Do the Little Things Add Up? National Energy Consumption of 80 Miscellaneous End-Use Products

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ABSTRACT

Considerable attention has been paid to the impact that major appliances and equipment have on residential energy consumption. However, as efficiency program managers come under pressure to further reduce energy consumption, they are looking beyond large end uses and focusing on the growing array of small appliances and portable electronics in homes. Hundreds of these "miscellaneous end uses" together constitute a small but growing portion of residential energy consumption. Many obtain their power from battery chargers and/or external power supplies, all of which will be subject to federal standards in the coming years.

This paper quantifies the per-unit and national energy consumption of these end-use products and shows what portion of this consumption is currently addressed by standards and voluntary programs. The data presented will help efficiency program managers better understand the energy savings opportunities presented by miscellaneous end uses and the relative importance of each end-use product.

The paper draws heavily on a recent analysis DOE performed as part of its standards rulemaking for battery chargers and external power supplies, in which it tested an array of products and compiled shipments, lifetime, and usage data in an effort to quantify national energy consumption. (DOE 2012a, 2012b, 2012c, 2012f) That analysis, in turn, drew upon more than a decade of research on this topic conducted by Ecos Consulting, Lawrence Berkeley National Laboratory (LBNL), TIAX, RLW Analytics, the Energy Center of Wisconsin, and others.

Introduction

This paper characterizes the electricity consumption of 78 electrical products that were analyzed as part of DOE's standards rulemaking for battery chargers and external power supplies (EPSs), sometimes referred to as the "BCEPS rulemaking".[1,2] The Energy Independence and Security Act of 2007 created federal energy conservation standards for certain EPSs, which took effect on July 1, 2008. On March 8, 2012, DOE issued a notice of proposed rule in which it proposed strengthening the existing standards and creating new standards for battery chargers and certain EPSs not already covered by standards. The potential impact of these proposed standards on miscellaneous end-use load (MEL) energy consumption is examined later in this paper. (DOE 2012c)

[1] The authors of this paper were part of the team of contractors DOE assembled to conduct the analysis.

[2] For the purposes of this paper, we use the definitions of battery chargers and EPSs found in U.S. Code. "The term battery charger means a device that charges batteries for consumer products, including battery chargers embedded in consumer products." (42 U.S. C. 62941(32) as amended by Section 135 of the Energy Policy Act of 2005 [EPACT 2005]) "The term external power supply means an external power supply circuit that is used to convert household electric current into DC current or lower-voltage AC current to operate a consumer product." (42 U.S.C. 6291(36)(A) as amended by Section 135 of EPACT 2005)

While this analysis does not attempt to cover all miscellaneous electric products, the products analyzed represent a significant portion of miscellaneous electric loads in U.S. households and businesses. In total, the installed base of the products analyzed uses an estimated 56,000 gigawatt-hours (GWh) of electricity per year, which equates to 0.19 quads of site energy or 8.8% of total miscellaneous site electricity consumption in U.S. buildings. (EIA 2012) In comparison, U.S. buildings consumed 9.49 quads of site electricity in 2010. Miscellaneous site electricity consumption, defined here as the sum of site electricity consumption in the electronics, computers, and other categories, equaled 2.18 quads in 2010. This sum does not count electricity used by space heating, space cooling, lighting, water heating, refrigeration, ventilation, cooking, or wet cleaning.

In recent years, other studies have attempted to quantify the energy used by MELs. In 2008, TIAX focused on 30 common plug-in devices, including many that were not covered in our analysis, such as outdoor lighting, ceiling fans, microwave ovens, and televisions. The products analyzed by TIAX used a total of 359,000 GWh, or 27% of residential electricity consumption in 2006. (TIAX 2008)

TIAX considered rechargeable electronics as a group, estimating that there was an installed base of 590 million such products in the residential sector in 2006. Our analysis estimated the installed base of rechargeable electronics to be 1.66 billion in both the residential and commercial sectors out of a total of 2.14 billion miscellaneous electric products in 2012.

