Residential Energy Baseline Study: Technical Appendix

Prepared for

Department of Industry and Science

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Methodology – Further Details

Introduction

This Methodology section provides details of the methods used in the RBS model for users of the RBS report and model. The major components of the Methodology have been described in the project report, and should be read first. The sections covered in the Methodology section of this Appendix include:

- Space Conditioning Method- Building Shell Impact
- Peak Demand Method
- Model Calculations and Data Use
- Forecasting- Model Inputs for 2015-2030.

Space Conditioning Method- Building Shell Impact

As previously described in the main report, there are two main components of the combined modelling approach used in the RBS model, these being the engineering algorithm modelling and the building thermal modelling. The following sections describe the rationale for using a combined modelling approach and the two aspects of the modelling in further detail.

Choice of Method

There are many methods for estimating space conditioning energy use and demand, but broadly they can be divided into the measurement/metering based approaches (billing, metered data, hours of usage analysis), building thermal modelling, and the engineering algorithm approach as identified by Stern (2014). In Australia and New Zealand there appears to be insufficient data to use measurement/metering based approaches, but the building thermal modelling, using AccuRate software developed by CSIRO, and engineering algorithm approaches have been used to predict both energy use and demand.

A thermal modelling approach appears to have been used in the previous national residential baseline study (EES 2008), combined with some elements of an engineering algorithm approach, though the report does not make it clear how these two approaches were integrated or executed. The main emphasis of the EES approach seems to have been on estimating space conditioning energy loads from data on building shell thermal efficiency, using AccuRate modelling, while making allowance for other variables such as locality, building size, building structure, zoning, thermostat settings, equipment type, equipment efficiency and occupancy. However there was insufficient information supplied in the EES (2008) report to enable this approach to be replicated or for the validity of its underlying calculations, algorithms and assumptions to be examined. Thermal modelling has been used in numerous other energy studies, but it does not appear that it has been used for national studies forecasting energy use and demand apart from regulatory impact assessment of the potential impacts of building energy efficiency standards.

In comparison, the engineering algorithm approach has been widely used in national studies of the energy use of many different types of appliances, such as the studies undertaken in the preparation of regulatory impact statements (RIS) on the potential impacts of minimum energy performance regulations, including space conditioning appliances (e.g. EC 2010, E3 2011, EC 2012, E3 2012). The underlying approach, calculations, algorithms and assumptions used in these RIS models, plus their energy usage estimates and forecasts, have been extensively examined and accepted by stakeholders. This experience suggests there is broad community support for the use and overall accuracy of the engineering algorithm approach in energy usage studies. A comparison of the energy consumption estimates from EnergyConsult's engineering algorithm model developed for a potential review of the current air conditioning MEPS (EC 2014) and the thermal modelling based findings from the previous residential energy study (EES 2008) also showed a close relationship between the model outputs, suggesting the use of the engineering algorithm can achieve at least a similar degree of accuracy to a thermal modelling approach.

The main limitation of the engineering algorithm approach in the modelling for the RBS was that on its own this approach does not allow the influence of building shell efficiency to be considered in the energy usage calculations. Consequently it was decided for the RBS to use a mixture of the engineering algorithm and the thermal modelling approaches, but with greater emphasis placed on the engineering algorithm aspects of the approach. This approach estimates the energy use and demand using engineering algorithms (the Unit Energy Consumption approach previously described), and then adjusts these estimates according to outcomes from thermal modelling as required. (See Combined Approach: Space Conditioning Method, for further details). This combination of approaches has enabled the modelling and examination of the impacts of space conditioning appliances, captured in the engineering algorithms, and the impacts of the buildings in which the appliances are used, captured by the thermal modelling, to be incorporated in the modelling of the space conditioning energy use.

The key strength of this approach has been the emphasis on the use of engineering algorithms allows for the large amounts of accurate data and research available on the nature, performance and usage of space conditioning equipment to be incorporated into the modelling. This will help to make it possible to assess the accuracy of the modelling and for its underlying data to be verified. It also allows the calculation of energy use and demand to be undertaken in a transparent manner that is consistent with the method used for all other appliance types.

The use of thermal modelling approaches allows the impact of changes in building shell efficiency in different climates to be estimated and can be used to adjust engineering algorithm based estimates accordingly. However, by not using the thermal modelling/AccuRate as the key mechanism for estimating space conditioning energy use and demand, this approach avoids the limitations of the thermal modelling. Such limitations include:

- AccuRate contains numerous default settings and some of these, e.g. occupancy, zoning and thermostat settings, are known to be much more variable across households in reality (EES 2008), which means there is an array of factors which must be researched/estimated and whose eventual accuracy and impacts are unknown
- To use the thermal modelling/AccuRate rating driven approach it is necessary to have statistically valid research on the housing in each locality which provided detailed information on the design, construction, orientation, insulation, glazing and dimensions of each housing type but currently this information does not exist
- There is no strong empirical evidence that shows estimated building shell efficiency (e.g. as determined from AccuRate assessments) is directly or clearly linked to space conditioning energy use, e.g., see a recent CSIRO study, (Michael Ambrose et al, 2013), of 414 homes across Australia.

Nevertheless, despite these limitations, the decision to use AccuRate modelling results as an input into the space conditioning module allowed the impact of changes in building shell efficiency to be estimated, explored and incorporated into the RBS model.

Combined Approach: Space Conditioning Method

The Unit Energy Consumption in its relevant form was stated as:

*UEC = Hours of usage * Unit Capacity * Unit Efficiency*

There was extensive information available on the Unit Capacity and Unit Efficiency of space conditioning equipment, so the information is available 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 information was also available in New Zealand (e.g. MfE, 2005). For the year in which the usage data was obtained, this data combined with information on the average unit capacity and average efficiency should provide an accurate estimate of average UEC for specific different equipment types.

However, before and after the year in which space conditioning usage data was available, the average thermal efficiency of housing stock will vary, as the proportion of insulated and more efficient houses in the housing population changes. It was reasonable to assume that will affect the average *UEC,* as the goal of introducing more efficient housing was to reduce energy consumption. Assuming unit capacity and efficiency were held constant, for the sake of calculating the impact on the UEC formula, this would mean that for the *UEC* to vary the *Hours of usage* would have to vary.[1]

Consequently a *Usage Adjustment Factor- Building Shell* (*UAF Building Shell*) was added to the *UEC* formulae to allow for this variation in usage behaviour in response to changes in the building stock. The Unit Energy Consumption can then be stated in it revised form as:

UEC = Hours of usage[2] ** UAF Building Shell * Unit Capacity * Unit Efficiency*

The *UAF Building Shell* can then be determined for any given year based on the difference between the AccuRate predictions of heating and cooling energy requirements for the housing stock composition in any given year, in each relevant locality/climate zone, compared to the base year. Average heating and cooling energy requirement can be determined for any given year using information on the composition of the housing stock in any given year, combined with AccuRate modelling or other information on AccuRate predictions of heating and cooling energy requirements. The ratio of the energy requirement in a given year versus the base year will determine the *UAF Building Shell*.

For example, if in Melbourne the average NatHERS star rating of housing went from 3.0 in the base year to 3.5 stars in a later year, the *UAF Building Shell* for the later year might be 230/271 MJ/m^2 which is 0.85.

This approach leaves the thermal efficiency of the building as a variable which influenced the *UAF Building Shell* and which varied across building stock over time, across dwelling types, by locality/climate zone and with building regulation intervention, all of which are topics of interest within the RBS. The implication is the use of the above UEC method allowed building shell thermal efficiency in different localities/climate zones to be included in the modelling of space conditioning energy use, and the method supported the option to explore the impact of variations in building shell thermal efficiency independently from variations in appliance efficiency.

However, the relationship of building shell thermal efficiency to the *UAF Building Shell* is a bit more complex than described above. As noted in the main report, the CSIRO study (Michael Ambrose et al, 2013) showed there was a strong relationship between AccuRate/NatHERS ratings and heating energy use, but a negative or insignificant relationship with cooling loads. This indicated that the *UAF Building Shell* in any given year needs to be varied by the nature of the space conditioning (heating or cooling) and possibly by locality, such that:

UAF Building Shell = Energy Load in Given Year/Energy Load in Base Year

** Relevance Factor*

[1] Note: It is recognised that for inverter systems the situation is more complex, as both operating capacity and efficiency can vary, but for modelling purposes these will be assumed to be constant and usage to vary.

