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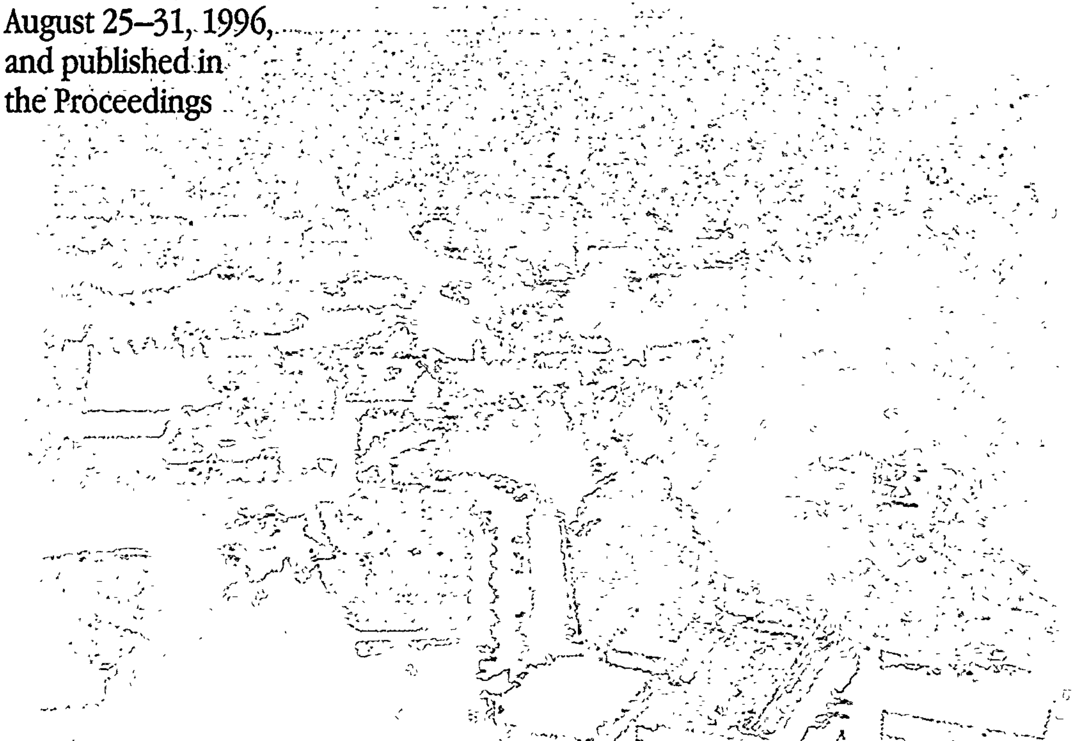

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# You Won't Find These Leaks with a Blower Door: The Latest in "Leaking Electricity" in Homes

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sumption, or (2) direct measurement of each appliance in

average American home based on these measurements and leaks and the opportunities for reducing it. The categories are:

(1) always on

(2) always ready to be on

(3) only wasting

Appliances in the "always on" category provide a service 24 hours/day, such as clocks, thermostats, GFCIs, etc. These appliances have a constant power draw.

Appliances in the "always ready to be on" category are on all the time, but are waiting to provide a service. These include alarm systems and smoke detectors. All electronic equipment with remote controls fit into this category, as do cordless telephones and other rechargeable appliances. These appliances have a low power draw in their quiescent mode, but will typically use much more when the service is being provided. The control for intermittent ignition devices (IIDs) used in some gas appliances such as furnaces also continuously draw power.

Appliances in the "only wasting" category can't be switched off, yet provide no services even when consuming power. Some appliances in this category are cable TV boxes, satellite signal converters, many portable stereos, and electronic equipment with "soft switches."

# TECHNICAL OPTIONS TO REDUCE LEAKING ELECTRICITY

Most leaking electricity is caused, or exacerbated, by the low-voltage power supply. The present power supply technology is typically an unregulated linear power supply. It works reasonably well, is very reliable, and is extremely cheap. These factors must be considered when evaluating energy-saving alternatives.

