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The Baseload and Standby Power Consumption of New Zealand Houses

Michael Camilleri, Andrew Pollard, Albrecht Stoecklein, Lynda Amitrano and Nigel Isaacs

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The Baseload and Standby Power Consumption of New Zealand Houses

Michael Camilleri*, Andrew Pollard*, Albrecht Stoecklein*, Lynda Amitrano*, Nigel Isaacs*

BRANZ is collecting energy usage information in a representative number of New Zealand households as part of the Household Energy End-Use Project (HEEP). For the first time in New Zealand this data base allows an in depth analysis of true energy usage patterns in households. The lower and upper limits of base loads for 98 HEEP houses were estimated. The base loads consists of individual appliance loads which are continuously in use such as clocks, aquarium pumps etc., and also of the standby power consumption of household appliances. The standby power of some common appliance types has been measured, and preliminary estimates of the average standby power contribution per household given for these appliances. These estimates are compared with estimates from other countries and to some national and international guidelines. The scope for reductions is discussed, as is the impact of the increasing use of electronic and automatic controls in appliances. Results of this analysis are currently representative of Wellington and Hamilton, and will be nationally representative with the conclusion of the HEEP monitoring program.

***Keywords**:, Appliance Energy Use, Standby Power Consumption, "Leaking" Electricity,*

* *Building Research Association of New Zealand (BRANZ)*

1. Introduction

Standby power is drawn by an appliance when it is not in operation but connected to the mains. Depending on the appliance type, this can range from 0 W (for example, a non-electronic dryer) to as much as 20 W or more (for example, a television). These power consumptions may seem trivial, as 1 W continuous power is approximately 9 kWh per year and costs about $1, but since most households have many such appliances, the actual energy consumption may be a significant fraction of the total energy consumption of a household. A survey of international studies reported that around 10% of domestic electricity consumption is from standby power consumption. Much of this consumption is a waste of money and energy, a source of unnecessary Greenhouse Gas (GHG) emissions, and can be reduced through good electrical design.

Among the outcomes of an international workshop on standby power waste (IEA, 1999) was the statement:

'As much as 10% of domestic electricity use is consumed as standby power. The consumption is notably consistent across OECD member countries. If the other sectors are included, standby power is responsible for as much as 1% of these countries' CO_2 emissions. – More analysis is required to validate these figures'

and

'Very large reductions in standby power consumption are technically feasible, cost-effective and can be achieved without sacrificing any features or amenities expected by consumers'

With appliance standby power being a sizeable consumption of electricity it is a good target for energy conservation programmes. Appliances are required to meet energy performance targets specified in national test standards (where these exist). These requirements have generally been based on the running costs of the appliance and have neglected standby power, however targets based on the standby performance of appliances are being introduced. A standby power consumption of 1 Watt has been widely touted internationally as a worthwhile and achievable target.

Before standby power targets are established, or energy efficiency programs are put in place, it is essential to know how much power is being used by appliances on standby, how much power could potentially be saved, and at what cost, and what are the most significant appliance types.

Standby power also appears to be growing rapidly due to standby power being a feature of many modern appliances, the proliferation of electronic and computer controllers in appliances, and the increasing household ownership of electrical goods. For example, appliances that were uncommon 10-20 years ago, such as microwave ovens, VCRs, multiple TVs, video games, dishwashers etc, are now common.

The 1-Watt Plan has been proposed by Alan Meier of Lawrence Berkeley National Laboratory and calls for an international effort to overcome obstacles, and collaborate on definitions and test procedures.

2 Definition of Standby Power and Baseload

A definition of standby power has recently been made by a consensus panel for the IEA (International Energy Agency), to aid in the development and harmonisation of appliance standards internationally.

Definition (IEA, 1999)

Standby power use depends on the product being analysed. At a minimum, standby power includes power used while the product is performing no function. For many products, standby power is the lowest power used while performing at least one function.

This definition covers electrical products that are typically connected to the mains all of the time.

Based on this definition, certain types of products generally do not have standby power consumption. This includes, for example, products that have only two distinct conditions: "on" and "off", where the product does not consume power when it is off.

