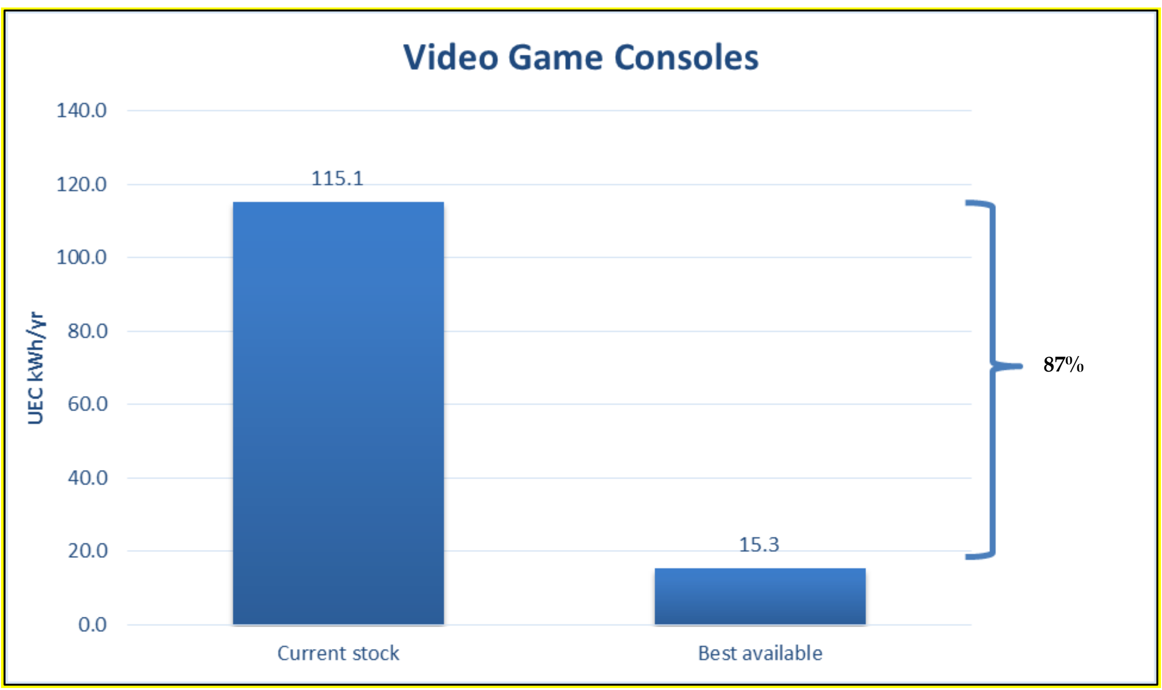
STANDARDS

Federal Standards	Currently not covered
ENERGY STAR	Version 1.0 Recognition Program announced in March 2013
Other	Game consoles included in California Energy Commission Phase I rulemaking

ENERGY SAVINGS

Anecdotal evidence suggests that many users leave their game consoles on when not in use. Given the very low standby power levels of the newest game consoles, auto power down and other advanced power management features (e.g., saving the user's place in the game to RAM, quick resume) have the potential for significant energy savings. Other opportunities include improved power scaling so that game consoles better match the power requirements to the function in use, allowing lower power draw for navigation and media playback. Improvements in the power supplies used with video game consoles could yield further efficiency gains across all modes. Finally, as with set-top boxes, manufacturers should explore opportunities to download software to existing game consoles to reduce energy use and install/activate power management features.

Figure 18: Energy Saving Potential



Source: Desroches and Garbesi 2011

Portable Electric Spa

Portable electric spas are pre-fabricated, self-contained electric spas or hot tubs, as opposed to "in-ground" units (such as those attached to a pool), other permanently installed residential spas, public spas, or spas that are operated for medical treatment or physical therapy (PG&E 2004). There are two operating modes — in-use and standby. While in-use the spa pump provides jet, filtering, and circulation functions, while in standby heat is provided to maintain desired temperature with periodic low speed filtering (Roth et al. 2008). The heating system consumes over half the energy used by a typical electric spa. Heat is lost directly during use and through the cover and shell during standby mode[17]. TIAX estimates that the spa is in standby mode for 8735 hours in a year, which contributes to the high UEC value of 2500 kWh/year. Without constant heating, a spa may take up to 10 hours to attain operational temperatures after days of non-use (Roth et al. 2008).

Annual spa sales doubled over the period 1996 to 2006 and TIAX projects spa sales to continue to increase faster than the population growth rate.

STANDARDS

Federal Standards	Currently not covered
ENERGY STAR	Currently not covered
Other	California, Connecticut, Oregon, Arizona and Washington have set up standards to limit standby energy consumption

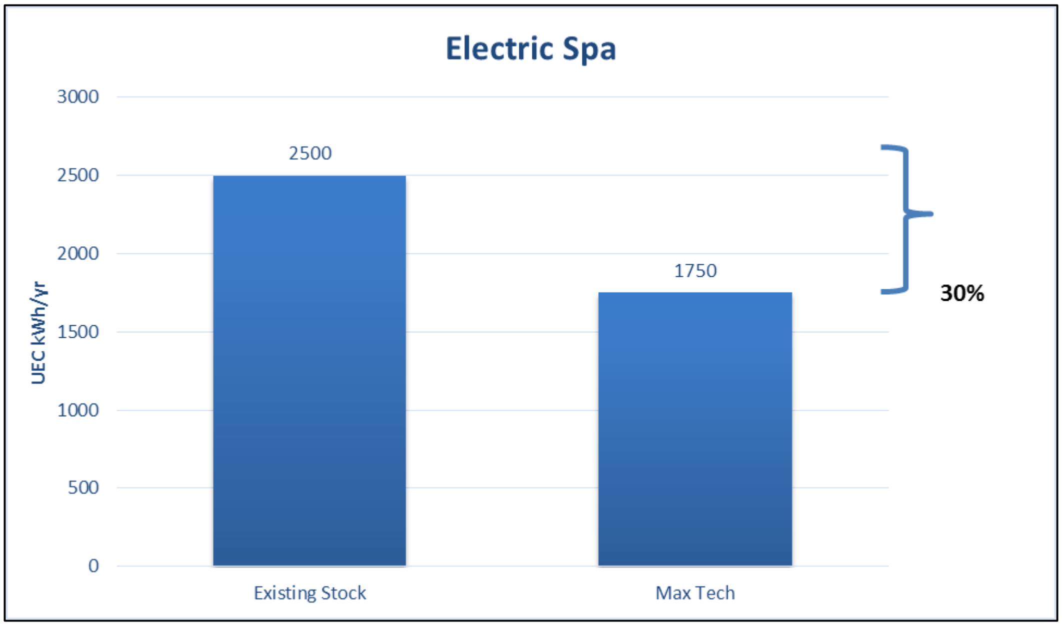
ENERGY SAVINGS

- Improved cover and shell insulation levels are key measures to improving efficiency and can decrease standby energy use by up to 30% for a spa of average to low efficiency (PG&E 2004).
- Another measure is the addition of a low-wattage circulation pump or improvements to pump efficiency that would generally save 15% of standby energy consumption of an average-efficiency spa.
- Programmable controls, which allow users to customize settings based on predicted usage patterns, are a third measure to improve efficiency and could save roughly 5% of a spa's standby energy consumption.

Estimates, such as that by Western Area Power Administration (WAPA 2009), suggest that annual energy savings of 30% are achievable by moving to the best technology (Figure 19).

[17] http://www.appliance-standards.org/product/portable-electric-spas

Figure 19: Energy Saving Potential



Data Source: WAPA 2009

DVD and Blu-Ray Players

This category includes DVD players, recorders and DVD-VCR combos, and Blu-ray disc players. The installed base of DVD players (or recorders) was 223 million units in 2010 with an average of 2.1 players per household (Urban et al. 2011). Home video products have seen a rapid switchover in the last decade from VCRs to DVD players. The next decade may see yet another transition to online streaming, video on demand, and integrated media devices like video game consoles thus making future projections of DVD energy use more uncertain. There are four recognized modes of operation for DVD players -active, idle, sleep and off. The device is on in the idle mode, but not performing any motor function. Idle mode power draw can be as high as two thirds of the active power draw, and accounts for almost 60% of the annual UEC. Home video systems are typically not switched off most of the time.

STANDARDS

Federal Standards	Currently not covered
ENERGY STAR	Version 2.0 for Audio/Video devices effective since March 2012
Other	California, New York, Oregon and Connecticut have state standards

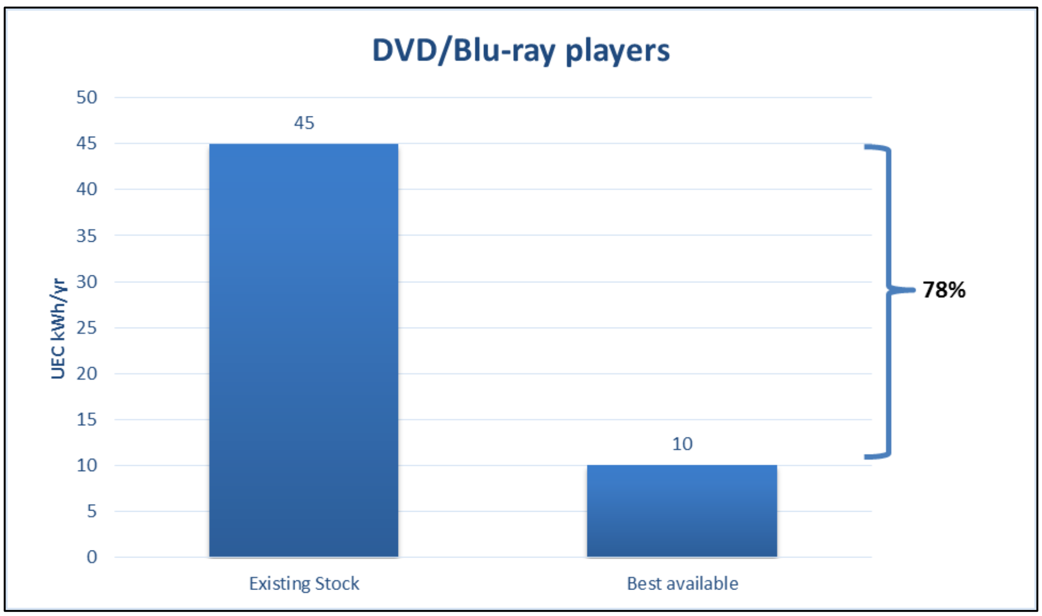
The most recent ENERGY STAR specifications (version2.0) make the Auto Power Down (APD) feature mandatory. APD refers to the capability to automatically switch a device from On mode to Sleep mode after a predetermined period of time (APD timing) has elapsed. ENERGY STAR Specifications also set limits on power draw during sleep mode. Over 80 % of the units shipped in 2009 and later meet ENERGY STAR version 1.0 requirements, and thus consume less than 1W power in the sleep mode.

ENERGY SAVINGS

- Smart power strips, as discussed earlier, seek to reduce standby electricity consumption by peripheral devices.
- When not in use, ENERGY STAR models consume as little as one quarter of the energy used by standard models[18]. Increase in penetration of ENERGY STAR can therefore lower the AEC.
- There is still potential to reduce active mode power consumption. Best-on-market products have active mode power draw as low as six watts about two watts lower than the nearest ENERGY STAR rated models.[19]

Overall, on an annual basis there is a potential to save 79% of the energy by shifting to the best available products in the market today (Figure 20).

Figure 20: Energy Saving Potential



Data Source: Desroches and Garbesi 2011

COMMERCIAL SECTOR (ELECTRIC)

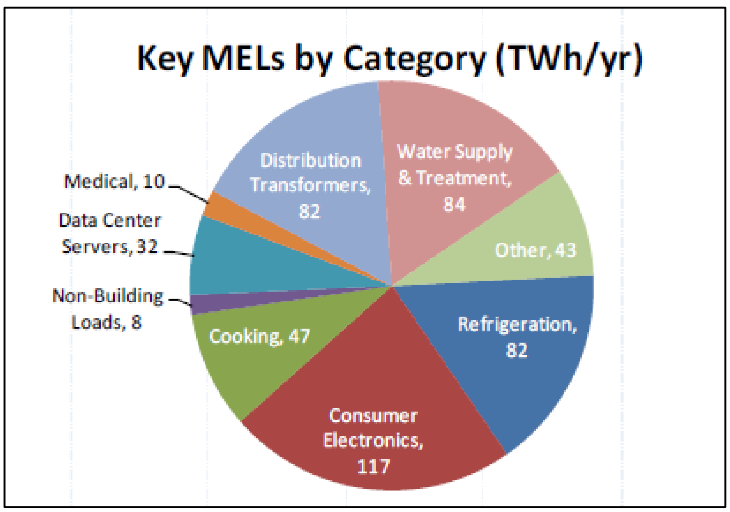
Although concentrated in fewer buildings, commercial MELs are even more diverse than residential. In the commercial sector, each set of key MELs can vary dramatically among buildings of different types. For example, office buildings exhibit high energy consumption from consumer electronics including PCs and monitors, while food sales buildings, such as

[18] http://www.energystar.gov/index.cfm?fuseaction=find_a_product.showProductGroup&pgw_code=DP
[19] http://dvd-players.toptenreviews.com/standard/toshiba/toshiba-sd7300-review.html

supermarkets, have considerably fewer consumer electronics, and significantly more energy consumption associated with refrigeration systems (McKenney et al. 2010).

For many energy loads, the usage patterns across building types vary a lot which adds yet another dimension of complexity. While, for example, a residential refrigerator generally has the same load no matter where it is located, cooking equipment loads vary significantly by commercial building type. A restaurant may have a high concentration and usage of broilers and ranges for preparing customer meals, while a supermarket may have a high concentration and usage of ovens for baked goods(McKenney et al. 2010). The largest MELs analyzed in the TIAX study across all commercial buildings are depicted in Figure 21. This chart can be very different for specific building types for example in office buildings 80% of miscellaneous energy use is by computers and office equipment.