[2] The "hours of usage" will be 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.

where the Energy Load is the AccuRate/NatHERS predicted space conditioning load for the average house in the relevant locality.

The results of the CSIRO study were used to develop relevant factors for the current study, but if in the future research shows a different relationship is relevant, then this use of a relevant factor in the RBS model will mean the model can be modified to change the influence of the UAF as required.

Building Stock Model and Building Shell Efficiency

In order to determine the potential influence of building shell efficiency on space conditioning, via the *Usage Adjustment Factor- Building Shell*, it was necessary to develop a method for obtaining AccuRate measurements of the space conditioning energy requirements of the 'average' dwelling in each year of the forecast period. To determine such an average it is necessary to collect information on what constitutes the building stock, which in turn means the different type of housing need to be categorised and information collected on each building category. The key information to be collected and analysed is the AccuRate assessments of the key categories of houses, the numbers of such houses. Doing this for each year of the forecast period requires:

- Choosing the categories of housing
- Developing a building stock model of the categories of housing
- Using AccuRate measurements of the building shell efficiency of representative categories of housing
- Determining the weighted average energy requirements.

The categories of housing types chosen correspond to the main divisions in housing types which significantly affect their building shell efficiency. These dwelling divisions include Class 1 versus Class 2, low-rise versus high-rise[3] Class 2, pre-regulation (i.e. before building shell regulations) versus post-performance housing, different regulatory requirement (i.e. star ratings) periods for performance housing, insulated versus uninsulated pre-performance housing. It is recognised that there are numerous construction variations in pre-performance housing besides the presence of insulation, but the presence of insulation is by far the biggest factor influencing the thermal efficiency of the average dwelling, hence this was used to categorise the pre-performance housing.

Using these divisions housing was divided into building categories as follows:

- Class 1, pre-regulation, insulated
- Class 1, pre-regulation, uninsulated
- Class 2, low-rise, pre-regulation, insulated

[3] Low-rise Class 2 buildings refer to buildings of 1 to 3 stories and high-rise buildings are greater than 3 stories.

- Class 2, low-rise, pre-regulation, uninsulated
- Class 2, high-rise, pre-regulation, insulated
- Class 2, high-rise, pre-regulation, uninsulated
- Class 1, 3 Star
- Class 1, 4 Star
- Class 1, 5 Star
- Class 1, 6 Star
- Class 2, low-rise, 3 Star
- Class 2, low-rise, 4 Star
- Class 2, low-rise, 5 Star
- Class 2, low-rise, 6 Star
- Class 2, high-rise, 3 Star
- Class 2, high-rise, 4 Star
- Class 2, high-rise, 5 Star
- Class 2, high-rise, 6 Star

A stock model was then developed that kept track of the number of dwellings in each building category in each year of the RBS forecast period. This was separately done for each State.

The stock model was designed to also contain the measurements of the building shell efficiency for each of the building categories. The building shell efficiency measure used was the average NatHERS building shell Star rating of the building category, which directly relates to an AccuRate measurement of the space conditioning energy requirement for the building category.

As discussed in Data Sources, Input Processing and References, a wide variety of research is available on the building shell efficiency of dwellings of different types in Australia, and this research was used to obtain the building shell efficiency measurements used to populate the building stock. However, the research used to supply the building shell efficiency measurements of both insulated and uninsulated pre-performance housing (i.e. the vast majority of the housing) was obtained from "*The Value of Ceiling Insulation: The impact of retrofitting ceiling insulation to Australian homes*" (EES 2011B). The underlying research for this study was AccuRate modelling of representative housing designs in the ten climate zones used in the previous RBS (EES 2008), which means the AccuRate measurement approach used was consistent with that of the previous RBS, and with the department's requirements regarding the use of AccuRate. For the regulated housing, no additional AccuRate measurements or research was required as by definition these dwellings had to meet minimum Building Code requirements, which could directly be used as a conservative estimate of the building shell efficiency for these dwellings.

The resulting stock model therefore contained both the dwelling numbers and building shell efficiency measurements for each building category per year, allowing the weighted average building shell efficiency per year across all the building categories to be calculated using the data available for each year.

The space conditioning energy load that corresponded to these average star ratings was then determined from the star rating bands table (Star Bands, 2015), which defines the star ratings in terms of the forecast space energy use per m^2 for conditioned dwellings.

Finally the *Usage Adjustment Factor- Building Shell* for a given year was calculated from the ratio of the predicted space conditioning energy load compared to that in the base year, 2012.

The Demand Adjustment Factor (DAF) was defined as equalling the Usage Adjustment Factor- Building Shell, i.e. if the Usage Adjustment Factor- Building Shell indicated that a 10% decrease in usage had occurred, then a 10% decrease in the DAF was also assumed. However, the ratio of the DAF to the Usage Adjustment Factor- Building Shell can also be varied if required.

Peak Demand Method

As described in the main report, the underlying formulae for calculating peak demand for each product in any given year is:

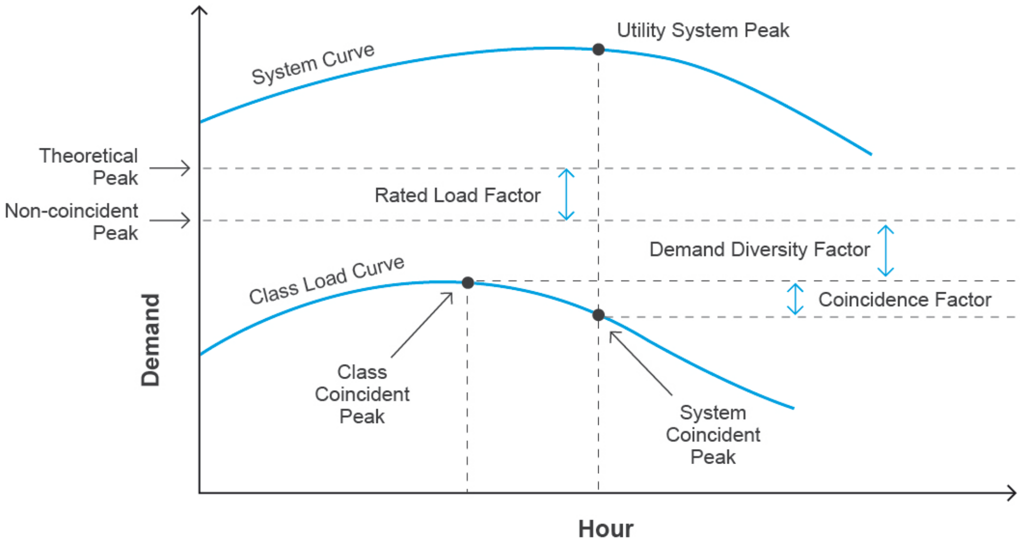
$$kW\text{Demand} = units \times kW/unit \times RLF \times DF \times CF$$

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.

Some of these terms are illustrated in Figure 1 by Stern (2013) below and defined as follows:

Figure 1: Demand relationships



Source: Stern 2013, cited Jacobs 1993

- **Peak period** is the period during which peak demand savings are estimated, and corresponded to the period when commonly extreme system peaks occur. The two periods modelled are 5.00pm-9.00 p.m. during extremely hot summer periods and 5.00pm-9.00 p.m. during extremely cold winter days.

- **Rated load factor (RLF)** is the ratio of maximum operating demand of a population of equipment to the rated input power. It is the ratio of non-coincident peak to theoretical peak. For example, a population of air conditioners which can operate above their rated input power could result in a RLF of greater than 1.0.

- **Demand diversity factor** is the ratio of the peak demand of a population of units to the sum of the non-coincident peak demands of all individual units. This factor takes into account the fact that while an individual technology may contribute a certain amount of demand, those technologies are not all operating at the same time throughout a peak period. Some equipment may not be switched on, either due to the household not choosing to use it or it being in an unoccupied dwellings, and the duty cycles of other equipment may reduce their total operating demand. The energy efficiency of building shell could also potentially affect either of these variables and hence the demand diversity factor for space conditioning equipment.

