

# *Residential Energy Baseline Study: New Zealand*

*Prepared for*

*Department of Industry and Science on behalf of the  
trans-Tasman Equipment Energy Efficiency (E3) programme*

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### *Basis of EnergyConsult Work*

The work of EnergyConsult in connection with this assignment has been reliant on information and analyses supplied by third parties and the Department of Industry and Science. We have performed research and analysis using this data and publicly available information drawn from a wide range of information services, output of analyses conducted by third parties, and other information which was available to use within the timeframe specified for the preparation of the report. This data was used in order to provide the Department of Industry and Science with analysis which may be relevant to the requirements of the Department of Industry and Science. The analysis also relies on a number of assumptions, both stated and unstated in the report, which are in turn based on our analysis of third party information.

EnergyConsult has not independently verified, nor can we accept any responsibility or liability for independently verifying, any of the information on which our work is based, and nor do we make any representation as to the accuracy or completeness of the information which has been used in our analysis. We accept no liability for any loss or damage which may result from the Department of Industry and Science reliance on any research, analyses or information so supplied, nor from our report, research and analyses based on this information.

## *Executive Summary*

The Department of the Industry and Science (the Department), on behalf of the trans-Tasman Equipment Energy Efficiency (E3) programme, commissioned EnergyConsult to undertake an update of the Residential Baseline Study (RBS), a study into energy use in the Australian and New Zealand Residential Sectors which was previously undertaken in 1999 and 2008. The study was extended to include both Australia and New Zealand and to cover the period 2010 to 2030. The current report only focuses on New Zealand and a separate report has been prepared for Australia.

### *Objectives and Limitations*

The prime objectives for the RBS were to develop a model of energy consumption that covers all categories of residential appliances/equipment and that provides projections of energy consumption, and related greenhouse gas emissions, until 2030. The study examined energy use in total, by end-use and by fuel. It also examined and modelled potential maximum residential electricity peak demand during extreme weather events. The RBS model was designed so Department and E3 users can input appliance, building and energy data as this becomes available, and be able to alter modelling factors in order to undertake policy research.

The key limitations of the RBS modelling and report are due to gaps and limitations in the data/information concerning residential appliances and equipment and their use, which require the need to make assumptions or estimations to address these gaps. For the modelling of projections of future energy use, such projections are largely based on existing product trends and current usage behaviour but in some cases further assumptions had to be made. For example, a conservative assumption is used that only current regulatory settings will impact on a product's efficiency, i.e. current Minimum Energy Performance Standards (MEPS) and any other efficiency improvements are based on past trends. Another key assumption is that appliance usage will remain unchanged, unless existing trends clearly indicate otherwise.

There are further limitations regarding the modelling of peak power demand as there is less known about the usage and operation of appliances and equipment during extreme weather events, when peak residential power demand occurs. This meant additional assumptions were required to fill data gaps.

### *Approach*

This study is an attempt to model total energy use and demand from thousands of individual pieces of data on the hundreds of different types and models of residential appliances and equipment installed in Australian and New Zealand homes. The modelling tool, the RBS model, is a bottom-up, end-use energy model of the residential sector in Australia and New Zealand. The resulting RBS modelling enables the contribution of

individual end-uses, product groups and products to national energy use to be examined and understood.

The RBS model incorporates data from a wide variety of sources and takes into account the following major factors:

- Sales and stock of all residential appliances
- The energy usage, demand and efficiency of all appliances, which varies by appliance type, technology, size and year sold
- Usage patterns and user behaviour regarding all appliance use, varied by locality where relevant
- Building type, insulation and thermal efficiency varied by locality and over time
- The impact of climate on space conditioning requirements and usage
- The impact of locality on PV generation.

The RBS modelling used a consistent engineering algorithm and calculation methodology that focuses on determining the Unit Energy Consumption and Unit Energy Demand in each year for all of the 129 residential products modelled. This approach allows data on product efficiency, sales and stock over time to be separately incorporated into the model, as well as projections of these factors for future years to be separately developed, assessed and incorporated into the model. The result is that the RBS model is based on a consistent methodology which permits the examination of the drivers of energy and demand trends.

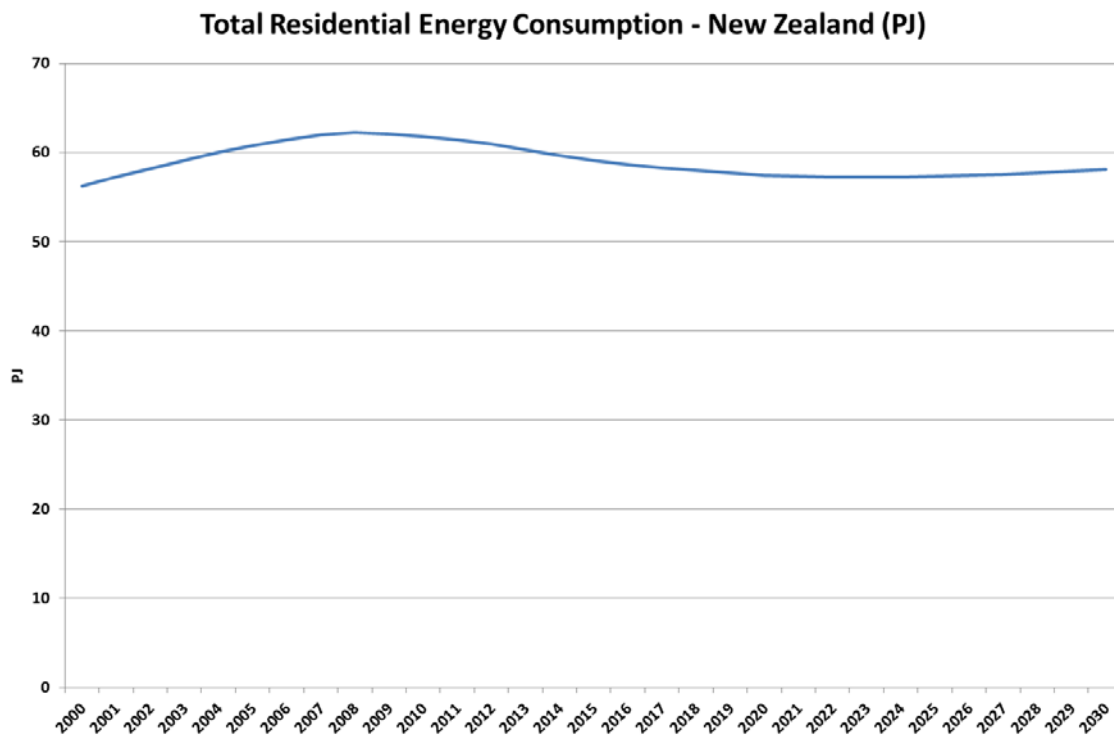
The potential impacts of improvements in building shell efficiency over time were also incorporated into the RBS model. Using existing AccuRate research, and research conducted specifically for this study, estimates of the average building shell efficiency and space conditioning energy requirements for all dwellings in each year of the study period covered by the RBS (i.e. 2000-2030) were determined. These estimates were then used to modify the engineering algorithm (i.e. product information based) estimates of space conditioning energy consumption and demand.

## *National Results*

The most important result is that the current study predicts that national residential energy consumption, after peaking at 62 petajoules (PJ) in 2008, will decrease until 2020 after which consumption remains relatively stable until 2030. Current consumption is 60 PJ in 2014.<sup>1</sup> This trend is conservative in that the model does not anticipate further energy efficiency regulatory requirements or new energy efficiency programs being introduced, unless the regulation has already been announced.

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<sup>1</sup> Note: All results are reporting gross energy consumption or gross demand, excluding the impacts of PV generation, which is reported separately



This decline in total consumption and then stable consumption is a consumption trend that differs from the decades of growth seen leading up to 2008. However, the RBS results are consistent with most trends in the measurement of actual total residential energy consumption over the last few years. Declines in the use of the main energy sources, i.e. electricity and wood which form 87% of all residential energy use, have been reported by the Ministry of Business, Innovation and Employment (MBIE 2014).

As will be further discussed later in this report, the main reason for the rises and falls in total energy consumption over the study period is changes in energy use per dwelling. Average energy use per dwelling, has been falling since 2004 and is expected to continue to decline to 2030, based on projected trends. Since 2008 the saving in energy due to the decreased use per dwelling has exceeded the growth in energy use due to increasing numbers of dwellings, so there is a net reduction in total energy use. Later in the 2020s, the increased energy use due to increasing housing numbers is expected to exceed the savings in energy from decreased use per dwelling, so total energy use is expected to start to slowly grow again. This increase in the 2020s follows from the model making the conservative assumption that no new regulatory changes will occur to drive further significant energy efficiency improvements.

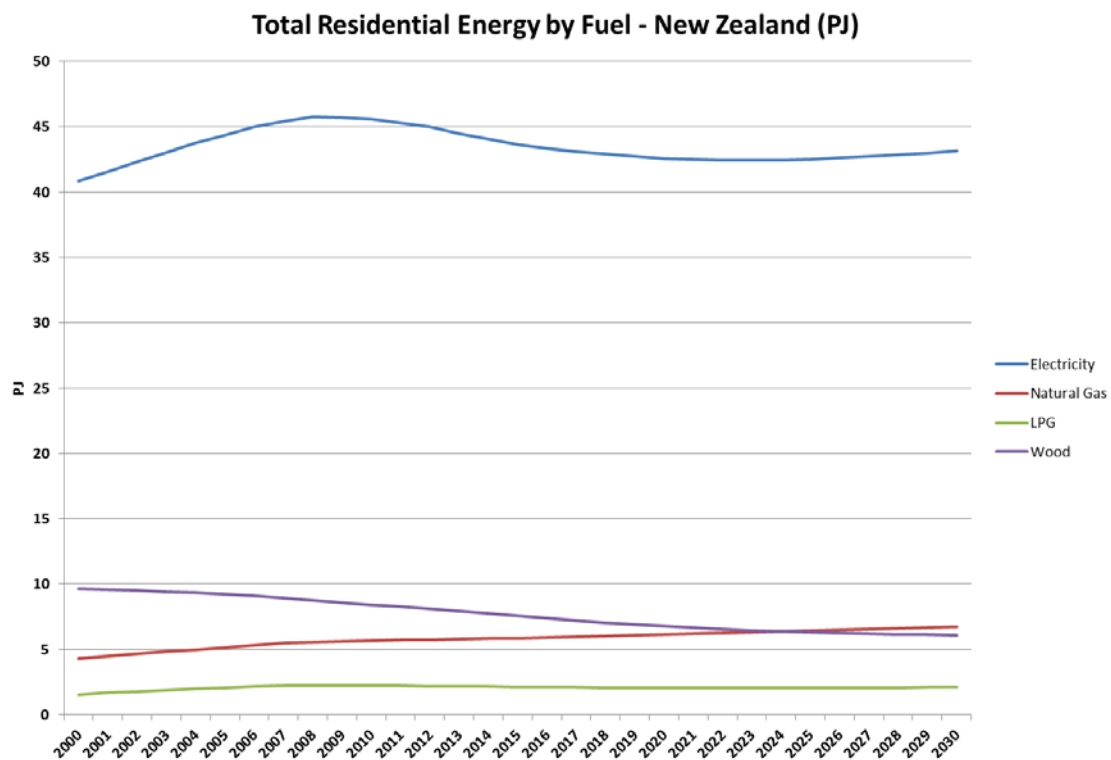
The decrease in energy use per dwelling is principally due to improvements in space conditioning, water heating and lighting appliance energy efficiency, combined with fuel switching in space conditioning, which are further discussed in this report.

These energy usage trends have led to greenhouse emissions rising rapidly between 2000 until the mid-2000s, peaking, and then declining from 2008. Greenhouse gas emissions

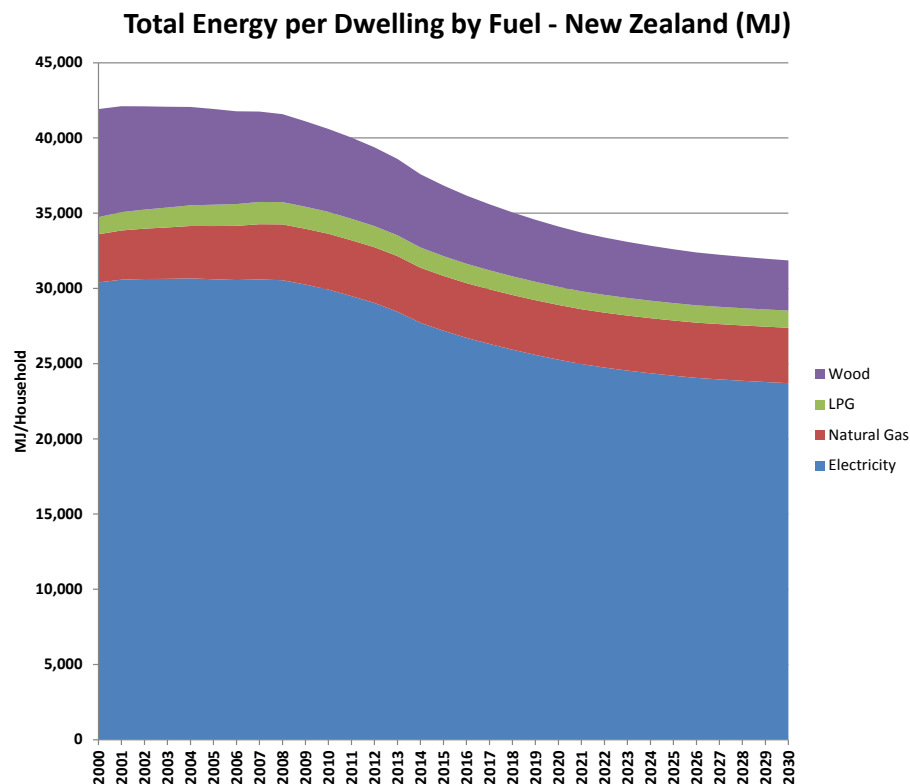


continue to decline throughout the study period, even though energy use stabilises in the 2020s, mainly due to the forecast decline in the emissions intensity of electricity.

Broken down by fuel type, the national results show usage trends differing by fuel, as shown below. Electricity is the dominant form of energy used, followed by wood. The use of electricity and wood are declining, with wood use expected to continue to decline but electricity use stabilises and starts to slightly increase post 2025. Natural gas and Liquid Petroleum Gas (LPG) use are increasing slowly.

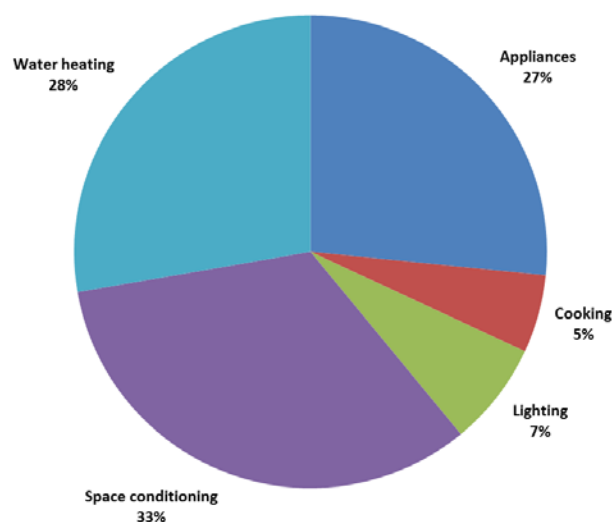


The main driver of the trend towards decreasing or stable total residential energy use is the declining total energy use per dwelling since 2004, which in turn is driven by declining electricity and wood use per dwelling, as shown below.

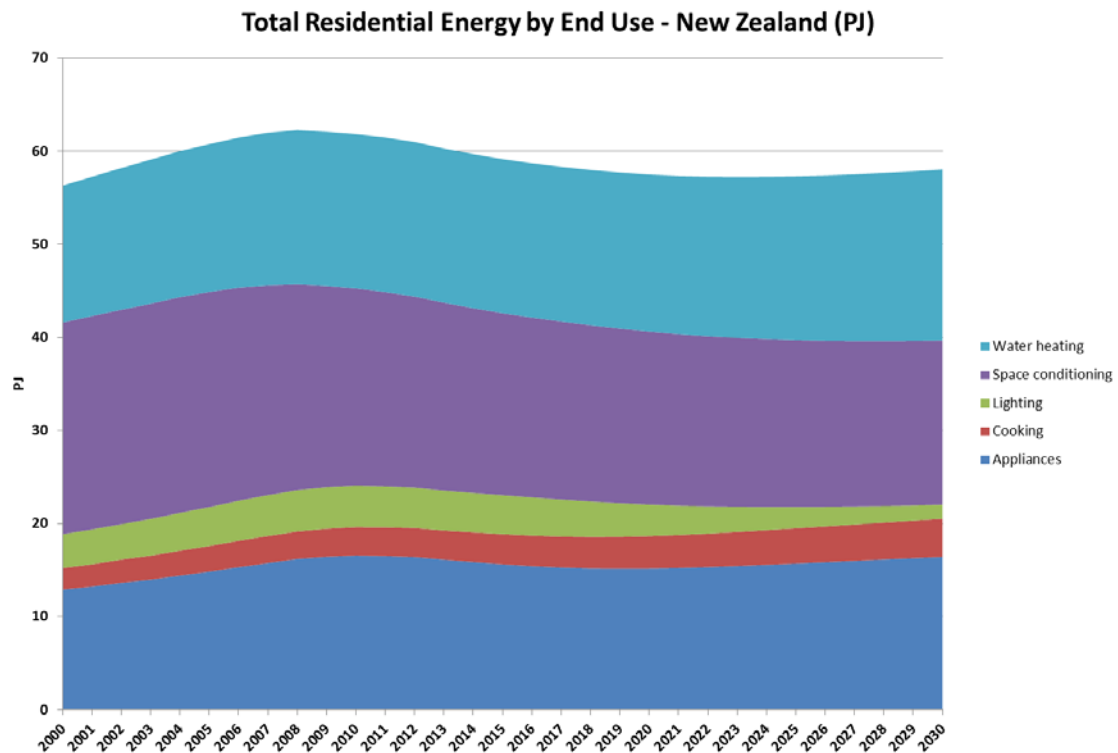


In terms of the contribution of the different energy end-uses to overall residential consumption, space conditioning is the dominant end-use, followed by water heating and appliances. Lighting and cooking are minor energy users.

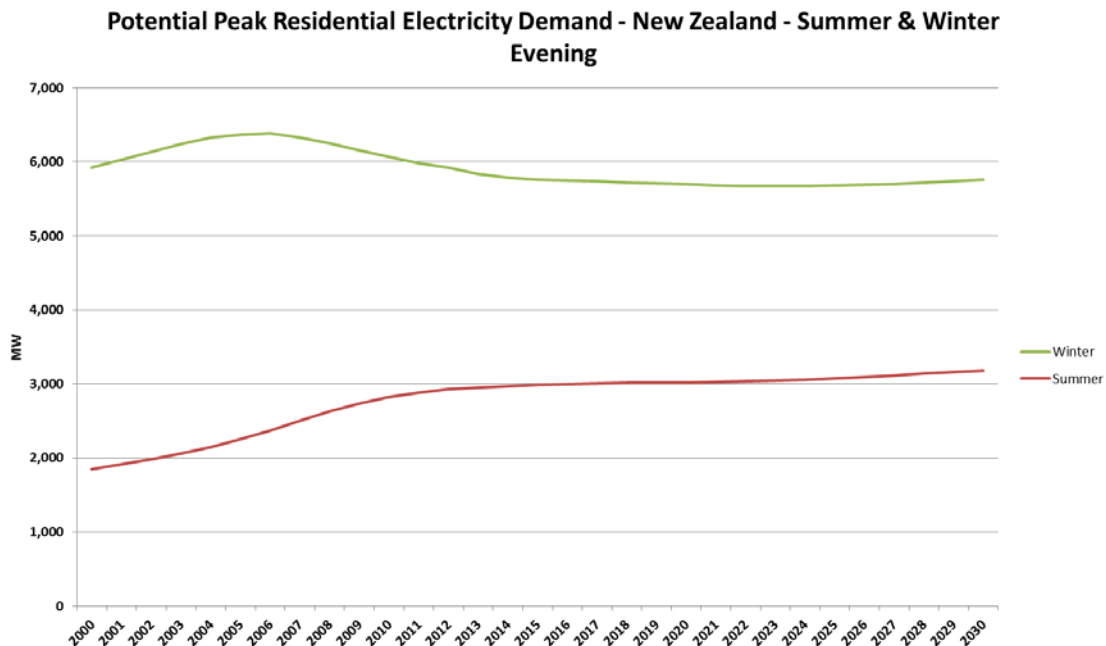
**Share of Total Residential Energy by End Use - NZ - 2014**



There are also changes in the contribution of different end-uses over time. The RBS projections of total residential energy use by both space conditioning and lighting decline through to 2030, but water heating and cooking energy use increases. Appliance energy use is in decline but should start to increase from 2020.



Potential maximum peak demand was calculated for an extreme<sup>2</sup> summer evening and an extreme winter evening. The results are illustrated in the chart below. The trend in winter peak demand is similar to that of total energy consumption, rapidly rising in the 2000s, peaking in the mid-2000s and then declining before stabilising in the 2020s. Analysis shows the main driver of this trend is the changes in space conditioning demand over time.



The key driver in its ongoing growth in the summer peak is the steadily increasing influence of space conditioning, due to increasing penetration of air conditioners (i.e. heat pumps) which potentially could be used extensively during extremely hot weather. However, it must be remembered that this is the potential demand if extreme weather led to almost all available air conditioners being used simultaneously for cooling during an evening, which is unlikely given New Zealand's climate.

### *Energy Use by End Use*

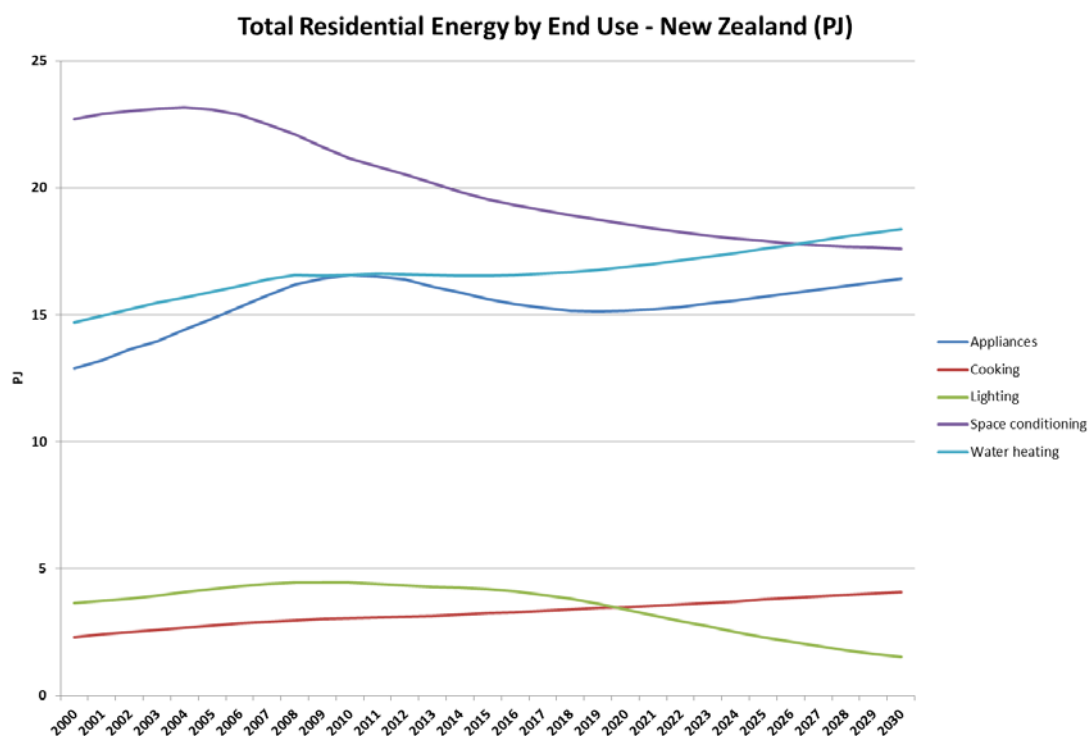
The trend lines for energy consumption by end-use in the chart below show both the contribution of each end-use to the overall energy consumption and how energy use by end-use is changing. This chart shows:

- Space conditioning energy use has been in decline since 2004 and is expected to continue to decline throughout the projection period. Improvements in the energy efficiency of products is a major contributor to this decline, and the trend for

<sup>2</sup> What constitutes an extreme summer or winter evening will vary with locality, but they are the evenings when the maximum proportion of dwellings are operating their space conditioning and coincide with very hot or cold weather.

householders to use more efficient air conditioners for heating, instead of electric resistive heaters, gas non-ducted heaters or wood heaters, is adding to the decline.

