Global Implications of Standby Power Use

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ABSTRACT

Separate studies indicate that standby power is responsible for 20–60 W per home in developed countries. Standby power is responsible for about 2% of OECD Countries total electricity consumption and the related power generation generates almost 1% of their carbon emissions. Replacement of existing appliances with those appliances having the lowest standby would reduce total standby power consumption by over 70%. The resulting reductions in carbon emissions would meet over 3% of OECD's total Kyoto commitments. Other strategies may cut more carbon emissions, but standby power is unique in that the reductions are best accomplished through international collaboration and whose modest costs and large benefits would be spread over all countries.

Introduction

Standby power has recently gained recognition as a unique and significant use of electricity. A recent study (Rosen and Meier 2000) of videocassette recorders (VCRs) in the United States showed that more electricity is consumed while VCRs are in the standby mode than while actively recording or playing. A study in New Zealand (EECA 1999) revealed that over 40% of microwave ovens consumed more electricity over the course of a year in standby mode, powering the clock and keypad, than in cooking food. Many countries have already begun programs to reduce standby power in the most prominent appliances, such as televisions (TVs), VCRs, and audio equipment. However, more recent investigations and calculations suggest that standby power is a more pervasive and a larger problem than first thought. Field measurements in a few homes scattered around the world demonstrated that standby power consumed 1–25% of those homes' total electricity. Standby also appears to be growing rapidly as more appliances are built with features that lead to standby power consumption.

The need to find measures to reduce CO_2 emissions has heightened interest in standby power. Standby power has several features that make it especially attractive as a CO_2 mitigation measure. First, it is technically feasible to greatly reduce standby power use without causing any reduction in features or amenities. Second, it is already cost-effective in most situations. Third, standby power use is generally similar in most developed countries and is caused by appliances that are internationally traded. Finally, actions undertaken now could influence the projected rapid growth in standby power consumption. These unique characteristics make standby power an ideal candidate for international, coordinated action.

Before starting a vigorous international program to reduce standby power consumption, it is essential to know how much power is currently being used and how much might be saved by prompt actions. Does the size of the problem justify international action? If yes, at what level compared to other mitigation measures? This paper addresses the first

question, that is, "how much electricity does standby power consume globally?" With this in hand, we can estimate standby's contribution to global CO_2 emissions.

Definition of Standby Power

There are many definitions of standby power use. Some describe it in functional terms, such as, "the power consumed by an appliance when switched off or not performing its primary functions." Some implicitly limit their definitions to electronic products, while others include pilot lights in natural gas appliances, storage losses in water heaters, and certain features of refrigerators that constantly draw power. Others have tried to use a technically simple definition, such as, "the minimum power consumption of a device while connected to the mains." There is no single correct definition, but the diversity of definitions was a major obstacle to making a global estimate of standby power consumption.

In 1999, the International Energy Agency created a group to develop a definition of standby power that would be suitable for estimating the size of standby and to develop policies options and further collaborative action. The consensus definition (International Energy Agency 2000) is rather complex and depends upon the device being measured. For practical reasons, most of the measurements in this study were taken when the devices were at their lowest electrical power consumption while connected to the mains. This definition is consistent with that used to measure standby power in most of the Energy Star electronic devices (Environmental Protection Agency 2000). The appliances were also limited to those used in the residential sector.

Existing Estimates of Residential Standby Power in Individual Countries

One perspective on global standby can be obtained by compiling estimates from individual countries. The approaches used by researchers to make the estimates vary greatly, but fall into two categories: "field studies" and "bottom-up" estimates. These are described briefly below.

Field studies were conducted in France, Japan, and New Zealand. The estimates were based on a group of carefully monitored homes. The French field study (Sidler 2000) was one of the largest end use studies in the world and the largest single compilation of standby power measurements. The sample of 178 individual households around France is believed to be representative of the entire housing stock at least regarding the average penetration of specific types of equipment and regarding the average electricity consumption. Despite the extreme care taken by the researchers while on site, the standby power of some appliances (e.g., doorbells) could not be checked and recorded. In other cases, the researchers simply overlooked appliances with standby power consumption. (This is easy to do.)