As rechargeable electronics and other plug-in devices become more ubiquitous, it is important to consider the energy consumption of these products in greater depth. Table 1 lists the devices that were included in this analysis.

Table 1. Products Included in the Analysis

Category	Application
Audio	Amateur Radios, Pre-Amps, Wireless Speakers, Guitar Effects Pedals, Keyboards, MP3 Speaker Docks, Clock Radios, Wireless Headphones, MP3 Players
Computers and Peripherals	Personal Digital Assistants, Netbooks, Notebooks, Media Tablets, Computer Speakers, External Hard Drives, Uninterruptible Power Supplies, LED Monitors, Image Scanners, Handheld Image Scanners, Ink Jet Imaging Equipment, Portable Printers, E-Books, Mobile Internet Hotspots, LAN Equipment
Geospatial Equipment	In-Vehicle GPS, Handheld GPS
Telephony	Bluetooth Headsets, Consumer Two-Way Radios, Mobile Phones, Smartphone, Caller ID Devices, Cordless Phones, Answering Machines, VoIP Adapters
Household	Baby Monitors, Breast Pumps, RC Toys, Portable Video Game Systems, Video Game Consoles, Handheld Vacuums, Robotic Vacuums, Stick Vacuums, Home Security Systems, Irrigation Timers, Water Softeners/Purifiers, Blenders, Can Openers, Mixers, Camcorders, Digital Cameras, Digital Picture Frames, Portable DVD Players, Wireless Charging Stations, Air Mattress Pumps, Aquarium Accessories, Indoor Fountains, Flashlights/Lanterns, Universal Battery Chargers

Category	Application
Outdoor Appliances	Rechargeable Garden Care Products, Lawn Mowers
Personal Care	Rechargeable Toothbrushes, Rechargeable Water Jets, Beard and Moustache Trimmers, Hair Clippers, Shavers, Sleep Apnea Machines, Medical Nebulizers, Portable O2 Concentrators, Blood Pressure Monitors
Power Tools	DIY Power Tools (Integral), DIY Power Tools (External), Professional Power Tools
Transport	Electric Scooters, Motorized Bicycles, Golf Carts, Toy Ride-On Vehicles, Wheelchairs, Mobility Scooters, Marine/Automotive/RV Chargers

Methodology

Our analysis relied heavily on the product surveys, market assessment, and energy use analysis conducted by DOE as part of its battery charger and EPS standards rulemaking. (DOE 2012d, 2012e, 2012f) All of the products listed in Table 1 above are end-use applications of battery chargers and EPSs, and many of them employ both a battery charger and an EPS. The analysis conducted for the rulemaking calculated only the energy "consumed" by the battery chargers and EPSs – that is, the energy lost during conversion from line power and in battery charging. However, with small adjustments to the methodology and the assumptions, we have estimated the electricity consumption of the whole product (end-use product including the battery charger and/or EPS).

The products analyzed vary widely in their electrical characteristics. Instead of attempting to measure the nameplate output power and battery energy of all products, DOE grouped products with similar electrical characteristics. Those applications with a large range of nameplate output powers or battery energies were assigned to multiple product categories. Table 2 shows an example of this grouping for applications of AC-DC Basic Voltage EPSs.

Table 2. Grouping of Top Applications for AC-DC Basic Voltage EPSs

Assumed Nameplate Output Power	Top Applications by Shipments
2.5 Watts	Answering Machines, Cordless Phones, Mobile Phones, Portable Video Game Systems, Beard and Moustache Trimmers
18 Watts	LAN Equipment, Digital Picture Frames, MP3 Speaker Docks, Media Tablets, VoIP Adapters
60 Watts	Notebook Computers, Video Game Consoles, Netbook Computers, Ink Jet Imaging Equipment, LED Monitors
120 Watts	Notebook Computers, Portable O2 Concentrators