The basic concept is that standby power is the power used when the appliance is not performing its' primary function.

The baseload of a house is defined as the typical lowest power consumption when there is no occupant demand, and may be thought of as the 'standby' of the entire house. It includes the standby power of appliances, plus any appliances that operate continuously (such as heated towel rails, clocks, security systems etc). The baseload is important for two major reasons: it defines the lowest continuous power demand that must be met by a network (or generation system), so having a large part to play in the network load factor, and it includes a group of appliances that has the potential for demand reductions.

3. The HEEP project

The House Energy Enduse Project (HEEP) is a nationwide survey and monitoring project which includes monitoring the electrical power of individual appliances in the home, a survey of the occupants, building, and building services, and monitoring of internal temperatures. Its' aim is to understand the relationship between monitored energy use and the physical characteristics of the house, and the relationship between the occupants and energy use.

The electricity data are collected at either a 10 or 15 minute resolution, and a power resolution of 1 W. This is ideal for measuring the standby power, as it is often in the 1-3 W range – less precise monitoring, or at coarser time resolution makes the measurement of standby power more difficult.

The appliance dataset is unique in several respects:

- It is a random sample of existing NZ houses and appliances
- It measures the actual usage pattern of appliances
- It includes all appliances in NZ houses, including old, obsolete, and malfunctioning equipment.

These factors enable an accurate, comprehensive, and statistically representative examination of appliance standby power that would be difficult or impossible to achieve with other methods.

For each enduse monitored house, 2-3 appliances are monitored per month over a 12 month (approx) period, so as many as 36 different appliances may be monitored in a single house.

Currently, 98 houses have been monitored in Wanganui, Wellington, and Hamilton, and monitoring is under way in 50 houses in Auckland, with approximately one year of monitoring for each house.

4. Standby Estimation

The standby power of an appliance is defined as the power used when the appliance is not doing any functional work. For example, for a video, it is the power used when it is not playing or recording.

For a range, it is the energy used by the clock (and other electronics) when no cooking is being done. For a washing machine it could be the power used by the LED indicator light or electronics when no washing is being done. For a fridge it is the energy used when the fridge compressor is off, and it is not defrosting, which could be the butter conditioner, or transformer and electronics. Many modern appliances require a transformer to supply DC power for electronic and computer controls, and this transformer may consume power continuously, even if it there is no power drawn.

The following graph of washing machine power consumption serves as a good example. The washing machine is used a few times each day, for about 60 minutes for each cycle. In between cycles, the power does not drop to zero, but to about 9 W. This off-duty power consumption of 9 W is the standby power of the washing machine. As this washing machine is used only a small fraction of the day, 44% of the consumed energy is for the 9 W standby power, and not for washing clothes, so 44% is “wasted” in the sense that it performs no useful work.

