Appendix 1: Notes on residential energy modelling performed by EES

This section provides selected details of input assumption for simulation by individual appliance end use in the residential sector. Generally, end-use and modelling assumptions in this section are uniform at a national level, however, data at a state level is used for some end uses like space heating and cooling.

All modelling for this project is in accordance with *Energy Use in the Australian Residential Sector 1986-2020*[1] except where noted in this section.

1 Overview

This section provides an overview of the input data and assumptions regarding appliance and equipment attributes as well as usage patterns that have been used to determine total energy consumption estimates for appliances and equipment. Specific aspects and details that have been updated since the 2008 report[1] are noted below.

From a modelling perspective, there are a number of important elements that can affect the energy consumption of a product. These are:

- Attributes – some of the key characteristics of the product will affect its energy consumption such as size, capacity, energy consumption or energy efficiency.
- User interaction with the product – how often the product is used and what mode it is left in when not in use.
- Climate and weather – this is important for heating and cooling loads, but also for some products that are affected by temperature such as refrigeration. Building shell characteristics also influence indoor conditions.
- Stock – the number of products in use in each state will impact on the total energy consumption. The stock is estimated using ownership (ratio of stock to the number of households) – this facilitates the assessment of the impact of different household projection scenarios (see separate Annex).

2 Attributes

2.1 Attribute overview

Appliance attributes are key parameters that affect, directly or indirectly, the energy consumption of a product. These are typically capacity or other attributes that are related to energy consumption that are used to determine energy efficiency. However, for some products, only the raw energy consumption is used as the key attribute for the purposes of energy modelling.

Examples of key attributes are the size and efficiency of refrigerators and freezers and efficiency and capacity of air conditioners. Some products have a much more complex set of attributes such as clothes washers, where the rated capacity, volume of water used, hot water imported and electrical power consumption all impact on the energy consumption of the product (also noting that consumer use of the product such as loads washed and the temperature setting and program selected have an impact – this is covered in user interaction). The spin performance of a washing machine also has an impact on the performance of clothes dryers. Products like space heaters and air conditioners are complex because the final demand is a function of both the climate and the building shell performance in which the appliance is located, as well as user related aspects (occupancy, zoning, desired comfort levels).

The energy consumption of some products such as water heaters are complex in that there is heat loss (in storage systems), conversion efficiency factors and, in the case of solar systems, interaction with the weather and climate. The performance of a water heater and ultimately its auxiliary energy consumption (supplied externally) depends on these factors as well as the hot water demand of the user.

For each product, the average attributes of new products that flow into the stock for each year of the modelling period are estimated from 1966 to 2020. No attempt has been made to estimate the distribution of energy consumption of products sold within each year, but in reality there will be products that use both more energy and less energy than the assumed average values.

2.2 Attribute data sources

Attributes are estimated from a wide range of sources: some of these are described below. The source document EES 2008[1] should be consulted for further details.

- Registration data – Many of the larger energy consuming products are regulated for energy efficiency and there is detailed data on the attributes including energy consumption.
- Sales data – Some sales data has been used to determine the sales-weighted efficiency trends of products over time. This mostly covers whitegoods and air conditioners. The most recent data used is published in Greening Whitegoods (EES, 2010a)[2] and this has been incorporated into the input data.
- Standby store surveys – Since 2001 EnergyConsult[3] (on contract to E3) and in recent years Maia Consulting (2011)[4] has been measuring the power of a wide range of modes for new products which have been offered for sale in retail stores. This provides a database of over 10,000 products.
- Standby intrusive surveys – In 2000 a survey of 64 homes by EES in 3 states documented every appliance present as well as the power consumption in all relevant modes. This covered some 2,500 appliances. The survey was repeated in 2005 for 120 homes (8,000 appliances) and again in 2010 (10,000 appliances). The 2010 report (EES 2011a)[5] and data collected has been used to update input attributes.
- Published product information – For some products, data published by the manufacturer or supplier on attributes and energy consumption was used to determine the profile of attributes over time.
- Laboratory data – For some products, detailed test data from selected laboratories was reviewed in order to provide information on product performance and trends.
- Simulations – For water heaters, detailed simulation data on a wide range of delivery conditions and 4 climate zones to AS4234 was conducted to determine generalised attributes for modelling purposes for about 20 water heater types including a range of solar systems. Modelling inputs were updated with information on the best systems available in 2011. Additional analysis and optimisation work was undertaken on water heaters in a number of climate zones.
- Regulatory Impact Statements – for some products, regulatory proposals for new MEPS levels have been released. Where these have been close to finalisation, the projected future impact resulting from regulation has been incorporated into the business as usual case. However, regulatory proposals are in progress for a wide range of products and most of these are in preliminary stages and so most have not been incorporated in the business as usual case (refer to the following section for details).

Any additional key data sources used to determine attributes are listed within each product type subsection.

2.3 Attributes – programs included

At any particular time there are a wide range of energy programs in force or under development that are intended to influence the future energy consumption of appliances and equipment. The majority of these are operated on a Federal-State basis by the E3 committee, but there are a number of state-based programs that also have an influence. State-based programs primarily revolve around building shell performance requirements, although uniform star rating requirements have recently been set under the Building Code of Australia at 6 stars and these are being progressively implemented at a state level. This is discussed in more detail in the building shell section.

Energy programs that are well progressed and that are in the process of implementation have been included into the forward projections for product attributes. However, many programs that are proposed or in the early stages of development have not been included into the future projections of product attributes. The details are set out in the table below.