- **Coincidence factor** is the fraction of the peak demand of a population that is in operation at the time of system peak. Thus, it is the ratio of the population's demand at the time of the system peak to its non-coincident peak demand. As the RBS is only modelling the residential peak demand, the coincidence factor is by default 1.0.

As the RBS is only modelling the residential peak demand, the coincidence factor is by default 1.0 and effectively can be ignored in the calculation of the peak demand. This leaves four main variables being used to calculate the peak demand per product and these are used in the RBS model as follows:

- Units: This is the number of products in the stock in any given year. This number is drawn from the product stock model.

- kW/unit: This is the average power of the product and is a direct input into the RBS model. Usually the average power of the product equal to the average of the maximum power inputs of the different models of the product in the market, with the maximum power inputs indicated on the registration plate of the products or in their registration details. Occasionally average power will be the average of the power input of a population of units, e.g. refrigerators, to allow for the cycling on and off of the units or to allow for a varying power draw from the units depending on their use.

- RLF/ Rated Load Factor: This factor is used to express the ratio of a product's average power compared to its maximum input power during a peak period. For most products this will be 100%, i.e. not alter because it is a peak load event. However some space conditioning products, such as air conditioners, have the capacity to operate at greater than their average power and will do so during a peak load event, so their RLF may exceed 100%. This factor is directly entered into the model.

- DF/ Diversity Factor: The RBS model combines several sub-factors to calculate the Demand Diversity Factor. This allows the factors that influence the Diversity Factor to be separately input or calculated in the model.

The sub-factors in the Diversity Factor are as follows:

- **Occupancy Factor**: This is the percentage of units which could potentially be switched on, allowing for the percentage of dwellings occupied. This factor usually simply corresponds to the proportion of occupied dwellings in each State in a given year.

- **Saturation Factor**: This is the same factor used in the energy usage calculations for space conditioning. If there are multiple appliances in the home, then the more the number of appliances the less each additional appliance will be used. The saturation factor is calculated from penetration and ownership data on the products, with consideration also given to likely use of the product.

- **Usage Factor**: This is the percentage of appliances expected to be operating during the peak period and is driven by usage behaviour.

- **Demand Adjustment Factor**: This is the factor that allows for the influence on building shell efficiency on space conditioning to be incorporated into the estimation of potential peak demand. The value of this factor for each product equals the Usage Adjustment Factor calculated to determine space conditioning product energy use.

The RBS model allows for the input of the Saturation factors and Usage factors of all products via a matrix in the Aggregator module. Rated Load Factor and Average Power are input in the end-use module relevant to each particular product. The Demand Adjustment Factor is calculated in the Building module.

Model Calculations and Data Use

Appliance and Equipment End Use Modules

All appliance/equipment modules will have the similar basic energy end-use calculations, which consist of calculating aggregated energy use within an end-use through combining data on equipment stock with calculated Unit Energy Consumption (UEC) or Unit Power Demand (UPD). The majority of the calculations and logic behind determining energy usage and demand have been described in the main report, but further details regarding key components and elements of the data storage and calculations for these modules are as follows:

- **Stock/Sales Cohorts and Retirement functions**: The stock model was built around inputting and developing cohorts of stock for each year, based on the sales/installation of the product in the specific year. The characteristics of the products in the year, such as their average size/capacity or efficiency, were made properties of the cohort, and the numbers of products in the cohort were assigned based on sales. However, as each cohort of stock gets older, some of their numbers are retired, i.e. break down, discarded etc., so the number of products in the cohort decreases over time, though the characteristics of the cohort remain the same. The retirements in any year are determined using estimates of the average life of the products and are calculated according to logistic functions with specific values set for the percent of remaining products (i.e., 99%, 50% and 25%). These functions are similar to normal distributions, but allow for greater control of the shape of the estimated life; with some products there is evidence of longer life (such as gas space heaters which have a very long 'tail') or in the case of home entertainment products the effective life is often shorter than the service life due to rapid technology change.

- **Stock Profile and Product Characteristics**: The stock profile in any year consisted of aggregations and weighted averages of the numbers and characteristics of the cohorts from all preceding years. Stock numbers consist of the sum of all preceding sales of the product, less retirements. Average characteristics, such as average weighted efficiency, consist of the average of the characteristic for each product cohort, weighted by numbers of units in each cohort. They are built around inputting and developing cohorts of stock for each year, based on the sales/installation of the product in the specific year whenever possible. When such data is not available then estimates of average efficiency, power/energy input etc. are used based on the best data available. The stock model collects and manipulates the information about the stock cohorts in order to provide the stock profile data for each year.

- **Usage**: Usage data was collected for all products. The generalisation used in most of the modelling is that the usage will be constant for all products regardless of their cohort, however this can be adjusted if required.

- **Capacity/Size and Mode:** The model holds different data for and processes differently the energy/demand used in different modes of operation. The model uses these mode descriptors to identify standby (or non-operating) energy use so this can be separately reported and to allow for the use of different fuels in different modes. This flexible approach enables product use to be modelled with greater accuracy and to assess the impact of policy interventions affecting only one mode (i.e., the heat losses of electric storage water heaters). Although there are several different modes of operation found in appliances these have been condensed to the modes shown in Table 1.

- **Energy efficiency metric**: that can change over time to allow for modelling of the impacts of policy interventions that improve the efficiency of products sold/installed. The model has the capability to adjust the efficiency metric as the product ages (i.e., there is evidence that PV output decreases over time and this can have an effect on the output of the PV system). The default is no degradation, unless there is evidence to support a value.

- **Annual energy generation** – For the Solar PV module, the output will be annual energy generation which will be generated from the average system size by and the stock numbers by cohort in each region. Climate regions needed to be considered as this affects generation output.

The calculations were undertaken on a jurisdictional basis (state/territory/country) and by relevant climate zone where this was applicable (space conditioning, water heating, PV).

Table 1: Modes of operation used in the RBS model

Mode	Description
Operation 1	Main operation mode for all equipment and heating mode in space conditioning equipment.
Operation 2	Supplementary main operation mode and cooling mode in space conditioning equipment
Auxiliary	Auxiliary mode used by some appliances such as energy use by fans in gas heaters
Standby	The modes that are non-operating (standby/off), but consuming power.

Forecasting- Model Inputs for 2015-2030

The RBS model inputs, e.g. sales, average efficiency, size etc. for the forecasting period were produced using several approaches, as follows:

- Using modelling period trends: The RBS calculated a series of trend measurements for the input values leading up to 2014. By examining these trends, and external information on relevant product trends, post-2014 input values could be calculated so the resulting values were consistent with the pre-2014 trends. If reliable sources indicated particular trends were relevant to a product, then these trends would be used to forecast input values. In many cases the trend might be for no change, for example product size may remain constant for years, and so the RBS model parameters would be set for model input to equal that of the preceding year. In other cases the trend might indicate a consistent rate of growth or decline, and the RBS model parameters would be set so post-2014 inputs grew or decline in a manner consistent with the trend. The RBS model would then be run and the results examined to check whether the results and trends produced were consistent with pre-2015 data and trends, and that this did not produce unrealistic results when viewed in a broader context. For example, that forecast sales values did not lead to unrealistic ownership levels of the product or product group. If required, the parameters would then be altered to refine the future input forecasts and avoid such unrealistic results.

- Automatically using default growth/improvement assumptions: When the data on a product input up until 2014 suggested that the model input was following a common trend, e.g. sales numbers growing with dwelling numbers or efficiency improving at about 0.5% p.a., then default parameters were used in the RBS model to calculate future values for the inputs. For example, the sales in 2015 might be calculated as 2% higher than for the 2014 sales numbers, the 2016 as 2% higher than 2015 etc. Default values were also used when there was insufficient information to produce alternative forecasts.

  The process of creating these forecasts was the forecasts for the model inputs would initially be made using these default values and then the results examined to check whether the results and trends produced were consistent with pre-2015 data and trends, and that this did not produce unrealistic results when viewed in a broader context. When default parameters did appear to be producing unrealistic results, the parameters were then varied to correct this.