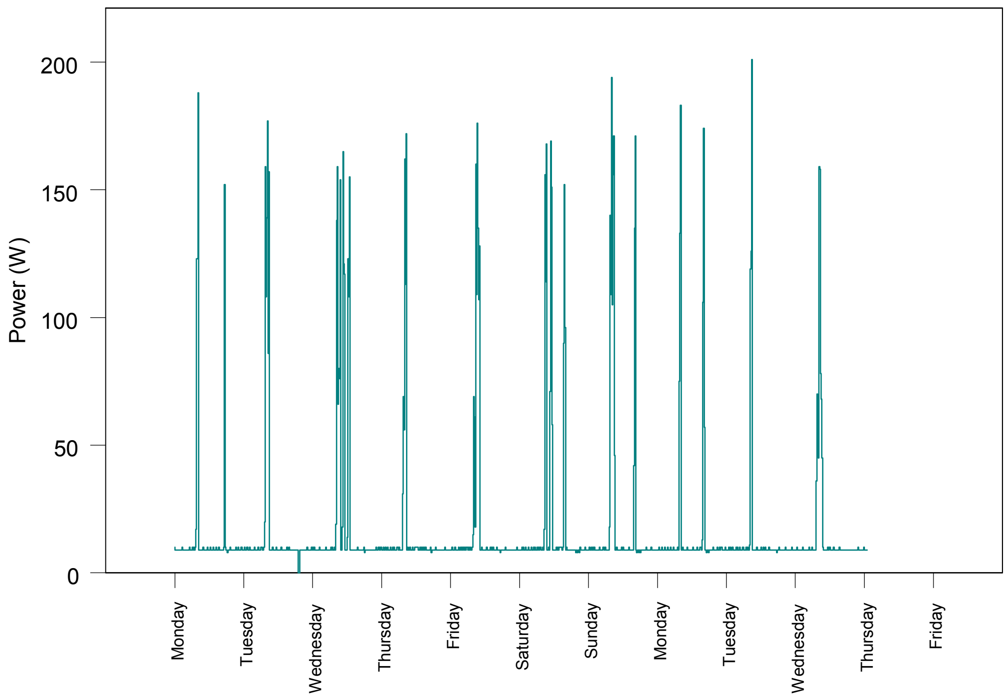

Figure 1. Washing Machine example of Standby Power.

The analysis method for calculating the standby power and losses is based on the frequency distribution of the appliance power consumption. For example in Figure 2, the fridge compressor is on for most of the time, and the compressor switches off to a standby power of about 17 W. The frequency distribution for this fridge is given in Figure 3. The histogram has two strong peaks: one at about 190 W corresponding to full compressor power, and another at about 17 W corresponding to the standby power. Powers in between these peaks are the fridge switching on or off some time during the 15 min sampling interval, so an intermediate power consumption is recorded.

The method for calculating the standby power is to find the standby power peak in the histogram. Mathematically, the standby power is the **mode** of the distribution, which is defined as the value that occurs most often. As the data are quantized in steps of 1 W (i.e. 1,2,3,4… W), finding the mode is easily done by finding the most common value in the data.

For some appliances, the most common value is larger than the standby power, as they rarely switch to standby. In these cases the modal value of the data values less than the mean power is taken.

Once the standby power is known, the standby loss can be calculated. The standby loss (or energy consumption) is defined as the energy consumed when the appliance is in standby mode, rather than being ‘on’ or disconnected from the mains. This distinction is important as some appliances, such as televisions, are not always left in standby mode.

