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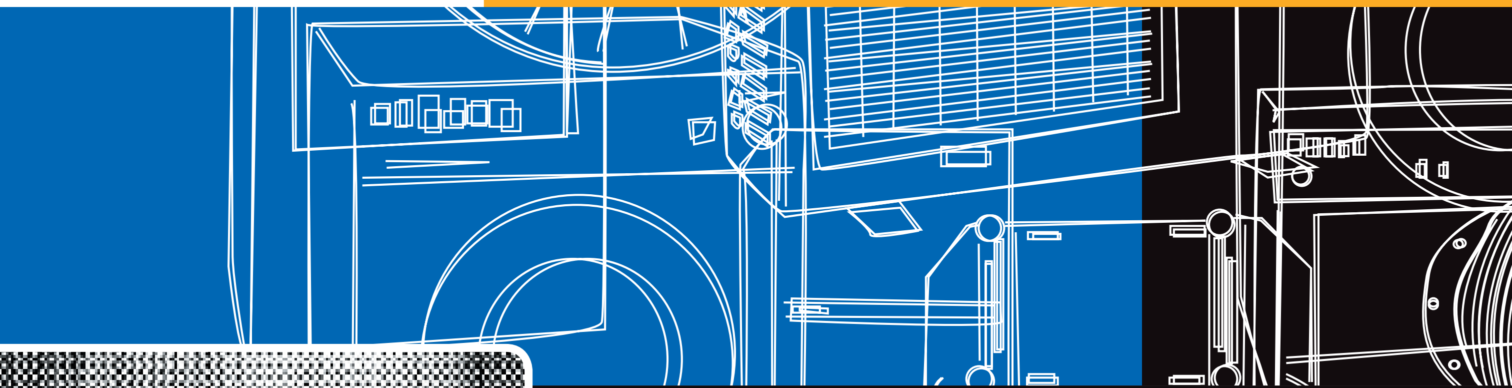
NATIONAL APPLIANCE AND EQUIPMENT
ENERGY EFFICIENCY PROGRAM

A STUDY OF HOME ENTERTAINMENT EQUIPMENT OPERATIONAL ENERGY USE ISSUES



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A Study of Home Entertainment Equipment Operational Energy Use Issues

Final Report

Prepared for

THE AUSTRALIAN GREENHOUSE OFFICE

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1 Background

This is the second of a pair of reports prepared for the Australian Greenhouse Office (AGO), acting on behalf of the National Appliance and Equipment Energy Efficiency Committee (NAEEEC), that examine issues associated with the operational energy use of office equipment and of home entertainment equipment. The first report deals with office equipment.

Programs such as ENERGY STAR, initiated by the US Environmental Protection Agency, and NAEEEC's *One Watt Target* (NAEEC, 2002) focus on limiting the standby energy use of equipment and, secondarily, cutting the operating energy use by facilitating switching to low power mode when equipment is not carrying out its core functions. Given that standby power consumption has been estimated to be approximately 12% of all household electricity and growing at 8% per annum, reduction of standby power is certainly a major issue **(**Harrington and Kleverlaan, 2001**)**.

However, as standby power consumption is being brought under control, barriers to users actually switching to low power modes have proved difficult to overcome, and it is becoming increasingly clear that the operational energy of home equipment is also a major issue. There is scope for substantial improvement in operational energy efficiency for many items of home entertainment equipment. This report highlights that the potential gains from such improvements are significantly greater than those from the remaining opportunities from the important standby energy efficiency programs.

For equipment that operates for long periods – such as the main television in a household, the potential significance of operational energy efficiency is large. For example, measurements by Harrington (2002) showed that the most efficient 68 cm screen television used for 5 hours per day and on standby for the rest of the time consumed 110 kWh per year while the least efficient consumed 340 kWh per year. The difference of 230 kWh per year is equivalent to the amount of energy saved by improving the energy rating of a refrigerator, clothes dryer or dishwasher by two stars or more. Therefore, the reported range of variation in energy use of a small sample of televisions could be as significant as major improvements in efficiency of products that already carry appliance energy labels. This example, and other data presented in this report, highlight the importance of identifying the scale of variation in operating energy efficiency for home entertainment equipment items when exploring options, such as information programs and development of standards, for government action to provide impetus to improvements in energy efficiency and greenhouse gas emissions reductions. In developing such programs it is also important to recognise the potential for further improvement beyond today's best practice.

There are very rapid, indeed almost explosive, developments in the home entertainment equipment area. New types of equipment are emerging rapidly and many of these could use very large amounts of energy if proper consideration is not given to design and energy management.

There is very little information on the Power Factors of home entertainment equipment, and their significance for overall energy efficiency of the electricity supply system. This project provides an opportunity to collect preliminary data and consider options for policy response.

This Report examines the following items of home entertainment equipment:

- Televisions (TVs):
  - Conventional
  - Digital set-top boxes
  - Digital TVs
  - Flat screens – LCD(liquid crystal display) and plasma
  - Back projection
- Video projectors
- Video Cassette Recorders (VCRs)
- Digital Versatile Discs (DVDs)
- Compact Discs (CDs)/Stereos

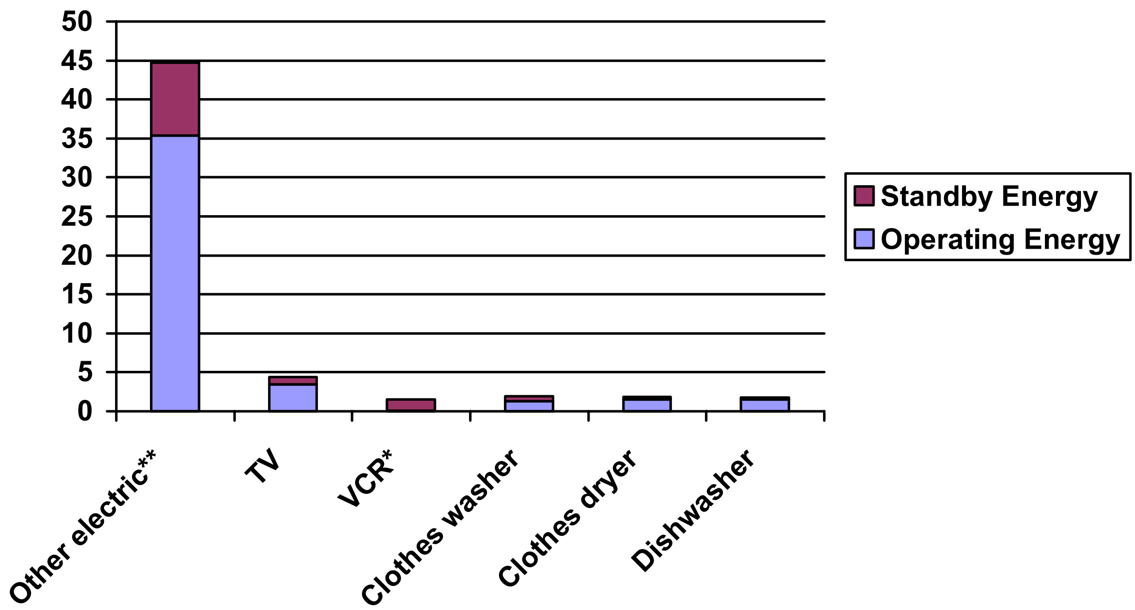
- Home entertainment systems
- Wireless networks

2 Introduction

Detailed data on energy use by home entertainment and other small items of equipment are not thoroughly documented, largely due to the diversity of products and the variation in usage. The most recent Australian study of household energy use is by Wilkenfeld for the Australian Greenhouse Office (in press). This is based on recent work by Energy Efficient Strategies and others, as well as reviews of global data. Figure 2.1 shows the estimated contributions of these items to Australian electricity consumption, and includes, for comparative purposes, a number of appliances that already carry appliance energy rating labels.

Figure 2.1

Contributions to Australian electricity use (Petajoules/Year) by home entertainment and other small electrical equipment compared with some products that already carry energy labels (Wilkenfeld, in press).



* Note that for VCRs, standby energy in this graph seems to include electricity use in *active standby* mode, which we believe is better considered as a component of operating energy (see Section 3.1)

** Electricity by all other small electrical equipment, such as stereos, CDs, smoke alarms, intercoms etc (including that necessary to make the numbers add up for the overall analysis)

Points emerging from this include:

- energy use by TVs and VCRs is greater than or comparable to that of several products that already carry energy labels
- operating energy use is over three-quarters of the total electricity used by TVs and other electric equipment and, according to US data (Rosen and Meier, 1999) is almost 50% of total energy use by VCRs.

3 Existing Energy Efficiency Programs

3.1 Defining Equipment Power Modes

There is a somewhat confusing range of terms and definitions used in the literature for the various equipment power modes. For the purposes of this report:

- **Operating Mode** will be taken to mean when the equipment is performing any of its intended functions, ie, when it is 'in use', and it will also include what is often referred to as 'active standby mode', where the equipment is in a state of instant readiness to perform an intended function. If, for example, a CD finishes playing, the unit usually remains on active standby until it is switched 'off' (actually switched to standby mode) either by remote control or on the unit. For the purposes of this report the energy used in active standby mode will be regarded as a component of the operating energy;
- **Standby Mode(s)** is a lower power mode which may be activated by programming (eg, the sleep mode of an ENERGY STAR computer) or by physical intervention (eg, pressing the off button on a CD player). Where equipment consumes energy in 'off mode' (ie, where the equipment has been turned off, remotely or otherwise, and is still connected to the power supply), for the purposes of this report this energy will be regarded as a component of standby energy.

3.2 Existing Home Entertainment Equipment Energy Efficiency Programs

For the past decade, the predominance of government effort to improve the energy efficiency of home entertainment equipment and to reduce associated greenhouse gas emissions has been directed towards reducing standby energy. The flagship program for this effort has been the US EPA-initiated ENERGY STAR (USEPA, 2002; AGO, 2002). This has been buttressed in recent times with the initiation of the *One Watt Standby* program (NAEEEC, 2002; Bush 2001).

3.2.1 Energy Star

ENERGY STAR is a voluntary program originally negotiated in 1992 between equipment manufacturers and the United States Environmental Protection Agency (USEPA). For the right to display the ENERGY STAR logo, manufacturers agree to make and promote electrical equipment satisfying established, and progressively-tightening standby energy efficiency standards and time limits in which equipment not in use will switch to a lower power mode.

The first standards for home entertainment equipment were those for TVs, VCRs and TV/VCR combination units (combos). These were promulgated in 1997 and were followed by audio equipment and DVD players the next year. Standards for set-top boxes (used for cable TV) were promulgated in 2001.

In the US, ENERGY STAR has expanded far beyond its initial emphasis on office equipment and as well as the above items of home entertainment equipment it now covers appliances, residential heating and cooling equipment, lighting, housing, home envelope products, traffic signals, transformers and more.

In Australia, the National ENERGY STAR Program is a co-operative energy efficiency program between Commonwealth, State and Territory government agencies to promote the use and purchase of ENERGY STAR equipment. It is funded by the National Appliance and Equipment Energy Efficiency Committee (NAEEEC) and managed by the Sustainable Energy Development Authority (SEDA) in NSW on behalf of all participating jurisdictions. In this country the program currently applies to home entertainment equipment (consumer electronics) and office equipment only.

Tables 3.1, 3.2 and 3.3 provide details of the ENERGY STAR criteria for the items of home entertainment equipment currently covered by the program.