- Using external modelling: For one product group, air conditioning, forecasts had been separately modelled for other research tasks and the results of this modelling could be imported as inputs into the RBS model. Again the RBS model results were checked to ensure this did not produce unrealistic results.

Whichever forecasting approach was used, the goals of the modelling were to produce model input values consistent with existing pre-2014 trends, unless there was strong evidence not to do so, and to ensure the inputs produce realistic results. However, as is always the case when forecasting, developing the forecast inputs involved both a mixture of technique and judgement. For example, incandescent lamp sales are in rapid decline, but there is no way of knowing exactly when their sales will cease or how quickly an emerging technology like Light Emitting Diodes will be taken up. Assumptions about situations like this had to be made in order to develop the RBS input forecasts, but these were judgement calls and it is recognised alternative assumptions could have been made and justified.

Another key assumption was made that affected the RBS and that was that no new regulatory energy efficiency requirements will be introduced. It is highly likely that this assumption will be incorrect, but using this assumption is better than the alternative of attempting to guess the nature of future regulations affecting residential products.

Despite these qualifications, the forecast inputs to the RBS model are all considered reasonable, consistent with all relevant pre-2014 trends and produce feasible and realistic outcomes.

Data Sources, Input Processing and References

Introduction

The following section aims to document in greater detail the data sources and the main data processing methods that have been used to produce the RBS model inputs[4]. The data sources and input processing for the following critical inputs to the model are described:

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

Obviously these data sources are only applicable for the modelling period, 2000-2014, as this is when modelling of energy use could be undertaken using 'actual' data on sales, efficiency etc. All model input for the forecasting period, 2015-2030, rely on forecast inputs, and the processes used to create such forecasts are described above. In addition, some details about forecasting assumptions relevant to specific products are mentioned in the sections below.

Data Sources and Input Processing

The data sources and input processing are described for each product category in turn.

White Goods

Australia

Sales

White good sales were derived principally from GfK[5] sales data, where available from 1993 to 2014, though for some years data may be missing for a specific product. It is unusual to have sales data available for such a long period. There is also minimal impact from missing the odd year of data in this situation, as these years can be estimated by determining the average between surrounding years, and there is plenty of data to establish clear sales trends.

Sales are adjusted up, in proportion to the estimated share GfK have of the total market. As generally GfK data covers the vast majority of sales in the market, and efficiency levels

[4] It is recognised that not all the processing methods and the assumptions underlying these are documented, due to there being hundreds of different data inputs used in the model.

[5] GfK is a market research firm that tracks sales of a wide range of residential products.

could be different in uncovered market segments, however impacts on the analysis should be minimal due to the high (often 70 – 90%) market coverage by GfK. This adjustment will not affect the accuracy of product information. The proportions of the market covered by GfK were obtained from EES, 2010, *Greening Whitegoods*, p12. Sales for individual models were summed to produce aggregated total sales for each product used in the RBS model, e.g. refrigerators, dishwashers etc. Due to the aggregation process, none of the underlying GfK data can be identified, which is also necessary due to intellectual property requirements.

For all products, when only national sales data was available, a proportion of the national total for any product was assigned to each state depending on dwelling numbers as a proportion of the national dwelling numbers.

The sales and resulting stock numbers and ownership rates produced by the model were cross checked against ownership statistics obtained from the ABS 4602 Environmental Issues: Energy Use survey series (ABS 4602 Surveys). This set of surveys has been conducted every three years since 1999 (and earlier for some product categories). If the model indicated ownership levels that significantly differed from the ABS survey results, the reasons for such differences were investigated and sales data or share of sales by state refined if required to reflect the most accurate data available.

Usage

Usage is irrelevant for refrigerators and freezers as they operate continuously.

Dishwasher and clothes washer usage comes from ABS 4602 Surveys (2005, 2008, 2011). Their usage was calculated from the survey data which reported the proportions of owners using the appliances less than 3 per week, 4-6 per week, daily etc. This survey data was converted to estimates of the mean average number of times the appliance was used annually.

Dishwasher usage was estimated at 200 cycles p.a. and clothes washer usage estimated at 229 cycles p.a.

Clothes dryer usage in Victoria and NSW ABS surveys appears to be around 20 cycles p.a. In the warmer states, 18 uses p.a. is used reflecting that not all cycles will be full cycles and the warmer climate may reduce the need for dryers.

Size and Efficiency

Sales data for individual product models were matched with each model's data in Australian Energy Rating registration data, to produce sales data matched with size and efficiency data. The resulting data was used to determine sales weighted energy consumption averages, product size and product efficiency across each white good product.

For fridges and freezers, annual energy use from Comparative Energy Consumption (CEC) was divided by its size, expressed as adjusted volume (a standardised measure which gives greater weight to freezer volume), in order to get average efficiency for each model. Combined with sales data and adjusted volume data, a sales volume weighted efficiency measure was produced indicating average energy use per year.

For clothes washers, clothes dryers and dishwashers, the average energy per load was calculated from the sales weighted CEC divided by the standard's assumed number of loads per year (e.g. CW 365, DW 365, CD 52) or directly from the registration data. Similarly, average program cycle times (i.e. product size) expressed in hours were obtained from the registration data.

Clothes washers' main energy use is when heating water, but it is assumed that clothes washers doing a warm wash are connected to a water heater, hence the water heating component of the wash will be captured under the energy use by water heaters. This leaves the electric only energy consumption of the appliance, as listed in the Energy Rating registration data, as the desired input for the model. However, the electric only energy consumption data may include some clothes washer water heating, as especially for front loaders, some of these electricity consumption values are larger than cold only CEC values. It appears some front loader machines automatically heat the water to 20°C before operating.

It is worth noting that front loaders are using two to four times more energy than top loaders, measured by both electric only and by Cold wash CEC. This may be a result of them taking around two to three times longer in their program cycle.

Standby

For clothes washers, standby has been measured since 2006 when relevant to a machine, and is provided in the Energy Rating registration data. The average standby, the average between the End of Cycle and the Off modes standby power use, is what was input to the model.

The standby average used assumes that user behaviour results in 50% of clothes washer being switched into off mode, and 50% remain in End of Cycle mode, so the average sales weighted standby is the sales weighted average of Off Mode and End of Cycle standby (which is the same assumption used in the standard to calculate the CEC). Sales weighted averages were obtained in the same way that sales weighted efficiency was obtained, through matching sales data to model registration data.

For dish washers, likewise standby has been measured since 2006 when relevant to a machine and is provided in the Energy Rating registration data.

Life

The operating life of white good appliances has been derived from replacement ages provided in BIS 'The Household Appliances market in Australia 2002-2004'. It is appreciated that this reference is now dated but alternative data was not available. Also life value for front loading clothes washers was leading to incorrect ownership/penetration levels for the product concerned and was reduced by 30% compared to the BIS value for top-loader clothes washers.

New Zealand

Sales over the last decade were obtained from the EECA registration database.

Usage rates were assumed to match Australian usage.

Cooking Appliances

Sales

Cooking appliance sales data was available from GfK data for the period 2008-2013. This data divided cooking appliances into ovens and uprights (sometimes called cookers), plus divided the cooking appliances into electric and gas.

The sales of cooktops were not available but traditionally a cooktop is installed when an oven (wall or under-bench) is installed. This implies cooktop sales numbers can be assumed to equal the sales figures for ovens, and so cooktop sales were estimated from oven sales. However, this did not provide a breakdown of cooktops by fuel type but earlier data from BIS Schrapnel (BIS 2015) provides a proportional breakdown of cooking appliances by fuel and a breakdown of cooking appliances per fuel. Combining this information with the Gfk sales data, estimates of cooktop sales by fuel type for 2008-2013 were produced.

The BIS data also supplied sales for an earlier period, 1991 to 2004, and this data was combined with the GfK data from 2008-2013. Estimates then made for missing years based on sales trends and in this way long term sales numbers and trends were estimated.

The combined sales numbers were then adjusted again to compensate for the sales data lack of total market coverage, with coverage again estimated from EES, 2010 data. The resulting stock numbers were then examined to determine if they were consistent with ownership expectations. Sales were then allocated to states based on dwelling numbers as a proportion of national dwellings.

