Results from the investigations on leaking electricity in the USA

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Synopsis

This paper presents measurements of standby energy consumption of appliances in the residential sector in the U.S.

Abstract

Standby electricity use or leaking electricity is the energy consumed by appliances when they are switched off or not performing their principal function. The combination of field measurements and estimates of appliance saturation suggests that the average U.S. house leaks constantly about 50 Watts. This is approximately five percent of the residential electricity use in the U.S. Leaking electricity falls into three major categories: video, audio and communication. Video equipment such as TVs, VCRs, cable boxes and satellite earth stations account for the largest share of residential leaking electricity, approximately 35%. Audio equipment accounts for 25% of standby consumption, and communication devices (answering machines, cordless phones and fax machines) are responsible for an additional 10%. We present detailed field measurements for TVs, VCRs, Compact Audio Systems, Cable Boxes and Digital Satellite Earth Stations.

There are several different approaches to reduce leaking electricity including: redesigning appliance circuits, replacing linear transformer with more efficient switched mode power supplies, adding an energy saving circuit to the appliance, or simply raising consumer and manufacturer awareness. Redesigning appliance circuits can reduce standby consumption up to 90%. Leaking electricity is likely to increase as a new generation of consumer electronics penetrates the market. To reduce leaking electricity in the future all the possible policies have to be taken into account. This is a global problem and therefore a close international cooperation is important.

1. Introduction

The rapid proliferation of electronic devices, which are consuming electricity in the standby mode or when they are switched “off”, has created a new category of electricity consumption. There are several names for this category, including “standby use”, “minimum use”, and “leaking electricity”. While “standby use” is technically more accurate, the expression “leaking electricity” is rapidly gaining popularity because it is easy to understand. Leaking electricity is a global phenomenon because the largest “leakers” are internationally-traded appliances, such as televisions, audio equipment and cordless telephones.

Researchers in several countries have measured leaking electricity and have reported their results (BEW 1993, NOVEM 1995, Herring 1996, Rainer et al. 1996, Molinder 1997, Nakagami et al 1997). Many of these appliances are virtually identical in all countries because they are manufactured by only a few, large, multinational companies; as a result, data collected in one country often apply to others. Together, these results give us general understanding of the major contributors of leaking electricity and rough estimates of total leaking electricity in the

residential sector. There are nevertheless unique aspects in each country. In this paper, we describe the leaking electricity situation in the United States and present our most recent measurements. In addition, we propose a strategy to reduce leaking electricity in future appliances.

2. Definition

In this paper, we define leaking electricity as the energy consumed by appliances when they are switched *off* or not performing their principal function. Other definitions have been proposed which differ slightly (Nakagami 1997, Molinder 1997). In the future, however, a fairly strict definition may be required. This will be discussed later.

Many appliances have three or more different modes of operation, each with a corresponding level of electricity use. It has become increasingly difficult to determine in which mode an appliance is functioning. The following table shows the differences among the four modes used in this report.

Table 1. Definition of modes

mode	function	leaking electricity
off	no function at all	transformer losses battery overcharging poor design ("internal" on)
passive standby	not performing principal function	ready to be switched on ready to receive information
active standby		additional function support function
on	principal function	not leaking

There is a passive and an active standby. In the "passive standby" the appliance is waiting to be switched on by a remote control or is waiting to receive information. In "active standby" the appliance is performing some additional or support function. There are cases in which these two standby functions are combined.

3. Measurements

3.1 Methodology

Data are from a variety of sources. Spot measurements of standby electricity consumption are from the Florida Solar Energy Center (FSEC), the US Environmental Protection Agency (US EPA) and the Lawrence Berkeley National Laboratory (LBNL). Over 400 appliances were metered in two large retail electronic stores and in fifteen homes. This data were compared with published estimates.

To calculate the saturation of appliances in U.S. homes, a model developed to describe residential miscellaneous end use was applied. The model is based on historic shipment data from *Appliance Magazine* or reported saturations from *Appliance Magazine* and the U.S. Department of Energy's *Residential Energy Consumption Survey* (RECS).

Standby losses can be described analytically as follows:

$W_{sb} = P_{sb} \times t_{sb} \times s \times n$

W_{sb}: Standby losses in terms of watt-hours per day or year

P_{sb} : Effective output consumed, watt

t_{sb}: Time in the standby mode

s: Saturation in % ofU.S. households

n: Number of households

3.2 Results

Thirty three different types of appliances were metered. Table 2 shows a list of the 10 major leaking appliances. They account for about 70 % of all standby power consumption in the residential sector. There are 98 million households in the U.S.