- Water heating energy use has been stable since 2008, but is expected to start to increase in 2018. This is due to an increase in natural gas and LPG use, largely caused by the growth in the use of instantaneous gas water heaters.
- Appliance energy use has been declining since 2010 but is expected to start to increase from 2022. Improvements in the energy efficiency of appliance products, especially of televisions, have been the main driver of the recent decline for appliance energy use. However, unless new improvements in appliance energy efficiency occur, which the model conservatively assumes will not occur, increasing appliance numbers will lead to increases in total appliance energy use in the 2020s.
- Lighting energy use has been in decline since 2010 and is expected to continue to decline throughout the projection period. Improvements in the overall energy efficiency of the mix of lighting technologies used in the home are the major contributor to the decline in the energy use of lighting products. Householders are changing from using inefficient incandescent lamps to more efficient compact fluorescent lamps and halogens, and are expected to increasingly use even more efficient light emitting diode lamps in the future.
- Cooking energy use has been increasing for fifteen years and projections indicate it will to continue to do so, but at a relatively low rate of increase driven by increasing dwelling numbers, hence cooking appliance numbers.

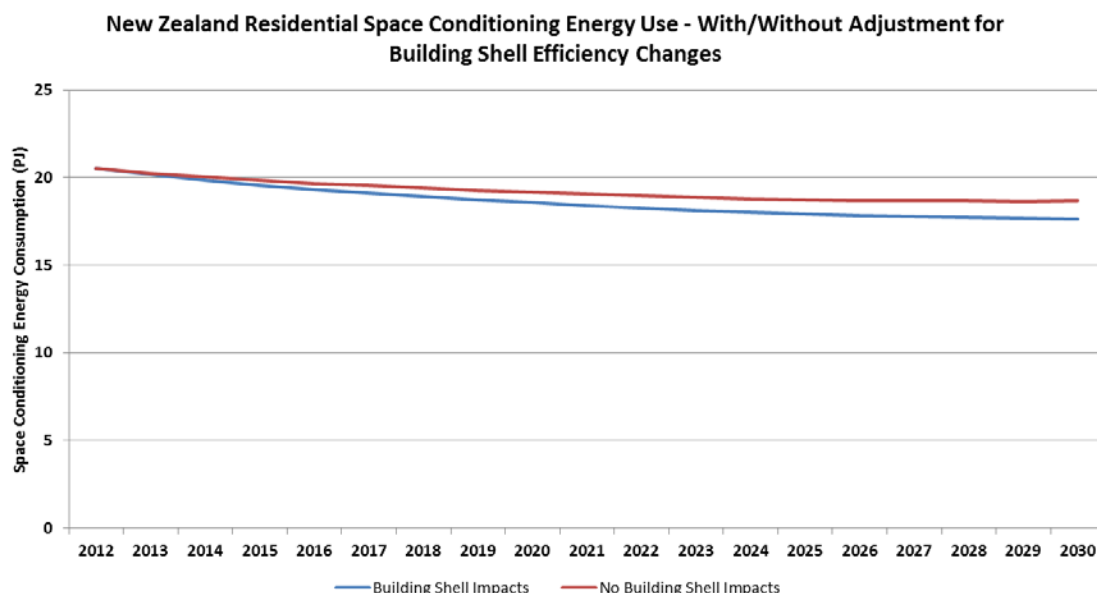


## Impact of Building Shell Efficiency Improvements

The RBS model was developed so the impact of residential building shell efficiency improvements on space conditioning energy use could be examined. AccuRate based assessments of the average building shell efficiency of dwellings in each year, in six New Zealand climate zones were undertaken for the RBS by Sustainability House, and input into the RBS model. The changes in average building shell efficiency compared to a base year were then used to calculate the potential impact of building shell changes on space conditioning energy use.

The only comprehensive study of whether AccuRate measurements of building shell efficiency actually correspond to 'real life' energy use was a CSIRO study (Ambrose et al, 2013), of the energy use in 414 Australian homes in Adelaide, Melbourne and Brisbane. The results of this study showed that improvements in the building shell efficiency of dwellings, as measured by AccuRate, did not relate to savings in space conditioning energy use in Brisbane or Adelaide, and only related to heating energy use in Melbourne homes. This strongly suggests AccuRate based measurements of building shell efficiency improvements are only clearly applicable to space heating energy use in colder climates.

Consequently the RBS model settings were adjusted so the impact of building shell efficiency improvements on space conditioning energy use would only be included in the energy modelling for the heating of dwellings in New Zealand. The resulting modelled national space conditioning energy use, with and without the impacts of adjustments for improvements in building shell efficiency, is shown below. The impacts are modelled from a base year of 2012, when the best available usage data was available.



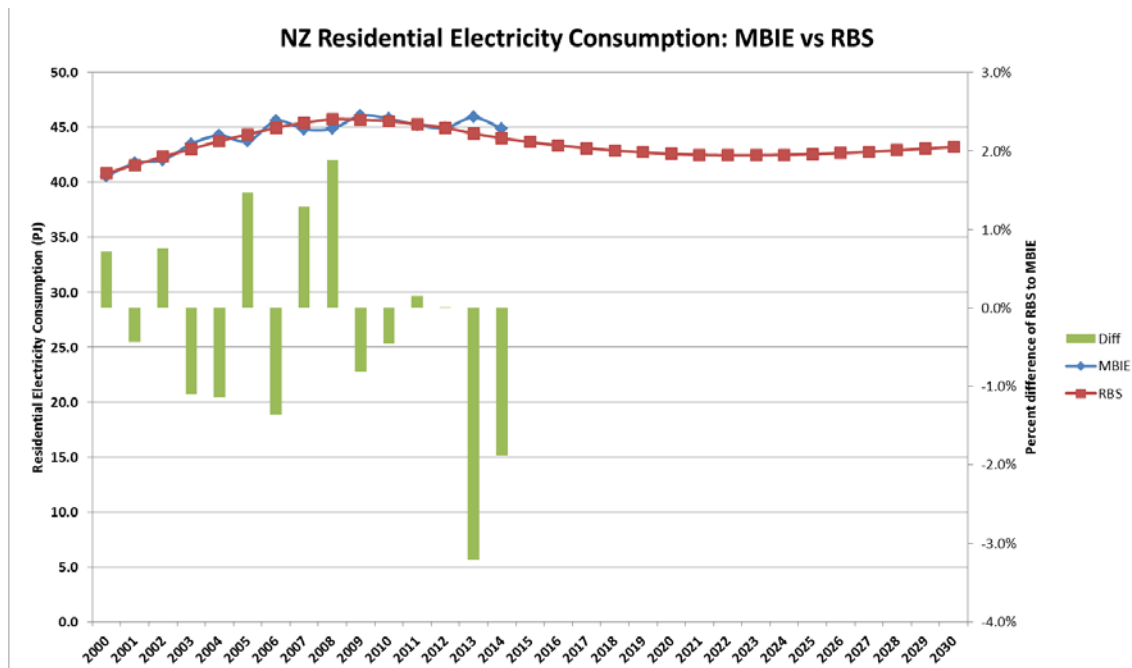
These results suggest as much as 1 PJ of energy, 6% of total consumption, may be saved in 2030 from projected improvements in the building shell efficiency of the average dwelling in 2012 compared to the efficiency of that in 2030. The impact of these building

shell improvements on peak demand was also modelled but indicated these might result in an impact of only 2% on winter peak demand by 2030. Due to it being probable that heat pumps will operate at maximum power even in dwellings with improved building shell energy efficiency, the impact would probably be even less.

### *RBS Model Accuracy and Comparison to Top-down Data*

The results of the RBS modelling were compared to other sources of estimates of residential energy use from the Ministry of Business, Innovation and Employment (MBIE 2014) (MED 2012).

The RBS and MBIE estimates of national residential electricity use were compared for the period 2004-2013, in Figure 32. For all the years compared there was an acceptable difference of no more than 3% in the estimates, and for most years a difference of 2% or less was found. In addition, the MBIE figures for recent years support the RBS's identification of a downward trend in energy consumption. This suggests the RBS is an accurate model of electricity use, which is important as this forms 74% of the total residential energy use.



Comparisons were also undertaken for the top-down data for the other residential fuels, with mixed results:

- Wood use: comparison of RBS model outputs and MBIE estimates of use showed a maximum of 16% variation, and much less in recent years. This is acceptable given the inaccuracies in estimating wood energy use and the extent annual weather variations will affect wood use.

- Natural gas: The MBIE estimates of use and RBS model outputs varied by less than 15% since 2007, which is an acceptable variation given the extent to which annual weather variations will affect natural gas use. However, there was a much higher variation of up to 40% for results for 2000-2006. This may be due to a significant gas price change in 2007 which lead to a major change in behaviour regarding gas usage. As the RBS model is based on more recent usage behaviour, this may have resulted in the model under-estimating natural gas consumption pre 2007 when usage behaviour was different.
- LPG use: comparison of RBS model outputs and MED estimates of use showed a maximum of 16% variation, which also appears acceptable given the extent to which annual weather variations will affect LPG use.

## *Conclusion*

The RBS modelling has produced extensive insights into the current and future New Zealand residential energy consumption trends and the drivers of these trends. The RBS predicts a decline in total national energy consumption before consumption stabilises in the 2020s. This is a significant divergence from the rapid increases in consumption witnessed during the 2000s, but decline in consumption is consistent with recent national residential energy data and with trends in Australia.

The current decline in total energy use is being driven by a decline in energy use per dwelling and that this trend is expected to continue throughout the study period. The major contributor to this trend is a decline in the energy used per dwelling for space conditioning, driven by households moving from using wood burners and electric resistive heaters to more energy efficient air conditioners/ heat pumps. Improvements in the energy efficiency of appliances, especially televisions, and the greater use of more energy efficient forms of lighting are also decreasing the amount of energy used on appliances and lighting per household, and contributing to the decline in energy use per dwelling.

Since 2008 the rate of decline in energy use per dwelling has exceeded the rate of increase in dwelling numbers, so total energy use has declined. In the 2020s the projections indicate the rate of decline in energy use per dwelling reduces, partially because the recent improvements in the energy efficiency of new products by then will have flowed through into the product stock in homes and will start to have a declining influence. The result is that increasing dwelling numbers in the 2020's will again begin to drive an increase in the total residential energy use. However, these projections follow from the model conservatively assuming that no future regulatory changes will occur to drive further significant energy efficiency improvements. If the introduction of effective initiatives to further improve residential product efficiency were to occur, these might lead to a continuing reduction in total residential energy consumption throughout the study period.



## *1. Introduction and Background*

The Department of Industry and Science, on behalf of the trans-Tasman E3 programme has commissioned EnergyConsult to undertake an update of the Residential Baseline Study (RBS), a study into energy use in the Australian and New Zealand Residential Sectors. A similar study 'Energy Use in the Australian Residential Sector' covering just Australia was last published in 2008 and prior to that in 1999. The Department now wishes to extend the study to both Australia and New Zealand. This current report only focuses on New Zealand. A separate report has been prepared for Australia.

### *Objectives and Scope*

There were a number of objectives for the RBS but prime requirements for the study include:

- Developing a model of energy consumption that covers all categories of residential appliances/equipment and that enables projections of energy consumption, and related greenhouse gas emissions, until 2030
- Modelling potential residential electricity peak demand during extreme weather events
- Ensuring that alterations to appliance efficiency can be undertaken separately to building shell efficiency, so the impact of policy changes on building efficiency can be undertaken with the model
- Provide facilities so policy makers can input appliance, building and energy data as this becomes available, and be able to alter modelling factors in order to undertake policy research.

The model and report are to encompass:

- In New Zealand, the building classifications of separate dwellings, and two or more dwellings joined together
- Residential energy use of electricity, natural gas, liquid petroleum gas, and wood, and solar photovoltaic electricity generation
- The six grouped climate zones defined in the project Request for Quotation
- Results and modelling at the national level.

The report describes the research, modelling and results obtained from undertaking the Residential Baseline Study. It covers the following topics:

- RBS Methodology chosen, the underlying calculation approaches and modelling architecture
- Overall national results, the total energy consumed, the main end-uses contributing to that consumption, and peak demand
- Details of energy consumption at the end-use level and the main drivers of such consumption

- Data sources and the data processing used to populate the RBS model.

The key outputs of this study are the current report and provision of the RBS model which was used to provide the outputs required to prepare this report.

## *Limitations*

The key limitations of the RBS modelling and report are due to data/information limitations concerning residential appliances and equipment and their use, and due to the assumptions required when making projections about future residential energy use.

Generally there is considerable information available on the numbers, nature, characteristics and use of residential appliances and equipment, but there are gaps and limitations on the information available for some products which resulted in the need to make assumptions and estimations. The nature of the information used is described in Data Sources, Input Processing and References and also in more detail in the Technical Appendix.

For the modelling of projections of future energy use, such projections are largely based on existing product trends and current usage behaviour but in some cases further assumptions had to be made. For example, a conservative assumption is used that only current regulatory settings will impact on a product's efficiency, i.e. current Minimum Energy Performance Standards (MEPS) and any other efficiency improvements are based on past trends. Another assumption is that appliance use will remain unchanged, unless existing trends clearly indicate otherwise.

There is less known about the use of appliances and equipment during extreme weather events, when peak residential power demand occurs, or about how space conditioning equipment operates during extreme weather events. This limitation on the data available means additional assumptions were required to fill data gaps and there is a lower level of confidence in the peak demand results of the RBS.

## *Project Team and Acknowledgements*

This report was prepared by Paul Ryan and Murray Pavia of EnergyConsult Pty Ltd.

The authors would like to acknowledge the contribution of Glenn Seymour of Strategic Energy Ltd (N.Z.), who assisted in researching and analysing New Zealand residential appliances and energy use data, and in the reviewing of this report. We would like to thank Richard Collins of Punchline Energy for his analysis and input regarding appliances.

We would also like to acknowledge the contribution of Sustainability House who were commissioned to provide the AccuRate estimates of the space conditioning energy loads of New Zealand housing.

Finally, we would like to thank the Department of Industry and Science, the Energy Efficiency and Conservation Authority, and all the people whose research we have drawn on to prepare this report and to develop the RBS model.

## *2. Methodology*

### *Introduction*

This report presents the main output and results of the RBS model developed for this study. The RBS model is a bottom-up, end-use energy model of the residential sector in Australia and New Zealand. This chapter describes the methods and approach used to estimate the energy use and demand of the different residential energy end-uses in the RBS model, and the overall architecture of the RBS model.

The RBS model incorporates data from a wide variety of sources and takes into account the following major factors:

- Sales and stock of all residential appliances
- The energy usage, demand and efficiency of all appliances, which varies by appliance type, technology, size and year sold
- Usage patterns and user behaviour regarding all appliance use, varied by locality where relevant
- Building type, insulation and thermal efficiency varied by locality and over time
- The impact of climate on space conditioning requirements and usage
- The impact of locality on PV generation.

In total 129 different appliances and products were modelled. The main aspects of the RBS modelling methodology is presented in the following sections:

- Underlying Method
- Space Conditioning Method
- Peak Load Method
- Model Architecture.

### *Underlying Method*

The underlying method on which the residential energy end-use model and study is based is classified as a bottom-up engineering model (Yuning Ou, 2012). It involves calculating the energy end-use consumption at the household end-use level and aggregating these consumptions to estimate the total locality or national consumption.<sup>3</sup> The end-use modelling approach involves estimating the energy use at the appliance (unit) level and

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<sup>3</sup> It should be noted that this approach will provide reasonable estimates of average consumption levels across the population of all dwellings but is not intended to be used as an estimate of the energy use of any specific, individual dwelling, as the consumption of individual dwellings will vary considerably.

then aggregating the energy use across all appliances and households to get the total energy use.

This approach is summarised in the calculation that for each energy end use:

$$\text{Annual Energy Consumed (AEC)} = \text{Stock Numbers} * \text{Unit Energy Consumption (UEC)}.$$

Likewise for energy demand in principle:

$$\text{Total Power Demand} = \text{Stock Numbers} * \text{Unit Power Demand (UPD)}^4.$$

The RBS model determines total energy consumed or demanded through the use of a Stock Model, and through the Calculation of Energy Impacts, both aspects of the model that are described below.

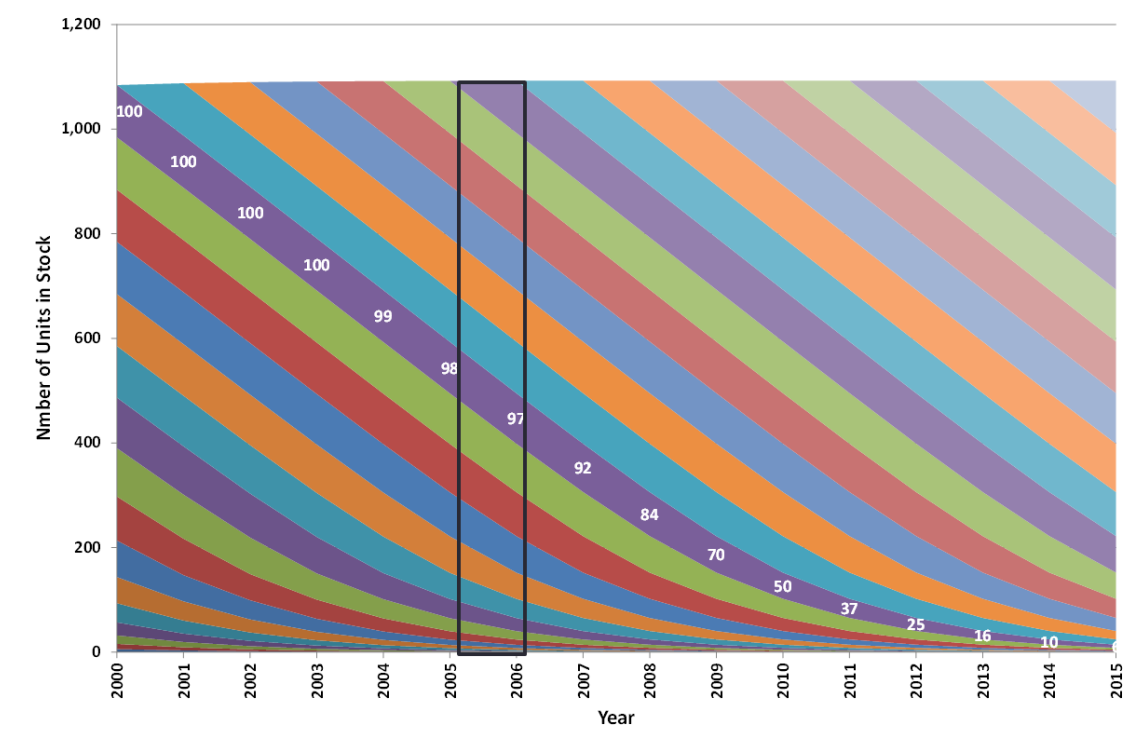
### ***Stock Model***

The energy consumption and power demand of particular appliance and equipment products are calculated using the characteristics of the products obtained from stock models. The stock models are effectively databases that keep a running tally of the number of each product in the residential market in any year, and the average characteristics of each product in any year. The stock in any year will be the sum of all past stock sales, less retirements of equipment.

Figure 1 shows that stock is added to by the sales in each year, and these products remain part of the stock into the future, but gradually reduce in number as they are retired (i.e. shown as going from 100 to 10 over time in the diagram). In any given year, (e.g., the year 2005 shown within the black rectangle in the diagram), the stock will consist of a mixture of the units sold in all previous years. Importantly, this means that equipment characteristics of the stock in any given year will also reflect the equipment characteristics of the stock of all previous year.

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<sup>4</sup> For solar PV systems, similar equations are used for determining energy generation and power demand. These gross amounts are calculated and also combined with other model outputs to determine net generation when required. Impacts on locality of PV arrays on output and seasonal variations will be considered as required.

**Figure 1: Stock Composite of Sales from Previous Years**

The stock models of the RBS model therefore collect data on the required equipment characteristics of the products sold in every year, e.g. the average size, power, and efficiency of the units in any given year. These are the equipment characteristics which are used to calculate average energy consumption and power demand for the product. The stock model then keeps track of the data needed to calculate these average characteristics for each year, based on the characteristics and number of the new equipment sold in the year, as well as that of all previous years.

### ***Calculating Unit Energy Impacts***

The next aspect of the energy modelling is determining the value of the Unit Energy Consumption (UEC) for each end-use in the residential energy end-use model. At its most basic level, UEC is determined by:

$$UEC = \text{Hours of usage} * \text{Unit Energy Input}, \quad \text{or}$$

$$UEC = \text{Hours of usage}^5 * \text{Unit Capacity} * \text{Unit Efficiency}.$$

The energy use of residential equipment can be calculated from these formulae, or from a variation of these formulae for more complex products operating in different modes or

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<sup>5</sup> Operating hours for appliances are hours the appliance is used, and efficiency and capacity are changed in more complex equipment that can operate at part loads.

different measurement and usage metrics (such as wet appliances where UEC is a function of the usage per cycle). For products with multiple modes (e.g., products which have a standby energy consumption element), energy consumption while in operating mode must be separately calculated and added to obtain the total energy consumption in all modes.

Unit Power Demand (UPD) is determined in a similar way to UEC, but the focus is on the proportion of equipment operating at a given time which is mainly derived from their usage profile, and can be expressed as:

$$UPD = \text{Proportion of equipment operating} * \text{Unit Power Input.}$$

Consequently UPD is determined for particular time periods, e.g. time of day or specific peak demand periods during a year. This means information on the usage behaviour for the equipment during the periods of interest, and on the operating power input requirements of the equipment, are essential for determining UPD in any period. The calculation of estimated peak demand is further explained in the section Peak Electricity Demand Method.

## *Space Conditioning Method*

Though there are plenty of complexities and challenges in determining UEC and UPD for all types of appliances, one of the main challenges in the calculations comes when considering space conditioning equipment. For space conditioning equipment the use will vary with the locality, weather, building shell efficiency, building size, zoning, equipment type and occupant usage behaviours, plus through the interaction of these variables. As space conditioning is typically a large driver of energy consumption, some additional complexity is required in the methodology for modelling space conditioning in order to obtain reasonable model accuracy.

There are many methods for estimating space conditioning energy use and demand, but broadly they can be divided into three approaches as identified by Stern (2013):

- measurement/metering based approaches (billing, metered data, hours of use analysis)
- engineering algorithm models
- building thermal modelling.

In Australia and New Zealand there appears to be insufficient data to use measurement/metering based approaches, whereas the building thermal modelling, using AccuRate software developed by CSIRO, and engineering algorithm approaches have both been used to predict energy use and demand.

