Leaking Electricity in Domestic Appliances

Alan Meier and Karen Rosen
MS 90-2000, Lawrence Berkeley National Laboratory
University of California, Berkeley, CA 94720
Tel: (510)486-4740; Fax: (510)486-4673

Abstract—*Many types of home electronic equipment draw electric power when switched off or not performing their principal functions. Standby power use (or "leaking electricity") for most appliances ranges from 1 - 20 watts. Even though standby use of each device is small, the combined standby power use of all appliances in a home can easily exceed 50 watts. Leaking electricity is already responsible for 5 to 10 percent of residential electricity use in the United States and over 10 percent in Japan. An increasing number of white goods also have standby power requirements. There is a growing international effort to limit standby power to around one watt per device. New and existing technologies are available to meet this target at little or no extra cost.*

INTRODUCTION

A surprisingly large number of appliances – from TVs to air conditioners – continue to consume electricity even after they have been switched off. Other appliances, such as cordless telephones, remote control garage door openers, and battery chargers have no “off” switch, and draw power even when they are not performing their principal functions. The energy used while an appliance is switched off or not fulfilling its primary purpose is called “standby power” or, more generally, “leaking electricity.” This power consumption allows TVs, VCRs, and garage door openers to be ready for remote control signals, microwave ovens to display digital clocks, and fax machines to become active when the telephone rings.

Each appliance “leaks” anywhere from less than one watt to over twenty watts. While these individual values are small, a typical American house has a dozen such appliances, which together use about 50 watts of standby power. (For comparison, a new refrigerator consumes about 60 watts when active.) This corresponds to 5% of total residential electricity use. Nationwide, leaking electricity requires the operation of eight large power plants that emit roughly twelve million tons of carbon into the atmosphere every year. This problem is not confined to the United States. Indeed, an even greater proportion of Japanese residential electricity is used for standby mode (about 13%) and European countries appear to be close behind the United States.

In this paper, we review the causes of leaking electricity in consumer electronics and white goods, and summarize measurements that others and we have made. We also discuss opportunities to reduce this consumption. Details of many of these topics, plus more recent information are available on the worldwide web [Rosen and Meier (a), 1999].

WHY DO APPLIANCES USE STANDBY POWER?

Despite the diversity of appliances with standby losses, relatively few components are actually responsible for standby functions. Standby losses are commonly caused by components such as microcontrollers, infrared sensors, memory, and clock displays that must continuously draw power to maintain the benefits of certain appliance functions that consumers have come to expect. A large portion of standby losses can also be attributed to power supplies, which must be active to power these standby components. Figure 1 shows a generic appliance with possible locations of standby losses identified.

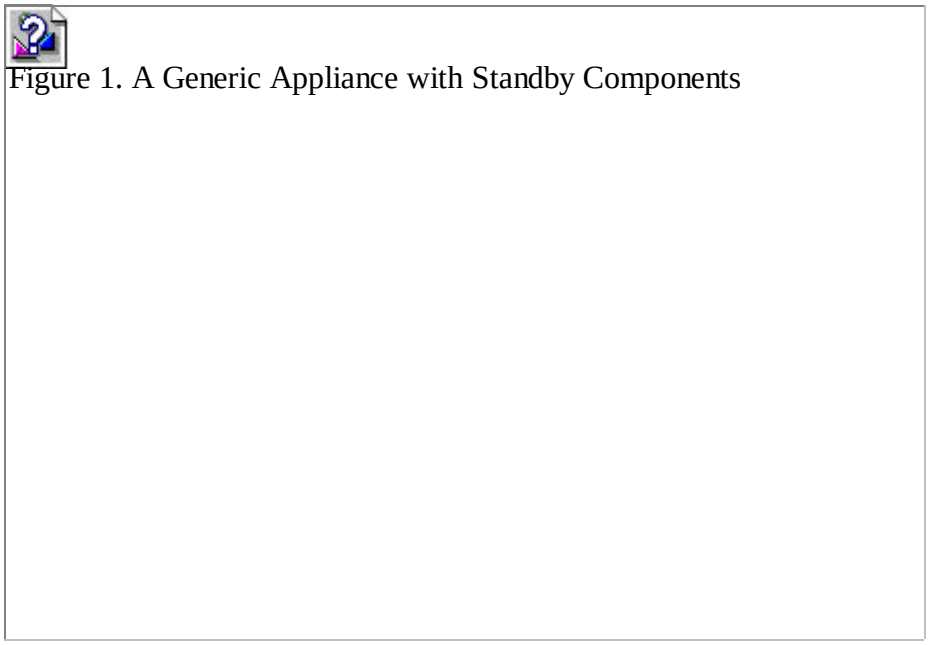

Figure 1. A Generic Appliance with Standby Components

When an appliance is in standby mode, power losses occur whenever current flows from the source through the power supply to provide power for standby functions performed by the components of the appliance circuitry. If the appliance needs power in standby mode, therefore, at least the power supply must be active. This nearly always generates some losses, the magnitude of which depends on the efficiency of the power supply. For each additional component that receives power, more losses accrue.