All options to reduce leaking electricity must save money or offer some other benefit. The incentives to invest in energy saving improvements are severely constrained by the small energy savings. For example, if we assume an appliance lasts 7 years and the electricity it consumes costs $.08 per kWh, a 1 Watt reduction in leaking electricity has a discounted present value of $4.

There are non-quantitative benefits to reduction or elimination of leaking electricity. Elimination of leaking electricity will remove potential fire and shock hazards; when an appliance is switched "off", it is truly off. Much of the electricity has a poor power factor and generally degrades the quality of the electricity for the whole building. In low energy use houses, where leaking electricity can be a large percentage of the total use, lower leakage may permit use of another electricity source, such as a photovoltaic (PV) array.

The heat generated by leaking electricity is either a benefit (in homes requiring space heat) or a cost (in homes requiring air conditioning). Air conditioned homes will suffer a little more because leaking electricity is the equivalent of a small heater operating constantly. The utility benefits from peak power reductions are smaller than the energy savings, about $1 per Watt. (Note that reductions in leaking electricity save peak power regardless of the utility's demand profile.) In any event, investments of greater than a few dollars per Watt saved are unlikely to be cost effective.

There are three approaches to reducing leaking electricity:

(1) eliminate leakage entirely (suitable for category 3 leaks)

(2) eliminate constant leakage and replace with intermittent charge plus storage

(3) improve efficiency of conversion (from 115V AC to low-voltage DC)

Given the diversity of applications with leaking electricity, no single strategy will be universally appropriate. Indeed, the diversity of designs within a single appliance is so great (due to small differences in function), different strategies may even be appropriate for the same appliance.

## Eliminate leakage entirely

On many small electronic devices the power switch is located on the low voltage side of the transformer. This is true for all devices that use a "wall-pack" transformer and even many with line voltage cords due to the lower cost and ease of design with low voltage switches. In addition, manufacturers can get code approval (UL or CSA, for example) by simply using an already-approved external power supply. However, because cheap transformers have high core losses, leaks up to 3 Watts can result. It is relatively easy to reconfigure the circuit such that the off switch is on the high voltage side of the power supply. Indeed, we found that portable stereo/CD players ("boom boxes") were available in both configurations, with no obvious difference in price. Some boom boxes actually had a 3-way switch, with "off", "ready", and "on." It is probably cost-effective for consumers to search out those models with a true-off switch.

Another method that removes the leaking electricity from the grid (for both category 2 and 3 type leaks) is to use a photovoltaic (PV) array to replace the grid as a source of electricity. Various PV kits are now available to charge batteries for flashlights and computers. The PV provides sufficient electricity to meet the leaking and recharge needs of the battery charger. Other PV packages provide electricity for low voltage exterior lights. Here the PV package (array plus battery) eliminates the leakage caused by the transformer and the entire end use.

## Eliminate constant leakage and replace with intermittent charge plus storage

Many appliances constantly draw power in order to provide instant response and to switch to full operation. All appliances with remote controls (TVs, VCRs, some ACs, etc.) need enough power to receive a signal.

An alternative configuration would rely on limited energy storage in the appliance. This battery would operate the sensor so that it can always receive a signal from the remote control. An additional circuit would periodically recharge the battery when reserves fell below a pre-set level. The advantage of this design is that the appliance would have zero leakage most of the time and recharge would be more efficient.

The logic required for such a circuit is shown in Figure 1. The items to be added to a typical appliance are marked with an asterisk (*). The input solid-state switch is a simple triac device; the manual over-ride is a push-button switch which triggers the triac in case of battery failure. Note that with a large enough battery, the switch control could be programmed to prevent charging during utility peak times.

The storage device need not be a conventional battery. Recent improvements in supercapacitors may offer the same capacity as a battery, but have better charging and lifetime characteristics. Indeed, several devices, such as VCRs, already use supercapacitors to maintain their clocks during power failures. The proposed circuit is more complicated than the current power supply circuits and will certainly cost more. However, it has the added benefit of maintaining appliance settings (such as the time of day) during power failures. Economies due to mass production, added consumer value, and the value of energy savings may make these modification worthwhile.