Thermal modelling involves the modelling of the energy requirements of a building to achieve agreed internal conditions, such as temperature ranges, with the modelling being based on the specific design, construction and orientation of the building. Such



modelling is conducted by programs such as AccuRate and other software tools accredited by the Nationwide House Energy Rating Scheme (NatHERS) (NatHERS 2015) to model the building shell efficiency of residential dwellings and can be used to estimate the heating and cooling energy demanded by the average dwelling in different climate zones to meet specified interior climate conditions. A version of AccuRate has been developed for New Zealand climate zones.

However, on its own, thermal modelling cannot meet the requirements of the RBS to determine the energy used in Australia or New Zealand for space conditioning. Information on the heating/cooling demand (i.e. the output of thermal modelling) needs to be combined with information on what actual space conditioning equipment is installed and on usage behaviour in order to estimate actual energy use. In other words, thermal modelling on its own cannot be used to determine energy use unless it is combined in an engineering algorithm model that incorporates equipment and usage data.

This combined thermal modelling/engineering algorithm approach is what was used in the previous Australian RBS (EES 2008) and a combined approach will again be used in the current RBS, though the details of the approach differ from that used in the previous RBS<sup>6</sup>. The two key components of the current modelling approach are:

- Engineering algorithm modelling that uses data on space conditioning stock numbers, equipment efficiency and usage behaviour to determine the energy use of space conditioning equipment. This modelling is fundamentally the same as that used for all other products in the RBS model and is driven by stock models and calculation of Unit Energy Consumption (UEC) as previously described.
- Thermal modelling used to estimate the potential impact of changes in building shell efficiency over time on space conditioning energy demand. The RBS approach uses a stock model of housing stock to determine the changes in average thermal efficiency over time, with building shell thermal efficiency determined through AccuRate modelling. These changes in estimated energy requirements are then expressed as a 'Usage Adjustment Factor- Building Shell', which was a percentage increase or decrease in estimated energy required compared to a base year<sup>7</sup>. The Usage Adjustment Factor- Building Shell could then be fed into the engineering algorithm component of the model and impacts on energy use directly determined.

The RBS space conditioning method therefore starts with the engineering algorithm approach, hence with Unit Energy Consumption. UEC in its relevant form is stated as:

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<sup>6</sup> Details of the differences with the previous approach and justification of the present method are contained in the Technical Appendix.

<sup>7</sup> The base year was 2012, chosen as it was the year where the most recent and accurate space conditioning usage data was available.



$$UEC = \text{Hours of usage} * \text{Unit Capacity} * \text{Unit Efficiency}$$

There was extensive information available on the Unit Capacity and Unit Efficiency of space conditioning equipment, so the information was obtained to enable this part of the modelling method to be implemented. There was also information available on the operating hours of space conditioning equipment across different types of equipment and States in Australia (e.g. ABS HEC 2014) and on sufficient equipment in New Zealand (BRANZ, 2010) to enable reasonable estimates of New Zealand use to be developed.

A further complication for the model was that Hours of Usage<sup>8</sup> does not directly equate to the number of hours that each unit is operating at its Unit Capacity (registered capacity). Issues affecting the calculation of a relevant Hours of Usage variable include:

- **Duty Cycle:** Most space heating equipment is thermostatically controlled and is automatically switched on and off, or its output up or down, according to the temperature requirements of the space being conditioned. The proportion of the Hours of Usage that the equipment operates depends on its duty cycle<sup>9</sup>.
- **Reverse Cycle Use:** Reverse cycle air conditioning equipment introduces another modelling issue in that the proportion of equipment used for heating and/or cooling varies between climate zones. So only 5% of AC units may be used for heating in Australia's Northern Territory, but 95% may be used for heating in New Zealand.
- **Saturation:** When a dwelling has multiple heaters or air conditioners, they will not all be used equally, with the second and third unit generally being used less. So allowance needs to be made for the saturation of equipment.
- **Housing Occupancy:** Approximately 10% of dwellings are unoccupied at any given time, so use of equipment needs to account for this. This applies to space heating and all other equipment, to varying degrees, too.

To accommodate all of these factors that influence Hours of Use a series of Usage Adjustment Factors (UAF) has been developed and included in the model, which correspond to the factors listed above. So there is a Usage Adjustment Factor- Duty Cycle, a Usage Adjustment Factor- Reverse Cycle, etc. as well as the Usage Adjustment Factor- Building Shell previously mentioned. The total impact of these factors is calculated in the model by multiplying the different factors together to determine the overall *Usage Adjustment Factor*.

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<sup>8</sup> The "hours of usage" is defined as the operating hours, i.e., the time that the user has switched the unit on. When relevant, standby hours will be calculated using the non-operating hours.

<sup>9</sup> For air conditioners/heat pumps, their efficiency is calculated using a seasonal energy efficiency ratio (SEER) value which takes into account variations in duty cycle or partial load use, so duty cycle was not relevant for this equipment.

The *Usage Adjustment Factor* is included in the *UEC* formula and expressed in its revised form as:

$$UEC = \text{Hours of usage} * \text{Usage Adjustment Factor} * \text{Unit Capacity} * \text{Unit Efficiency}$$

The resulting approach means space conditioning energy use can be calculated in a manner consistent with that used for other residential equipment, but the modelling approach can still incorporate all the complexities of space conditioning and the impact of building shell efficiency on its energy use.

## Peak Electricity Demand Method

The peak demand modelling of the RBS is aimed at facilitating the development of measures to address peak load as well as energy efficiency. The model was designed to estimate the trends in potential maximum peak demand during winter evenings and summer evenings, in response to changes in appliance and building shell efficiency over time. Winter and summer evenings were the time period modelled as this is when the residential maximum electricity demand occurs in response to extreme weather events.

The peak load of space conditioning equipment is calculated using a variation of the 'Combined Approach', one of the six peak demand savings estimation approaches identified by the US National Renewable Energy Laboratory, Stern (2013). This approach was defined to estimate the demand savings from energy efficiency actions, but has been varied to simply estimate residential peak demand. The Combined Approach is an engineering algorithm approach to calculating maximum potential demand, with the impact of building shell efficiency also integrated into the model, which is a similar combination of methods to that used for modelling space conditioning energy use.

TecMarket Works (2004, cited Stern, 2013) summarises the relevant engineering algorithm for estimating demand savings from equipment, and a variation of this for estimating demand is presented as follows:

$$kW\text{Demand} = \text{units} * kW/\text{unit} * RLF * DF * CF$$

Where:

- kW Demand = demand from relevant equipment that contributes to the system peak
- Units = units of relevant equipment
- kW/unit = unit demand of equipment (for space conditioning the maximum input power rating)
- RLF = rated load factor (the ratio between non-coincident peak and theoretical peak)

- DF = diversity factor
- CF = coincidence factor.<sup>10</sup>

Implementing the engineering algorithm approach has involved obtaining data on the number and characteristics of all residential equipment potentially operating during systems peaks, and the development of programs to execute the demand equation specified above. The potential contribution of all products modelled is calculated and the results summed to estimate the aggregate potential maximum demand for each year of the study period.

The impact of building shell efficiency changes was integrated into the demand model in a similar way to the manner that was used to integrate building shell efficiency changes into the modelling of space conditioning energy use. Research was conducted using AccuRate modelling to determine how building shell efficiency has changed over time and the resulting changes were then incorporated into the Demand Diversity Factor, via multiplying this by “Demand Adjustment Factor”. The model allows the user the option of using, or not using, the Demand Adjustment Factor when calculating peak demand.

Research (such as that of Home Energy Rating (2007)) suggests there is a strong and quantifiable link between AccuRate theoretical predictions of space conditioning peak demand and NatHERS building star ratings. Likewise, the AccuRate modelling for dwellings with a range of efficiency undertaken for this RBS found a very high degree of correlation between modelled peak energy load in the coldest week and modelled overall annual energy consumption (i.e. 0.92 for detached housing and 0.94 for semi-detached). The results imply that the changes in AccuRate estimated energy efficiency of dwelling stock in a given year, compared to the base year, will strongly correspond to changes in Accurate estimated peak energy loads. Consequently the Usage Adjustment Factor-Building Shell previously discussed, was used as a Demand Adjustment Factor reflecting the impact of building shell changes on estimated power demand. So if the Usage Adjustment Factor- Building Shell for a year indicated energy use was 25% less than the base year energy usage, so energy demand would also be 25% less.

However, it should be noted that there is limited research on the relationship of AccuRate ratings to real peak demand, so results will be reported for the modelling of maximum potential peak demand with and without adjustment for the estimated impact of building efficiency changes. The RBS model can also be used by the Department to model the potential impacts of building efficiency on peak demand over time.

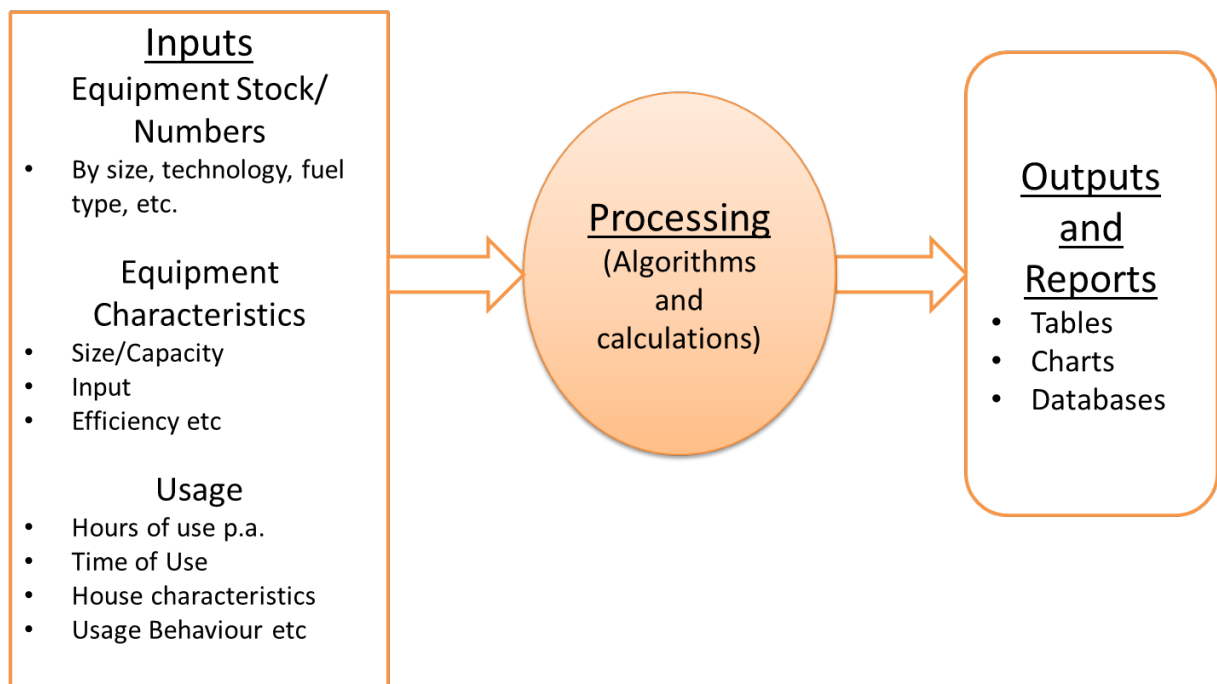
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<sup>10</sup> Further explanation of the calculation of potential maximum demand and of these terms is provided in the Technical Appendix.

## Model Architecture

A new RBS energy end-use model had to be developed to meet the requirements of the current study of residential energy use. An overview of the architecture of the RBS model developed to meet the requirements of the RBS, in terms of the information flows and main processes represented, is shown in Figure 2. Examples of the types of input data are also shown.

**Figure 2: Overview of Model Architecture: Information flows**

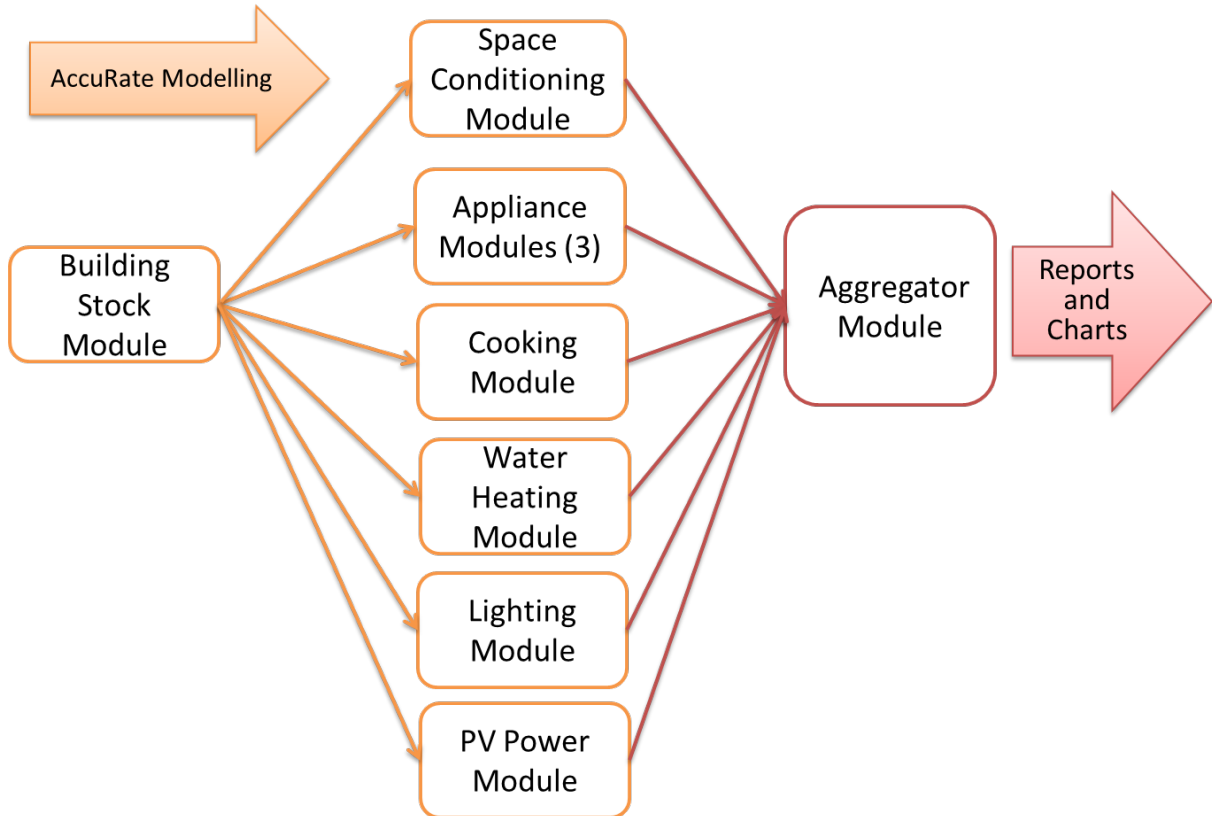


A modular approach was used to develop the model, with each module focused on either an energy end-use or a specific input/output of the model. The main modules of the model are:

- Water heating
- Space conditioning
- Lighting
- Cooking
- Appliances – White Goods
- Appliances – Information Technology and Home Entertainment
- Appliances – Other Equipment
- PV Power
- Building Stock (including thermal demand requirements)
- Aggregator (which includes Peak Demand aggregation).

A schematic of the end-use model is provided in Figure 3 below.

**Figure 3: Schematic of Energy End-use Model Modules and Linkages**



Within each end-use module, calculations were undertaken on each individual product for each year of the study period to determine UEC and UPD, and then these were aggregated by product group, category and end-use as appropriate. The calculations were undertaken on a national level and by relevant climate zone where this was applicable (space conditioning, water heating, PV). The results were then produced as tables and charts within each module, as well as exported to the Aggregator. The nature of the different calculations used is described further in the Technical Appendix.

The model processed data and provided results on the energy end-uses, product categories and product groups that are listed in Table 1.

**Table 1: List of Product Groups included in RBS Model**

End Use	Category	Group
Space conditioning	Combined space heating and space cooling equipment	AC ducted
	Combined space heating and space cooling equipment	AC non-ducted (split and WW)
	Space cooling equipment	Evaporative (mostly central)
	Heating Equipment	Electric resistive
	Heating Equipment	Mains gas non-ducted
	Heating Equipment	Mains gas ducted
	Heating Equipment	LPG non-ducted
	Heating Equipment	Wood Heaters
	Space cooling equipment	Fans
Appliances	White goods	Refrigerators
	White goods	Freezers
	White goods	Dishwashers
	White goods	Clothes washers
	White goods	Clothes dryers
Appliances	Other Equipment	Pool Equipment - Elec
	Other Equipment	Pool Equipment - NG
	Other Equipment	Pumps
	Other Equipment	Battery chargers
	Other Equipment	Miscellaneous
Appliances	Other Equipment	Class 2 (Apartment building) Common Areas
	IT&HE	Television - composite average
	IT&HE	Set-top box - free-to-air
	IT&HE	Set-top box - subscription
	IT&HE	Video players and media recorders
	IT&HE	Home entertainment - other (mostly audio equipment)
	IT&HE	Game consoles
	IT&HE	Computers - desktop
	IT&HE	Computers - laptop
	IT&HE	Monitors (used with desktop computers)
	IT&HE	Wireless/Wired networked device
	IT&HE	Miscellaneous IT equipment
Lighting	Lighting	MV incandescent
	Lighting	MV halogen
	Lighting	ELV halogen
	Lighting	CFL
	Lighting	Linear fluorescent
	Lighting	LED
Cooking	Cooking Products	Uprights

End Use	Category	Group
	Cooking Products	Cooktops
	Cooking Products	Ovens
	Cooking Products	Microwave
Water heating	Hot water heaters	Electric Water - Small
	Hot water heaters	Electric Water - Med/Large
	Hot water heaters	Gas storage (mains)
	Hot water heaters	Gas storage (LPG)
	Hot water heaters	Gas instant (mains)
	Hot water heaters	Gas instant (LPG)
	Hot water heaters	Solar electric
	Hot water heaters	Heat pump
	Hot water heaters	Solar gas
	Hot water heaters	Wood
Generation	PV	PV 2kW
	PV	PV 4kW
	PV	PV 6kW
	PV	PV 10kW
	PV	PV NZ <sup>11</sup>

Note: Groups are further divided into 129 products, which are listed in the Technical Appendix

<sup>11</sup> PV generation systems were not subdivided by size due to the lack of available data and small numbers, so a separate product group (PV NZ) containing all PV sizes was created and used in the New Zealand analysis.

### *3. Overall Results*

#### *Introduction*

Estimates of New Zealand residential energy use and PV generation are presented in this section. These are the top-level results of the RBS modelling and will be presented first at the national level. Results at the end-use level are presented in section 4. National Results by End-use. Detailed results, such as the tables of information that underlie the charts presented, are provided in Excel format in the Output Table sheets which are separate to this report.

The energy consumption estimates reported in the RBS represent the delivered energy to the households. Energy used to deliver, transmit, transport, generate, refine or extract the energy is not considered. The embodied energy used in creating appliances is also not considered. Energy used for transport is also not included, except for a very small amount of electricity used for recharging mobility devices. Greenhouse emissions are also provided (see Residential Greenhouse Emissions).

The PV generation is presented separately to consumption data. This separate presentation is for two reasons. Firstly, so energy consumption trends can be examined independently from any generation effects and secondly because not all electricity generated by residential PV can be assumed to be consumed by the residential sector. This means providing net consumption data, gross energy consumption less PV generation, may be misleading.

All years relating to the RBS outputs in this report are calendar years. The 'study period' is used to refer to the entire period modelled, from 2000 to 2030, while the 'projection period' refers to results for 2015-2030, which rely on projections of product sales, efficiency, etc., while the 'modelled period' refers to period 2000-2014 where results are modelled mostly using actual data on products.

Naturally, the results for the modelled period can be interpreted with a greater level of confidence, as these rely on historic data, while results for the projection period ultimately are based on projections of sales, product efficiency, use etc. and the accuracy of these remains unknown.

It should be noted that there is an absence of accurate and recent data on the penetration of appliances and equipment in New Zealand dwellings, and a lack of current usage data, especially regarding space conditioning. This lack of data reduces the author's confidence regarding the accuracy of the RBS modelling for New Zealand, especially for specific products or end-uses. However, despite this, the RBS appears to be producing total energy use results that are of acceptable accuracy, in that they have a maximum of only 3% variation from top-down energy measurements for electricity, which forms 74% of the total energy use (See Electricity Use Comparisons.)



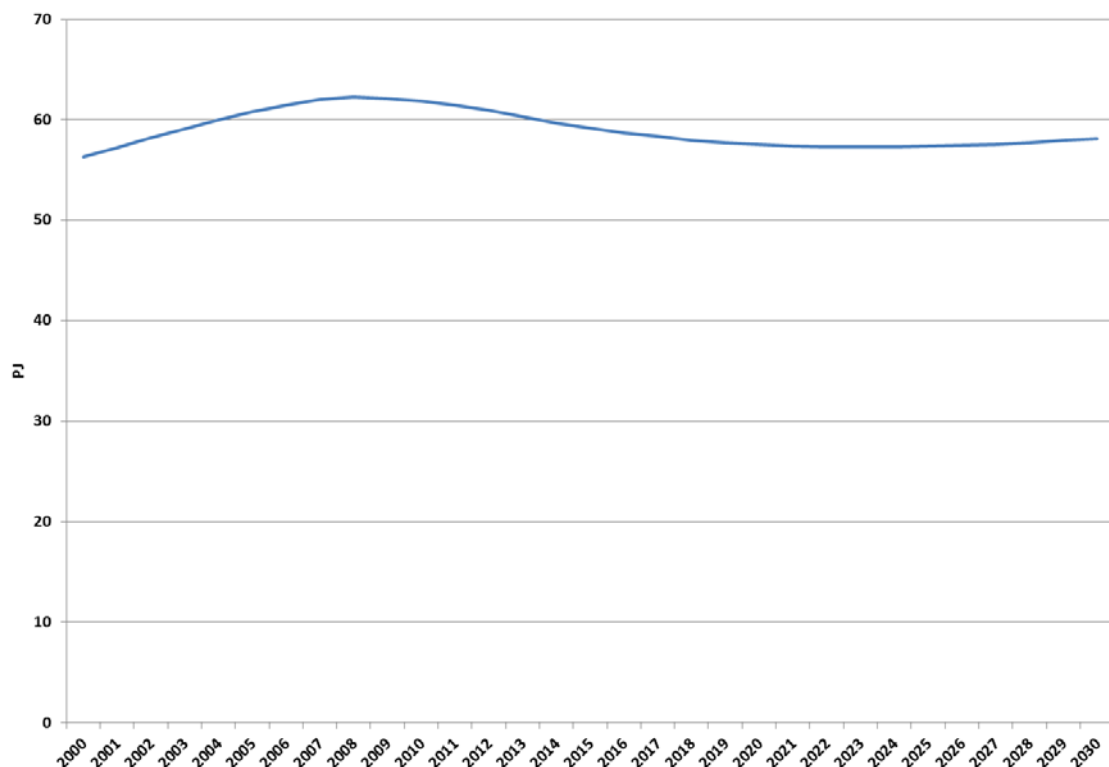
## National Residential Results

The overall national residential energy consumption results, aggregated across all households and end-uses, and the average energy consumption per household, also aggregated across end-uses, are the first two key results which provide insight into the current state of energy use in residential homes in New Zealand. Potential national peak demand results are also presented.

### Total Residential Energy Use

The total residential energy consumption is shown in Figure 4. This shows total energy consumption growing to around 62 PJ in 2008 but then decreasing slightly until 2020, after which consumption remains relatively stable until 2030. Current consumption is 60 PJ in 2014. Energy consumption therefore declines or remains unchanged for around twenty years, despite population growth, due to efficiency improvement in the stock of appliances, as will be further discussed in later sections. Consequently, total energy use is projected to not reach the peak consumption of 2008 during the projection period.

