SUSTAINABLE ENERGY AUTHORITY OF VICTORIA

ENERGY EFFICIENCY IMPROVEMENT in the RESIDENTIAL SECTOR

Prepared by

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This document contains predictions and estimates of energy use and potential savings. The information is calculated by EMET Consultants Pty Ltd using available and specifically sourced data; and proprietary analysis techniques. The results are provided by EMET in good faith and are believed to be the best available estimates at the time of producing this report. However the results are subject to variable influences such as weather patterns, relative energy costs, consumer expectations etc. and therefore EMET makes no guarantee in relation to the repeatability of the these results and estimates in their application to the intended target sector(s).

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1 Introduction

In November 2002, the Ministerial Council on Energy (MCE), comprising commonwealth, state and territory energy ministers, endorsed a proposal for development of a National Framework for Energy Efficiency (NFEE or National Framework) to define future directions for energy efficiency policy and programs in Australia. The objective of the National Framework is to unlock the significant economic potential associated with increased implementation of energy efficient technologies and processes, to deliver a least cost approach to energy provision in Australia.

As part of the work on the National Framework, the Sustainable Energy Authority (SEAV), in conjunction with the consultant Graham Armstrong, undertook a project to assess the demand-side energy efficiency improvement potential and costs for the residential, commercial and industrial sectors(9). This data was used as the basis for the economic modelling presented in the NFEE Discussion Paper.

To assist with the on-going development of the NFEE, SEAV commissioned EMET Consultants Pty Ltd (EMET) to undertake some case studies of the energy efficiency improvement potential for a number of key areas of energy application within the residential sector. This work would complement the work being undertaken at the same time by George Wilkenfeld and Associates (GWA)(1) on the application of water heating within the residential sector.

The aim of the project was to refine the preliminary energy efficiency potential estimates developed in the Armstrong/SEAV work.

More specifically, the objectives of the project were to produce:

1. An energy service and energy consumption model (broken down into main fuel types) for the residential sector;
2. For each energy service (see above), a list of the energy efficiency improvement (EEI) measures up to and including a 6-year simple payback (based on national averages);
3. For each energy service / EEI measure, an estimate of the EEI potential (%), energy saving, and implementation cost for the residential sector (based on national averages), ranked in order of increasing simple payback;
4. Tabulate data for the residential sector, based on all measures ranked in increasing order of simple payback. Build up cumulative data for implementation cost, energy savings ($, PJ), paybacks and EEI potential (%);
5. Prepare cumulative cost curve (implementation cost vs $ savings) and EEI potential curve (cumulative simple payback vs EEI potential %);
6. Estimate the EEI potential, savings and costs for all measures up to and including a 4-year payback;
7. Provide an estimate of the expected business as usual uptake of energy efficiency over the period 2005 to 2014, eg expressed as a PJ saving in 2014. This will be used to derive an estimate of EEI potential above BAU;
8. If possible, provide an estimate of the effect of the measures up to a 4-year payback on peak electricity demand in winter and summer;
9. Complete a report based on 1 to 8 above.

Clarifications

- Existing dwellings and new dwellings to be treated separately;
- EEI estimates will take 'additionality' into account, eg building shell improvements reduce potential energy savings from heating and cooling improvements; water efficiency measures reduce potential energy savings from water heating measures;
- 'Rebound effects' will be ignored as they are dealt with in the economic modelling.

Variation of the Objectives

As the analysis in the Residential Sector was undertaken in two separate studies, and due to the availability of data for this sector, the cumulative curves referred to in objectives 5 and 6 could not be prepared. Also for the same reasons, objective 7 was modified for this sector analysis. For this study, the approach taken was to define the BAU energy consumption for a given application/energy end-use over the study period, and then apply a range of cost-effective EEI measures to determine the energy savings (PJ and $M) and implementation costs ($M) on a year by year basis.

1.1 Analysis Methodology

a) Residential Sector Energy Consumption Model

The residential sector energy consumption model was created by a combination of energy consumption trends developed by ABARE(2), and energy applications within the residential sector consistent with Armstrong/SEAV work(9). These were supplemented by recent work undertaken by EMET(3) on electricity consumption and demand patterns for the residential, commercial and industrial sectors in New South Wales.

Variations in the proportions of energy used by specific applications between 2005 and 2014 were derived by using the combined factors of forecast penetration levels for relevant technologies and expected changes in the energy efficiency and/or energy intensity of those technologies. These factors were obtained from the most recent data available from one or more of the following sources:

- Energy Efficient Strategies/AGO(4)
- ABS Reports 3236.0(5) and 4602.0(6)
- EMET/ NSW MEU(3)

Energy used by buildings existing in 2005 and new buildings introduced during the analysis period was separated throughout the analysis, to enable alternative measures or costings to be applied, as appropriate. Similarly, data from diverse climatic zones (States) was analysed separately where applicable and where data was available (refer to the individual EEI discussions).

b) Analysis of Energy Efficiency Improvement Measures (EEI)

A range of energy efficiency improvement measures for each application of energy within the residential sector were selected and applied to the relevant component use of energy. Measures from the original Armstrong/SEAV(9) work were used in the analysis, in addition to measures sourced from previous EMET research and experience. It should be noted that the EEIs were generally based on the improvement in the efficiency of systems and/or technology. The reduction in energy use brought about through the improved use of equipment by the users has not been included in the analysis, except where it relates to the use of alternative technology.

Energy savings relative to business as usual (BAU) were calculated as appropriate for each case. Savings related to heating and cooling improvements (including House Energy Rating improvements) generally used the results of NatHERS or FirstRate modelling for representative home designs and climatic zones. Other measures were directly applied to the relevant component of energy use and established efficiency improvement quantities.

Measures with simple payback periods of up to 6.5 years (based on national averages – except for the case of State related initiatives) were included in the results. Measures considered to be Business as Usual (BAU) were not included except where necessary to account for reduction in energy use, which would negate or reduce subsequent savings. These BAU measures included such measures as the adoption of 5 Star rating requirements for new homes in Victoria and other measures which would be applied automatically, due to an inherent improvement in efficiency of appliances, an obvious cost benefit or other compelling reason.

c) Estimation of Potential Reduction in Electricity Demand

EMET is conducting a separate analysis and report(7) on the potential impact of EEIs in the Commercial and Residential sectors on electricity demand levels. The results of this separate analysis have been used to calculate the electricity demand reduction potential related to the EEIs included in this report. Refer to the separate EMET study for additional details on methodology and sources of data.

d) Energy Rates

The energy rates used in the analysis are as shown below:

Energy Type	Rate $M/PJ
Electricity	36
Gas	13
Wood	5
Other	26

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2 Energy Use and Trends in the Residential Sector

ABARE(2) forecasts that the Australian Residential sector will consume 447 PJ of energy in 2005[1] and its forecast consumption for the year 2014 is 536 PJ, corresponding to an increase in energy use by 19.9%.

Figure 2.1 shows the breakdown of the forecast trends in energy use between 2000 and 2014, by source of energy. Under current predictions, Solar Energy will sustain the greatest growth in utilisation between 2005 and 2014, at 28.1%. This is expected to be followed by Natural Gas with a growth of 26.1% and Electricity with 22.1%.

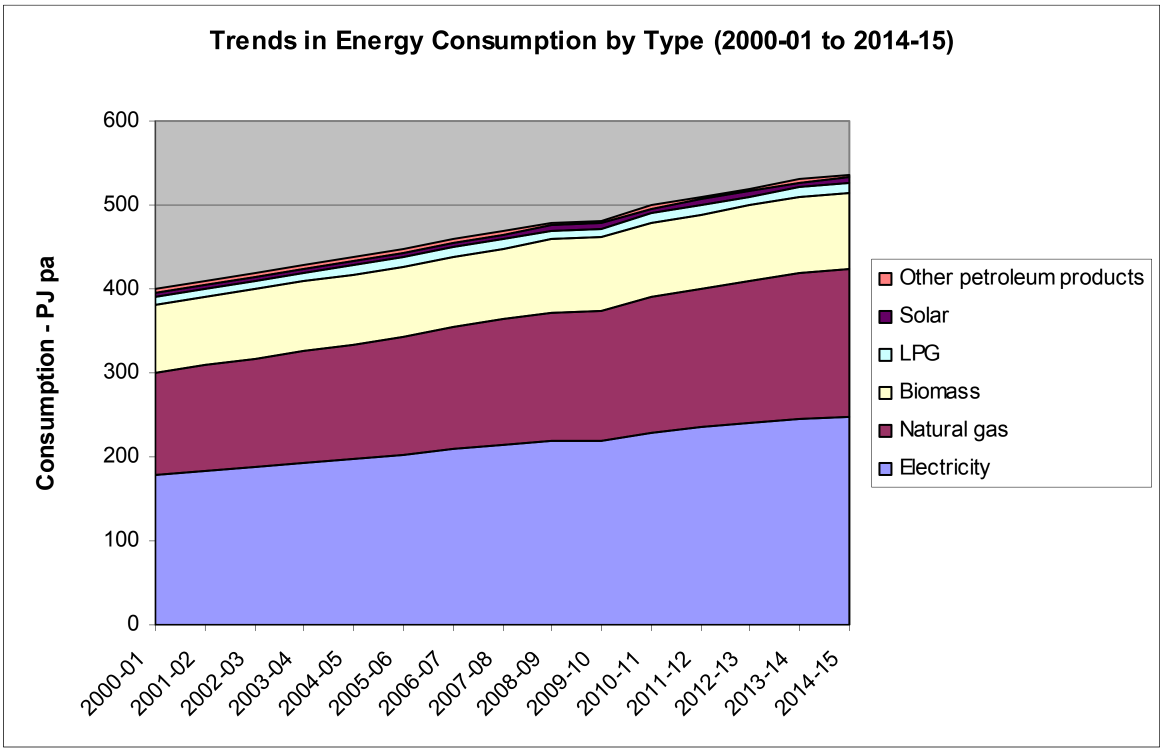

Figure 2.1: Australian Residential Sector – Trends in Energy Consumption by Energy Source (ABARE(2))

Table 2.1 shows the breakdown of energy use by fuel type as at 2005. Electricity is the major energy source within this sector, with over 45.4% of total consumption, followed by Natural Gas with 31.3%

1 Please note that for the purposes of this analysis, the ABARE energy consumption figures for financial years have been allocated to the beginning calendar year (eg. 2005-06 is allocated to 2005)

of total consumption. Biomass provides 18.8% of total energy use in the sector, while all others combined constitute less than 5% of total energy use.