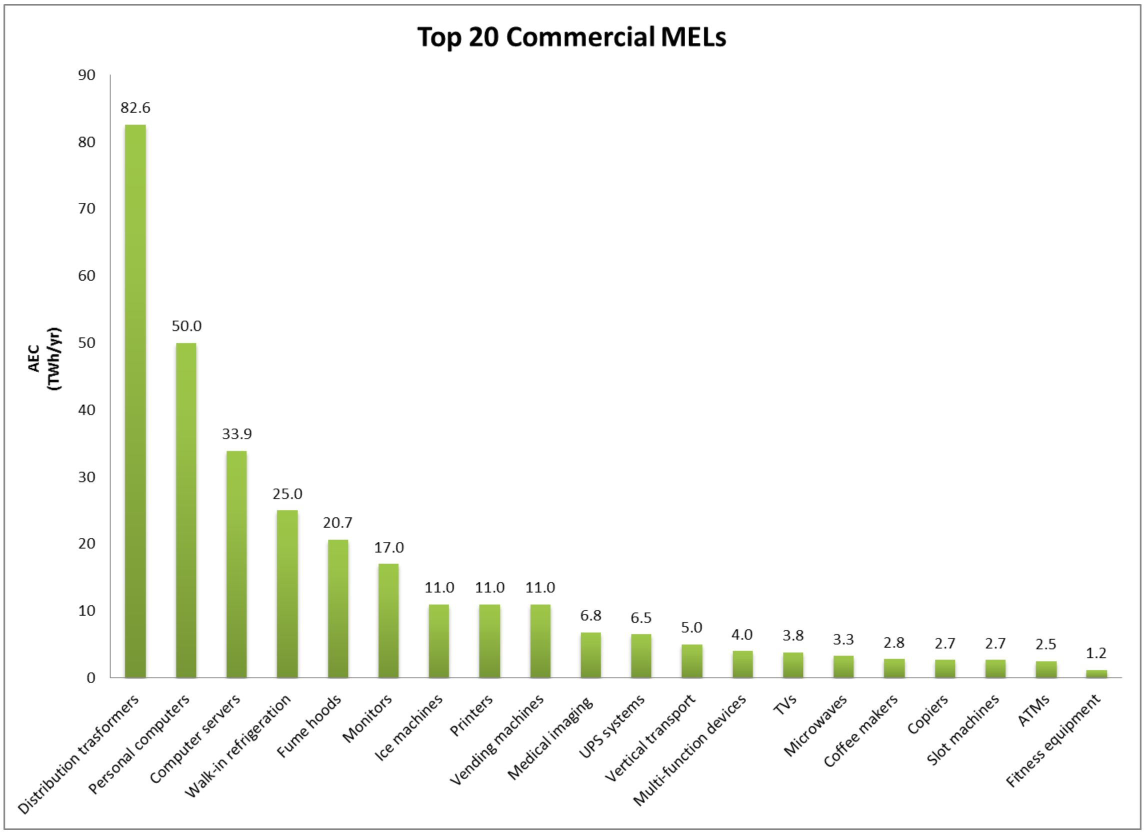
Figure 21: Commercial MELs by Category



Source: McKenney et al. 2010

We have aggregated and analyzed the results of multiple studies to arrive at the list of the largest commercial MELs by overall energy use. Figure 22 depicts AEC values of the top 20. Out of these, given our definition, we do not discuss commercial refrigeration and refrigerators in detail; we have also left out those products that have limited data sources (see Table A-2 for detailed AEC, UEC, installed base and data quality for commercial MELs). The following section has a write up on the top ten excluding these.

Figure 22: Top Commercial MELs on the Basis of Annual Energy Consumption[20]

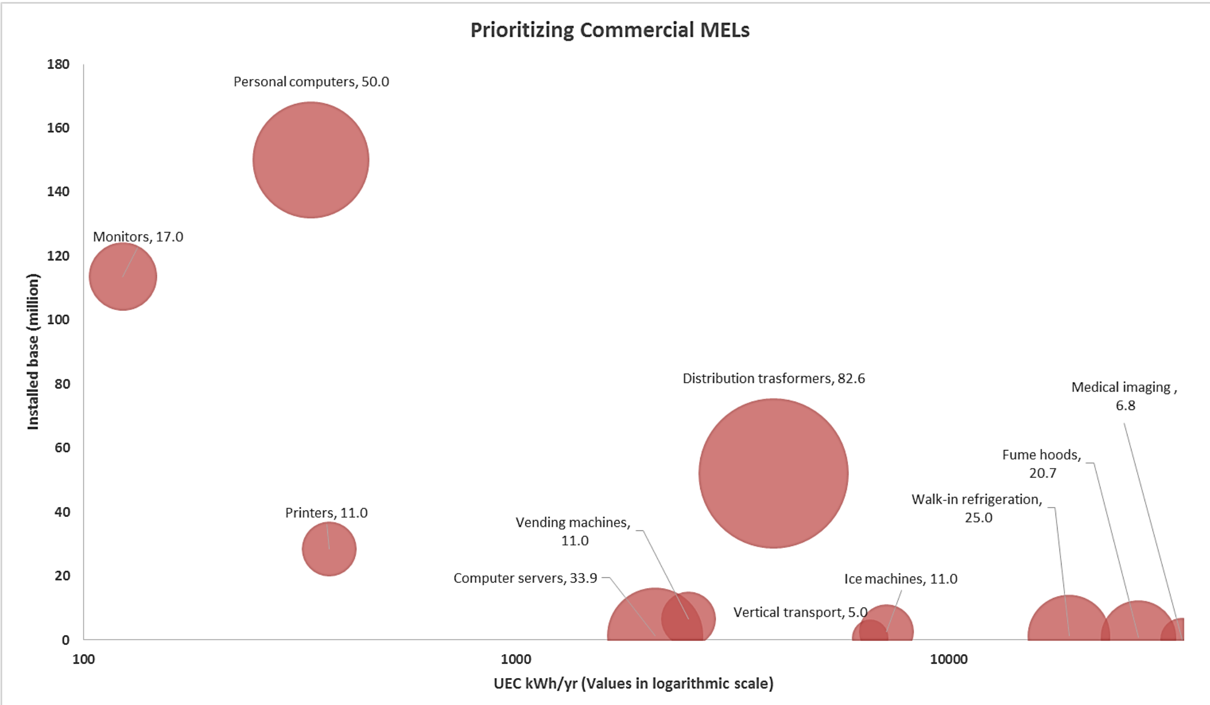


Source: ACEEE analysis

For the highest energy consuming commercial MELs, we depict the three dimensions of unit energy, annual energy and installed base graphically in Figure 23. The size of the bubble represents AEC in TWh/year.

[20] Some other key MELs, excluded from our scope, are Waste-water treatment (AEC 47 TWh/year); Central refrigeration (19 TWh/year); Mobile phone towers (4.4 TWh/year) as data availability for these is 'Low' (see Appendix B)

Figure 23. 3-D Positioning of Commercial MELs



Note: Size of the bubble represents AEC in TWh/year (as given in the data labels)
Sources: ACEEE analysis, data from multiple sources

Distribution Transformers

Distribution transformers are devices that transform high voltage (4-35 kilovolts) electricity in utility power distribution lines to lower secondary voltages (120-480 volts) as is needed by the most common electric devices. There are two basic types of distribution transformers, as defined by their insulation: liquid-immersed or dry-type. Utilities generally own and operate the liquid immersed type, while low-voltage dry-type transformers (LVDT) are generally used inside buildings and owned by building owners (ASAP 2012).

Energy 'used' by distribution transformers is actually energy lost during repeated cycles of operation. There is a constant core loss because of being continuously energized and ready to serve a needed load. In addition, there is winding loss associated with temperature and the average load on transformers, which is expressed in terms of percentage of transformer capacity (McKenney et al. 2010). This energy loss comes from inefficiencies in distribution transformers that are on the customer side of the electric meter.

STANDARDS

Federal Standards	Standard for low-voltage dry type transformers released in April 2013
ENERGY STAR	Not Covered
Other	The National Electrical Manufacturers Association (NEMA) has developed and published the voluntary industry standard, test method and labeling standard for transformers.

National standards for low-voltage dry type transformers have been in effect since 2007 and were revised recently in April 2013. These standards stipulate minimum efficiency levels by voltage and indicate reduction in losses by 20% over the previous standard.

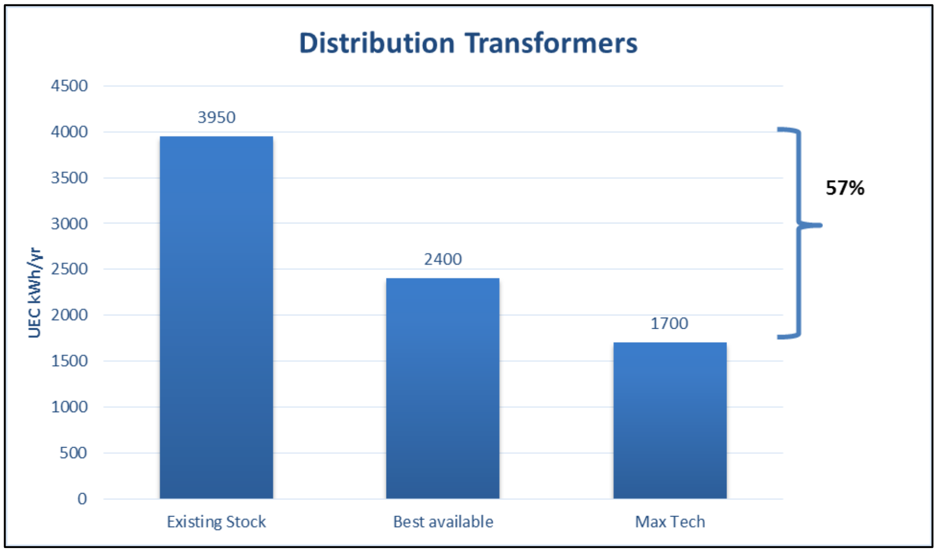
ENERGY SAVINGS

Distribution transformers have a high efficiency typically ranging from 97% to 99.5% (McKenney et al. 2010). However, since all electricity passes through one or more distribution transformers, even a slight improvement in efficiency has a significant commutative effect on energy savings. Changes to transformer design, core or winding material, and type and amount of insulation in the transformer can affect energy losses (CEE 2011). A 2012 ASAP/ACEEE report (Lowenberger et al. 2012) analyzed the standard levels that represent average energy savings (i.e., reduction in losses) of about 42% for low-voltage dry-type (the most cost effective level using silicon steel core material and conventionally available manufacturing techniques). Other possible efficiency suggestions come from an LBNL study (Desroches and Garbesi 2011) on best-on-market technology:

- Hexaformer[21] distribution transformers utilize an atypical geometry that can reduce losses by 30% (consistent with the annual energy consumption values for the "best-on-market" case)
- Coupling hexaformer transformers with an intelligent control system, and replacing a single large transformer with several smaller ones, can reduce losses by approximately 50%
- Amorphous core materials offer the potential to reduce energy losses significantly

[21] http://www.hexaformer.com/Home.htm

Figure 24: Energy Saving Potential

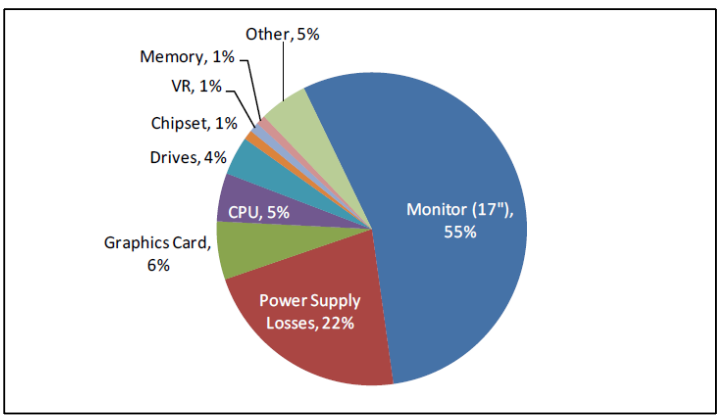


Data Source: Desroches and Garbesi 2011

Personal Computers[22]

Personal computers, either in the form of desktops or notebooks, have an installed base of over 120 million in the commercial sector in addition to 138 million in residences. They are the most ubiquitous commercial energy load in our study and are employed in diverse work environments across all building types.

Figure 25: Estimated Power Budget for Personal Computers



Source: McKenney et al. 2010 based on Intel 2003

[22] Note: Also refer to the discussion of PCs in the residential sector

STANDARDS

Federal Standards	Not covered
ENERGY STAR	Version 5.2 since July 2009
Other	Other major environmental footprint reduction programs, such as EPEAT, are applicable to computers and base the energy portion of their rating criteria on ENERGY STAR standards (Zogg et al. 2009).

ENERGY SAVINGS

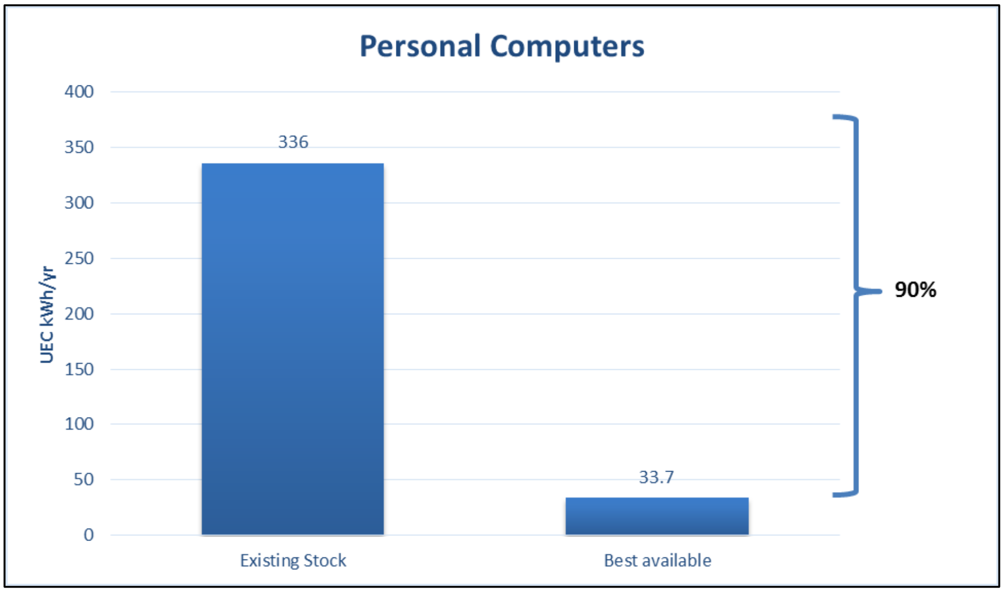
- Almost all PCs possess power management[23] with many having power management factory enabled. However, the use of power management is more widespread in notebooks than in desktop computers.
- At the microchip level there is potential for more efficient design and operation — such as consolidating activity in high-use circuits and blocking idle circuits,[24] as is used in certain smart phones where conserving battery power is given more importance (Desroches and Garbesi 2011).