The most common devices with standby losses are small appliances that rely on external AC/DC adapters, sometimes called "wallpacks" or "bricks." These external power supplies convert the mains' 118-volt AC power to low-voltage DC power. Some appliances that are commonly shipped with wallpacks include cordless phones, battery chargers, carbon monoxide sensors, and telephone answering machines. These power supplies usually draw 0.5–3 watts even when the appliance has been switched off.

Standby Power Measurements of Consumer Electronics and other Small Domestic Appliances

Leaking electricity in the consumer electronics category has perhaps received more attention than in any other appliance category. This category includes TVs, VCRs, and many different types of audio and telephony products. Presently, consumer electronics are responsible for the majority of leaking electricity

in homes. The standby energy consumption of these devices often matches or even exceeds the active energy use. In a few cases, the device's "off" power consumption was nearly the same as when switched "on." Other small appliances, such as battery-charged devices, appear to be responsible for a smaller amount. Results of an ongoing power measurement campaign are summarized in Table 1. Below, we describe measurements of the major leaking appliances.

Table 1. *Standby Power Use of Selected Residential Appliances*

	Minimum	**Average**	**Maximum**
Audio			
Portable Stereo	0.7	2.2	3.2
Compact system	1.3	9.7	28.6
Component System	1.1	3.0	15.1
Radio	0.9	1.7	3.2
Video			
TV	0.3*	4.5	21.6
VCR	1.5	5.9	12.8
TV/VCR	1.1	7.6	19.5
Set-top			
Cable Box	4.6	10.8	24.7
Satellite Receiver	8.8	12.6	18.8
Video Game	0.9	1.3	2.0
Telephony			
Answering Machine	1.8	3.0	5.2
Cordless Phone	1.1	2.6	5.0
Home Office			
Personal Computer	0.5*	1.7	3.5
Modem, analog	1.0	1.4	1.8

*Appliances with no standby losses are excluded.

Among consumer electronics, the TV and VCR sub-category has the highest standby power consumption. Together, TVs and VCRs are responsible for about 3.6% of U.S. residential electricity use. Of that, standby power accounts for 23% of TV energy consumption, 55% of VCR energy consumption, and a full 1% of total national residential electricity consumption (Rosen & Meier (b), 1999). In televisions, these losses can be attributed to the remote control and instant-on features, while in VCRs, these losses are results of several functions, including remote control capability, memory, and clock displays.

Audio equipment is a diverse category, but our investigations indicate that they consume about 10 TWh/yr, about 70% of which is used during standby. An increasing fraction of audio products have remote control, hence assuring standby power consumption. Most separate components draw less than 3 watts each in standby mode, but they use considerably less than the sum of their parts if components are

plugged into the amplifier instead of directly into an outlet.

Set-top boxes include all units that are used in combination with the television set. Some of the most common set-top boxes are cable boxes, satellite receivers, Internet appliances and video game units. Excluding video game units, these devices have unusually high standby losses of about 15 watts each. In many cases, switching the units off does nothing more than turn off the "on" light, which has a negligible effect on power draw.

Battery-charging devices include not only alkaline, nickel cadmium (NiCd) and lithium battery chargers, but also small portable appliances that are powered solely by battery. Such appliances include cell phones, personal stereos, electric shavers and toothbrushes, and portable drills, lawnmowers and vacuums to name a few. These devices have standby losses for two reasons: there is no off switch to stop the current from reaching the transformer (no-load losses), and (2) some battery chargers do not reduce the current once the battery is fully charged.

NiCd battery chargers are particularly inefficient in this respect because there is no immediate penalty for overcharging NiCd batteries, whereas lithium batteries, for example, will explode when overcharged. While battery charger transformers consume power at a rate of 1 to 3 watts, overcharging tends to draw 5 to 40 watts, depending on the device.

Small kitchen appliances such as blenders, bread makers, rice cookers and toasters are now available with soft touch controls, microprocessors and displays, placing them among our database of leaking appliances. These appliances typically draw from 1 to 3 watts.

As prices of computer equipment continue to plummet, PCs, external modems, phone/fax/copier combos, and scanners are becoming more and more common in the residential sector. While most draw less than 3 watts in standby, some, including phone/fax/copiers and some printers draw significantly more. An increasing fraction of these appliances do not even have off switches. This category of appliances is constantly changing but standby power continues to rise. For example, digital modems, which are expected to replace the now common analog modem, use 10 to 15 watts even when not connected to the network.