Table 2.1: Energy Consumption in the Australian Residential Sector
(Source – ABARE [2])

Energy Source	Energy Consumption (PJ pa)
	Year 2005
Electricity	203
Natural Gas	140
Biomass	84
LPG	11
Solar	5
Other petroleum products	4
Total – PJ	447

Note: numbers may not add due to rounding off

2.1 Applications of Energy

Figure 2.2 shows the residential sector's projected breakdown of energy use by application for the year 2005. Space heating is the largest component at 42% (192.2 PJ pa), followed by Water Heating at 28% (124.5 PJ pa). Appliances and Home electronics together are responsible for 13% of energy use and refrigeration 7%.

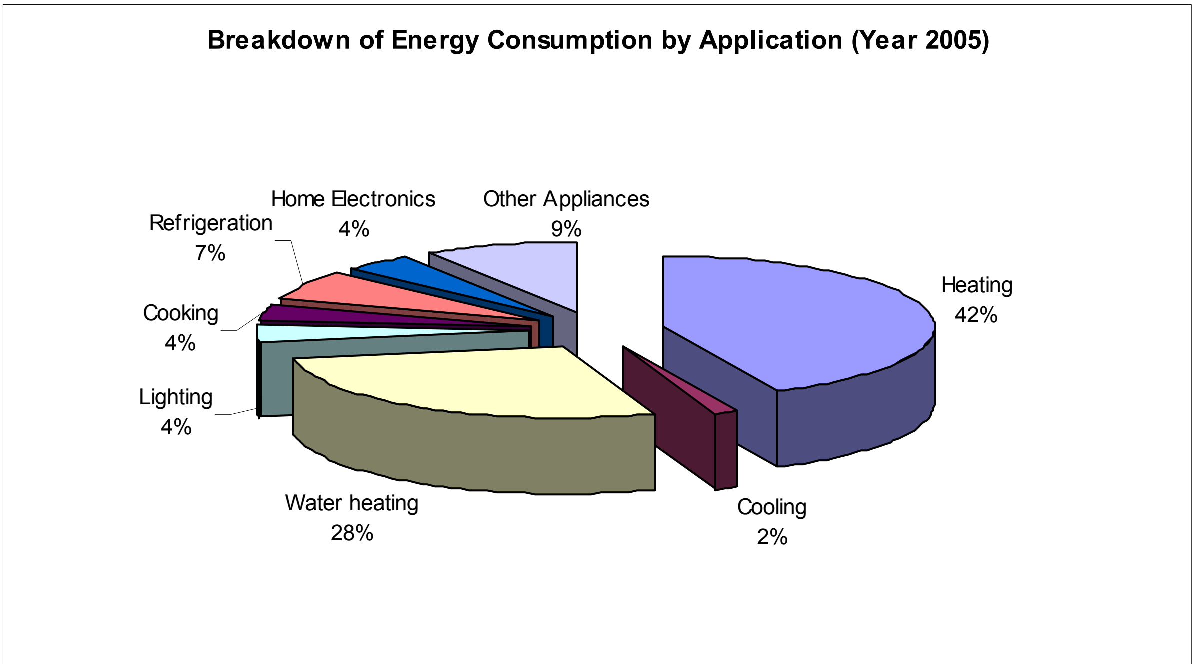

Figure 2.2: Residential Sector 2005 – Breakdown in Energy Consumption by Application

Table 2.3 and Figure 2.3 show the variation in the application of energy across the residential sector over the analysis period 2005 to 2014. Note that Solar Energy is not shown in these figures as they only include purchased energy. The totals are therefore lower than those shown at the beginning of this section.

At 32.2%, the growth in cooling energy consumption is somewhat larger than for heating (22.2%), which reflects the high adoption rate of this technology as well as the impact of air conditioners with reverse cycle heating on consumption for this service. Home Electronics (38.4%), Cooking (37.8%) and Other Appliances (32.4%) are the services which show the highest growth rates.

Table 2.3: Variation in Energy used by Application – Residential Sector – 2005 to 2014 - PJ pa

Application	2005	2014	Growth
Heating	192.2	234.9	22.2%
Cooling	6.8	8.9	32.2%
Water heating	125.4	139.5	11.3%
Lighting	17.5	21.9	24.6%
Cooking	16.0	22.0	37.8%
Refrigeration	30.1	32.1	6.5%
Home Electronics	17.9	24.7	38.4%
Other Appliances	41.4	54.8	32.4%
Totals	447.3	538.8	20.5%

Note: Includes purchased energy only. Solar energy is excluded.

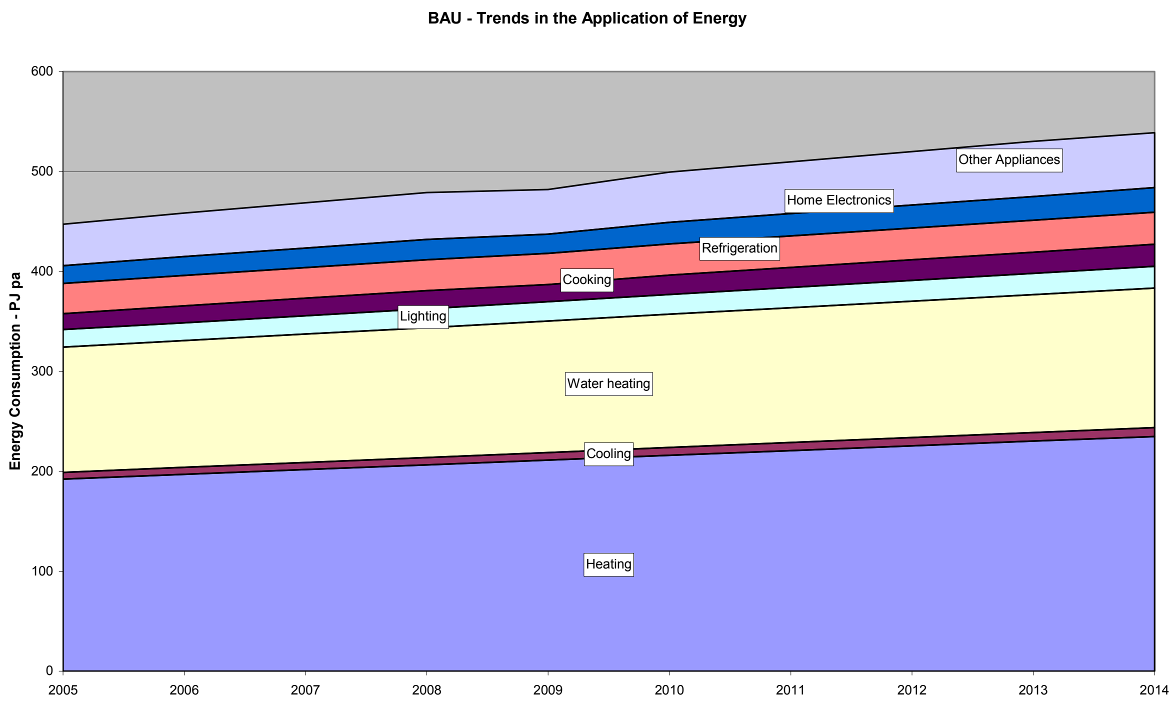

Figure 2.3: Trends in the Application of energy within the Residential Sector – 2005 to 2014

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3 Introduction

This section of the report discusses the specific scope, methodology and results of the analysis of 15 Residential Sector energy efficiency improvements (EEIs) evaluated in this study. The initiatives are broken down into the following 6 applications of energy:

- Building Thermal Performance and Heating and Cooling Systems
- Lighting Systems
- Cooking Systems
- Refrigeration Systems
- Dishwashers (excluding associated hot water)
- Clothes Washers (excluding associated hot water)

Initiatives belonging to the Heating and Cooling systems are further subdivided into measures which relate to the improvement of the thermal performance of a building and those which relate to the operating efficiency of heating and cooling appliances.

In each case, the Business as Usual energy consumption trends between 2005 and 2014 are established and then each of these is subjected to the application of each EEI. The effects of 'additionality' do not arise in the Residential Sector EEIs except for those related to Building Thermal Performance and Heating and Cooling Systems. In this case, measures are prioritised in order of decreasing cost-effectiveness (ie. the most cost-effective are given highest priority) with lower order measures suffering some loss in impact and cost-effectiveness due to the reduced scope. These effects are shown in the summary results (see Section 4.1).

Sections 3.1 to 3.6 discuss the EEIs for each of the above 6 applications respectively. Section 4 provides a summary of the results for the entire Residential Sector (not including applications relevant to Hot Water energy use – refer to earlier discussions).

3.1 Building Thermal Performance and Heating and Cooling Systems

3.1.1 Energy Efficiency Initiatives

The energy efficiency initiatives analysed under the category of Building Thermal Performance and Heating and Cooling Systems are divided into measures which improve the performance of the building shell and those which relate to the efficiency of heating and cooling appliances. Those included in the analysis were:

Building Shell Measures:

- Increase ratings of new homes in all States to 5 Stars, from 3.5 & 4 Stars, as appropriate.
- Insulation of existing dwellings.
- Weather stripping & Sealing of buildings.

Appliance Related Measures:

- Improvement in COP for reverse cycle heating and cooling.
- Improve the efficiency of larger gas and solid fuel burners.
- Replace the remainder of gas and solid fuel heaters with higher efficiency units.
- Improve the efficiency of ducted heating & cooling (reduce losses).
- Replace electric heating with Heat Pumps.

Refer to Section 3.1.2 for the establishment of the base energy consumption levels applicable to heating and cooling systems in the Residential sector, and Section and 3.1.3 for a more detailed description of the scope, methodology and assumptions used in the analysis each EEI and the estimated impact of their adoption across the Residential Sector.

3.1.2 Trends in related Energy Use

The projected trends in Business as Usual energy use for heating and cooling purposes used as the basis for the evaluation of Building Shell and Heating and Cooling appliances EEIs were calculated as follows:

- The year 2000 breakdown of energy use for heating and cooling by energy source were used as the base consumption (consistent with Armstrong/SEAV work[9]).
- BAU trends in energy use were initially calculated on the basis of increased floor area, which was in turn calculated using the projected growth in housing numbers (Source ABS[5]); trends in style of housing (eg. Detached and non-detached) (Source EES[4]); and trends in dwelling floor areas (Source EES[4])
- BAU trends were then adjusted for variations in equipment penetration (eg. Increased use of air conditioners, changes to the type of heaters used etc.) (Source ABS[6]).

Appendix 1 contains a summary of key factors used in the above analysis. Where necessary, for specific EEIs, the above calculations were repeated for individual States and/or additional relevant factors were taken into consideration. Refer to the discussion of individual initiatives in the next section.