As shown in Figure 26, there is an energy saving potential of 90% of annual UEC by replacing the existing stock with the best products in the market.

[23] A discussion of different power modes from (Bensch et al. 2010) is relevant here: "*Sleep* and *hibernate* are two different power management options available on most computers. *Sleep* retains data in the volatile memory, which allows the computer to go to sleep and reawaken very quickly—usually within seconds. However, if power to the computer is interrupted, unsaved files will be lost. *Hibernate* saves the existing session to the hard drive, thus eliminating the risk of lost data. However, recovering from *hibernate* takes longer—generally a minute or so. (Some systems support a hybrid *sleep/hibernate* setting that provides both the fast re-start of *sleep* with the non-volatility of *hibernate*.) In terms of electricity consumption, while *hibernate* always reduces electricity consumption to near zero, savings from *sleep* mode can vary: newer computers draw only a few watts when asleep, but power consumption for older computers may be reduced only slightly in *sleep* mode."

[24] A recent example of a system on a chip (SoC) targeted for handheld devices such as smartphones (where battery life is a prime concern) uses 19 different controlled power domains to optimize power consumption. Adding the isolation and control circuits reduced the chip standby power by 50x compared to the previous generation SoC (Desroches and Garbesi 2011).

Figure 26: Energy Saving Potential

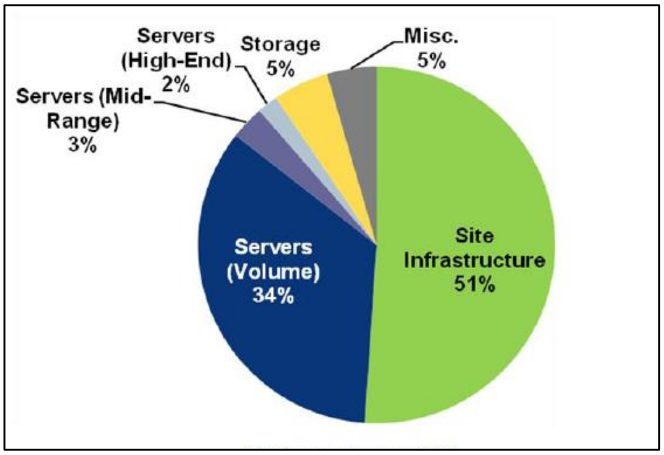


Data Sources
Current stock: this study
Best available: TopTen USA (www.toptenusa.org)

Computer Servers

In this section we cover both data center servers and smaller but numerous computer servers employed in office buildings. Servers are computers used to store and process data, and transmit it to other computers connected via a network. Servers may have their own dedicated infrastructure called data centers or may be part of a building that supports other functions. While servers in data centers constitute a very large component of commercial energy consumption in the United States, little detailed information is available on their characteristics (McKenney et al. 2010). To a certain extent, this is due to a wide range of data center configurations used by different companies. For example, for search indexing, advertisement and search result serving, and 'cloud' based application companies generally utilize hundreds of thousands of "volume servers." On the other end of the spectrum are high intensity processing applications that require large, high-end servers which can consume as much as 100 times as much power as a volume server (Koomey 2007). Each data center may contain more than 45,000 servers (Data Center 2009) and require 10 MW power to run.

Figure 27: Breakdown of Data Center Energy Use



Source: Koomey 2007; Zogg et al. 2009

STANDARDS

Federal Standards	Currently not covered
ENERGY STAR	EPA released Version 1.0 of the Computer Server specification in 2009 and is currently revising this to Version 2.0 which is expected to be published soon

Volume servers, such as the ones shown below, account for the most energy waste (Peters et al. 2010) and have been the target of initial ENERGY STAR efficiency efforts.

Figure 28: Scope of ENERGY STAR V 2.0 for Computer Servers

Source: EPA Energy Star[25]

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25 http://www.energystar.gov/products/specs/sites/products/files/Computer%20Servers%20Version%202%200%20Kickoff%20Webinar.pdf

ENERGY SAVINGS

Energy savings can be realized both by cutting down on non-computing energy like HVAC and lighting and by making each device more efficient.

- Servers, unlike PCs, do not use power management to reduce energy consumption during periods of reduced usage. However, energy savings potential exists in powering down a significant number of servers based on computation load, particularly during nights and weekends when workloads decrease. Strategies that power down certain server hardware components (such a hard drives) or scale server microprocessors operating voltage/clock frequency in response to server demand can reduce energy consumption by servers in many scenarios. These strategies, however, would be most beneficial in servers exhibiting large variations in load and might not be appropriate for servers that run applications that continuously process data (McKenney et al. 2010).
- While efficiency measures at the single device level may be commercially viable, all solutions must be fully integrated in the network design to optimize and fully capture their collective energy efficiency potential. This is especially relevant for data center designs, where different design considerations (e.g., power circuit design, waste heat management, HVAC system integration, and software solutions) dynamically influence how they are implemented.
- Furthermore, a LAN-level management of end-use devices (e.g., PCs) may improve the enabling rate or after-hour turn-off rate of these devices (Zogg et al. 2009).
- Blade servers have a modular and highly compact design, which minimizes physical space and reduces energy use (Network World 2013). Blade servers are gaining popularity, especially for small businesses (Peters et al. 2010).
- Other suggestions for improving Power Usage Effectiveness (PUE)[26] of data centers is by encouraging the decommissioning of older, less efficient servers and increasing the use of virtualization software (Peters et al. 2010). Virtualization reduces the number of physical servers by separating the software from the underlying hardware and thus lowers the rate of energy consumption (Laitner and Ehrhardt-Martinez 2008).

Walk-in Refrigeration

Walk-in refrigeration refers to large capacity units that are used for short-term storage of perishable goods before shelving or prior to food preparation. There are estimated to be 1.3 million units installed across the nation (McKenney et al. 2010). Walk-ins are used primarily in the food industry. DOE differentiates between walk-in coolers that operate between 32°F and 55°F, and walk-in freezers that operate below 32°F. In food sales, one common configuration has display cases that face outwards. These combination units help storeowners with little floor space to make good use of their square footage by combining refrigeration units together. Additionally, it reduces shelf-stocking time since all stocking is done from the rear. Though it

[26] PUE is defined as the ratio of total energy consumption to energy consumption used for actual computing. For example if a data center uses 6 MW out of which 2 MW is for space conditioning and lighting, then the PUE is 6/4 or 1.5.

can be an efficient use of the area, the loads can fluctuate more frequently as customers open display doors on an irregular and potentially frequent basis (McKenney et al. 2010).

STANDARDS

Federal Standards	In effect since 2009	An update to the standard is currently under review with DOE
ENERGY STAR	Not covered	

The federal standard includes prescriptive requirements for enclosure insulation levels, automatic door closure, and motor and light efficiency. An update to the standard is currently under review with DOE and is scheduled for completion later this year (Lowenberger et al. 2012).

ENERGY SAVINGS

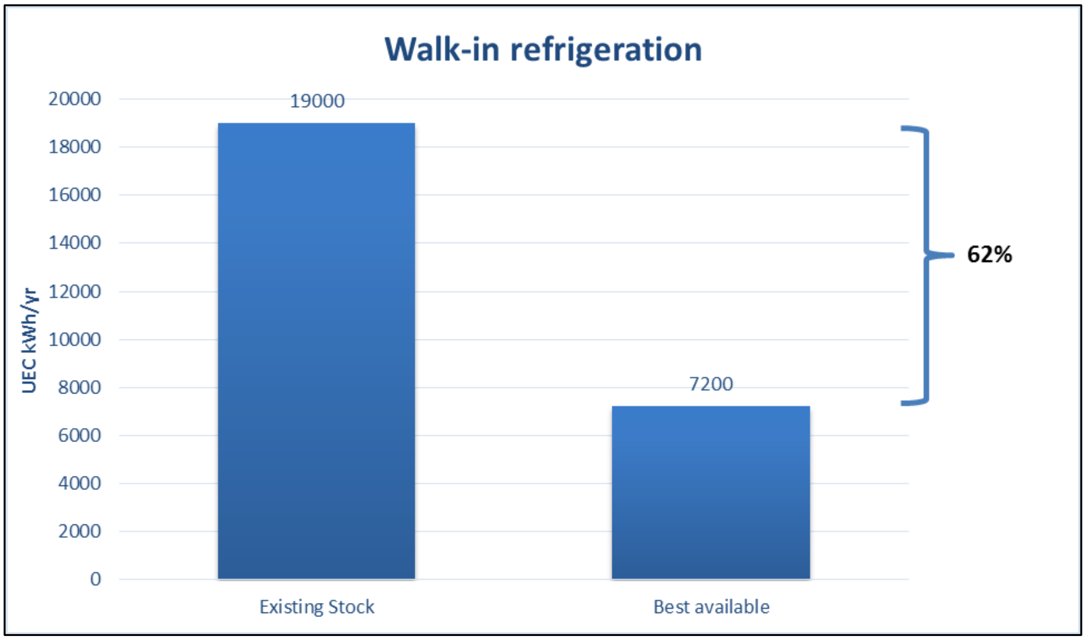
Some of the energy savings measures are:

- ECM[27] motor control: installing a control to reduce the speed or to turn off the evaporator fan motors when there is no call for cooling. Generally, the fan runs continuously in freezers (except during defrost cycle).
- Economizer cooling by utilizing cold outdoor air in northern climates to reduce cooling load, ADL estimates that compressor electricity can be reduced by up to 26% (ADL 1996).
- Floating head pressure: a control that allows the compressor to respond as outdoor temperature go up and down instead of responding to 'fixed' high and low pressure set points
- Using high efficiency lighting and fans, and advanced defrost and anti-sweat systems(ADL 1996).

TIAX estimates an energy savings potential of over 60% over the current stock by utilizing these technologies (Figure 29).

[27] Electronically Commutated Motor is a high efficiency programmable DC motor

Figure 29: Energy Saving Potential



Data Source: McKenney et al. 2010

Fume Hoods

Fume hoods are local ventilation chambers found predominantly in laboratory environments and are used to protect workers from exposure to gases, fumes and small particles that could be generated from the substances that are being handled or stored (McKenney et al. 2010). There are approximately 150,000 laboratories in the United States and estimates of installed base of fume hoods range between half to one million. However, both TIAX (McKenney et al. 2010) and LBNL (Mills and Sartor 2006) have assumed a conservative value of 750,000 units. Due to their large power draw and predominantly 24-hour usage, fume hoods are one of the biggest energy consumers of any laboratory equipment. Fume hood energy use is the product of a number of support systems, including: supply and exhaust fans, space-cooling energy, space-heating energy, and (in some cases) humidification or de-humidification and terminal reheat (Mills and Sartor 2006).

STANDARDS

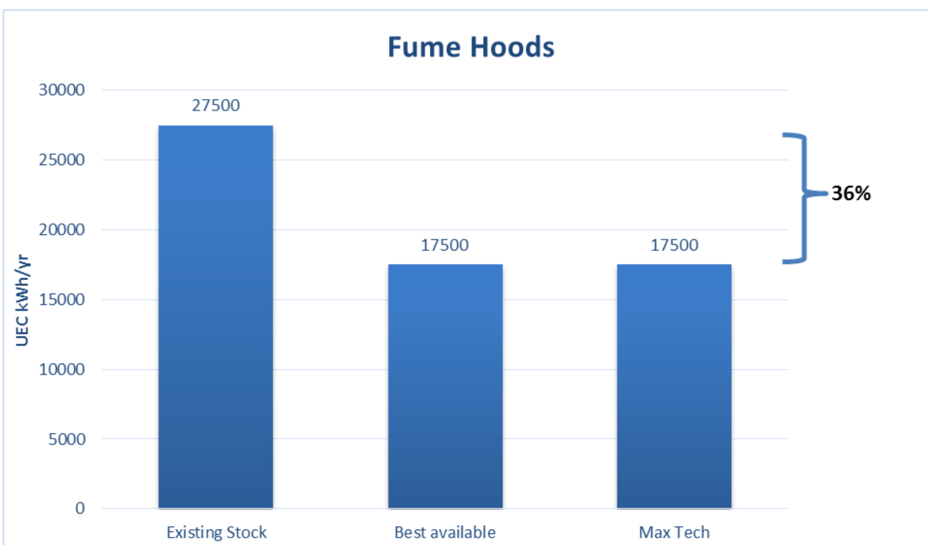
Federal Standards	Currently not covered	DOE has issued a proposed determination of coverage signaling their intent to begin a rulemaking[28]
ENERGY STAR	Not covered	

ENERGY SAVINGS

According to an LBNL study (Mills and Sartor 2006), an estimated 36% energy reduction can be achieved for each fume hood through a variety of methods, including:

- Use of a combination of dampers, variable speed ventilation, and digital controls to vary air volume while maintaining constant face velocity
- Restriction of the hood's face opening area while maintaining a constant airflow
- Introduction of tempered outdoor air near the face of the hood (space conditioning savings)
- Use of advanced hood designs to contain fumes and exhaust them from the hood.

Figure 30: Energy Saving Potential



Data Source: Desroches and Garbesi 2011

[28] http://www.appliance-standards.org/product/fans-blowers-and-fume-hoods

Monitors

Refer to the discussion in the residential section of this report.