Of course, the simplest solution in many cases is to unplug the device when it is not being used. Alternatively, it easy to install a manual switch between the plug and the outlet. Hardware stores sell extension cords with built-in toggle switches. Some cords have the toggle switch on an extension of its own so that it is not necessary to reach into an awkward place to switch the appliance on and off. Some countries—notably the United Kingdom—require all outlets be equipped with power switches, so no retrofits are necessary.

## Improve efficiency of conversion

Because of the emphasis on low first cost, low-voltage transformers typically exhibit high core loss, relatively low conversion efficiency, and low power factor. All of these characteristics can be improved by using more metal and more and thinner laminations in the core. Another way to improve efficiency is to replace the unregulated linear power supply with a switching power supply. This provides both high conversion efficiency and flexible input voltage and frequency capability. Because switching power supplies use mostly semiconductors in combination with a much smaller transformer core, switching power supplies could compete with present wall-pack power supplies if they achieved high volume production.

# CONCLUSIONS

A variety of strategies are available to reduce or eliminate the 5 GW of leaking electricity found in homes. Some are trivial lifestyle changes, while others involve technical fixes. Once mass produced, the latter may be cost effective, even though the acceptable added cost is only a few dollars. It is unlikely that manufacturers will reduce leaking electricity on their own initiative except where it leads to other benefits. National standards may be the only way to realize these potential energy savings.

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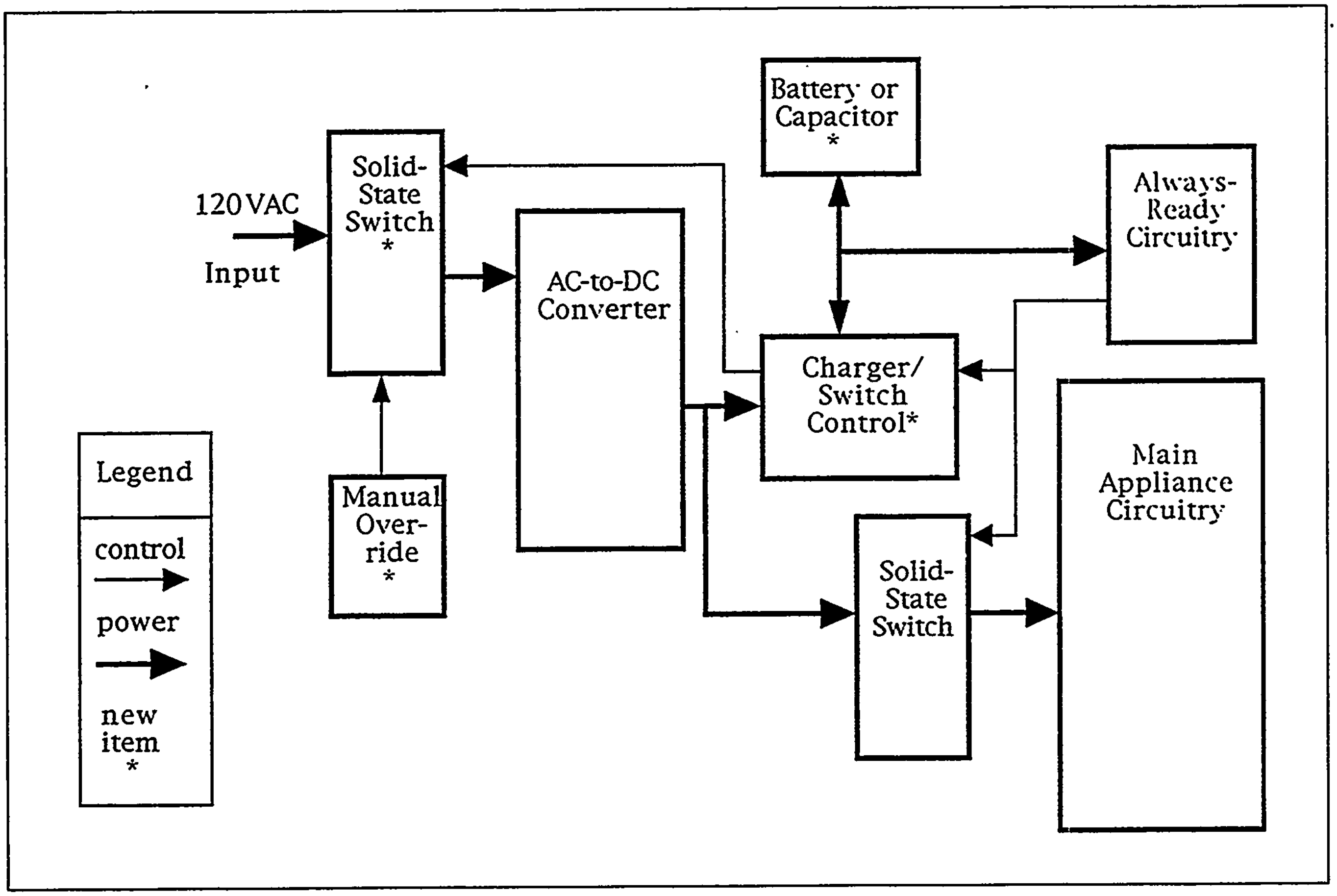
*Figure 1. Energy-Saving Modifications to a Typical Leaking Appliance*