The resulting national trends in energy consumption and the key residential sector statistics related to heating and cooling energy use are shown in Table 3.1.

3.1.3 Methodology and Assumptions for Heating and Cooling EEI Calculations

a) Increase ratings of new homes in all States to 5 Stars, from 3.5 & 4 Stars, as appropriate.

Based on currently implemented measures, new homes are required to be designed to an energy performance level of 5 Stars (VIC), 4 Stars (ACT) or 3.5 Stars (elsewhere) as measured by approved energy simulation software such as NatHERS and FirstRate. The effect of these existing measures has been included in the BAU case and this EEI refers to the improvement achievable by bringing all housing developments to a 5 Star performance level.

The impacts of this EEI are State-based, and have been calculated separately for each case. The following additional factors and data were used in calculating the effects of this EEI:

- The number of households per State was sourced from ABS.

- The floor area per State was calculated using the above household numbers and average areas for dwellings developed in EES[(4)]
- The proportion of housing stock per climatic zone (NatHERS climatic zones) was consistent with those developed in the EES[(4)] study and are tabulated in Appendix 1.
- The housing construction profile (eg. Double brick/tile, Brick Veneer/Metal etc) for each State was assumed to be the same as that developed in EES[(4)] .
- The level of heating and cooling energy improvements achievable by a specific change in Star rating were calculated using the typical energy application levels required for each construction type at each climatic zone and summating these in accordance with the proportions of housing stock per climatic zone in each State.
- The average marginal cost per dwelling to achieve a 5 Star rating was assumed to be $1,500 (based on an average combination of measures including the addition or improvement to insulation levels, sealing and weather-stripping, better curtaining and other similar measures).

<u>All fuels results</u>

The results of the analysis are shown in Table 3.2 (a). This EEI is estimated to produce annual energy savings of 8.84 PJ pa, or 3.63% of total heating and cooling energy end use, by the year 2014 comprising a 16.9% and 18% reduction in heating and a 1.5% and 18.1% reduction in cooling in new dwellings in ACT and other States (excluding VIC) respectively.

The annual energy savings achieved by 2014 are $173.8M for a total implementation cost of $1,132M, resulting in a payback period of 6.5 years. Refer to Table 3.2 (a) for an annual breakdown of energy and cost savings for this EEI.

<u>Gas and electricity only results</u>

The results of the analysis for electricity and gas only are shown in Table 3.2 (b). This EEI is estimated to produce annual energy savings of 6.47 PJ pa (excluding biomass energy), or 2.65% of total heating and cooling energy end-use, for the same proportions of heating and cooling reductions itemised above for the all fuels case.

The annual energy savings achieved by 2014 are $161.92M for a total implementation cost of $1,035M, resulting in a payback period of 6.4 years. Refer to Table 3.2 (b) for an annual breakdown of energy and cost savings for this EEI.

b) Insulation of Existing Homes.

ABS (4602.0) data indicates that 60.5% of existing dwellings will be insulated by the year 2005. It is assumed that for practical reasons (eg. roof space not accessible, etc.) there would be a limit of approximately 70% of existing homes that could be insulated. This is consistent with the proportion used in previous studies such as EES[(4)]. This EEI was calculated on the basis that a further 1% of dwellings would be insulated per annum until the 70% penetration level is achieved.

The impacts of this EEI are State-based, and have been calculated separately for each case. The same process as that used in the EEI relating to the upgraded efficiency of new houses (Star Rating increase) (refer to (a) above) was applied in this case in addition to the following:

- The proportion of non-insulated buildings was assumed to be the same across all States.
- The level of heating and cooling energy improvements achievable by the addition of insulation was based on NatHERS modeling of alternative building constructions and conforms to the results calculated by EES[(4)].

- The average cost of insulating a dwelling was assumed to be $750 (based on contractor installation on an average house size and typical accessibility).

<u>All fuels results</u>

This EEI is estimated to produce annual energy savings of 2.99 PJ pa, or 1.23% of total heating and cooling energy end use, by the year 2014 comprising a 13.4% and 15.6% reduction in heating and cooling respectively in the treated buildings.

The annual energy savings achieved by 2014 are $34.1M for a total implementation cost of $639M, resulting in a payback period of 18.8 years.

<u>Gas and electricity only results</u>

This EEI is estimated to produce annual energy savings of 1.59 PJ pa (excluding biomass energy), or 0.65% of total heating and cooling energy end-use, for the same proportions of heating and cooling reductions itemised above for the all energy case.

The annual energy savings achieved by 2014 are $27.1M for a total implementation cost of $580M, resulting in a payback period of over 20 years.

The results for this EEI are not included in Table 3.2 a & b, as their payback period is excessive.

c) Weather stripping & Sealing of buildings

Buildings constructed prior to the current BCA did not have a requirement for effective sealing of gaps and other draft excluding devices. In addition, older homes have suffered additional causes of drafts through movement and aging/maintenance effects. This EEI is based on the assumption that 50% of dwellings would be retrofitted with weather stripping and sealing of gaps during the 10 year analysis period, resulting in 5% of households treated annually.

The impacts of this EEI are State-based, and have been calculated separately for each case. The same process as that used in the Star rating EEI (refer to (a) above) was applied in this case in addition to the following:

- The proportion of buildings applicable to the EEI was assumed to be the same across all States.
- The level of heating and cooling energy improvements achievable by the application of the EEI was calculated using the FirstRate software on typical building constructions and representative climatic zones as per initiative (a) above.
- The average cost of weather stripping and sealing a dwelling was assumed to be $100, based on materials only and the work being predominantly undertaken by householders.

<u>All fuels results</u>

The results for this analysis are shown in Table 3.2 (a). The analysis indicated that this EEI would produce annual energy savings of 7.33 PJ pa, or 3.01% of total heating and cooling energy end-use, by the year 2014, comprising a 7% and 5% reduction in heating and cooling energy respectively in the treated buildings.

The annual energy cost savings achieved by 2014 are $81.2M for a total implementation cost of $423M, resulting in a payback period of 5.2 years.

Electricity and gas only results

The results for this analysis for electricity and gas only are shown in Table 3.2 (b). The analysis indicated that this EEI would produce annual energy savings of 3.87 PJ pa (excluding biomass energy), or 1.59% of total heating and cooling energy end-use, for the same proportional reductions in heating and cooling as those itemised above for the all energy case.

The annual energy cost savings achieved by 2014 are $63.9M for a total implementation cost of $386M, resulting in a payback period of 6.0 years.

d) Improvement in COP for reverse cycle heating and cooling

This EEI assumes that existing air conditioners are replaced over a period of 10 years with units which have a COP level 0.5 better than the minimum specified by MEPS at the time of purchase. This also applies to air conditioners purchased for new dwellings.

This EEI is proportional to the energy used by the relevant appliances and uses the equipment penetration rates tabled in Appendix 1 and relevant energy use quantities from Table 3.1. In addition, the following assumptions have been made:

- The proportion of new buildings which are equipped with air conditioners (both cooling only and reverse cycle) are the same as the penetration rates in existing buildings (refer to Appendix 1).
- The proportion of electricity used for reverse cycle heating compared to other electric space heating was calculated assuming equivalent operating patterns and current average COP of 2.0.
- The marginal cost of purchasing a more efficient appliance was assumed to be $400, based on an assumed 25% premium cost on typical domestic air conditioners.

This EEI is estimated to produce annual energy savings of 1.16 PJ pa (biomass energy not applicable) by the year 2014.

The annual energy cost savings achieved by 2014 are $41.9M for a total implementation cost of $1,000M, resulting in a payback period of 23.9 years.

The results for this EEI are not included in Table 3.2 as its payback period is excessive.

e) Improve the efficiency of larger gas and solid fuel burners.

This EEI relates to solid fuel heaters and larger flued gas heaters with little or no draft control on their flues and fire-boxes (if any exists). GWA[8] indicates that 29% of gas heaters fall into the category of flued gas heaters and that this proportion remains steady during the study period. All solid fuel heaters are assumed to be flued. The proportion of heaters subject to poor draft control and excessive losses is not readily available and has been assumed to be 30% for gas heaters and 60% for solid fuel heaters. This EEI involves improving the efficiency of these heaters by retrofitting them with more efficient controls, balancing and closing off flues and chimneys as required, using alternative heaters when smaller areas are occupied etc.

This EEI is proportional to the energy used by the relevant appliances and uses the equipment penetration rates tabled in Appendix 1 and relevant energy use quantities from Table 3.1. In addition, the following assumptions have been made:

- It is assumed that it is only practical to undertake the above works cost-effectively for 50% (ie. 5% per annum) of the heaters relevant to this EEI (the remainder are assessed for replacement in the following EEI).
- Energy savings for the heaters are estimated to be 28%, based on reduced draft losses through open chimneys as well as improved efficiency of firing in the heaters (adapted from the Cool Communities program abatement actions – AGO).
- The proportion of new buildings which would have been equipped with similar heaters remain in proportion with the relevant penetration rates in existing buildings (refer to Appendix 1).
- The cost of undertaking the improvements in existing buildings was assumed to be $200, based on the cost of materials only; and the marginal cost of purchasing a more efficient appliance was also assumed to be $200, based on a premium of 15% over the cost of a medium/high quality appliance.

All fuels results

The results of the analysis are shown in Table 3.2 (a). This EEI is estimated to produce annual energy savings of 13.89 PJ pa (excluding biomass energy), 5.70% of total heating and cooling energy end-use, by the year 2014.

The annual energy cost savings achieved by 2014 are $110.84M for a total implementation cost of $155M, resulting in a payback period of 1.4 years.

Electricity and gas only results

The results of the analysis for electricity and gas only are shown in Table 3.2 (b). This EEI is estimated to produce annual energy savings of 5.17 PJ pa (excluding biomass energy), 2.12% of total heating and cooling energy end-use, by the year 2014.

The annual energy cost savings achieved by 2014 are $67.24M for a total implementation cost of $111M, resulting in a payback period of 1.6 years.

f) Replace other (ie. not included in EEI (e) above) Fixed Gas and Solid Fuel Heaters with higher efficiency units (than would have otherwise been selected) at the time of Economic Replacement.

As for item (e) above, this EEI relates solid fuel heaters and larger flued gas heaters, however, in this case the EEI relates to those not retrofitted above, but those due for economic replacement during the study period. It is assumed that at this time consumers would be encouraged to choose the more efficient heaters, rather than open, “Log” style heater or similar. A life cycle of 20 years has been assumed resulting in a replacement rate of 5% and involving all of the heaters of this nature not covered in item (e) above.