Ice Machines

Commercial automatic ice makers are common in lodgings, healthcare and educational buildings. TIAX estimates[29] that there are about 2.6 million ice machines installed in the United States. More than 80 percent of ice machines sold in the U.S. make cube ice[30]. The rest produce flakes, crushed ice or nuggets. DOE standards categorize ice machines according to the type of the condenser into three main categories- air-cooled remote condensing units (RCUs), and water-cooled or air-cooled self-contained units (SCUs) and ice making heads (IMHs). Water-cooled systems generally use less energy than air-cooled ones (McKenney et al. 2010).

STANDARDS

Federal Standards	DOE standards for ice makers become effective in January 2010
ENERGY STAR	ENERGY STAR Version 2.0 effective as of February 2013

Federal standards for ice makers became effective in 2010. The standards cover maximum energy use and maximum condenser water use of cube ice machines with harvest rates between 50 and 2,500 lbs of ice per day. They do not apply to flake or nugget ice machines. Latest ENERGY STAR specifications cover air-cooled batch-type and continuous-type automatic commercial ice machines. These ENERGY STAR ice makers, especially RCU and IMH configurations are on average 10%-15% more energy efficient and 23% more water-efficient than standard models.

ENERGY SAVINGS

- Heat of the inlet water can be used to aid ice harvesting, thereby also helping to pre-chill the water.
- ECM condenser fan motors (see Walk-in Refrigeration) are more efficient that shaded pole motors that are commonly used.
- Using high efficiency compressors and better insulation can further cut down energy use.
- Early retirement of older ice machines and replacement with larger capacity ENERGY STAR models has the potential for demand shifting as well as efficiency gains (Fisher et al. 2012).

Although the annual energy consumption of icemakers varies with the size, type and harvest rate of the unit, estimates such as those shown in Figure 31, suggest average energy savings of about 30% are available in the best models today.

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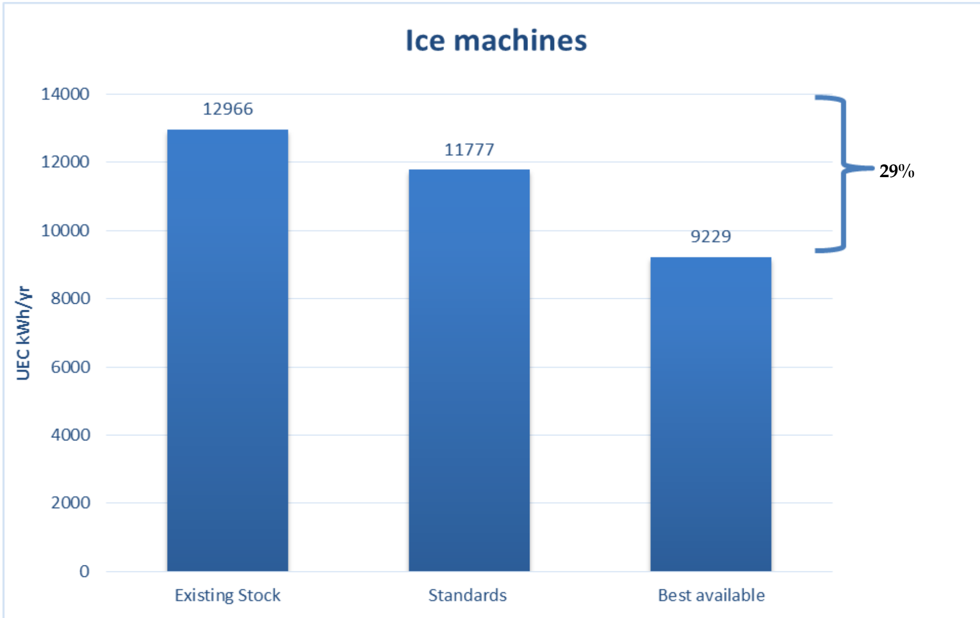
[29] TIAX projected this from a base data of 1991, further research is needed to corroborate with current stock.
[30] http://www.esource.com/escrc/0013000000DP22YAAT/BEA1/PA/PA_Refrigeration/PA-31

Figure 31: Energy Saving Potential



Data Sources: DOE PTSD, EPA Energy Star[31]

Printers

Office equipment is present in almost all work environments and is a sizeable load in office, education and healthcare buildings. This category generally includes printers, scanners, copiers, fax machines, multi-function devices, often computers and sometimes servers. Out of these, printers have a high installed base and relatively high standby power draw of up to 77W (McKenney et al. 2010) and account for the highest AEC (excluding computers and servers). The vast majority of printers in commercial buildings are laser printers accounting for about 75% of printers, the rest are primarily inkjet (McKenney et al. 2010).

STANDARDS

Federal Standards	Currently not covered
ENERGY STAR	The current ENERGY STAR specification Version 1.1 for imaging equipment became effective in July 2009.

[31] http://www.energystar.gov/index.cfm?c=new_specs.ice_machines

Other	Other major environmental footprint reduction programs, such as EPEAT, are applicable to computers and base the energy portion of their rating criteria on ENERGY STAR standards (Zogg et al. 2009).

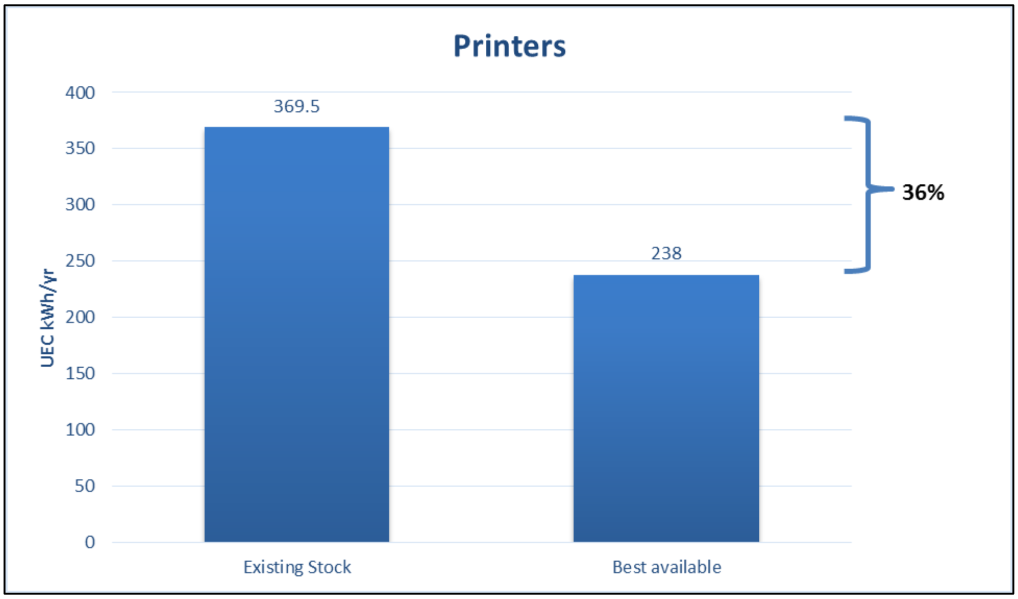
The specification uses the typical energy consumption as a metric that sets limits for the total amount of energy the device can use in a set time. Four of the top five inkjet printer manufacturers and all five of the top laser printer manufacturers make at least one ENERGY STAR-qualified printer (Peters et al. 2010).

ENERGY SAVINGS

- Printers are often used infrequently and rarely without being connected to a computer. Thus, aggressive power management settings are essential for energy savings from printers. These settings can be enabled centrally through network software that works across a range of interconnected devices.
- Advances in fuser rolls and toner materials could potentially reduce total laser printer as well as copier energy consumption by 50% (McKenney et al. 2010).
- Other measures include installing smart power strips or digital timers to turn off equipment during non-business hours and encouraging staff to minimize printing (NBI 2012).
- Opting for Managed Printing Services (that is imaging services provided by a third party) may serve to reduce energy use in some office contexts.

EPA estimates about 36% reduction in annual energy consumption by upgrading to the most efficient models in the market (Figure 32).

Figure 32: Energy Saving Potential



Data Source: EPA ENERGY STAR [32]

Vending Machines

As per TIAX estimates (McKenney et al. 2010) there are approximately 6.7 million vending machines in the United States, of which only 35% are refrigerated. These two million refrigerated units however, account for 74% of the AEC of the vending machines in the United States. Energy consumption in the refrigerated machines is primarily for keeping the products cool at all times. This typically comprises 65–76% of the total energy consumption of the machine, while lighting accounts for another 5–20%. Some closed-front vending machines are used outdoors and have higher energy consumption for refrigeration.

STANDARDS

Federal Standards	DOE standards for refrigerated beverage vending machines become effective in August 2012
ENERGY STAR	ENERGY STAR Specification Version 3.0 finalized in June 2012.
Other	The National Electrical Manufacturers Association (NEMA) has developed and published the voluntary industry standard, test method and labeling standard for transformers.

DOE standard sets a limit on the maximum daily energy consumption (as a function of volume) depending on whether the machine is fully cooled or zone cooled. In addition to meeting the 24-hour energy consumption requirements, the new ENERGY STAR specification requires all

[32] www.energystar.gov/ia/products/fap//Calc_office_eq.xls

qualifying models to come equipped with hard-wired controls and/or software capable of placing the machine into a low power mode during periods of extended inactivity.

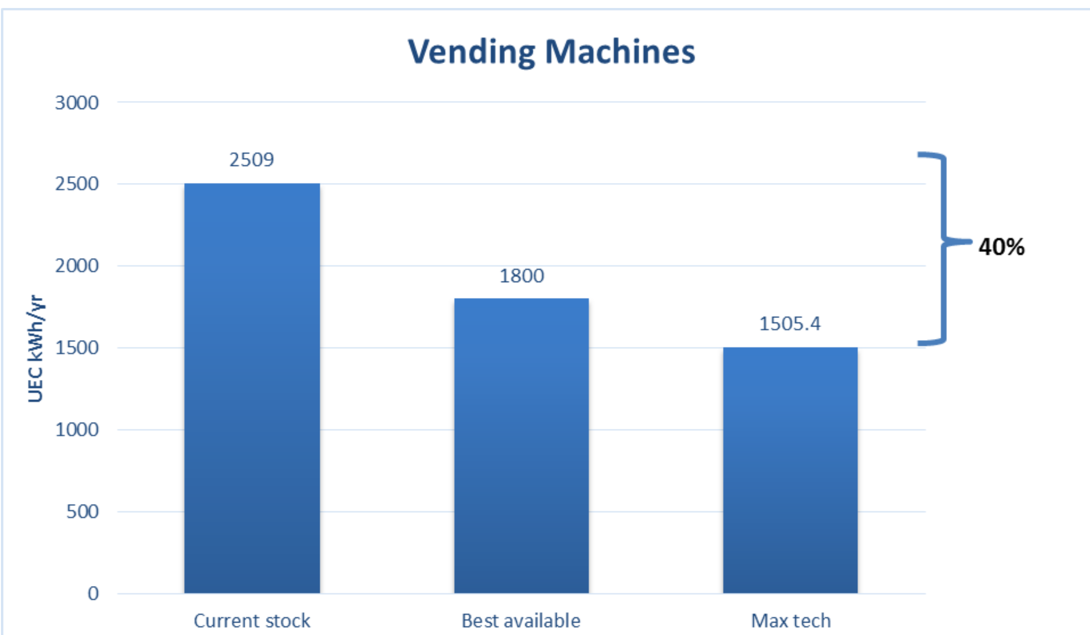
ENERGY SAVINGS

Since the use is intermittent, load management offers potential for energy savings beyond the ENERGY STAR specification.

- Using sensors to detect occupancy and to measure ambient temperatures can lead to savings by powering down the machine when there is no occupancy or when the ambient temperature is cold enough.
- Various load managers claim potential savings of upwards of 40% on refrigerated vending machines, and upwards of 50% on non-refrigerated machines.[33]

ENERGY STAR rated vending machines are significantly more efficient than most of the older models (see 'Best available' in Figure 33). Further adoption of the best available technology can lead to savings of up to 40% of annual energy use.

Figure 33: Energy Saving Potential



Data Sources:
Best available: EPA ENERGY STAR[34]
Max Tech: (McKenney et al. 2010)

[33] http://www.vendingmiserstore.com/p2150/usat_vending_miser_master_unit_model_vm150.php
[34] See http://www.energystar.gov/ia/products/vending_machines/Vending_Machine_Webinar_Transcript.pdf

Medical Imaging

Healthcare facilities are among the most energy intensive commercial buildings in the United States (Singer and Tschudi 2009). TIAX hypothesizes that "there may be an installed base of over 30 million miscellaneous medical devices" in the country. Energy load profiles for most medical equipment are not well studied and we have restricted our analysis to medical imaging that includes magnetic resonance imaging (MRI), computerized tomography (CT) and X-ray equipment[35]. There are 170, 000 X-ray systems installed in the U.S. and the estimates of the AEC range from 0.7 (Zogg et al. 2009) to 4.7 (McKenney et al. 2010) TWh/year. Installed base of MRI machines is estimated to have increased by over 40% in just three years from 7000 in 2005 to 9400 in 2008 (Zogg et al. 2009). All three equipment have a very high power draw and are often left in standby mode when not in use. TIAX (2010) estimates the standby power draw of MRI machine as 14kW and even an off mode power draw as high as 7 kW. The energy consumption of MRI and CT equipment has grown considerably as more powerful technology provides better resolution and advanced diagnostics.

STANDARDS

Federal Standards	Currently not covered
ENERGY STAR	Currently not covered
Other	No state standards

Supported by California Energy Commission, Lawrence Berkeley National Lab has developed a tool for benchmarking and quantifying medical equipment energy use (Black et al. 2011).