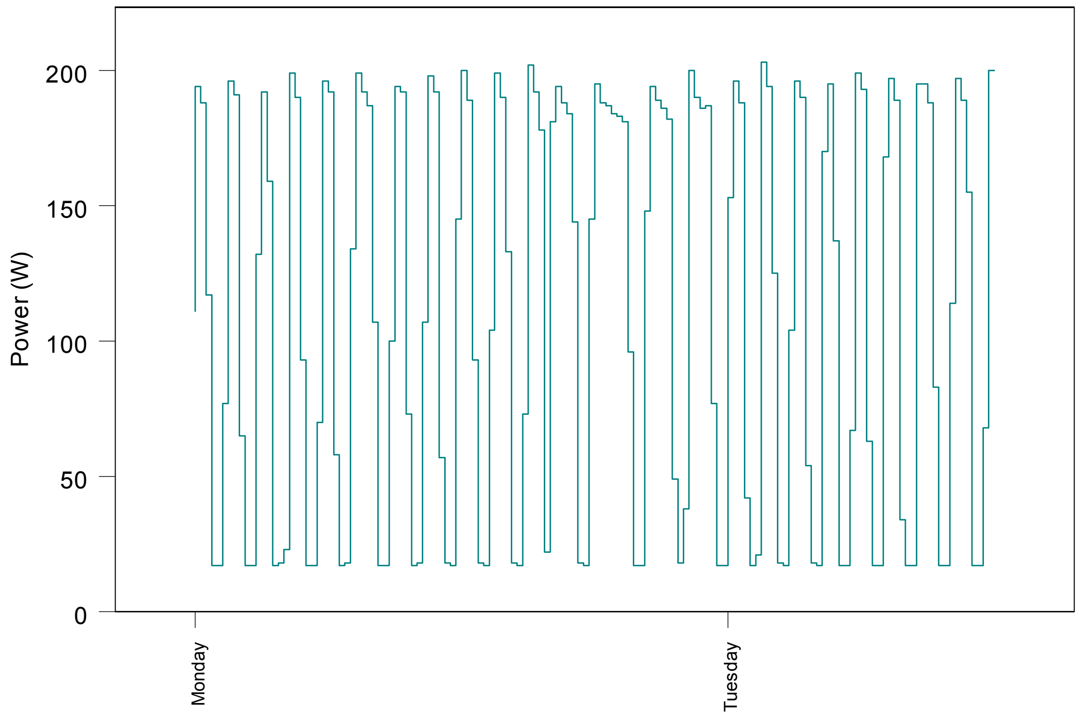

Figure 2. Fridge Electricity Consumption.

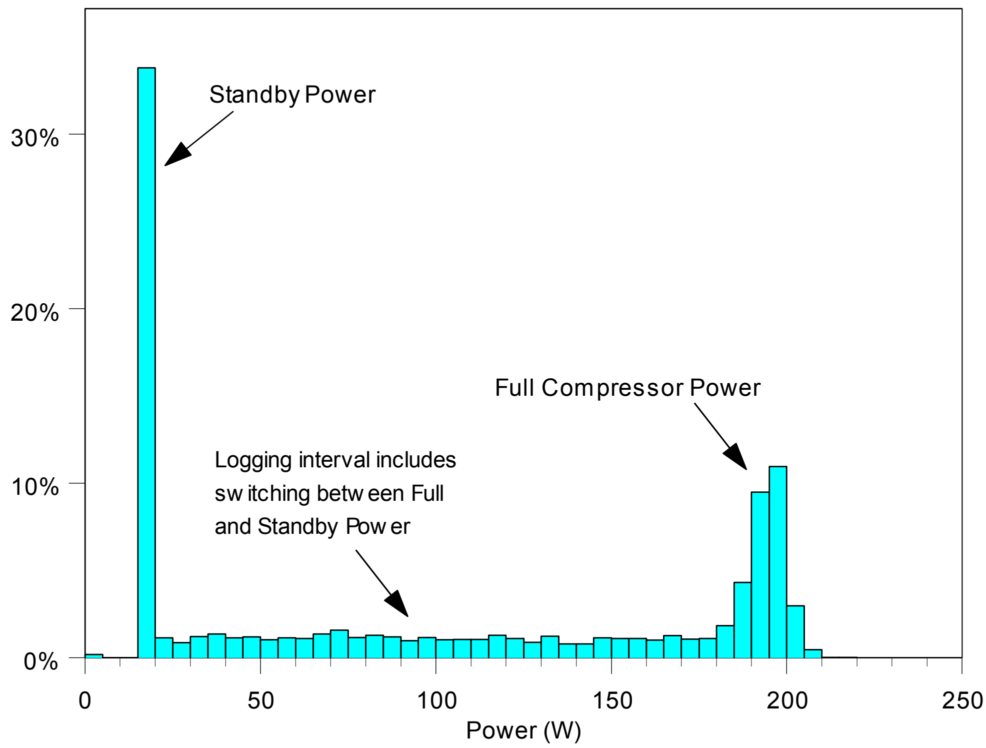

Figure 3. Fridge Histogram.

5. Baseload Estimation

The estimation of baseload is analogous to the estimation of standby load, as the baseload can be thought of as the standby power load of the entire house mains electricity circuit. Estimation is more complex, because there are a large number of appliances switching on and off during the course of a day, so that the total power may only be rarely at its' baseload level, for example, perhaps in the middle of the night when everyone is asleep, and all appliances are switched to off or standby, and the refrigeration appliances are off-cycle. To find the baseload, the minimum monitored power for each day is taken, and a histogram created. The baseload is expected to be the most commonly occurring daily minima, which should be at the low end of histogram (Figure 4). Calculating the mode generally gives a good estimate of the baseload. In houses with many refrigeration appliances (or other fast switching, automated appliances) the histogram of daily minima may not be so easy to interpret, as it is rare (or impossible) that all of the fast switching appliances are off concurrently. In such cases, a good estimate of the baseload cannot be found. For the HEEP sample houses, this occurred only rarely.