This EEI is proportional to the energy used by the relevant appliances and uses the equipment penetration rates tabled in Appendix 1 and relevant energy use quantities from Table 3.1. In addition, the following assumptions have been made:

- No reliable efficiency figures are available for these heater types as the installation is an important determinant of final efficiency. Energy savings resulting from a better choice of heater and more effective installation from the average choice is assumed to be 14% (half of the worst case losses assumed for item (e) above).
- This option does not apply to new buildings, as they are covered under item (e).

The marginal cost of purchasing a more efficient appliance was assumed to be $500, based on a 20% ($300) premium over the cost of a standard heater plus $200 for a more complicated installation.

All fuels results

The results of the analysis are shown in Table 3.2 (a). This EEI is estimated to produce annual energy savings of 6.84 PJ pa (excluding biomass energy), 2.81% of total heating and cooling energy end-use, by the year 2014.

The annual energy cost savings achieved by 2014 are $51.59 M for a total implementation cost of $328M, resulting in a payback period of 6.4 years.

Electricity and gas only results

The results of the analysis for electricity and gas only are shown in Table 3.2 (b). This EEI is estimated to produce annual energy savings of 2.17 PJ pa (excluding biomass energy), 0.89% of total heating and cooling energy end-use, by the year 2014.

The annual energy cost savings achieved by 2014 are $28.24 M for a total implementation cost of $217M, resulting in a payback period of 7.7 years (this item is included in Table 3.2b although its payback period is greater than 6.5 years, as the payback period for the all-fuels analysis is below 6.5 years).

g) Improve the efficiency of ducted heating & cooling (reduce losses).

This EEI assumes that 15% potential energy savings can be achieved by undertaking simple repairs to reduce losses and better control the output of ducted heating and cooling systems (eg. Zone dampers and duct and joint maintenance). This is considered to be a conservative of saving potential typically identified in EMET surveys on systems of this nature. It is assumed that all relevant units would be retrofitted in the 10 year analysis period (ie. 10% per annum).

The scope of this EEI is assumed to be proportional to the penetration rate of the relevant appliances. Additional assumptions used in this analysis are listed below:

- Ducted R/C air conditioners are installed in 6.4% of dwellings; ducted Cooling-Only air conditioners in 2.5%; and ducted heating systems in 10% of homes (Source – EES(4)).
- The proportion of new buildings which are equipped with ducted systems is the same as the penetration rates in existing buildings.
- Energy used by ducted systems is double the quantity used by non-ducted systems.
- The marginal cost of undertaking the improvements was assumed to be $200, based on typical material costs only with repairs largely conducted by householders.

All fuels / Electricity and gas only results

The results of the analysis are the same for both all fuels and electricity and gas only, and are shown in Tables 3.2 (a) and (b). This EEI is estimated to produce annual energy savings of 3.0 PJ pa (biomass energy not applicable), 1.23% of total heating and cooling energy end-use, by the year 2014.

The annual energy cost savings achieved by 2014 are $41.4M for a total implementation cost of $136M, resulting in a payback period of 3.3 years.

h) Replace electric heating with Heat Pumps.

This EEI involves replacing 70% of electric resistance heating systems with reverse cycle heating, achieving an assumed efficiency improvement of 50%. It is assumed that all relevant units would be retrofitted in the 10 year analysis period (ie. 10% per annum).

This EEI is proportional to the energy used by the relevant appliances and uses the equipment penetration rates tabled in Appendix 1 and relevant energy use quantities from Table 3.1. In addition, the following assumptions have been made:

- The proportion of new buildings which are equipped with ducted systems is the same as the penetration rates in existing buildings.
- The marginal cost of undertaking the improvements was assumed to be $1,000, based on an average installation of 1.5 kW heat output (EMET data).

All fuels / Electricity and gas only results

The results of the analysis are the same for both all fuels and electricity and gas only. This EEI is estimated to produce annual energy savings of 2.55 PJ pa (biomass energy not applicable) by the year 2014.

The annual energy cost savings achieved by 2014 are $91.8M for a total implementation cost of $1,171M, resulting in a payback period of 12.7 years.

The results for this EEI are not included in Table 3.2 a & b, as their payback period is excessive.

Table 3.1- Trends in Key Residential Sector Statistics and Energy Consumption for Heating and Cooling by Energy Type – 2005 to 2014

Year		**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**
Key Residential Sector Statistics											
Total Households - '000s		7960.8	8078.8	8190.5	8302.3	8413.4	8525.4	8636.8	8741.8	8845.7	8949
Total Effective Floor Area – 10^6x m^2		963	990	1,016	1,044	1,071	1,099	1,127	1,154	1,182	1,210
Energy Consumption for Heating and Cooling by Energy Type - PJ											
Heating	Gas	85.6	88.0	90.4	92.8	95.2	97.7	100.2	102.7	105.2	107.7
	Electric	8.3	8.5	8.8	9.1	9.3	9.6	9.9	10.1	10.4	10.7
	Wood	95.0	97.0	99.0	100.9	102.9	104.8	106.8	108.6	110.5	112.3
	Other	3.4	3.5	3.6	3.7	3.8	3.8	3.9	4.0	4.1	4.2
	Sub-total heating	192.2	197.0	201.7	206.4	211.2	216.0	220.8	225.5	230.2	234.9
Cooling	Electric	6.8	7.0	7.2	7.5	7.7	7.9	8.2	8.4	8.7	8.9
TOTAL	heat +cool	199.0	204.0	208.9	213.9	218.9	223.9	229.0	233.9	238.9	243.9

Table 3.2 – Impact of Building Shell and Heating and Cooling Systems EEIs

a) Heating and Cooling – All Fuels (paybacks <6.5 years, ex BAU)

Cumulative Improvements - PJ	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	Heat/Cool Energy Savings	Energy Savings ($M pa)	Payback (Yrs)
Increase VIC new homes from 3.5 stars to 5 stars	0.00	0.27	0.54	0.81	1.08	1.35	1.63	1.90	2.16	2.43	1.00%	$28.03	-
Weatherstripping & Sealing	0.66	1.34	2.03	2.74	3.46	4.20	4.96	5.74	6.53	7.33	3.01%	$81.18	5.2
Increase all other States to 5 Stars from 3.5 & 4 resp	0.00	0.98	1.95	2.92	3.90	4.90	5.90	6.88	7.86	8.84	3.63%	$173.80	6.5
Improve the efficiency of larger gas and solid fuel burners	1.27	2.57	3.89	5.24	6.61	8.02	9.45	10.90	12.38	13.89	5.70%	$110.84	1.4
Replace the remainder with high efficiency units	0.62	1.25	1.90	2.57	3.24	3.94	4.64	5.36	6.09	6.84	2.81%	$51.59	6.4
Improve the efficiency of ducted heating & cooling (reduce losses)	0.27	0.54	0.82	1.11	1.40	1.71	2.02	2.34	2.66	3.00	1.23%	$41.38	3.3
Total - all measures with paybacks < 6.5 years, ex BAU	**2.81**	**6.68**	**10.59**	**14.57**	**18.62**	**22.76**	**26.97**	**31.21**	**35.53**	**39.91**	**16.37%**	**$458.79**	**4.7**

Cumulative Savings - $M pa	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	Cost ($M)	Payback (Yrs)
Increase VIC new homes from 3.5 stars to 5 stars	$0.00	$3.09	$6.12	$9.20	$12.30	$15.45	$18.63	$21.74	$24.87	$28.03	BAU	-
Weatherstripping & Sealing	$7.22	$14.64	$22.25	$30.06	$38.07	$46.29	$54.71	$63.33	$72.15	$81.18	$423	5.2
Increase all other States to 5 Stars from 3.5 & 4 resp	$0.00	$19.06	$37.81	$56.84	$76.03	$95.55	$115.28	$134.64	$154.13	$173.80	$1,132	6.5
Improve the efficiency of larger gas and solid fuel burners	$10.12	$20.47	$30.99	$41.73	$52.70	$63.92	$75.37	$86.97	$98.79	$110.84	$155	1.4
Replace the remainder with high efficiency units	$4.64	$9.40	$14.27	$19.25	$24.35	$29.57	$34.90	$40.35	$45.91	$51.59	$328	6.4
Improve the efficiency of ducted heating & cooling (reduce losses)	$3.65	$7.41	$11.27	$15.24	$19.32	$23.51	$27.81	$32.22	$36.75	$41.38	$136	3.3
Total - all measures with paybacks < 6.5 years, ex BAU	**25.63**	**70.98**	**116.59**	**163.12**	**210.48**	**258.84**	**308.07**	**357.52**	**407.74**	**$458.79**	**$2,175**	**4.7**

b) Heating and Cooling – Electricity and Gas only (paybacks <6.5, ex BAU)

Cumulative Improvements - PJ	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	Heat/Cool Energy Savings	Energy Savings ($M pa)	Payback (Yrs)
Weatherstripping & Sealing	0.34	0.69	1.06	1.43	1.81	2.20	2.60	3.01	3.44	3.87	1.59%	$63.85	6.0
Increase all other States to 5 Stars from 3.5 & 4 resp	0.00	0.71	1.40	2.11	2.82	3.55	4.28	5.01	5.73	6.47	2.65%	$161.92	6.4
Improve the efficiency of larger gas and solid fuel burners	0.47	0.95	1.44	1.94	2.46	2.98	3.52	4.06	4.61	5.17	2.12%	$67.24	1.6
Replace the remainder with high efficiency units*	0.19	0.39	0.59	0.80	1.02	1.24	1.46	1.69	1.93	2.17	0.89%	$28.24	7.7 *
Improve the efficiency of ducted heating & cooling (reduce losses)	0.27	0.54	0.82	1.11	1.40	1.71	2.02	2.34	2.66	3.00	1.23%	$41.38	3.3
Total - all measures with paybacks < 6.5 years, ex BAU	**1.27**	**3.28**	**5.32**	**7.39**	**9.51**	**11.67**	**13.88**	**16.10**	**18.38**	**20.68**	**8.48%**	**$362.63**	**5.2**

Cumulative Savings - $M pa	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	Cost ($M)	Payback (Yrs)
Weatherstripping & Sealing	$5.63	$11.43	$17.39	$23.51	$29.81	$36.27	$42.91	$49.72	$56.70	$63.85	$386	6.0
Increase all other States to 5 Stars from 3.5 & 4 resp	$0.00	$17.67	$35.09	$52.77	$70.63	$88.81	$107.20	$125.29	$143.51	$161.92	$1,035	6.4
Improve the efficiency of larger gas and solid fuel burners	$6.13	$12.41	$18.76	$25.27	$31.92	$38.74	$45.70	$52.74	$59.92	$67.24	$111	1.6
Replace the remainder with high efficiency units*	$2.50	$5.08	$7.72	$10.43	$13.22	$16.07	$19.01	$22.01	$25.09	$28.24	$217	7.7*
Improve the efficiency of ducted heating & cooling (reduce losses)	$3.65	$7.41	$11.27	$15.24	$19.32	$23.51	$27.81	$32.22	$36.75	$41.38	$136	3.3
Total - all measures with paybacks < 6.5 years, ex BAU	**$17.91**	**$54.00**	**$90.23**	**$127.23**	**$164.90**	**$203.41**	**$242.63**	**$281.98**	**$321.96**	**$362.63**	**$1,885**	**5.2**

* This item is included in Table 3.2b although its payback period is greater than 6.5 years, as the payback period for the all-fuels analysis is below 6.5 years.