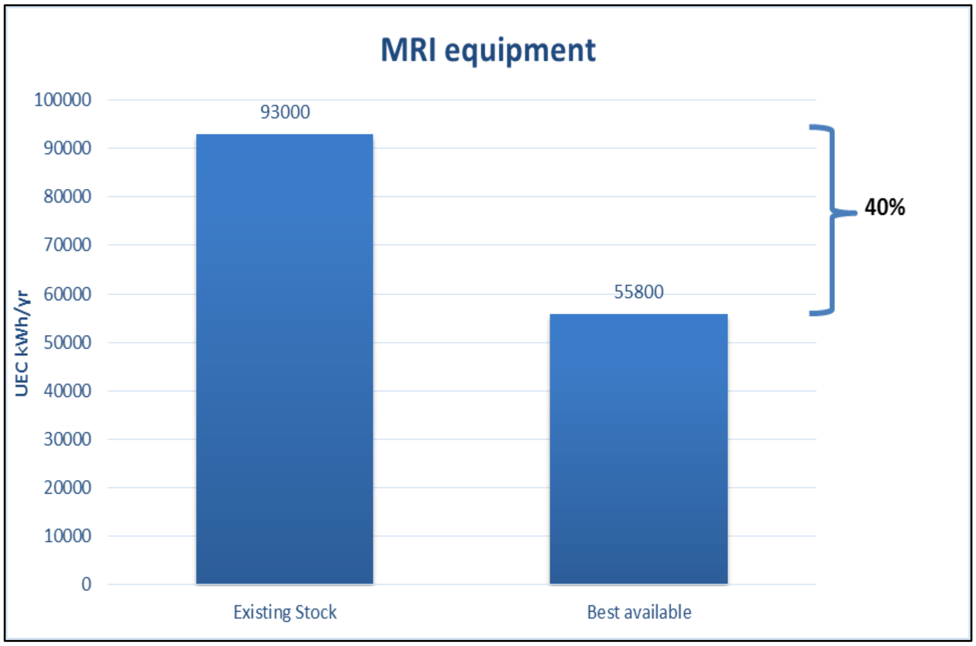
ENERGY SAVINGS

- Digital X-ray technology eliminates the need for film processing and uses less energy than conventional analog systems.
- Given the intermittent use of medical imaging services, efficient power management should offer substantial energy savings.
- Energy efficiency rating systems for medical equipment should help to create a market for more efficient products by providing the buyers with more information and giving manufacturers an incentive to differentiate (Singer and Tschudi 2009).

TIAX estimates about 40% savings in annual energy consumption from MRI machines (Figure 34).

35 Other medical imaging equipment like ultrasound, dental x-ray, mammography, and fluoroscopy equipment are not studied here

Figure 34: Energy Saving Potential



Data Source: McKenney et al. 2010

Vertical Transport

There are more than 700,000 elevators in the United States (Sachs 2005; Zogg et al. 2009). Most of these are in low-rise buildings (less than seven floors) since high-rise buildings are much fewer in number. Typically, elevators in low-rise buildings are hydraulically driven, those in mid-rise buildings have a geared traction, and those in high-rises (above 20 floors) use gear-less traction (McKenney et al. 2010). Elevators consume about 80% of the total vertical transport energy. Energy consumption in elevators is a function of many variables like elevator speed and payload, frequency of use, motor efficiency, friction losses and regenerative drives and some energy is also used by lighting and fan systems.

There are approximately 35,000 escalators in the United States (McKenney et al. 2010) and about 40% of them are in office buildings. An escalator typically uses one electric motor to power the gears and conveyor belt system. Efficiency of the escalator is thus dependent largely on the electric efficiency of the motor and the mechanical efficiency of the gear train.

STANDARDS

Federal Standards	Currently not covered
ENERGY STAR	Currently not covered
Other	The U.S. Green Buildings Council's (USGBC) Leadership in Energy and Environmental Design (LEED) program promotes the energy efficiency of elevators by giving a higher rating to facilities with optimized elevators (Zogg et al. 2009)

The Energy Policy Act of 1992 and the Energy Independence and Security Act of 2007 (EISA) established and revised federal motor efficiency performance standards for electric motors, including those used in escalators.

ENERGY SAVINGS

Elevators: Energy savings are possible in the motor and drive combinations.

- Variable-voltage, variable-frequency (VVVF) drives and gearless permanent magnet motors offer efficiency gains over typical AC induction motors or DC shunt field motors (Zogg et al. 2009).
- There is energy absorbed during acceleration that must be removed during deceleration (or braking). If this energy is not recovered, it is wasted as heat. Regenerative drive can recover excess braking energy from the elevator and feed it to the building's power grid. There are industry claims of recovering 25% of the total energy used by the elevator (KONE 2013).
- Use of efficient lighting and controls for fans, lights and signaling lights can provide additional savings (DOE 2011).

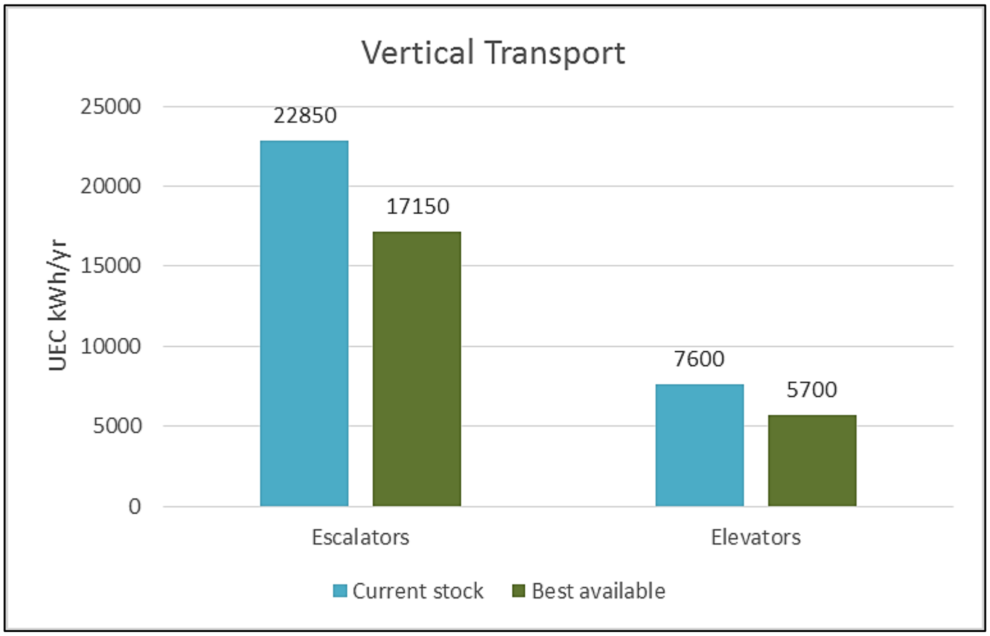
Escalators:

- Controls to turn off or slow down the escalator when inactive are employed in many places. Modern building codes such as ASHRAE 90.1 specifications also require the use of such controls in compliant buildings.

Motor efficiency controller is a technology that optimizes energy of AC induction motors that operate at a constant speed and are often lightly loaded. This can improve system efficiency of escalators (Zogg et al. 2009).

Overall, estimates suggest energy savings of about 25% are possible by upgrading existing escalators and elevators to the most efficient available (Figure 35).

Figure 35: Energy Saving Potential

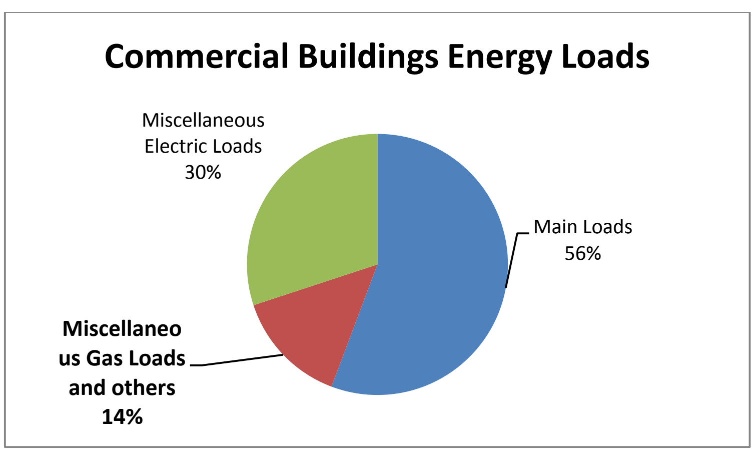


Data Source: Desroches and Garbesi 2011

GAS MELS

Miscellaneous gas loads may be as high as 14% of total commercial building energy use (Figure 36). Primarily due to its low cost, gas finds its way into many commercial applications including space and water heating, cooking, and laundry equipment as well as some residential applications such as outdoor lighting, outdoor grilles, and fireplaces

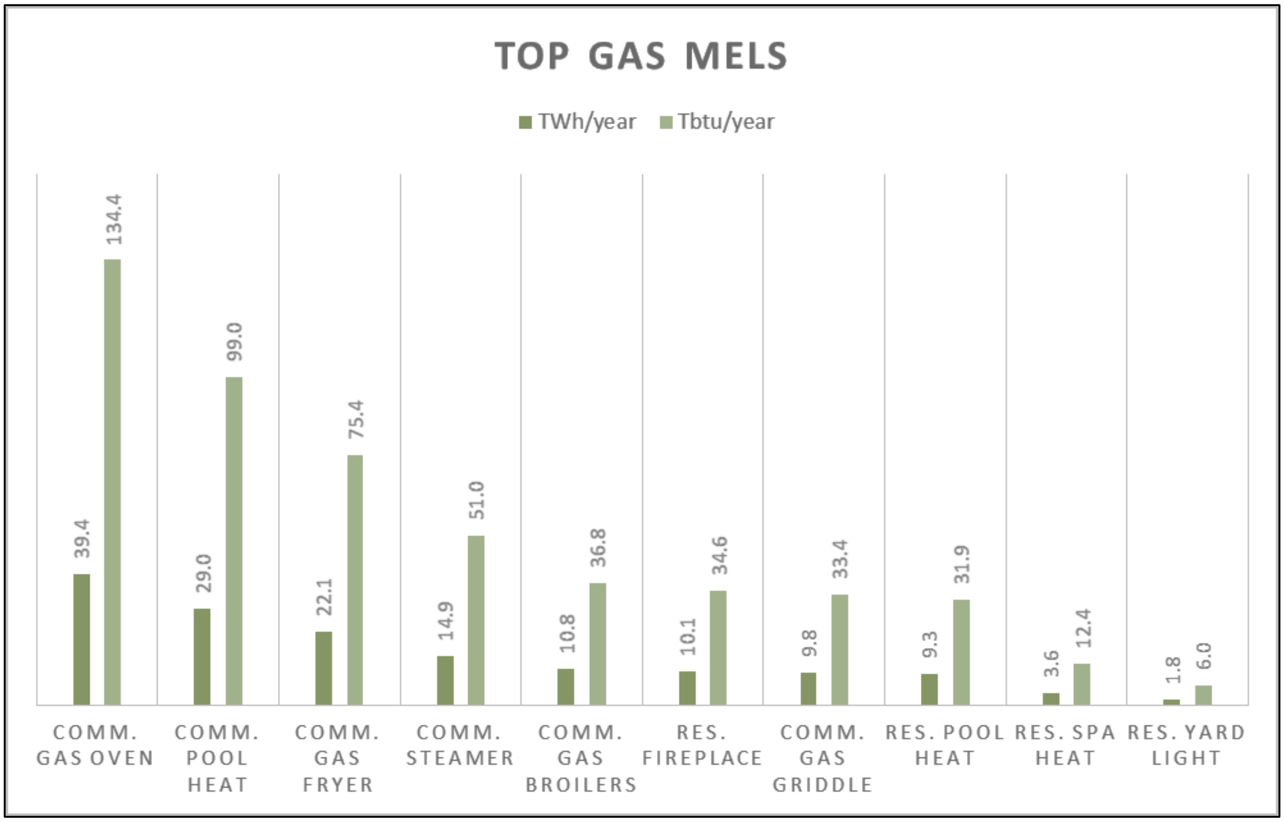
Figure 36: Composition of Commercial Building Energy Use



Source: McKenney et al. 2010

In keeping with our scope, we do not include residential cooking ovens, washers and dryers, and dishwashers as MELs because they are treated as 'major end-uses'. We have included commercial kitchen equipment in line with our treatment of other business process loads like walk-in refrigeration discussed earlier. A ranking of major gas MELs is given in Figure 37 and more details are available in Table A-3.

Figure 37: Top Gas MELs (Residential and Commercial) on the Basis of Annual Energy Consumption



Source: ACEEE Analysis, (Zogg et al. 2009), RECS 2009

Notes: 1. Gas loads are usually measured in 'therms' or 'MMBtu'; we have converted to TWh in this graph to provide a comparison with other electric MELs discussed before. Conversion: 1Quad = 1 billion MBtu = 293 TWh

2. We have excluded from our analysis commercial multi load washers (AEC = 69.1 TWh/year) and commercial dishwashers (AEC =12.6 TWh/year)

Commercial Gas Cooking Equipment

This category includes commercial gas ovens, fryers, griddles, steamers and broilers. Together these appliances consume more energy than all 120 million personal computers in commercial buildings. Many cooking appliances are often turned on in the morning, and then left in an idle state for most of the day so that they are ready to quickly process orders. This is because most of these appliances take as long as 15 to 25 minutes to preheat which is precious time during peak demand. Most energy consumed in a fryer is to heat and maintain oil at the desired temperature. Pilot lights, sensors, timers and temperature controls consume additional energy.

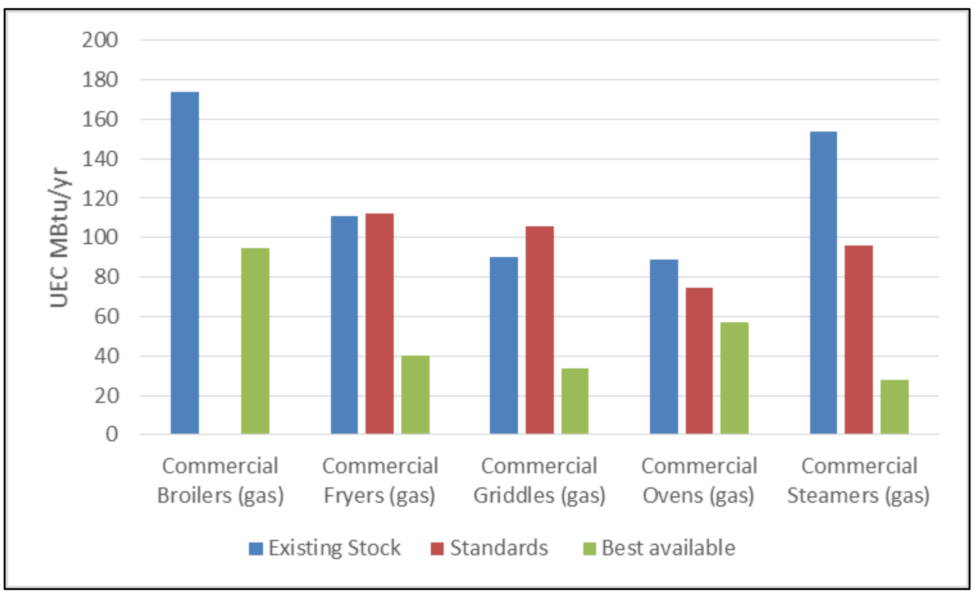
STANDARDS

There are no federal standards currently for any of the gas cooking equipment discussed above. California has several regulatory programs that cover these products. In California, any gas-cooking appliance that has an electric cord cannot have a standing pilot light. ENERGY STAR has specifications for fryers, steamers, griddles and ovens, although the penetration of ENERGY STAR products is reportedly not very high (Zogg et al. 2009).

