MISCELLANEOUS ELECTRICITY USE IN U.S. HOMES

Marla C. Sanchez, Jonathan G. Koomey, Mithra M. Moezzi, Alan Meier
and Wolfgang Huber, LBNL Berkeley CA

ABSTRACT

Historically, residential energy and carbon saving efforts have targeted conventional end uses such as water heating, lighting and refrigeration. The emergence of new household appliances has transformed energy use from a few large and easily identifiable end uses into a broad array of "miscellaneous" energy services. This group of so called miscellaneous appliances has been a major contributor to growth in electricity demand in the past two decades.

We use industry shipment data, lifetimes, and wattage and usage estimates of over 90 individual products to construct a bottom-up end use model (1976-2010). The model is then used to analyze historical and forecasted growth trends, and to identify the largest individual products within the miscellaneous end use. We also use the end use model to identify and analyze policy priorities. Our forecast projects that over the period 1996 to 2010, miscellaneous consumption will increase 115 TWh, accounting for over 90% of future residential electricity growth. A large portion of this growth will be due to halogen torchiere lamps and consumer electronics, making these two components of miscellaneous electricity a particularly fertile area for efficiency programs. Approximately 20% (40 TWh) of residential miscellaneous electricity is "leaking electricity" or energy consumed by appliances when they are not performing their principal function. If the standby power of all appliances with a standby mode is reduced to one watt, the potential energy savings equal 21 TWh/yr, saving roughly $1-2 billion dollars annually.

Introduction

Historically, programs and policies to reduce residential energy use have targeted conventional end uses such as water heating, lighting and refrigeration. The success of past efficiency programs combined with the emergence of new household appliances has transformed energy use from a few large and easily identifiable end uses into a broad array of "miscellaneous" energy services. In the past, there has been little research emphasis on understanding the miscellaneous end use. One of the most referenced estimates of current miscellaneous consumption and forecasted growth is presented in the Annual Energy Outlook (AEO), published by the U.S. Energy Information Administration (EIA). Estimates from AEO97 show that miscellaneous electricity is one of the largest and fastest growing U.S. residential energy end uses. If AEO97 estimates are correct, the miscellaneous end use is a potential focus point for policy makers interested in reducing U.S. carbon emissions.

In order to provide a useful cross-check on AEO97 estimates, we developed a detailed bottom-up model of the miscellaneous end use. By disaggregating the miscellaneous end use into more than ninety products, our study provides the product-specific information that is necessary for directing future research and policy efforts. Detailed documentation of our model, methodology, and data is located in Sanchez et al., 1998.

Definition

The definition used in this study is consistent with EIA's miscellaneous electricity end use definition in AEO97. Definitions are necessarily the same so that our results can be compared to the estimates published in the AEO97. Several products included in our study belong in more conventional end use categories. For example, microwave ovens are technically a "cooking" end use, but the AEO97 treats them as a miscellaneous end use. Other examples of potentially mis-classified miscellaneous products include furnace fans, ceiling fans, dehumidifiers and evaporative coolers (intuitively, these are thought of as space conditioning end uses). The miscellaneous definition used in this study reflects EIA's accounting practices in AEO97. Our definition is consistent with the AEO97 for the purpose of comparison.

Our miscellaneous end use definition also includes new products that have not yet been incorporated into EIA's conventional end use categories. The AEO97 forecast for miscellaneous energy use is based on extrapolation of recent trends embodied in the US DOE's market surveys (US DOE 1989, US DOE 1992, US DOE 1995). EIA's Residential Energy Consumption Survey (RECS) did not include a halogen torchiere question in the lighting component of the survey. Without asking a separate question, results of the lighting survey cannot capture halogen torchiere lamps (since the energy use is substantially different than that of a conventional lamp-300 W vs. 75 W). As a result, the energy use from torchieres is included in EIA's miscellaneous end use as opposed to the lighting end use. For the purpose of model comparison, torchieres are included in our analysis.