3.2 Lighting Systems

3.2.1 Energy Efficiency Initiatives

The energy efficiency initiatives analysed under the lighting category are listed below:

- Improvement in Lighting Efficiency (beyond BAU).
- Improvement in Lighting Controls.

Refer to Section 3.2.2 for the establishment of the base energy consumption levels applicable to lighting systems in the Residential sector, and Section and 3.2.3 for a more detailed description of the scope, methodology and assumptions used in the analysis each EEI and the estimated impact of their adoption across the Residential Sector.

3.2.2 Trends in related Energy Use

The projected trends in Business as Usual energy use for lighting were calculated as follows:

- The year 2000 breakdown of energy use for residential energy services, by energy source, were used as the base consumption (consistent with Armstrong/SEAV work[9]).
- BAU trends in energy use were initially calculated on the basis of increased floor area, which was in turn calculated using the projected growth in housing numbers (source ABS[5]); trends in style of housing (eg. Detached and non-detached) (Source EES[4]); and trends in dwelling floor areas (Source EES[4]).
- BAU trends were then adjusted for variations in average lighting efficiency over the study period. Lighting efficiency was calculated using a weighted average of the lighting source penetration extrapolated from EES[4]. Refer to Appendix 1 for the projected trends in lighting source penetrations and the calculated average efficiency factor used to adjust the frozen efficiency scenario trends.

The resulting national trends in energy consumption for lighting energy use are shown in Table 3.3.

Table 3.3 - Trends in Energy Consumption for Lighting Systems – 2005 to 2014

Application (PJ pa)	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Lighting (including BAU improvements in efficiency)	17.5	17.8	18.4	18.9	19.4	19.9	20.3	20.8	21.4	21.9

3.2.3 Methodology and Assumptions for Lighting EEI Calculations

a) Improvement in Lighting Efficiency.

This initiative assumes that the penetration of efficient lighting systems is increased in more commonly used rooms during evening hours. It is assumed that 30% of Kitchens are improved from Quartz-Halogen lamps to Fluorescent; and 30% of Lounge rooms and 50% of Bedrooms are converted from Incandescent to Fluorescent.

The following additional factors and data were used in calculating the effects of this EEI:

- A 15 year changeover rate was used (7% per annum) in existing homes and all new homes were assumed to be captured (at the penetration rates per room type, as noted above).
- The average marginal cost per dwelling to implement all of the conversions was assumed to be $130, based on typical costs for medium quality residential light fittings.

The results of the analysis are shown in Table 3.4. This EEI is estimated to produce annual electricity savings of 2.34 PJ pa, 10.7% of total lighting energy end-use, by the year 2014.

The annual energy cost savings achieved by 2014 are $84.2M for a total implementation cost of $321M, resulting in a payback period of 3.8 years.

b) Improvement in the control of Lighting.

This initiative relates to operating efficiencies achieved in lighting by the addition of automatic controls and does not relate to changes in usage patterns which might be made available through better awareness etc.

It is assumed that external (driveway, porch and passageway) lights are chosen with integrated movement and daylight detectors in 25% of homes.

The following additional factors and data were used in calculating the effects of this EEI:

- A 15 year changeover rate was used (7% per annum) in existing homes and all new homes were assumed to be captured (at the penetration rates per room type, as noted above).
- The average marginal cost per dwelling to implement all of the conversions was assumed to be $40, based on typical retail costs for control-integrated fittings v's plain fittings.

The results of the analysis are shown in Table 3.4. This EEI is estimated to produce annual electricity savings of 0.37 PJ pa , 1.7% of total lighting energy end-use, by the year 2014.

The annual energy cost savings achieved by 2014 are $13.4M for a total implementation cost of $63M, resulting in a payback period of 4.7 years.

Table 3.4 – EEI Impacts - Lighting Systems

Cumulative Improvements - PJ	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	Lighting Energy Savings	Energy Savings ($M pa)	Payback (Yrs)
Improvement in Lighting Efficiency	0.20	0.44	0.68	0.92	1.15	1.39	1.63	1.87	2.10	2.34	10.70%	84.16	3.8
Improvement in the control of Lighting	0.03	0.07	0.11	0.15	0.18	0.22	0.26	0.30	0.33	0.37	1.70%	13.40	4.7
Total for measure, excluding BAU	**0.23**	**0.51**	**0.78**	**1.06**	**1.34**	**1.61**	**1.89**	**2.16**	**2.44**	**2.71**	**12.40%**	**$97.56**	**3.9**

Cumulative Savings - $M pa	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	Cost ($M)	Payback (Yrs)
Improvement in Lighting Efficiency	$7.09	$15.77	$24.35	$32.94	$41.52	$50.12	$58.70	$67.20	$75.68	$84.16	$321	3.8
Improvement in the control of Lighting	$1.13	$2.51	$3.88	$5.25	$6.61	$7.98	$9.35	$10.70	$12.05	$13.40	$63	4.7
Total for measure, excluding BAU	**$8.22**	**$18.28**	**$28.23**	**$38.19**	**$48.14**	**$58.10**	**$68.05**	**$77.90**	**$87.73**	**$97.56**	**$384**	**3.9**

3.3 Cooking Systems

3.3.1 Energy Efficiency Initiatives

The energy efficiency initiatives analysed under the cooking category are listed below:

- Increased use of Microwaves.
- Improved efficiency of burners & ovens.

Refer to Section 3.3.2 for the establishment of the base energy consumption levels applicable to cooking systems in the Residential sector, and Section and 3.3.3 for a more detailed description of the scope, methodology and assumptions used in the analysis each EEI and the estimated impact of their adoption across the Residential Sector.

3.3.2 Trends in related Energy Use

The projected trends in Business as Usual energy use for cooking were calculated as follows:

- The year 2000 breakdown of energy use for residential energy services, by energy source, were used as the base consumption (consistent with Armstrong/SEAV work(9)).
- BAU trends in energy use were assumed to follow the average BAU increase projected by ABARE for the entire sector.

The resulting national trends in energy consumption for cooking energy use are shown in Table 3.5.

Table 3.5 - Trends in Energy Consumption for Cooking Systems by Energy Type – 2005 to 2014

Application (PJ pa)	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Gas	7.1	7.5	7.8	8.2	7.8	8.8	9.1	9.4	9.7	9.8
Electric	8.8	9.3	9.7	10.1	9.6	10.8	11.2	11.6	12.0	12.2
TOTAL Cooking	16.0	16.9	17.5	18.2	17.4	19.6	20.3	21.0	21.7	22.0

3.3.3 Methodology and Assumptions for Cooking EEI Calculations

a) Increased Use of Microwaves.

This initiative assumes that Microwaves are used in lieu of conventional electric/gas cooktops on at least two occasions per day, and in lieu of ovens on two occasions per week.

The following additional factors and data were used in calculating the effects of this EEI:

- Burners are rated at 1000 W and 1600 W for electric and gas respectively and the ovens are rated at 1600 W and 2560 W respectively. The Microwave is rated at 850 W.
- The initiative involves behavioural changes and does involve additional expenditure.

The results of the analysis are shown in Table 3.6. This EEI is estimated to produce annual energy savings of 2.35 PJ pa (biomass energy not applicable), 10.7% of total cooking energy end-use, by the year 2014.

The annual energy cost savings achieved by 2014 are $44.8M for no implementation cost. This EEI is not included in the final table as it is involves behavioural change.

b) Improved efficiency of cooktops & ovens.

This initiative assumes that existing gas and electric cooktops and ovens are progressively changed over to more efficiently performing versions (ie. better flame efficiency, lower losses in operation, better control of heat etc.). New households would be fitted with the higher efficiency appliances.

The following additional factors and data were used in calculating the effects of this EEI:

- A 10 year changeover rate was used (10% per annum) in existing homes and all new homes were assumed to be captured.
- The average efficiency improvement was assumed to be 25%.
- The average marginal cost per dwelling to implement all of the conversions was assumed to be $225, based on approximately 25% premium over the typical medium/high quality appliance cost.

The results of the analysis are shown in Table 3.6. This EEI is estimated to produce annual energy savings of 3.90 PJ pa (biomass energy not applicable), 17.7% of total cooking energy end-use, by the year 2014.

The annual energy cost savings achieved by 2014 are $100.3M for a total implementation cost of $330M resulting in a payback period of 3.3 years.

Table 3.4 – EEI Impacts - Cooking Systems

Cumulative Improvements - PJ	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	Cooking Energy Savings	Energy Savings ($M pa)	Payback (Yrs)
Increased use of microwave	2.09	2.13	2.15	2.18	2.21	2.24	2.27	2.30	2.33	2.35	Not considered as it is a behavioural change		
Improved efficiency of cooktops & ovens	0.24	0.70	1.11	1.52	1.55	2.34	2.75	3.17	3.58	3.90	17.74%	$100.37	3.3
Total for measure, excluding BAU and behavioural changes	**0.24**	**0.70**	**1.11**	**1.52**	**1.55**	**2.34**	**2.75**	**3.17**	**3.58**	**3.90**	**17.74%**	**$100.37**	**3.3**

Cumulative Savings - $M pa	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	Cost ($M)	Payback (Yrs)
Increased use of microwave	Not considered as it is a behavioural change											
Improved efficiency of cooktops & ovens	$6.16	$18.05	$28.45	$39.17	$39.81	$60.12	$70.70	$81.39	$92.04	$100.37	$330	3.3
Total for measure, excluding BAU and behavioural changes	**$6.16**	**$18.05**	**$28.45**	**$39.17**	**$39.81**	**$60.12**	**$70.70**	**$81.39**	**$92.04**	**$100.37**	**$330**	3.3

3.4 Refrigeration Systems

3.4.1 Energy Efficiency Initiatives

The energy efficiency initiatives analysed under the refrigeration category are listed below:

- Selecting more efficient refrigeration equipment at the time of economic replacement.
- Retrofitting/maintaining older refrigeration equipment for better efficiency.