**Figure 4: National Residential Energy Consumption Trends**



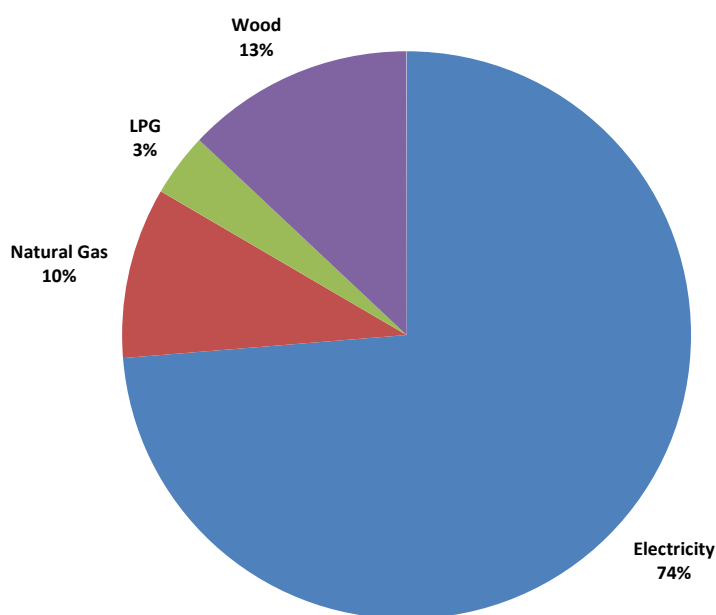
This decline in total consumption and then stable consumption is a consumption trend that differs from the decades of growth seen leading up to 2008. However, the RBS results are consistent with the measurement of actual total residential energy consumption over the last five or more years. Declines in electricity consumption have been reported

since 2009 and in the natural gas trend since 2006 by Ministry of Business, Innovation and Employment (MBIE 2014)

As will be shown later in this report, the change in total energy consumption post 2008 is declining or almost static consumption, despite the ever increasing New Zealand population. This is a result of households becoming more energy efficient, which is occurring due to fuel switching by households and the improved energy efficiency of buildings and appliances, especially space conditioning and lighting.

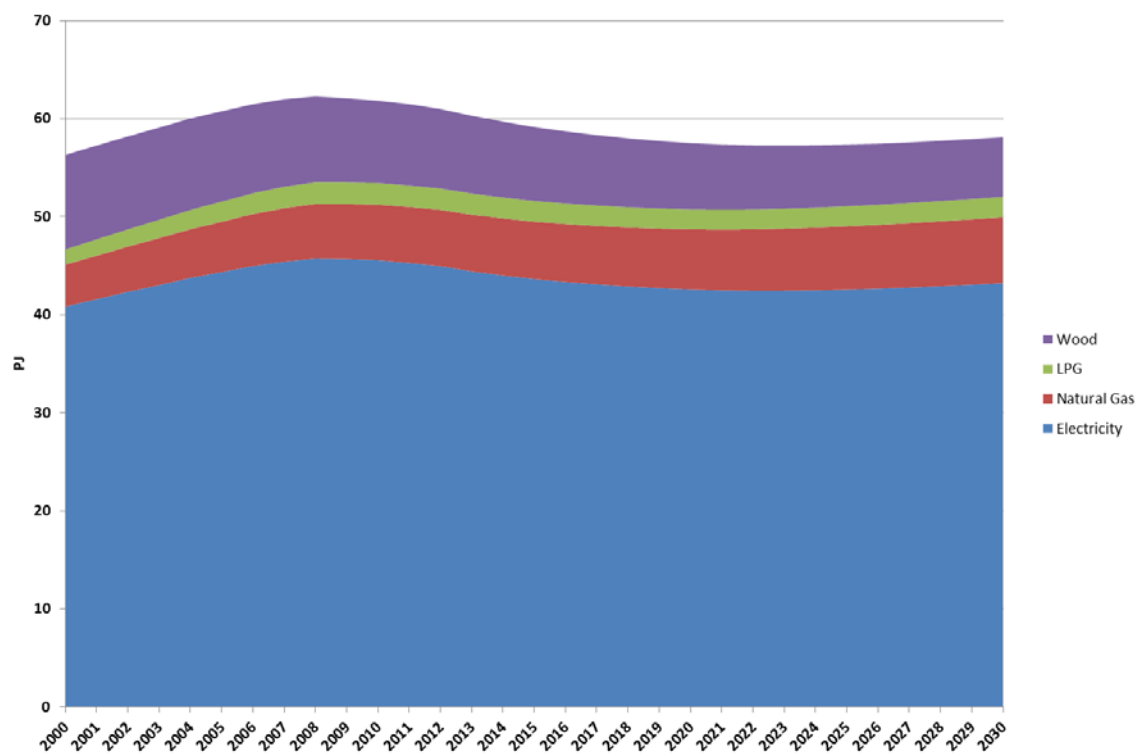
Total residential energy consumption is the sum of the consumption of energy from electricity, natural gas, LPG and wood. Figure 5 below shows the RBS estimates of the relative proportion of energy used by different fuels in 2014. It indicates that electricity use dominates residential energy use, with gas and wood contributing minor parts to the total consumption.

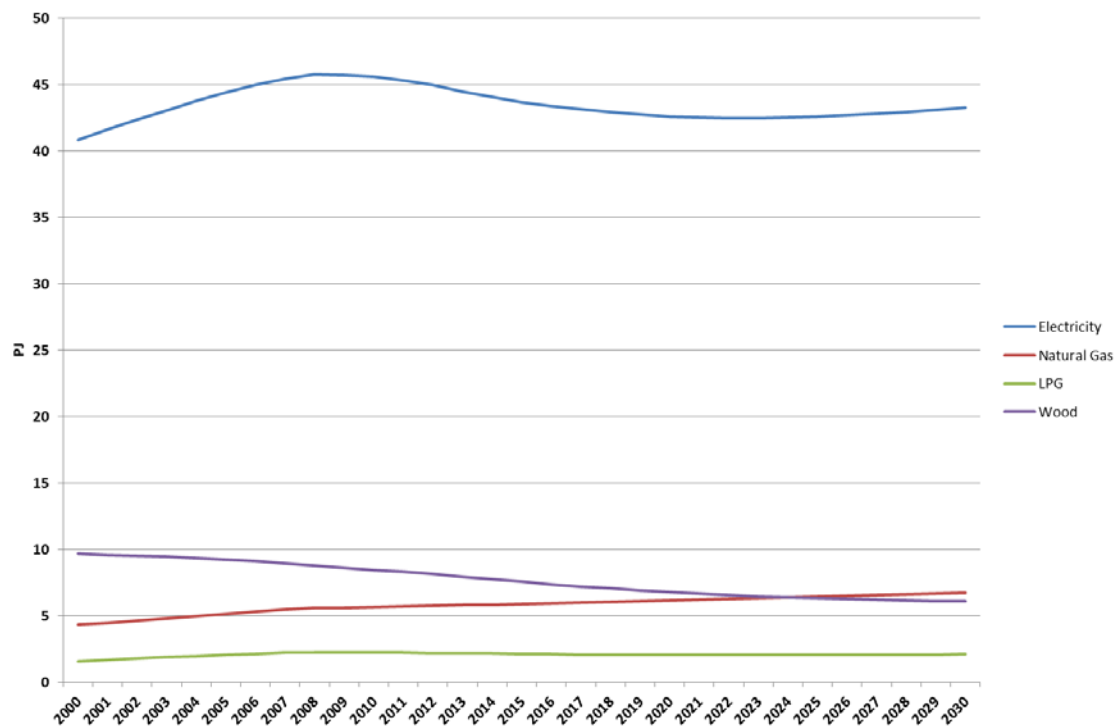
**Figure 5: Proportions of Total Residential Consumption by Fuel for 2014**



The contribution of the different fuels to total residential energy use over time is shown in Figure 6. This figure shows that electricity will remain the dominant form of energy consumed by the residential sector, but the use of natural gas is expected to increase over time. The energy from wood use though is expected to decline over time.

**Figure 6: Total Residential Consumption by Fuel**



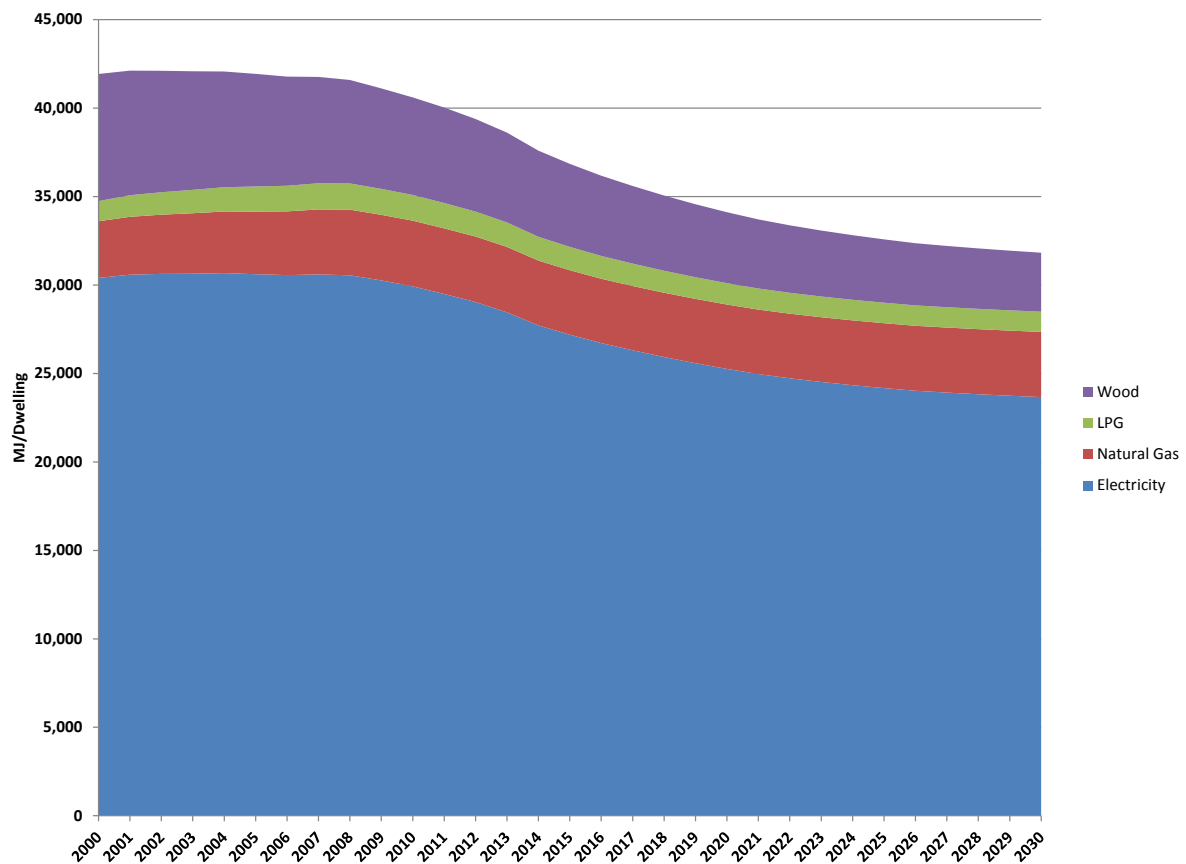
**Figure 7: Trend Lines for Residential Consumption by Fuel**

The underlying trends in energy consumption by fuel type are shown in Figure 7. These trend lines show that the total energy use trend, i.e. of a peak in 2008, a decline, then stabilising in the 2020s, is largely the result of the underlying trend in electricity consumption which follows a similar but slightly more exaggerated trend. Electricity use peaked in 2008, is currently in decline and is not expected to increase until after 2025. In comparison, natural gas and LPG use is expected to slowly grow over the study period, while wood use has declined and will continue to do so.

### *Background and Causes of Trends*

The main reason for the rises and falls in total energy consumption over the study period is due to changes in energy use per dwelling. Average energy use per dwelling, as shown in Figure 8, has been falling since 2000 and the energy efficiency of the average dwelling is expected to continue to improve to 2030, based on projected trends. The average energy use was 42 GJ in 2000 but in 2014 was 38 GJ.

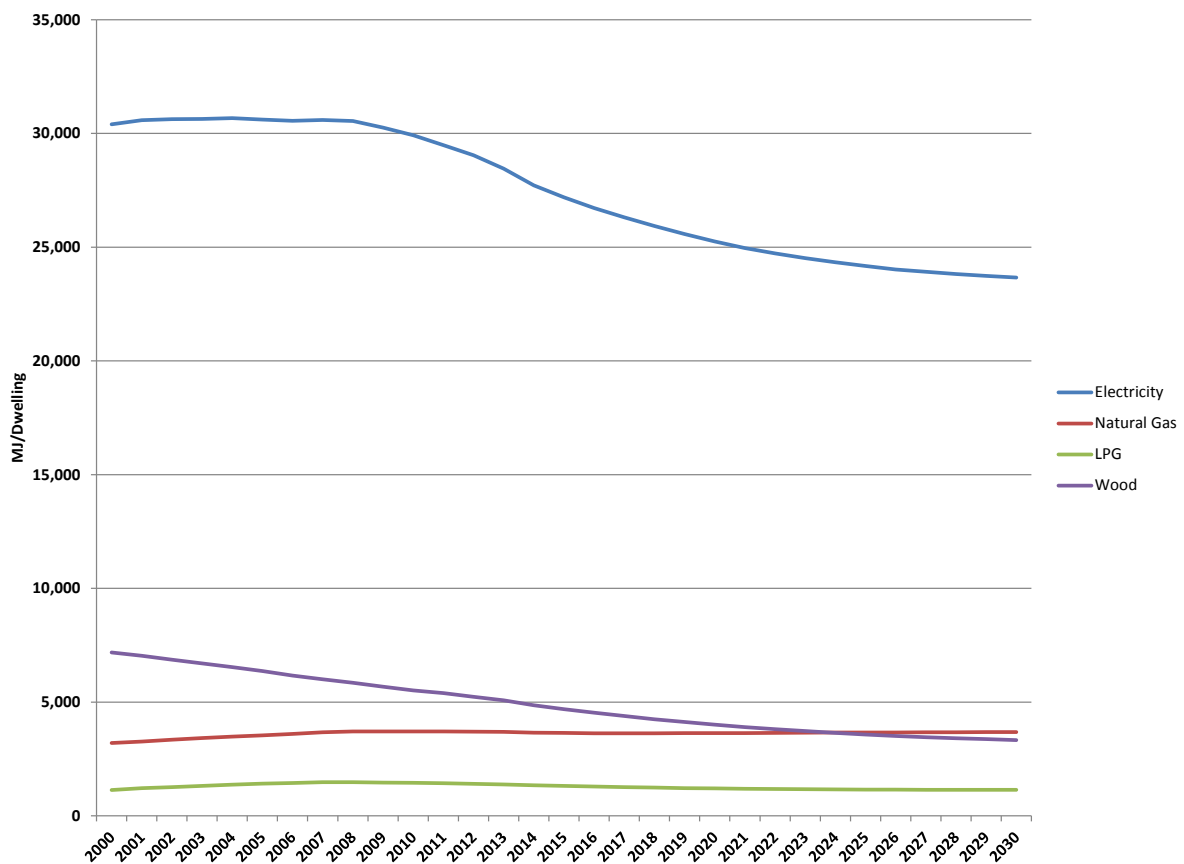
Initially the rate of decline in consumption per household in the early 2000s was less than the rate that dwelling numbers increased, so total energy consumption increased, but by 2009 the pace of decline in energy consumption per dwelling started to exceed the increase in dwelling numbers, so total consumption began to fall. Only when the rate of decline in average energy use starts to slow in the 2020s is it predicted that increases in dwelling numbers will lead to a stabilising of total energy consumption. These efficiency trends, and the growth in dwelling numbers, are expected to be the trends that drive energy consumption in the near future.

**Figure 8: Total Residential Consumption per Dwelling by Fuel**

It should be noted that these predictions of future energy use are based both on sales of future products leading to the integration of more efficient product into the appliance stock, and on there being some ongoing improvement in the efficiency of most products. However, these predictions are conservative in so far as they do not anticipate further MEPS or energy efficiency programs being introduced, unless the regulation has already been announced. If further energy efficiency initiatives are introduced, then the energy use per dwelling may further decline and a decline in energy use during the 2020s may occur.

An examination of the trend lines for energy consumption by fuel per dwelling, shown in Figure 9, reveals that the decline in energy use is driven by a decline in the average use of electricity and wood. There is slight increase in the use of natural gas per household but LPG use remains constant. The decline is most pronounced in electricity, but also strong in wood use. The decline in total energy use per dwelling has accelerated since 2008 as the use of electricity started to quite rapidly decline. This trend in electricity use is expected to be one of the main drivers of future decreases in total energy use.

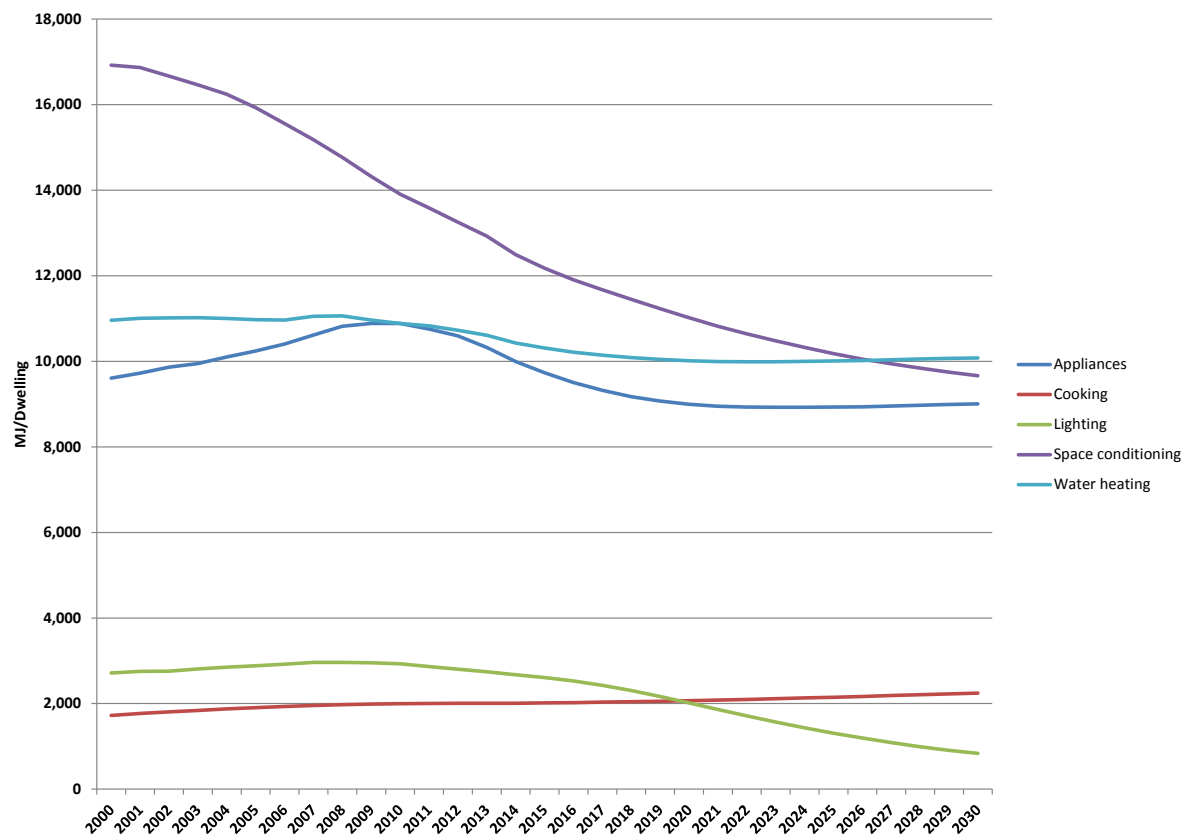
**Figure 9: Trend Lines for Total Residential Consumption per Dwelling by Fuel**



Further insight into the drivers of the current reduction in total energy use can be obtained by examining the energy consumption per dwelling for the individual end-uses, as shown in Figure 10 below. This chart shows that the energy used by each end-use, for the average dwelling, started declining for space conditioning from 2000, and for appliances and lighting from the late 2000s, and continues throughout the study period. The energy use by water heating also starts to decline from 2010 but stabilises or increases slightly in the 2020s. Space conditioning contributes the greatest amount to the decline in total energy use per dwelling, followed by lighting and then appliances and water heating. The reasons for the declines in energy consumption for each end use are discussed later in

this report, but are largely due to appliance efficiency improvements, changes in the technologies being used and fuel switching.

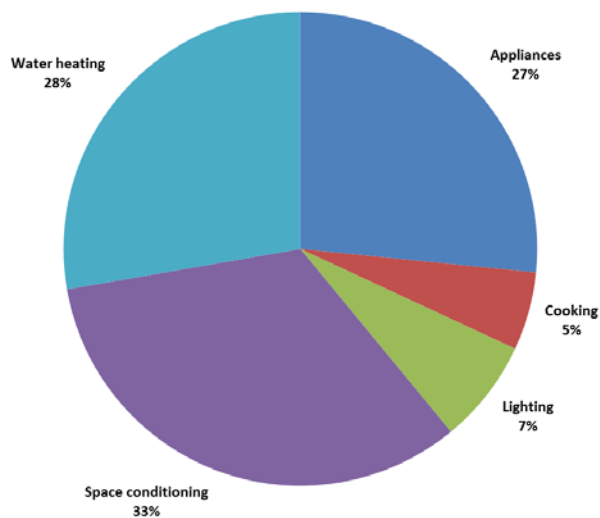
**Figure 10: Trend Lines for Total Residential Consumption per Dwelling by End Use**



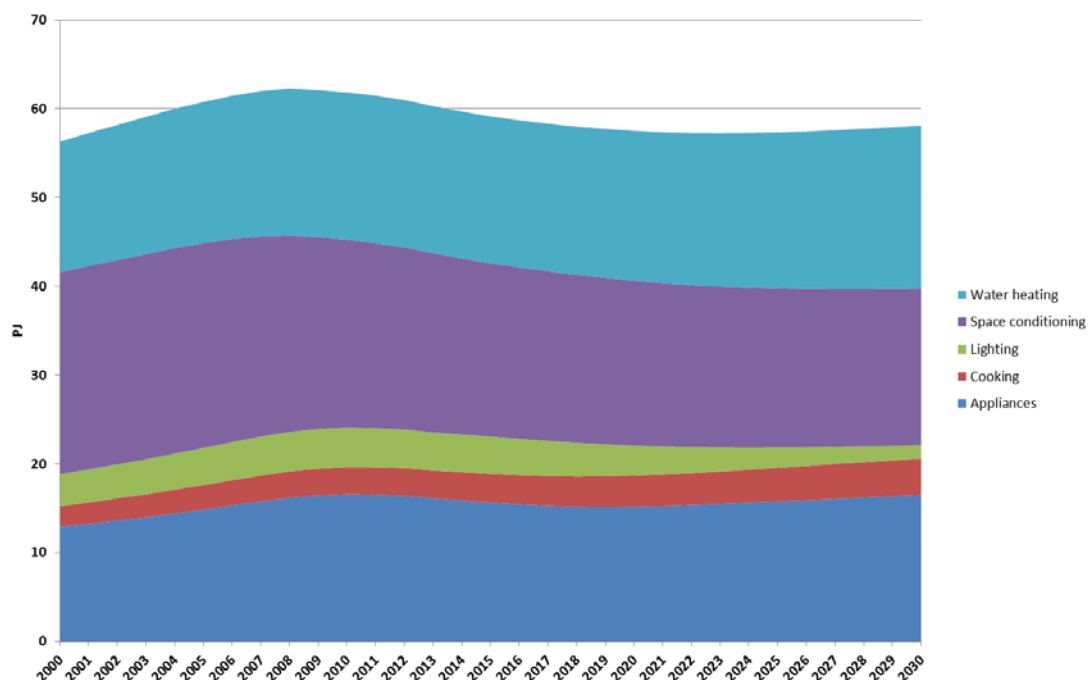
### Total Residential Energy Use by End Use

The relative contribution of the different end uses to total consumption is shown in Figure 11. The largest share of total energy consumed is by space conditioning (33%), while slightly more than a quarter each is used by water heating (28%) and appliances (27%). The remainder is used by Lighting (7%) and Cooking (5%). However, these proportions change over time, as is shown in Figure 12.