We do not know the extent to which torchieres are displacing other lighting sources within the conventional lighting end use. There are two plausible scenarios. People may be substituting halogen torchiere lamps for conventional lamps in a one to one ratio. In this scenario, the amount of light remains the same, but the lighting source efficiency declines (the lumens/watt of torchieres is lower than that of conventional lamps). It is also possible that people are supplementing their lighting with torchieres. In this scenario, more light is provided, and it is provided with a comparatively less efficient source. In both scenarios, the energy use of lighting increases because of the efficiency of halogen torchiere lamps. The amount of increase is still unknown. Our study does not include this potential substitution effect or its energy implications within the lighting end use, but our estimates of total torchiere consumption are the first step to assessing its importance.

In the future, it may be appropriate for EIA to re-assign some currently defined miscellaneous end uses to conventional end use categories. This potential restructuring of end use categories will reduce the amount of energy consumption attributed to "miscellaneous" uses in the AEO. EIA has begun to address this issue in AEO98 by creating separate forecasts for clotheswasher and dishwasher motors, color televisions, personal computers, and fans for fuel-fired furnaces (previously in the "other" category). In AEO98, the energy use of torchiere lamps was included in the lighting end use category. One result of re-thinking the miscellaneous end use may be newly defined or expanded end use categories that better capture how energy is used in the home. Important miscellaneous products identified in this study are still key energy users independent of their end use categorization.

Methodology

In this study, we develop a bottom-up model of the miscellaneous end use. Using historic shipment data and a consistent stock accounting framework, we track the energy use of more than 90 products over a 34 year period (1976-2010). Our study has two components: a historical analysis of miscellaneous electricity use 1976-1995, and an end use forecast 1996-2010.

Data on miscellaneous electric uses is sparse, and in some cases simply non-existent. Developing a detailed bottom-up estimate entailed assembling appliance stock data from disparate and sometimes obscure sources, conducting a metering campaign to derive estimates of average product power, and making engineering estimates of consumption when alternative methods were unavailable. The approach used in this study is best classified as "back-of-the-envelope". A detailed methodology is available in Sanchez et al., 1998.

Historical Analysis (1976-1995)

Historical energy use is calculated according to the following assumptions:

1. Stocks in a given year are based on either shipment data or saturations, varying by product (Appliance Magazine, 1996a: Appliance Magazine, 1996b: Appliance Magazine, 1990: Appliance Magazine, 1986: US DOE 1995: US DOE 1992: US DOE 1989)
2. Stocks represent all existing products held by consumers regardless of usage

3. The unit energy consumption (UECs) of stock and replacement products are held constant through time [meaning that the efficiency and usage of a product bought in 1995 is assumed to be the same as that bought in 1976]. UECs are taken from a variety of sources (AHAM: California Energy Commission, 1992: Davis Energy Group, 1996: Koomey et al., 1996: Huber, 1997: Meier et al., 1992: Meier, 1987: PG&E, 1991: Rainer et al., 1995: Calwell, 1996).
4. National appliance energy consumption is the product of UEC and stock
5. National miscellaneous electricity use is the sum of the national appliance energy consumption for all products
6. All growth in miscellaneous energy use is attributed to either changes in the saturation of existing miscellaneous products, new miscellaneous products, or growth in the housing stock (since UECs were held constant).

The Miscellaneous Electricity Forecast (1996-2010)

This study uses three models to develop the miscellaneous forecast: industry, ARIMA, and subjective. Appliance Magazine publishes a five year forecast of product shipments based on industry estimates of future growth (Appliance Magazine, 1997). For all products included in the Appliance Magazine forecast, we use the industry projections for our forecast and extrapolate through 2010. For end uses not included in the industry forecast, but that account for a substantial amount of miscellaneous energy, we use a statistical technique known as an auto regressive integrated moving average (ARIMA). For the remaining end uses, we employ a subjective model to forecast future shipments or saturations. The miscellaneous forecast is bracketed by developing high and low growth scenarios for each model employed in the study.