Table 3.1
Energy Star Criteria (Watts) for Various Combinations of TVs, VCRs and associated DVDs

Product Category	Phase 1 Standby	Phase 2 Standby (effective 1/7/04)	Phase 3 Standby (effective 1/7/05)
TV	≤3	Analogue: ≤1 Digital: ≤3	≤1
VCR	≤4		≤1
Television Monitor	Analogue: ≤1 Digital: ≤3	Analogue: ≤1 Digital: ≤3	≤1
Component Television Unit	≤3	≤3	≤1
TV/VCR Combination Unit	≤6	≤6	≤1
TV/DVD, VCR/DVD and TV/VCR/DVD Combinations	≤4	≤4	≤1

Table 3.2
Energy Star Criteria (Watts) for Consumer Audio and DVD Products

Product Category	Phase 1 Standby	Phase 2 Standby
Consumer Audio Products	≤2	≤1
DVD Products	≤3	≤1

Table 3.3
Energy Star Criteria (Watts) for Set-top Boxes

Product Category	Tier 1 Standby	Tier 2 Standby
Category 1 Analogue Cable TV Set-top Box Advanced Analogue Cable TV Set-top Box Digital TV Converter Set-top Box Internet Access Device Video Game Console Videophone Set-top Box Set-top Box (eg, internet access device) with Cable Modem for enhanced communications in Standby Mode	≤3	
Category 2 Digital Cable TV Set-top Box Satellite TV Set-top Box Wireless TV Set-top Box Personal Video Recorder	≤15 (for satellite systems, add ≤5 watts for each LNB[1])	≤ 7(for satellite systems, add ≤5 watts for each LNB)
Category 3 Multifunction Device (ie a physically integrated device that has the core function of a satellite TV set-top box, digital cable TV set-top box, or personal video recorder plus one or more additional functionalities, such as an internet access device or video game	≤20 (for satellite systems, add ≤5 watts for each LNB)	≤ 7(for satellite systems, add ≤5 watts for each LNB)

[1] Low Noise Block-downconvertor (so called because it converts a whole band or *block* of frequencies to a lower band.

Table 3.4 lists the ENERGY STAR standby criteria for various home entertainment equipment types and provides data from the USEPA database for the most efficient equipment on standby. It is clear that equipment is available that beats the criteria by a very wide margin, although there is great variation in performance (often unrelated to price) in the market place. There is a lot of equipment that narrowly qualifies for ENERGY STAR and there is even some equipment on the database that appears not to conform to the criteria

Table 3.4
Energy Star Standby Criteria for Various Equipment Types Compared to Most Efficient Equipment Under the Criteria

Equipment Type	Energy Star Criterion (Watts)	Best of Type (Watts)	% Savings of Best Relative to Criterion
TVs/VCRs			
TVs	≤3	0.18	94
VCRs	≤4	0.85	79
TV/VCR Combination	≤6	1.60	73
TV/DVD, VCR/DVD and TV/VCR/DVD combinations	≤4	0.60	85
Consumer Audio and DVD Products			
DVDs	≤3	0.28	91
Microsystems	≤2	0.90	55
PWRD Speakers	≤2	0.80	60
Mini Midis	≤2	0.25	87
Minidiscs	≤2	1.40	30
Receivers	≤2	0.26	87
CDs	≤2	1.00	50
CD Record Burn	≤2	2.00	0
Stereo Amplifiers	≤2	0.70	65
Rack Systems	≤2	0.60	70
Set-top Boxes			
Digital Cable TV Set-top Boxes	≤15	6.70	55
Satellite TV Set-top Boxes	≤15	7.00	53

The first report for this project (dealing with office equipment) showed that across the range of ENERGY STAR criteria, the best performing office equipment beat the criteria by at least 10-fold and sometimes by 100-fold or more. It can be seen that for most types of home entertainment equipment covered by ENERGY STAR, the best performing equipment does not beat the ENERGY STAR criteria by such a wide margin. Nevertheless, large potential for energy savings relative to ENERGY STAR standards is evident.

In part, the size of the gap for office equipment is due to some of the earlier criteria set for this equipment not being very challenging, and the initial criteria for home entertainment equipment being made somewhat more stringent based upon prior experience of achievability for office equipment. However, it also true that for most types of office equipment market-leading performance in terms of standby energy is far more efficient than is the case for most types of home entertainment equipment. Table 3.4 reveals that there is still significant scope for reducing the standby energy for many types of home entertainment equipment. There is, for example, no obvious technical reason for the best-performing VCR to have nearly five times the standby power consumption of the best-performing TV or three times that of the best-performing DVD player.

3.2.2 One Watt Standby

The significant gap between most of the current ENERGY STAR criteria and the best performing equipment for standby power demand has highlighted that there are still large available gains in energy efficiency and greenhouse gas reductions through reductions in standby power.

The International Energy Agency has called upon member countries to develop programs to reduce waste standby power (Lebot, 2001).

In August 2000, Australian governments agreed to a one watt standby target as policy for all electrical products. Following consultation a *Standby Power Response Strategy* was released in late 2002 (NAEEEC, 2002); this will result in specific product plans being published progressively over the next 10 years on the following timetable:

- high priority (2003-2004)
- medium priority (2005-2007)
- low priority (2008-2012)

Of the equipment types being considered in this report, analogue TVs, digital TVs, VCRs, DVDs, digital TV set-top boxes and converters, pay TV set-top boxes and integrated and portable stereos have been initially assessed as being high priority and will be subject to profiling for development of specific implementation plans from early 2003; indeed a draft profile for analogue TVs has already been prepared. Sound system components (receivers, amplifiers, tuners, CD players and tape decks have been prioritised for action from mid 2004 (NAEEEC, 2002).

On 31 July last year, US President Bush (2001) issued an Executive Order requiring Federal Agencies to purchase "products that use no more than one watt in their standby power consuming mode. If such products are not available, agencies shall purchase products with the lowest standby power wattage while in their standby power consuming mode". The order is subject to life-cycle cost-effectiveness and practicability considerations. The President's enthusiasm for vampire slaying (vampires being machines that suck electricity) has led to opposition from some sections of the US electronics industry (Landers, 2001).

The European Union, Japan and others are also vigorously engaged in one watt programs. The benchmarks established by ENERGY STAR to date have only been modestly challenging as revealed by the wide gap between best performance and mere qualification for ENERGY STAR. However, ENERGY STAR has provided enormous impetus for better, more energy-efficient product design and consumer awareness of the importance of, at least, those elements of energy efficiency covered by the program. A one watt program would have been almost unthinkable in 1992, when ENERGY STAR was launched with benchmarks clearly designed to raise awareness and encourage improvement without creating conflict with industry. Now industry innovators have much more efficient products and are thinking of ways of improving them further, so that one watt programs (or even more stringent targets) are a logical progression with far wider support from industry than opposition.

The focus on standby energy over the past decade has led to very significant gains in efficiency with the promise of more to come. It could be argued that attention on operating energy has languished in comparison. As deeper cuts are made to standby energy, operating energy performance is likely to be thrown into stark relief with a corresponding appreciation of the opportunities it presents for increasing energy efficiency and reducing greenhouse gas emissions.

Further, for home entertainment equipment, rapid technological development and increasing sales of more energy intensive options increase the importance of effective action on operating energy.

3.3 Other Energy Efficiency Programs for Appliances and Equipment

3.3.1 Australia

In Australia, well-developed mandatory appliance energy labelling and Minimum Energy Performance Standards (MEPS) programs are being pursued for a small range of household appliances and equipment, and for some commercial equipment. These are described in detail in a range of Australian Greenhouse Office publications available at www.greenhouse.gov.au.

Appliance energy labelling was introduced in the mid 1980s, initially in Victoria and New South Wales, for household refrigerators and freezers, and was extended progressively to national coverage and to cover other major whitegoods – clothes washers and driers, and dishwashers – and single phase air-conditioners. Key criteria for application of energy labelling were that the products were significant energy consumers, and that individual households were a significant proportion of the market.

Australia's appliance energy label is well-regarded internationally, and market research has demonstrated that it works well (Colombier and Menanteau, 1997). The graduated scale means that users can easily compare products' relative performance, and the label also offers recognition of ongoing improvement of market leaders – at least within the boundaries of the scale used. Because of significant improvements in products, the scales used on Australia's energy labels were updated in 2000, so that products that previously rated 5 stars now score around 3 stars.

The original appliance energy labelling scheme looked only at operating energy. Where this involves continuous consumption (for example, refrigerators), this necessarily included standby power usage but, for appliances used for specific tasks such as dishwashers and clothes dryers, only the energy used during a program or cycle was measured, and standby power was ignored. In recent years, it has been recognised that standby power can be quite a significant issue for energy labelled appliances. It has therefore been agreed as part of the national standby strategy that by 2006 the energy labelling test procedures will be modified to include measurement of standby power, and this energy use will be included in the consumption data presented on the label (NAEEEC, 2002). The Australian energy label is therefore adapting into a form of label that takes into account all aspects of energy use.

MEPS have been applied to products - electric storage water heaters, three phase airconditioners and three phase electric motors - where end-users/owners may have little influence on the purchasing decision (for example, plumbers and builders often specify hot water services), and/or where there is little variation in performance across the product range (again, pre-MEPS most resistive electric HWS units consumed similar amounts of energy because space constraints and capital cost led to manufacturers using limited insulation). For refrigerators and freezers, MEPS have been introduced to complement appliance energy labelling. Here it was found that while appliance energy labelling was driving improvement in the efficiency of many products, significant numbers of poor performers were still being sold to purchasers who, for a variety of reasons, were not responding to the energy label. MEPS remove such products from the market. MEPS rely upon the same tests as are used for appliance energy labelling where this is appropriate.

3.3.2 Other Countries

A variety of other labelling, standards and efficiency improvement programs have been pursued around the world. Harrington and Damnics (2001) provide a comprehensive review of these.

Most of the approaches used for labels involve either endorsement or comparative labels. ENERGY STAR is an endorsement label, while the Australian appliance energy label is a comparative label.

Despite the broad reach of the ENERGY STAR label in the US (and to a lesser but significant extent globally) US market research (Brown *et al* 2002) shows a low level of consumer understanding of what the label means, and low media awareness of the label. While there was a 30% unprompted recognition of the label itself, ie it was a gold star that appears on equipment, few people knew what the gold star really meant.

Japan has a mandatory comparative label for televisions, while there are voluntary endorsement labelling programs in the European Union (EU), India, Korea, Mexico, Norway, the Philippines, Switzerland, Taiwan and (of course) the USA. There are voluntary endorsement labelling programs for VCRs and/or DVDs in the EU, Korea, Norway, Switzerland and the USA (Harrington and Damnics, 2001)

China, Korea and Russsia have mandatory MEPS for televisions and Korea has mandatory MEPS for VCRs (Harrington and Damnics, 2001). Japan is applying its *Top Runner* approach to televisions and VCRs. In this program, the best performer in a category in a specific year is identified and all other products are expected to improve to match its performance within a specified period.

3.4 Conclusions

In reality, energy efficiency programs for home entertainment equipment are not very well advanced, and are significantly less well developed than those for office equipment (which are also not particularly well advanced) and major white goods. The major international program is ENERGY STAR, which is voluntary and seems to be poorly understood by consumers in the USA - where it is best established and applies to a very wide range of products. Further, because it is an endorsement type label, the basis of the label not only requires updating to reflect improvements in performance but the criteria often lag significantly behind the performance of the best equipment. Lastly, for home entertainment equipment it sets requirements only for standby energy consumption and, unlike for many types of office equipment, it does not specify a time period in which switching to standby must occur. This greatly increases the likelihood that such equipment will be in high energy-consuming active standby mode for considerable periods of time. It therefore does not relate directly to actual energy use.

The *One Watt Standby* program will achieve a reduction in standby power consumption, but it will also only partly address overall energy use of home entertainment equipment.

The Australian Energy labelling scheme applies to major electrical appliances rather than to home entertainment equipment. In focusing on operating energy it has approached the issue from the reverse direction from that taken for the two standby programs. It is also beginning to incorporate standby energy in its considerations.

MEPS also do not apply to home entertainment equipment in Australia, but where they do apply they have the advantage of driving energy wasteful models out of the market. Under the standby programs, it is still possible for products that are very wasteful in terms of their operating energy to qualify on the basis of their standby performance.