The annual unit energy consumption (UEC) was calculated using essentially the same methodology as was used in the rulemaking, taking into account the power consumed by each application in each mode of operation and the time each application spent in each of those modes. The power required by the application in each mode was estimated to be a specified percentage of the assumed EPS nameplate output power for the product category. For example,

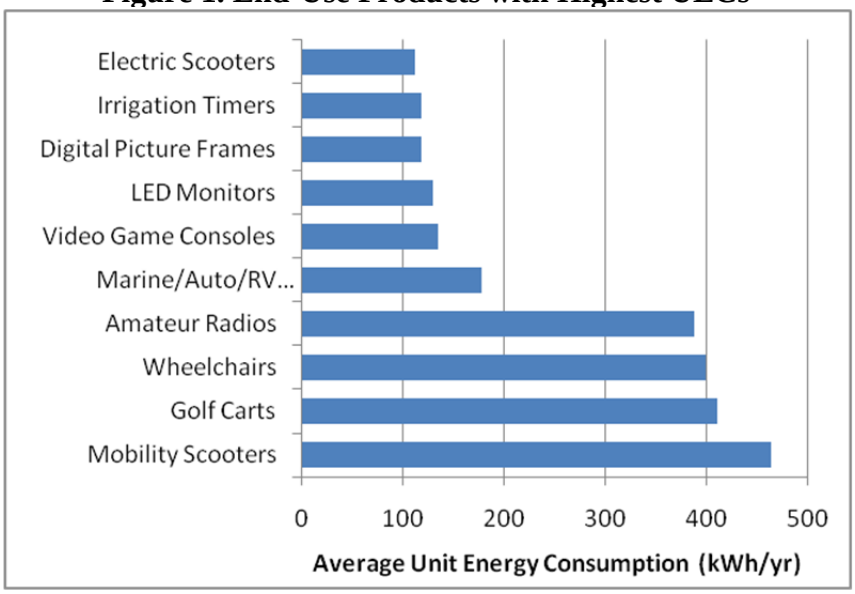
DOE assumed a notebook computer that was in use and charging drew only 66% of its EPS's nameplate output power (0.66×60W=40W). Usage profiles were also developed for each battery-powered application specifying how much time each battery charger spent plugged in and how many times the battery was charged in an average week. Documentation for all usage assumptions can be found in the *Energy Use Analysis Spreadsheet* posted on the rulemaking website for BCEPS. (DOE 2012d)

The BCEPS analysis measured applications by their shipments in the base year and counted energy savings over the lifetime of that application. Because the analysis did not specifically estimate the installed base of each application, we adopted the "steady-state" assumption—that the size of the installed base was equal to the annual shipments multiplied by the average lifetime of the application.[3]

Product Analysis

The average UEC of the products ranged widely, from 463.8 kWh per year for mobility scooters to 0.2 kWh per year for household appliances like battery-powered electric mixers. In fact, 52 of the 78 products analyzed used less than 20 kWh per year. The products that had the highest UECs were products with large battery capacities, such as electric transportation products; products that draw a lot of power, such as amateur radios and video game consoles; and products that are used very heavily, such as LED monitors and digital picture frames. The 10 products with the highest UECs are shown in Figure 1.

Figure 1. End-Use Products with Highest UECs



It is important to note that many of the products that use the most per-unit energy are fairly uncommon, meaning that they do not constitute a large share of aggregate MEL energy consumption. To get a better sense of the total energy consumption of these products, we multiplied the average UEC by the estimated installed base of each product in 2012 (DOE

[3] In those cases where some models of a given application use battery chargers and/or EPSs while other models do not, we attempted to include only the former in our estimates of shipment volumes.

2012d, 2012e). Table 3 presents the 10 products with the highest share of aggregate energy consumption along with the aggregate energy consumption of several other important product categories.