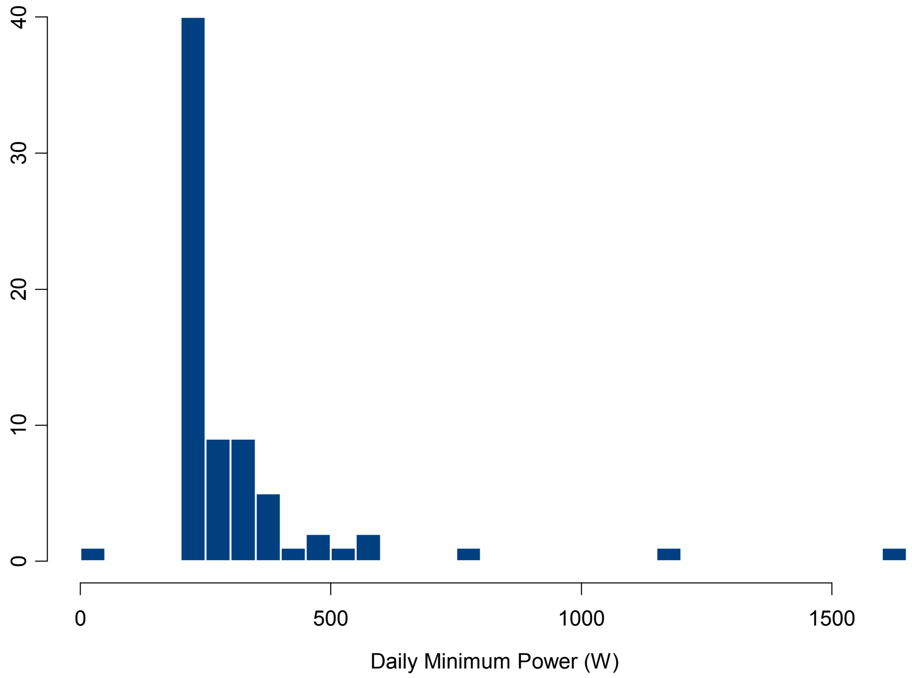

Figure 4. Example of baseload estimate. Baseload estimated at 215 W.

6. Results

The average baseload of the randomly selected Wellington and Hamilton houses is (103 ± 10) Watts with 90% of houses in the range of 15-205 Watts. If the average national baseload is similar, then the total baseload is around 130 MW continuous, with a yearly consumption of 1,100 GWh, which has a retail price of approximately $115 million dollars, and CO_2 emissions of around 730,000 tonnes, if supplied by thermal generation. This is approximately 3% of New Zealand's total electricity generation, and up to 1% of New Zealand's total GHG emissions (if supplied by thermal power stations). Clearly, the potential reductions of baseload and standby consumption in NZ houses are large, and has potential for Demand Side Management and GHG reductions.

The measured average standby powers of various appliance types are presented in Figure 5. Note that these are from houses in Wanganui, Wellington, and Hamilton, and not all were randomly selected, so the figures are not nationally representative. The average standby power for most appliance types is in excess of the proposed 1 Watt limit, indicating that there is a lot of scope for reductions. About 50% of all the appliances monitored were found to have a standby greater than 2 W, demonstrating the proliferation of appliances with standby.

The contribution of standby to the baseload can be estimated by combining the standby power measurements with the surveyed appliance stock levels in New Zealand. Appliance stock levels have been estimated by EERA (Roussouw, 1997) and have also been estimated from HEEP. Stock levels and standby estimates were available for the following appliance types: air conditioner, computer, dehumidifier, dishwasher, dryer, electric blanket, freezer, fridge, fridge freezer, heater, jug, microwave, night store heater, range, television, toaster, video, washing machine, and waterbed.