It could be argued that a comprehensive approach for driving energy efficiency would include labelling based upon total energy use, with MEPS to drive very inefficient equipment out of the market place. However, as discussed later in this report, such an approach may still fail to address issues such as the rapid rate of turnover of models.

Harrington and Damnics (2001) point out that it is important for energy labelling schemes to fit the cultural context in which they operate, and that this varies from country to country. They suggest that this implies poor prospects for harmonised labels, but that it is not a barrier to international standard test procedures. It should also be recognised that substantial cost and time is involved in building consumer awareness of new types of labels and information programs. Where there are well-established labelling programs, building upon them rather than introducing different schemes for different products allows potentially for the efficient utilisation of previous investment in building consumer awareness of existing schemes.

The home entertainment equipment market is very much an international one. There are concerns that if one country introduces programs that differ from those used elsewhere, it could limit the range of product available, increase prices of equipment in that country, or reduce the range of choice available in that country. However, there is also wide diversity in energy efficiency of equipment and a rapid rate of innovation, so any country that introduced energy efficiency programs in this area could play a catalytic role with potential global benefits as improved products flowed into markets in other countries. Leadership in this area might well be seen as an important contribution to international greenhouse response.

4 Operating and Standby Energy: Relative Significance

To date, the focus of energy-saving action for home entertainment equipment has been on standby power consumption. This reflects the realisation in the early 1990s that a surprisingly high proportion of the energy used by much electrical equipment came from equipment being left on when it was not being used, or from equipment consuming significant amounts of energy when users thought it was in low power mode or even thought it was consuming no energy because it was turned off.

The major programs that have targeted standby energy use are ENERGY STAR and, more recently, the *One Watt Standby* program. These have been discussed in Sections 3.2.1 and 3.2.2. Regardless of the effectiveness of these programs at reducing standby power usage, there are several good reasons for considering operating energy:

- when equipment is operating, its power usage is higher than when it is on standby – indeed, with the increasing impact of efforts to reduce standby power usage, this gap is widening rapidly;
- a lot of home entertainment equipment, for example the main (or sole) television in many households, runs in operating mode for quite long periods;
- some equipment, perhaps best typified by VCRs, is left on active standby for much, and perhaps most of the time. Rosen and Meier (1999) estimate that a typical US VCR is in active standby (referred to by them as 'idle' mode) for 25% of the time it is not being used for playing and recording (the latter being estimated at 5.2 hours/week). However, they note that this is a judgement, as no data on time spent in active standby mode were available. Most VCRs *Sustainable Solutions* observe are on active standby permanently or for most of the time.
- unlike for office equipment such as computers or monitors, there is no requirement under ENERGY STAR for home entertainment equipment to power down to a lower energy-consuming mode within a specified time period;
- power factors (see Section 6) of home entertainment equipment in operating mode are generally relatively poor, adding to electricity supply losses;
- there is substantial scope to reduce operating energy through technological improvement, as will be discussed in Section 5.

4.1 Modelling Equipment Operation

Models of television and VCR operation were developed for this Report to gain an appreciation of the interaction between the efficiency of various power modes and operator behaviour and to act as a basis for identifying, and potentially prioritising options for energy efficiency.

4.1.1 Televisions

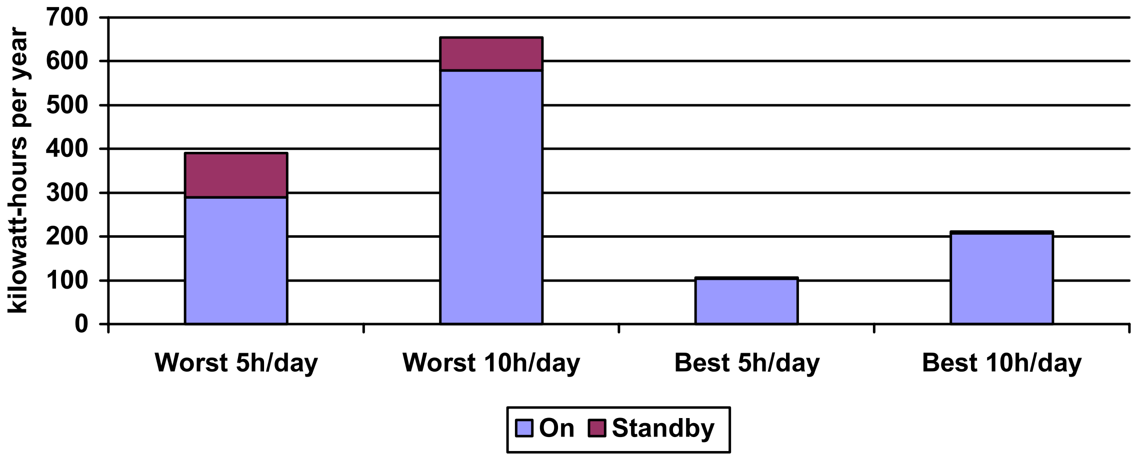
Models were developed for 68cm Cathode Ray Tube (CRT) televisions, operated for both 5 and 10 hours per day and on standby for the rest of the time. Worst and best equipment were modelled based upon the measurements of Harrington (2002). The worst TV is a composite of the highest operating energy (159 watts) and highest standby energy (14.7W), while the best TV is a composite of the lowest operating energy (57W) and the lowest standby energy (0.5W). The results are shown in Figure 4.1

Key conclusions that can be drawn from the modelling include:

- in all cases operating energy dominates energy consumption, varying from 74% of consumption (worst 5h/day) to 99% of consumption (best 10h/day);
- there are very large energy consumption benefits in moving from the worst to the best equipment, with reductions of approximately 70% resulting;
- for the worst currently available equipment, standby energy is still a significant issue. This component of energy use could be saved by turning the television off at the unit or power point instead of using the remote control.

- for the best currently available equipment standby energy consumption is already very small.

Figure 4.1
Annual Electricity Consumption for 68cm CRT Televisions



4.1.2 Video Cassette Recorders

Models were developed for ‘average’, ‘good’ and ‘best’ VCRs and for an ‘average’ VCR with one watt standby, which had been used to play video tapes for one hour per day. Two cases were considered:

1. the machine was left on active standby all of the time (the more likely case in our experience);
2. the machine was left on active standby for one quarter of the time that it is not playing, with the remaining time spent on standby as assumed by Rosen and Meier (1999)

The assumed power consumption in various operating modes for these VCRs is shown in Table 4.1.

Table 4.1
Power Levels (Watts) of Modelled VCRs

VCR	Play	Active Standby	Standby
Average	14.3	10.9	3.8
Average, 1W standby	14.3	10.9	1
Good	8.5	6.9	1
Best	3	1.5	0.5

The best VCR is hypothetical, but the power levels selected seem technically achievable. This machine is also assumed to be programmed to power down to standby if it has not been used for an hour.

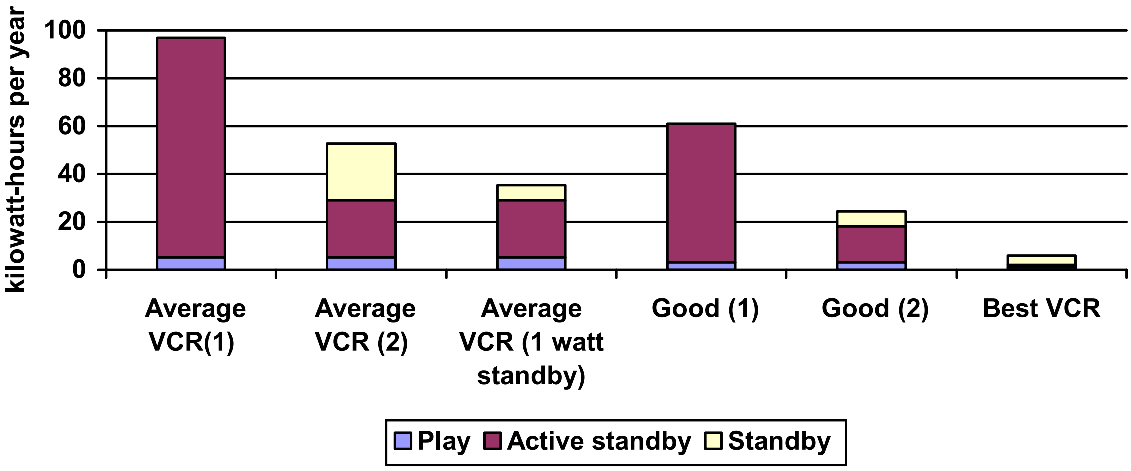
The results of the modelling are shown in Figure 4.2.

Key conclusions that can be drawn from the modelling include:

- in all circumstances only a small proportion of energy consumption occurs while the VCR is actually performing useful work playing or recording tapes, varying from 5% when both the average and good VCRs are never switched to standby to 18% for the best VCR;
- active standby energy consumption is the largest component of energy use for all equipment in all scenarios, varying from 45% for the average VCR(2) to 95% for the equipment left on active standby all the time;
- under the assumptions in the modelling there are very large reductions in energy consumption from manually switching to standby (50-64%) rather than leaving the VCR on active standby;

- there is enormous scope through design and power management to reduce energy consumption by VCRs. The best VCR has only 6% of the energy consumption of average VCR(1);
- if VCRs were required to power down automatically to standby after 1 hour, energy savings of 60-80% could be made relative to the base case of being left on active standby all of the time.

Figure 4.2
Annual Electricity Consumption for VCRs



5 Factors Influencing Future Energy Consumption of Home Entertainment Equipment

The home entertainment equipment arena is dominated by high rates of innovation, unexpected developments and changing consumer desires/expectations. This leads to a wide range of possibilities in terms of home entertainment equipment energy consumption over the coming years. This potentially volatile situation highlights the importance of effective policy development and delivery to achieve energy efficient and greenhouse gas mitigating outcomes.

In this Section, we consider some of the possible drivers of future energy use of home entertainment equipment, including technological developments, to show that there is potential for large savings or, alternatively, potential for substantial growth in energy consumption, and that public policy should facilitate capture of savings.

Broad drivers that may influence the energy consumption and greenhouse gas emissions from demand for home entertainment equipment services include:

- increasing disposable incomes and declining prices for many home entertainment products;
- rising expectations of the quality of sound and visual reproduction, including larger visual images;
- rapid expansion in the range of products available;
- trends towards smaller households and individual (rather than group) usage of items of equipment; and
- priority given to energy efficiency in the design phase.

These trends reinforce the need for policies that drive development activity towards energy efficiency improvement, and for information and education of users so that the potential savings are adopted quickly.

5.1 Trends and Issues for Specific Types of Equipment

5.1.1 Video Cassette Recorders (VCRs), Compact Disc (CD) Players and Digital Versatile Disc (DVD) Players

Household VCR, CD and DVD systems convert recorded information into signals suitable for reproduction as visual and/or audio services. In this sense, apart from personal CD players playing through headphones or earplugs (which usually run on batteries or external power supplies) they are elements of a system rather than being appliances in their own right. Indeed, where a television has no remote control, VCRs have often been used to provide the remote control feature.

The fundamental energy requirement of a VCR, CD or DVD player/recorder is very small, as demonstrated by the fact that a personal CD player can operate for many hours on small batteries – equivalent to a power consumption of less than 0.5 watts. The mechanical energy requirement for driving a videotape, CD or DVD is also small, with measurements showing the difference in power usage when playing or not playing a tape or DVD differing by as little as 1 to 5 watts for modern equipment (Harrington, 2002). In comparison with the amount of energy consumed by a television or stereo amplifier, this is a minor issue.