Table 3. Energy Consumption of Miscellaneous End-Use Products

	Average UEC (kWh/year)	Installed Base in 2012	Estimated Total Energy (GWh/year)
Top 10 Products			
1. Video Game Consoles	135	95,957,000	12,950
2. Notebooks	74	102,835,000	7,657
3. LAN Equipment	89	77,632,000	6,934
4. Digital Picture Frames	119	46,595,000	5,553
5. Ink Jet Imaging Equipment	78	20,423,000	1,598
6. Home Security Systems	35	42,192,000	1,465
7. Netbooks	44	31,811,000	1,415
8. Aquarium Accessories	70	17,500,000	1,227
9. Mobile Phones and Smartphones	4	270,804,000	1,078
10. LED Monitors	130	7,798,000	1,013
Other Key Categories (Not Including Top 10)			
Large Electric Transportation	247	13,725,000	3,391
Small Electronics	3	710,834,000	2,452
Other Computer Peripherals	22	99,609,000	2,202
Home Telephone Equipment	10	201,974,000	1,980
Power Tools and Lawn Equipment	9	105,569,000	952
Medical Devices	42	19,099,000	805
Other Products Not Included Above	-	279,224,000	3,714
Total	-	2,143,581,000	**56,386**

Video game consoles had the highest total energy consumption of all products, accounting for almost a quarter of the energy consumed by all of the products we analyzed. Because the DOE's analysis did not consider products that use internal power supplies, the above estimates do not account for energy used by the Sony PlayStation® 3, one of the three most common video game consoles. The Natural Resources Defense Council (NRDC) estimated that video game consoles consumed approximately 16,000 GWh per year in 2008 (Calwell et al. 2008), which we believe is consistent with our estimate of 13,000 GWh per year (excluding PlayStation 3). As discussed below, policy makers in California have begun developing efficiency standards for these products.

Computers and computer peripherals make up a significant portion of miscellaneous electricity loads. Notebooks and netbooks are extremely common, with a total installed base of 135 million products, and together they account for 9,072 GWh per year. These estimates include notebooks and netbooks used in the commercial sector, but they do not include desktop computers, which utilize internal power supplies. Products intended to be used peripherally with

computers are responsible for a similarly large share of total MEL energy consumption. LAN equipment alone consumes 6,934 GWh per year, and all other computer peripherals add another 4,813 GWh per year (see Table 4).

Table 4. Energy Consumption of Computer Peripherals

Products	Average UEC (kWh/year)	Installed Base in 2012	Estimated Total Energy (GWh/year)
Ink Jet Imaging Equipment	78	20,423,000	1,598
LED Monitors	130	7,798,000	1,013
Uninterruptible Power Supplies	17	58,400,000	990
Computer Speakers	47	19,576,000	929
Image Scanners	18	12,554,000	228
External Hard Drives	16	2,690,000	44
Portable Printers	2	6,390,000	10
Total	**38**	**127,830,000**	**4,813**

Mobile phones and smartphones together consume an estimated 1,078 GWh per year. These products have very low UECs—only 4 kWh per year—but have very high market saturation, with an installed base of more than 270 million products. Similarly, home telephone equipment, which includes cordless phones, answering machines, caller ID devices, and voice-over-Internet Protocol (VoIP) adapters, consumes 1,980 GWh per year. These products use more energy per unit than mobile telephones because they are typically left plugged in, even when they are not in use.

The large electric transportation category has very high total energy use despite having a relatively small installed base. Together, these products consume 3,391 GWh per year. On their own, none of the products shown below in Table 5 represents a large proportion of total MEL energy consumption, but the aggregate is significant. Because of the relative inefficiency of its battery charging technology, this group of products will benefit greatly from DOE's proposed battery charger standards. As shown in the next section, DOE's proposed standards would greatly decrease the energy consumption of these products, bringing the total annual electricity consumption down to 1,709 GWh per year.