We adjusted our forecast upwards to account for new products (products with no existing saturation or shipments in 1995) that may penetrate the market 1996 through 2010. We disaggregated our forecast into two variables, growth from new products and growth from increasing stocks (increasing stocks are caused by increases in product saturation or in total number of households). While we calculate growth from increasing stocks using our model, we are (of course) unable to precisely predict growth from new products. We use the relationship between new products (products with no existing saturation or shipments in 1976) and increasing stocks from our historical analysis to adjust our forecast upwards.

From 1976-1995, the relationship between increasing stock growth and new product growth was 4:1, meaning that for every four TWh of growth from increasing stocks there was one TWh of growth from new products. We assume that this relationship is constant over time and adjust our forecast accordingly. The forecast that results from this adjustment is referred to as the LBNL predicted scenario-adjusted for new products. Our forecasted end use growth rate and absolute growth includes the new products adjustment since from an overview perspective, accounting for new products provides a better estimate of total projected growth and makes a comparison to AEO97 more consistent. However, our breakdown of forecasted miscellaneous growth into individual products does not include new products since this is only calculated as an aggregate sum.

Results

Overview

Miscellaneous electricity is one of the fastest growing residential end uses. From 1976-1995, miscellaneous electricity increased at an annual rate of 4.6%. The growth rate (1996 to 2010) for the LBNL predicted scenario-adjusted for new products is 2.7%/yr. Though the projected miscellaneous growth rate is lower compared to the historical analysis, it is much greater than the aggregated growth rate for all non-miscellaneous electricity end uses (**Figure 1**[1]).

Our results show that from 1996-2010, miscellaneous electricity will increase by 115 TWh, accounting for over 90% of future residential electricity growth. Low growth rates for non-miscellaneous end uses explain the substantial fraction of future growth attributed to miscellaneous uses. Of the 90 products included in our study, only ten account for over half of current consumption (1995) and forecasted growth (1996-2010) (**Tables 1 and 2**).

Disaggregation of the Miscellaneous Electricity End Use

Because the miscellaneous end use is composed of a vast number of products, this study has been instrumental in identifying the segments of miscellaneous electricity that drive end use consumption and growth. We found that consumer electronics and halogen torchiere lamps account for a substantial amount of both current miscellaneous consumption and forecasted miscellaneous growth. Our study also revealed that several frequently overlooked miscellaneous products account for a surprising amount of residential electricity. Some of these more interesting end uses include aquariums, waterbed heaters, and women's hair products.

Consumer Electronics.

From 1976 to 1995, the energy consumption of consumer electronics increased by 64 TWh, accounting for nearly half of total miscellaneous growth (Figure 2). Increasing stocks of microwave ovens, color televisions, cable boxes and VCRs accounted for 60% of consumer electronics growth and approximately 10% of total residential electricity growth. In 1995, the energy use of consumer electronics totaled 87 TWh.

Table 1: Top Ten Miscellaneous Electricity Uses in 1995

Ranking	Product Name	TWh in 1995	Percent of Total Misc. Energy Use
10	Video Cassette Recorder	6.9	3.0%
9	Ceiling Fan	7.0	3.0%
8	Dishwasher Motor	7.4	3.2%
7	Clotheswasher Motor	7.9	3.3%
6	Auto Drip Coffee Maker	9.4	4.0%
5	Microwave Oven	11.3	4.8%
4	Torchiere Lamps	11.9	5.1%
3	Waterbed Heaters	13.2	5.6%
2	Furnace Fan	21.4	9.1%
1	Color Television	26.3	11.2%
	Top Ten Cumulative % of total miscellaneous electricity		53%

[1]Estimates for 2010 consumption reflect the LBNL predicted scenario-adjusted for new products and includes an adjustment for expected growth from new products described in the methodology section. 1976 source for total residential electricity consumption is from Pierce 1994, 1976 estimate for miscellaneous is from LBNL. The 1995 and 2010 estimate for total residential electricity consumption is from AEO97, miscellaneous estimates for these years are from LBNL.