The following efficiency cases have been modelled:

- Base Case Efficiency of appliances, which incorporates energy program measures already implemented in 2011 or that are guaranteed to be implemented by 2012/2013.
- Best Available Technology (BAT) for selected large appliances, which looks at the most efficient products on the market in 2011 and assumes all new and replacement products reach this level of efficiency from 2012 to 2020. This is useful as it quantifies the potential impact of currently available technologies through natural replacement in the stock to 2020.

BAT technologies explicitly modelled for this project include: refrigerators, freezers, air conditioners, clothes washers, dishwashers, clothes dryers, space heaters (heat pump), televisions and lighting.

The following additional special appliance technology cases are also modelled:

- All new and replacement electric cooktops use induction based cooking systems from 2012;
- Lighting stock is expected to shift significantly to high efficacy LED by 2020; accelerated improvements in all lighting technologies are examined under the BAT scenario;
- For appliances, the main option modelled for BAT televisions is to retain the forecast mix of plasma and LCD models to 2020. A separate case was examined under BAT that looks at all new TVs being BAT LCD(LED) technology. Significant technology changes are expected over the period to 2015, so making any energy projections for this appliance is somewhat uncertain;
- A limited range of low energy electric water heater systems (solar and/or heat pump) are examined for water heaters.

Table 1: Overview of Energy Programs Included in Baseline Energy Estimates

Product	Programs included (under consideration but not included in Base Case)
Refrigerators and Freezers	Energy labelling from 1986, MEPS 1999 and MEPS 2005, energy labelling algorithm regrade in 2010 (future MEPS levels on 2017 not included)
Clothes Washers	Energy labelling from 1986, label regrade in 2000, WELS water labelling from 2006, standby in energy label from 2007 (future water and energy MEPS not included)
Clothes Dryers	Energy labelling from 1986, label regrade in 2000, (MEPS on standby not included, disclosure of water consumption on the energy label not included)
Dishwashers	Energy labelling from 1986, label regrade in 2000, WELS water labelling from 2006, standby in energy label from 2007 (future water and energy MEPS not included)
Microwaves	Mandatory 1 watt target by 2013
Lighting	MEPS for linear fluorescent lamps and ballasts, MEPS for CFLs, MEPS for low voltage transformers (MEPS on other technologies not included) [special LED scenarios are separately discussed]
Other Standby	Mandatory 1 watt/ 0.5 watt target by 2013
Pools and Spas	Voluntary pool label (proposed MEPS and labelling scheme not included)
Air conditioners (single phase, vapour compression, air to air) - cooling	Energy labelling from 1987, MEPS 2004, MEPS 2006, MEPS 2007, MEPS 2010, MEPS April 2011, MEPS October 2011, energy labelling algorithm regrade in 2010 (future MEPS not included) (programs to improve duct performance not included)
Air conditioners (single phase, vapour compression, air to air) - heating	Energy labelling from 1987, heating modes MEPS 2010, MEPS April 2011, MEPS October 2011 (future MEPS not included) (programs to improve duct performance not included)
Air -conditioners – Evaporative	No programs (water labelling or energy/water consumption standards not included)
Electric Space Heating (resistive)	No programs (assume 100% effective efficiency) [special scenarios to examine shift to heat pumps]
Gas Space Heating (ducted/room)	AGA energy labelling scheme since late 1980s (no government MEPS)
Wood Space Heating	No programs other than emission requirements (virtual elimination of open fireplaces by 2000)
Water Heating Electric	MEPS 1999, MEPS 2005 which includes heat exchange and low pressure (future MEPS increases or harmonisation with NZ or any further bans of new or replacements not included other than current state requirements, which mostly cover new houses)
Water Heater Gas Storage	AGA energy labelling scheme since late 1980s, mandatory 4-star MEPS from 2011
Water Heater Gas Instant	AGA energy labelling scheme since late 1980s, mandatory 4-star MEPS from 2011

Water Heater Solar Flat Plate	Current trends driven by STCs assumed, tank heat loss static from 2000, solar performance static but higher future share of selective surface assume (MEPS not included)
Water Heater Heat Pump	Current trends driven by STCs assumed, includes performance improvements to 2011
Water Heater Solar Gas in tank	Current trends driven by STCs assumed, performance static from 2000
Water Heater Solar Gas in line	Collector and tank attributes from solar electric, boost efficiency from gas instantaneous
Cook-top Electric	No programs, assumes replacement with induction cook-tops [under No Gas Ownership scenario]
Cook-top Gas	No programs, static efficiency
Ovens Electric	No programs, small natural decrease in oven heat loss due to technology improvements (spillover from European labelling), small decrease in standby under mandatory 1 watt (oven heat loss MEPS not included)
Ovens Gas	No programs, static efficiency, very small decrease in standby under mandatory 1 watt
Televisions	Mandatory labelling and Tier 1 MEPS from October 2009, Tier 2 MEPS at 4 stars from 2013 plus label regrade
Set-top Boxes	MEPS in 2009
Home Entertainment Equipment	Mandatory 1 watt/0.5 watt target by 2013, Energy Star for selected products
Games Consoles	No programs (proposed MEPS not included)
Computers, Monitors, Laptops	Energy Star (MEPS and/or energy labelling in 2013 not included)
Other Computer Equipment	Mandatory 1 watt target by 2013, Energy Star for selected products
Other Equipment Standby	Mandatory 1 watt target by 2013 where applicable
Miscellaneous Electricity	No programs

As part of the modelling work for BZE, special scenarios to examine the impact of “Best Available Technology” (BAT) has been included for selected major appliances. The products covered in by the BAT scenario and the process for determination of their attributes is set out in the following table. Generally, the range of product efficiency on the market in 2011 was examined and the most efficient product or product group was selected. Under the BAT modelling scenario, it is then assumed that all new sales from 2012 to 2020 have attributes comparable to the BAT selected model(s) in 2011. For most products, the BAT is typically about 50% of the sales weighted energy consumption (except for air conditioners, which already have quite stringent MEPS levels in force). Assumptions for each product group are set out in the following table.