Table 2. Top ten appliances with leaking electricity

End Use Name	Millions of Units	Standby Power (W)	Total Standby Loss (TWh/year)
TV set	186	4.0	5.4
VCR	120	5.6	4.9
Compact Audio	53	10.6	4.7
Cable Box	58	11.6	3.7
Rack Audio	55	7.0	3.2
Microwave Oven	78	3.1	2.1
Battery Charger	98	2.4	2.1
Answering Machine	66	3.3	1.9
Clock Radio	105	2.0	1.8
Cordless Phone	61	2.8	1.5

4. Field Measurements

Even though many different appliances have standby losses, only a few appliances account for most of the residential standby losses. We present below field measurements for the four largest leaking appliances. The measurements show the range in standby losses in addition to the potential for energy savings as the stock turns over. For clarity of presentation, we present only selected data rather than all of our measurements. The model and manufacturers are listed, but one should not infer that any particular manufacturer is more efficient than another; a different selection of measurements could have easily reversed the rankings.

Most of the appliances measured were manufactured in the last two years. However, we have also included a few measurements of older units to illustrate the trends in standby losses and the potential for energy savings. We also charted the shipments of each appliance to demonstrate the national energy impacts.

4.1 Televisions

Televisions have the highest amount of standby losses of any electronic appliances. Our measurements indicate a standby electricity consumption of 5.4 TWh per year. There are approximately 186 million Televisions in the U.S. corresponding to a saturation of 1.9 per household. Sixty-five Televisions were metered. The range for the standby power is from 0.5 to 12.3 Watts with the average at 4.0 Watts. Figure 1a shows the electricity consumption in the standby mode compared to the on mode in kWh per year. The average usage time is assumed at 4 hours per day.

Figure 1a. Energy consumption in the standby and on mode

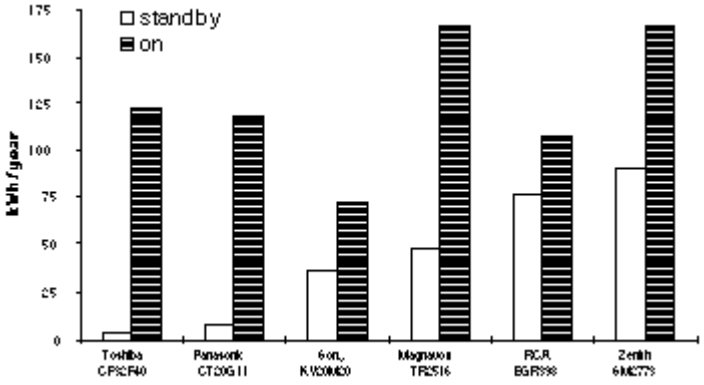
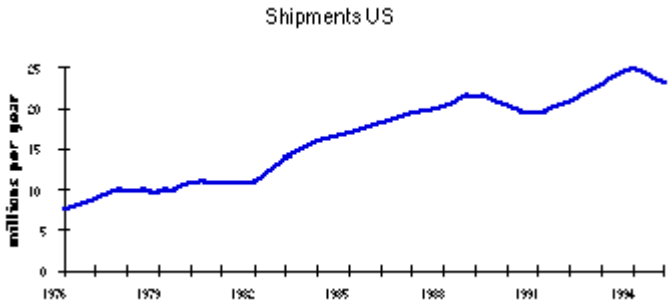


Figure 1b. Shipments from 1976 to 1995



4.2 Video Cassette Recorder

The second largest leaking appliances are VCRs with 4.8 TWh per year. There are approximately 120 million VCRs in the USA. Data were collected for 69 VCRs. The range of the standby power was from 2.0 to 12. 8 Watts with an average at 5.6 Watts. Figure 2a shows a comparison of different models.