Table 5. Energy Consumption of Large Electric Transportation Products

Products	Average UEC (kWh/year)	Installed Base in 2012	Estimated Total Energy (GWh/year)
Marine/Automotive/RV Chargers	178	5,000,000	888
Mobility Scooters	464	1,865,000	865
Wheelchairs	399	1,611,000	643
Golf Carts	411	1,369,000	563
Electric Scooters	112	2,425,000	271
Motorized Bicycles	112	1,455,000	162
Total	**247**	**13,725,000**	**3,391**

Policy Activity

While none of the products identified in this paper have had their energy use directly regulated at the federal level, multiple government programs are either in place or under consideration to address their energy use. The program with the greatest potential impact is DOE's Appliance and Commercial Equipment Standards Program, which recently proposed new and amended standards for battery chargers and EPSs. (DOE 2012c) As explained in the introduction, all of the MELs analyzed in this paper have a battery charger and/or EPS as a component and will thus be affected directly by these standards.

Building on our analysis of energy consumption of the 2012 installed base and projected percent savings from standards, we estimated total energy consumption and savings following full implementation of the proposed battery charger and EPS standards. Once the current stock of products is turned over, battery charger and EPS standards are projected to save 6,723 GWh per year, or 12% of the consumption of the 2012 installed base.

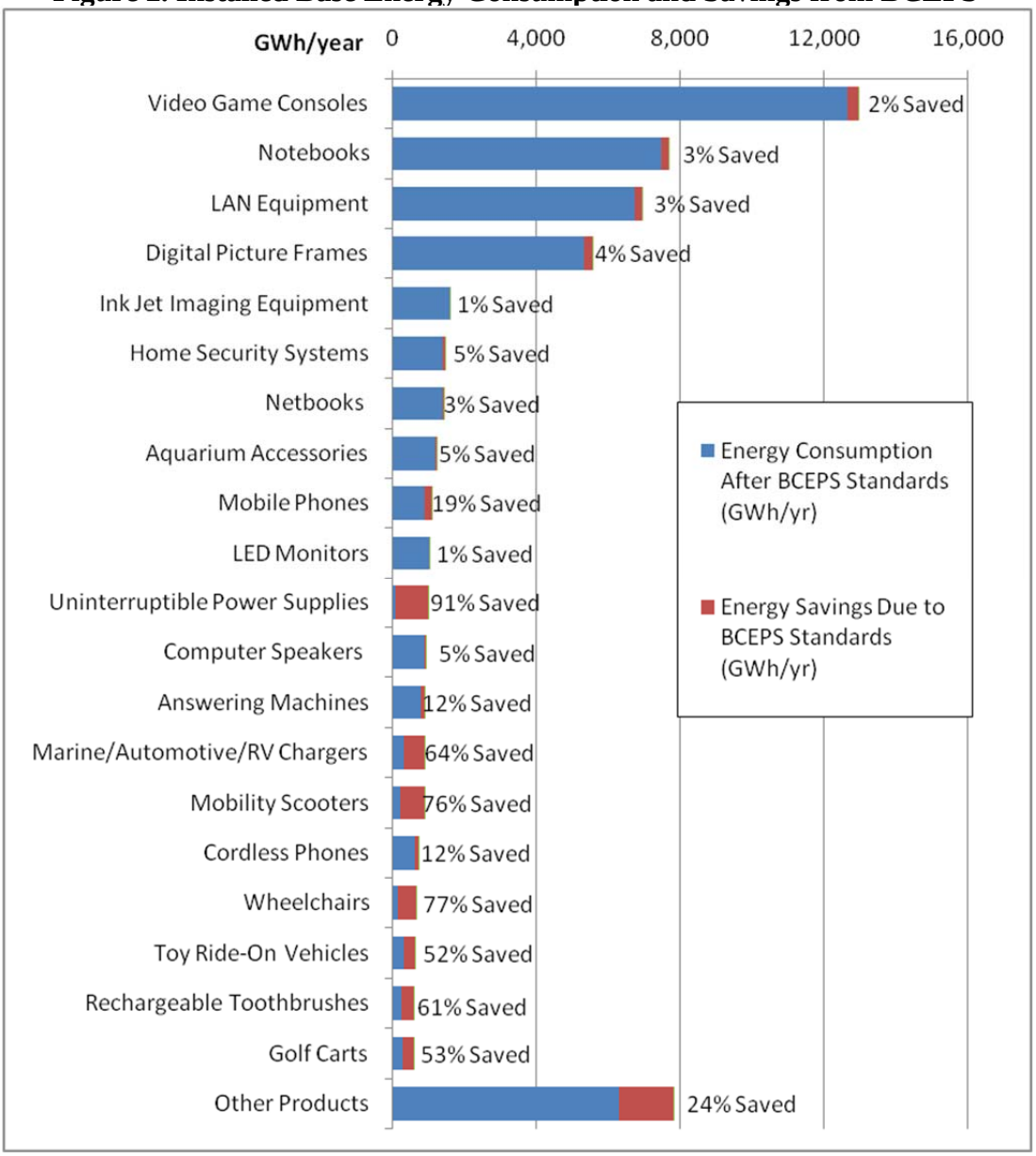
The proposed standards for battery chargers and EPSs will have a substantial impact on the energy consumption of certain MELs, reducing unit energy consumption more than 50% in some cases. Table 6 shows the 10 MELs that we estimated would have the greatest percentage of unit savings.

