A Worldwide Review of Standby Power Use in Homes

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Abstract—**Standby power use is the electricity consumed by appliances when they are switched off or not performing their primary purpose. Results from 21 separate field studies of residential standby power use and eight bottom-up national estimates of standby power use in 17 countries were compiled. Average standby power use in the field measurements ranges from about 30 W in China to over 100 W in New Zealand and the United States. The weighted average of the measurements was about 50 W. The bottom-up estimates found that standby power was responsible for 3–12% of residential electricity use. There is insufficient information to determine if standby power use is increasing or declining.**

Index Terms—**standby power, leaking electricity, whole-house measurements, bottom-up estimates, new-product measurements, appliances, residential electricity use.**

I. INTRODUCTION

STANDBY power use is the electricity consumed by appliances and other equipment when they are switched off or not performing their primary purpose. The most common occurrences of standby power use are in TVs and video equipment using remote controls, electrical equipment with external low voltage power supplies (such as cordless telephones), and devices with continuous digital displays (such as microwave ovens). The actual power draw in the standby mode is small, typically 0.5–10 W [1]. However, standby power consumption occurs 24 hours per day and is present in many new appliances. These small consumptions together represent a unique and significant use of energy. Recent estimates of standby use range from 3–10% of residential electricity use, depending on the location and assumptions [2]. Standby power use in commercial buildings (from office equipment, appliances, and building-related equipment) also exists but has not been studied.

Standby power use is also uniquely international in nature because many of the devices responsible for standby power use (TVs, VCRs, mobile phones, computers, etc.) are deeply connected to international trade. A computer, for example, may be designed in the United States, assembled in China, using parts from Japan and Korea, and sold in Europe.

Estimates of standby power use and savings opportunities are based on just a few, scattered measurement studies of homes (and essentially none for commercial buildings). These measurements are sufficient to roughly quantify the size of standby power use in that particular region, but they are inadequate for other purposes. More complete information is needed to answer these questions:

- What is the overall size of standby (nationally and globally)?
- What are the key contributors to standby?
- Is standby growing or declining?
- What are the potential savings from reducing standby?
- Are present policies to reduce standby succeeding?

These questions are important to answer because many governments have already begun large programs to reduce standby. For example, the United States, along many other partner countries, have invested heavily in the *Energy Star* program [3] to reduce standby power in consumer electronics (and encourage use of low-power, sleep modes in office equipment). Australia has formally adopted a "1-watt plan" to reduce standby power [4] and other countries, such as China, are now seriously considering their own programs [5]. Finally, reducing standby power may be one of the first opportunities for coordinated international action in the framework of global climate protection.

For these reasons, it is important to have an accurate description of standby power. It is unlikely that there will be a coordinated international estimate; instead, it will be necessary to rely on careful compilations of local investigations. One such compilation was prepared by Lebot et al. [2] in 2000. Measurement activity has greatly increased since then, both in number and quality. This paper includes the older measurements but also adds many newer ones including, for the first time, measurements in less developed countries.

II. TYPES OF STUDIES

Standby power use has been estimated in three separate ways:

- Whole-house measurements
- Bottom-up estimates
- New-product measurements

Details of the three methods are described below

Whole-house measurements involve visiting a home and measuring the standby power use of every device consuming standby power. These consumptions are tabulated and reported for each home. Measurement teams sometimes compare the sum of their measurements to the consumption

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shown on the utility meter when all appliances have been switched "off" [6]. This provides a means of confirming that no appliances were overlooked. By monitoring a representative group of homes, a survey can establish a reasonably accurate and highly credible estimate of standby power use in that region. The problem, however is to develop a representative group of homes; most surveys rely on volunteers.

It is easy to overlook devices drawing standby power in homes. Most surveys made sincere efforts to measure all the devices but excluded a few because they were either too difficult to access (and the teams did not want to inconvenience the residents) or the teams simply failed to find all of the devices. For example, in the Colorado survey [7], all of the homes had clock-controlled garden sprinklers (each with a large external power supply). The survey team did not notice them until after they had finished measuring four of the five homes. Other frequently overlooked devices included security systems, garage door openers, and exercise equipment. Some surveys, such as those undertaken in China [8], focused on the large appliances–TVs, VCDs, computers, etc.—and did not measure some of the smaller sources of standby power use. These omissions and oversights mean that actual standby power use was probably larger than reported.

It is also easy to be inconsistent with respect to defining and measuring standby power. A New Zealand [9] and a few European surveys [10-12] included the energy consumed by heated towel racks and electric water heaters. There is no consistent definition of standby power in a refrigerator, so its contribution can either be absent or a significant fraction of the total. Virtually every survey accidentally (or deliberately) included some computer-related equipment in sleep modes (rather than off-modes). These actions will result in a higher estimate of standby power. Most of the careful studies describe the operating mode of the appliance when the standby power measurement was performed so that a reader understands the elements of the standby measurements.