Table 2: Top Ten Product Type Energy Growth (1996-2010)
Predicted Scenario-does not include adjustment for new products

Ranking	Product Name	TWh Growth (1995-2010)	Percent of Total Misc. Growth (1996-2010)
10	Computer	2.7	2.3%
9	Pool Pump	3.2	2.7%
8	Satellite Earth Station	3.2	2.7%
7	Projection Television	3.5	3.0%
6	Microwave Oven	3.6	3.0%
5	Compact Audio System	4.8	4.1%
4	Security System	5.2	4.4%
3	Dehumidifier	5.8	4.9%
2	Color Television	11.2	9.5%
1	Torchiere Lamp	27.5	23.3%
	Top Ten Cumulative % of total projected miscellaneous growth		60%

From 1996 to 2010, we project that the energy consumption of consumer electronics will increase by 38 TWh, roughly 40% of total miscellaneous growth. In our forecast, consumers are expected to purchase projection televisions or the TV/VCR combination, satellite dishes, and compact audio systems. Energy use of these four emerging product types (sales primarily increased after 1990) is expected to be 22 TWh in 2010. From 1996 through 2010, we project that energy from these products will increase 14 TWh, accounting for over 40% of consumer electronics growth.

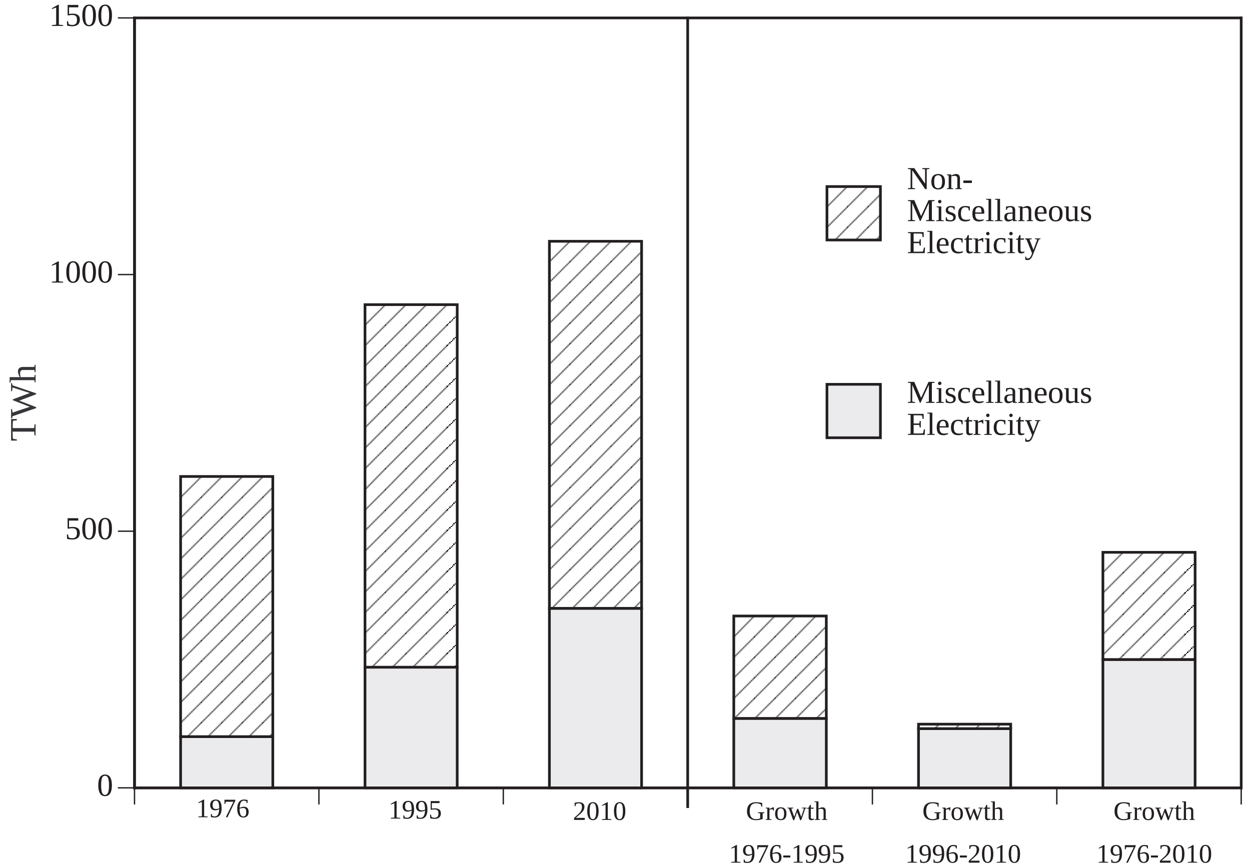

Figure 1: Total Electricity Use in the Residential Sector
Estimates on this graph for 2010 miscellaneous consumption reflect the LBNL Predicted Scenario-Adjusted for New Products and includes the adjustment for expected growth from new products described in our methodology

Halogen Torchiere Lamps.

In 1990, one million halogen torchiere lamps were sold in the U.S. By 1995, annual sales had increased to 17 million (Calwell, 1996). Quality lighting, affordability and availability prompted consumer demand. Growth in sales is a policy concern since the average power of a halogen torchiere lamp is 300 watts. From 1990 to 1995, the energy use of torchieres increased at a rate of over 200%/yr, and in 1995 halogen torchiere lamps consumed 12 TWh nationwide (**Figure 2).**

Torchieres are the most difficult miscellaneous product to forecast. Though torchiere lamp sales have skyrocketed in the past five years, the associated fire hazard has become increasingly publicized. While a future ban cannot be predicted, we can (at least) imagine one. In this study, we cap the saturation of torchiere lamps at approximately one per household in 2010. Based on this assumption, the energy consumption of torchiere lamps is projected to increase by 27 TWh from 1996 to 2010 (30% of total miscellaneous growth).