Until the 1990's, most telephones received all the power they needed from the phone line. Now, cordless phones, and phones with answering machines are the norm – and each comes with its own power cord and AC/DC adapter. Most of these appliances draw between 1 and 5 watts each in standby, but since most homes have more than just one, we estimate that telephony accounts for about 4 TWh/yr nationally.

Leaking Electricity in White Goods

To date, most of the effort to reduce standby power use in residential appliances has been directed towards consumer electronics and small appliances. While these are presently the largest "leakers," white goods are expected to become increasingly important as well. White goods are beginning to have standby power use because of wider use of:

- digital displays
- remote controls
- standby functions requiring microprocessors
- soft-touch keypads

In addition, manufacturers are planning to make their appliances network-ready, which will also require standby power. Table 2 summarizes limited measurements of standby power use of white goods in the United States, Japan, and Europe. These measurements are not representative but do show that an increasing number of appliances have standby losses.

Table 2. Standby Power Use in White Goods

Appliance	**Average Standby Power Use (Watts)**
Air conditioners	
-Mini-split (w/ remote control)	2 – 5
- Room	> 2
Clothes Washer	0 – 3
Clothes Dryer	0 – 3
Dishwasher	0 – 4
Microwave oven	0 – 3
Range	0 – 3
Refrigerator/Freezer	0 – 3
Gas heater (Japan)	2 – 3
Water Heater (gas, Japan))	4 – 8

Most energy test procedures test the appliances while they are in steady-state mode and ignore off-cycle energy consumption – refrigerators and freezers are the exceptions. As a result, the energy consumed during off-mode operation does not get included in energy labels nor is it considered in current energy efficiency standards. Test procedures will probably be modified to include off-mode consumption in the near future. If these changes do occur, then there will be an incentive to reduce standby energy use.

Opportunities to Reduce Standby Losses

It is technically feasible to significantly reduce standby power in nearly all cases. Some of the simplest strategies are:

- Improve the efficiency of power supplies (AC to DC conversion) to reduce no-load losses
- Avoid energizing circuits and components not needed while in standby
- Use energy-efficient components and power management software

These strategies are discussed in greater detail by in previous papers [Meier, Huber and Rosen 1998].

The most promising strategy is improving the efficiency of the power supply. New power supplies are available with no-load losses of only 30 milliwatts (0.03 watts) [Power Integrations, 1999]. The incremental cost of using efficient power supplies is very small and, in some cases, zero [The Cadmus Group, Inc. 1998].

Since the components that are actually energized during standby rarely consume more than 0.5 watts, it appears that most appliances can operate in standby mode on less than 1 watt. Certain networked appliances may use more because they must upload or download information (active standby mode) for long periods of time.

Programs To Reduce Leaking Electricity

Several voluntary programs in the United States and elsewhere are underway to reduce standby power consumption in appliances. The U.S. Environmental Protection Agency (EPA) and Department of Energy

(DOE) operate the Energy Star program for TVs, VCRs, audio equipment, and computers.

In 1998, participating manufacturers began producing Energy Star® compliant TVs, VCRs, and TV/VCR combination units, which meet the EPA's standby limits of 2, 3, and 4 watts, respectively. The EPA and audio manufacturers have now agreed on standby limits for Energy Star® compliant audio equipment. Until the year 2002, audio equipment standby requirements must be 2 watts or less. After 2002, this limit will be reduced to 1 watt.

Internationally, Europe's Group for Efficient Appliances (GEA) worked closely with industry to develop their criteria for receiving the GEA-label. The agreed upon criteria are 3 watts for TVs and 4 watts for VCRs by 1999 [GEA 1999]. In Japan, the Ministry of International Trade and Industry (MITI) has informally requested that Japanese appliance manufacturers voluntarily reduce standby power to 1 watt.

Finally, discussions are underway to coordinate an international effort to reduce standby power in appliances. International actions would include coordination of test procedures, equipment covered, levels and a timetable. While no specific levels have been selected, many parties believe that it will be near 1 watt for most appliances.

Conclusions

A large number of consumer electronics and white goods continue to consume electricity even when they are not active. While individual power losses are small, appliances in a typical American house use about 50 watts of standby power. In the U.S., standby power use comprises about 5% of total residential electricity consumption. We believe that it is technically feasible and economically viable to significantly reduce standby power in nearly all appliances. Several voluntary programs to reduce standby power consumption are already underway in the United States, Europe and Japan, and discussions are currently underway to coordinate an international effort.

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