Efficiency and Usage

There is very little information available on the usage of cooking appliances, and the best available data is on NZ electrical cooking energy consumption in the Branz HEEP SR155 report (Branz, 2006). There is also some limited IPART research on gas usage. This lack of data reduces confidence in the accuracy of the cooking energy and power use results.

Given the limited information, usage estimates were derived from the NZ data on annual energy use, taking into account the energy consumed in oven versus cooktop aspects of a typical upright cooker. These estimates of usage were then checked against total annual usage based on estimating times to undertake different cooking tasks.

The efficiency metrics, in this case wattage, of different cooking appliance types were determined by examining the specifications of a range of currently marketed cooking appliances. These efficiency values were held constant over time as there is little reason to assume appliance size and efficiency has significantly varied. Standby power was derived from the Standby Power Surveys (EES 2011).

A USA DOE study (DOE 2005) also gave usage times for microwave and some standby data.

Induction cooktops were identified as a separate appliance in the project scope, but could not be separately modelled as no sales data was found that would have made it possible to model these cooktops as a separate sub-category of electric cooktops.

Life

The average operating life of cooktops, ovens and uprights is estimated at 14 years. This is based on the BIS 2005 report previously mentioned which examined replacement patterns since 1998.

No evidence was found indicating appliance lives will have altered significantly since then.

New Zealand

Sales

No direct sales data was available for NZ cooking appliances, nor was penetration data available. Consequently the sales and stock needed to be estimated.

It was assumed that those dwellings with gas space heating would also have gas cooking, and division into uprights, cooktops and ovens would also approximately match Australia's. This meant that numbers of gas space heaters could be used to estimated gas cooking appliances, and from this the sales of appliances were back calculated.

It was assumed non-gas cooking would be electric and again the division into uprights, cooktops and ovens would also approximately match Australia's. So dwelling numbers and gas appliance numbers could be used to estimate electric cooking appliance stock, and from this the sales of appliances were back calculated.

Microwave ovens were estimated from the approximate penetration of microwaves in Australia, so stock numbers could be estimated from dwelling numbers. Sales of appliances were then back calculated.

Efficiency and Usage

The best available data is on NZ electrical cooking energy consumption in the Branz HEEP SR155 report (Branz, 2006). There is also some limited IPART research on gas usage. Given the limited information, usage estimates were derived from the NZ data on annual energy use, taking into account the energy consumed in oven versus cooktop aspects of a typical upright cooker. This is the same process that was used for the size, efficiency and usage for Australia and the same values were used for both countries.

Lighting

Sales

There is no single reliable source of lighting sales data, due to the large volume of sales, the variety of products and the large number of retail outlets. Consequently sales numbers were estimated using a variety of data sources and using a national model of lighting stock developed by EnergyConsult for this purpose. This stock model was derived from the findings and modelling undertaken for the Residential Lighting Overview (RLO) Report (Draft), S. Beletich, 2014, which in turn relied on the E3 "2010 Residential Lighting Report" (E3 2010) survey data from a survey of 150 homes in Queensland, NSW and Victoria.

The lighting stock model assumed lights per house increase to 2010, in line with the Beletich model, but then for the forecast period assumes very slow increases to 2030. The rapid increase in lights per house in the decade prior to 2010 was driven by both increases in house size and a move to extensive use of down lights. However, the IEA 2014 study, referred to below, shows that sales numbers have generally been declining for the last five years, which is consistent with a reduction in lights per house. A conservative assumption was therefore made to assume minimal future growth in light numbers per dwelling.

Stock numbers are calculated from national dwelling numbers, historic and projected, and the number of lights per dwelling in a given year. It allocates lighting stock between lighting technologies based on proportions of the total stock, and these proportions vary over time, so lighting stock numbers by technology per year are produced.

The lighting stock models also used the assumptions that future sales for all incandescent lamp sales would cease by 2020, and LED sales will continue to increase and lead to a decline in halogen, CFL and fluorescent lamp sales from 2017.

Another source of lighting sales data was the lighting sales numbers obtained from 1999 to 2013 from an IEA 2014 study. These lighting sales numbers were regarded as the maximum possible sales, as some of these sales would have been to the non-residential sectors. These sales figures were fed into the model and the resulting stock numbers compared to the lighting model. The sale numbers were then adjusted down to produce stock numbers in the model that were consistent with the lighting stock model, with the adjustment being the sales that presumably went to the non-residential sectors.

Again sales figures were first derived at a national level and then proportionally applied to each State.

Though the residential lighting sales data is not of high quality, the use of sales data combined with the lighting stock modelling of S. Beletich, 2014 should result in reasonably accurate historic data. However, forecasting future lighting sales with confidence is difficult given how quickly the lighting technology mix has changed in the past and LEDs remain a new product with currently a small market share.

Efficiency and Usage

The Efficiency metric, in this case Wattage, for the different lighting products was obtained from the Beletich modelling. The average wattage of halogen and LED lamps declined in the decade up to 2010, according to Beletich, but it was conservatively assumed that the average wattage of all lamp technologies would be constant from 2010 for the energy model.

The average hours of usage, 1.4 hours per lamp per day, was obtained from the E3 2010 lighting reports, which reported lighting survey data.

Life

The life of lamps varies with technologies and this is reflected in both the lighting stock model and energy models.

Beletich (2014) provides estimates of lamp life based on typical technologies average operating hours, as determined by testing to the relevant standards. By dividing the lamp operating hours by the estimated usage per year, the average operating life in years was calculated for each technology, with two exceptions. The exceptions were Linear Fluorescent and LED lamps, as follows:

- Fluorescent tube life is tested assuming the period the lamp is on is 3 hours at a time, and if they are switched on and off more quickly, this significantly decreases their operating lives. As the average time a light is one is less than three hours, the assumed life was decreased from 20 years to 15 years to reflect this.
- LEDs in theory can operate for 40 years, but if installed randomly in houses, then on average the house they are installed in will only have another 20 years before it is demolished or renovated, assuming houses last 40 years on average. The assumed life was therefore decreased from 40 years to 20 years to reflect this.

New Zealand

The RBS analysis for NZ was driven by a mixture of lighting installation data obtained from research by J. Burgess et al, 2010, 'Lighting in New Zealand Homes', combined with the modelling approach used in the Residential Lighting Overview (RLO) Report (Draft), S. Beletich, 2014

The J. Burgess et al study provided data for lighting stock in 2009, plus data from a BRANZ study in 2001-2004, and some data for earlier periods, plus lighting usage data. This data was used to modify the RLO model.

EECA sales data, for registered products, provided some sales data on CFLs. The data on linear fluorescents could not be used as most of these are installed in the commercial sector.

The RLO model was modified so it could operate with the range of NZ data available and variables such as dwelling numbers and size were also altered in the model to conform to the NZ situation.

For the forecast period, in this case post 2010, estimates were made of the expected take up on new technologies in NZ, based on comparisons with trends to date in NZ, and trends compared to Australia. Increased use of CFLs and LEDs were assumed.

Note: The resulting energy use for lighting per dwelling based on the J. Burgess et al study data is significantly more than that found in the BRANZ HEEP studies (2000-2006), but no discussion of this difference is provided.

Water Heating

Sales

Electric storage water heaters, including solar electric and heat pumps, have been the subject of a Product Profile 2012 (EC 2012), and a Consultation RIS in 2013 (EC 2013), both of which provided information on sales. The underlying sales data come from BIS Schrapnel and industry surveys, or from data on Renewable Energy Certificates (REC) for solar electric/gas and heat pumps, and provides reasonably accurate sales data for the last decade or more.

Likewise gas water heaters have been investigated in a Consultation RIS in 2009 which provided information on sales, as well as an earlier RIS in 2003.

Information on sales of solar gas water heaters was provided through analysis of Clean Energy Regulator information on REC granted for the solar gas water heaters.

The sales numbers for water heaters for each state were calculated from the national sales numbers, with the proportion of sales allocated per state corresponding to the proportion of national stock the state had in 2012. This proportion was determined from data from the ABS HEC (2012) survey and ABS 4602 series of surveys.