Refer to Section 3.4.2 for the establishment of the base energy consumption levels applicable to refrigeration systems in the Residential sector, and Section and 3.4.3 for a more detailed description of the scope, methodology and assumptions used in the analysis each EEI and the estimated impact of their adoption across the Residential Sector.

3.4.2 Trends in related Energy Use

The projected trends in Business as Usual energy use for refrigeration were calculated as follows:

- The year 2000 breakdown of energy use for residential energy services, by energy source, were used as the base consumption (consistent with Armstrong/SEAV work[(9)]).
- BAU trends in energy use were initially calculated on the basis of increased household numbers (source ABS[(5)]); and trends in penetration rates for refrigerators and freezers (extrapolated from ABS figures). Refer to Appendix 1 for Refrigerator and Freezer penetration rate projections used.
- BAU energy use trends were then adjusted for variations in the operating efficiency for new and existing refrigeration equipment over the study period. These were extrapolated from MEPS performance evaluation models for these appliances and include the MEPS upgrades expected from 2005. Refer to Appendix 1 for Refrigerator and Freezer trends in energy use.

The resulting national trends in energy consumption for refrigeration energy use are shown in Table 3.7.

Table 3.7 - Trends in Energy Consumption for Refrigeration Systems – 2005 to 2014

Application (PJ pa)	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Refrigeration	30.1	30.4	30.6	30.8	31.1	31.3	31.5	31.7	31.9	32.1

3.4.3 Methodology and Assumptions for Refrigeration EEI Calculations

a) Selecting more efficient refrigeration equipment at the time of economic replacement

This initiative assumes that the penetration of new, higher efficiency refrigerators (reaching a 20% improvement on MEPS by 2008) is increased by encouraging consumers to switch to the better models when a replacement to a new appliance is cost-effective. A 5% annual replacement rate is assumed.. Refer to Appendix 1 for the assumed annual energy use for existing appliances and trends in new appliances over the study period.

The following additional factors and data were used in calculating the effects of this EEI:

- The average marginal cost per appliance between one of average efficiency and one of higher performance was assumed to be $50, based on approximately 5% premium over the typical medium/high quality appliance cost.

The results of the analysis are shown in Table 3.8. This EEI is estimated to produce annual electricity savings of 1.55PJ pa, 4.82% of total refrigeration energy end use, by the year 2014.

The annual energy cost savings achieved by 2014 are $55.75M for a total implementation cost of $353M, resulting in a payback period of 6.3 years.

b) Retrofitting/maintaining older refrigeration equipment for better efficiency.

This initiative relates to 50% of the existing stock which is not replaced in the above initiative and involves a program of basic repairs and management of refrigeration plant to bring about an improvement in efficiency. Measurements of refrigerator performance (eg. Project CIEL - A DOMESTIC ELECTRICAL END-USE MEASUREMENT CAMPAIGN IN FRANCE, Commission of the European Community, 1993) showed that refrigerator and freezer maintenance and operational issues can result in energy consumption doubling the base level. Measures included in this EEI are those available to the householder at little or no cost and include such items as: Cleaning the condenser coils, shielding or locating the refrigeration equipment away from heat sources, defrosting regularly, repairing damaged or dislocated door seals, adjusting the operating temperature of the units etc. An average potential saving of 25% is assumed although this is conservative when compared to the measurements made under the above study, to allow for cases where only a select number of measures are applicable. A 2.5% annual retrofit rate is assumed as noted above.

The following additional factors and data were used in calculating the effects of this EEI:

- The average cost of parts per appliance was assumed to be $25, based on the possible replacement of some door seals and other spares only on selected units.

The results of the analysis are shown in Table 3.8. This EEI is estimated to produce annual electricity savings of 1.96PJ pa, 6.11% of total refrigeration energy end use, by the year 2014.

The annual energy cost savings achieved by 2014 are $70.61M for a total implementation cost of $86M, resulting in a payback period of 1.2 years.

Table 3.8 – EEI Impacts - Refrigeration Systems

Cumulative Improvements - PJ	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	Refrigeration Energy Savings	Energy Savings ($M pa)	Payback (Yrs)
Selecting more efficient refrigeration equipment at the time of economic replacement	0.05	0.16	0.33	0.50	0.67	0.84	1.01	1.19	1.37	1.55	4.82%	55.75	6.3
Retrofitting/maintaining older refrigeration equipment for better efficiency	0.19	0.38	0.57	0.76	0.96	1.16	1.36	1.56	1.76	1.96	6.11%	70.61	1.2
Total for measure, excluding BAU	**0.24**	**0.54**	**0.90**	**1.26**	**1.63**	**2.00**	**2.37**	**2.75**	**3.13**	**3.51**	**10.93%**	**$126.36**	**3.5**

Cumulative Savings - $M pa	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	Cost ($M)	Payback (Yrs)
Selecting more efficient refrigeration equipment at the time of economic replacement	$1.94	$5.91	$11.87	$17.91	$24.03	$30.22	$36.50	$42.84	$49.26	$55.75	$353	6.3
Retrofitting/maintaining older refrigeration equipment for better efficiency	$6.78	$13.63	$20.55	$27.52	$34.56	$41.66	$48.82	$56.03	$63.29	$70.61	$86	1.2
Total for measure, excluding BAU	**$8.72**	**$19.54**	**$32.42**	**$45.44**	**$58.59**	**$71.88**	**$85.32**	**$98.87**	**$112.55**	**$126.36**	**$439**	**3.5**

3.5 Dishwashers (excluding associated hot water)

3.5.1 Energy Efficiency Initiatives

The energy efficiency initiatives analysed under the dishwasher category are listed below:

- Selecting more efficient Dishwashers at the time of economic replacement.

Refer to Section 3.5.2 for the establishment of the base energy consumption levels applicable to Dishwashers in the Residential sector, and Section and 3.5.3 for a more detailed description of the scope, methodology and assumptions used in the analysis each EEI and the estimated impact of their adoption across the Residential Sector.

3.5.2 Trends in related Energy Use

The projected trends in Business as Usual energy use for dishwashers were calculated as follows:

- The base year (2005) energy consumption rate was calculated on a 1.5-day cycle of dishwashing involving internal water heating and drying as well as motor energy to a level of 0.49 kWh and 0.50 kWh per cycle respectively. Total annual energy use of 240 kWh per household (correlates with previous studies – eg EMET(3)).
- BAU trends in energy use were initially calculated on the basis of increased household numbers (source ABS(5)); and trends in penetration rates for dishwashers (extrapolated from ABS figures – refer to Appendix 1).
- BAU energy use trends were then adjusted for variations in the operating efficiency between new and existing dishwashers over the study period. These were based on a continued improvement of by 1.8% per annum (source: unpublished MEPS background survey data).

The resulting national trends in energy consumption for Dishwashers energy use are shown in Table 3.9.

Table 3.9 - Trends in Energy Consumption for Dishwashers – 2005 to 2014

Application (PJ pa)	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Dishwashers	2.6	2.7	2.8	3.0	3.1	3.2	3.3	3.4	3.5	3.6

3.5.3 Methodology and Assumptions for Dishwasher EEI Calculations

a) Selecting more efficient Dishwashers at the time of economic replacement

This initiative assumes that the penetration of new, higher efficiency dishwashers is increased by encouraging consumers to switch to the better models when a replacement to a new appliance is cost-effective. All new appliances are assumed to be captured.

The following additional factors and data were used in calculating the effects of this EEI:

- Refer to Appendix 1 for relevant appliance penetration rates from ABS[6].
- The energy use per appliance is assumed to be reduced by approximately 25% over the alternative new appliance by the combined improvement of pumping system design, reduction of heating losses and in better cycle design.
- The average marginal cost per appliance between one of average efficiency and one of higher performance was assumed to be $43, based on approximately 5% premium over the typical medium/high quality appliance cost.

The results of the analysis are shown in Table 3.10. This EEI is estimated to produce annual electricity savings of 0.29 PJ pa (biomass energy not applicable), 8.0% of total dishwasher energy end use, by the year 2014.

The annual energy cost savings achieved by 2014 are $10.5M for a total implementation cost of $63M, resulting in a payback period of 6.0 years.

Table 3.10 – EEI Impacts - Dishwashers

Cumulative Improvements - PJ	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	Dishwasher Energy Savings (PJ pa)	Energy Savings ($M pa)	Payback (Yrs)
Selecting more efficient Dishwashers at the time of economic replacement	0.03	0.06	0.09	0.12	0.15	0.18	0.21	0.23	0.26	0.29	0.08	10.49	6.0
Total for measure, excluding BAU	**0.03**	**0.06**	**0.09**	**0.12**	**0.15**	**0.18**	**0.21**	**0.23**	**0.26**	**0.29**	**7.99%**	**$10.49**	**6.0**

Cumulative Savings - $M pa	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	Cost ($M)	Payback (Yrs)
Selecting more efficient Dishwashers at the time of economic replacement	$1.09	$2.16	$3.21	$4.26	$5.31	$6.36	$7.42	$8.45	$9.47	$10.49	$63	6.0
Total for measure, excluding BAU	**$1.09**	**$2.16**	**$3.21**	**$4.26**	**$5.31**	**$6.36**	**$7.42**	**$8.45**	**$9.47**	**$10.49**	**$63**	**6.0**

3.6 Clothes Washers (excluding associated hot water)

3.6.1 Energy Efficiency Initiatives

The energy efficiency initiatives analysed under the clothes washer category are listed below:

- Selecting more efficient Clothes Washers at the time of economic replacement.

Refer to Section 3.5.2 for the establishment of the base energy consumption levels applicable to Clothes Washers in the Residential sector, and Section and 3.5.3 for a more detailed description of the scope, methodology and assumptions used in the analysis each EEI and the estimated impact of their adoption across the Residential Sector.

3.6.2 Trends in related Energy Use

The projected trends in Business as Usual energy use for Clothes Washers were calculated as follows:

- The base year (2005) energy consumption rate was calculated on a 2-day cycle of clothes washing involving motor energy to a level of 0.31 kWh per cycle. Total annual energy use of 55.8 kWh per household (correlates with previous studies – eg EMET(3)).
- BAU trends in energy use were initially calculated on the basis of increased household numbers (source ABS(5)); and trends in penetration rates for clothes washers (extrapolated from ABS figures – refer to Appendix 1).
- BAU energy use trends were then adjusted for variations in the operating efficiency between new and existing clothes washers over the study period. These were calculated as described under section 3.5.3.