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# You Won't Find These Leaks with a Blower Door: The Latest in "Leaking Electricity" in Homes

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Leaking electricity is the energy consumed by appliances when they are switched off or not performing their principal functions. Field measurements in Florida, California, and Japan show that leaking electricity represents 50 to 100 Watts in typical homes, corresponding to about 5 GW of total electricity demand in the United States. There are three strategies to reduce leaking electricity: eliminate leakage entirely, eliminate constant leakage and replace with intermittent charge plus storage, and improve efficiency of conversion. These options are constrained by the low value of energy savings—less than $5 per saved Watt. Some technical and lifestyle solutions are proposed.

## INTRODUCTION

Electricity use in homes is undergoing a transformation, from a few distinct end uses to a broad array of appliances providing more specialized and new services. One consequence of this transformation has been the emergence of the "miscellaneous" end use of electricity, representing about 20% of total residential electricity use (Meier et al. 1992). Both large and small appliances exist in the miscellaneous end use. Among the small appliances, low-voltage power supplies appear to be responsible for a significant fraction of the total consumption. Recently, Sandberg (Sandberg 1993), Schaefer (Schaefer 1995), Perez (Perez 1993), and Meier (Meier 1993a, Meier 1993b) have reported limited measurements for some small appliances in their "standby" modes, including those where the principal load is caused by the power supplies. Sandberg called this consumption 'leaking' electricity because the appliances consumed electricity when the appliance was switched off or not performing its principal function. In this paper, we report further measurements of leaking electricity, and describe technical approaches to limiting the growth in leaking electricity.

## WHOLE-HOUSE MEASUREMENTS

There are two techniques to measure the leaking electricity in homes: (1) observation of the lowest whole-house consumption, or (2) direct measurement of each appliance in the house. The direct measurement is more satisfying because leaks can be attributed to individual appliances. On the other hand, the whole-house measurement catches all leaks. In this study, we drew upon results from both approaches.

Homes in California, Florida, and Japan were extensively monitored. Many end uses were separately monitored but measuring leaking electricity was incidental to the projects. The primary objective of each monitoring project was slightly different. The six California homes (Rainer 1995) were designed or retrofitted to have the highest possible efficiency and were equipped with the most efficient appliances available. Leaking electricity was defined as the lowest observed consumption when none of the major appliances were operating. Some individual appliances were also directly monitored. The Florida house (Parker 1996) was a demonstration of maximum savings possible through retrofits. Leaking electricity was measured by short-term monitoring of specific "suspect" appliances. The four Japanese homes (Nakagami 1996) were monitored to gather accurate load forecasting data. Here, too, only appliances suspected of leaking were monitored.

Table 1 summarizes the electricity use for the US and Japanese homes. The US houses continued to draw anywhere from 53 to 115 Watts even though no appliances were being used. This represents about 5% to 23% of the houses' total electricity consumption. The Japanese homes leaked similar amounts, from 61 to 82 Watts. Here the fraction of leaking electricity is similar—10% to 17%—because the monitored US homes are more efficient than typical US stock.