ENERGY SAVINGS

Insulation at major heat loss locations in cooking appliances can reduce standby heat loses by 25% in both electric and gas powered models. Insulation is usually not used on commercial fryer, griddles, broilers, and ranges for safety reasons. Most steamers and ovens make use of insulation as well as a few, high-end appliances and ENERGY STAR models. Electric ignition can replace the need for a standing pilot light reducing gas use in commercial cooking appliances. Standing pilot lights dominate gas appliances in the commercial cooking industry. Pilot lights burn gas 24 hours a day; they waste gas during downtime, which could be up to 14 hours a day depending on the appliance and usage patterns. In early 2009, DOE established standards requiring electric ignition in new gas cook tops and ovens for the residential market eliminating standing pilot lights. However, there is little discussion on extending this to the commercial sector (Zogg et al. 2009). Figure 38 summarizes the energy savings available by switching to the best available units as estimated by Zogg et al. (2009).

Figure 38: Energy Saving Potential



Data Source: Zogg et al. 2009

Commercial Pool Heaters

The most recent and comprehensive review of energy use and savings potential for commercial size pool heaters (500,000 to 5 million Btu/hr) was carried out by Navigant (Zogg et al. 2009). Navigant estimates a population of about 55,000 commercial pools, principally in hotels and motels, and school/university facilities. The estimate is probably 'soft,' for example omitting neighborhood membership pools.

Analyses assume that almost all commercial pool heaters are gas-fired, although there are some heat pump water heater units — particularly also used to provide dehumidification for indoor pools. Navigant provides the following estimates of annual energy consumption:

Table 4. Commercial Pool Heaters Energy Use

Location	# of Pools	Typical Heater Capacity, Btu/hr	Heating Hours per Year	Unit Energy Consumption, MMBtu/yr	Total Energy Consumption (MMBtu/yr
Indoor	43,000	500,000	3600	1800	77,000,000
Outdoor	12,000	1,500,000	1200	2100	22,000,000
Total	55,000				99,000,000

Source: Zogg et al. 2009

Thus, the 'fleet' annual energy use is about 0.01 Quads (99 TBtu) or 29 TWh.

STANDARDS

There are no federal minimum energy standards for commercial pool heaters >1 million Btu/hr. The residential pool heaters standard (82% Thermal Efficiency (T.E.) as of April 16, 2013) also covers small commercial units. It appears that available commercial units of all sizes meet this standard (Zogg et al. 2009).

ENERGY SAVINGS

Standard efficiency commercial pool heaters are typically 82% T.E.; high efficiency ones are typically 85% T.E. (Zogg et al. 2009) , and there are few condensing units on the market. Because there is a 55–75% price premium for higher thermal efficiency, other energy savings opportunities warrant close attention.

Table 5: Summary of Pool Heating Equipment Technical Potential Energy Savings

Technology	Potential Energy Savings (%)	Total Energy Savings Technical Potential (MMBtu/yr)
Pool covers	60%	59,000,000
Condensing pool heaters	15%	15,000,000
Heat pump pool heaters	45%	45,000,000
Solar pool heaters	60%	61,000,000

- Because evaporation is the dominant heat loss mechanism for pools, the least expensive option, pool covers, has the highest energy saving potential.
- Where feasible, solar pool heaters can be very cost effective, too. Both of these can be required by building codes.
- Combined heating and dehumidification is an important opportunity, because reducing humidity can extend the life of the enclosure where condensation is a problem.
- There are also some other ventilation strategies, too, such as capturing the saturated air layer just above the water surface, and dehumidifying that only.

Residential Pool Heaters

Approximately 1.1 million gas-fired pool heaters are installed for residences in the United States (EIA 2009) , implying that about 1% of residences have swimming pools of some size. DOE estimates that 1 million of these have pool heaters to extend the swimming season by boosting temperatures in spring and fall, when solar insolation is low. Eighty percent are natural gas-fired and 20% use propane (PTSD Table 7.4.1). We treat these interchangeably, following industry practice. Since shipments for 2006–2011 show an increasing trend from 309,000/yr to 357,000/yr (PTSD Table 3.2.20), we infer a very short life for these products (1 million installed/350,000 per year sold implies effective life less than three years). DOE considers this a minimum, with an average of 6 years. We have no explanation for the discrepancy, unless sales are rapidly increasing — doubtful in the context of the collapse of the residential real estate market.

We use the DOE estimate of 53.6 MMBtu/yr instead of the California RASS (KEMA-XENERGY et al. 2004) estimates of 22 or the MUD[36] estimate of 36; DOE's estimate is derived from RECS (PTSD Table 7.4.4.). DOE estimates savings from replacing the standing pilot with intermittent ignition as comparable to those from better heat exchangers, and this would not affect amenity at all — it is a simple add-on product change with many technology options. Functionally, eliminating the standing pilot on gas appliances is the equivalent of regulating stand-by power for electric equipment

STANDARDS

DOE's baseline is 78% T.E., with condensing at 90% T.E. and the "MaxTech" at 95% T.E. (PTSD Table 7.4.4). From April 16, 2013 forward, the minimum energy efficiency standard will be T.E. 82% (10 CFR Ch.II Subpart C, §430.31)[37].

California has established additional standards for oil-fired pool heaters (78% T.E.) and electric pool heaters (3.5 average coefficient of performance, COP, which requires heat pump or solar hybrid technology).

ENERGY SAVINGS

The 2013 PTSD suggests that the market now offers a wide range of efficiencies for the covered capacities between about 50,000 and 1 million Btu/hr (Figure 3.2.19), although there is apparently only one condensing model (T.E. ≥ 0.90%). The 2013 standard at T.E. 0.82 will be above half of the roughly 200 models that conformed to the 0.78% standard in 2009. Pool heaters are subject to very corrosive conditions from chlorinated water, and frequent chlorine-contaminated combustion air. As noted above, the service life averages about 3 years.

The 2009 PTSD suggests that intermittent ignition would become standard at 83% T.E. and above. This is a modest-cost improvement.[38] All other technology options examined are likely to be much more expensive, given the need for corrosion-resistant materials for improved (larger)

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[36] Metropolitan Utilities District: Annual gas use by appliance http://www.mudomaha.com/service/pdfs/gasappliancecosts.pdf
[37] The Preliminary Technical Support Document is available at http://www.eere.energy.gov/buildings/appliance_standards/residential/heatingproducts.html
38 The DOE data have an anomaly. Comparing PTSD Tables 5.13.9 and 5.13.10, the MPC (production cost) increase for electronic ignition is only $3 at lower efficiency levels, but about $20 at levels above T.E. 83. At .83 and above, power venting is specified, so we suspect that the price bump comes from attributing more elaborate controls to the ignition rather than the power venting.

heat exchangers, power-venting, sealed combustion, and condensing, although some might also reduce life cycle cost by extending the service life. A 50% first cost increment that reduces replacement intervals from 3 years to 6 years would be cost-effective at reasonable discount rates, for example. However, the route to that life extension involves stainless steel heat exchangers and fabrication that is more expensive. Moving to electronic ignition would save about 8% of annual unit gas energy use. We have no estimate of the fraction of units with intermittent ignition today, so we cannot calculate national energy savings.

We also note that there are large potential savings from alternative approaches that might cost less. These include pool covers, since evaporation is the major heat loss source for pools. They also include using solar water heaters and the use of more efficient pool pumps.

Residential Gas Fireplace Equipment

Fireplaces, originally intended for cooking and space heating, were designed to burn wood, with little regard for efficiency. Today, they are generally amenities that add a decorative element or supplement central heating systems, accounting for approximately 10.1 TWh/yr (34.6TBtu/yr) of gas use. We only treat *vented* systems.[39] Approximately ¾ of gas fireplaces are used strictly decoratively, while ¼ of gas fireplaces are used for heating. Decorative and heating appliances have different characteristics (no thermostats on decorative products, for example), and are built to different ANSI safety standards. Three-quarters of units shipped between 2004 and 2007 were "purely" decorative, the remainder were designed for heating (Houck 2010).

Energy use data on fireplaces are limited. DOE considers most vented gas fireplace products to be "Gas Room Direct Heating Equipment." If all of this equipment is fireplace equipment, and the median size is 30,000 Btu/hr, that would correspond to 700 hr/yr use on average. In contrast, the HPBA estimate is 75 hr/yr for heating products and 37 for decorative (Houck 2010). This disparity causes estimated annual gas use to range from 1.1 MMBtu/yr (decorative only) to 22 MMBtu/yr (all room direct heating equipment). DOE's estimated efficiency improvements through improved heat exchange might improve AFUE by 10–17% (PTSD Table 5.2.2, 5.7.9, 5.7.11).

DOE estimates savings from replacing the standing pilot with intermittent ignition as comparable to those from better heat exchangers, and this would not affect amenity at all — it is a simple add-on product change with many technology options. Functionally, eliminating the standing pilot on gas appliances is the equivalent of regulating stand-by power for electric equipment

STANDARDS

The trade association representing hearth products has litigated to prevent DOE from regulating the efficiency of decorative products. Hearth heating products are subject to AFUE minimum standards. Manufacturers argue that the principal value, even for heating products, is the warm, billowing flame and its radiant energy. It is difficult to increase AFUE without

[39] Unvented combustion devices lose no energy exporting combustion products to the outdoors, so they are inherently 100% efficient. They raise indoor air quality and safety concerns for some observers and are not treated here.

affecting amenity. The most recent rule sets standards by capacity, ranging from 61% to 68%, and eliminates standing pilots.[40]

Energy Savings

Regardless of the burn time assumed, intermittent ignition would save 1–7 MMBtu/yr per unit, depending on pilot size and whether it is assumed to burn 3 or 12 months/yr, regardless of need. This is the vast majority of decorative fireplace energy use, and 1/3 of the DOE estimate of annual gas energy use. Assuming an installed base of 4.8 million units (EIA 2009), this would save about 5–35 MMBtu/yr nationally, a large fraction of annual energy use by any accounting.

Estimated Savings from MELs

As we have discussed in preceding product descriptions, significant savings in annual energy consumption are possible from each of the product that we analyzed. Most often just switching to a more efficient product currently available in the market or adopting an already proven technology is all that is required to achieve these savings. Aggregated over the lifetime of these products the impact of accumulated energy savings is significant. There are studies that have tried to estimate the long-term potential of making MELs more efficient. We have not ventured to do that here. However, we underscore the point that even with current technology and current products there is a great opportunity to save enormous energy not just in the future but right now.

[40] "Energy Conservation Program: Energy Conservation Standards for Direct Heating Equipment." *Federal Register* / Vol. 76, No. 141 / Friday, July 22, 2011 / Proposed Rules 43941- 43953.

Table 6. Estimated Annual Savings from Key MELs

Electric MELs	Res. or Comm.	Current Stock (kWh/yr)	Standards (kWh/yr)	Best Available (kWh/yr)	Max Tech (kWh/yr)	Savings % (Best over Current Stock)	AEC Savings (TWh/yr)
TVs	R	213.3		62.7	24	89%	62.2
Distribution Transformers	C	3950		2400	1700	57%	47.1
Personal computers	R,C	336		33.7		90%	45.0
Ceiling fans	R	152.4	109.6	58.5	23.8	84%	23.6
Monitors	R, C	96.2		37.7		61%	18.2
Walk-in refrigeration	C	19000		7200		62%	15.5
STB	R	151.5			74.4	51%	14.2
Video game Consoles	R	115.1		15.3		87%	9.1
DVD/Blu-ray players	R	45		10		78%	8.1
Microwaves	R	121	94.7		86.1	29%	7.8
Fume hoods	C	27500		17500	17500	36%	6.9
Computer Servers	C	2100		1701		19%	6.4
Ice machines	C	12966	11777	9229		29%	4.9
Vending Machines	C	2509		1800	1505.4	40%	4.4
Printers	C	369.5		238		36%	3.9
Electric Spa	R	2500			1750	30%	2.6
MRI equipment	C	93000		55800		40%	2.5
Escalators	C	22850		17150		25%	1.3

Electric MELs	Res. or Comm.	Current Stock (kWh/yr)	Standards (kWh/yr)	Best Available (kWh/yr)	Max Tech (kWh/yr)	Savings % (Best over Current Stock)	AEC Savings (TWh/yr)
Elevators	C	7600		5700		25%	1.3
					Total Electric Savings	47%	**285.2**

Gas MELs	Current Stock (MMBtu/yr)	Standards	Best Available	Savings % (Best over Current Stock)	AEC Savings (TBtu/yr)
Commercial broilers	174		95	45%	16.7
Commercial fryers	110.9	112.2	40	64%	48.2
Commercial griddles	90.15	106	34	62%	20.8
Commercial ovens	89	74.6	57	36%	48.3
Commercial steamers	153.9	96.1	28	82%	41.7
Commercial pool heater	~2000			45%	45.0
			Total Gas Savings	43%	**220.8**

Our calculations suggest for electric MELs savings of 285 TWh are possible every year with full application of the highly efficient units and efficiency measures now on the market. This equals 47% of the total annual consumption of the top 20 residential and top 20 commercial MELs that we analyzed. To achieve all of these savings will require the full turnover of the current equipment stock. Hypothetically, if one were to extrapolate the percent savings to the entire base of MELs, 40 to 50% of 7.8 quads now used by MELS could be saved, or more than 3 quads every year. We also estimate 203 TBtu per year of savings from some of the gas loads that we analyzed which equals 43% of the total annual consumption of these loads. TIAX estimated an overall 35% (176 TWh/yr) energy savings potential through 2020 by replacing the current installed base with best-in-class devices. Our mix of products is slightly different and the energy consumption data is aggregated from multiple sources. However, the high savings potential given in various studies including the current report highlight the importance of focusing on MELs as a category.