The resulting national trends in energy consumption for Clothes Washers (excluding hot water) energy use are shown in Table 3.11.

Table 3.11 - Trends in Energy Consumption for Clothes Washers – 2005 to 2014

Application (PJ pa)	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Clothes Washers (not including water heating)	1.5	1.6	1.6	1.6	1.6	1.6	1.7	1.7	1.7	1.7

3.6.3 Methodology and Assumptions for Clothes Washer EEI Calculations

a) Selecting more efficient Dishwashers at the time of economic replacement.

This initiative assumes that the penetration of new, higher efficiency clothes washers is increased by encouraging consumers to switch to the better models when a replacement to a new appliance is cost-effective. All new appliances are assumed to be captured.

The following additional factors and data were used in calculating the effects of this EEI:

- Refer to Appendix 1 for relevant appliance penetration rates from ABS(6).

- The energy use per appliance is assumed to be reduced by approximately 8%, through an improvement in motor operating efficiency resulting from by combined improvement of motor and ancillaries and in better cycle design.
- The average marginal cost per appliance between one of average efficiency and one of higher performance was assumed to be $30, based on approximately 5% premium over the typical medium/high quality appliance cost.

The results of the analysis are shown in Table 3.12. This EEI is estimated to produce annual electricity savings of 0.24 PJ pa (biomass energy not applicable), 13.5% of total clothes washer energy end-use, by the year 2014.

The annual energy cost savings achieved by 2014 are $8.47M for a total implementation cost of $35M, resulting in a payback period of 4.1 years.

Table 3.12 – EEI Impacts – Clothes Washers

Cumulative Improvements - PJ	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	Clothes Washer Energy Savings	Energy Savings ($M pa)	Payback (Yrs)
Selecting more efficient Clothes Washers at the time of economic replacement	0.03	0.05	0.07	0.10	0.12	0.14	0.17	0.19	0.21	0.24	13.54%	$8.47	4.1
Total for measure, excluding BAU	**0.03**	**0.05**	**0.07**	**0.10**	**0.12**	**0.14**	**0.17**	**0.19**	**0.21**	**0.24**	**13.54%**	**$8.47**	**4.1**

Cumulative Savings - $M pa	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	Cost ($M)	Payback (Yrs)
Selecting more efficient Clothes Washers at the time of economic replacement	$0.93	$1.82	$2.66	$3.51	$4.35	$5.21	$6.06	$6.87	$7.67	$8.47	$35	4.1
Total for measure, excluding BAU	**$0.93**	**$1.82**	**$2.66**	**$3.51**	**$4.35**	**$5.21**	**$6.06**	**$6.87**	**$7.67**	**$8.47**	$35	4.1

4 Summary of Results

All fuels results

The analysis has shown that 25.1 PJ of energy saving potential exists in the Residential Sector through the application of EEIs with simple payback periods of up to 4 years (excluding savings related to hot water systems, saving potential relying on behavioural changes, and BAU improvements). This relates to 4.7% of the total projected energy use by the Sector at 2014.

For the 6.5 year payback case, the estimated energy saving potential is 50.6 PJ (refer to exclusions above), which relates to 9.4% of the total projected energy consumption by the sector in 2014.

Table 4.1 provides a breakdown of the above energy savings by the application and the results are illustrated in Figure 4.1 (a).

Electricity and gas only results

The analysis has shown that 16.4 PJ of energy saving potential exists in the Residential Sector through the application of EEIs with simple payback periods of up to 4 years (excluding savings related to hot water systems, biomass energy savings, saving potential relying on behavioural changes, and BAU improvements). This relates to 3.1% of the total projected energy use by the Sector at 2014. Electricity comprises 6.5 PJ, equivalent to 39.5% of the total projected energy savings for this case.

For the 6.5 year payback case, the estimated energy saving potential is 31.3 PJ (refer to exclusions above), which relates to 5.8% of the total projected energy consumption by the sector in 2014. The proportion of electricity savings for this case is 41.0% at 12.8PJ

Table 4.1 provides a breakdown of the above energy savings by the application and the results are illustrated in Figure 4.1(b).

Table 4.1- Energy Saving Potential by Application of Energy Efficiency Initiatives
(Figures exclude initiatives related to Hot Water systems and applications, and initiatives which relate to behavioural change. Figures are ex BAU)

<=4 YEAR PAYBACK

Application	All fuels Total (PJ pa)	All fuels % of 2014 Total	Elec/Gas Total (PJ pa)	Elec (PJ pa)	Elec/ Gas % of 2014 Total
Building Shell	0.00	0.0%	0.00	0	0.0%
Heating/Cooling Appliances	16.89	3.1%	8.17	0.10	1.5%
Lighting	2.34	0.4%	2.34	2.34	0.4%
Cooking	3.90	0.7%	3.90	2.16	0.7%
Refrigeration	1.96	0.4%	1.96	1.96	0.4%
Dishwasher	0.00	0.0%	0.00	0.00	0.0%
Clothes Washer	0.00	0.0%	0.00	0.00	0.0%
TOTALS	**25.09**	**4.7%**	**16.38**	**6.56**	**3.1%**

<=6.5 YEAR PAYBACK

Application	All fuels Total (PJ pa)	All fuels % of 2014 Total	Elec/Gas Total (PJ pa)	Elec (PJ pa)	Elec/ Gas % of 2014 Total
Building Shell	16.18	3.0%	10.34	3.83	1.9%
Heating/Cooling Appliances *	23.73	4.4%	10.34	0.10	1.9%
Lighting	2.71	0.5%	2.71	2.71	0.5%
Cooking	3.90	0.7%	3.90	2.16	0.7%
Refrigeration	3.51	0.7%	3.51	3.51	0.7%
Dishwasher	0.29	0.1%	0.29	0.29	0.1%
Clothes Washer	0.24	0.0%	0.24	0.24	0.0%
TOTALS	**50.56**	**9.4%**	**31.33**	**12.83**	**5.8%**

* Note – includes items which show a payback of less than 6.5 years in the all fuels case although it may have a higher payback for the electricity and gas only case

The most significant change noted in Figure 4.1 is the significant impact provided by improvements in Building Shell related initiatives between the 4 year payback scenario and the 6.5 year payback case, providing the bulk of the additional improvements between the 2 cases.

The relativity between the various areas of application is also noted, with the Building Shell and Heating and Cooling appliances being responsible for almost 80% of the total estimated potential (32.0% and 46.9% respectively) for the all-fuels case. In the electricity and gas case, the above two sets of EEIs remain the highest but in this case are responsible for 33.0% each only.

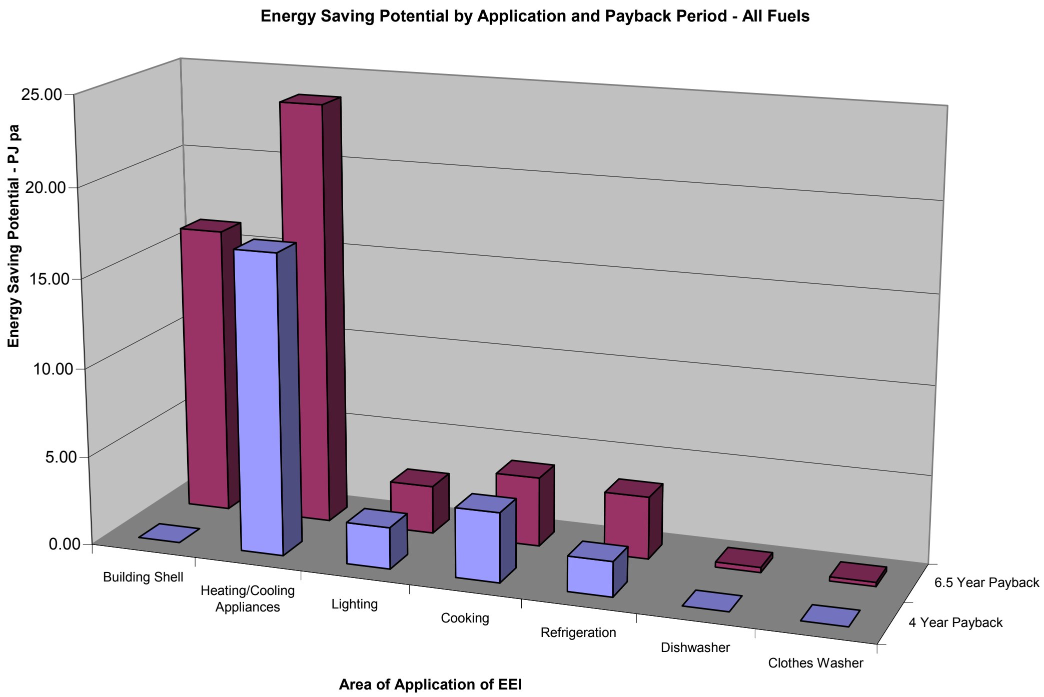

Figure 4.1 (a) – Energy Saving Potential by Application of Energy Efficiency Initiatives (All Fuels) *(Figures exclude initiatives related to Hot Water systems and applications and initiatives which relate to behavioural change. Figures are ex BAU)*

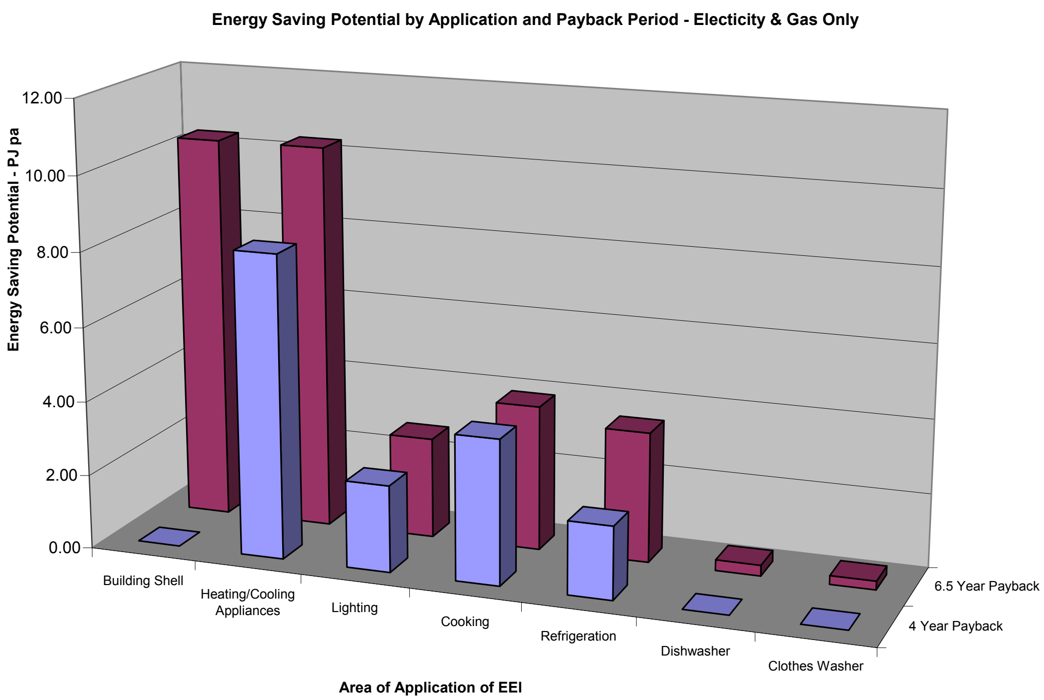

Figure 4.1 (b) – Energy Saving Potential by Application of Energy Efficiency Initiatives – Electricity and Gas Only *(Figures exclude initiatives related to Hot Water systems and applications, biomass related initiatives, and initiatives which relate to behavioural change. Figures are ex BAU)*

4.1 Additionality Affects

Additionality issues cause a reduction in the impact of individual EEIs as a result of other initiatives which have been carried out before or at the same time and which affect the same component of energy use.