However, because of inefficiencies in design and the large numbers in use, energy use by these equipment types in aggregate is significant. Further, there is potential to reduce it. Reasons for its significance are:

- Typical annual consumption of each VCR is estimated at around 71 kilowatt-hours (Rosen and Meier, 1999), but consumption could be much higher if many are left on active standby – see Section 4;
- There is very high penetration of these products into the marketplace and there is potential for ownership of several units per household – Rosen and Meier (1999) suggest that 68% of US homes have one VCR, 28% have two and 8% have three, giving an average penetration of 1.48 VCRs per household, with an average annual consumption of 100 kWh per household. Harrington and Kleverlaan (2001) estimate penetration of VCRs in Australian homes at 1.21 and rising and 0.089 and rising for DVDs.

- Many models, when connected to mains power supply, use inefficient power supplies, often with very high losses at low loads (see discussion in Section 5.1.4)
- Many of these products may be left on active standby for long periods or even continuously, either because it is not obvious to a user that they are using power unnecessarily, or because their remote control function is being used to switch channels on a TV. The ENERGY STAR and *1 Watt Standby* requirements do not apply to active standby mode, and energy consumption on active standby is often far higher than on passive standby or low power mode. This gap may widen as passive standby power consumption is reduced in response to programs such as *1Watt Standby*. Rosen and Meier (1999) estimated that a typical US VCR is in active standby (referred to by them as 'idle' mode) for 25% of the time it is not being used for playing and recording (the latter being estimated at 5.2 hours/week). However, they note that this is a judgement, as no data on time spent in active standby mode were available. Most VCRs we observe are on active standby permanently or for most of the time.
- When not in operating/active standby modes, many models cannot be switched fully off at the unit, or can only be switched into a standby or low power mode. This means they draw power continuously, although usually at a fairly low rate. The ENERGY STAR and *1 Watt Standby* programs target this aspect of consumption.

The major opportunities for efficiency improvement are therefore:

- use of high efficiency power supplies (and ongoing improvement in motor and drive efficiency),
- reduction of power usage in active standby (or automatic power down to low power standby) and
- reduction in standby energy consumption.

Measurements have indicated that a recently-purchased DVD player automatically powered down from active standby (at 9 watts) to 2 watts within a few minutes of completing playing a DVD (Andrews, 2003). So at least one product seems to have utilised automatic switching to low power standby mode, and there seems to be no reason why this could not be applied by others.

Table 5.1 shows averaged data from the Australian 2001 in-store survey (Harrington, 2002) for VCRs and DVD players in each mode of operation. It can be seen that the change in power requirement between active standby and playing is a few watts (3.3 and 2.5 watts for average VCRs and DVDs respectively) but the gap between active standby and passive standby (or 'off' at the unit or via remote control) is much larger (8.2 watts for average DVD and 7.1 W for average VCR).

Table 5.1
Averaged Power Data (Watts) for VCRs and DVDs

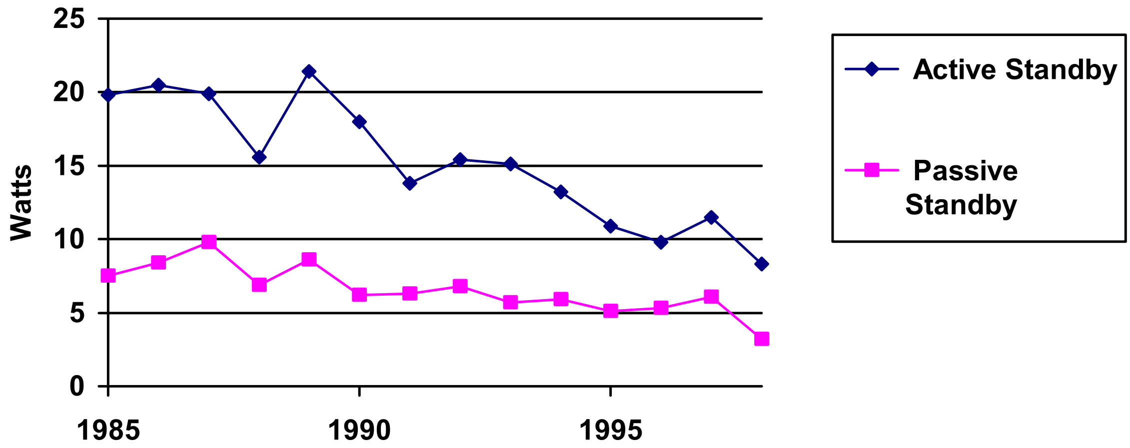
Mode	VCRs	DVDs
Play	14.25 (100%)	16.13 (100%)
Active Standby	10.93 (77%)	13.6 (84%)
Passive Standby	3.81 (27%)	5.4 (33%)

Given the range of performance of the best existing products (including battery-operated products), it seems technically feasible to reduce their power consumption to around 3 watts or less when operating, less than 1 watt on active standby, and less than 0.5 watts on passive standby or 'off'. Pressure to improve battery life for portable CD and DVD players is likely to drive ongoing efficiency improvement in that sector of the market, but the challenge will be to translate the application of these developments to the rest of the market.

However, given the relatively low energy consumption of these appliances already, and their lack of obvious indications of energy waste to users, it may be difficult to generate strong consumer demand for more efficient products. So, while energy labels or other information programs would be potentially useful, they may have limited impact in comparison with design initiatives; research, demonstration and development incentives; procurement policies; minimum performance standards or preferential labelling of poor performers (Columbier and Menanteau, 1997).

Figure 5.1 depicts the long–term trend in power consumption for VCRs studied by Rosen and Meier (1999) and shows a gradual decline in power consumption in both active standby, in particular, and passive standby modes. This indicates worthwhile improvements but large opportunities remain, as shown in Section 4.

Figure 5.1
Trends in VCR Power Consumption



5.1.2 Televisions and Home Entertainment Systems

Stereo systems for audio entertainment and televisions for visual/audio entertainment have traditionally been separate. However, over the past 25 years, there has been a trend towards combining them into home entertainment systems. Increasingly, this trend has moved towards equipment capable of providing a high standard of visual and aural experience, with large screens and powerful sound systems. As noted earlier, the energy used by the products that generate the signals (VCRs, DVD players, digital signals via cable or satellite) is either small or potentially small in comparison to the energy used to operate this equipment.

At the other end of the spectrum, developments in Liquid Crystal Displays (LCDs), computer games, computers and communications technologies have led to the evolution of a variety of portable, low power visual/audio devices intended for personal use.

In the middle of the spectrum, conventional Cathode Ray Tube (CRT) televisions have become much cheaper, and it is increasingly common to have several TVs of varying sizes in a home. Indeed, as new technologies are adopted, older VCRs and other equipment may also migrate to other parts of the home. Declining costs and changing demographics (for example children living at home after they have begun to earn an income) mean ownership of multiple units in a household is increasingly common.

Development of home communication networks adds to the complexity of the situation, as appliances in different parts of the house may share common signals or be used independently.

The diversity of these trends makes it extremely difficult to forecast future equipment ownership and usage, and hence energy consumption. Trends that seem feasible as an upper limit include:

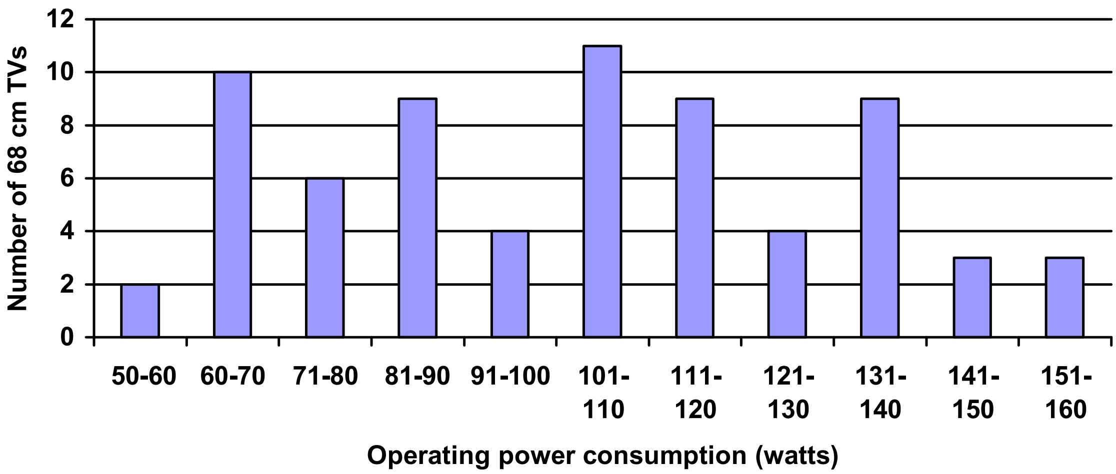
- Widespread ownership of large screen (projection or flat screen) high audio quality home theatre systems for use in family living/entertainment areas and, to some extent, in the bedrooms of teenagers and adults

- Widespread ownership of portable entertainment equipment with small screens, and even virtual reality
- Proliferation of equipment into bedrooms and entertainment rooms, and even into kitchens, as more individual use of televisions and the Internet occurs for entertainment and access to information (eg, recipes): indeed, an internet refrigerator with LCD screen has recently been launched in Australia (Lebihan, 2002)
- Increasing usage due to demographic trends (ageing population spending more time at home, more households) and more individual use instead of communal use.

5.1.2.1 Televisions

Energy use by televisions is very sensitive to both screen size and of technology type, as well as to usage patterns. There is also significant variation in consumption across the range of manufacturers, as shown in Figures 5.2 and 5.3. For most screen sizes, the variation in energy use across the sample of models of identical size measured by Harrington (2002) was at least a factor of 1.7. There is at least a factor 2.6 variation in operating power consumption of large 68 cm TVs on Australian market. If such a TV were used for 5 hours per day, the annual operating energy saving from using the best in sample (57W) instead of the worst in sample (159W) would be 186 kilowatt-hours. Indeed, the average operating power consumption of 51 cm TVs in the survey was 67 watts, so the most energy efficient large TVs use less energy than the average smaller unit.

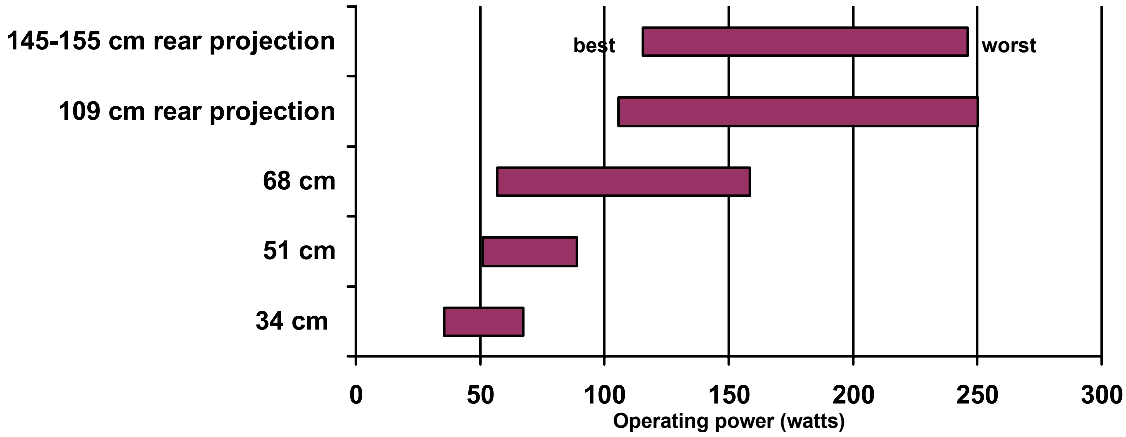
Figure 5.2
Operating Power Consumption of a Sample of Seventy 68 cm Televisions Measured in Australian Stores in 2001 and 2002



Even for relatively new technologies such as rear projection TVs, there is a wide range of variation between models. For example, four rear projection TVs in the 145-155 cm size range were measured at between 116 and 246 watts respectively.

Clearly there is large potential for energy savings through selection of market leading models rather than poorer performers.

Figure 5.3
Operating Power Consumption Performance for Different Television Types



In the longer term, energy trends will be determined by the developments in technology, and their relative rates of adoption. The major technologies in use or emerging are listed in Table 5.2.