Table 1. Survey of the Standby Power Mode for Video, Hi-fi, and Information Equipment Found in 178 French Households (1998-99)

Category	Appliances	Max. Standby Power (W)	Min. Standby Power (W)	Average Standby Power (W)	No. of Models Monitored
Video	Television Set	22	1	7.3	205
	Individual TV Amplifier	4	1	1.8	33
	VCR	30	1	9.9	169
	K7 Video Rewinder	1	1	1.0	3
	CDV Player	5	5	5.0	1
	DVD Player	15	15	15.0	1
	Infrared headphone	5	1	2.1	8
	DSP Sound System	1	1	1.0	1
	Pro Logic Speakers	2	2	2.0	1
	Infrared Speakers	9	9	9.0	1
	Video Games	7	1	1.7	20
	Hertz TV Decoders	16	9	11.0	34
	Satellite Dish Decoders	17	5	8.7	26
	Cable TV Decoders	23	3	9.5	4
	UHF Connector	10	10	10.0	1
Hi-Fi	Hi-fi Stereo	24	1	7.2	108
	Hi-fi Amplifier	9	1	4.0	5
	Vinyl Disc Player	1	1	1.0	3
	Tuners	5	1	2.4	7
	CD Player	7	1	3.1	18
	K7 Player	6	1	2.2	6
	DiscMan	1	1	1.0	1
	Radio K7 tape	4	1	1.7	41
	Radio Alarm Clock	4	1	1.4	175
	Alarm Clock	2	1	1.7	3
	Miscellaneous HIFI TV Video	34	4	14.4	8
Informa-tion Tech.	PC Central Unit	2	2	2.0	2
	PC monitor	10	1	6.5	4
	PC Central Unit + monitor	3	2	2.7	3
	PC Whole Unit	27	1	6.9	14
	Tension Stabilizer	18	14	15.7	3
	PC Laptop	20	1	6.5	4
	Modem	6	3	4.3	3
	Ink Jet Printer	8	1	3.8	13
	Laser Printer	4	4	4.0	2
	Scanner	6	5	5.5	2
	PC Speakers	5	1	3.0	2
	Desk Calculator	2	2	2.0	1
	Typewriter	5	5	5.0	1
	Photocopy Machine	10	10	10.0	1

Table 1 and Table 2 present the standby power from appliances found in the 178 French households surveyed in 1998 and 1999. The table illustrates the diversity of the equipment found with standby power corresponding to the definition given above. More than 70 categories of appliances are listed. Secondly, this survey shows the range of standby power within each category of equipment. Thirdly, depending on the type and actual power consumption, the total average household standby power ranges from 29 W to a possible 38 W (depending on the assumption on the time of use of the standby mode for some appliances). Standby in individual homes ranged from 1 W to 106 W.

Table 2. Survey of the Standby Power Mode Found in Telephone, Cooking, and Miscellaneous Equipment in 178 Individual French Households (1998-99)

Category	Appliances	Max. Standby Power (W)	Min. Standby Power (W)	Average Standby Power (W)	No. of Models Monitored
Telephone System	Wireless Telephone	7	1	2.6	100
	Independent Answering Machine	6	1	2.8	56
	Combine Phone-Answ. Machine	11	1	5.1	31
	Cellular Phone Recharger	3	1	1.5	4
	Interphone	3	3	3.0	1
	Minitel (basic internet access unit)	9	5	6.2	11
	ADSL Connection Boxes	3	3	3.0	1
Cooking	Coffee Machine	1.5	1	1.1	7
	Induction Cooktop	18	4	13.2	10
	Micro-Wave Oven	12	1	3.5	32
	Kitchen Oven	18	6	14.5	4
Misc.	Battery Recharger	2	1	1.3	4
	Musical Keyboard	3	1	1.8	4
	Electric Fence	1	1	1.0	1
	Security Systems	1	1	1.0	2
	Kitchen Cordless Vacuum Cleaner	4	1	1.9	27
	Wireless Electric Plug	3	1	1.2	9
	Electric Toothbrush	3	1	1.8	12
	Perfume Burner	5	1	3.3	3
	Low Voltage Halogen Lamp	3	3	3.0	1
	Clothes Washers	7	1	4.0	2
	Electric Bed	5	5	5.0	2
	Lightning Protecting Device	1	1	1.0	1
	Baby Monitor	3	1	2.0	3
	Water Treatment	7	2	3.2	5

The average annual consumption from the standby power mode is 235 kWh/year, representing 7% of the total electricity consumption (after excluding electric space and water heating) in the sample of households.