**Figure 11: Proportions of Total Residential Consumption by End Use in 2014**



**Figure 12: Total Residential Consumption by End Use**

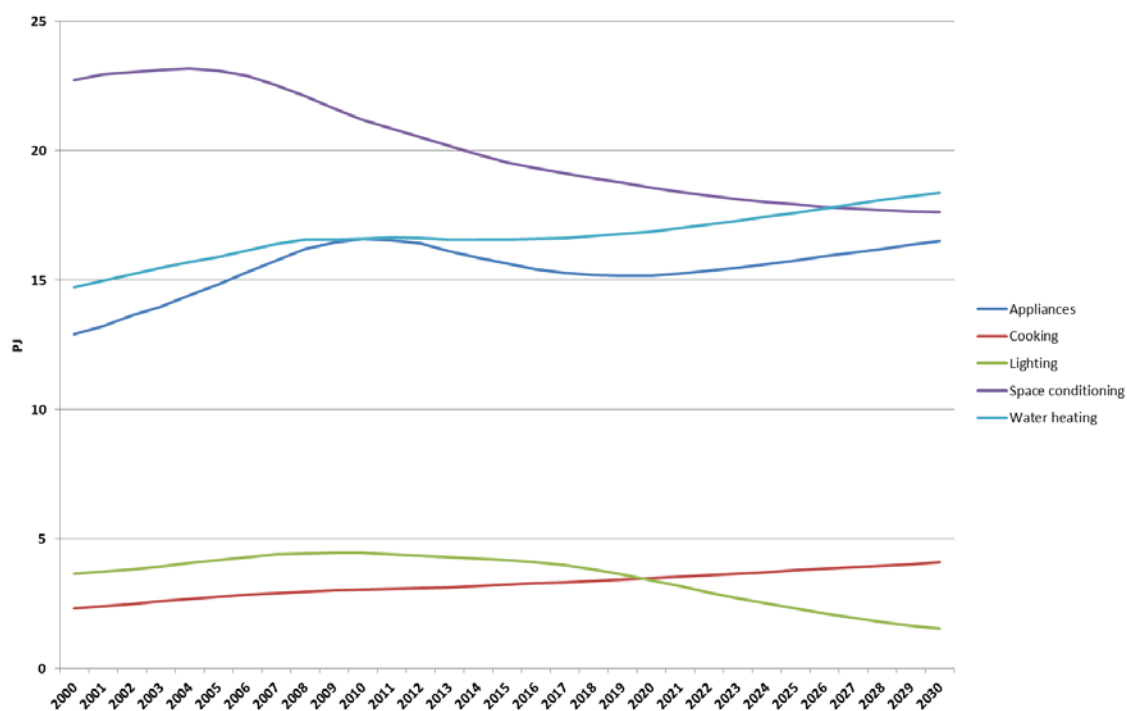




The dominance of space conditioning to energy consumption is again clearly shown, as are the large contributions made by water heating and appliances to total energy use. However, this chart also shows the trend for the energy use of water heating and appliances to make up an increasing proportion of the overall energy consumption. The decline in energy use by lighting since 2010 has also added significantly to the overall decline in total energy use and is expected to continue to do so throughout the projection period.

Examining the trend lines for energy consumption by end-use, shown in Figure 13, clearly shows the contribution of each end use to the overall energy consumption trend. This chart shows consumption by space conditioning has been in decline since 2004, and is expected to continue to decline throughout the projection period. Likewise consumption by lighting has been in decline since 2010, and is expected to continue. Energy use by water heating, appliances and cooking though is growing slowly throughout the study period, off-setting some of the savings from declining space conditioning and lighting use.

**Figure 13: Trend Lines for Total Residential Consumption by End Use**



## Peak Electricity Demand

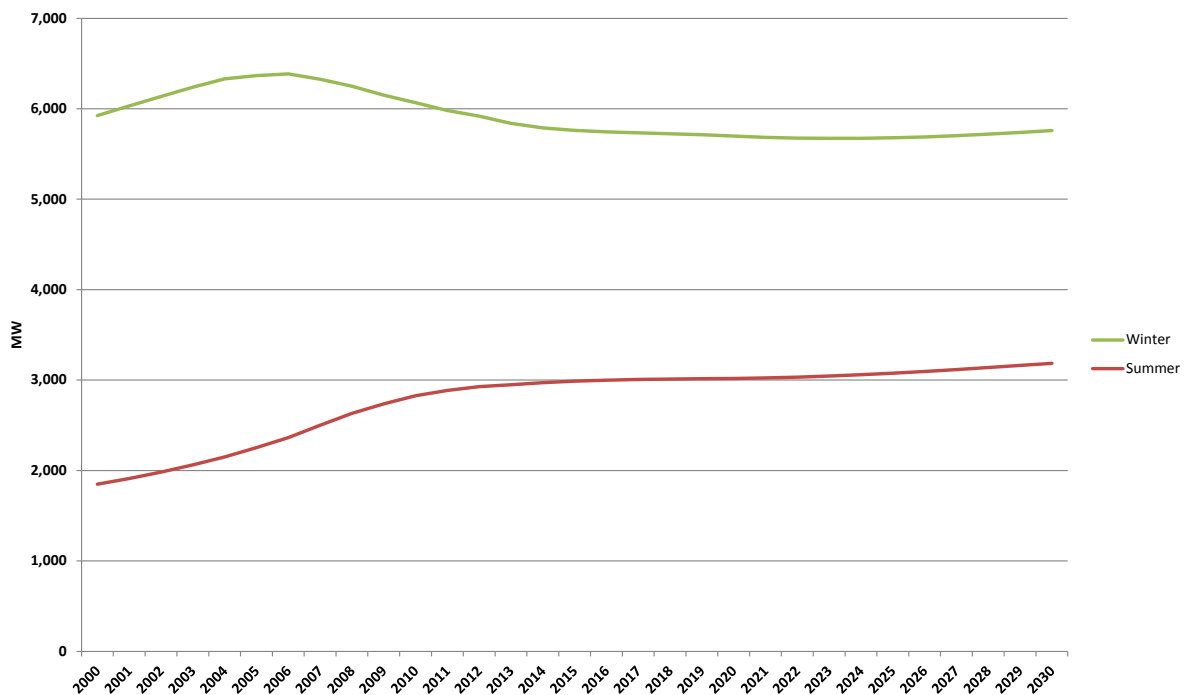
Before presenting the peak demand results, it should be noted that these results are unlikely to be as accurate as the energy consumption model results due to the poor quality and relative shortage of data on the factors that are used to estimate maximum potential peak demand. Though data on stock numbers and equipment characteristics is generally

as good as that used for energy consumption calculations, the data on the use of equipment in extreme weather events, when residential peak load events occur, is poorer. There is also limited data on how equipment, especially space conditioning equipment, operates in these extreme conditions. Consequently there is a lower degree of confidence in the peak demand modelling results.

It also should be noted that the maximum potential peak demand discussed is an estimate of the potential maximum demand that could occur if extreme weather were to lead to the maximum use of electrical space conditioning devices during a summer/winter evening. It is not an estimate of past actual demand or correlated to past actual extreme weather events. It is especially unlikely that New Zealand would experience the extremely hot conditions likely to lead to the maximum summer peak occurring.

Figure 14 shows the trends for the national maximum potential peak demand for summer and winter evenings, and clearly reveals that the trends in peak demand for summer and winter evenings differ. The summer peak demand grows throughout the study period, though its rate of growth is much more rapid in the 2000s and then increases more slowly from around 2012. In contrast, the winter peak only grows till 2006, after which it declines for most of the study period, except for a small rise from 2025. The decline in the winter peak is consistent with many dwellings changing from using resistive electric heating to using air conditioning/heat pumps, which are more efficient, as explained later in the section Space Conditioning.

**Figure 14: Trends for National Potential Maximum Summer and Winter Evening Peak Demand**



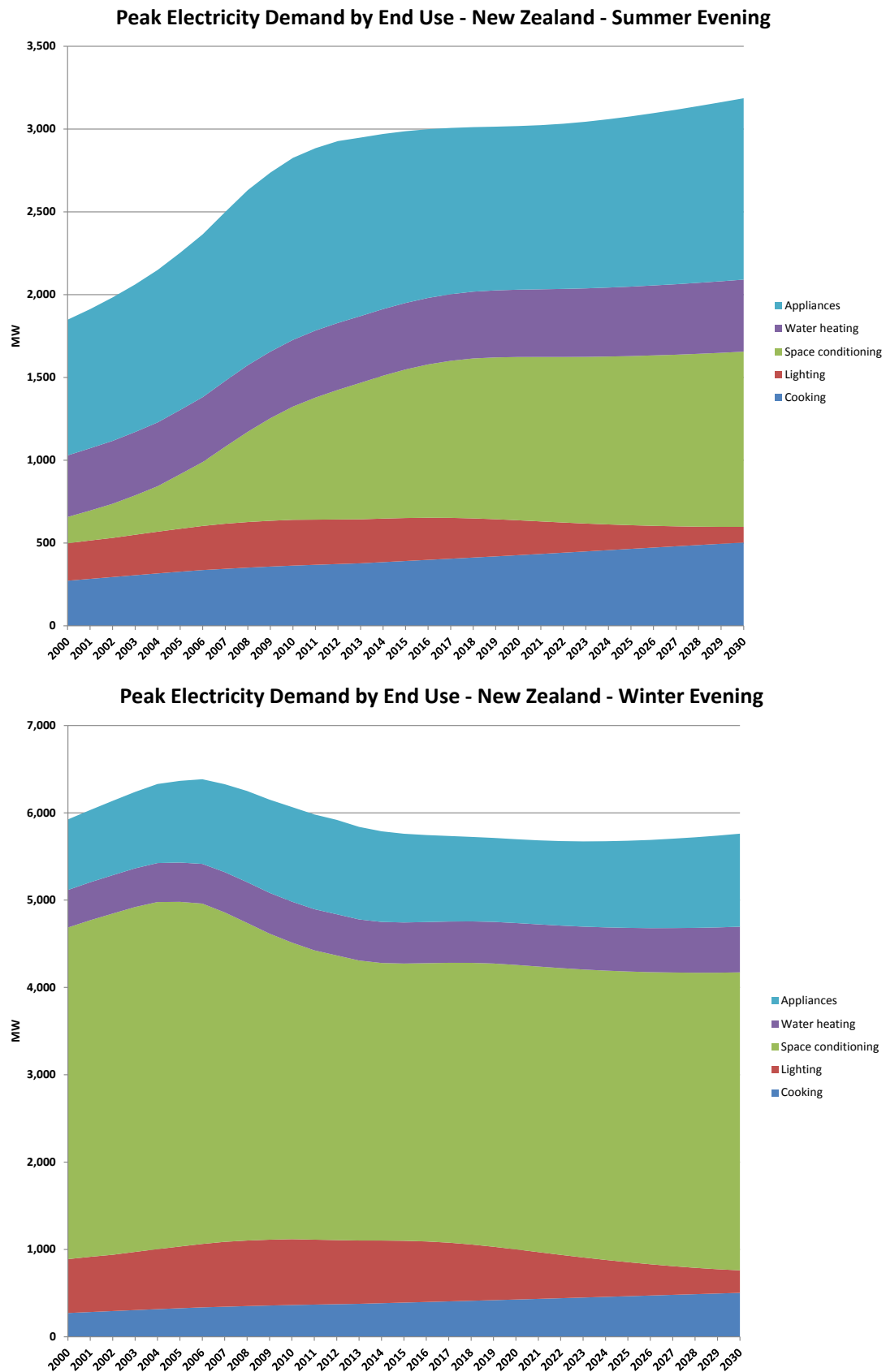
The overall trend in total peak demand and the drivers in peak demand can be seen in Figure 15 which shows the end use contribution to total peak demand at a national level

for summer and winter evenings. The contribution of end-uses to the winter and summer peaks varies significantly.

For the summer peak, appliances have to date been the biggest contributor to potential peak demand, but as the penetration of air conditioners/heat pumps increases, space conditioning contribution to the summer peak is also rapidly increasing. This increase in potential space conditioning summer demand is the key driver of the increase in overall potential summer peak demand. By the 2020s space conditioning will potentially contribute a similar amount to summer peak demand as appliances. The contribution of water heating and cooking to peak demand is much smaller, but steadily increasing. The contribution of lighting is also smaller, but grew in the 2000s and peaked in 2010, before declining.

The potential winter peak demand in contrast is in decline, and the key driver of this change is again space conditioning. Space conditioning is the dominant contributor to the winter evening peak demand, but its contribution peaked in 2004 and is estimated as declining till 2015, leading to the current decline in total peak demand. This decline in space conditioning demand is due to many dwellings changing from using resistive electric heating to using air conditioning/heat pumps, as previously mentioned.

Post 2015 the trends driving winter peak demand change. Projections for space conditioning indicate that demand starts to slowly increase from 2015 to 2030, and appliances' contribution to peak demand, the second largest contributor, is also projected to increase during the 2020s. Cooking and water heating's contribution to peak demand is smaller but the projections indicate their demand will also grow throughout the projection period. The only end-use with a decreasing demand is lighting, which is projected to rapidly decline. However, the decrease in lighting's demand is sufficient to keep total potential winter peak demand declining until 2023, and then only growing very slowly to 2030. The projected potential winter peak demand in 2030 is slightly lower than the estimated demand in 2014, despite this increase late in the 2020s.

**Figure 15: National Potential Maximum Summer and Winter Evening Peak Demand by End-use**

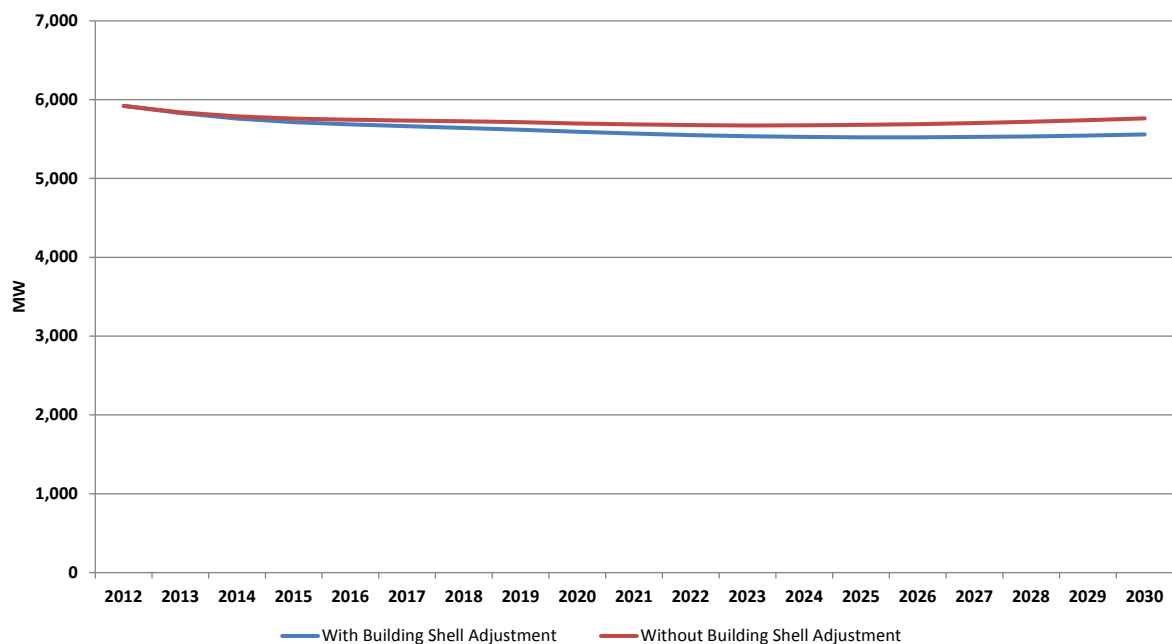
The drivers of these changes in the peak demand include:

- Decreasing demand from space conditioning due to a move away from electric resistive heating toward the use of more efficient and lower power rated air conditioners, plus towards gas heating, which drives down winter peak demand
- Improved energy efficiency of air conditioners, largely due to the introduction of MEPS and labelling which have significantly improved their efficiency and rated power requirements, which increases the decline in winter demand from space conditioning
- Improvements to the efficiency of lighting, and hence lowering of power requirements, due to the replacement of many incandescent lamps since the mid-2000s by more efficient lamps, is driving down power demand from lighting and hence peak demand
- For summer peaks, the increased penetration of air conditioners increases the potential for larger peak demand.

Another factor possibly affecting maximum peak demand could be changes in building shell efficiency. However, the CSIRO study (Ambrose et al, 2013) results, discussed later in the Impact of Building Shell Efficiency Improvements section, do not show a significant and consistent relationship between AccuRate measurements of building shell efficiency and cooling energy use. This suggests it is highly unlikely that it is possible to predict how summer peak demand will be affected by building shell efficiency, as measured by AccuRate. Consequently, estimates of potential maximum peak demand were not modified in the RBS to allow for changes in building shell efficiency.

However, the CSIRO research showed there was a significant relationship between AccuRate estimations of building shell efficiency and heating energy use in Victoria, and this result which may be applicable to heating energy use in New Zealand dwellings. In addition, AccuRate modelled peak demand and modelled space conditioning energy requirements also appear to be strongly related, as discussed in Peak Electricity Demand Method. Together these findings support the idea that building shell efficiency improvements, as estimated by AccuRate would be related to the potential maximum peak demand on winter evenings. This possibility was modelled and the resulting national potential peak demand compared against the model results based on the assumption that building shell improvements made no impact. As is shown in Figure 16, the RBS modelling suggests inclusion of the impacts of building shells on winter peak electricity demand made little impact on the estimated peak demand, and by 2030 the difference between the two estimates of demand was only 3.7%.

**Figure 16: National Potential Maximum Winter Evening Peak Demand With and Without Building Shell Efficiency Impacts**



It is worth noting that this estimate of the impact of building shell improvements on potential maximum winter peak demand assumes that the impact of building shell improvements on power demand will be equivalent to the impact on space heating energy use. However, it is quite possible that building shell improvements will have a much smaller impact. This is because in extreme weather the space conditioning equipment may be functioning at full capacity in both lower and higher building shell performance homes, due to the equipment being undersized for the heating load demands that occur during extreme weather. Given there is some evidence of this occurring (e.g. observations in Ambrose et al, 2013), it is probable that the estimate of the impact of building shell improvements on potential maximum winter peak demand presented above is an over-estimate of the building shell impacts. Consequently the impacts of building shell efficiency on peak demand were not included in earlier estimates of peak demand presented in this report.

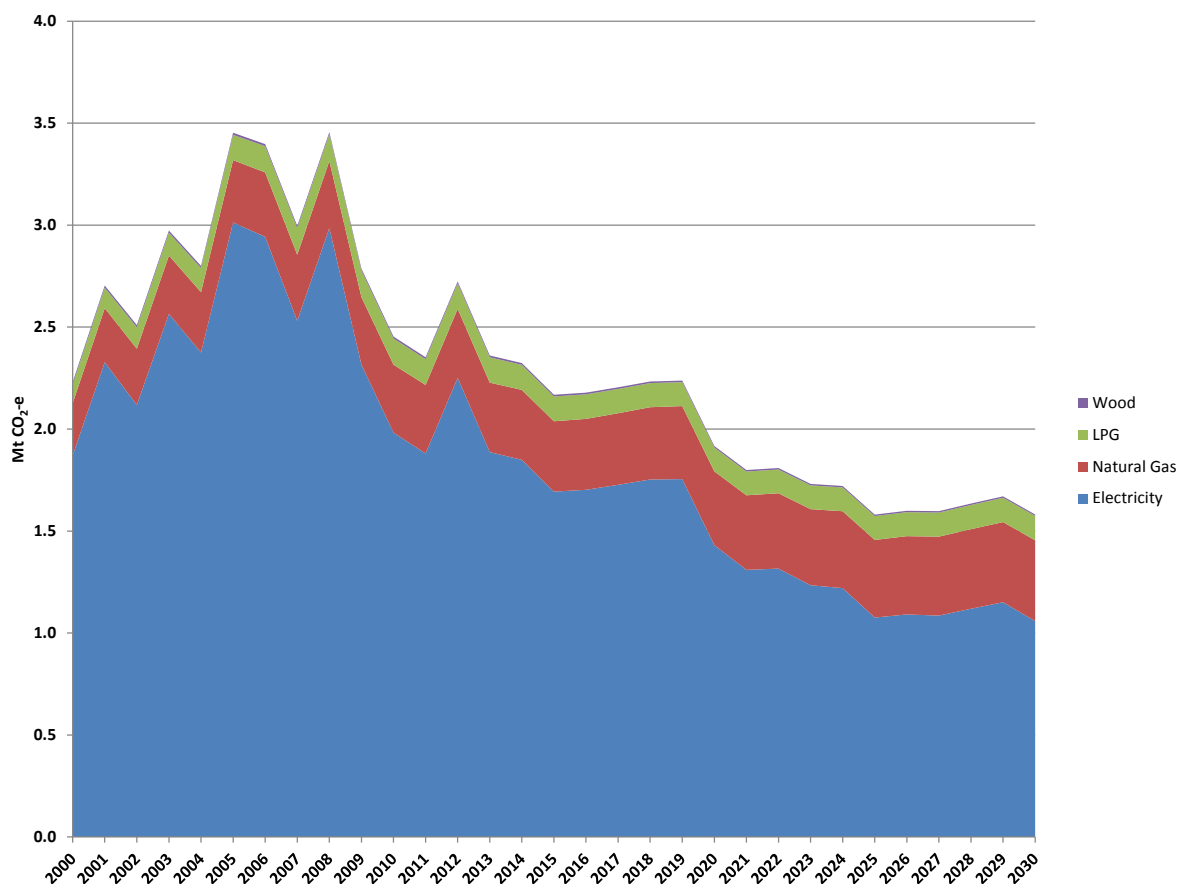
## Residential Greenhouse Emissions

The national greenhouse emissions from residential energy use were calculated by multiplying the energy consumption by fuel by the greenhouse emission factors for the fuels. The results in Figure 17<sup>12</sup> show that the trend for greenhouse emissions largely mirrors the trend for energy use over the study period. Greenhouse emissions rose

<sup>12</sup> The erratic slope of the chart is a result of a wide variation in electricity greenhouse emission factors, on a year to year basis, probably due to the varying use of coal and hydro power in the power generation mix.

rapidly between 2000 until the mid-2000s, peaked, and then declined from 2008. However, though energy use stabilises in the 2020s, greenhouse emissions continue to decline throughout the study period, mainly due to the projected decline in the emissions intensity of electricity. Emissions started at 2.2 Mt CO<sub>2</sub>-e in 2000, the peak occurred between 2005 and 2008 at 3.5 Mt CO<sub>2</sub>-e, has dropped to 2.3 Mt CO<sub>2</sub>-e in 2014 and is projected to be 1.6 Mt CO<sub>2</sub>-e from 2020 to 2030. In total, residential greenhouse emissions are projected to decline 27% from 2000 to 2030. Electricity contributed 79% of residential greenhouse emissions in 2014.