Table 6. Unit Energy Consumption of MELs Before and After DOE Standards

Product	Unit Energy Consumption in 2012 (kWh/yr)	Projected Unit Energy Consumption after DOE Standards (kWh/yr)	Portion of 2012 Consumption Saved	Total Energy Consumption of Installed Base After Standards (GWh/yr)
Uninterruptible Power Supplies	17.0	1.5	91%	87.0
Portable O2 Concentrators	78.3	15.5	80%	1.5
Wheelchairs	399.0	92.9	77%	149.6
Mobility Scooters	463.8	109.8	76%	204.8
Electric Scooters	111.6	37.0	67%	89.7
Motorized Bicycles	111.6	37.0	67%	53.8
Marine/Automotive/RV Chargers	177.5	63.7	64%	318.3
Rechargeable Toothbrushes	7.9	3.0	61%	228.0
Rechargeable Water Jets	7.9	3.0	61%	1.5
Flashlights/Lanterns	13.9	5.8	58%	2.9
All Other Products	23.1	21.6	16%	48,526
Shipment-Weighted Average	**23.1**	**20.8**	**10%**	**-**

For many MELs, the amount of energy saved is astounding, particularly considering that the standards regulate only inefficiencies in the power conversion and battery charging portions of the devices and ignore other potential inefficiencies. However, many of the MELs with the highest percentage savings had small shares of total installed base energy consumption. 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. Figure 2 shows the estimated annual energy consumption of the installed base of the 20 MELs that consume the most energy and the relative effects of BCEPS standards.

Figure 2. Installed Base Energy Consumption and Savings from BCEPS



Note: "% Saved" value indicates the portion of energy consumption in the installed base expected to be saved due to BCEPS standards after the entire installed base has turned over.

Overall, DOE's proposed standards will result in significant energy savings for the miscellaneous end-use products discussed in this paper. On average, these products will become 12% more efficient. However, the standards appear to fall short in regulating the efficiency of many of the top energy-consuming products. While most of the products covered are small and portable (and therefore frequently disconnected from the power grid), eight of the ten highest-consuming products are not portable and, therefore, typically are left plugged in drawing power all the time. A few of these, such as LAN equipment, digital picture frames, and home security systems, are designed for continual active-mode use, resulting in relatively high energy consumption. Thus, significant potential remains for reductions in energy consumption for these products—particularly for video game consoles and LAN equipment, some of which may be addressed by other energy efficiency programs.