The estimate for the United States is an example of a bottom-up estimate. Hundreds of individual appliances (of all ages) were measured in homes, stores, and repair shops. The average annual standby energy consumption for each appliance was then multiplied by the number of those appliances found in American home (which was known from several surveys conducted by the government and private firms). The process was repeated for each appliance found in American homes. The total electricity consumption for all appliances was then divided by the 100 million U.S. homes to give the average standby energy consumption per home.

Similar approaches were used in Germany, Switzerland, the Netherlands, and Australia, although fewer types of appliances were included or directly measured. The German and Swiss studies, for example, relied heavily on standby power measurements of new appliances reported in consumer magazines. The standby power in new appliances does not always equal that of older appliances (it can be higher or lower).

Table 3 summarizes estimates of residential standby in eight countries. The listed values have been adapted from sources indicated to facilitate comparison.

Some countries have unique appliances that have standby power consumption. In Japan, the "shower-toilet" consumes 5 W and rice cookers consume 1–2 W. In France, the minitel communications systems draw 5–9 W. In Australia, the chargers for electrified fences consume standby power.

Table 3 presents standby power levels with three different metrics (to reflect the different types of estimates made by the original researchers). New Zealand and Australia appear to have the highest average standby power consumption. Several factors may account for this high value. First, the New Zealand estimate is based on a field study of only 29 homes, so the sample may not be representative. Second, it includes the energy used by some appliances that clearly do not fit into the standby definition, notably heated towel racks and several defective refrigerators. Third, New Zealand and Australian appliances operate at 240 volts. Since power supplies have higher losses at higher voltages, the same appliance may have higher standby power consumption in Australia (240V) than in Japan (100 Volts)

Average standby levels are also very high in Japan and may be the highest of any country. This is a result of high penetration of electronic appliances and white goods with microprocessor controls (such as in air-conditioners, gas water heaters, and clothes washers).

Two countries (Switzerland and the Netherlands) appear to have the lowest values but this is probably because only the most widely used appliances were included in the estimate.

Table 3. Estimates of Residential Standby in Eight Countries

Country	Average Resid. Standby Power (W_{avg})	Annual Elec. Use (kWh/yr)	Fraction of Total Resid. Elec. Use	Source of Estimate and Type of Estimate	Notes
Australia	60	527	13%	(Harrington 2000), Bottom-up	Includes all major appliances.
France	38	235	7%	(Sidler 2000) Field	Based on measurements in 178 homes. Some appliances with standby may have been overlooked
Germany	44	389	10%	(Rath, Hartmann et al. 1997) Bottom-up	May include standby losses from storage water heaters
Japan	60	530	12%	(Nakagami, Tanaka et al. 1997), Field	Based on field measurements in 32 homes
The Netherlands	37	330	10%	(Siderius 1995), Bottom-up	Based on typical standby power use of major appliances. It does not include less common appliances, so the actual value may be higher
New Zealand	100	880	11%	(EECA 1999), Field	Based on a field study of 29 homes. It includes a few heated towel racks and malfunctioning appliances
Switzerland	19	170	3%	(Meyer & Schaltegger AG 1999), Bottom-up	Only includes the standby of TVs, VCRs, satellite receivers, stereos, some re-chargeable appliances, cordless phones, and PCs
USA	50	440	5%	(Rainer, Meier et al. 1996), Bottom-up	Based on measurements of individual appliances and then adjusted for the number of each appliance in an average home

In spite of the uncertainty and known errors in some of these estimates, the absolute levels of standby power use are similar. The range in percentages of residential electricity consumed as standby is much larger because total electricity consumption in homes varies much more. The general agreement of the two approaches adds robustness to an estimate that standby in developed countries ranges from 30 – 60 W/household.

A Global Estimate of Standby Power Consumption in the Residential Sector

Our goal is to estimate the global consumption of electricity caused by standby power and the CO_2 emissions that results from power generation to meet this power demand. The data presented in Table 3 describe the residential standby power consumption in several developed countries. Even though the approaches toward estimation were different, similar types of appliances and appliance penetration are good reasons to believe that similar levels of standby exist in other developed countries. The level of standby power consumption in less developed countries (non-OECD countries) is uncertain.