Usage, Size and Efficiency

The Efficiency metrics used for usage and efficiency varied with the type of WH.

For electric storage water heaters, the efficiency measure is a measure of the system's standing losses, measured in kWh p.a., while the usage reflects the annual energy in kWh required to heat the reference amount of water allowing for 100% energy transfer. The reference amount of water is given in the relevant standard.

A usage adjustment factor has been used in the model which varies annually from 2008 and affects the usage from electric storage water heaters, reducing it from the usage given in the standard. This adjustment was required as analysis of energy consumption for water heaters on controlled/off-peak tariffs showed they were not using the amount of energy anticipated and their energy use was declining (QLD and NSW data). This implies that water usage must be declining and is consistent with the rapid and extensive penetration of low flow showerheads in Australia since 2008. Results from Energex (QLD) and AusGrid (NSW) controlled tariff data over the same period were very similar.

The electric storage water heater efficiencies post 2004 are based on analysis conducted for the Consultation RIS in 2014, and earlier efficiencies are based on the varying MEPS requirements since 1985. Sizes for electric storage water heaters efficiencies were also obtained from this RIS.

Gas water heater efficiency was determined from data published in the gas water heater RIS of 2009, referring to average star ratings of the different heater types over time and converted to an efficiency measure.

Gas water heater usage comes from the reference amount quoted in ASNZS 4234. The usage * efficiency = total energy consumption per GWH.

Solar Electric water heater and heat pump water heaters usage and efficiency was obtained from the analysis used for Consultation RIS – Electric Storage Water Heaters (EC 2013). Sizes were derived from a Pitt & Sherry (2012) water heater study.

Solar Gas usage and efficiency reflect the sales weighted analysis of the efficiency of SGWH, with data obtained from CER.

Life

Lives were based on operating lives supplied in the Product Profile and RIS documents previously mentioned. There was also some slight adjustment of the lives used in the energy model to ensure the stock numbers produced by the model were reconciled with the data on penetration of water heaters.

New Zealand

Sales

Sales for electric WH were largely obtained from the EECA registration database, for 2000 to 2013.

Sales of gas water heaters have been investigated in a Consultation RIS in 2009 which provided information on sales, as well as an earlier RIS in 2003. Sales for 2012-2014 were obtained from the EECA registration database. Estimates of the distribution between LPG and natural gas appliances were based on RIS data.

Solar Electric WH and HP WH usage and efficiency was obtained from the analysis used for the Consultation RIS – Electric Storage Water Heaters (EC 2013).

The NZ Branz HEEP study, especially 2005, provided information on Wetback WH penetration, as did the 1986 and 1996 census data quoted in the HEEP study. This penetration data was used to calculate stock numbers and then used to estimate sales numbers.

Usage, Size and Efficiency

Where usage is based on reference loads in the standards, the difference between NZ and AU usage was incorporated in the model, with NZ usage being calculated from the Au usage multiplied by a relevant factor.

The Gas WH efficiency was determined from data published in the gas water heater RIS of 2009, and as almost all GWH were imported from Australia, it was assumed similar efficiencies were relevant in NZ.

The NZ ESWH efficiencies post 2004 are based on analysis conducted for the Consultation RIS in 2014, and earlier efficiencies are based on the varying MEPS requirements since 1985. Sizes also came from the RIS.

The NZ Branz HEEP study, especially 2005, provided information on Wetback WH usage and efficiency.

Life

The lives of NZ water heaters is significantly longer than Australian water heaters and hence separate products are created for ESWH of NZ.

Space Conditioning

Sales

Sales numbers were derived from different sources depending on the product type. Air conditioning sales come from the latest Air Conditioning Decision RIS, 2015. Sales are divided by State in this RIS. The underlying sales data comes from a variety of sources, e.g. GfK market research and industry surveys etc.

Electric heating sales were derived from ABS 4602 Surveys data on heater ownership and use and GfK Sales data.

Gas product sales come from the Gas Space Heater Product Profile, 2012, and Gas Ducted Heating Product Profile, 2012.

Wood heater sales and shares by State were derived from ABS survey data on heater use (ABS 4602 Surveys).

The sales shares for air conditioners and gas heaters were obtained from the previously mentioned RIS and product profiles.

Usage, Size and Efficiency

The hours of usage for air conditioning, electric heaters, evaporative cooling and fans were obtained from the ABS HEC (2012) survey on household energy use, which provides hours of usage by State.

There was no survey data on wood heating usage so the average hours of usage of wood combustion heaters was estimated as 130% of the average gas space heaters usage. This was based on 1) hours of usage derived from tonnes wood used (BDA, 2006) and 2) by wood heater average output (2-5 kW) being approx. equivalent to a gas wall heater (maximum 3.5-6 kW) with an additional 30% allowance due to wood heaters being operated overnight and used more due to their lower operating cost for those with wood supplies. Wood usage survey results (BDA, 2006) were also used to estimate the state by state variation in wood use. However, there is only moderate confidence in the accuracy of the resulting estimates of wood heater usage due to the lack of directly relevant and accurate underlying data.

The air conditioner efficiency for air conditioners/heat pumps used sales weighted efficiency by climate and operating load characteristics (coefficient of performance and energy efficiency ratio at different loads and outside temperature conditions) and these were derived from the Air Conditioning RIS 2015. Air conditioner sales weighted size was also obtained from the RIS.

The Efficiency and Size metric for evaporative coolers, in this case wattage, was estimated as the average input power from the range of coolers available, as researched by Saman (2010). For fans, this was estimated from a review of the fan models currently available on a range of large retailers' websites.

For electric heaters, average wattage was also estimated from GfK sales data and also after considering the wattage used in the previous RBS (EEE 2008).

Gas product efficiency and size were obtained from the relevant gas product profiles for 2005-2009. Efficiency values for groups of gas products, e.g. natural gas flued space heaters, were calculated using efficiency of individual products, e.g. wall heaters, and weighting this by their proportion of sales.

Wood heater and open fire size and efficiency were obtained from the Branz HEEP studies (e.g. 2010).

Air Conditioner Saturation, Reverse Cycle and Usage Adjustment

In some States many dwellings have more than one air conditioner, expressed as the product saturation exceeding 1.0. In this situation, the second, third etc. air conditioner is expected to be used less than the first air conditioner installed, typically in the main living area. As the data on hours of usage for air conditioners does not provide usage for additional air conditioners, the usage of these appliances needs to be derived from those of the first/main air conditioner.

The model did this by discounting the average usage of air conditioners according to the degree of saturation of the air conditioners, obtained from ABS 4602 Surveys, with greater saturation leading to a greater discount. Saturation data was available for all states, so state specific usage adjustments could be developed.

Another variable affecting the usage of air conditioners was the proportion of devices that were used for heating (effectively 100% are used for cooling), which varies between states. A 'reverse cycle' factor was developed that reflects the proportion of dwellings with air conditioners that use them for heating. The proportion of air conditioners used for heating in each state was calculated from ABS HEC survey data.

A combined saturation and reverse cycle usage adjustment factor for each State was calculated, based on its device saturation factor multiplied by its reverse cycle factor, that reflects the proportion of dwellings with reverse cycle air conditioner that use it for heating.

Life

Operating lives for air conditioners come from the latest Air Conditioner Decision RIS, 2015.

Electric heater lives were estimated from data in the Product Profile for gas heaters (EC 2012) and market data. Evaporative cooler and fan lives were also estimated from market data (e.g. AIRAH 2005).

Some products, such as open fires, have potential operating lives as long as the buildings they are installed in. However, moves to improve the efficiency of houses have meant many fireplaces are removed or blocked off, lessening operating lives.

New Zealand

Sales

Air conditioning sales again come from the latest AC Decision RIS, 2015. The underlying data mainly comes from EECA collected sales data.