## NATIONAL TRENDS

We estimated the amount of such electricity used in an average American home based on these measurements and national saturations (Appliance Magazine 1995a, Appliance Magazine 1995b) of the principal contributors to the leaking electricity. Table 2 shows that the average US home leaks about 50 Watts or 450 kWh/year. Since the average residential electricity consumption is about 9965 kWh/year (Energy Information Administration 1994), leaking electricity represents about 450/9965 or 5% of an average home's electricity use. For comparison, this is about 2/3 of the typical consumption of new refrigerators. However, the leaking electricity

*Table 1. Summary of Monitored Leaking Electricity*

| House | Total Use (kWh/yr) | Leaking Electricity (watts) | (kWh/yr) | (% of total) |
|---|---|---|---|---|
| California new #1 | 4320 | 53 | 464 | 11% |
| California new #2 | 3072 | 80 | 701 | 23% |
| California new #3 | 10950 | 66 | 578 | 5% |
| California retrofit #1 | 5532 | 100 | 876 | 16% |
| California retrofit #2 | 5028 | 90 | 788 | 16% |
| California retrofit #3 | 4944 | 115 | 1007 | 20% |
| Florida retrofit | 9638 | 88 | 771 | 8% |
| Japan #1 | 4289 | 82 | 720 | 17% |
| Japan #2 | 3698 | 68 | 596 | 16% |
| Japan #3 | 3643 | 61 | 537 | 15% |
| Japan #4 | 6428 | 74 | 648 | 10% |

*Table 2. National U.S. Estimate of Leaking Electricity*

| Appliance | Saturation | Watts | Watts / House |
|---|---|---|---|
| TV | 180% | 6 | 10.8 |
| Cable boxes | 50% | 20 | 10.0 |
| VCR | 80% | 10 | 8.0 |
| Compact audio | 67% | 10 | 6.7 |
| Answering machines | 60% | 5 | 3.0 |
| Alarms | 19% | 15 | 2.9 |
| Video games | 55% | 5 | 2.8 |
| Portable stereos | 65% | 3 | 2.0 |
| Rechargeable vacuum | 20% | 5 | 1.0 |
| Cordless phones | 49% | 2 | 1.0 |
| Fax | 4% | 15 | 0.6 |
| Satellite | 5% | 11 | 0.6 |
| Toothbrush | 13% | 3 | 0.4 |
| Smoke detectors | 84% | 0.4 | 0.3 |
| TOTAL | | | 50.0 |

is spread among dozens of appliances and electrical components, so it is much more difficult to both identify and reduce. The national consumption due to leaking electricity is about 5 GW, that is, equal to the output of five standard power plants.

Current trends will result in a decline of leaking electricity in some components. Televisions draw electricity constantly—up to 40 Watts—in order to maintain the remote control and instant-on features. New TVs, however, draw substantially less, from 5 to 20 Watts. Standby power consumption of computers, monitors, fax machines, and other appliances have also fallen, especially with the advent of machines meeting the EPA ''Energy Star'' guidelines.

Other trends, however, are likely to increase the leaking electricity use. Building codes are requiring components that leak electricity. Ground Fault Circuit Interrupter (GFCI) protected outlets were originally just required in bathrooms, but now are required in kitchens and other special rooms (each GFCI draws about 1 Watt or 8 kWh/year). For new construction, smoke alarms must now be hard-wired into a house's electrical system. One alarm is required for each bedroom, plus others for the hallway and garage. Thus, each new home will have about four smoke alarms constantly drawing power. (Our measurements indicate that each hard-wired unit draws about 0.34 Watts, so the total demand is likely to be less than 2 Watts.) The saturations of emerging electronic appliances, from telephone answering machines to home security devices, to cordless telephones are still increasing rapidly (Nore and Roberts 1994). All of these typically leak electricity. In addition, many conventional appliances are acquiring leaks. New refrigerators typically draw 3 Watts which, for an efficient model, represents over 5% of total consumption.

## CATEGORIZING LEAKING ELECTRICITY

Appliances that leak electricity can be separated into three categories. These categories help explain why electricity