There are other appliance types that have standby, which are not included in the estimate, so the estimate is a lower limit. By combining these two sets of numbers with the estimated standby loss for each appliance class two estimates of the average total standby per house is made. Using the EERA appliance stock levels gives (27±2) W, and using the HEEP stock levels (36±4) W. Note that the actual total standby is expected to be higher than this, because not all possible appliances with standby were monitored. The largest five contributors to the household standby were (in order) fridge freezer, television, video, washing machine, and microwave, with each of these appliance type responsible for around 3-6 W of household standby.

The difference of (76±10) W has not yet been quantified in the HEEP program. It is likely to be from appliances that have not yet had standby estimated (perhaps another 10+ W per household for Sky decoders, stereos, clock radios and chargers), and appliances that are on all the time, such as heated towel rails. We aim to refine these estimates in future work, add other appliance types, and try to determine the most significant non-standby appliances in the baseload.

7. International Comparisons

Lebot and Meier (2000) reported estimates of household standby power from eight countries (including New Zealand), as listed in the following table. The estimates are not directly comparable, as the range of appliances measured varied from country to country. The New Zealand estimate (Camilleri, 1999; and updated later in this paper) is actually of the baseload, so the total standby power is somewhat lower. Despite this, the percentage of the total electricity use is similar for most countries at around 10%.

Country	Average Residential Standby Power (W)	Annual Electricity Use (kWh/yr)	Percentage of total Electricity Use
Australia	60	527	13%
France	38	235	7%
Germany	44	389	10%
Japan	60	530	12%
The Netherlands	37	330	10%
New Zealand	100	880	11%
Switzerland	19	170	3%
USA	50	440	5%

There are a number of energy efficient appliance energy label programmes around the world. The most recognised is probably the Energy Star program developed in the US by the Environmental Protection Agency (EPA) in 1992. A number of countries including Australia and New Zealand have adopted the Energy Star programme. Energy Star labelling was initially applied to office equipment but is now expanding to a range of household appliances. As part of the requirements to receive certification to label appliances with an Energy Star logo is a requirement than the standby power consumption be below a certain threshold. There are other energy efficient appliance labelling programmes around the world such as the 'Top Runner' program in Japan and the GEA-label from the Group for Efficient Appliances (an umbrella organisation for a number of national and manufacturers organisations throughout Europe).

8. The Future

The future of standby and baseload is presently uncertain. For some appliance classes such as televisions and VCR's the future standby consumption demand may decrease, as modern appliances have lower standby power than older units, and the total number is not growing quickly. However, there are a host of other rapidly growing appliances that may increase standby consumption, and a proliferation of electronic and computer controls replacing manual control. Examples include computers, TV cable and satellite decoders and receivers, video games, faxes, answering machines, cordless phones, and various battery charges for portable devices. For whiteware in particular, computer controls are becoming more and more common. Unless measures are taken to reduce the standby power of these appliances, then standby and baseload losses may increase dramatically.

The emergence of digital television is set to give a big jump in standby consumption. For Britain, the extra demand may peak at 500 MW for digital televisions and the satellite receivers, and cost an extra much as £15 per household per year (Fox, 1998). For the US, LBNL (1999) has estimated an extra demand of up to 18 TWh per year!

The recent announcement that TVNZ will go digital implies that eventually perhaps 1 million households will have a digital receiver, and perhaps digital television, so a new demand of 10-20 MW or more could result unless low standby receivers are adopted.

Rainer, Greenberg and Meier (1996) noted that changes in the US building regulations now requiring protected electrical outlets in kitchens and other special rooms, and mains-wired smoke alarms in bedrooms, hall, and garage were increasingly common, creating new standby loads. In New Zealand, Residual Current Devices are required in wet areas, and security systems are also becoming more common.

There are many drivers for increased standby consumption, and the 1 W programme appears to be a sound step to containing or reversing this growth. In addition to the potential savings in direct energy costs, standby power reduction may help to postpone investment in new generation, and perhaps also transmission capacity. One barrier to achieving this, is the inability of investors in generation and transmission to invest in standby reduction. Investors can reap returns for new generation to supply inefficient appliances, but cannot easily reap the returns for standby reductions.