Table 5.2
Summary of Television Technologies and Their Possible Energy Use

Technology	Energy Use	Comments
Cathode Ray Tube (CRT) – traditional TV	Trend over time has been gradual improvement in efficiency, but average screen size has also increased. As noted in the text, there is large variation in energy efficiency across models. Huenges Wajer and Siderius (1998) have developed an Energy Efficiency Index in which the performance of a TV can be compared with a standard unit whose consumption is given by: P=16+[12 if digital]+(0.91 x screensize in cm) x [0.8 if 4:3 format or 0.87 if 16:9 widescreen] +0.46 x (screen area in dm^2) + [27.9 if scan rate is 100Hz]	Evolution towards wide screen, higher resolution, higher frequency (100 Hz instead of 50 Hz) scan rate, and digital, cable, satellite and internet connected units. Average new TV operating energy use of a sample in stores is just under 100 watts while average existing stock uses just under 70 watts (Harrington and Kleverlaan, 2001) The best 68 cm TV measured in Harrington (2002) is almost 20% more efficient than the 'standard' product proposed by Huenges Wajer and Siderius (1998)
Projection – rear projection units and projectors	Energy efficiency is sensitive to brightness, image size, lamp efficiency, and losses when light is passed through or reflected by a LCD image. Losses from transmission are typically 30%, from reflection 7% (Huenges Wajer and Siderius, 1998)	Projector units have been measured for this report at 150 to 270 watts. Rear projection TVs measured at 116 to 246 watts (Harrington, 2002). Ongoing energy efficiency improvements may be counteracted by increased brightness
Flat screen – LCD and similar	These TVs are much more efficient than conventional CRT ones (up to 85% savings) but have traditionally been available only in smaller sizes. Screen size is increasing, but it is technically difficult to make very large screens	In theory, 17 inch (43 cm) screens should use 17 watts, but measurements indicate 30-34 watts, so efficiency at present seems to decline with screen size.

Flat screen – plasma	Large flat screen TVs typically use this technology, which is relatively inefficient and has difficulties delivering high visual quality.	NEC MP2 (50 inch) was measured at 440 watts, 42" Fujitsu measured at 303 watts (compares with CRT unit of same size at around 165W). Manufacturers have suggested that eventually plasma screens should match the energy efficiency of CRT screens – but their larger size means they will use more power overall
Emerging flat screen technologies	Organic LEDs, reflective LCDs, and other developments (TIAX, 2002) have potential for savings	Maximum savings seem likely to be halving of LCD energy use

Huenges Wajer and Siderius (1998) suggest that savings of 8% (larger units) to 18% (small units) can be achieved if manufacturers of CRT TVs set luminance to 130 cd/m^2 (down from 230 cd/m^2) at the factory. Attention to the efficiency of audio amplifiers and speakers, digital decoders, power supplies, etc could deliver worthwhile savings in the order of 10 watts relative to products that meet their 'standard' performance as estimated using the equation shown in Table 5.2. Since the best of recent 68 cm models have already achieved a level of energy efficiency almost 20% better than this 'standard', there seems to be further scope for savings. These improvements over less than five years highlight the importance of encouraging innovation in this area, and ensuring that information programs and MEPS incorporate scope to reward significant improvements. Future power consumption of large TVs seems uncertain, but is likely to increase. At worst, rapid adoption of large plasma screens could see power consumption of 300 watts or more. But if projection techniques are the popular choice or plasma screens achieve manufacturers' expectations, consumption could be half or two-thirds that level. If best technology 68 cm CRT models dominate the market, consumption may fall slightly. If high efficiency flat screen technologies can be scaled up, consumption of relatively large units could fall below 50 watts. This wide range of possibilities highlights the importance of policies that encourage manufacture and adoption of the most efficient options. Huenges Wajer and Siderius (1998) estimate that operating energy use by televisions in the European Union could increase from 23,200 Gigawatt-hours per year in 1995 to 38,900 GWh in 2010, a 68% increase. This represents an increase in electricity consumption per household from 160 to 240 kWh per year for TV usage, a 50% increase per household.

For small to moderately sized TVs, adoption of best CRT technologies could deliver substantial savings compared with today's average new products, as shown in Figure 5.3. If the achievements in 68 cm models can be applied to these smaller-sized units, even larger savings could be gained. LCD and emerging technologies seem likely to replace conventional CRTs in this size range over time, bringing savings of 30-80% for a given size. However, the number of such products in each home may proliferate as more people use them individually instead of communally. Conversely or in addition, there may be a shift towards smaller screens, as the portability of LCDs may lead to greater dependence on battery-powered units, and it may become easier to have the TV close to the viewer, where smaller units may be quite sufficient.

5.1.2.2 Home Stereo and Sound Systems

Rosen and Meier (1999) estimate that the 101 million US households use around 20 TWh pa of electricity for stereos and clock radios – almost 200 kWh/household pa. Given their conservative assessments of the time spent in active standby (discussed below), actual consumption could be significantly higher. If Australian households have similar levels of penetration and usage of these appliances, they could be responsible for around 3% of household electricity usage, making them comparable with televisions, and more significant than a number of appliances that already carry energy labels and are seen as 'energy guzzlers'.

A typical modern home may have a number of sound systems including several portable units, small 'packaged' units, possibly a high quality components-based unit, and a sound system attached to the main television or home theatre equipment. Some of this equipment may be used rarely, while other units may be used for lengthy periods.

The energy use characteristics and levels of usage estimated for the USA for these types of equipment are summarised in Table 5.3. Estimated usage patterns for stereo equipment, are shown in Table 5.4 (Rosen and Meier, 1999).

Table 5.3
Average Power Use (Watts), Ownership Patterns and Usage (USA, 1998) for a Range of Home Stereo Equipment (Rosen and Meier, 1999), and for Surround Sound (Harrington, 2002).[2]

TYPE OF UNIT	OWNERSHIP - % of homes with at least 1; (ave number/home)	OPERATING POWER	ACTIVE STANDBY POWER	'OFF'/ PASSIVE STANDBY POWER	USAGE (see Table 5.4)
Clock radio	84% (1.5)	2.0	-	1.7	0.36h/day for radio
Portable stereo	56% (1.2)	5.0/5.9/8.6	-/4/5.8	1.8	0.72h/day for radio + 0.72h/d for CDs or tapes
Compact 'Package' stereo	34% (1.16) + 6.4% (1.16) connected to TV	21/ 22/24	20/20/21	9.8	As for portable
Component stereo	27% (1.12) + 38% (1.12) connected to TV	42.9/47.1/47.1	42.9	3.0	As for portable
Surround sound amplifier		Not measured	48	2.2	

Table 5.4
Estimates of Usage Patterns for Stereos in the USA (Rosen and Meier, 1999)

Audio System	Disconnected	Standby	Active standby*	TV/tuner play	CD/tape play	Total
Clock radio	0%	99%	-	1.5%	-	100%
Portable stereo	30%	51%	13%	3%	3%	100%
Compact stereo	0%	75%	19%	3%	3%	100%
Compact stereo +TV	0%	56%	14%	27%	3%	100%
Component stereo	0%	75%	19%	3%	3%	100%
Component stereo + TV	0%	57%	14%	26%	3%	100%

*Our observations indicate that many Australian stereos are left on active standby most of the time they are not playing, as it is not obvious that they are wasting power in this mode, and it is the natural default mode of the product.

[2] Where three values are shown, they are for: connected to TV or tuner/tape/CD. That is, the latter two values include operation of a motor driving a tape or disk

Based on the above assumptions regarding usage, and the data from measurements, Rosen and Meier determined the following annual consumption estimates for various types of stereo equipment (Table 5.5).

Table 5.5
Estimates of Annual Electricity Consumption of US Stereo Equipment in Each Mode and in Total (Rosen and Meier, 1999).

Audio System	Standby (kWh/year)	Active standby (idle) (kWh/year)	TV/tuner play (kWh/year)	CD/tape play (kWh/year)	Total Consumption (kWh/year)	% of annual consumption in play and active modes
Clock radio	15	-	0.3	-	15	2%
Portable stereo	8.2	5.5	1.3	1.9	17	51%
Compact stereo	62	32.3	12.8	6.1	113	45%
Component stereo	17	60.7	61.3	12.4	151	89%

Points that can be drawn from the above information and analysis include:

- For clock radios and portable stereos, addressing standby energy use would achieve substantial percentage savings. However, these are not a large proportion of energy use at a household level –for example, a household with two clock radios and two portable stereos would, on average, consume 64 kWh per year, around 1% of typical household consumption. Around 30% of this would be saved through compliance with *One Watt* program, and it is likely that much lower standby consumption could be achieved – for example battery-powered clocks run on a few milliwatts, and the bulk of the power requirement of an efficient clock radio (possibly apart from when it is playing) could potentially be provided by a small solar panel.
- For compact stereos, almost half of energy consumption is estimated to occur during operation and active standby. However, Rosen and Meier have estimated (based on very limited data) that active standby occurs for only 14-19% of the time, and operation is for 6-30% of the time, depending on whether the system is connected to a TV or not. They have based their electricity consumption estimates on an average of around two-thirds of the time being spent on standby. The units measured by Rosen and Meier (1999) had quite high standby power consumption (9.8 watts), while a more recent sample measured in Australia (Harrington, 2002) had an average standby power consumption of 4.4 watts, with actual values ranging from 0.3 watts to 13 watts. Clearly there is scope to almost eliminate standby power usage, but this would still leave average annual energy consumption at around 50 kWh per unit and, if a unit were left on active standby all of the time it is not in use, annual consumption would be around 175 kWh. It is interesting to note that Harrington's recent measurement of active standby power consumption for compact stereos gave an average of 20.6 watts, almost exactly the same as the values used by Rosen and Meier.
- For component stereos, Rosen and Meier estimate that almost 90% of annual energy consumption occurs in operation and active standby, even though they assume they are on standby for around two-thirds of the time. This is partly due to the relatively low standby power consumption measured (3 watts) – a value confirmed by Harrington's more recent measurement of 2.2 watts (see Table 5.3). If a component stereo were left on active standby all the time it is not used, annual consumption would be close to 380 kWh.
- Since component stereos linked to televisions for home theatre systems are a potential growth area, it seems doubly important to encourage reduction in both operating energy and active standby. Potentially reduction of active standby power consumption should be straightforward, through application of the power management strategies developed for computers and/or other efficiency improvements. But there is also scope for large savings in operating energy. For example, CADDETT (2001) reports on an improved ICE amplifier being developed by Bang & Olufsen in Denmark. They note "about 99% of the energy fed into conventional amplifiers is wasted as heat…. Not only is the energy consumption of an ICEpower amplifier reduced by 80-

> 90%, but the amplifier can also be more compact and requires no cooling. It gives a 'bigger' sound and is cheaper to produce."

A potentially important issue is the impact of sound level on energy consumption of stereos. Data in Rosen and Meier (1999) indicates that the bulk of the power consumption of stereo systems occurs independently of the sound level. For example, measurements showed an increase in consumption of only around two watts when packaged stereo systems were switched from active standby to playing at an 'average' listening level. Power consumption was measured over a wide range of sound levels and it was found that, as sound level increased beyond 10 dB above 'pleasant' (that is, 10 times louder), power consumption began to rise rapidly. At the level of pain, power consumption was around 70% higher than on active standby. However, in urban areas at least, it seems unlikely that many sound systems would be operated at such high sound levels for long periods, due to impacts on neighbours.

There is a need for research to clarify whether equipment is commonly left on active standby or, alternatively, programs should be put in place to ensure that power consumption in this mode is minimised by energy-efficient design or automatic power management down to close to the standby power consumption. Then we could be confident of low energy consumption when equipment is not producing sound, regardless of the behaviour of users.