ENERGY STAR

The U.S. Environmental Protection Agency's (EPA) ENERGY STAR® program provides a label for the most efficient products in select categories. This is a voluntary program intended to reward manufacturers that achieve the highest levels of energy efficiency and direct consumers to those products. In addition to directly limiting the power draw of qualified products, EPA has requirements for some miscellaneous end-uses that limit the power drawn by the product when not in use. The following product categories are particularly relevant to this paper:

- 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. (EPA 2012c)

- ENERGY STAR for Computers – 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. (EPA 2012a)

- ENERGY STAR for Imaging Equipment – applies to multifunction devices. Limits products to a maximum "typical energy consumption" and requires duplexing and "sleep" modes for many devices. (EPA 2012b)

While ENERGY STAR has been instrumental in driving efficiency for many products, EPA has not yet issued proposed specifications for some of the highest energy-consuming products discussed in this paper, such as video game consoles. However, 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.

State Efficiency Standards

To our knowledge, no state has regulations in place that govern the efficiency of these products. However, in January 2012, California published standards for consumer battery

chargers that will take effect on February 1, 2013. For some products, these standards are more efficient than those proposed by DOE and could, therefore, reduce consumption further.

Efficiency Standards under Consideration

DOE announced its intention to consider efficiency standards for personal computers in 2012 by issuing a request for information. California is also working toward setting state-level standards for these devices. The American Council for an Energy-Efficient Economy (ACEEE) projects that California's final rule will be issued in 2013 with an effective date of 2014, while DOE's final rule will be issued in 2014 with an effective date of 2019 (Amann et al. 2012).

DOE also issued a request for information for video game consoles in 2012, indicating that it may set standards for these products. ACEEE reported that a final rule for California's video game console standards could be published as early as 2013 with an effective date of 2014. DOE's would be published in 2015 and take effect in 2020.

Conclusion

Products that utilize battery chargers and EPSs represent a significant and growing portion of residential energy use. The products analyzed in this paper consume more than 56,000 GWh per year—8.8% of total miscellaneous electric loads in U.S. residential buildings—and demand for portable electronics, home entertainment systems, and computer peripherals will likely continue to grow. As demand grows, policymakers should concentrate efforts on improving their understanding of how these products are used and focus energy efficiency programs on those products that consume the most energy.

The recently proposed federal standards for battery chargers and EPSs would save 6,723 GWh of energy per year, or 12% of the consumption of the 2012 installed base, once new, efficient products have replaced the older, inefficient products. These standards would have the greatest effect on motorized battery-powered products (large electric transport, rechargeable power tools, and lawn equipment) because they are currently very inefficient. However, while these products account for 40% of the potential energy savings, they currently represent only 8% of total energy consumption.

Home telephone equipment and portable electronics, such as mobile phones, would also be strongly affected by battery charger and EPS standards because of the high frequency of their use. While these products have high shipment volumes, the power requirements are generally low and the existing EPS and battery charger equipment is relatively efficient. As a result, the savings from these products accounts for only 748 GWh per year, or 11% of the total savings.

The proposed battery charger and EPS standards will have little effect on many home entertainment and computer products because existing EPS efficiency standards are fairly stringent. While energy savings resulting from proposed battery charger and EPS standards for video game consoles, notebook computers, LAN equipment, and digital picture frames was estimated at more than 950 GWh per year, this represents only 3% of their total baseline energy consumption. These products are used heavily and draw significant amounts of power, and because they also have high shipment volumes and relatively long lifetimes, they consumed the most energy of all the MELs that we analyzed.

Because the energy consumption of home entertainment and computer peripheral products is strongly affected by their use, it is extremely important to develop accurate usage profiles to inform efforts to improve efficiency. Many of these products have low-power and

maintenance modes that can reduce power consumption significantly, so annual energy consumption can differ widely among users based on their usage patterns. For each product, this analysis estimated an average usage profile among all consumers based on available data, but further research is needed, especially for the products with the largest installed base.

Based on the results of this analysis, upcoming state and federal efforts to improve the efficiency of personal computers and video game consoles are warranted. All home entertainment and computer peripheral products should be investigated in greater depth to determine how they are used, how much energy they consume in practice, and how they can be made more efficient while still maintaining utility for consumers.

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