Bottom-up estimates of standby power use are used to estimate either average standby per home or national standby power consumption. The estimate is based on measurements of standby in specific appliances and then multiplied by the average saturations of those appliances. For example, fifty measurements of TVs may show that the average standby power use is 4.0W. If the average home has 2.3 TVs, then the average home would have 9.2W of TV standby. The average house's standby power use would be assembled from the combination of field measurements of standby power and known appliance saturations.

The bottom-up estimate is accurate for common appliances (where there are typically large numbers of measurements and saturations are well known) but fails for minor appliances (where much of standby power use occurs). There is little information about the saturations of cordless phones, garage door openers, coffee makers, etc. As a result, bottom-up estimates probably underestimate actual standby power use.

In at least three countries (China [8], Argentina [13], and the United Kingdom [14]), surveys have reported that occupants unplug appliances when not in use. Annual standby energy use in these cases will be less than predicted by simple multiplication of installed power by the number of hours per year. Unfortunately, there are no reliable surveys of consumer behavior. Lin et al. [5] estimated the energy impact of different scenarios for China and found huge uncertainties in the final estimate of standby energy use. Anecdotal evidence in China suggests, however, that the trend is toward keeping appliances plugged in all the time.

New product measurements involve visiting a store or factory and measuring the standby power use of many new products at one time. This is an excellent technique to quickly assess levels of standby; however, the results may not match in-home measurements. New TVs in Europe [15] and Japan [16] consume far less standby power than those found in homes. It will take many years for the performance of the entire stock to catch up with the performance of the new products. Some organizations, such as the Energy Conservation Center of Japan [16], the Group for Energy Efficient Appliances [15], the U.S. Department of Energy [17] and the Energy Star Program [3] collect standby power measurements (submitted by manufacturers) and post them on the worldwide web.

A. Whole House Measurements

Twenty-one surveys of whole-house standby power consumption were compiled. Together, these surveys represent measurements of over one thousand homes around the world. These are listed in Table 1. About half of the studies listed

TABLE I
WHOLE-HOUSE MEASUREMENTS OF STANDBY POWER

Country/Region [Reference]	Homes	Year	Standby Power (W)	Standby Energy (kWh/yr)
Australia [18]	64	2000	87	760
Australia [19]	1	2001	112	980
Canada/Nova Scotia [20]	79	2001	38	329
China/Beijing [8]	42	2001	33	n.a.
China/Guangzhou [8]	115	2001	35	n.a.
Denmark [21]	100	2001	60	530
France [11]	178	1999	38	235
France/Paris [22]	1	1999	70	600
Greece [21]	100	2001	50	440
Italy [21]	100	2001	57	500
Japan [23]	36	1997	60	530
Japan [24]	42	2000	45	398
Japan/Tokyo [25]	1	1999	80	700
New Zealand [9]	29	1999	100	880
New Zealand/North Island [26]	1	2001	125	1100
Portugal [21]	100	2001	46	400
Sweden [27]	1	1997	80	475
United Kingdom [14]	32	2000	32	277
USA/California [6]	10	2000	67	590
USA/California	4	2001	115	1010
USA/Colorado [7]	5	2001	46	405

here have not yet been reported in the literature. The largest survey involved 178 homes in France [11], followed closely by China [8] and several European countries. Six studies involved more than one hundred homes. Fewer than twenty whole-house measurements have been conducted in the United States. Studies consisting of measurements in a single home occurred in several countries.

The results are not fully comparable because each survey's measurement procedure differed in important details. Most studies defined standby power as the minimum power of a device while still plugged into the electrical mains. Thus, if the device has a hard-off switch, standby power use would be zero. (Other opportunities for differences are described above.) These differences will generally be small.

Average standby power use ranges from over 100 watts in New Zealand and the United States to about 30 W in China. The weighted average of the measurements was about 50 W. (Future studies will also include a population weighting.) The high values are somewhat misleading because these studies consisted of relatively few homes. In addition, the New Zealand measurements captured several heaters and defective appliances. The data can be more easily interpreted in Figure 1.

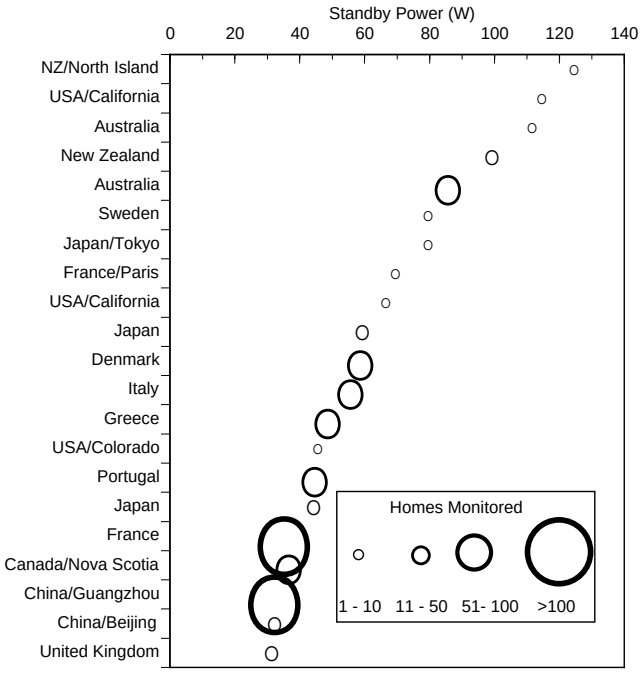

Figure 1. Summary of whole-house measurements. The size of the symbol corresponds to the size of the survey.