Table 2: Device assumptions

Product	Best Available Technology Assumptions
Refrigerators and Freezers	Each of the 10 product groups under AS/NZS4474.1 were examined. Lowest kWh/adjusted litre was selected for each group while controlling the volume range within 20% of the market average in 2010. Assumed sales share by group assumed to remain unchanged.
Clothes Washers	Lowest energy product for warm wash was selected within 0.5kg of the market average capacity in 2010. Top and front loaders were separately examined and it is assumed that the share by type remains unchanged. Lower standby attributes and ability for low energy cold wash assumed.
Clothes Dryers	Heat pump unit with a specific energy of 0.43 kWh.kg moisture removed selected, capacity 6kg (which is slightly higher than average). Lower standby attributes assumed.
Dishwashers	Lowest energy product with 12 or 14 place settings selected. Lower standby attributes assumed.
Air conditioners cooling non ducted	While some small split system air conditioners have an Energy Efficiency Ratio of 5.5, these have a small capacity and could not be readily substituted for many mainstream product sizes. An assumed EER of 4.4 is used, which is the highest efficiency which has a range of available products up to 8kW output. Lower standby attributes assumed.
Air conditioners heating non ducted	While some small split system air conditioners have an Coefficient of Performance of 5.5, these have a small capacity and could not be readily substituted for many mainstream product sizes. An assumed COP of 4.6 is used, which is the highest efficiency which has a range of available products up to 8kW output. Lower standby attributes assumed.
Air conditioners cooling ducted	An assumed EER of 4.0 is used, which is the highest efficiency which has a range of available products up to 12kW output. Lower standby attributes assumed.
Air conditioners heating ducted	An assumed COP of 4.2 is used, which is the highest efficiency which has a range of available products up to 12kW output. Lower standby attributes assumed.

Televisions	The most efficient television technology currently on the market is LCD(LED) technology. A substantial number of products already exceed 7 stars (2009 algorithm = 4 stars 2013 algorithm). New generation OLED products are expected in 2014/5, but none are on the market in Australia in mid 2011. The BAT model selected is based on a 90cm LCD(LED) model with an active power level of 37W. There are a range of other sized products of equivalent efficiency which could effectively meet the current range of consumer demands by size. A sub-scenario includes a BAT plasma system at 120cm and 97W active power. For modelling purposes, two BAT cases have been examined – 1) all products LCD(LED) and 2) current mix of plasma (20% and slowly declining) with the balance of LCD(LED). Case 1 needs to have the energy adjusted up slightly as average screen sizes for plasma are larger than average LCD(LED) and LCD (assuming that market average screen sizes are kept constant).
Lighting	All cases assume that incandescents are removed from the stock by 2020 and the only 20% of quartz halogens remain in 2020. Base case assumes significant penetration of LEDs into the market (50%) by 2020 with an increase in efficacy to 80 L/W by 2020 but with no improvement to current CFL and linear fluorescent stock efficiency by 2020. The BAT scenario assumes comparable penetration LEDs but with an average efficacy of 160 L/W by 2020 and some small improvements in linear fluorescent technology to 115L/W and CFL technology to 100L/W by 2020.

3 User interaction with products

User interaction with appliances covered by the bottom-up model includes a wide range of parameters. These elements include consumer use of the product (including settings/programs), climate effects and complex effects such as hot water demand (which is dependent on climate, cold water temperatures and hot water use by other appliances, as well as user interaction and demands).

For products that are based on distinct cycles (for example appliances such as clothes washers, dishwashers and clothes dryers) the main factor is the average number of cycles per year plus the standby power for the remaining time when not in use (which is partly dependent on cycle time). For televisions the key usage parameter is the number of hours that the television is on per year, but the time spent in each other relevant mode when not in operation is also important (standby, off mode and disconnected). For the majority of products, the time in active mode and the time spent in remaining low power modes is estimated in order to calculate overall annual energy consumption. In most cases, data on usage patterns is fairly scarce, so the best data possible has been compiled from a range of available sources in order to prepare these estimates. In most cases, the time spent in each of the relevant modes is assumed to be static over time, but in some cases where more data is available (eg hours of television use) a trend of time is used.

The Intrusive Standby Surveys (EES 2001[6], EES 2006a[7], EES 2011a[5]) provide reasonable data on the typical modes in which products are left for a wide range of product types. These surveys also included questionnaires on usage patterns and modes which have been utilised.

The other important data source for usage patterns is end-use metering data, noting that these sources are very scarce. The most useful sources are the Pacific Power Domestic End-use Study in NSW (Pacific Power 1994[8] and BRANZ 2000[9]) and the Household Energy End-use Project (HEEP) in New Zealand (BRANZ 2005[10], BRANZ 2006[11]). For most products it has been assumed that usage parameters will be comparable in Australia and New Zealand apart from obvious climate related end uses. These studies are most useful for determination of patterns in active mode – in most cases, the metering equipment used in the above surveys was not sufficiently accurate to provide reliable information on low power modes.

Information on cycles per week for major laundry appliances and dishwashers was also obtained from ABS4602, which asks some questions on usage patterns (although the reported frequency distribution is very coarse). This ABS survey also tracks over time (since 1994) typical washing temperatures for clothes washers at a state level, which has been built into the modelling system. A range of other surveys conducted by Choice (ACA 1995)[12] and The Sustainable Home (Connection Research 2007)[13] also provides some usage data for some products.

A summary of the key assumptions regarding usage are included in Table 3 below. More information is included in the relevant appliance summaries below.