Gas product sales come from the Gas Space Heater Product Profile, 2012, and Gas Ducted Heating Product Profile, 2012. Penetration data from Statistics New Zealand Quickstats was also used to estimate stock levels and then to back calculate sales. (Data for i.e. http://www.stats.govt.nz/Census/2013-census/profile-and-summary-reports/quickstats-about-housing/heating-fuels.aspx)

The QuickStats data, together with results from the Branz HEEP studies (e.g. 2010) was also used to derive product penetrations, hence stock numbers and then electric and wood heater sales

Usage, Size and Efficiency

The hours of usage for equipment were estimated from Australian data, allowing for the mix of comparable climates in New Zealand. The adjustment was based on HEEPS data on wood heating compared to Australian, and the ratio of that used to adjust usage for other heating types, via the Hours of Use Adjustment for Climate matrix.

(Please note: The resulting estimates for space conditioning usage can only be considered approximate at best. However there appears to be no accurate usage data available in New Zealand, and even the Branz HEEPS residential energy usage data is now ten years old. This may affect the accuracy of the RBS NZ space conditioning results and overall residential energy use findings.)

Wood heater usage in NZ was derived from the Branz HEEP studies (e.g. 2010), which measured energy usage in a sample of NZ dwellings.

AC efficiency for AC/heat pumps uses sales weighted and derived from the AC RIS 2015, which in turn used EECA sales data combined with Energy Rating Registration data. Sizes also came from the RIS.

For non- AC products, efficiency values and sizes are assumed to be effectively the same for NZ and Au. This reflects shared standards and markets.

Gas product efficiency and size was obtained from the relevant gas Product Profiles for 2005-2009. Efficiency values for groups of gas products, e.g. natural gas flued space heaters, were calculated using efficiency of individual products, e.g. wall heaters, and weighting this by their proportion of sales.

Wood heater and open fire efficiency and size were obtained from the Branz HEEP studies (e.g. 2010).

Information Technology and Home Entertainment Equipment

Sales

Most of the product sales data were derived from GfK, which provided sales from 2000 to 2013. Sales are adjusted up, in proportion to the estimated share GfK cover of the total market. Sales for individual models were summed to produce aggregated total sales for each product used in the RBS model, e.g. PCs, DVDs, TV-Plasma, etc. Due to the aggregation process, none of the underlying GfK data can be identified, which is also necessary due to intellectual property requirements. Some product type sales were sourced from the modelling EnergyConsult undertook for regulatory impact statements for Standby Power (E3 2013) and Home Entertainment (E3 2007).

When only national sales data was available, a proportion of the national total was assigned to each State, depending on dwelling numbers as a proportion of the national dwelling numbers.

The sales numbers and resulting stock numbers and ownership rates produced by the model were cross checked against ownership statistics obtained from the ABS 4602 Environmental Issues: Energy Use survey series (ABS 4602 Surveys) and ABS 8146 Household Use of Information Technology. These surveys have been conducted periodically since 1996 (ABS 8146) or 1994 (ABS 4602). If the model indicated ownership levels that significantly differed from the ABS survey results, the reason for such differences were investigated and sales data refined if required.

Usage

Usage for products was based on various sources, as shown in the Table 2.

Table 2: Usage inputs, sources and assumptions for IT&HE products

Product	Hours pa	Source / Assumption
TVs (All types)	2,190	TV RIS (E3 2009, E3 2014)
STB - FTA	2,190	Same as TVs
STB - STV	2,190	Same as TVs
DVD/Blu-ray players	548	Standby RIS (E3 2013)
VCRs	548	Standby RIS (E3 2013)
HDD Video Recorders & Media Players	2,190	Standby RIS (E3 2013)
Audio/Home Theatre	2,190	Standby RIS (E3 2013)
Game consoles	913	Game Consoles (DCCEE 2012)
Misc HE	730	Standby RIS (E3 2013)
PC - Separate Monitor	1570	PC & Monitor RIS (E3 2012
PC - Integrated Monitor	1570	PC & Monitor RIS (E3 2012
PC - Notebook	1570	PC & Monitor RIS (E3 2012
Monitors	1570	PC & Monitor RIS (E3 2012
Routers, Access Points, Modems, Switches, etc	7,890	90% in on mode (EES 2011)
Drives, other	183	On mode = 30 mins/day
Printers/MFDs, Fax	12	On mode = 2 mins/day

Efficiency, Size and Standby

For televisions (TVs,) set-top boxes for free to air television (STBs-FTA), personal computers (PCs) and monitors, the sales data for individual product models were matched with each model's data in Australian Energy Rating registration data, to produce sales data matched with efficiency/standby data. The resulting data was used to determine sales weighted energy consumption averages across each product by mode of use. A similar approach and data were used to obtain TV sizes, though for OLED, Ultra-HD and Projection TVs, model weighted sizes were used due to lack of appropriately sales matched data.

For other IT+HE products, the efficiency was determined from reports and cost benefit models RIS for Standby Power (E3 2013) and Home Entertainment (E3 2007). Size was not a not a model input for non-TV IT&HE products.

Life

The operating life of IT&HE products used in the study were the same as reported in regulatory impact statements for Standby Power (E3 2013), Home Entertainment (E3 2007), PC & Monitor RIS (E3 2012) and TV RIS (E3 2009, E3 2014).,

Other Equipment

Due to the variety of appliances grouped under this category, the sources of data will be discussed with regard to each product. The Size metric was only relevant to battery chargers.

- Kitchen Appliances: An intrusive house survey (EES 2011) provided information on penetration of common kitchen appliances and estimates of daily/annual usage and efficiency (wattage) were obtained, primarily from the previous RBS (EES 2008). This allowed average stock weighted usage and efficiency values for kitchen appliances as a whole to be developed. A life of five years was assigned to these appliances, and estimates of national sales numbers were then back calculated from the stock numbers and proportionally assigned to states based on dwelling numbers.

- Other miscellaneous: The size of the miscellaneous appliance annual energy use was derived from the previous RBS (EES 2008) and efficiency back calculated by assuming this load was distributed across the entire year. A life of five years was assigned to these appliances, and sales back calculated on stock numbers, which were deemed to equal dwelling numbers.

- Other standby: This was standby loads from products not already specifically included in the RBS model, e.g. clock radios, security alarms etc. The penetration of these products, percentage plugged in and on, and standby wattage were all obtained from the EES intrusive house survey (EES 2011). These values were used to calculate weighted average standby per dwelling. Again a life of five years was assigned to these appliances, and sales back calculated on stock numbers, which were deemed to equal dwelling numbers.

- Pool Pumps and Pool Chlorine Cells: Data on pool penetration by state was obtained from the ABS 4602 Surveys and on pool chlorination penetration from GWA 2009. Combining the penetration rates with dwellings numbers from the ABS census data enabled pool and chlorinator numbers to be estimated. Sales were then back calculated using these stock numbers and appliance lives, which were obtained from GWA 2009. Efficiency (wattage) and lives of pumps and chlorinators was derived from GWA 2009 and BIS 2006 data, and usage from BIS 2006.

- Pool Heating-Solar (pumps): The penetration of solar heating was derived from BIS 2006 and ABS 4602 Surveys, from which stock and sales were derived. Efficiency (wattage) was obtained from GWA 2009. Pump lives were obtained from GWA 2009 and usage was obtained from BIS 2006.

- Electric Spas: The penetration of electric spas was derived from BIS 2006 and ABS 4602 Surveys, which when combined with ABS dwelling numbers enabled stock to be calculated. Sales numbers were then back calculated. Efficiency (wattage) and lives of spas was derived from GWA 2009.

- Class 2 Common Areas: The energy use of class 2 buildings has been researched overseas but less has been done on Australian Class 2 common area energy use. The Myors 2005 study provides a breakdown of the common energy use in several case study buildings with over 150 dwellings per building, from which an estimate of the average energy use per dwelling was obtained. This estimate was compared to other estimates of the additional energy use in class 2 dwellings which confirmed it was in the range anticipated. Assuming a constant load over the year to create this consumption, an estimate of efficiency (wattage) was obtained. An average life of 5 years was given to this load (so as to allow for efficiency changes over time) and sales then back calculated from the class 2 dwelling numbers.

- Water Pumps: The number of dwellings using non-town water was assumed to equal the number using water pumps. The ABS 4602 Water (2013) provided the number of dwelling using non-town water, and pump life was assumed to be 10 years based on swimming pool pump lives (GWA 2009), so sales could be back calculated. A range of pump sizes are available on the market but 700W was chosen as the apparent medium model size for this product. Usage was estimated at 2 hours per day based on EnergyConsult monitoring of dwelling water pumps.