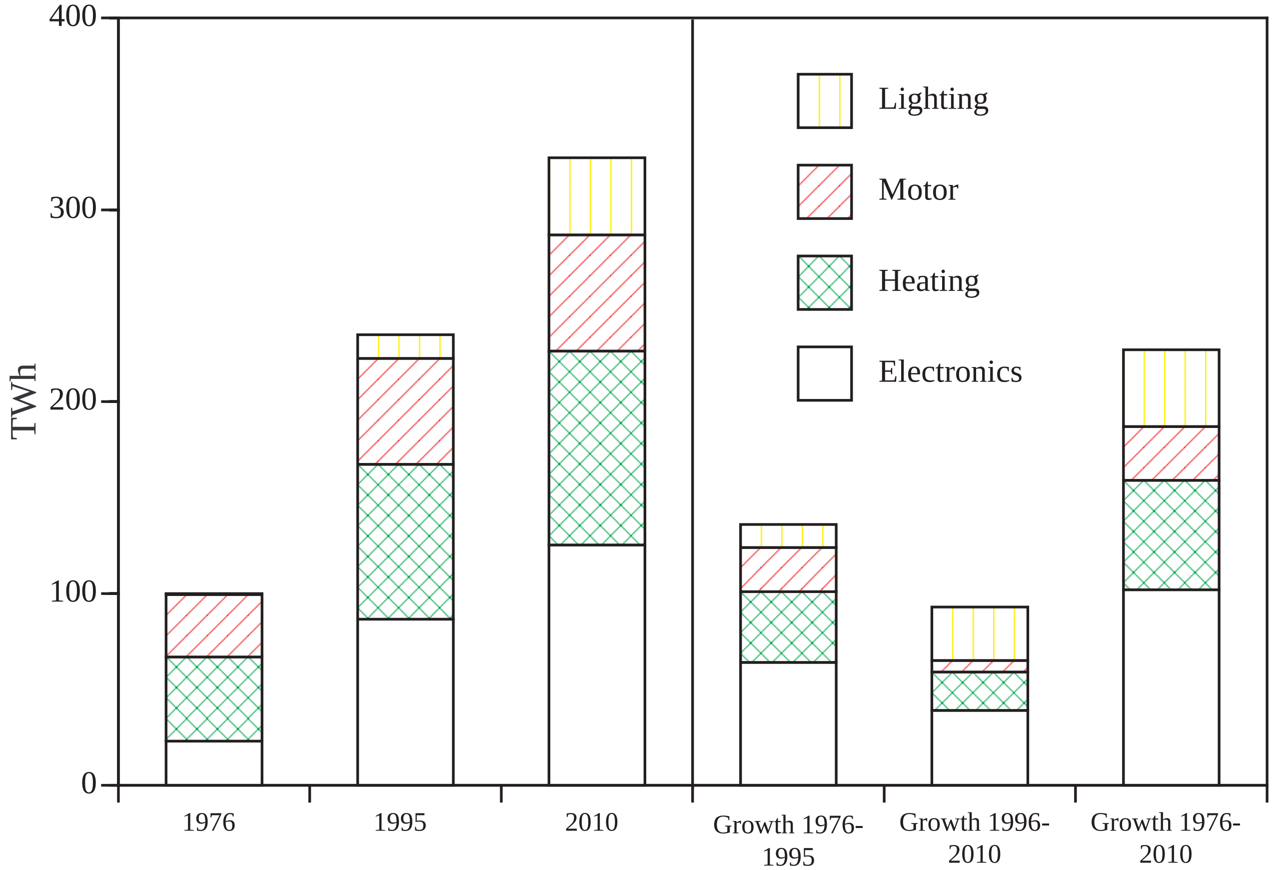

Figure 2: Disaggregation of Miscellaneous Energy Use by Major End Use Category
Estimates on this graph for 2010 reflect the LBNL-Predicted Scenario and do not include an adjustment for new products as described in the methodology

Aquariums.

Whereas most pet owners incur costs due to vet bills and food supply, we found that the cost of fish ownership primarily shows up on the monthly utility bill. Of particular interest are reef tank owners whose tanks simulate the environment of a tropical coral reef.

Reef tanks are set up as a sump and pump combination system. One large pump (~150 Watts) returns water from the sump to the main tank. Another pump removes phosphorous, nitrogen and amino acids which prevents algae growth. Powerheads are installed to increase water movement. In order to recreate turbulent reef conditions, an electronic wavemaker is used to turn power heads on and off. The lighting requirement of an average tank is six watts per gallon (tanks are typically over 100 gallons). Tank lights are on a minimum of ten hours per day. Due to the heat generated by the enormous amount of lighting and the powerful pumps that circulate the water, reef hobbyists need to cool their tank. Cooling is accomplished by fans or an actual mini-AC unit attached to the tank.

The energy consumption of a typical 180 gallon tank is over 6000 kWh/yr. To put this number in perspective, the energy from a reef tank frequently exceeds the combined annual electricity consumption of a residential central electric heating system and a refrigerator. During our research, we encountered one fish owner who was seriously considering installing a wind powered generator just to power her fish house.

On the national level, we estimate aquarium consumption at four TWh/yr, making aquaria the twentieth largest miscellaneous end use. Reef tanks (1%) and non-reef salt water tanks (9%) are only a small fraction of U.S. aquarium stock. The energy use for the remaining ninety percent of tanks ranges from 150-400 kWh/yr. It is certainly worth noting that reef tanks account for one quarter of total national aquarium energy use (Sanchez and Meier, 1997).

Waterbed Heaters.

Even though the product saturation is only around 15%, waterbeds are the third largest miscellaneous end use (13 TWh/yr) in 1995. Previous studies show measured waterbed energy use ranging from 500 to 3000 kWh/yr (Meier et al., 1992). Major determinants of energy consumption are temperature, size, and bed coverings. Efficiency measures include insulating sides and base or encouraging owners to make their beds (the latter resulting in a 50% reduction) (Meier, 1987).