Table 3: Key Usage Parameters by Product

Product	Life (years)	Usage	Usage Unit	% sby	% off	% discon	Comment
Refrigerator	16	N/A	N/A	N/A	N/A	N/A	Assumed continuous operation. Climate factors applied
Freezer	21	N/A	N/A	N/A	N/A	N/A	Assumed continuous operation. Climate factors applied
Clothes Washers – top and front	12	312	Cycle pa	0%	100%	0%	Off mode derived from AS/NZS2040 registration data and is an average of off and end of cycle modes
Clothes Dryers	16	60	Cycle pa	0%	100%	0%	Average – varies by state. Reduced moisture and smaller loads than rated assumed
Dishwashers	16	175	Cycle pa	0%	100%	0%	Off mode derived from AS/NZS2007 registration data and is an average of off and end of cycle modes
Microwaves	8.5	50	Hours pa	95%	5%	0%	Off is mechanical type
Lighting – living areas	N/A	2	Hours/ day	N/A	N/A	N/A	Per fitting, based on technology share and light intensity/floor area
Lighting – non living	N/A	0.5	Hours/ day	N/A	N/A	N/A	Per fitting, based on technology share and light intensity/floor area
Television	10*	2600	Hours pa	40%	50%	10%	Hours increasing over time. Average new composite TV based on sales weighted model for LCD and plasma types. CRT disappeared by 2010, * CRT life of 15 years.
VCR	8	429	Hours pa	88%	2%	10%	Few units have off mode
DVD	6	358	Hours pa	65%	25%	10%	Hours increasing. Composite of players and hard drive/recorders
Set-top Box – free-to-air digital	7	2600	Hours pa	50% *	40% *	10%	*Modes are:Active Standby/Passive Standby
Set-top Box – subscription	7	2600	Hours pa	50% *	50% *	0%	*Modes are:Active Standby/Passive StandbyPay TV boxes rarely disconnected as access key data can be lost
Home Entertainment Other	10	550	Hours pa	60%	20%	20%	Intrusive data: 20% unplugged, 18% off, 8% AS and 53% PS
Games Consoles	6	110	Hours pa	5%	75%	20%	0.3 hours per day usage
Computers – desktop	6	875	Hours pa	4%	86%	10%	Off may allow soft boot in some cases
Computers – laptop	6	600	Hours pa	25%	30%	45%	400 hours usage plus 50% added for battery charge periods
Monitors	6	390	Hours pa	60%	30%	10%	65% PC on time for usage, balance assumed to be standby
Miscellaneous IT Equipment switched	6	875	Hours pa	60%	30%	10%	Products that are usually switched off with the PC
Miscellaneous IT Equipment unswitched	6	875	Hours pa	85%	5%	10%	Products that are not often switched off with the PC
Other Standby	10	1200	Hours pa	20%	40%	40%	Based on 2005/2010 Intrusive, hours on=active standby

Notes: Refrigerators and freezers do not have individual usage impacts that can be modelled, only climate impacts. Percentage of modes are share of time for non-active period. Assumed lifetimes for other products: all water heaters 12 years (except solar 15 years), cooking 20 years, AC non-ducted 10 years, AC ducted 14 years, gas non-ducted 14 years, gas ducted 20 years.

4 Climate and weather

Climate and weather has a major impact on a few major end uses, namely heating, cooling as well as some impact on refrigeration. The process of generating heating and cooling demand is complex and is described more fully in the sections on building shells. Households are split into one of 10 national climate zones. A wide range of representative building shells are modelled in each climate zone and an average house performance in each state is complied based on the share of different building shell types in each state. The presence or not of a primary heating or cooling device is then applied to the households in each state. Different appliances are assumed to have various levels of restrictive “zoning” (depending on their capability – eg small electric heaters can only heat part of the house, central ducted systems can heat most of the house). Air conditioning and heating is only assumed to occur in houses that have the appliance (eg if 50% of houses in one state have an air conditioner, the total cooling demand for the state is divided by 2). See EES (2008)[1] for technical details.

Climate-based adjustments were made for water heaters in terms of ambient air temperatures (for heat losses where applicable) and cold water inlet temperatures (to determine energy consumption for different temperature rises – hot water temperature minus cold water temperature). Detailed simulations to AS4234 for all 4 climate zones identified in AS4234 and for a wide range of water heaters and hot water loads were also used to determine climate-based impacts for water heating, including the response of a range of solar systems. Hot water consumption adjustments were made at a state level to reflect available data.

For the purposes of this study, no other equipment types are adjusted in response to climate.

5 Ownership and stock of appliances

5.1 Ownership overview

The number of products in use in each state (together with the other factors outlined above) will impact on the total energy consumption. In simplistic terms, more items in use means more energy consumption (other things being equal). The stock is estimated using ownership (ratio of the total stock to the number of households) – this facilitates the assessment of the impact of different household number projection scenarios.

Ownership is data on the presence of the total number of products that consume energy in households. Penetration and ownership are both estimated where relevant. The ownership of some products varies considerably by state (e.g. space heating and cooling equipment, which is dependent on climate and the availability of various fuels) whereas other products are fairly uniform across all states (e.g. home entertainment equipment, refrigerators, but not freezers). Data on ownership and penetration from 1966 to 2020 at a state level is estimated as a modelling input for this report. Published data sources are used wherever possible, the most important being from the Australian Bureau of Statistics. The trend data used for this report includes the results up to and including ABS4602 in 2011.

The following important definitions are used in this report:

Penetration – the proportion of households in which one or more of a particular appliance type is present (irrespective of the number of units of that appliance in the household). This value is usually given as a percentage and the maximum value is 100%.

Stock – the total number of a particular appliance type in use within households. This value is given as an integer (usually thousands or millions). The stock refers to the number in regular use, or a proxy for the number in regular use.