5.1.3 Networks

A fundamental shift that is changing lifestyles is the interconnection of equipment within a home, and interaction with external networks such as the Internet.

The vision of the fully networked home is one in which all appliances and equipment can interact, instructions can be sent to them from remote sites, faults can be diagnosed via networks, sensors can be used to control household functions such as shading and lighting, and users can access information and multi-media services of all kinds from anywhere in the house.

This vision is rapidly moving towards fruition in developed countries, as appropriate equipment is developed and communication networks are upgraded.

As in other areas considered in this report, the future of networking is very uncertain. However, the issue to be considered here is the possible energy (and greenhouse) impacts of such trends, rather than prediction of their detail. To facilitate networking requires extra sensors, communications equipment and control systems. Further, networks facilitate much heavier use of equipment, for example each individual in a home may be watching a television on a different channel or using a computer while security cameras monitor activity. Networks also require a capacity to interact with other systems at any time, so the need for equipment to respond quickly when it is 'off' becomes increasingly important. From an energy perspective, then, home networks could drive growth in energy use through greater use of more equipment, and an increase in standby energy use.

However, home networks also offer potential to reduce energy use and manage energy better. For example, remote diagnosis of faulty appliances saves transport energy. Downloading movies avoids car trips to the video store, and so on. Intelligent controls could switch off non-essential equipment at times of peak demand, or could ensure lights were not left on unnecessarily.

Aebischer and Huser (2000) analysed energy use by home networks in Switzerland. They concluded that the upper limit would be that networks and the additional usage of equipment linked to them could use the equivalent of 30% of today's household electricity by 2020. Around a quarter of this power usage is attributed to standby and off modes – so the significance of operating energy in their scenario is obvious. They estimated that just running the network in a networked home would consume an average 30 to 75 watts of power – up to 650 kilowatt-hours per annum, around 10% of average Australian household electricity use. The energy growth predicted beyond that is due to the higher usage of equipment induced by the capacity of the network.

A key point made by Aebischer and Huser is that the energy characteristics of equipment are unlikely to have a major influence on which equipment is adopted: there are powerful commercial interests driving each option, and consumers are most interested in functionality. For comparison, an additional 1500 kilowatt-hours of electricity per year would cost less than $250, equivalent to the cost of 10 CDs, and less than the cost of maintaining a connection to cable TV and other information services likely to be considered 'essential'.

In a network, the boundary between operating energy and standby energy becomes even more blurred. For example, security monitors would operate continuously, but would only operate equipment that is on standby when it is required.

Despite the lack of focus on energy efficiency with regard to networks, there are ongoing improvements in the energy efficiency of most components of networks, and of the equipment connected to them, often as spin-off outcomes of other developments. For example, while hard disks have become more efficient, new solid state memory devices require little or no energy to maintain data. Aebischer and Huser expect to see sensors that require no external energy in the near future – and small solar cells could provide the energy required by many small devices.

Clearly, it will be important to drive the energy efficiency of network equipment, its functional design, and the equipment attached to networks, in order to limit energy use resulting from their widespread adoption. At the same time, the complexity and vast range of possible systems and equipment make it difficult to apply blanket solutions.

While it seems feasible to develop and apply Minimum Energy Performance Standards (MEPS) to specific items of equipment that may be incorporated into networks, it may also be necessary for governments to fund (or at least assist) specific energy efficiency RD&D activities integrated into the development of equipment, so that energy efficiency becomes a normal aspect of the development of new equipment. Where there are choices of alternative solutions with differing energy implications, it will be important for governments to have in place programs that alert them to the situation, and strategies to promote the superior energy efficient solutions to consumers. For example, articles in homemaker or consumer magazines comparing the energy performance of alternative systems could be effective.

A further important area is the development of protocols that facilitate automatic switching to low power modes, collect information that allows optimisation of energy use, etc. Active involvement in development of these protocols by governments with a view to ensuring energy efficiency would also be important.

5.1.4 Power Supplies

Most consumer electronic devices run on low voltage DC (Direct Current) power, not the 240 Volt AC (Alternating Current) power supplied via power points. Power supplies are used to convert the electricity supply to the DC voltage required. There are two fundamentally different types of power supply in widespread use: linear and switched mode. Linear devices typically use a transformer (coils of wire around a steel core) to change the voltage, then electronic components such as diodes to convert it from AC to DC. Switched mode power supplies are much lighter, and use electronic components for the whole process. Power supplies may be built-into equipment, or external. For example, the plug-pack, a power supply that plugs directly into a power point, is very common.

Traditionally, small power supplies such as those used in small electrical appliances, or as external power sources for small appliances, have been quite inefficient. Indeed, much of the standby power measured for small appliances can be attributed to losses in power supplies. For example, Calwell and Reeder's (2002) measurements have shown efficiencies of as low as 20 to 75% for traditional linear power supplies.

They state: "Our research indicates that the efficiency of most linear power supplies could be improved from the 50 to 60% range to 80% or more. Switching power supply efficiencies could be increased from the 70 to 80% range to roughly 90%. In most cases the incremental cost for the improved power supply is less than [US]$1. The resulting electricity savings for these products pay for their incremental cost very quickly – typically in 6 months to a year."

A key barrier to improvement identified by Calwell and Reeder is that few power supplies are purchased by the end user. Instead, the equipment supplier, who has a focus on reducing initial cost, buys the power supply but does not benefit from the ongoing energy savings. Further, the efficiency of a power supply is not generally a major criterion for buyers of consumer electronics, for whom other costs are much higher, and as they are generally poorly informed of the energy issues.

However, there are some benefits for product suppliers through use of more efficient switched-mode power supplies. Often they are smaller and lighter. They run cooler, and are less likely to need a cooling fan. Switched mode power supplies are also able to operate from a range of input voltages, making them very suitable for internationally distributed products. These advantages are leading to a gradual transition to the more efficient class of switched mode power supplies, but are not necessarily leading to optimisation of efficiency within the class, or achievement of high Power Factors and low Harmonic Distortion (see Section 6 for discussion of these issues).

The total number of low voltage power supplies in use globally is estimated to be more than 6 billion (of which almost half are in North America), and annual sales are 1.5 to 2.5 billion globally and over 450 million in North America. Around 6% of all US electricity passes through power supplies. Replacing linear power supplies and existing efficiency switch-mode power supplies with power supplies of 80% efficiency or better would save 1% of all US electricity, worth at least US$2.5 billion per year (Calwell and Reeder, 2002).

Most power supplies are less efficient at low load than at full-rated load. But total losses may be greater at higher load.

Discussions have been held within the European Commission (Bertoldi, undated) to support development of power supplies with low losses at low or zero load. However, what is required is a strategy that achieves high efficiency over the full operating range of power supplies.

6 Power Factor and Distortion

Power Factor and distortion (often measured by Crest Factor) are important characteristics of electric and electronic equipment that impact on the electricity supply system and other electricity consumers.

For perfect 240 Volt Alternating Current power supply, the voltage and current both vary smoothly over time, following a sine wave pattern with a frequency of 50 cycles per second. The variation between positive and negative values is reflected in the term 'alternating'. Voltage and current peak at the same time, have zero values at the same time, and reach maximum negative values at the same time. Electronic components can affect the current flow and voltage variation so that they become out of phase – for example, current may reach its peak value a short time after voltage peaks. Power Factor is a measure of the extent to which the current and voltage of the electricity supply system are forced out of phase.

A Power Factor of 1 occurs when voltage and current are exactly in phase, rising and falling together. This situation is shown in Figure 6.1, where the curves for voltage and current coincide. At the other extreme, a Power Factor of zero occurs when current is zero as voltage peaks, current peaks when voltage is zero, and so on. The lower the Power Factor the greater is the phase difference between voltage and current (see Figure 6.2). The further out of phase the voltage and current are, the higher the current required to achieve a given amount of useful work – the higher the 'apparent power' compared with the quantity of 'real power' delivered. This higher current leads to increased losses in the electricity supply network and increases the amount of fuel consumed to make electricity.

Figure 6.1
Relationship Between Voltage and Current when Power Factor = 1

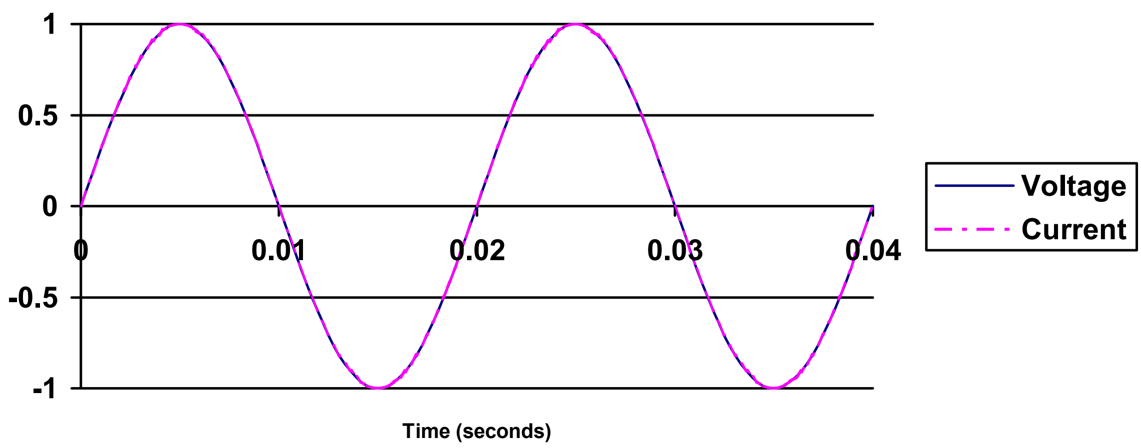
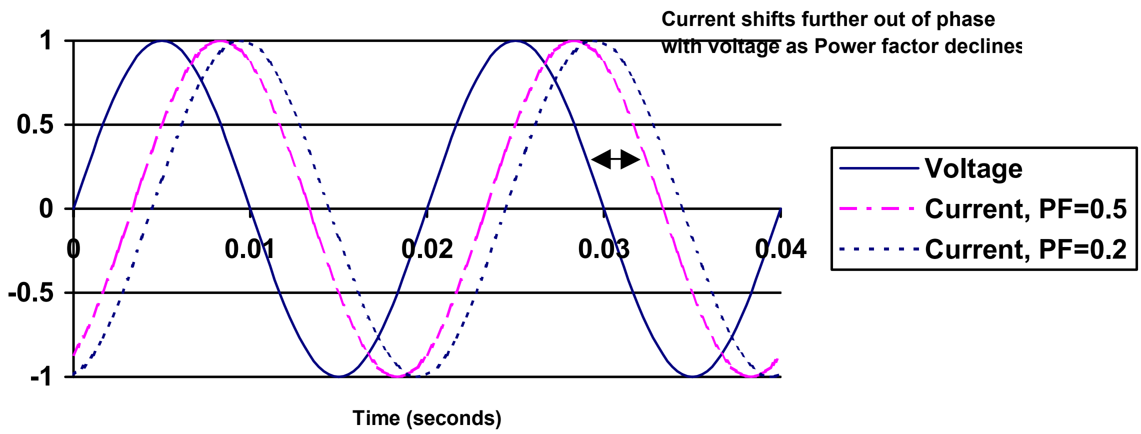


Figure 6.2
Relationship Between Voltage and Current when Power Factor < 1

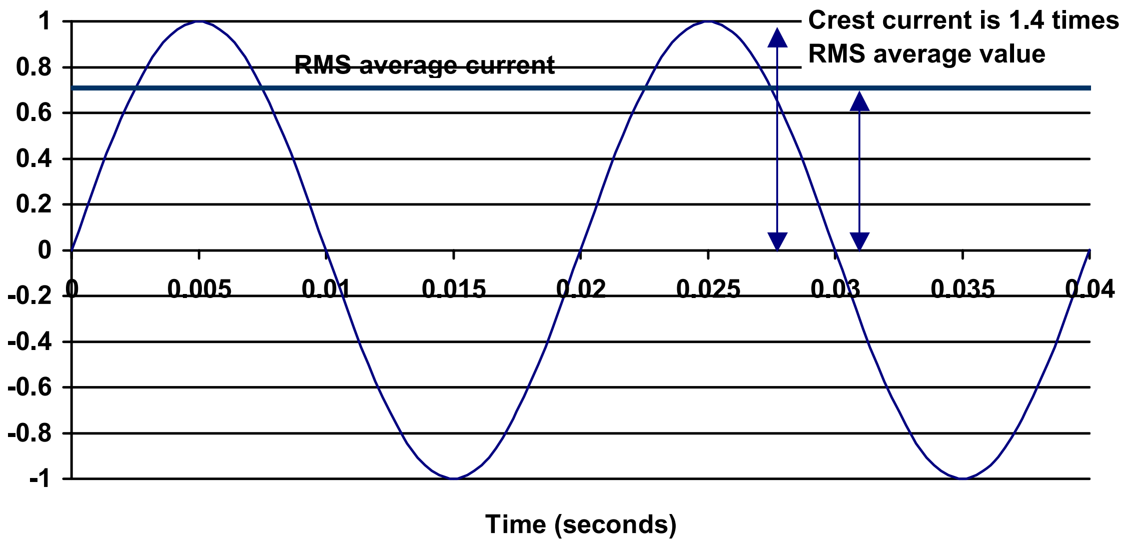


A simple analogy to Power Factor is pushing a swing. When a swing is pushed just as it reaches the extreme of its arc, energy is transferred efficiently, and with a small amount of energy input the swing can keep going. But if the swing is pushed part-way through its arc, the transfer of energy is inefficient, and overall more energy is needed to keep the swing going.