Women's Hair Products (hair dryers, curling irons, and electric hair setters).

Hair products are a good example of the aggregated impact of individually small energy consumers. Assuming that a household owned each of these products and used them on a regular basis, annual product energy consumption would total 47 kWh/yr, a negligible 0.5% of average annual household electricity use. However, when you consider that four out of five U.S. households owns a hair dryer (the most energy intensive hair product), total national electricity use is no longer so trivial. Assuming that all households with hair products use them regularly, end use consumption equals roughly 3.5 TWh/yr.

Energy Efficiency Potentials for the Miscellaneous End Use

Efficiency options for hair products and aquariums may not be feasible; however, our miscellaneous electricity study identifies key opportunities that are cost-effective and that can substantially reduce miscellaneous electricity. The remainder of this paper details only one option, reducing appliance standby losses. Other opportunities include improving the efficiency of fans for fuel-fired furnaces, and replacing halogen torchieres with more efficient CFL models (Sanchez et al, 1998).

Reducing Standby Losses

Many consumer electronics products have a standby mode and consume energy even when they are switched off or not performing their principal function (Huber, 1997). The standby mode performs one or some combinations of the following services: maintaining an internal clock or memory, maintaining signal reception capability, maintaining battery charge, displaying settings or transformer losses (Huber, 1997). Because of the number of electronic products with standby modes, the hours operated in standby mode and the power used to provide the services, the amount of electricity "leaking" from electronics is quite high. In 1995, nearly half of all electronics energy was consumed while in standby mode (~40 TWh).

While acknowledging the convenience of services such as remote control, we believe that these same services can be provided with substantially less power. Several design options are currently available to reduce standby consumption: using flash memory to maintain programming/settings, using more efficient components in the circuit design, or using a switch mode power supply for products with wall packs (answering machines, cordless phones) (Webber, 1997).

Table 3: Potential Savings from a 1-Watt Action Plan

End Use	1995 Consumption (TWh/yr)	1-Watt Consumption (TWh/yr)	Potential Savings (TWh/yr)
Microwave	2.11	0.68	1.43
Battery Charger	2.05	0.85	1.20
Men's Shaver	0.46	0.33	0.13
Women's Shaver	0.13	0.09	0.04
Electric Toothbrush	0.23	0.10	0.13
Satellite Earth Station	0.57	0.04	0.53
Home radio, small/clock	1.77	0.88	0.88
Boom Box	1.34	0.61	0.73
Answering Machine	1.92	0.58	1.34
Hand-Held Rechargeable	0.34	0.19	0.15
Cordless Phone	1.49	0.53	0.96
Cable Boxes	3.69	0.32	3.37
Video Games	1.07	0.54	0.54
Compact Audio	4.73	0.45	4.29
RACK Audio System	3.21	0.46	2.75
Garage Door Opener	0.80	0.20	0.60
Doorbell	1.20	0.60	0.60
Security System	0.88	0.07	0.81
Halogen Lights	0.17	0.17	0.00
Modem	0.20	0.15	0.06
Power Strip	0.26	0.26	0.00
Timer	0.45	0.21	0.23
TOTALS FOR TARGETED END USES (1)	29.06	8.30	20.76
TOTAL U.S. STANDBY CONSUMPTION	43.06	22.30	48% Reduction in Standby Losses

For most products, we believe that standby power can be reduced to one watt or less. A "1 watt standby power" labeling program is currently under consideration by policy makers in the U.S**.** A program that reduced all standby power consumption in residential appliances to one watt per unit has the potential to reduce U.S. standby consumption to 22 TWh, nearly a 50% reduction from current levels[2]. By focusing only on standby losses, U.S. miscellaneous electricity consumption would be reduced by 21 TWh, saving roughly $1-2 billion annually (**Table 3**).