Figure 2a. Comparison of standby and on power of VCRs

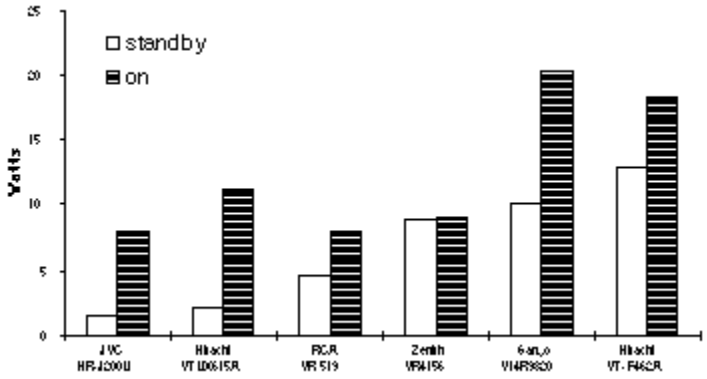
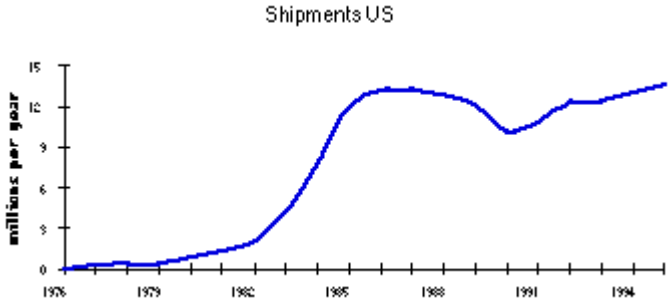


Figure 2b. VCR shipments from 1976 to 1995



Leakage rates for new Televisions and VCRs are likely to fall rapidly due to the EPA Energy Star programs.

4.3 Compact Audio Systems

These are audio systems where all components are in one common housing. A typical unit consists of an amplifier, CD player, cassette deck, radio and a clock. Thirty six different compact audio systems were monitored. Nationally, Compact Audio Systems leak about 4.7 TWh per year, making them the third biggest leaker in the U.S. Figure 3a shows a sample of appliances.

Figure 3a. Comparison of Compact Audio Systems

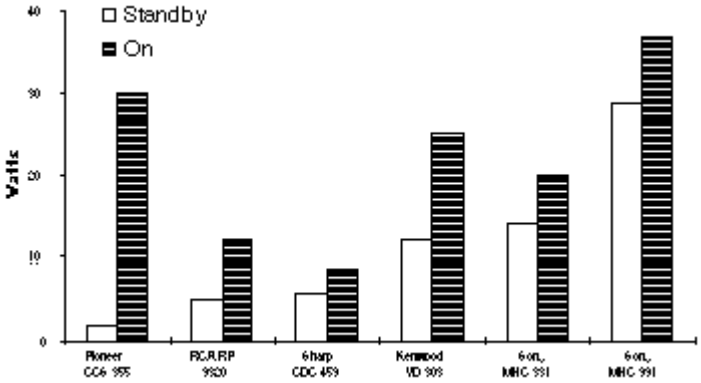
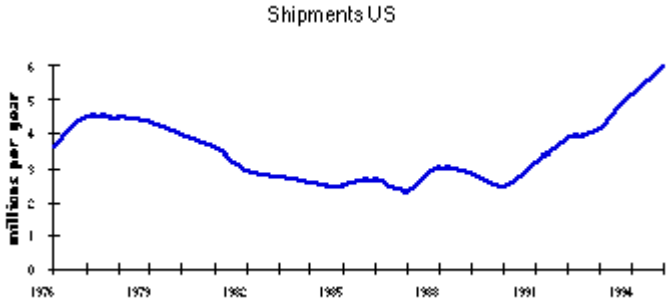


Figure 3b. Shipments from 1976 to 1995



There is a wide range in the standby mode among compact audio units from 2.1 up to 28.6 Watts, even though the features were essentially the same. For example, all appliances showed the time constantly. (The only exception was the one with the lowest standby power. This appliance could be set up to show the time on request.)

4.4 Cable Box

The fourth largest consumer of standby power are cable boxes with 3.7 TWh per year. The stock of cable boxes is approximately 45 million units. Most of them are cable television boxes but in the future, there might be also more multi-media boxes and digital music boxes. Seventy five percent of all cable television subscribers have a cable box. Even though an increasing fraction of televisions are manufactured “cable ready”, the number of cable boxes is unlikely to decline. The boxes are still needed for new features such as “pay per view”. There were 7 different units metered with a range of the standby power from 4.8 to 18.0 Watts and an

average of 11.6 Watts. Figure 4a shows a comparison of the energy consumption of different cable boxes.