Recommendations

Each miscellaneous product has its own unique energy use characteristics and hence may require tailor-made strategy for improving its efficiency. As a precursor to programmatic interventions, there is a need to understand the current energy profile and technological potential for improvement for each of them. While traditional efficiency targets like heating, cooling and insulating are approaching their technological limits, many of the MELs offer significant potential for efficiency improvements. Opportunities for efficiency are increasingly available not just at the product level but for the wider system as a whole. There is the advent of 'smart appliances' that communicate to the grid and hence self-power down in times of peak demand. In another instance of system-wide efficiency, the premise is that most of today's plug-in and wireless electronic equipment run on DC power. Therefore, for buildings that have photovoltaic or other DC on-site power generation systems, it is more efficient to directly use DC rather than convert it to AC for distribution throughout the building and then later convert it back to DC for use in individual equipment (Kaneda et al. 2010). While these technological advancements are exciting and offer paradigm changes to the way we consume energy, there is still the need for much research and demonstration before these become a part of our lives.

In addition to the research on consumption and technology, we recommend planned interventions that can influence MEL energy consumption in a more predictable manner. We outline three approaches that have some, but not all, common stakeholders. The first is the use of mandatory and voluntary efficiency standards that affect the manufacture, or assembly, of these products. Second, is a bunch of behavioral initiatives that can be undertaken by a variety of entities including building owners, conservation groups, program administrators, facility managers and building occupants. These initiatives aim to raise awareness and modify service consumption habits to encourage energy conservation through reinforcing messages and sometimes even redesign of environment. Finally, we suggest strategies that energy efficiency program administrators can employ to include MELs in their portfolios.

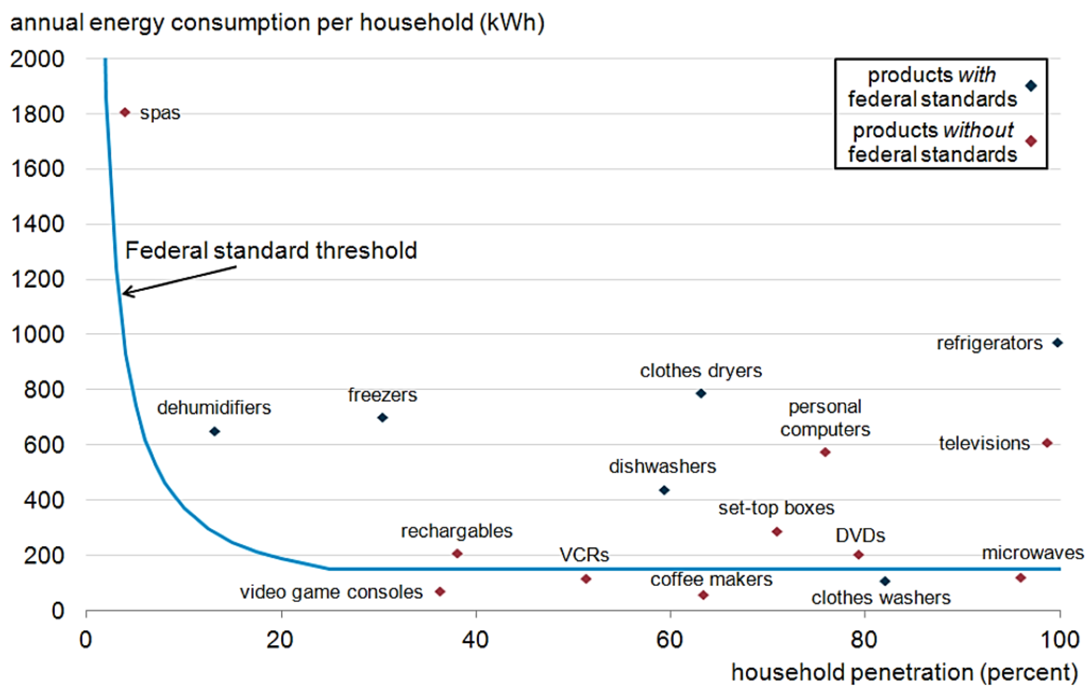
Often these three approaches are complementary and should be pursued synergistically. Utilities, for example, may choose to promote ENERGY STAR labeled products through their incentive programs. Similarly, behavioral programs can be launched at the same time as an equipment upgrade to maximize the savings. Some MELs, though, can be targeted better through a particular approach. For example given the lead-time built in the federal rulemaking process, it might be more effective in the short term to target reduction in energy use for highly dynamic products like personal computers, through behavior and utility programs.

ROLE OF STANDARDS AND LABELING

Various studies, for example (Comstock and Jarzomski 2012), have shown that federal standards result in significant energy savings for the covered products. As we have discussed, several MELs like TVs, microwaves, and computers do not yet have a federal standard. Figure 39 gives a snapshot of the coverage and penetration of key residential products. Medical equipment, personal computers, spas, microwave ovens are some of the products that make a good case for federal standards. Some U.S. states have taken a leading role in setting standards for these products and the success of those may act as a precursor to national level standards.

There are, however, limitations to what standards can achieve especially with MELs. The rulemaking process has inherent time lag between initiation, analysis, public comments and final date of effect. Standards are therefore not the ideal solution for highly dynamic products that require more immediate intervention. Moreover, standards are applicable to new shipments and do not impact the huge installed base of these devices in homes and commercial buildings (Bensch et al. 2010).

Figure 39: Role of Standards



Notes: Clothes washer and dishwasher consumption represents machine use only; energy consumption associated with water heating is not included here. 'Set-top boxes' refers to cable boxes, satellite boxes, digital-to-analog converters, and digital video recorders.
Source: Residential Energy Consumption Survey 2009 (household penetration) (EIA 1981-2012); Annual Energy Outlook 2012 Early Release Reference Case (annual energy consumption, 2009) (EIA 2012)

Product Labeling

Energy labels provide information about the energy consumption and efficiency of a product in an easy to understand manner to the end consumer. Energy labels can be important in influencing the purchase consideration and thus provide an incentive for manufacturers to invest in research and development of more efficient products. Many state and non-state agencies worldwide have created energy labels that enjoy a high recognition. Some jurisdictions have regulations that mandate labeling for specific products. Some other energy labels are voluntary in nature. We discuss some examples for each of these categories.

ENERGYGUIDE

The U.S. Federal Trade Commission requires all covered appliances — clothes washers, dishwashers, refrigerators, freezers, televisions, water heaters, window air conditioners, central air conditioners, furnaces, boilers, heat pumps, and pool heaters — to display yellow EnergyGuide label. This label estimates how much energy the appliance uses, compares energy use of similar products, and lists approximate annual operating costs.

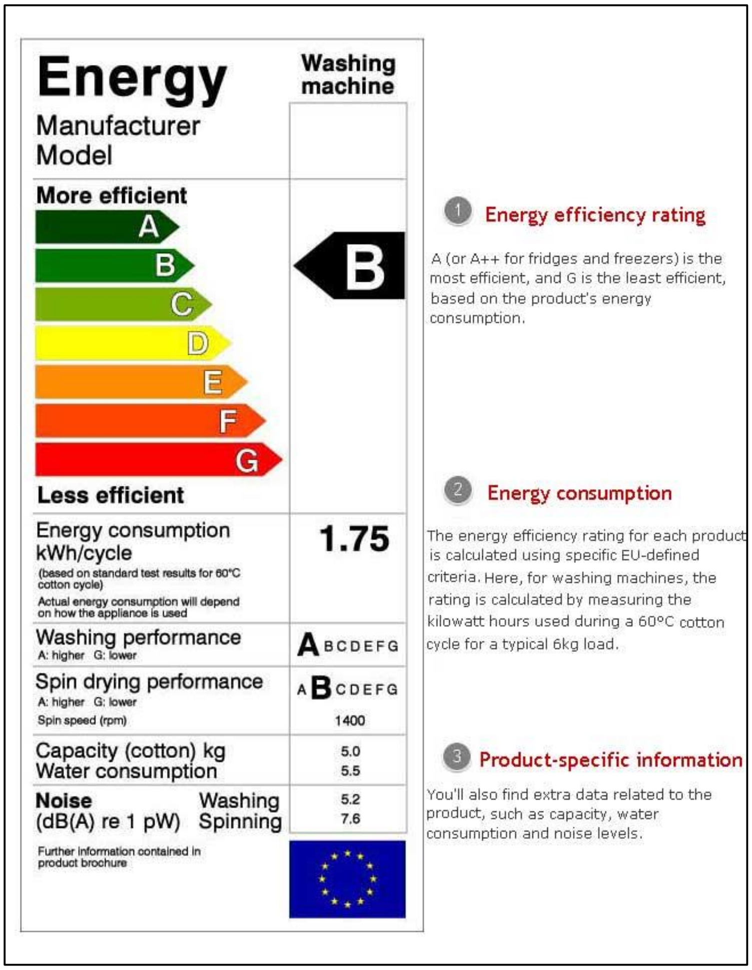
Figure 40: EnergyGuide Label for Televisions

Source: ftc.gov

EUROPEAN UNION ENERGY LABELING

The European Union (EU) adopted a system of comparative energy labeling in 1992, wherein most of the products are assigned to one of seven different energy classes from A (green) — the most energy efficient, to G (red) — the least efficient. The label also shows the annual energy consumption under standard use conditions. Manufacturers must provide the label and retailers must display it on appliances and show the label class in advertisements (DEFRA 2010).

Figure 41: EU Energy Label

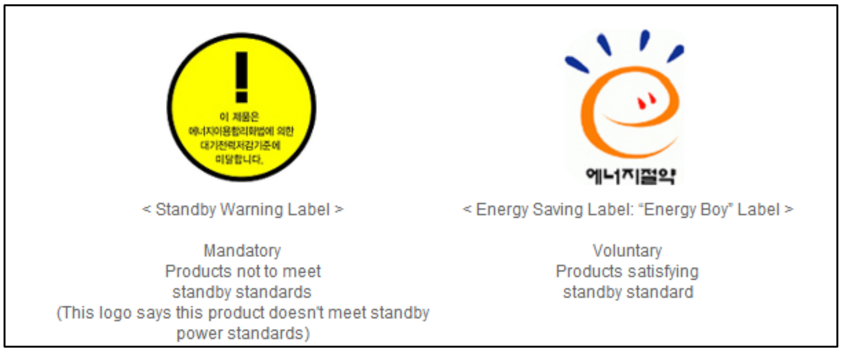


Source: DEFRA 2010

SOUTH KOREAN WARNING LABEL

South Korea is the first country in the world to introduce mandatory Standby Power Warning Label. This label differentiates those products that do not conform to the standby power consumption standards.

Figure 42: South Korean Warning Label



Source: Korea Energy Management Corporation[41]

ENERGY STAR

ENERGY STAR is one of the most commonly recognizable energy labels, especially in the U.S. Voluntary programs like ENERGY STAR direct customers to more energy efficient products and have affected MELs in many ways:

- ENERGY STAR for battery charging systems: applies to many of the portable miscellaneous end-use products discussed, including power tools, small household appliances, and personal care products like electric shavers (Reeves et al. 2012).
- ENERGY STAR for computers and imaging equipment — applies to a wide array of personal computing products, including notebooks, tablets, and monitors. Computers that meet the ENERGY STAR specification may be up to 65% more efficient than standard models. Additional requirements limit the power requirements of the EPSs for portable computers and require monitor and system sleep modes. ENERGY STAR for imaging applies also to multi-function devices and limits products to a maximum "typical energy consumption" and requires duplexing and "sleep" modes for many devices (Reeves et al. 2012).

While ENERGY STAR has been instrumental in driving efficiency for many products, specifications for some of the highest energy-consuming products discussed in this paper, such as video game consoles are not yet available. Even for those products that are covered by the ENERGY STAR program, the movement toward a more efficient installed base can be accelerated by utility programs that incentivize the sale of efficient miscellaneous end-use products.

EPEAT

EPEAT is another labeling scheme for desktops, notebooks and monitors that conforms to ENERGY STAR specifications in addition to ensuring other environmental benefits[42].

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[41] http://www.kemco.or.kr/new_eng/pg02/pg02100300.asp
[42] EPEAT website: http://www.epeat.net/

TOP RUNNER PROGRAM

Japan implements the Top Runner Program for many MELs like televisions, computers, DVD players, microwave ovens and vending machines. On a regular basis, officials test all the products currently available in a category, determine the most efficient model, and make that model's level of efficiency the new baseline (METI 2010). Manufacturers have the obligation to make efforts to achieve the new baseline within four to eight years. If a manufacturer does not meet the target or fails to make a good faith effort, this fact is publicized (METI 2010).

80 PLUS

The 80 PLUS performance specification requires multi-output power supplies in computers and servers to be 80% or greater energy efficient at 20%, 50% and 100% of rated load with a true power factor of 0.9 or greater. This makes an 80 PLUS certified power supply substantially more efficient than typical power supplies and creates a unique market differentiation opportunity for power supply and computer manufacturers (ECOVA 2013).