In this study, additionality issues only affect the heating and cooling EEIs, as the scope for each of the other initiatives is distinct and separate from others.

Assuming that EEIs are implemented in order of cost-effectiveness, the Heating and Cooling EEIs would be expected to be carried out in the order shown in Table 4.2. This table also shows the additionality factor as calculated for each EEI and the affect on energy savings potential and payback period. The net effect of additionality is to reduce energy saving potential by 5.6% (2.24 PJ pa) and increase the overall payback period from 4.7 years to 5.0 years.

Table 4.2- Impact of Additionality Affect on Energy Saving Potential

Energy Management Measure	Original payback (yrs)	Original Total Energy Saving (PJ pa)	Original Proportion of Saving to Total Consumption	Additionality Factor	Adjusted Saving (PJ pa)	Adjusted Payback (yrs)
Increase VIC new homes from 3.5 stars to 5 stars	n/a	2.43	1.0%	0	2.43	n/a
Improve the efficiency of larger gas and solid fuel burners	1.4	13.89	5.7%	0.99	13.75	1.4
Improve the efficiency of ducted heating & cooling (reduce losses)	3.3	3.00	1.2%	0.99	2.97	3.3
Weatherstripping & Sealing	5.2	7.33	3.0%	0.92	6.75	5.7
Replace the remainder with high efficiency units	6.4	6.84	2.8%	0.96	6.57	6.6
Increase all other States to 5 Stars from 3.5 & 4 resp	6.5	8.84	3.6%	0.86	7.63	7.6
Total - all measures with paybacks < 6.5 years, ex BAU *	**4.7**	**39.91**	**16.37%**	**0.94**	**37.67**	**5.0**

* Note: VIC homes 5 star EEI is not included in the totals as it is part of BAU, but is included in the analysis as it affects the starting quantity of energy use.

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5 References

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2. ABARE, 2003 – Australian Supply and Disposal Tables

3. EMET Consultants Pty Ltd for NSW Ministry of Utilities and Energy, December 2003 – *NSW Electricity Demand Study and Scope for the Application of Electricity Restrictions within the State*

4. Energy Efficient Strategies / AGO et al, July 1999 - Australian Residential Building Sector Greenhouse Gas Emissions 1990–2010

5. ABS - Population and Household Number Projections (ABS 3236.0)

6. ABS – Environmental Issues – People's Views and Practices (ABS 4602.0)

7. EMET/ SEAV, February 2004 – Electricity Demand Reductions related to Efficiency Improvement Measures in the Australian Commercial and Residential Sectors

8. George Wilkenfeld and Associates/SEAV, February 2004 - Energy Labelling and Minimum Energy Performance Standards for Gas Appliances: Economic and Environmental Impacts

9. Armstrong, G., SEAV, *Preliminary Assessment of Demand-Side Energy Efficiency Improvement Potential and Costs,* SEAV, November 2003.

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Appendixes

5.1 Appendix 1 – Key Factors and Appliance Penetration Rates related to EEI Analyses

This Appendix contains a series of factors, appliance penetration rates, assumed efficiency trends and other factors used in the evaluation of the EEIs for the Residential Sector. These are contained in the following Tables:

Table A1.1 - Key Factors in the Development of Heating and Cooling BAU Energy Levels

The following presents the factors used in calculating the effective area of households based on the breakdown of household types (detached and non-detached) and trends in areas per household. Refer to the body of the report for the various sources of this data.

Heating and cooling appliance penetration data are also contained in this table and represent proportions of the total number of households.

Factor		Year 2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	Source
# of Households (‘000)		7,961	8,079	8,191	8,302	8,413	8,525	8,637	8,742	8,846	8,949	ABS(6)
Detached Housing (‘000)		5,413	5,477	5,537	5,596	5,654	5,712	5,769	5,822	5,874	5,924	Extrap from EES(5)
Non-Detached Housing (‘000)		2,547	2,601	2,654	2,707	2,760	2,813	2,867	2,920	2,972	3,025	Extrap from EES(5)
Aver Area – Detached – m^2		140	142	143	145	146	148	150	151	153	154	Extrap from EES(5)
Aver Area - Non-Detached – m^2		81	83	84	86	88	90	92	94	96	98	Extrap from EES(5)
Heating/Cooling Appliance Penetrations												
Type of appliance												
Heating	Gas	34.1%	34.1%	34.1%	34.2%	34.2%	34.2%	34.2%	34.3%	34.3%	34.3%	ABS(6)
	Electric	31.5%	32.0%	32.4%	32.9%	33.3%	33.8%	34.2%	34.7%	35.1%	35.6%	ABS(6)
	Wood	11.8%	11.1%	10.5%	9.8%	9.2%	8.5%	7.9%	7.2%	6.6%	5.9%	ABS(6)
	Other	3.5%	3.5%	3.4%	3.4%	3.2%	3.1%	3.1%	3.0%	2.9%	2.8%	ABS(6)
Cooling	Electric	49.1%	49.6%	50.2%	50.8%	51.4%	52.0%	52.6%	53.1%	53.7%	54.3%	ABS(6)
Proportion of R/C Heating		11.8%	12.1%	12.4%	12.8%	13.1%	13.5%	13.8%	14.1%	14.5%	14.8%	ABS(6)

Table A1.2 – Distribution of Housing Stock by Climate and State (source EES[5])

The EES 1999[5] study provided a simplification of the climatic distribution of the residential sector housing stock by State as a function of 5 primary Climatic Zones. The Zones were based on the NatHERS zones of Canberra (Can24), Melbourne (Mel21), West Sydney (Wys28), Brisbane (Bris10) and Townsville (Twn05). This table presents the factors applicable to each State.

Climatic Zone (NatHERS weather file)	Proportion of Housing Stock by State (%)							
	NSW	VIC	QLD	SA	WA	TAS	NT	ACT
Can24	5	8	0	0	0	99.3	0	100
Mel21	0	82.5	0	7	0	0.7	0	0
Wys28	91	9.5	5	91	89	0	0	0
Bris10	4	0	80.5	2	8	0	19	0
Twn05	0	0	14.5	0	3	0	81	0
TOTAL	100	100	100	100	100	100	100	100

Table A1.3 – Distribution of Lighting Sources and Average Efficiency Factor

This table contains the projected distribution of lighting sources, which is used to calculate the tabulated energy efficiency factor for lighting systems within the residential sector.

The distribution of light sources is an extrapolation of data provided by EES[5]. The average efficiency factor is a calculated index which is used to evaluate changes in overall system efficiencies. This factor does not relate directly to energy efficiency of any one lighting source.

Year	Incandescent	Quartz Halogen	Fluorescent	Combined Efficiency Factor*
2005	58.10%	23.40%	18.40%	0.394
2006	57.50%	23.80%	18.80%	0.398
2007	56.90%	24.10%	19.10%	0.401
2008	56.30%	24.40%	19.40%	0.404
2009	55.60%	24.70%	19.70%	0.407
2010	55.00%	25.00%	20.00%	0.410
2011	54.37%	25.34%	20.34%	0.414
2012	53.74%	25.66%	20.66%	0.417
2013	53.11%	25.98%	20.98%	0.420
2014	52.49%	26.30%	21.30%	0.423

*Note: *Weighted average efficiency index for relative adjustment only. Not specific efficiency.*

Table A1.4 – Trends in the Distribution of Refrigeration Appliances and Energy Use of New Appliances

Number of refrigeration appliances per household (Refrigerators and Freezers) have been extrapolated from ABS[(6)] data. Trends in energy use by type of appliance have been extracted from MEPS performance evaluation models and assume a progressive improvement in performance to a level of 80% of MEPS. The performance level applicable to the year 1999 has been selected as representing the existing stock.

	Numbers per Household		Annual Energy Use of New Appliances kWh pa (80% of MEPS)		Annual Energy Use Improvement over MEPS (kWh pa)	
Year	Refrigerators	Freezers	Refrigerators	Freezers	Refrigerators	Freezers
2005	1.32	0.35	434	406	23	21
2006	1.33	0.34	411	384	46	43
2007	1.34	0.33	389	363	69	64
2008	1.34	0.33	366	342	91	85
2009	1.35	0.32	366	342	91	85
2010	1.36	0.31	366	342	91	85
2011	1.37	0.30	366	342	91	85
2012	1.37	0.29	366	342	91	85
2013	1.38	0.28	366	342	91	85
2014	1.39	0.27	366	342	91	85
Existing Stock Assumed annual consumption as at 2005			651	542	N/A	N/A

Table A1.5 – Trends in the Distribution of Dishwashers and Clothes Washers

The data presented in this table has been extrapolated from ABS[(6)] data and are expressed as percentages of household penetration.

	Percentage of Households with Appliance	
Year	Dishwasher	Clothes Washer
2005	37.8	95.5
2006	39.0	95.6
2007	40.2	95.8
2008	41.4	95.9
2009	42.5	96.0
2010	43.7	96.1
2011	44.9	96.3
2012	46.1	96.4
2013	47.3	96.5
2014	48.4	96.6

Source – extrapolated from ABS figures