**Figure 17: National Residential Greenhouse Emissions by Fuel**



## 4. National Results by End-use

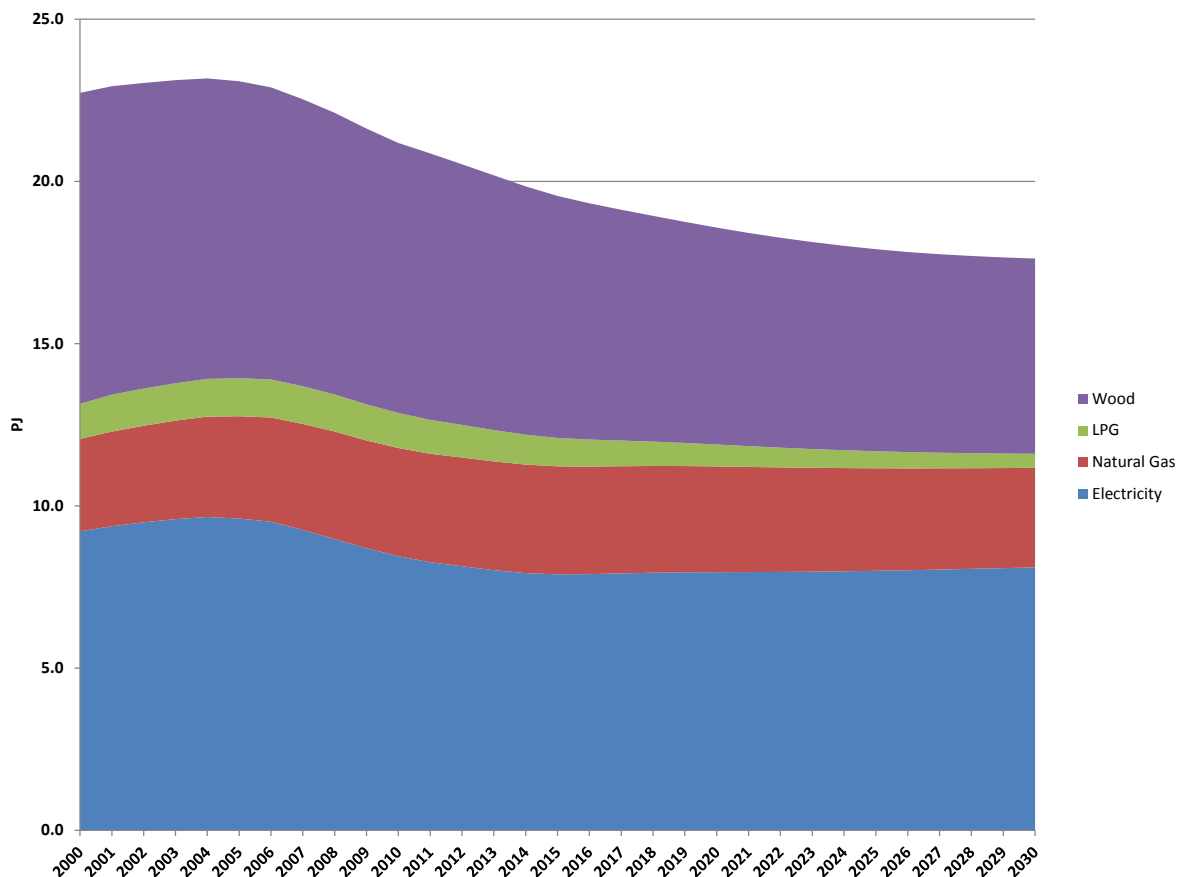
The relative contribution of the different end-uses to the total energy consumption has been previously discussed; (see Total Residential Energy Use by End Use) but the following results provide greater detail on the underlying drivers of energy use for each end-use and trends in energy consumption.

### Space Conditioning

Space conditioning energy use is the dominant driver of residential energy consumption nationally, using 20 PJ in 2014. The overall energy use by space conditioning peaked around 2004 at 23 PJ and since then is decreasing, and is expected to continue to decline to 18 PJ by 2030.

Space conditioning is an end-use that can be satisfied with a variety of fuels and Figure 18 shows the mix of fuels. Electricity is the dominant fuel in terms of energy consumption, closely followed by wood, then with natural gas being a lesser contributor currently providing 16% of space conditioning energy. LPG is a minimal contribution to the total space conditioning energy use.

**Figure 18: National Space Conditioning Energy Use by Fuel**



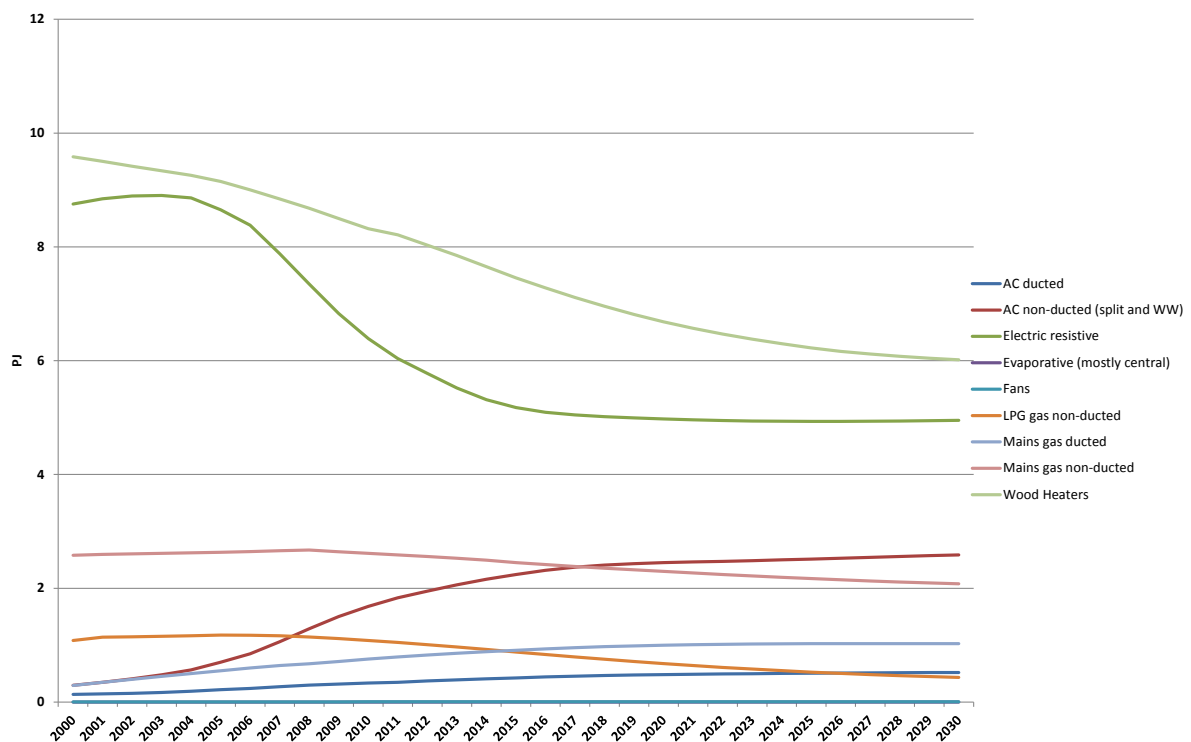


Fuel use changes over the study period, with electricity growing until 2004 but declining until 2015, and then remaining stable during the projection period. Energy used from wood declines throughout the study period. Natural gas energy use grows in the 2000s, is stable in the 2010s and then is projected to decline slowly in the 2020s. LPG energy use grows very slightly in the 2000s but then declines post 2007.

Figure 19 below shows the contribution of specific product groups to space conditioning energy use. Currently the major user of energy in this end use is wood heaters, which currently use 40% of space conditioning energy, with the next major user being electric resistive at 30%. Other significant current users of energy are non-ducted natural gas heaters and non-ducted air conditioners (i.e. heat pumps). Minor contributors are natural gas ducted heaters, LPG non-ducted heaters, ducted air conditioners and fans.

Though total space conditioning energy use is declining, as the chart below shows this is not true for all products. Energy use by the significant energy users, i.e. electric resistive, wood heaters, and natural gas non-ducted heaters, are all declining, but the energy use by non-ducted air conditioners is growing and becoming more significant. The energy used by minor contributors such as natural gas ducted heaters, ducted air conditioners and fans is slowly growing but that used by LPG non-ducted heaters is declining.

**Figure 19: National Space Conditioning Energy Use per Product Group**



The underlying drivers for the projected reduction in total space conditioning energy use appear to be:

- Fuel substitution: Households appear to be moving from using wood heaters or electric resistive heaters to air conditioners, which are much more energy efficient than wood or electric resistive heaters, so the energy consumption per dwelling declines.<sup>13</sup>
- Significant improvements in the efficiency of new air conditioners which continue to flow through to improvements in the overall stock of air conditioners
- Most other products also slowly improving in their efficiency.
- Improvements in building shell efficiency, discussed below.

### *Impact of Building Shell Efficiency Improvements*

The impact of building shell improvements over time on AccuRate estimates of the space conditioning energy consumption of the average house has been researched and modelled. The result is an annual Usage Adjustment Factor which can be used to adjust the energy use estimates and projections of the RBS so as to allow for the impact of building shell improvements.

However, before the Usage Adjustment Factor was used it was necessary to determine if there was evidence that improvement in building shells and AccuRate assessment of the impact of these changes, resulted in reduced energy use for space conditioning. There appears to be only one study conducted to test this issue.

The CSIRO study (Ambrose et al, 2013), was of 414 Australian homes built in the 2000s in Adelaide, Melbourne and Brisbane. The houses in each city were divided into older homes of less than 5.0 home energy rating stars, according to the Building Code of Australia, and those of 5.0 stars or more. Star ratings are measured with approved software tools such as AccuRate. The study found that dwellings' star rating was related to:

- Cooling energy use in Melbourne and Brisbane, but in an inverse manner to what was expected. The newer, higher rated homes used significantly more cooling energy in summer, instead of less as was expected. Cooling energy use in Adelaide also increased in the higher rated houses, but the difference was not statistically significant. In addition, the impacts appear to vary with the nature of the cooling systems.

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<sup>13</sup> This and similar comparisons of the efficiency of gas or wood energy use, compared to electricity use, are comparisons of the efficiency of the use of delivered energy. They ignore the energy used and lost in generating and transmitting the electricity to the home.

- Heating energy use was related to star rating in Adelaide and Melbourne, but not in Brisbane. There was a 19% energy saving in Adelaide and a 50% energy saving in Melbourne of the heating energy compared to the lower rated homes.
- Annual combined heating and cooling energy consumption was 48% lower in high rated houses in Melbourne, but virtually unchanged in Adelaide. In Brisbane though it was 12% higher in the higher rated houses, so the opposite of what was expected.

It is also worth noting that based on the energy use predicted by the star ratings system/AccuRate, there should have been an approximately 65% space conditioning energy saving between the low versus high rated houses in each of the three cities. This was not found in the result, and the closest to it was the 48% annual savings in Melbourne, which was 70% of the predicted savings<sup>14</sup>.

While it is the only study of this issue, the CSIRO study results imply that AccuRate/star ratings appear to be a useful guide to predicting the impact of building shell efficiency improvements on heating energy use in cooler regions, such as New Zealand, assuming the Melbourne findings are applicable to other regions. However, for cooling energy use the results are the opposite of that expected and difficult to interpret, but suggest AccuRate/star ratings may not be a useful in predicting cooling energy use in New Zealand.

Consequently for the RBS modelling, the impact of building shell changes on heating energy use were incorporated in the modelling for New Zealand, though the impact of the changes will be reduced to 70% of AccuRate predicted impacts. The impact of building shell changes on cooling energy use though was not included<sup>15</sup>.

The modelled national space conditioning energy use, with and without the impacts of adjustments for improvements in building shell efficiency, is shown in Figure 20.

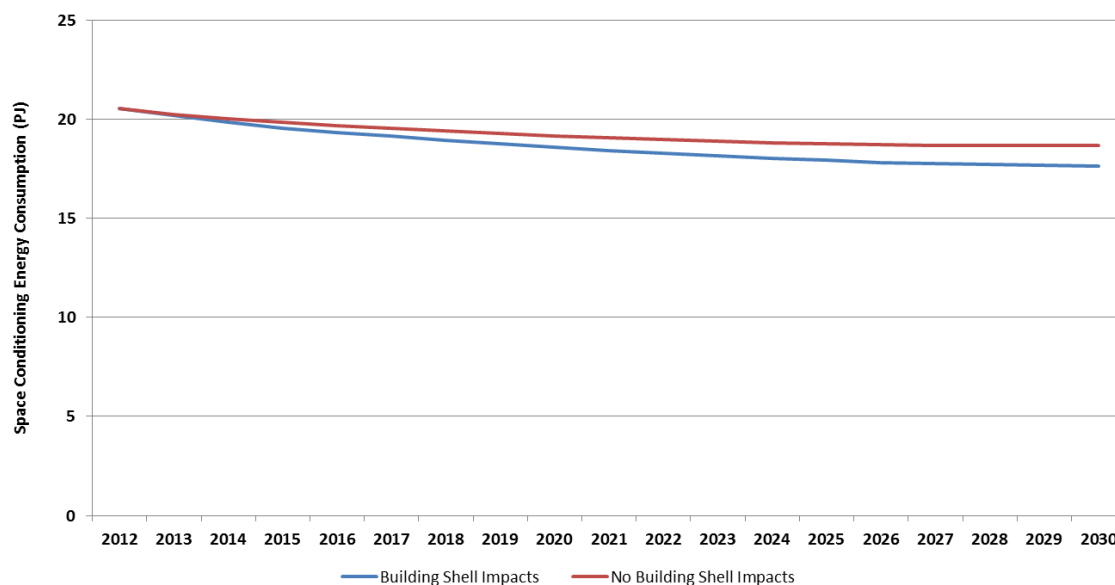
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<sup>14</sup> CSIRO notes that the findings of the study should be regarded as preliminary as research is ongoing and several factors made it difficult to draw robust conclusions about the differences in energy use between lower-rated and higher-rated houses that could be applied to other such houses in Australia. For example:

- The sample size was restricted and there was an uneven distribution of houses across star rating values in the three cities;
- There were above-average temperatures during the summer period monitored which made it likely that air-conditioning appliances were operating at full capacity, making it difficult to detect differences due to the star rating;
- The higher rated houses were generally constructed more recently than the lower rated houses, which may have caused some inherent bias, for example the newer houses were more likely to contain younger children and have someone home all day.

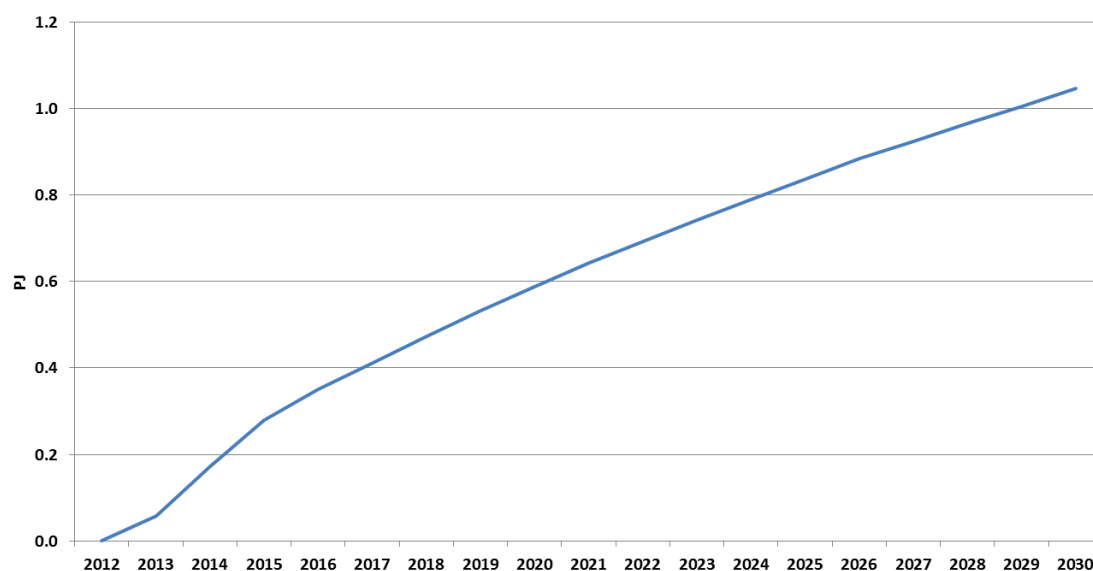
<sup>15</sup> Again an alternative would be to model the inverse impact of negative impacts (increases) on cooling energy use from improvements in building shells, but again there was insufficient data to accurately quantify this effect, especially as it varied with cooling appliance type.

**Figure 20: National Space Conditioning Energy Use- With/Without Adjustment for Building Shell Efficiency Changes**



The projected energy savings from building shell efficiency improvements implemented from 2012 onwards are shown in Figure 21. These savings are equal to the difference between the trend lines with building shell improvements versus without building shell improvements after 2012 and grow to 5.6% of the total residential energy use by 2030.

**Figure 21: National Energy Savings from Building Shell Efficiency Improvements: Post 2012**



The savings from building shell improvements implemented before 2012 cannot be directly estimated from the trends shown in Figure 20, as such estimates will depend entirely on what improvements were being examined, hence what the “no improvement” base case was assumed to be. The base case scenario would need to be defined to address

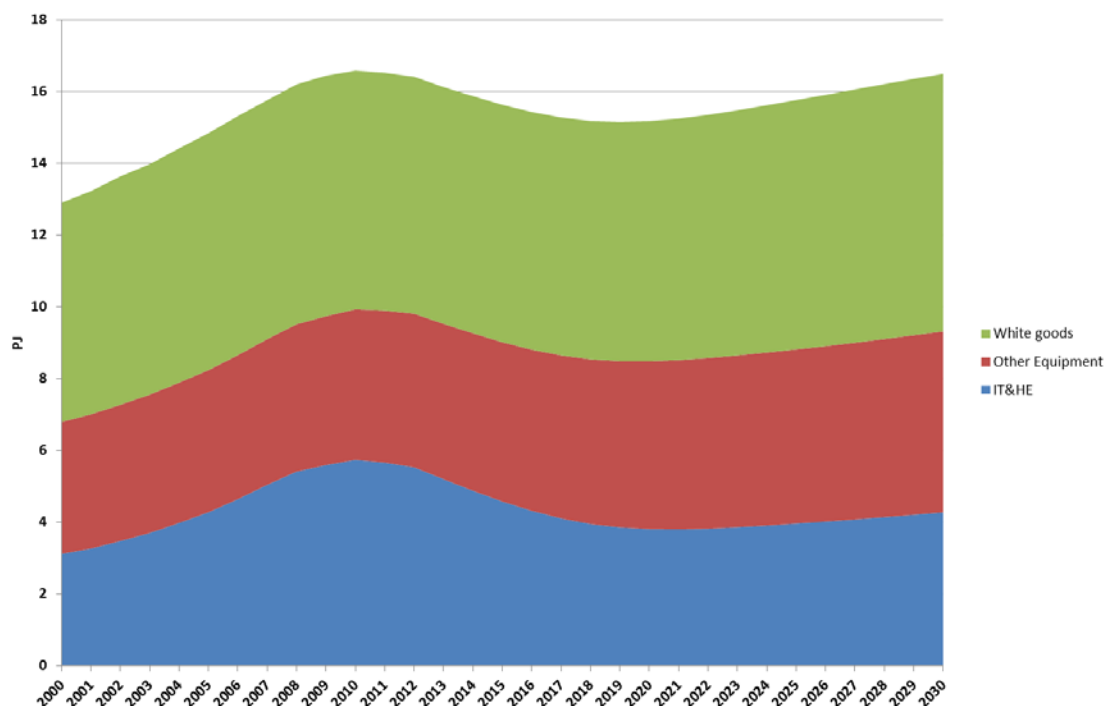
whether insulation retrofits have occurred, insulation in the ceiling of new homes occurred, what minimum insulation requirements in new homes have been required, etc. The RBS model is not designed for exploring such historic alternatives and scenarios, so estimating such savings is out of scope for this project, though the model could be modified to explore such questions.

## Appliances

Appliances as a group use around a quarter (27%) of the overall residential energy consumption of all end uses. Appliances all require electrical power and can be categorised into White Goods, Information Technology and Home Entertainment (IT&HE), and other equipment. Other Equipment includes large energy users such as swimming pools and spas (which can also use gas for water heating), pumps, battery chargers, apartment building common area energy use, and use from miscellaneous equipment (e.g. irons, personal care, cleaning equipment, fish tank heaters, etc.).

Appliance energy use in 2014 was 15 PJ but, as shown in Figure 22, peaked in 2010 to 2012 at over 16 PJ. Appliance energy use is expected to continue to decline until the 2020s where it is projected to again start to increase.

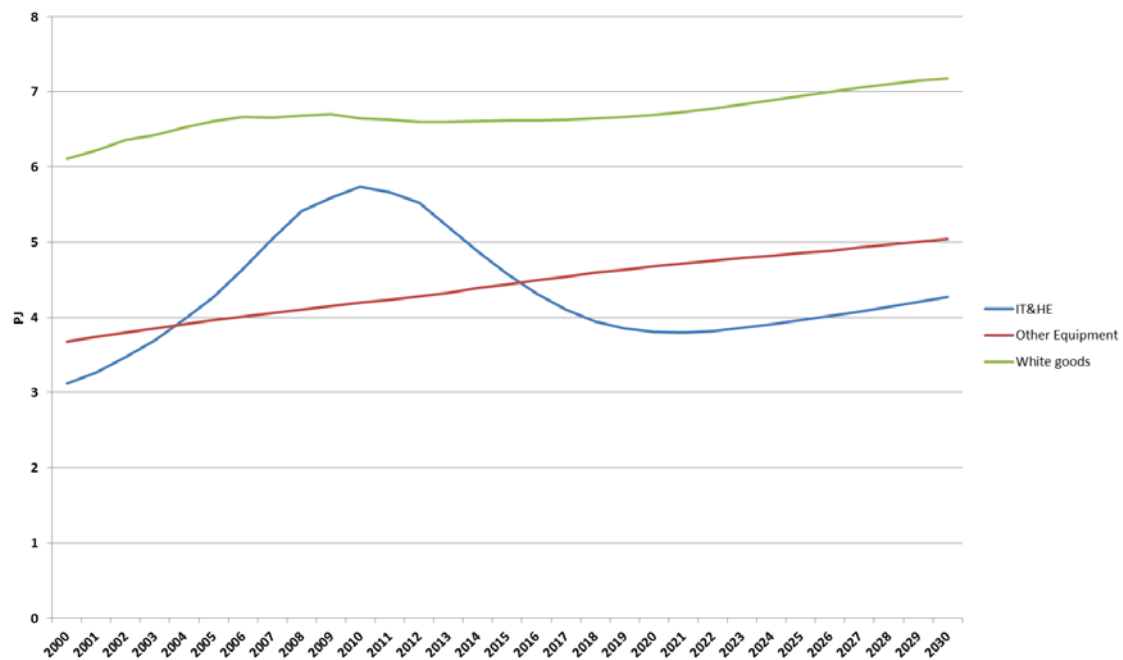
**Figure 22: National Residential Appliance Energy Use per Category**



The driver of this increase then decrease in appliance energy use is the energy use of the IT&HE product group, as shown by trend lines in Figure 23. This shows that though Other Equipment and White Goods energy use has continued to grow over the study period, IT&HE energy use grew rapidly in the 2000s, then declined rapidly, before being

projected to grow slowly again in the 2020s. The main reason for this trend in the IT&HE energy use was that product numbers peaked around 2010 and then started to decline, plus more energy efficient products, especially televisions, were introduced around 2010.