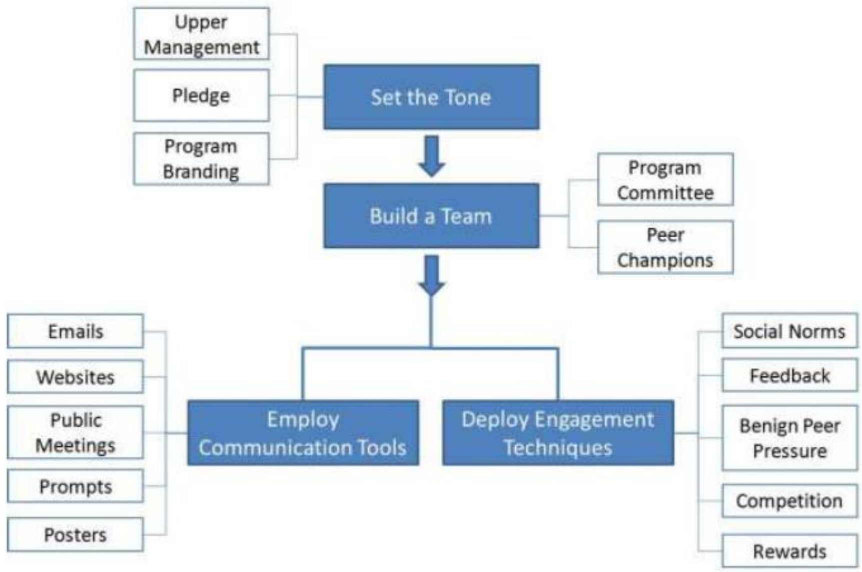
BEHAVIORAL APPROACHES

As discussed in our definition, users often introduce MELs to augment or modify their atmospherics or to perform subordinate tasks like brewing coffee, shredding paper and so forth. Human behavior is therefore often a prime determinant of the energy use of these products. Behavior programs can be designed for both residential (or community level) and commercial (especially office) settings. In certain cases, like in the case of split-incentive between the owner and the tenants, occupants of a building may not be interested in pursuing energy efficiency at all. Positive and negative reinforcement has an important role in learning and habit formation and has been employed, sometimes in the form of subtle environmental cues, to create motivation for people to act in an energy efficient manner (Mazur-Stommen 2012).

Investigating how people interact with their devices can provide insights that feed into technology. For instance, in a study conducted by the Energy Center of Wisconsin, Bensch et al. (2010) report in the case of personal computers —the disparity between monitor and computer sleep settings may be part of the problem. Some people are lulled into a false sense of security because they see the more highly visible monitor turning off automatically and they assume that the computer is switched off. Their analysis of metering devices from a sample of homes in Minnesota suggests that there is an average of about 450 (± 180) kWh per year worth of technical no- and low-cost savings opportunities per home, representing 3 to 6 percent of total home electricity use and roughly 20 (±8) percent of consumption by plug-in devices, by behavior based interventions.

In the office setting, Shui Bin (2012) has outlined a strategy for developing a behavior energy programs (Figure 43) that are designed and run by building owners and tenants to reduce energy use through change in employees' attitudes and behaviors. The report cites case studies that report energy savings as high as 75% when these programs have been integrated with comprehensive building energy efficiency initiatives run by program administrators.

Figure 43: Strategies from Development of an Energy Behavior Program



Source: Shui 2012

PROGRAM STRATEGIES

Historically, energy efficiency programs run by utilities and other program administrators have concentrated on large and easy-to-impact drivers of building energy use such as space conditioning, laundry, refrigeration and lighting. The fact these traditional uses consume significantly less energy today than a decade ago is a testimony to the power of these programs to influence the market. With these efficiency improvements, savings opportunities from traditional energy uses are diminishing which makes it more attractive for program administrators to focus on MELs.

Barriers and opportunities

Programs in recent years have targeted some MELs like consumer electronics, notably televisions, and computers through incentivizing models that are more efficient. However, a widespread inclusion of MELs in program portfolios requires overcoming some barriers. Next, we discuss some of the characteristic barriers and recommend innovative approaches to targeting MELs through efficiency programs.

RAPID EVOLUTION OF TECHNOLOGY

There are newer models of many of the top MELs like TVs, computers, set-top boxes, and video game consoles almost every year and sometimes even in the same year. This makes it harder to choose what to incentivize.

Integrating the program offering with publically available lists of high efficiency products is one way to manage this. As discussed earlier, ENERGY STAR Most Efficient and Top Ten USA are programs that regularly evaluate products and provide updates on the best in class on efficiency.

ECONOMIC FEASIBILITY

A single product from the MEL category, though easy to target (as evidenced through refrigerator replacement programs), may not be able to offer energy savings that justify the cost of running a program.

An MEL-protocol can be added to energy audits in residential and commercial buildings. This can help in comprehensive evaluation of available opportunity thus making it more feasible economically. There have also been cases of several program administrators joining hands to target a much larger catchment area thus benefitting from economies of scale.

Complexity

Some products such as set-top boxes and servers have multiple configurations often using diverse technologies making it difficult to set uniform efficiency standards for them.

These products can be tackled better by involvement with key stakeholders upstream in the supply chain.

ABSENCE OF BENCHMARK EFFICIENCY

Some products such as medical imaging equipment and microwave ovens do not have either mandatory or voluntary efficiency specifications. Again, this makes it hard to pick what to promote.

Program administrators often have the best access to data on benchmarking various facilities using the same type of equipment and can use this as a leveraging point.

LACK OF DATA

There is a scarcity of comprehensive data on measured energy use of many MELs.

With advances in sub-metering, net metering and disaggregation, utilities may be in the best position to synthesize end-use data.

BEHAVIORAL CHANGE

Unlike simple equipment upgrade programs, tackling MELs often requires changing the way people interact with these devices. It is often more difficult to change habits, preferences and existing knowledge of consumers.

As we have discussed before, behavior change can be integrated with traditional efficiency programs. Program administrators can make important contributions in raising awareness and providing information.

Program Approaches

Given the opportunities and barriers discussed above, there are several ways to incorporate MELs in program portfolios.

UPSTREAM APPROACHES

These involve financial and other incentives directed towards parties that are "up the supply chain" from the individual customer purchase transaction. Upstream incentives reach relatively far up the supply chain, typically to manufacturers.

- Program administrators can work with the manufacturers to increase the energy efficiency of devices. Decisions about product design are made at the very beginning of the development process, thus market transformation programs must focus their efforts on intervening at these early stages of product design. Manufacturers may make effective program targets because markets for many of these devices are consolidated and programs may be able to reach much of the market by targeting the few manufacturers with the most market share.
- Utilities can also provide technical support working with codes and standards organizations to influence specifications for more efficient products and designs.
- Manufacturers' design and market products for national and international markets and are more conducive to complying with uniform requirements across jurisdictions. Thus, programs will have the greatest impact on the MEL market if they coordinate with one another in setting energy efficiency targets, incentive levels, and program participation requirements.
- Utilities can also function as a conduit to provide feedback to manufacturers about the way their products are used by the consumers.

MID-STREAM APPROACHES

In this case, program incentives are directed to midstream channel partners like retailers and distributors for stocking, promoting and selling models that are more efficient.

- Programs can raise awareness among end-users and business-to-business customers about the benefits and availability of energy-efficient products. This may include providing point of purchase marketing material, training the store personnel on efficiency features and co-branding efficient models with the utility logo.
- For commercial products, energy efficiency is sometimes a key product feature, thus programs targeting these products should adjust their marketing efforts accordingly.

DOWNSTREAM APPROACHES

These include information campaigns, technical support and financial incentives like direct payments, tax incentives, or other subsidies to consumers for purchasing and implementing specified efficient products and practices. Some examples include:

- Energy saving tips inserted with utility bills and on utility web sites. For instance, highlight the savings opportunity by enabling power management in computers. Power management can be enabled through a downloadable application.
- Another low cost program approach to MELs entails a power meter loan or distribution program. Some power companies already place power meters in libraries so local residents can check them out. A power meter loan or distribution program could follow that model, or offer a discounted power meter for sale to households (Bensch et al. 2010).
- Similarly, smart power strips or remote switches could be offered by utilities, for example, in an effort to attract attention to the energy use from plug loads. These technological aides could be distributed with informational materials to help customers identify the most effective applications.
- Other ways to educate and provide technical support involve the use of a call center, hosted call-in radio program, or other source of remote assistance to households interested in saving energy in their home (Bensch et al. 2010).
- A formal plug-load audit component could serve as a very useful supplement to existing home audit programs that place professionals in people's homes for other reasons. Utility visits prompted by high bill complaints may offer another opportunity to help motivated households identify and take advantage of energy-saving opportunities. Homes that file high bill complaints probably have good savings opportunities among their plugged-in devices and a high motivation to save energy. Utility staff and contractors who visit homes of these customers could be trained to add a screening for energy-saving opportunities among plugged-in devices to their protocol and communicate their findings to the customer (Bensch et al. 2010).

Conclusion

This study is broad in scope and aims to stimulate the development of a more refined dataset for MELs. Currently, there is very limited data available from actual end-use metering and load-profiling studies. However, with increasing focus on real time data capture and advances in technology that makes this possible, we anticipate better information will be available in near future to help improve our characterization of MELs. The next version of CBECS, expected in 2014, should further our understanding of miscellaneous loads in commercial buildings. Many of the products analyzed show dramatic differences in installed base, usage, functionalities, characteristics, and underlying technologies and hence UECs over just a short period of time. This is particularly true for consumer electronics, which have changed dramatically over the last decade or so, and tend to have much shorter average product lifetimes (i.e., on the order of a few years compared to ten or more for white goods), but also true of some other products as well (e.g., the increased installed base of mobile phone antennas). Thus, it is important to regularly update this kind of study for a more robust approach to conserving energy from MELs.

In this report, while discussing elements common to both, we have tried to tease out the residential and commercial sectors from one another. However, we acknowledge that both the sectors have distinct energy consumption profiles and, given the variety and complexity of energy end-uses, deserve a commensurate study of their own. While some of the bigger electric loads that we have identified have started receiving attention from researchers, there is still very limited literature on gas-based miscellaneous applications. We recommend a targeted study of gas MELs for a more refined evaluation and characterization of energy saving opportunities. In all cases, the increase in MELs has significant ramifications for DOE's goal of net zero-energy buildings in the future. The magnitude of energy consumed by miscellaneous loads makes them impossible to ignore. We are confident in our belief that the technology to make these devices more efficient is ready and available. This report is an effort to highlight some of these options. What we need is an increased focus on implementation.

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Appendix A: Energy Use Details

Table A-1: Residential MEL Details

AEC Rank	Product	Average UEC (kWh/year)	Installed Base (million)	Average AEC (TWh)	Level of Agreement[43]
1	Televisions	213.3	329.3	70.1	High
2	Ceiling fans	152.4	225.0	31.6	Medium
3	Set-top boxes	151.5	192.0	28.0	Medium
4	Personal computers	158.1	181.0	27.1	Medium
5	Microwaves	121.0	116.0	15.0	Medium
6	Monitors	69.0	110.5	13.0	Medium
7	Cordless phones	28.0	170.0	12.9	Medium
8	Video game consoles	115.1	102.5	10.5	High
9	Portable electric spas	2500.0	3.5	8.8	Low
10	DVD and Blu-ray players	45.0	191.5	8.5	Medium
11	Compact audio	93.0	83.0	6.6	Medium
12	Audio receivers	65.0	99.0	6.4	Low
13	Vacuum cleaners	55.1	113.0	6.2	Low
14	Toasters	32.4	104.0	6.0	Low
15	Coffee machines	59.0	74.0	4.3	Low
16	Digital photo frames	66.9	42.1	3.9	High
17	Electric irons	30.6	106.0	3.2	Low
18	Home theater in a box	90.0	30.0	2.7	High
19	Routers	44.0	49.0	2.1	Low
20	Modems	48.5	46.0	2.0	Medium
21	Computer speakers	42.0	74.0	1.9	Medium
22	Home security systems	45.0	38.6	1.8	Medium
23	Radio	15.7	81.0	1.3	Low
24	MP3 player docking station	25.0	48.0	1.2	Low
25	Aquariums	70.0	16.1	1.2	Medium

Source: ACEEE compilation of data from multiple sources

[43] Low: only one source of information, Medium: two or more sources with wide range, High: two or more sources within close range (+ - 20%)

Table A-2: Commercial MEL Details

Serial Number	Product	Average UEC (kWh/year)	Installed Base (million)	Average AEC (TWh)	Level of Agreement[44]
1	Distribution transformers	3950.0	52.0	82.6	High
2	Personal computers	336.0	150.0	50.0	High
3	Wastewater treatment			46.7	Low
4	Computer servers	2100.0	1.3	33.9	High
5	Walk-in refrigeration	19000.0	1.3	25.0	Low
6	Fume hoods	27500.0	0.8	20.7	Medium
7	Central refrigeration	670000.0	0.0	19.0	Low
8	Monitors	123.3	113.6	17.0	Medium
9	Ice machines	12966.3	2.6	11.0	Medium
10	Printers	369.5	28.4	11.0	High
11	Vending machines	2509.0	6.6	11.0	Medium
12	Commercial refrigerators	4100.0	2.7	10.0	Medium
13	Refrigerator	445.0	20.0	8.7	Medium
14	Warehouse refrigeration	520000.0		7.8	Low
15	Medical imaging	34692.3	0.2	6.8	Medium
16	UPS systems	440000.0	0.2	6.5	Low
17	Vertical transport	6600.0	0.6	5.0	Medium
18	Mobile phone towers	24900.0	0.2	4.4	Low
19	Multi-function devices	59.0	14.5	4.0	Medium
20	TVs	940.0	16.0	3.8	Low
21	Microwaves	447.0	0.3	3.3	Low
22	Coffee makers	426.0	3.1	2.8	Medium
23	Copiers	710.0	3.7	2.7	Low
24	Slot machines	3500.0	0.8	2.7	Low
25	ATMs	3000.0	0.4	2.5	Medium

Source: ACEEE compilation of data from multiple sources

[44] Low: only one source of information, Medium: two sources with wide range, High: two or more sources within close range (+ - 20%)

Table A-3: Gas MEL Details

Gas MELs	Average UEC MMBtu/Yr	Installed base (mn)	AEC Tbtu/year
Commercial gas oven	89	1.01	134.4
Commercial Pool heat		0.055	99.0
Commercial gas fryer	110.8	0.649	75.4
Commercial gas broilers	174	0.182	36.8
Commercial steamer	153.8	0.195	51.0
Commercial gas griddle	90.1	0.276	33.4
Gas fireplace	7.2	4.8	34.6
Res pool heat	29	1.1	31.9
Spa heat	8.3	1.5	12.4
Outdoor yard light	30.2	0.2	6.0