Figure 4a. Comparison of the standby and on mode

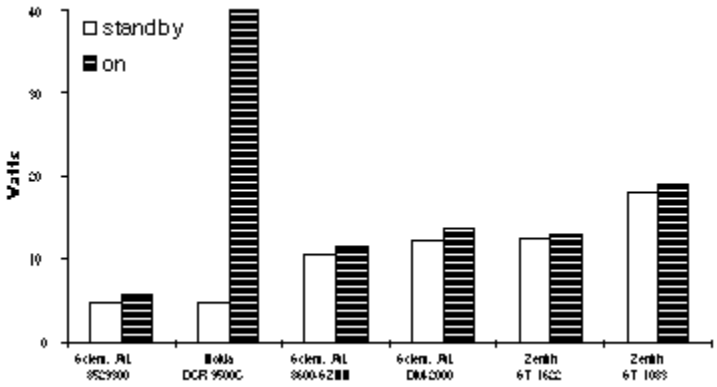
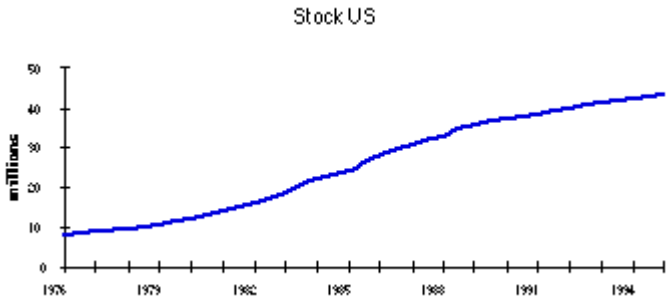


Figure 4b. Stock from 1976 to 1995



* The data for the Nokia DCR 9500 multi media box are from the manufacturer.

** Scientific Atlanta DM-2000 is a cable box for digital music.

4.5 Digital Satellite Receiver Box

The rankings presented in Table 2 are undergoing rapid change as the leakage rates in some appliances are cut and new appliances suddenly appear. We present here measurements of an appliance with standby losses that is experiencing rapid sales growth. Satellite receiver boxes are becoming very popular in the United States. Our measurements suggest that their standby losses range from 11.3-18.4 Watts. We expect that these units will soon become one of the largest leakers.

Figure 5a. Comparison of the standby and on mode

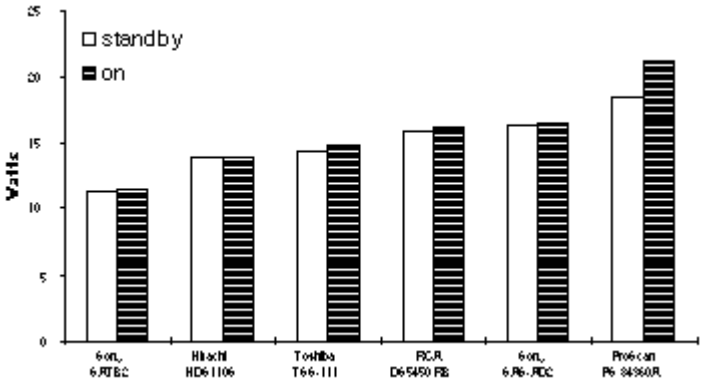
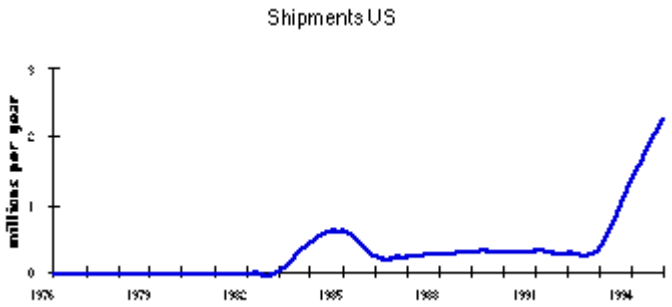


Figure 5b. Shipments from 1976 to 1995



There is almost no difference in the power level between the standby and the on mode.

5. Discussion of Measurements

These appliances are very similar to those sold in Europe and Japan, so the measured results are essentially same. The differences are principally in the ranking, the trends, and the presence of some appliances that are unique to the United States.

Televisions and VCRs are the largest leakers. We expect their contribution to fall rapidly as new machines, with much lower standby losses, gradually replace existing units. In addition the Energy Star programs will lower rates for new TVs and VCRs.