[2]The 1-W savings assumes that in 1995, every appliance (except home office equipment and TVs and VCRs) has a standby power of only 1-W. Savings are the difference between current consumption and the consumption at 1 Watt. Savings are not the result of a replacement/retirement calculation over time. We decided not to include home office equipment or TVs and VCRs in our calculation since they have their own Energy Star product labeling program (Energy Star TVs and VCRs and Energy Star Office Equipment). It is unlikely that one watt will apply to products with existing programs.

Conclusions

In this study, we developed a bottom-up model of the miscellaneous electricity end use. Our results show that from 1996-2010, miscellaneous electricity (adjusted for new products) will grow at an annual rate of 2.7%, accounting for over 90% of future residential electricity growth. Using the current miscellaneous electricity definition, we found that consumer electronics and halogen torchiere lamps account for a large portion of both historical and forecasted end use growth. Aquariums, waterbed heaters and women's hair products also account for surprisingly large amounts of miscellaneous energy. One energy efficiency opportunity currently proposed by U.S. policy makers is to reduce product type standby power. Such a program has the potential to reduce miscellaneous electricity use by 21 TWh, saving more than one billion dollars per year.

Acknowledgments

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References

AHAM. Association of Home Appliance Manufacturers. *Estimated Energy Data*.. Chicago, Il.

Appliance Magazine. 1997. "Annual Forecasts", January.

Appliance Magazine. 1996a. "Statistical Review, April."

Appliance Magazine. 1996b. "Portrait of the U.S. Appliance Industry", September.

Appliance Magazine. 1990. "Portrait of the U.S. Appliance Industry", September.

Appliance Magazine. 1986. "Statistical Review", April.

California Energy Commission. 1992. "Appliances-Efficiency and Use", Energy Specs, California Energy Commission, July.

Calwell, Chris (1996). ECOS Consulting, Durango CO.

Davis Energy Group. 1996. "Home Appliance Energy Consumption Background Information. *Prepared for Pacific Gas and Electric, Spot the Big Spenders*., February.

Huber, Wolfgang. (1997), *Standby Power Consumption in U.S. Residences.* M.S. Thesis, Technical University, Munich.

Koomey, Jon, Mary Ann Piette, Michael Cramer, and Joe Eto. 1996. "Efficiency improvements in US office equipment". *Energy Policy*: 24 (1101-1110).

Meier, Alan, Steve Greenberg and Leo Rainer. (1992), 'Emerging Miscellaneous Uses of Electricity in Homes'. Presented at ACEEE 1992 Summer Study on Energy Efficiency in Buildings in Asilomar, CA. Published by American Council for an Energy Efficient Economy, Washington DC.

Meier, Alan. 1987. "Saving the "Other" Energy in Homes". *Energy Auditor and Retrofitter*, Nov/Dec: 13-19.

Rainer, Leo, Steve Greenberg, and Alan Meier. 1995. *You Won't Find these Leaks With A Blower Door: The Latest In "Leaking Electricity" in Homes*. Davis Energy Group.

Sanchez, Marla C., J.G. Koomey, M.M. Moezzi, A.K. Meier and W. Huber. 1998. *Miscellaneous electricity use in the U.S. residential sector*. LBNL-40295.

Sanchez, Marla and Alan Meier. 1997. "Rage for Aquaria." *Home Energy Magazine*, vol. 14 (5): pp. 8-10.

Webber, Carrie. 1997. "An Analysis of Technical Potential Standby Power in Miscellaneous End Uses: Is a One-Watt Specification Realistic?". memo to EPA (October).

US DOE. 1995. *Housing Characteristics 1993*. DOE/EIA-0314(93). Energy Information Administration. Office of Energy Markets and End Use, Department of Energy. Washington, DC.

US DOE. 1992. *Housing Characteristics 1990*. DOE/EIA-0314(90). Energy Information Administration. Office of Energy Markets and End Use, Department of Energy. Washington, DC.

US DOE. 1989. *Housing Characteristics 1987*. DOE/EIA-0314(87). Energy Information Administration.. Office of Energy Markets and End Use, Department of Energy. Washington, DC.