Ownership – the ratio of stock to the total number of households. This value is usually given as a decimal number and can exceed 1.0.

Saturation – the average number of appliances per household only for those households with one or more of the appliance. The minimum value is 1.0.

The following important relationships are used in this report.

Stock = Ownership x Number of Households

Ownership = Penetration x Saturation

5.2 Ownership – product issues

In the case of water heaters, it is known that a small proportion of households (of the order of a few percent) have more than one water heater. However, the bulk of energy for water heaters is associated with hot water use and this is driven by a number of factors, such as appliance hot water use (clothes washers) and the number of persons per household. Additional losses from multiple water storage heaters have been ignored as these will be fairly small in overall energy terms.

In the case of air conditioners, the saturation is known at a state level with some degree of certainty (number of appliances per house for households with at least one of the appliance). On average the saturation Australia wide was about 1.28 for air conditioners in 2007 and this is rising slowly. For modelling purposes, it is assumed that only one central ducted system per house is installed (for heating and/or cooling) while the rest of the systems are allocated as multiple non-ducted air conditioners per house (in non-ducted households).

Space heaters are tracked as the “main” type of space heater by ABS4602 so only one per house is assumed. In most households there will be some secondary heating sources, although their use will be highly variable. Secondary space heating is not modelled explicitly for this study.

The ownership of “other home entertainment equipment” (which mostly consists of audio equipment such as portable stereos, integrated stereos, hi-fi components etc) has been lumped into a single end use with almost 4 items per average household. Televisions continue to climb in ownership with an average of over 2 per home in 2011. The transformation from CRT televisions was spectacular – with close to 100% market share in 2004, CRT models all but disappeared from the market by 2010. Plasma models have managed to retain almost 20% of the current market in 2010, but various forecasts suggest this share may slowly decline over time. LCD and LCD(LED) technologies now dominate, with LCD(LED) models generally (but not always) offering superior efficiency. OLED models are not yet available in larger sizes, but these are likely to appear within a few years, hopefully with additional energy reductions. Despite the dramatic improvements in television efficiency, even over the past 2 years (of the order of 20% energy efficiency increase per annum – EES 2011c)[15], some of these energy reductions have been wiped out by the rapid increase in screen sizes. Usage patterns for multiple televisions are not well documented, but metered data from the limited studies available show that usage is quite high for primary and secondary televisions, except those installed in bedrooms (BRANZ 2007, BRANZ 2000).

VCR ownership peaked at 1.1 per home in 2002 and is now falling rapidly. It was almost impossible to purchase a new VCR in 2007. There are already 1.1 DVDs per household and about 25% of new units sold have multiple capabilities such as digital tuners and/or hard disks and/or DVD burners, making them an obvious replacement for the now obsolescent VCRs. Set top boxes with digital tuners and hard disk recorders are replacing VCRs (many of these have a DVD drive as well). Simple digital conversion adaptors are expected to spike in ownership just after 2012 when analogue broadcasts are scheduled to be phased out in capital cities. However, the rapid increase in integrated digital tuners in new televisions (together with DVD recorders with integrated digital tuners) may dampen this future demand for simple digital converters. Increased use of on line viewing services is likely to reduce use and ownership of these types of devices into the future.

Computer ownership increased rapidly to around 2005 where 72% of households had at least one computer. The latest data from ABS4602-2008 appears to suggest that desktop computer ownership is now falling significantly, and this has been largely confirmed by recent household audits (EES 2011a)[5]. *The Age* newspaper in February 2008 noted that 91% of households now have an internet connection (*The Age*, 10 February 2008). There has been a rapid changeover from CRT to LCD computer monitors which started shortly after 2000. CRT monitors are no longer available (for non-professional applications) and will naturally disappear form the stock over the next 5 years.

Establishing laptop ownership (or a proxy for units usually present) is somewhat mercurial as many will be “owned” by employers but will spend some of their life in a household environment. 2010 data suggests that there are now more households with at least one laptop than desktops and many households have multiple laptops. There has also been an explosion in ownership of small PC tablets of various types (e.g. iPads) which is creating a continuum of technologies ranging from Smart Phones through tablets through to laptops which have similar usage. Although these types of devices are proliferating rapidly, they are generally low energy because mobile devices designs have to offer long battery life to attain user acceptance.

In addition to computers, there are about 1.5 so called “switched” miscellaneous PC peripherals per computer (typically printers and speakers) and 1.7 so called “unswitched” miscellaneous PC peripherals per computer (MFDs, routers, modems and other network equipment).

Lighting is, of course, found in every home. There are on average about 50 separate lights in an average home (the number per house ranges from 20 to 220). A new approach was developed for a recent study that estimates the share by lighting technology, lighting intensity, lighting efficiency and hours of use for living and non-living areas. An audit of household lighting technologies (EES 2011b)[14]has provided new information on the share of lighting types in the household sector, and this data has been largely incorporated into current data and projections. Future penetration of LED technologies is somewhat uncertain. These are assumed to be moderate to 2015 and then accelerate after that year as costs are expected to fall and efficacy increases. LEDs are very likely to completely transform the lighting stock within 10 years.

5.3 Ownership – future estimates

The end-use model developed for this project is not a formal forecasting model for future end-use energy consumption. However, it can provide insights into current trends of appliance ownership and the likely impact that these changes may have on energy consumption, now and in the future. It can also help to identify end uses that may be subject to future energy growth (and hence may be suitable targets for energy regulation) or opportunities for fuel switching to reduce emissions. As a general rule, ownership projections, which are a key input into future energy projections, are based on historical trends together with information on the sales and ownership of products where this is known.