So the lower the Power Factor, the greater the energy losses in supplying electricity. Since power generation and supply systems have to be designed for Apparent Power, poor Power Factors also increase capital cost of electricity supply systems (as Real Power = Apparent Power x Power Factor). Many electricity suppliers now charge business customers for peak electricity demand on the basis of their 'Apparent Power' requirement taking into account Power Factor. This is measured as Volt-Amps rather than Watts. At present, residential electricity customers are not charged for their Power Factor, but with the planned introduction of interval metering under the National Electricity Market, residential users may be billed for Power Factor in future. At present the main beneficiaries of improved power factors are electricity generators and suppliers and, to the extent that savings for them flow through to lower prices, consumers also benefit. But households with good Power Factors cannot at present benefit relative to those with poor Power Factors.

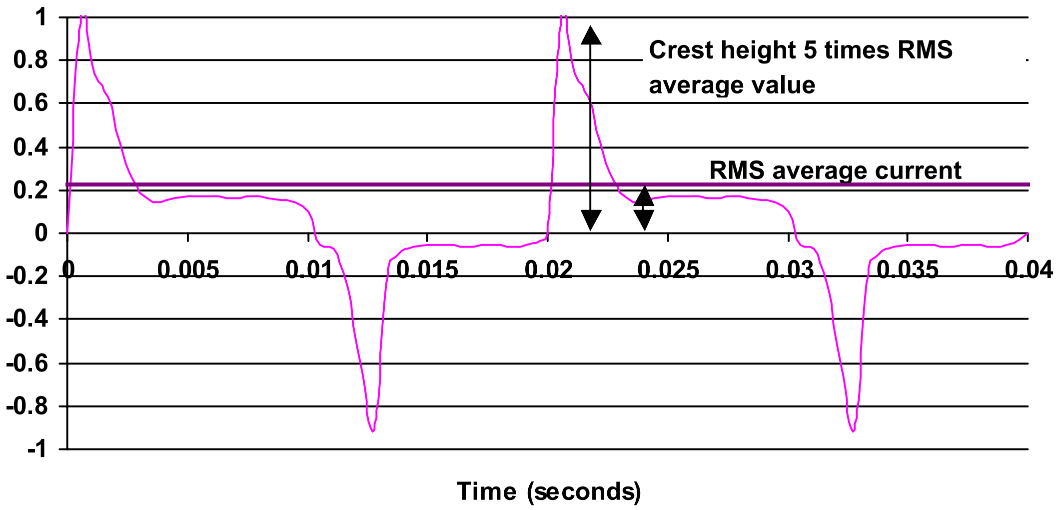
Electronic equipment can distort the waveform of electricity in other ways, too. *Harmonic Distortion* occurs where the smooth sine wave forms of the voltage and current are distorted by the effects of electronic components. For example, sharp spikes in current may occur. One measure of distortion is the *Crest Factor* which compares the peak current with the average current (actually RMS or root mean square current, as the simple average of a symmetrical oscillating current is zero). For a perfect sine wave, the Crest Factor is 1.4 times the RMS average current (see Figure 6.3). In practical terms the RMS average current is the height of a rectangle of the same area as the area between the current curve and the time axis (ie, with the areas below the axis being ascribed positive value).

Figure 6.3
Perfect Sine Wave, Crest Factor = 1.4



When a current wave form is distorted, the peaks (and hence the Crest Factor) can be much higher than the ideal. Figure 6.4 shows and example of a Crest Factor of 5. It can be seen that this wave form is greatly distorted from the ideal sine wave.

Figure 6.4
Highly Distorted Wave Form, Crest Factor = 5



It is also possible to measure *Total Harmonic Distortion* of the current flowing (ITHD**.** This is the total current flow (including all harmonics, which are signals of higher frequency super-imposed on the fundamental frequency of 50 cycles per second) divided by the average root mean square (RMS) current and converted to a percentage. (In the USA, the total current flow is compared to the average fundamental current - ie the lowest frequency waveform). ITHD is difficult to measure without an expensive power analyser.

Ideally, equipment should have Power Factor of 1, a Crest Factor of 1.4 and an ITHD of around 100%. Then it is not impacting adversely on the quality of power supplied. In practice, much electronic equipment has a Power Factor of around 0.6 when operating and even worse values of around 0.3 when on standby. Table 6.1 shows the ranges of values of Power Factors and Crest Factors measured for televisions in Australian stores in 2002 (Harrington, 2002). These show a wide range of variation and, on average, poor performance on these criteria .

Table 6.1.
Power Factors(PF) and Crest Factors (CF) for Televisions in Australian Stores (sample 112 units)

	PF operating	PF standby	CF operating	CF standby
Range	0.52-0.89	0.03-0.77 (second best 0.60)	1.8-4.0	1.4-8.3 (second worst 6.5)
Mean	0.62	0.32	2.9	3.7

Traditionally in Australia, appliance energy labelling and standards programs have not taken Power Factor or distortion into account. Given that there is significant variation in these factors across the range of products now on the market, and that poor performance impacts on both the cost and greenhouse gas emissions associated with electricity supply, there seems to be a case for considering these issues in future programs.

In practice, achieving a high Power Factor and minimising distortion involves appropriate design of circuitry and specification of electronic components. An initial step towards improvement would be to require manufacturers to state the Power Factor and distortion on each product's specification plate and in consumer literature. This would allow trends and the range of performance to be monitored. Since some manufacturers have already achieved quite high standards of performance on these criteria, it may be appropriate to apply the Japanese 'Top Runner' approach to Power Factor and distortion, and require all new models of products to comply with the performance demonstrated by the best on the market over a period of time. Alternatively, given the complexities of electronics design, it may be more appropriate to work with the industry to develop a program of progressively tougher targets.

7. Options for Action

The discussion in this report leads to a number of conclusions that can inform development of policy responses. They are:

1. Within each type of home entertainment product, models on the present market with similar performance vary markedly in their energy consumption
2. Relative to the 'best in class' now available, there are large potential energy savings opportunities, and indications are that much of the potential for savings can already or could be captured cost-effectively, or are likely outcomes of RD&D being undertaken
3. Without effective policy intervention, there is a significant risk, particularly for televisions and home entertainment centres, that very high energy intensity products could capture substantial markets, leading to growth in household electricity use and greenhouse gas emissions
4. There is very low consumer awareness of the significance of energy use by home entertainment equipment, and very little information is available from manufacturers. Even consumer magazines such as *Choice* provide very limited energy information, with the focus on standby energy
5. Energy performance does not seem to be a major concern of most manufacturers, although some companies in certain product categories seem to offer superior performance Consumer purchase decisions are likely to be strongly driven by desire for user features such as large screens, sound quality, convenience of operation, etc. Against such emotive issues, it is difficult to focus attention on energy efficiency, although where several products have similar features but differing energy efficiency, provision of energy information may influence the purchase decision
6. There are rapid rates of innovation and product turnover, with both energy efficient and inefficient technologies competing for similar markets
7. The home entertainment market is international, and virtually all products are imported
8. There is very little information on the proportion of time equipment spends on 'active standby' rather than the standby mode addressed by schemes such as ENERGY STAR and 1 Watt. If, as the authors have observed, a lot of equipment is routinely left on active standby, this means existing estimates of home entertainment energy use understate the actual level, and that this aspect of performance requires prompt action. In any case, the level of power use in active standby mode seems wasteful, and leaves open the possibility that energy will be wasted unintentionally. It should be addressed.

Energy use by home entertainment equipment can be further categorised into two groups of issues.

First, there are a wide variety of products that either already use small amounts of energy, or could be improved to the point where they use relatively little energy. This group includes power supplies (actually losses from power supplies), VCRs, CD and DVD players. With optimal design, none of these products need use more than 3-5 watts in operation, or more than 0.3 watts on standby. Energy use of these products is significant because of their very large (and growing) numbers, their poor Power Factors, and potentially high Harmonic Distortion. Electricity use by this equipment comprises a significant part of the 26% of Australian household electricity usage identified by Wilkenfeld (in press) as 'Other'.

Second, there are products that use substantial amounts of electricity: these include televisions and sound systems and, increasingly, combinations of the two. TVs and sound systems already comprise over 5% of Australian residential sector electricity use. Trends towards more sophisticated systems, larger TVs, higher usage, and increased linking of TV to stereo for home theatre systems mean that there is real danger of strong growth in electricity consumption. Yet there are technology options that could deliver reductions in total energy usage even while these growth trends occur. The challenge is to drive technologies in the energy-efficient direction.

A further key point is that the situation is clouded by uncertainties and possibilities. There is potential for either very energy-efficient or -inefficient technologies to dominate. Additionally, given the consumer-driven nature of this field, it is very difficult to predict exactly what types of products will emerge. But we can be very confident that energy efficiency will *not* be the dominant decision factor when people select their new super surround sound two metre square video projection home theatre. At the same time, the exciting technological developments identified show that any program that is introduced should aim to facilitate innovation and reward large improvements in energy efficiency.

7.1 Paths Forward

7.1.1 Driving Innovation: Influencing Designers and Manufacturers

Given the rapid rate of innovation and product turnover, it seems critically important to raise the priority of energy efficiency (across all modes of operation) among product designers and manufacturers. This would assist in adoption of best existing practices, while also skewing RD&D activity towards technologies that have greater efficiency potential. Both energy labelling/information programs and MEPS have potential to do this to some extent, but the effectiveness of energy labelling in this role is very dependent on manufacturers' judgements about the extent to which consumer choice may be influenced by the label: if they believe other factors will dominate, they may not change. Other options that could influence designers and manufacturers include:

- rewards for designers, such as awards, prizes and publicity (eg articles in design magazines) for the designers of the most efficient products and those that achieve the best performance with respect to Power Factor and distortion
- inclusion of energy efficient design techniques and methods of maximising power factor and minimising distortion in training of designers and electronics engineers
- cooperative training and information programs with relevant professional associations
- provision of information on the impacts of home entertainment equipment energy use and technical bulletins on how to improve efficiency

It may well be that a combination of all these actions is necessary.