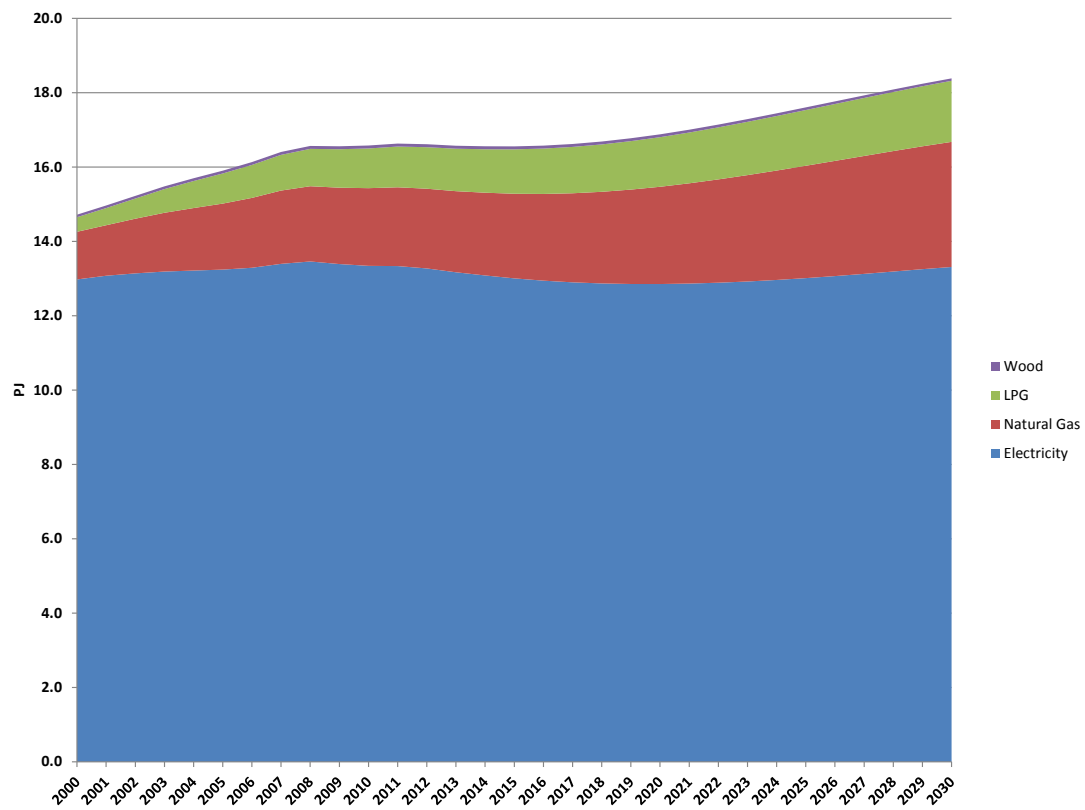
**Figure 23: Trend Lines for National Appliance Energy Use per Product Group**



## Water Heating

Water heating also contributes around a quarter (28%) of the overall residential energy consumption of all the end uses. Water heating's energy use was 16 PJ in 2014, and is slowly increasing to a projected 18 PJ in 2030, as shown in Figure 24.

This chart also illustrates the relative mix of fuels used in water heating. Electricity use dominates the water heating energy use and contributed 78% of the total use in 2014. However, electricity energy use is stable throughout the study period. In contrast, the use of energy from natural gas increases throughout the study period, as does that from LPG. Wood's use, via wet-backs, remains very small but steady during the study period.

**Figure 24: National Water Heating Energy Use by Fuel**

Note that wood water heaters (wetbacks) only consume a very small amount of energy as seen on the chart.

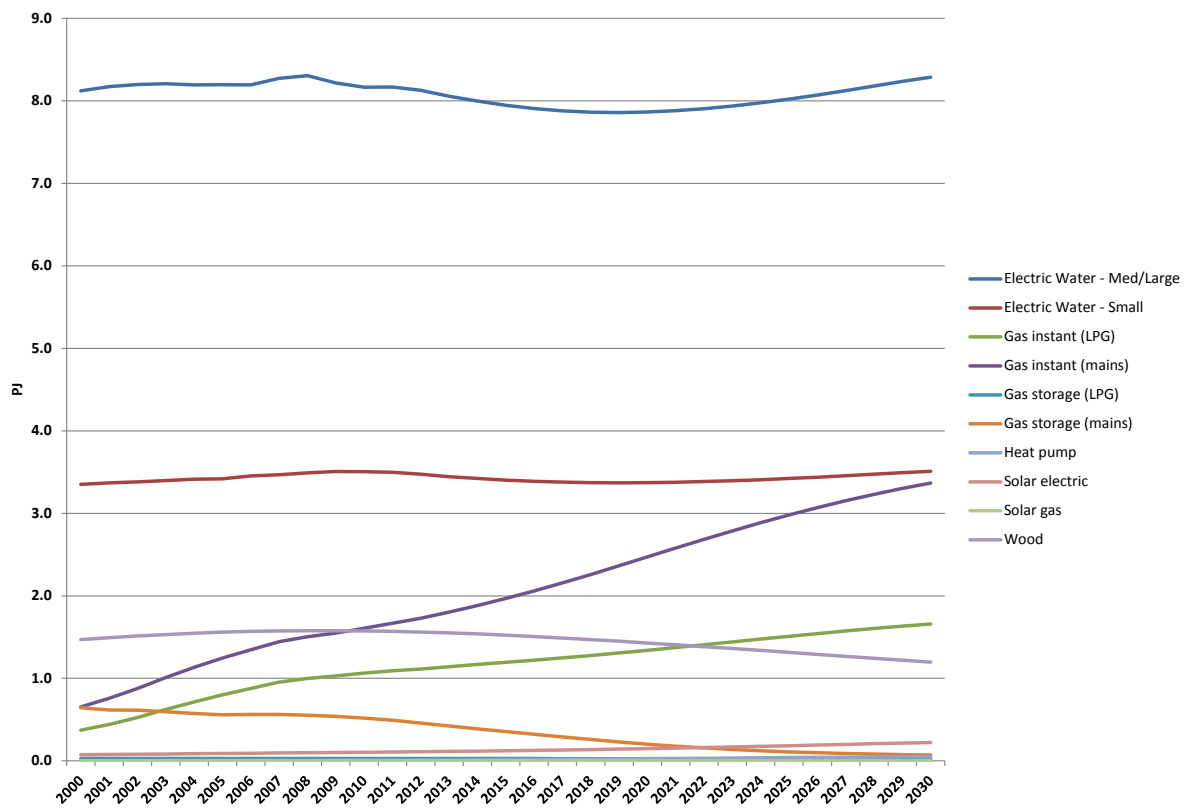
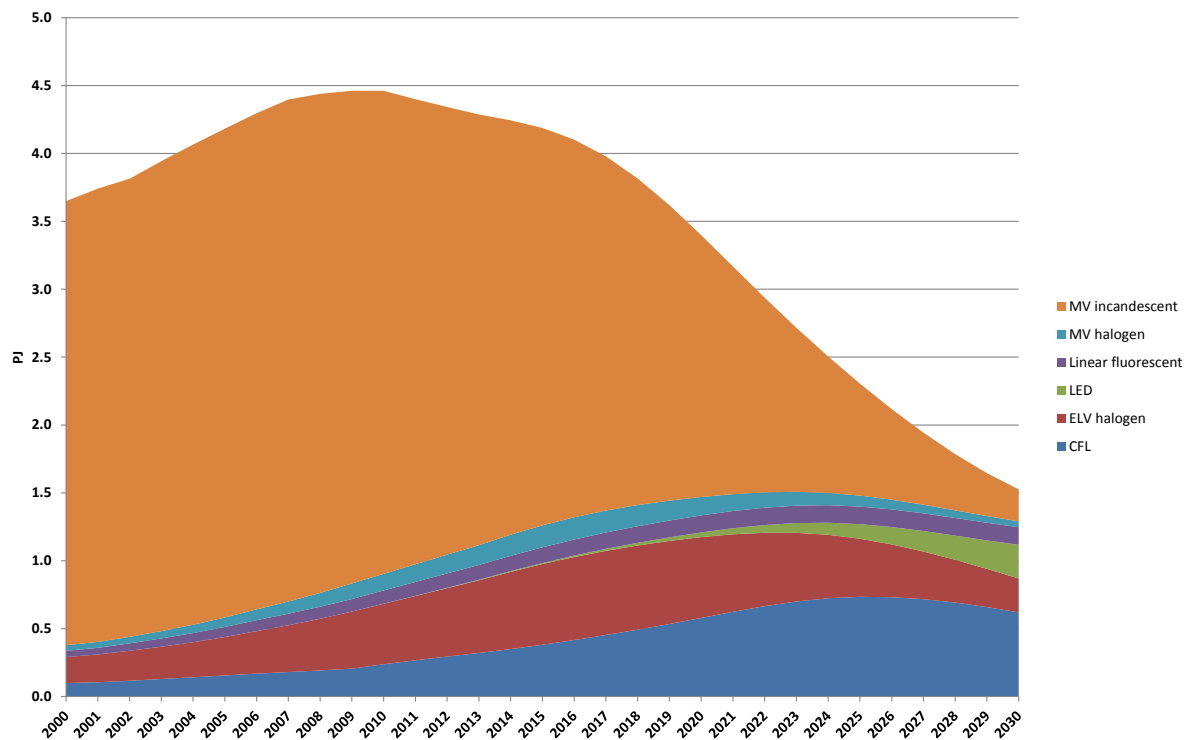
**Figure 25: National Water Heating Energy Use by Product Group**

Figure 25 above provides further insight into the drivers of the changes in energy and fuel use by water heaters. It shows the products showing the most significant change are natural gas and LPG instantaneous water heaters, whose energy use grows throughout the study period. This will partially be at the expense of the natural gas storage systems market share, whose energy use is falling.

## Lighting

The energy use of lighting is shown in Figure 26 below. This chart shows a clear peak in energy consumption in 2009 and 2010, at nearly 5 PJ, and then a steady decline in energy use is projected to continue through to 2030. Current energy use is 4 PJ in 2014.



**Figure 26: National Lighting Energy Use by Product Group**

The key drivers of these changes in lighting energy use over the three decades are the change in the lighting technology mix, and the associated change in the average efficiency of the lighting stock. The lighting stock can be seen as going through three technology phases over the thirty years, as follows:

- **Incandescent lamps:** During the 2000s incandescent lamps dominated lighting stock numbers and energy use. As these lamps produce energy intensive lighting, the energy use of lighting was at its highest during this decade
- **Declining Incandescent:** Use of halogen and CFL lamps grew during the 2000s and started to displace incandescent lamps in the 2010s. This resulted in energy used by incandescent lamps starting to fall and in increase in energy use by halogen and CFL lamps. However, because halogens, and especially CFL lamps, are more efficient than the incandescent lamps they had displaced, the total energy use by lighting declined.
- **CFLs and LEDs:** The use of CFLs is expected to increase during the 2020s as an easily installed replacement for incandescent lamps. LED lamp use is expected to grow during the 2020s and these lamps are predicted to gradually displace halogen lamps, and later CFL lamps. If this occurs, then LED energy use will eventually dominate lighting stock numbers around 2030. Again, as CFL and LED lamps are more efficient than any of the earlier lighting technologies, the total energy use by lighting is projected to decline as these lamps become more widespread.

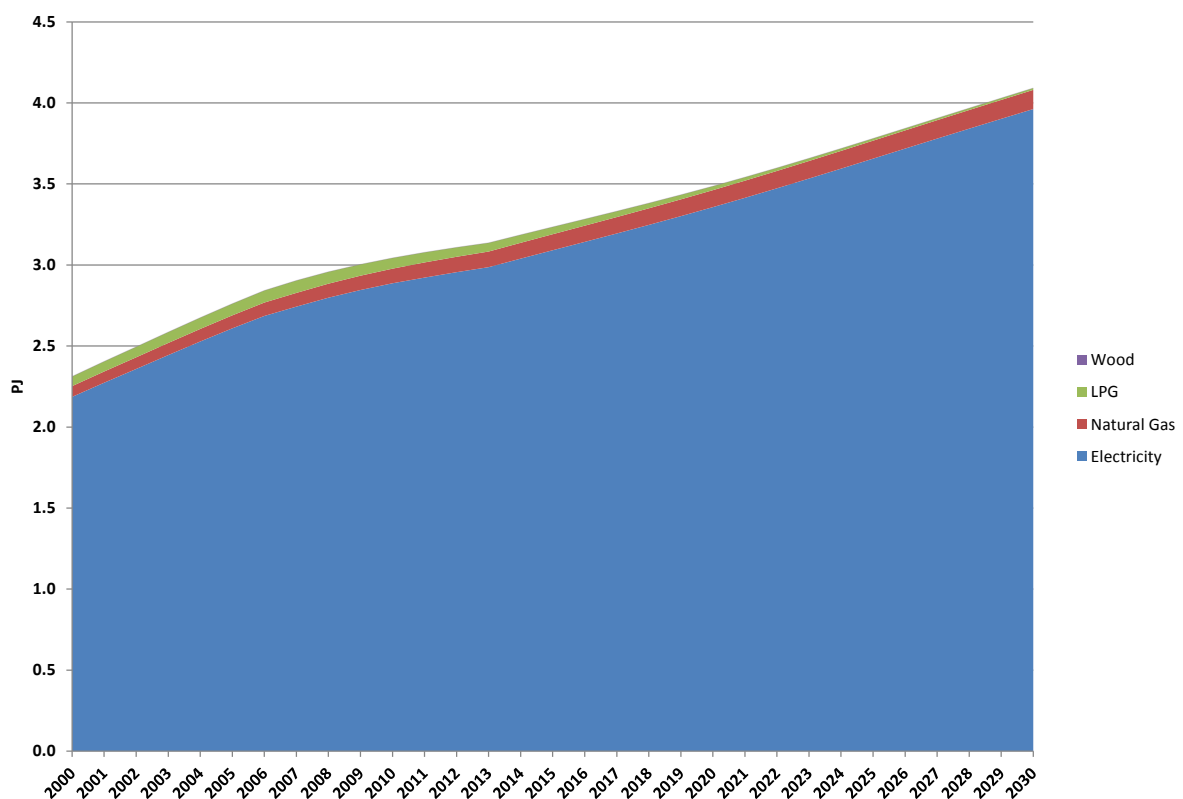
In addition to the lighting technologies mentioned above, linear fluorescent lamps are used in the residential sector but they have only contributed a relatively small proportion of the total lighting energy use. This reflects both their relatively high energy efficiency but also because their total numbers remain relatively small.

## Cooking

Figure 27 below shows that cooking energy is supplied by three fuels: electricity, natural gas and LPG. The total energy use in 2014 was 3 PJ, of which 95% was supplied by electricity. Energy use by cooking has grown steadily since 2000 and is expected to continue to grow, but almost all this growth is from growth in electric cooking. The use of natural gas is stable throughout the study period but the use of LPG is in decline.

There may also be a small amount of cooking undertaken on wood-fuelled stoves, but no information was available on the number of stoves and their energy use was considered likely to be immaterial and not modelled.

**Figure 27: National Cooking Energy Use by Fuel**



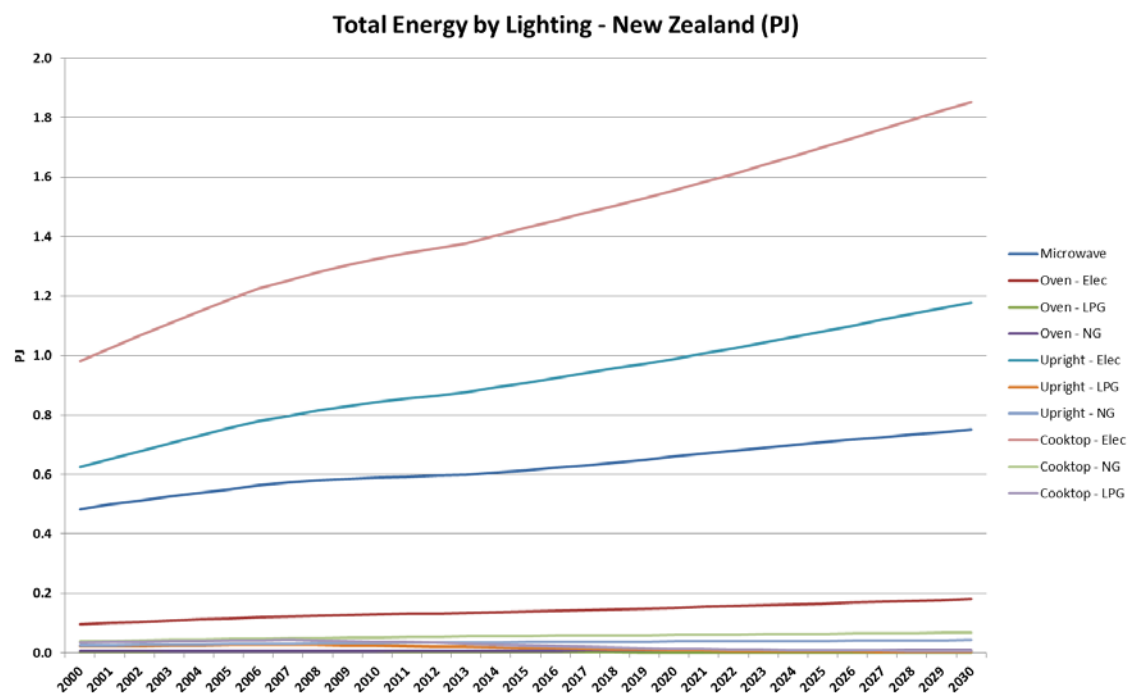
**Figure 28: National Cooking Energy Use by Product Group**

Figure 28 shows the energy contribution of different types of cooking appliances to the total energy use of cooking. Currently the largest single user of energy is electric cooktops, which is followed by electric upright cookers and then microwave ovens.

## Standby Power

Standby power is not an energy end-use as such but, as it is known to add significantly to the electricity in the average home, it is separately reported here.

**Figure 29: National Standby Energy Use by End Use**

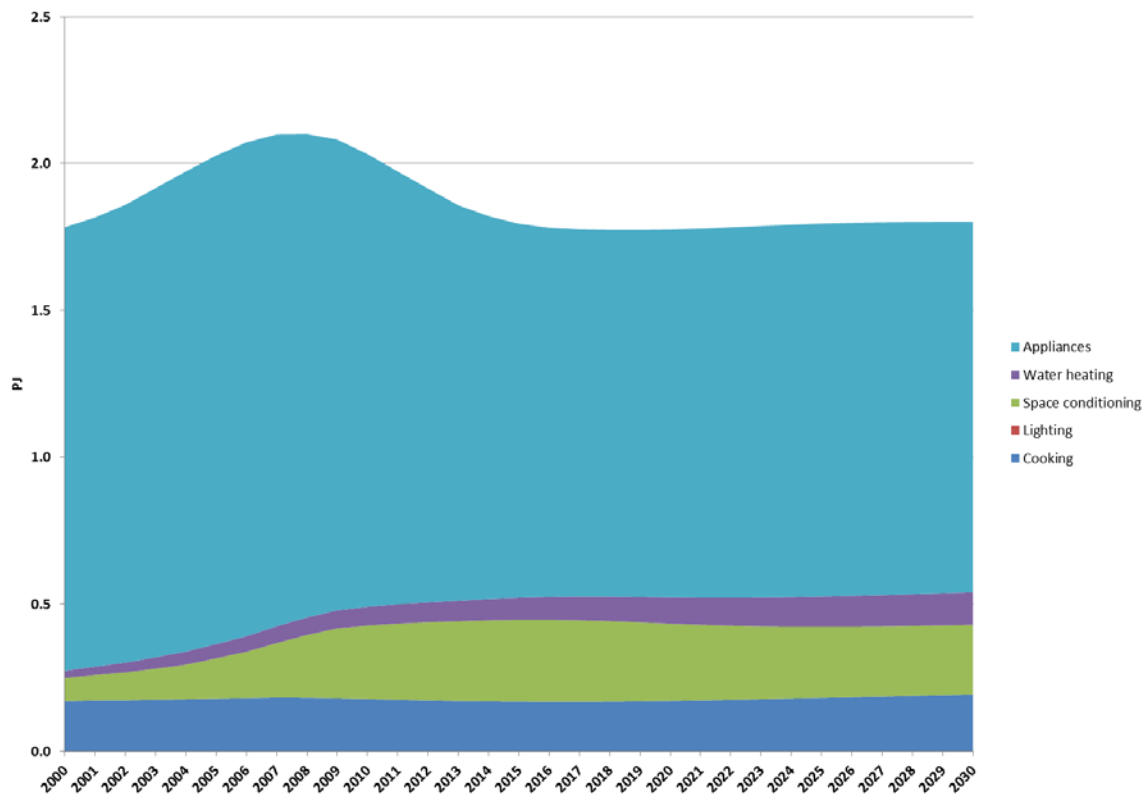


Figure 29 shows total standby power use slowly growing from around 1.8 PJ in 2000, rising until the mid-2000s and then starting to decrease again in 2010. It is projected to remain stable at around 1.8 PJ from 2014. The main contributor currently to standby power is the appliance products, followed by space conditioning then cooking. The small contribution from water heating will have started with the introduction of electric controls and ignitions to instantaneous gas water heaters.

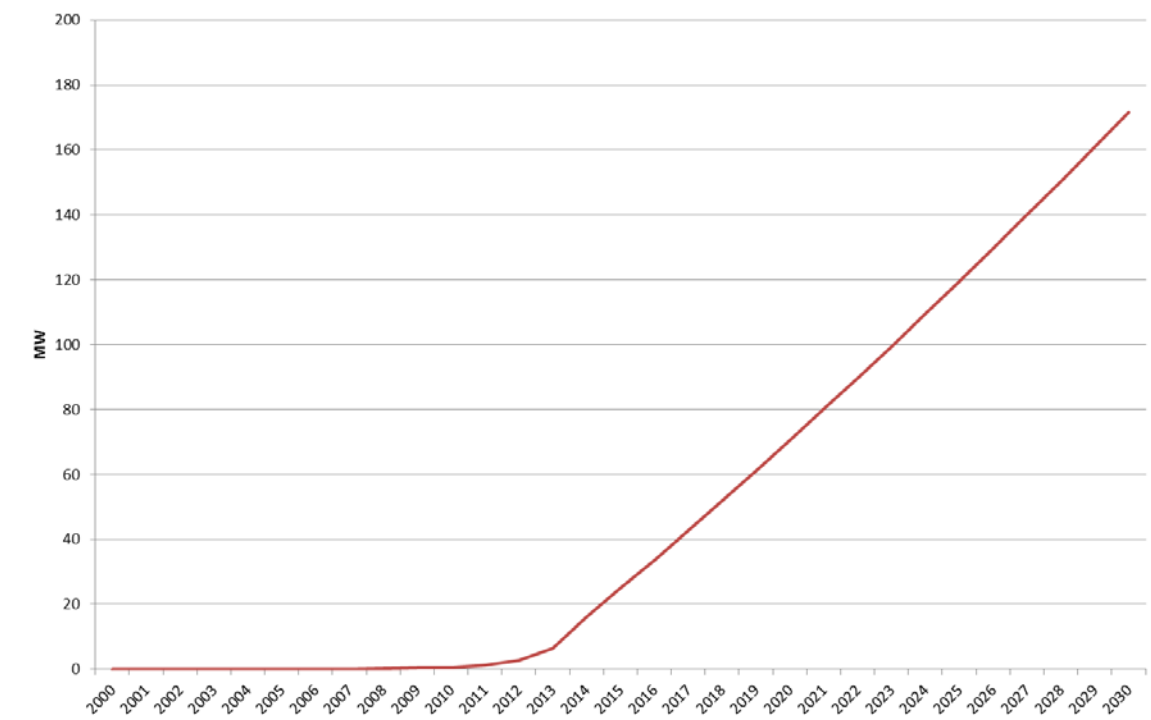
The contribution from appliances to standby power use peaked in 2005-2007 and has been in decline since, but is expected to remain stable throughout the projection period. The contribution from space conditioning and water has been growing since 2000 and is expected to continue to do so.