Projecting or extrapolating future ownership levels based on historical trends has inherent uncertainties. For example, the explosion in air conditioner ownership after 2000 could not be reasonably predicted on the basis of historical data prior to 2000, as air conditioner ownership remained fairly steady over the 1990s.

Over the period to 2020, which is covered by the end-use model, it is highly likely that a number of new end uses and new technologies will appear on the market and become prevalent in the home. There is no way to predict what these new end uses might be and what energy impact they may have. It is instructive to think back 15 years prior to 2010 and consider the changes that have happened since 1995: the DVD was invented, flat-screen televisions became commercialised and now dominate sales, VCRs have become obsolete, hard disk recorders are now common, digital television is available and will be universal by 2012, mobile phones are now ubiquitous (and these are rapidly being converted to smart phones), MEPS for more than 15 products have been introduced, computers in the home are now common (some 91% of homes have an internet connection in 2008, while this was just 7% in 1995 - *The Age*, 10 February 2008 but are probably already declining), personal digital music players are ubiquitous (eg iPod), the internet and broadband is now common, iPads and other personal products are rapidly being adopted, just to name a few items. It would be difficult to accurately predict such things in 1994. Some are having a large impact on energy consumption (eg flat-screen televisions) but for most, the energy impacts are modest (iPads for example can perform the tasks of most computers while using around 2 watts, so this is a good thing).

It is important also to understand that most econometric models use factors such as wealth and economic activity to indirectly predict energy consumption and the purchase of consumer goods. The end-use model developed for this report is diametrically opposed to this type of approach – all modelling explicitly tracks individual end uses to generate a total estimated energy consumption from the bottom up. Clearly both approaches have limitations. Econometric models provide no physical basis to understanding the drivers for energy consumption and just assume that historical relationships between energy consumption and economic activity continue to persist (less some allowance for energy-efficiency improvements). Econometric models for the residential sector are particularly tenuous as the measure of economic activity is usually very indirect and there are a lot of non-economic drivers for energy consumption. This is particularly true when there are external drivers to reduce energy such as regulatory programs and a price on carbon. On the other hand, end-use models provide an explicit explanation of the energy consumption by product type, but are generally unable to cope with the real cyclical nature of appliance and equipment purchases, which to some degree depend on the state of the economy. For example, the dramatic price fall for air conditioners due to increases in production in China and increases in household wealth together with a perception of increasing summer heat has probably accelerated demand for residential air conditioners in the past 10 year. This would be difficult to foresee for an end use or an econometric forecaster.

An orderly usage profile and replacement schedule is assumed for end-use modelling purposes – no exogenous impact from the economy is included. In reality, some core appliances will be replaced when they break down (eg water heaters and refrigerators) but many appliance acquisitions will be discretionary to some degree and purchasing cycles will depend on household wealth (spare cash) and the price of goods. Some other factors can also have an effect, such as the historical cycle of television purchases that used to appear to match the four yearly cycle of the Olympics – these are very difficult to explicitly model through any approach.

Neither approach can deal with the energy impacts of new technology. In the short term, an end-use model should give reasonable estimates on the basis of projected changes in ownership, assuming there is no substantial change in technology or end-use energy service. Even where this occurs, it takes some time for such technology to diffuse into the stock, so the changes are usually gradual. However, beyond 10 years, end-use models will become more uncertain because traditional end uses (water heating, cooking, space heating etc.) may be affected by new (hopefully more efficient) technologies and undoubtedly new end uses will appear while existing end uses will disappear (many associated with entertainment and computers). A case in point is networked equipment in the home – this is currently restricted to IT equipment, but if it becomes prevalent, there could be substantial energy penalties through increased standby unless strong policy actions are taken to control this aspect (so called network standby).

Traditionally, governments have not dictated policies that restrict the ownership of products that provide a particular energy service. This would (in most cases) be regarded as an unreasonable infringement on personal liberty or freedom. For example, it is unlikely (at least in the short term) to place a limit on the number of computers or televisions that a household can own or operate. So from this perspective, government policies (at least historically) tend not to have a large direct impact on ownership trends of appliances and equipment. However, in cases where there are multiple technologies that can deliver a comparable energy service, there are many past examples (and possible more examples in the future) where government policies aim to restrict the availability of certain technology types or fuels due to energy and/or greenhouse considerations. An example is the type of water heater in a new home – many states now have requirements regarding the type of water heater that can be installed. So while such a policy is not a direct restriction on the amount of hot water available to the household, it will impact on capital cost of water heater systems and also the amount of fossil fuel required to deliver the likely energy service demanded. Conceivably, future MEPS requirements could restrict the availability of certain technologies modelled within this report. Impacts on future ownership are difficult to establish until such policies are formally announced.

For this project, one special scenario in addition to the expected Business As Usual case has been developed to assist in assessing the feasibility of various low carbon paths into the future.

- BAU Ownership – this is the expected trend in energy for all fuels given current and projected ownership trends at a state level and assuming the current trend of encouraging gas reticulation for new developments in most states. The BAU case assumes that the current trends in gas distribution continue unchanged to 2020 (generally close to 100% connection to most new urban and urban fringe developments).

- No Gas Ownership – in this special case, an active program to eliminate all residential sector gas consumption is implemented as part of a zero carbon future. Generally, gas is substituted with electricity, except for water heating where solar assisted electric technologies are predominantly used.

The No Gas Ownership projections to 2020 are based on assumption of effectively zero ownership of gas appliances by 2020 for cooking, space heating and water heating. All other appliance ownership trends are the same as BAU ownership.

It is important to note that No Gas Ownership scenario is not necessarily advocated as the most economic or optimum policy path forward towards a zero carbon future. But it is useful because it quantifies for the first time the impact on the electricity supply system (in the residential sector) of complete substitution of current gas (fossil fuel) energy from electric and solar technologies. It is important to understand the likely future demand for electricity in an environment which is trending towards no fossil fuel use.