7.1.2 Influencing Consumers

Within each product type there is wide variation in energy efficiency. For televisions and stereos, this range is comparable with that for appliances that already carry energy labels, but for other equipment, both total consumption and the range of variation (in terms of annual operating costs) are modest. In some areas, such as televisions, markedly different technologies with differing energy efficiencies compete for the same customers.

We are starting from a very low base of consumer information. At present, even an enthusiast has difficulty selecting an energy efficient model. So the first step must be to provide convenient access to energy consumption information in a meaningful form. To do this will require manufacturers to supply information on the energy use of their products in all modes of operation, not just standby. In turn, doing this requires preparation of standard test procedures.

Once the basic information is available, it would be possible to develop weightings for each mode of operation (to reflect the proportions of time spent in each mode under a 'typical' usage pattern) so that an overall consumption value could be estimated and used for comparative purposes. It would also be possible for simple calculators to be developed for use on the internet, so that consumers could apply their own usage patterns to calculate the energy consumption. It may also be desirable to develop more sophisticated algorithms that adjust the energy consumption data to reflect 'energy efficiency', taking into account different features, as discussed earlier in the section on televisions.

Given the high rates of purchasing of home entertainment equipment, it is important that at least some information is made available as soon as possible, to begin to inform and educate consumers, and to demonstrate to manufacturers that governments are serious about encouraging improvement in energy performance. Actions could include:

- A case could be made to the Australian Consumers Association to include more comprehensive energy rating of home entertainment products in its consumer tests
- Articles could be written for popular media, based on the limited data now available, and further measurement work could be commissioned to provide up-to-date information which could also be publicized

- Benchmark consumption data for home entertainment products could be published and people encouraged to ask for evidence that products exceed them
- DIY meters could be made available, either through local libraries or at selected appliance stores, so that buyers could evaluate the performance of the products they are considering buying.

7.1.3 Information

A key initial step to underpinning any progress is introducing reporting of the performance of equipment, both on specification plates on the equipment itself, and in more comprehensive form on websites and in brochures and user manuals. This reporting needs to cover energy performance under the full range of operating conditions, as well as Power Factor and Total Harmonic Distortion.

Of course, it may be necessary to phase in information requirements to allow time for measurement and improvement, but the information requirements are not onerous for manufacturers of these products.

The impact consumer information programs might have in this field is unclear. On one hand, when energy consumption is a small factor, it may be seen as trivial. On the other hand, if products are fairly similar, except for their energy performance, consumers may use this factor as a key differentiator. Further, there is potential for manufacturers to reinforce their image of technological quality by demonstrating achievement of high standards of energy efficiency. The actual outcome is likely to vary from product to product, and depend on the quality of label design and level of government promotion and support, as well as the response of industry.

At a minimum, there seems to be a good case for introducing appliance energy labels or something similar for televisions and packaged stereos, which consume energy at a comparable or greater rate than some products that already carry energy labels. Such a program could follow the lines of the existing appliance energy labelling program, or could involve mandatory labels for poor performers and voluntary labels for good performers.

The combining of operating energy and standby energy into Australia's existing energy labels for major whitegoods provides a good model for application of an integrated approach with regard to energy labelling of major items of home entertainment equipment."

For televisions, it will be important that the scale on the label is sufficiently broad to allow comparison of plasma screens (the least efficient) against LCD and other possible developments, which could use 90% less energy. It will also be important to highlight to consumers that, all other things being equal, larger screens and higher brightness mean more energy use. On this basis, an algorithm that recognises the fundamental features of the equipment, but applies a scaling factor so that larger screens must be more efficient to match the ratings of smaller screens seems necessary. Huenges Wajer and Siderius (1998) provide a useful starting point for action. The algorithm(s) should also include credit for a high Power Factor and low harmonic distortion.

There is a good case for complementing broader information programs with Minimum Energy Performance Standards (MEPS).

7.1.4 Minimum Energy Performance Standards

MEPS has an important role to play in the home entertainment field, where many decisions relating to energy use are made by designers, manufacturers and OEM (Original Equipment Manufacturer) equipment specifiers, and where the energy impact of each decision is relatively small while the complexity of decision criteria is high.

However, to date MEPS in this area have focused on standby energy consumption, which is just one (admittedly important) aspect of the problem. It will be important to develop new MEPS that incorporate (rather than try to replace) existing programs such as the *1 Watt* program and the European Commission Code of Conduct for reducing 'no load' power consumption of power supplies (less than 15 Watt power supplies to 0.3W, 15-50 watt power supplies to 0.5W and 50-75 watt power supplies to 0.75W by 2005 – Bertoldi (undated)) and to incorporate additional requirements for energy efficiency under load, as well as Power Factor and Total Harmonic Distortion. There are some indications that at least the European Commission is considering incorporating operating energy consumption in future programs, so there seems to be some basis for international discussion/cooperation to progress this issue.

7.2 Challenges

Two important challenges must be dealt with in the home entertainment equipment sector. First, very little of the equipment is manufactured locally, and there is essentially an international market. Second, there is rapid turnover of products and a very large number of products.

The first issue means that action taken in Australia should not conflict with international developments – so international test procedures should be used (where they exist). However, this does not mean we cannot develop our own MEPS levels and/or appliance labelling schemes to suit our cultural context. Indeed, successful market influence relies upon active response to our local cultural context. Harrington and Damnics (2001) have noted the importance of ensuring energy labels respond to the local cultural context and therefore it seems that it is unlikely that effective international standard labels will emerge. At the same time, it must be recognised that manufacturers routinely respond to local differences in markets by including different features, adding sections to user manuals, developing unique marketing and advertising strategies, carrying out tests to different Standards, etc. So as long as the measurement tasks are not too onerous, the development of Australian programs need not be heavily constrained. Indeed, it could be argued that Australia is a world leader in energy labelling and appliance efficiency programs, so that development of a new program here can act as a pilot for application elsewhere. This view could lead manufacturers to actively assist in the development of an effective program, because the experience they gain could assist them in other markets over time.

The high turnover of products and their large numbers makes maintaining central databases a very difficult task, especially if the scheme is voluntary, or if enforcement of a mandatory scheme is lax. Review of the databases on the US EPA Energy Star website highlights the problems, as many new products are not listed, and some listed products are very old. This provides all the more reason to place clear requirements on manufacturers, distributors and retailers to make product-specific information available in a standard format in specified locations, including brochures, user manuals, acceptance specification plates and websites. Further, the role of governments to promote the best performers, support consumers who are seeking information, and enforce schemes is more critical when many different manufacturers and products are involved.

Since the bulk of these products are imported, it may be necessary to incorporate some aspects of enforcement in import documentation and monitoring, so that small operators cannot import single shipments of products that fail to comply.

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NAEEEC MEMBER ORGANISATIONS

The Commonwealth, New Zealand, each State and each Territory are represented on NAEEEC and participate in its deliberations. Representatives are drawn from officials within Government departments, agencies and statutory authorities or from persons appointed to represent those bodies. Representatives are usually a senior officer directly responsible for energy efficiency. The membership is currently under review and may expand to include other agencies working in these fields.

The *Australian Greenhouse Office* is the lead Commonwealth agency for greenhouse matters. The Australian Greenhouse Office (AGO) is responsible for monitoring the National Greenhouse Strategy in a cooperative effort with States and Territories and with the input of local Government, industry and the community. An AGO officer is the chair of NAEEEC and others provide support for its activities.

The NSW *Ministry of Energy and Utilities* provides policy advice to the NSW Government and operates a regulatory framework aimed at facilitating environmentally responsible appliance and equipment energy use. The Ministry is represented on the Energy Efficiency and Greenhouse Gas working group through which the appliance and equipment related elements of the National Greenhouse Strategy will be progressed.

The NSW *Sustainable Energy Development Authority* was established in February 1996 with a mission to reduce the level of greenhouse emissions in New South Wales by investing in the commercialisation and use of sustainable energy technologies.

The *Office of the Chief Electrical Inspector* is the Victorian technical regulator responsible for electrical safety and equipment efficiency. Its mission is to ensure the safety of electricity supply and use throughout the State. The corporate vision of the Office is to demonstrate national leadership in electrical safety matters and to improve the superior electrical safety record in Victoria. The Office's strategic focus is to ensure a high level of compliance is sustained by industry with equipment efficiency labelling and associated regulations.

The *Sustainable Energy Authority* was established in 2000 by the Victorian Government to provide a focus for sustainable energy in Victoria. The Authority's objective is to accelerate progress towards a sustainable energy future by bringing together the best available knowledge and expertise to stimulate innovation and provide Victorians with greater choice in how they can take action to significantly improve energy sustainability.

The *Electrical Safety Office, Department of Industrial Relations*, is the Queensland technical regulator responsible for electrical safety and appliance and equipment energy efficiency. The office ensures compliance with electrical safety and efficiency regulations throughout Queensland.

The *Environmental Protection Agency*, a Division of Sustainable Industries, is Queensland's lead agency in the promotion of energy efficiency, renewable power, and other initiatives that reduce greenhouse gas emissions throughout the State. The key aim of the unit is to achieve increased investment in sustainable energy systems, technology and practice.

Energy Safety WA seeks to promote conditions that enable the energy needs of the Western Australian Community to be met safely, efficiently and economically.

The Western Australian *Sustainable Energy Development Office* promotes more efficient energy use and increased use of renewable energy to reduce greenhouse gas emissions while increasing jobs in related industries.

The *Office of the Technical Regulator* seeks to ensure the coordinated development and implementation of policies and regulatory responsibilities for the safe, efficient and responsible provision and use of energy for the benefit of the South Australian community.

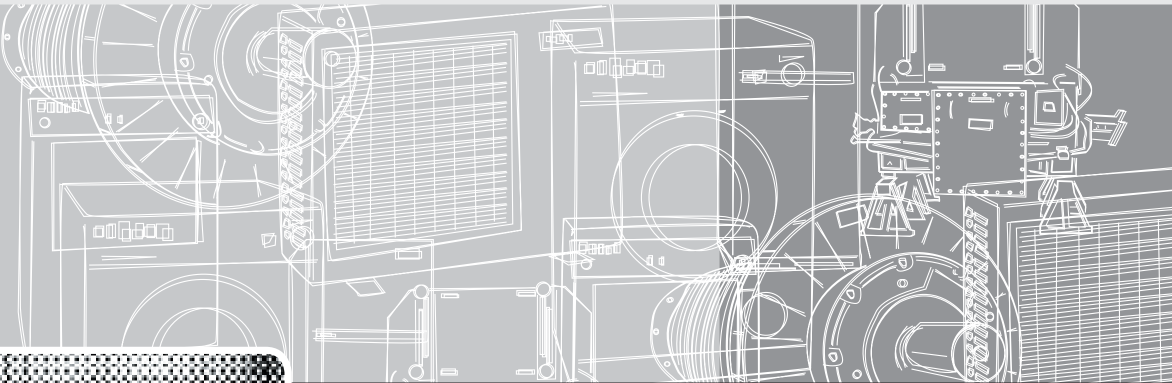
The Tasmanian Government's interest is managed by the *Office of Energy, Planning and Conservation.*

The Australian Capital Territory's interest is managed by the *Energy Policy Unit, Economic Management Branch, ACT Department of Treasury.*
(http://www.treasury.act.gov.au/energypolicy)

The *Department of Employment, Education and Training* is responsible for the administration of regulations in the Northern Territory regarding various aspects of safety, performance and licensing for goods and services including electrical appliances.

The *Energy Efficiency and Conservation Authority (EECA)* is the principal body responsible for helping to deliver the New Zealand Government's extensive sustainable energy future. EECA's function is to encourage, promote and support energy efficiency, energy conservation and the use of renewable energy sources.

The *Ministry for the Environment* (MfE) is the lead environmental policy agency in New Zealand and is the government policy agency which advises the Minister of Energy on energy efficiency and renewables policy. MfE administers the Energy Efficiency and Conservation Act 2000, and energy efficiency regulations made under the Act.



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on the National Appliance and Equipment
Energy Efficiency Program.