On a per household basis, standby power is estimated to use 1.13 GJ p.a., which is 3% of the total energy use of the average dwelling in 2014, and 4% of its average electricity use.

## PV Generation

PV generation is also not an energy end-use, but is presented here as it will increasingly contribute to the net energy consumption of New Zealand homes. Figure 30 shows the amount of PV generation was very small before 2012, after which it has rapidly grown to around 16 MW in 2014. This increase in installation numbers may be the result of recent decreases in equipment costs. Assuming the growth in PV generation installation observed over the last two years continues, gross PV generation is projected to grow to 170 MW by 2030.

**Figure 30: National PV: Gross Generation (MW)**



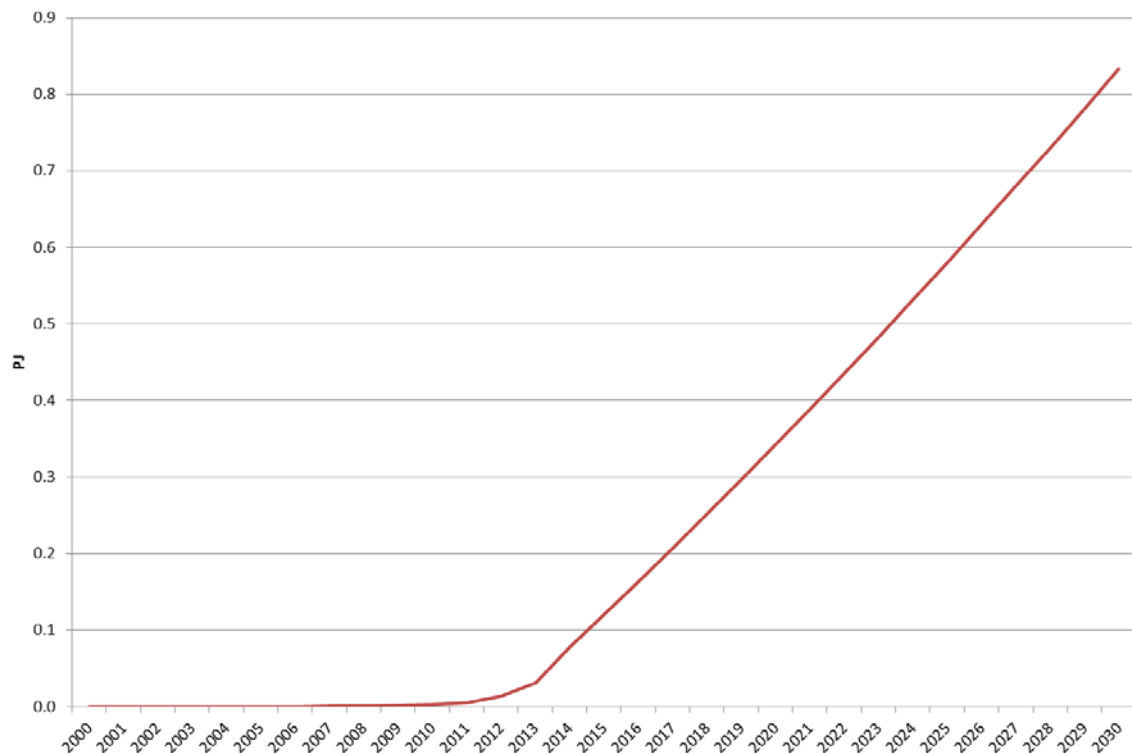
**Figure 31: National PV: Gross Annual Energy Output**

Figure 31 shows that annual gross PV energy generation has grown and by 2014 was 80 TJ p.a. and is expected to increase to 830 TJ p.a. by 2030.

The projected growth in generation capacity and energy output is based on the growth in sales and stock of PV systems. Growth rates for these projections are based on the sales and growth in sales over the last four years. Using these assumptions, the ownership of PV systems in New Zealand is projected to be 2.5% of households by 2030. However, the installation of PV generation will be an aspect of residential energy behaviour which can be strongly influenced by government incentives, regulations, electricity prices, technology costs and market players, so projections could significantly vary from those presented here.

## *5. Validity of RBS Results: Top-Down Comparison*

In order to check the accuracy of the RBS model results, it was necessary to compare them to alternative estimates of historic residential energy use. Such estimates are invariably measures of the aggregate energy use of the residential sector nationally, usually by fuel type. The sources of such data are the Ministry of Business, Innovation and Employment (MBIE 2014) (MED 2012).

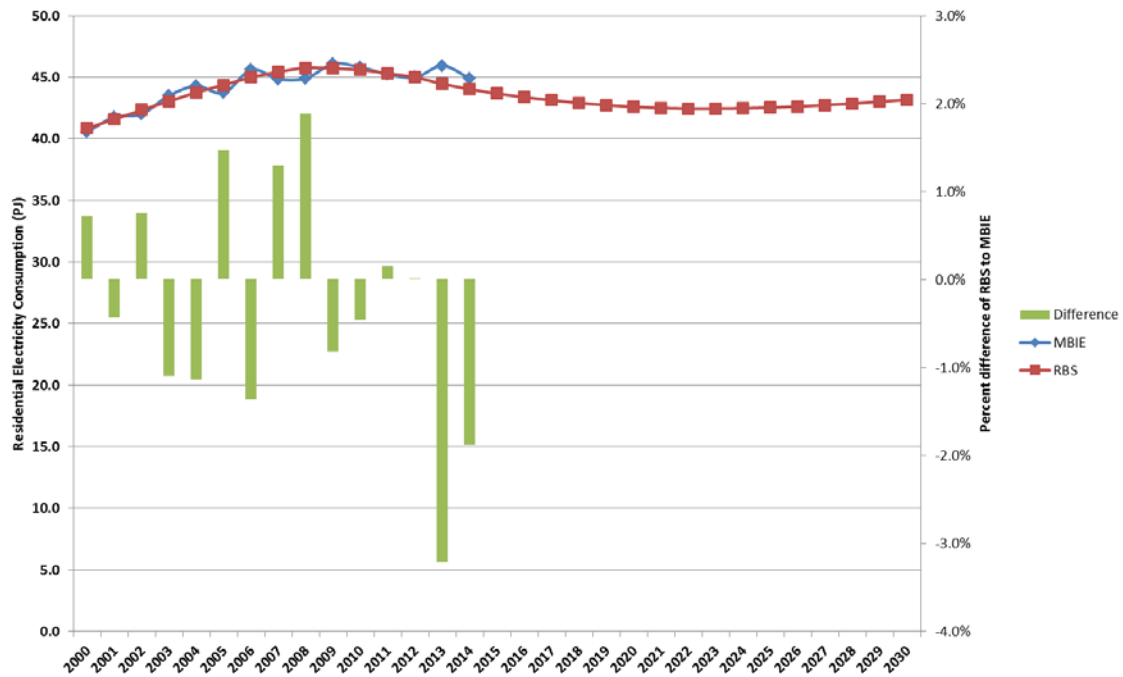
It is worth noting that the RBS model cannot be expected to produce 100% accurate estimates of energy use in a given year, as energy use will vary annually for many reasons, such as economic conditions, energy price variations and especially weather variations. Weather variations alone potentially could produce variations in energy use approaching 4%<sup>16</sup>. As the RBS estimates do not include any allowance for weather impacts in the energy estimations, some annual variation between the RBS results and actual, measured energy use p.a. is to be expected.

### *Electricity Use Comparisons*

The RBS and MBIE estimates of national residential electricity use were compared for the period 2004-2014, in Figure 32 below. For all the years compared there was an acceptable difference of no more than 3% in the estimates, and for most years a difference of 2% or less was found. In addition, the MBIE figures for recent years support the RBS's identification of a downward trend in energy consumption.

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<sup>16</sup> As space conditioning is around 40% of total residential energy use and assuming a conservative +/-10% variation in degree days p.a., this could potentially result in a 4% variation in energy use from variations in space conditioning alone.

**Figure 32: Comparison of MBIE and RBS Estimates of New Zealand Residential Electricity Consumption**

This finding clearly indicates that the RBS is providing valid estimates of national residential electricity consumption. The differences between the RBS and MBIE estimates are well within the boundaries of the variation in energy use that would be expected due to weather variations and other factors.

Given that electricity forms 74% of the current total residential energy use, this high degree of consistency with the top-down electricity data strongly supports the overall modelling accuracy of the RBS for New Zealand.

### *Gas Use Comparisons*

MBIE data was used as the basis for top-down natural gas consumption data and is shown in Figure 33. The comparison showed the RBS results were within a maximum of 10% of the MBIE estimates for the last five years and within 15% since 2007. This is an acceptable variation given that natural gas use will be strongly influenced by weather variations.

The MBIE estimates of use and RBS model outputs varied by less than 15% since 2007, which is an acceptable variation given the extent annual weather variations will affect natural gas use. However, there was a much higher variation of up to 40% for results for 2000-2006. This may be due to significant gas price change in 2007 leading to a major change in behaviour regarding gas usage. As the RBS model is based on more recent usage behaviour, this may have resulted in the model under-estimating natural gas consumption pre 2007 when usage behaviour was different.



**Figure 33: Comparison of MBIE and RBS Estimates of New Zealand Residential Natural Gas Consumption**

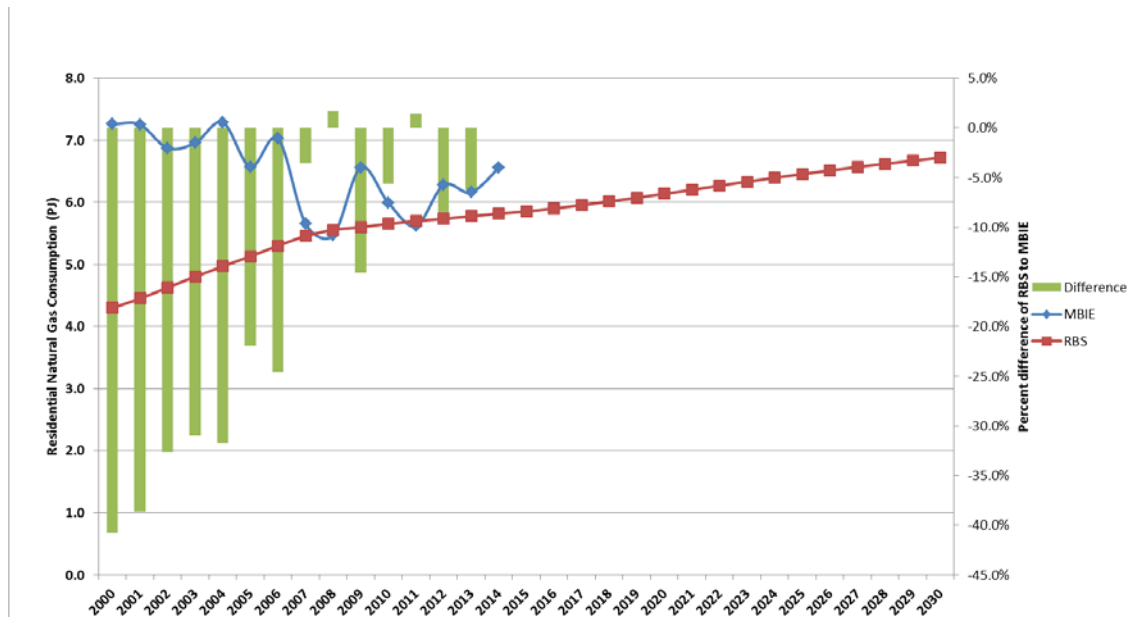
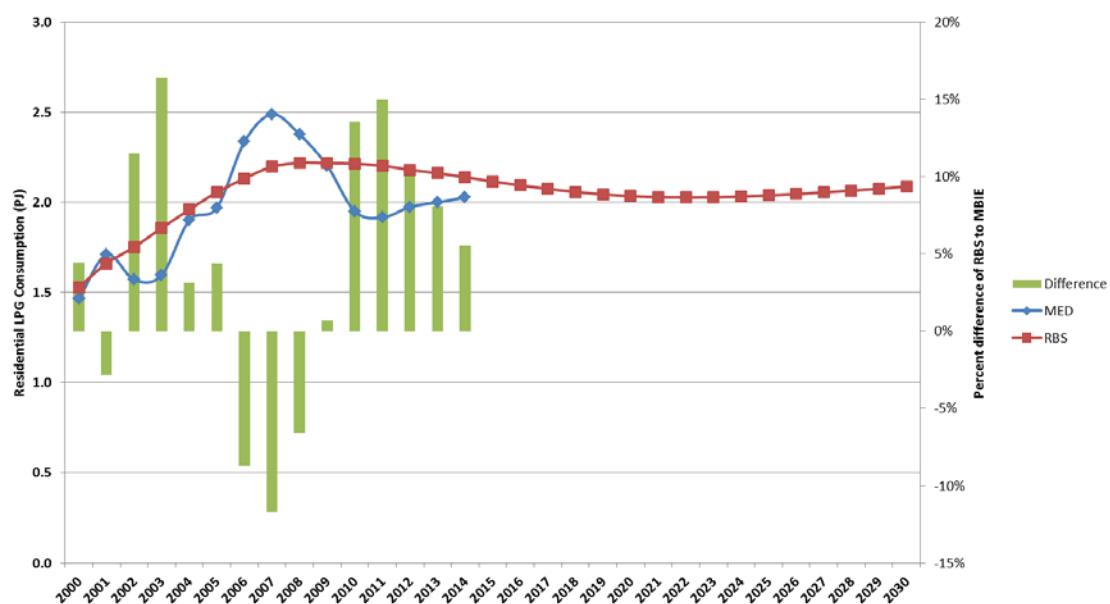


Figure 34 below shows the MED LPG top-down data comparison to the RBS results. These results show the RBS results to be within a maximum of 16% variation from the top-down data. This is an acceptable variation given that LPG use will be strongly influenced by weather variations, and the MED data is based on their forecast from 2011. The MBIE data did not provide a residential breakdown of LPG energy use, so older data was used.

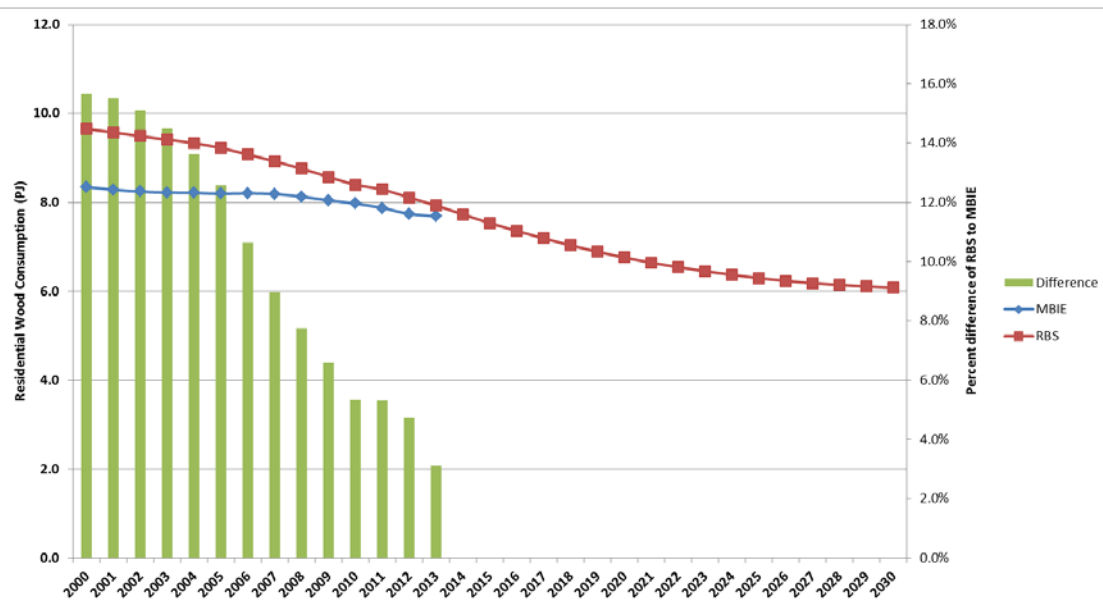
**Figure 34: Comparison of MBIE and RBS Estimates of New Zealand Residential LPG Consumption**



## Wood Use Comparisons

Again MBIE data was used as the basis for top-down wood consumption data and is shown in Figure 35. This comparison showed a maximum variation of 16%, the same as found for LPG and much lower variation for recent years. This is an acceptable variation given that wood use will be strongly influenced by weather variations, and due to the difficulty of accurately estimating wood usage.

**Figure 35: Comparison of MBIE and RBS Estimates of New Zealand Residential Wood Consumption**



## *6. Data Sources, Input Processing and References*

### *Introduction*

Data used as input for the model came from a variety of sources and, though there are some common sources used for most products, such as Statistics New Zealand census and industry sales data, there is considerable variation in data sources for many products. Whatever the data source, it is rare that data obtained can be directly used as an input to the model and usually it must be processed in some way so as to become applicable and in the right format to be used.

The nature of this input processing varies with the product and data sources concerned, and with the type of data input required by the model. For example, sales data on non-ducted air conditioners may need to be aggregated across equipment sizes, household numbers may need to be estimated for the years between censuses, or average television size may need to be estimated from data on model registrations in a given year.

This following section provides an overview of the type of processes used for preparing data so it may be entered into the RBS model. Typical data sources and input processing for the following critical inputs to the model are described:

- Sales
- Usage
- Efficiency
- Life
- Standby when relevant.

The data sources for the Building Stock module are also described. This section is then followed by a list of data sources and references used in preparing the RBS. Further details of data sources and input processing are provided in the Technical Appendix.

### *Data Sources and Input Processing*

#### *Sales*

Sales data is a key driver of the RBS model as it is used to determine the stock level for each product modelled. The two key sources of sales data are:

- Market and industry research on sales figures
- EECA collected sales data on MEPS and Labelled products
- Surveys of product penetration/ownership in the general population

Sales were derived principally from EECA product registration data. Such sales data was then supplemented by sales estimates reported in a variety of reference sources, including

the RIS and Product Profile documents from the Department, ECCA and E3, and also occasionally by interviewing appliance suppliers.

Surveys of product penetration in the general population are an alternative source of data, and generally this penetration information comes from Statistics New Zealand (SNZ) census data and also the BRANZ HEEP studies (BRANZ, 2006). The penetration data is converted to an estimate of the total stock of the relevant product in a series of years by multiplying the penetration of the product by the number of dwellings and products per dwelling in New Zealand in the relevant years. The sales numbers are then 'backcast' by a program that calculates what sales would be required to produce those stock numbers, allowing for the typical operating life of the product concerned.

In some cases New Zealand data was not available, or only available for a limited time period, in which case Australian penetration data or Australian sales trends were used to estimate New Zealand penetration and sales. Such Australian sales and penetration data came from the Australian Bureau of Statistics (ABS) and from a few key suppliers of market research data, including GfK and BIS Shrapnel<sup>17</sup>.

Penetration data is also used to develop estimates of stock and ownership levels which are compared to the output of the RBS modelling, when based on sales data, to double check the sales data and model outputs.

## *Usage*

Data on appliance use comes from a variety of sources, both New Zealand and Australian. The BRANZ HEEP studies (BRANZ 2006) were a main source of New Zealand usage data. Australian survey data such as the ABS 4602 Surveys (1999-2014) previously mentioned and the ABS Household Energy Consumption survey (HECS, 2013) were prime sources of such data, especially for space conditioning appliances.

Other sources include water usage surveys, for appliances also using water, overseas research, such as a USA DOE study (DOE 2005) on microwaves. A range of Department sources were also used, such as RIS and Product Profiles conducted on residential appliances, when these sources contained information on usage.

Again there was less New Zealand specific usage data than was available for Australia, so when New Zealand data was not available Australian data was used instead. In the case of space conditioning, a comparison of the heating degree days between Australia and New Zealand cities, and the proportion of population in the New Zealand cities/regions, was used to estimate a population/climate weighted ratio between average Australian and New Zealand heating usage. This was then used to derive New Zealand usage values from Australian usage of particular heating product types.

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<sup>17</sup> These are market research firms that track sales of a wide range of residential products.

The usage data collected would usually be presented as daily hours of use, hours used per week or number of loads done per week. In most cases this data would be converted to annual hours of use or number of cycles conducted annual (e.g. for dishwashers).

Usage rates sometimes vary with locality and such variations were included and input into the RBS model where relevant.

### *Efficiency*

When available, sales weighted efficiency data was used to estimate average efficiency for specific products. Such data was generally available when the product was subject to Minimum Energy Performance Standards (MEPS) requirements or mandatory energy labelling requirements and sales data could be sourced. So this high quality efficiency data was available for air conditioning equipment, most water heaters, white goods, some information and home entertainment products and PV systems. New Zealand specific values were available for space conditioning and water heating so these were used, and Australian values were used for the remaining equipment.

When sales weighted efficiency was not available, the main source of efficiency data was research reports. These included Department of Industry and Science sources, such as RIS and Product Profiles conducted on residential appliances. Overseas research was then used for products where Australian or New Zealand data was not available, which was mainly for miscellaneous appliances. In addition, for some products such as resistive electric heaters, data was not required as it is known that these are 100% efficient.

Once efficiency data was obtained on a product it was converted into the appropriate metric to be used in the RBS model and input.

### *Life*

The operating life of products was obtained from a wide variety of sources. Department sources, such as RIS and Product Profiles conducted on residential appliances, were the first source sought and provided information for the majority of appliances. Research papers prepared overseas, such as by the USA Department of Energy, were also used.

Occasionally market research data, concerning purchase intentions or age of products discarded, was found which could be used to determine operating life. Information was obtained for some products from the previous RBS (EES 2008). Occasionally also when no data was available, then estimates of operating life were made based on the life of comparable products and the known stock and estimated sales of products.

In almost all cases the same life was used for both Australian and New Zealand appliances, but there were a few products, such as New Zealand electric storage water heaters, which had different lives than the Australian equivalent. In these cases the New Zealand products were input as separate products into the RBS model

## *Standby*

For products subject to Minimum Energy Performance Standards (MEPS) requirements or mandatory energy labelling requirements, standby power data has been collected and is provided in the Energy Rating registration data, if relevant to the product. Such data was available for air conditioning equipment, most water heaters, white goods, some information and home entertainment products and external power supplies.

Another prime source of standby data was the series of residential standby energy surveys conducted by the Department both in stores (E3 2011) and in the field (e.g. EES 2011) and the Standby Power Consultation RIS (EC 2013). Occasionally, when no data was available, estimates of standby power consumption were made based on that of comparable products.

## *Building Stock Model*

The building stock model required different data inputs and calculations. The building stock model was developed in several stages, with the focus of the modelling in each stage being as follows:

- Dwelling stock numbers by dwelling type and by occupancy
- Dwelling construction, as it related to thermal efficiency
- Calculation of average relative thermal efficiency

Dwelling stock numbers, by housing type, were available from the SNZ census data, (SNZ 1986, 1991, 1996, 2001, 2006 and 2013). SNZ also provided both household projections and population projections for the project projection period (post the 2013 census) to 2030. Household projections were used for estimating dwelling numbers, allowing for the ratio of households to dwellings.

The key data required on dwelling construction were the penetration of insulation in housing, obtained from the SNZ data, and the annual number of new dwellings by building type, which was derived from the dwelling stock numbers.

The relative thermal efficiency of uninsulated and insulated pre-1978 dwellings, and then for regulated dwellings was obtained from AccuRate research undertaken for six climate zones in New Zealand, by Sustainability House for the current RBS.

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