Given the relatively short time horizon to 2020, the impacts of the BAT scenario will generally continue to increase well past 2020, especially for those appliances with a longer lifetime. For electrical appliances the expected long term BAT energy projection (under the no gas scenario) is expected to be less than 80PJ (compared to 140PJ to 150PJ under a business as usual scenario.

6 Input assumptions by product type

This section sets out the key assumptions and data sources for each of the modelled end uses only where these have significantly changed from the original study *Energy Use in the Australian Residential Sector 1986-2020*[1].

6.1 Space cooling equipment

These products are broken into:

- Air conditioners reverse-cycle non-ducted (room type systems).
- Air conditioners cooling only non-ducted (room type systems).
- Air conditioners ducted (includes cooling only and reverse cycle types).
- Evaporative air conditioners (mostly central).

The main changes for air conditioners are an update of ownership trends by type at a state level using ABS4602-2011 data and incorporation of the latest regulatory impacts for various increase in MEPS through 2010 to 2011.

6.2 Space heating equipment

These products are broken into:

- Electric resistive space heating
- LPG gas non-ducted space heating
- Mains gas ducted space heating
- Mains gas non-ducted space heating
- Reverse-cycle ducted space heating
- Reverse-cycle non-ducted space heating
- Wood space heating

The main changes for heating equipment are an update of ownership trends by type at a state level using ABS4602-2011 data and incorporation of the latest regulatory impacts for mandatory heating MEPS for all reverse cycle types through 2010 to 2011. The special No Gas Ownership scenario forced all gas products to zero ownership by 2020.

6.3 Water heaters

These products are broken into:

- Electric storage water heaters
- Gas instant (LPG) water heaters
- Gas instant (mains gas) water heaters
- Gas storage (LPG) water heaters
- Gas storage (mains gas) water heaters
- Heat pump water heaters
- Solar electric water heaters
- Solar gas in line boosted water heaters
- Solar gas in tank boosted water heaters

The main changes for water heaters are an update of ownership trends by type at a state level using ABS4602-2011 data and incorporation of the latest performance data for a range of solar and solar boosted technologies. There has been a fairly rapid increase in solar technologies in recent years (mostly through regulation of water heater type for new homes – requirements vary by state). However, national proposals to eliminate electric storage (resistive) systems are progressing and will eventually impact on all stock.

Table 4: Assumed Share of Water Heater Type by State in New Homes from 2013 to 2020 (Scenario 0)

State	Electric	Gas Stor	Gas Inst	LPG Stor	LPG inst	Solar elec	Heat pump	Solar gas (a)	Solar gas (b)
NSW	0.0%	25.0%	40.0%	1.0%	1.0%	15.0%	6.0%	5.0%	7.0%
Victoria	0.0%	30.0%	42.0%	1.0%	1.0%	9.0%	3.5%	3.0%	10.5%
Queensland	25.0%	3.0%	5.0%	1.0%	1.0%	35.0%	16.0%	2.0%	12.0%
SA	0.0%	10.0%	54.0%	1.0%	1.0%	10.0%	5.0%	5.0%	14.0%
WA	16.0%	38.0%	20.0%	1.0%	1.0%	10.0%	3.0%	3.0%	8.0%
Tasmania	30.0%	8.0%	12.0%	1.0%	1.0%	25.0%	21.0%	1.0%	1.0%
NT	20.0%	14.0%	8.0%	1.0%	1.0%	35.0%	7.0%	5.0%	9.0%
ACT	15.0%	10.0%	50.0%	0.0%	0.0%	15.0%	5.0%	0.0%	5.0%

Notes: Data developed on the basis of analysis of state based survey date –trends in ABS4602-2011. Solar gas (a) is a standard flat plate solar system with integrated in tank gas boosting. Solar gas (b) is a standard flat plate solar system (electric tank with no boost element with in-line instantaneous gas boosting).

For Scenario 1a and 1b, which is the No Gas Ownership Scenario – all new households use solar electric systems (Scenario 1a = flat plate or Scenario 1b = evacuated tubes). There is also active substitution out of gas systems from 2013 so that virtually no stock remains by 2020.

For Scenario 2, which is the No Gas Ownership Scenario – all new households use heat pumps (high end 2011 model). There is also active substitution out of gas systems from 2013 so that virtually no stock remains by 2020.

Table 5: Assumed AS4234 Climate Zones by State

State	Assumed AS4234 Climate Zone
NSW	Zone 3
Victoria	Zone 4
Queensland	Average of Zone 1 and Zone 3
SA	Zone 3
WA	Zone 3
Tasmania	Zone 4
Northern	Average of Zone 1 and Zone 2

Territory	
ACT *	Zone 4

Note *: According to AS4234, ACT should lie in Zone 3, but the colder air and water supply temperatures used for modelling in this report are thought to better reflect actual conditions in the ACT. A new climate for ACT is in development. However, winter irradiance is known to be higher than Zone 4, so this is slightly conservative.

6.4 Cooking products

These products are broken into:

- Electric cook-tops
- Electric ovens
- LPG cook-tops
- LPG ovens
- Mains gas cook-tops
- Mains gas ovens

The main change for cooking products is an update of ownership trends by type at a state level using ABS4602-2011 data. For the first time since the 1980's ABS separately recorded fuel for cooktops and ovens in 2008 and 2011. This has provided a more reliable estimate of trends since the 1990's (existing time series from other sources has been rebased using 2008 data) and this means that other data sources will no longer be required to track trends at a state level. The special No Gas Ownership scenario forced all gas products to zero ownership by 2020. This has only a small impact on ovens, which have been trending strongly towards electric for many years. But it does have a large impact on cooktop trends, which have been trending towards gas. It is assumed that all new gas cooktops from 2012 are based on induction technology, which has superior efficiency. However, it should be noted that these have higher capital costs (than radiant resistive systems) and there are other costs, such as changing all cookware (pots and pans) to those with an iron base, which are separately considered.