A global estimate of standby should, ideally, include estimates for the less developed countries. We believe that the situations in the developed countries are significantly different from those in the less developed countries; moreover, the data on stocks of appliances with standby in those countries is particularly poor (and changing rapidly). Even where stocks may be known, significant uncertainties exist. For example, most Chinese consumers unplug their VDRs (video disk players) and VCRs while not in operation. (This is to protect them against voltage spikes and because VDRs and VCRs are principally used to play disks and tapes, not to record broadcast material.) It is difficult to estimate standby power use when the major appliances are unplugged for large fractions of the day. Connection times may increase in the future, especially as more material is available via broadcast, satellite, or cable.

In a first step towards a global estimate, we sought to estimate standby in the 29 OECD countries. These countries represent roughly 65% of the world's electricity use and 54% of global CO_2 emissions. Table 4 presents a summary of this bottom-up estimation.

For each of the 29 OECD countries we began with the number of households (Euromonitor 1999). We estimated the average standby power for some individual countries based on findings summarized in Table 3. We lumped countries of similar economies (like Canada with USA, or Austria with Germany) to apply the same estimation of the average standby power per household. We were then able to derive an estimate of the total electricity consumed by the standby power in the residential sector. For OECD countries with the lowest GDP (namely Czech Republic, Greece, Hungary, Mexico, Poland, Portugal, South Korea, Spain, Turkey) we choose the conservative figure of 10 W standby per household.

The IEA statistics provide an estimation of the amount of CO_2 emissions from the electric production, in gCO_2/kWh.

Table 4 summarizes the energy demand and related CO_2 emission from the standby power in the residential sector of OECD member countries

Table 4. Assessment of 1998 Energy Demand and CO_2 Emissions from Standby Power in the Residential Sector of OECD Member Countries

OECD Member Countries	Number of Households Millions of units	Average Standby Power W/Home	Total Demand Standby MW	Total Energy Standby TWh/yr	Total National Cons.in TWh/yr 1997	Standby % of national elect.	CO_2 Emission Ratio 1997 gCO_2/kWh[i]	National CO_2 Mtons 1997	CO_2 from Standby Mtons	Standby as % of national CO_2
Australia	7.09	60	425	3.7	171	2.2%	942	306	3.5	1.1%
Austria	3.38	44	149	1.3	53	2.5%	237	64	0.3	0.5%
Belgium	3.85	27	104	0.9	78	1.2%	339	123	0.3	0.3%
Canada	11.70	50	585	5.1	514	1.0%	189	477	1.0	0.2%
Czech Rep.	3.48	10	35	0.3	58	0.5%	677	121	0.2	0.2%
Denmark	2.35	39	92	0.8	35	2.3%	554	62	0.4	0.7%
Finland	2.20	39	86	0.8	74	1.0%	294	64	0.2	0.3%
France	23.14	27	625	5.5	410	1.3%	82	363	0.4	0.1%
Germany	36.03	44	1,585	13.9	527	2.6%	690	884	9.6	1.1%
Greece	3.65	10	36	0.3	42	0.8%	980	81	0.3	0.4%
Hungary	3.85	10	39	0.3	33	1.0%	624	58	0.2	0.4%
Iceland	0.0001	39	0	0.0	5	0.0%	1	2	0.0	0.0%
Ireland	0.87	39	34	0.3	18	1.6%	875	38	0.3	0.7%
Italy	22.69	27	613	5.4	273	2.0%	605	424	3.2	0.8%
Japan	41.37	60	2,482	21.7	1,001	2.2%	439	1,173	9.5	0.8%
Luxembourg	0.0001	44	0	0.0	6	0.0%	1000	9	0.0	0.0%
Mexico	21.08	10	211	1.8	152	1.2%	629	346	1.2	0.3%
Netherlands	6.51	37	241	2.1	96	2.2%	522	184	1.1	0.6%
NewZealand	1.26	60	76	0.7	33	2.0%	145	33	0.1	0.3%
Norway	1.93	39	75	0.7	107	0.6%	3	34	0.0	0.0%
Poland	11.80	10	118	1.0	124	0.8%	921	350	1.0	0.3%
Portugal	3.66	10	37	0.3	34	0.9%	499	52	0.2	0.3%
South Korea	13.99	10	140	1.2	236	0.5%	411	422	0.5	0.1%
Spain	14.94	10	149	1.3	167	0.8%	408	254	0.5	0.2%
Sweden	3.97	39	155	1.4	136	1.0%	35	53	0.0	0.1%
Switzerland	2.98	19	57	0.5	52	0.9%	10	45	0.0	0.0%
Turkey	15.09	10	151	1.3	87	1.5%	685	187	0.9	0.5%
U K	21.93	39	855	7.5	337	2.2%	565	555	4.2	0.8%
USA	101.04	50	5,052	44.3	3,503	1.3%	648	5,470	28.7	0.5%
OECD	385.81	36818	14,205	124	8,362	**1.5%**	530	12,235	68	**0.6%**