For both TV cable boxes and satellite receiver boxes, we observed almost no difference in power consumption between the on and off modes (when set by the remote control). It appears that switching off these appliances does nothing more than turn off the digital display and the "power" light; all of the internal circuitry remains energized.

The high standby consumption by compact audio equipment surprised us. At the same time, we found some units providing the same service while drawing a fraction of the standby energy. The wide range in consumption suggests that modest design improvements can greatly reduce leaking electricity.

We have few measurements for home computers and peripheral devices. (There are almost equally large uncertainties in the power consumption and operating schedules for computer equipment.) We took data of power consumption from previous work (Koomey et al. 1995). For

operating schedule we assumed that computers used as home office (20% of computer in the residential sector) are used in the same way than computers in offices. In addition, we have not included leaking electricity from equipment in the commercial sector.

New appliances are constantly appearing. We believe that chargers for cellular telephones will soon be a significant leaker. Re-chargeable lawn mowers are being encouraged because they emit less air pollution than gasoline units. Recent measurements suggest that the charging unit leaks up to 30W. We expect other appliances, such as home digital satellite systems, to become more important sources of leaking electricity.

6. Technical Options to Reduce Leaking Electricity

Most of the sensors, displays, and memories need much less than one Watt. Unfortunately, the power supplies are inefficient and consume many times more power. We believe that it is now technically practical to reduce standby losses to less than one Watt. One or more of the following technologies could be employed to achieve the 1-Watt goal:

- improve the efficiency of the low-voltage transformer
- move the power switch to the high-voltage side
- energize only the components needed for the standby services
- install "smart" recharge circuit in rechargeable appliances

At least one company has developed more efficient low-voltage transformers. They easily achieved the 1-Watt ceiling for the three appliances measured with a new, switching power supply. The switchers cost only a little more than the popular linear power supplies and will soon be competitive in almost all situations.

Moving the switch to the high-voltage side is a simple measure, but can only be applied in some situations. The advantage is that the appliance is "off" but the disadvantage is that it can't perform any services. Finally, smarter re-charge circuits could greatly reduce battery overcharging and switch off power completely after re-charge is complete. Some circuits performing these tasks already exist and others have been proposed.

Together, these technologies could reduce leaking electricity by over 75% with little increase in first cost and probably life cycle savings to the consumers. Some technical problems certainly exists—such as radio interference by switching power supplies—but non appear insurmountable.

The 1-Watt ceiling may be achieved in most appliances with a combination of incentives and labels. However, a clear technical definition of leaking electricity still needs to be developed. There are also situations where the 1-Watt ceiling is not yet achievable, so further research will also be needed.

Acknowledgments

This work was supported by the Assistant Secretary for Energy Efficiency and Renewable Energy of the U.S. Department of Energy under Contract No. DE-AC03-76SF00098.

References

BEW 1993, "Die heimlichen Stromfresser", Bundesamt für Energiewirtschaft (Federal Office of Energy, Switzerland), BEW- Schriftenreihe, Studie Nr.51

Herring, Horace 1996, "Standby Power Consumption in Brown Goods: A Case Study of HI-FI Equipment", The Open University, EERU Report No. 73, UK

Koomey, Jon, Mary Ann Piette, Mike Cramer, Joe Eto 1995, "Efficiency Improvements in U.S. Office Equipment: Expected Policy Impacts and Uncertainties," Lawrence Berkeley National Laboratory. LBL-37383

Molinder, Olof 1997, "Study On Miscellaneous Standby Power Consumption of Household Equipment", Omvärden Konsult AB, EU-DG XVII, contract 4.1031/E/96-008

Nakagami, Hidetoshi, Akio Tanaka, Chiharu Murakoshi 1997. "Stand-by Electricity Consumption in Japanese Houses", Jyukanko Research Institute, Japan

NOVEM 1995. "Study of Standby Losses and Energy Savings Potential for Television and Video Recorder Sets in Europe". Netherlands Agency for Energy and the Environment, Contract EC-DGVII 4.1031/E/95-001

Rainer, D., Steve Greenberg, Alan Meier 1996, "You Won't Find These Leaks with a Blower Door: The Latest in 'Leaking Electricity' in Homes." Proceedings of the ACEEE 1996 Summer Study on Energy Efficiency in Buildings, Volume 1, pp. 1.187-1.191.