6.5 Major appliances

These products are broken into:

- Clothes dryers
- Clothes washers – front (drum type)
- Clothes washers – top (agitator/impeller, including twin tub)
- Dishwashers
- Microwaves
- Refrigerators & (separate) Freezers.

Major appliance ownership trends by type at a state level have been updated using ABS4602-2011 data. Major appliance attributes have also been updated using the latest published data from EES (2010a)[2].

Refrigerator characteristics have been more fully investigated in recent years. The time series for attributes for each of the 10 product Groups was updated in 2010. This study uses the updated base case set out in EES (2010b)[16] which includes sales weighted data to 2009 and the estimated impacts of the label regrade in 2010. This reappraisal does not change attributes for the period 1993 to date (which are based on sales weighted as shipped values), but it does use better data to provide improved trend estimates before 1993. These updates will have little material affect on the results modelled for this report.

6.6 Information technology products

These products are broken into:

- Computers – desktop
- Monitors (for desktop computers)
- Computers – laptop

- Miscellaneous IT equipment (switched) (MITS)
- Miscellaneous IT equipment (unswitched) (MITU)

Information technology ownership trends by type at a state level have been updated using ABS4602-2011 data. All elements associated with these products (attributes, ownership and usage) have been updated from a range of recent sources as previously noted.

6.7 Home entertainment equipment

These products are broken into:

- DVDs (players and recorders, including those with hard drives and tuners)
- Home entertainment – other (mostly stereo components such as amps, CD players, personal music systems, tape players, integrated and portable stereos etc)
- Games consoles
- Set-top box – free-to-air digital
- Set-top box – subscription
- Television – CRT
- Television – LCD
- Television – plasma
- Television – projection
- Video Cassette Recorder (VCR) (including DVD combos)

Home entertainment ownership trends by type at a state level have been updated using ABS4602-2011 data. All elements associated with these products (attributes, ownership and usage) have been updated from a range of recent sources as previously noted. The most important of these is the close tracking of television attributes (size and energy) over time. This is now based on detailed analysis of the registration system over the past two years (EES 2011c)[14] and the expected impact of the forthcoming MEPS levels in October 2012. It is expected that projection and CRT models have no effectively disappeared (negligible sales of these types were recorded in 2010).

6.8 Lighting

Lighting is a complex area and one end use that is poorly documented in ABS surveys. Fortunately, a detailed audit of residential lighting was undertaken in 2010/2011 (EES 2011c)[14] by the federal Department of Climate Change and Energy Efficiency and the results of this detailed field work has been incorporated into the stock model as far as possible. There is still some analysis under way to calibrate actual usage levels against the survey responses for individual households (by light) (through examination of a small selection of detailed end use metering data), but that work is still under way.

There have also been recent rapid developments in the field of LED lighting, and predicting where this may go even over the next 9 years is highly speculative. The approach used for modelling for this report is a relatively conservative assumption that incandescents will naturally disappear (these have been effectively banned since 2009) and quartz halogen (currently the highest Lumen output and lowest efficacy technology) will also decline in the stock, generally being replaced by LEDs. Several scenarios of efficiency trends are examined for different lighting technologies.

7 Building-Shell Assumptions

This section sets out the key assumptions and data sources for building shells where these have significantly changed from the original study *Energy Use in the Australian Residential Sector 1986-2020*[1]. The same climate zones have been used for modelling. Technical details are set out in chapters 7 and 8 of EES (2008)[1].

Specific changes and updates for this report include:

- Building shell stock model aligned with future household projections ABS3236-2010 Series III
- Insulation levels in the stock have been updated to include ABS4602-2011 data.

- Approximately 1.2 million Insulation retrofits conducted under the national Household Insulation Program (HIP) in 2008/2009 have been included in the base case.
- All new dwellings are assumed to comply with a 6 star requirement from 2011 as set out under the Building Code of Australia. Some states have already implemented this requirement, but actual practical implementation at a state level could be after 2012 in some cases. An attempt to model state variations has not been undertaken for this project.

Some retrofit scenarios have been modelled in conjunction with the base case. These are:

- BZE Improvement Level 1: all new 6 star from 2011[2], no retrofit of existing dwellings
- BZE Improvement Level 2: all new 6 star from 2011[2], with BZE upgrade package level 1[1] to all existing dwellings by 2020
- BZE Improvement Level 3: all new 6 star from 2011[2], with BZE upgrade package level 2[1] to all existing dwellings by 2020
- BZE Improvement Level 4: all new 6 star from 2011[2], with BZE upgrade package level 3[1] to all existing dwellings by 2020
- BZE Improvement Level 5: all new 6 star from 2011[2], with BZE upgrade package level 4[1] to all existing dwellings by 2020

Note 1 : Each successive level of “BZE upgrade package” is designed to deliver higher and higher levels of building shell thermal performance. (BZE to provide documentation)

Note 2 : It is assumed that by 2020, retrofit upgrade packages will be applied to any of the dwellings within the stock that do not currently meet the level of performance associated with that upgrade package. Generally this will not impact on dwellings already built to a performance standard within the BCA (4 – 6 star depending upon the jurisdiction and the year of build) except in the case of the higher levels of upgrade packages

Note 3 : No investigations on the impact of global warming on heating and cooling loads have been conducted for this study, as the projections horizon is too short (2020).

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