With this method, standby in the residential sector of OECD Member Countries is responsible for 1.5% of the total electricity consumption (124 TWh) and contributes 0.6% (68 Millions tons) of CO_2 emissions. This represents the annual CO_2 emissions of 24 million European-type cars.

The total power demand for standby power in the residential sector amounts to 14 GW. For comparison, the installed capacity of wind turbines (worldwide) is slightly over 10 GW, with a total electricity production below 30 TWh/year. Despite the rapid growth of this zero CO_2 emission power technique, it would take years and large capital investments to install enough wind turbines to offset the energy being consumed in the standby mode of numerous electric devices studied here.

Large Opportunities for Reductions

Several other studies have examined possible opportunities to reduce standby power consumption for individual appliances. The data presented here allowed us to estimate the global savings from reductions in standby power as old appliances are replaced with new, low-standby, units. From the field measurements reported in Table 3 we calculated the electricity savings that would be achieved if all the appliances in a given category matched the lowest measured standby value found in that category. Based on this assumption, the total standby power in an average household could be reduced by 72%. Applying this reduction to the OECD-wide figure gives a total annual C02 reduction of 49 millions tons. This is equivalent to removing more than 18 millions cars from European roads.

Some policy programs propose to set a uniform target to limit standby power consumption to a maximum 1 W (Meier, Rosen et al. 1998; National Appliance and Equipment Energy Efficiency Committee 2000). The savings would be only slightly larger if all appliances reach a uniform standby level below 1 W. The CO_2 emissions in the 1-W case would be reduced by 80% and represent a reduction of 54 millions tons of CO_2. The current effort of OECD countries to meet the Kyoto Greenhouse Gas target set for 2008-2012 corresponds to a reduction of 1600 millions tons of CO_2. Thus, achieving a 1-W standby level for home equipment would equal about 3.4% of the OECD's proposed reductions in CO_2 emissions.

Reducing standby will often stimulate design changes that also reduce energy consumption while the appliances are in active modes. These energy savings have not been calculated, but anecdotal evidence suggests that they could easily exceed the standby savings. We have not included these benefits.

Conclusions

In this paper, we sought to answer two questions. First, how significant is the contribution of standby power to global electricity consumption? There is insufficient data to give an accurate global estimate. However, we were able to estimate the residential contribution of the OECD countries (who currently represent the largest share of electricity and standby power consumption). Our compilation of regional studies, combined with our own calculations, indicate that standby power in the residential sector alone represents around 1.5% of OECD electricity use.

Lack of data did not allow us to take into account the standby power in the commercial sector. From a thorough German study (Rath, Hartmann et al. 1997) we note the ratio of 2 W standby found in the German residential sector for each 1W standby in the commercial sector. When applying this ratio to our estimation of residential standby consumption, we assess that standby power in both residential and commercial sector may account for 2.2% of OECD electricity consumption. There is every indication that standby power is growing rapidly as more appliances are built with standby functions. Thus, we believe that standby power consumption is already more important than what our estimation suggests.

The second question was how important are the CO_2 emissions caused by standby power? We found that residential standby is responsible for 0.6% of total energy related CO_2

emissions. Adding the standby power consumption in the commercial sector leads to a figure just under 1% of total OECD emissions. This appears to be a relatively small fraction of total emissions, although, again, current trends suggest that standby's contribution will increase rapidly.

More important is the magnitude of potential savings achievable by reducing standby power. We found that a conservative replacement scheme—replacing existing appliances with the units having the lowest standby available today—could cut standby power requirements by 72%. This is many times the present electrical output of a very popular supply alternative, wind turbines, but these savings can probably be achieved with much less capital investment and lower consumer costs. From an emissions perspective, the reductions estimated here equal about 5% of OECD's total Kyoto commitments.

Reducing standby power use is uniquely appropriate for international action. Most of the products with standby are similar in all countries and are internationally traded. A coordinated, international program will lower the already modest costs and extend the program's impacts to developing and non-participating countries.

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