Standby consumption also has a significant role to play in containing the growth of GHG emissions. Lebot and Meier (2000) reported that achieving the 1W standby power for all home appliances would reduce the CO_2 emissions by an amount equal to about 3% of CO_2 reductions required of OECD countries by the Kyoto protocol. They noted that although it is a minor contribution, it is technically feasible at costs likely to be much lower than costs of new renewable generation, and that unless such measures are taken, standby power is likely to increase rapidly.

For NZ, which under the Kyoto Protocol is required to return GHG emission to 1990 levels (a 23% reduction on 1997 emissions), reductions in standby could give reductions in nationwide GHG emissions of around 0.3%, which is around **1.5%** of the required Kyoto reductions, or about **7%** of the non-forest sink credits that the policy package of July 1994 indicated (80% of reductions were expected to come from credits for new forest growth). It appears that in terms of the Kyoto Protocol, standby reductions are far from trivial, with a significant chunk of emissions reductions possible from the reduction of standby power.

9. Conclusions

The baseload of houses in Wellington and Hamilton in New Zealand is (103 ± 10) W. Preliminary, non-representative estimates of the total standby power per household are a lower limit of (27±2) W. Further monitoring in the HEEP program will give a larger sample size, sample more appliance types, and make these figures nationally representative.

The difference (76±10) W results from appliances that have not yet had standby estimated (eg Sky decoders), and appliances that are on all the time (eg heated towel rails). These preliminary results suggest that the baseload could be about 10% of the total domestic electricity consumption, or approximately 3% of the national electricity generation. Based on overseas models, potential reductions in standby of 75% could be feasible and cost-effective, reducing national electricity demand by around 1% or more.

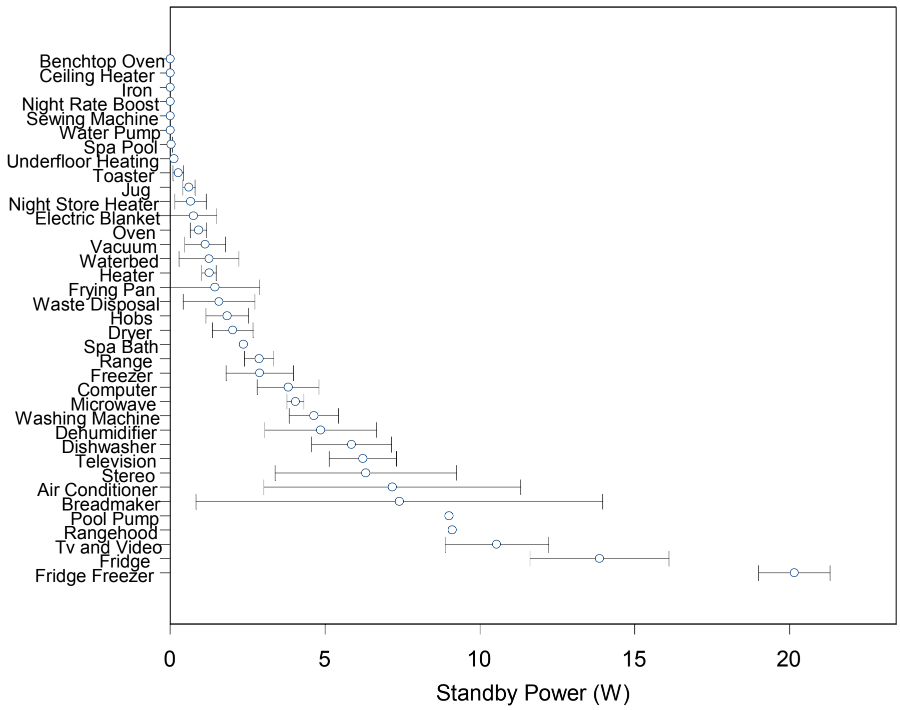

Figure 5. Average standby power of various appliance types. Error bars are ±1 standard deviation.

10. Acknowledgements

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