B. Bottom-Up Estimates

Eight bottom-up estimates of standby power use were compiled. These are listed in Table 2. Standby power appears to range from 7–86 W, corresponding to 3–12% of residential electricity use. Some of the estimates (such as those for Argentina and Switzerland) did not include all appliances, so these estimates are certainly lower than the actual situation. The Australian estimate, at 86 W, presumably excludes heat-generating appliances found in the field measurements, but Australia still appears to have the highest national level of standby power.

TABLE 2
BOTTOM-UP ESTIMATES OF STANDBY POWER USE

Country (year) [Reference]	Average Standby per Home (W)	Fraction of Total Residential Electricity Use	Other Items Included after TVs, VCRs, set-top boxes
Argentina (2000) [13]	7	3%	None
Australia (2000) [18]	86	12%	All and included a few heating devices and defective units
Canada (2001) [20]	41		All
France (2000) [11]	38	7%	All
Germany (2001) [10, 12]	52	n.a.	All and may include some heat standby
Netherlands (1995) [28]	37	10%	None
Switzerland (1999) [29]	19	3%	Stereos, some rechargeable appliances, PCs
USA (1996) [30]	50	5%	All

III. DISCUSSION

These compilations give a global perspective on standby power use. Some examples are given below.

The individual surveys revealed the number of appliances with standby in the homes. U.S. and Canadian surveys found about 20 appliances with standby in each home. Urban Chinese homes had about 11 appliances with standby power. In all three cases, this corresponds to roughly 3 W per device. This rule of thumb appears to be surprisingly robust.

Inspection of the detailed data from each country suggests that standby power use of common appliances (TVs, VCRs, etc.) is higher in less developed countries (China and Argentina) than in the developed countries. This appears to be a caused by less efficient appliances and older appliances. Nevertheless, several large power plants could be eliminated simply by lowering the standby power use of Chinese TVs (for example) to levels found in Japan.

The European situation with respect to standby is now unusually well documented, through several large surveys. Standby in those countries accounts for 30–60 W. But three large regions have essentially no information about standby power: South Asia (India, Pakistan, etc.), South America, and Africa. It is not necessary to have comprehensive data but important variations appear in various countries that may influence policies to reduce standby. China has two unique aspects: the high saturation of unique video compact disk players (VCD) and an unusually high fraction of time when the appli-

ances are unplugged.

Is standby power use increasing or declining? The information presented here is not sufficient to determine trends. New TVs, VCRs, and a few other appliances have significantly less standby power use than older models. These new models are clearly beginning to lower in-home standby power use. It appears that Japanese homes are now experiencing a decline in standby power use [24]. In the rest of the world, the simple number of appliances with standby power continues to increase. New appliances, such as DVD players, are appearing that consume standby, and updated models of older, traditional appliances, such as rice cookers, washing machines, and toilets, now have standby power consumption. The net effect of these trends is probably a continuing increase in global standby power use.

Standby power is also important to understand because of its contribution to a home's energy use. The growth of standby power reflects a trend in residential energy use, from a situation where appliances are either "on" or "off," to appliances being always "on," but at different modes. This trend greatly complicates the practical aspects of monitoring a building. Operating hours and cycles becomes less of an indicator of energy use and electricity consumption is distributed among many more appliances. In a more general sense, the rise in standby power (and the appliances that consume it) will make it more difficult to understand how occupants use energy in a building.

IV. Conclusions

We presented the results of 21 surveys of residential standby power use in countries and regions around the world and eight bottom-up national estimates of standby power. Each of the studies is unique and not completely comparable. But after understanding the limitations of each of these study, they give a good perspective on the size and composition of standby power use in homes. Standby power use is a small fraction of total electricity use and is distributed among many appliances. In spite of the low power use and dispersed nature of standby, it is possible to substantially reduce standby power. Collectively, the savings can be large. The opportunities in less developed countries appear to be particularly large, even if they replace existing units with the most efficient available in that country.

There is not yet enough information to decide if the developed countries have peaked with respect to standby power use. Some major electrical appliances now use much less standby but those savings may be offset by the simple increase in the number new appliances consuming power while switched off or performing their primary function. Further research similar to that described in this paper is needed to answer that question.

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