- Battery chargers: Stock, sales and energy use p.a. were obtained from the E3 Battery Chargers Product Review (EC 2013B). Cycles p.a. and program time (i.e. size metric) were also estimated from this source.

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:

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

Dwelling Stock Numbers

<u>Australia</u>

Dwelling stock numbers were available from the ABS census data, (ABS 1986, 1991, 1996, 2001, 2006 and 2011). This data was available only every five years, so intervening year numbers were estimated by assuming a consistent average growth in population and dwellings between censuses. For most censuses a breakdown by dwelling type is also provided. Breakdowns of Class 2 buildings were also provided, which were used to divide Class 2 into Low-rise dwellings (i.e. 1-3 storey buildings) and High-rise dwellings (i.e. greater than 3 stories)

The ABS provide both household projections and population projections for the project forecast period 2012 (post the 2011 census) to 2030. Household projections were used for estimating dwelling numbers, as these are more closely linked to dwelling number requirements then population alone. (see BIS 2012, Chap 4, 4.1)

The number of new homes and of demolition p.a. was calculated, and BIS 2012 data used to estimate average new home numbers. Demolitions were calculated as the difference between each year's stock, and the previous year's stock plus new homes.

In the forecast period, post the 2011 census, it was assumed that the relative ratio of dwelling types to total dwelling numbers, and dwellings to households, remained static. It is recognised that there are some predictions that medium & high density housing, i.e. Class 2 dwelling, will make up a slightly greater proportion of new buildings during the forecast period (e.g. BIS 2012, p115). However, as existing dwellings will still make up over 75% of the housing stock by 2030, the impact of this trend will be minimal on the distribution of dwellings by type. (e.g. less than 2% on detached housing numbers by 2030).

New Zealand

Population and dwelling stock numbers were available from the SNZ census data (SNZ 1986, 1991, 1996, 2001, 2006 and 2013).

As data is only available every five years, intervening year numbers are estimated by assuming a consistent average growth in population, dwellings etc. between census.

Numbers of dwellings are also available at each census and for most censuses a breakdown by dwelling type is also provided since 2001. The census breakdown is different than that used in Australia with the relevant categories are detached housing, medium density, high density, non-permanent and other. However, for modelling the impact of insulation and housing regulation on building shell efficiency, housing was simply divided into detached and duplex/flats to match the data available.

No data was found for the breakdown of unoccupied housing, so an estimated breakdown of these homes has been made based on the assumption the breakdown reflects that of occupied homes.

The SNZ provide both household projections and population projections (SNZ, 2011) for the project forecast period 2014 (post the 2013 census) to 2030.

Household projections were used for estimating dwelling numbers, as these are more closely linked to dwelling number requirements then population alone. (see BIS Chap 4, 4.1)

The population projections start form a 2011 base year, and comparison with the 2013 census shows the projection assumed a slightly higher base than actually occurred. Consequently the population forecast was adjusted accordingly.

In the forecast period, it was assumed that the relative ratio of dwelling types to total dwelling numbers, and dwellings to households, remained static. It is recognised that medium & high density housing will make up a slightly greater proportion of new buildings during the forecast period if existing trends continue, but there is insufficient recent data available to reliably estimate this trend. Also, as existing dwellings will still make up over 85% of the housing stock by 2030, the impact of this trend is expected to be minimal on the distribution of dwellings by type.

Stock Construction Modelling

The intention of this component of the modelling was to obtain data on key aspects of the construction that relate to building shell thermal efficiency, these aspects being whether the buildings had ceiling insulation and if they confirmed to building regulation efficiency requirements. Their dwelling type, including if they were low-rise or high-rise Class 2 dwellings also affected their efficiency. Consequently the aim of this modelling was to breakdown the modelled dwelling stock in any given year into building classes and then low/high-rise, into insulated and uninsulated, into pre-regulated and post regulated housing, and the regulated into which regulatory requirement that met. As building regulation vary between states, and the space conditioning loads corresponding to star ratings vary by locality, the stock construction modelling was done at the state level.

For Australia, the execution of stock breakdown via a building stock model was as follows:

- The number of dwelling of all types for each year was obtained from the previous modelling described above.
- The stock modelling/analysis then was conducted separately for Class 1 dwellings, for Low rise Class 2 dwellings and for high rise Class 2 dwellings.
- The penetration of insulation in housing was obtained from the ABS 4206 Environmental Issues surveys. These surveys contained a high proportion of 'don't know' responses and it was assumed the penetration of insulation in the 'don't know' housing was the same as in those that responded. For the years between surveys, the penetration rates were estimated by assuming straight-line change trends between the surveys.
- For pre performance housing (usually pre 2004), the number of insulated and uninsulated dwellings in each year was calculated from the housing numbers and insulation penetration.
- The number of new dwellings p.a. were calculated by comparing the number of dwellings to the previous year and by then adding a set percentage of the previous year to allow for demolitions, with the rate determined from previous modelling. The demolition rate was set at 0.5% and the resulting number of new homes calculated and compared to reported new home built nationally over the decade to

2014, which showed this was an accurate estimate of the demolition rate. (Note: Demolitions ideally should be calculated from new dwelling numbers in the 1950s, but as such information was not available.)

- New homes post 2004 were grouped in regulatory batches depending on what State building regulations were relevant in the years post 2004. , e.g. new dwellings between 2004-2008, then between 2009-2011 etc.

A similar process was followed for New Zealand with the following changes:

- Dwellings were divided into detached and duplex/flats
- The penetration of insulation came from Branz 2010: Housing Condition Report SR240 (Branz, 2011), and was assumed to be the same in all dwelling classes in pre-performance dwellings
- The post-performance houses were divided into regulatory batches, these being 1978-2000, 2000-2008, and 2008+ dwellings.

Calculation of Thermal Efficiency and Usage Adjustment Factor

Australia

The calculation of thermal efficiency was principally from the NatHERS star ratings of dwellings, using the relevant building regulation rating for houses constructed in a specific period or by deeming their star rating for pre-regulatory housing. For pre-regulatory housing the star rating depended on the type of dwelling and whether it was insulated or not. Star ratings in any locality correspond to an estimated space conditioning energy load, so they can be used to derive the relative thermal efficiency of buildings with different star ratings.

The calculation of the thermal efficiency of building stock involved first allocating a star rating to the different types of buildings in the stock in any given year, i.e. pre-regulation insulated, pre-regulation uninsulated etc. The allocation of the star ratings was done in Australia as follows:

- For Class 1 houses the star rating of both insulated and uninsulated pre-performance housing was obtained from EES (2011B), "The Value of Ceiling Insulation: The impact of retrofitting ceiling insulation to Australian homes". The underlying research for this study was AccuRate modelling of representative housing designs in the ten climate zones used in the previous RBS (EES 2008).
- For Class 2 dwellings, the modelling used was reported in Burghardt (2008) which also used representative building designs and AccuRate modelling across states.
- For Class 1 and 2 dwellings in the post regulation period, usually post 2004, the star rating assigned was the minimum performance required for houses in

that period, or the average rating as indicated by research for NSW which regulate performance using BASIX requirements (BASIX, 2011).

- The regulated star rating required of housing and when this was introduced was obtained from EES (2008) p114, and from Burghardt (2008), p7, plus a variety of state government notices advising of the performance requirements at different periods.

Once the star rating of each dwelling type sub-category was determined, and the number of dwellings in each sub-category, a dwellings weighted average star rating across all dwellings in the year was calculated. The space conditioning energy load that corresponded to the average star rating calculated for a given year was then determined from the star rating bands table, which defines the star ratings in terms of the forecast space energy use per m^2 for conditioned dwellings. Finally the Usage Adjustment Factor for a given year was calculated from the ratio of the predicted space conditioning energy load compared to that in the base year, 2012. The Demand Adjustment Factor was defined as equalling the Usage Adjustment Factor.

New Zealand

No allocation of the star ratings was done for New Zealand housing but instead a deemed space condition energy load was assigned after AccuRate modelling was conducted.

Sustainability House were commissioned to estimate the space condition energy loads of typical single and double story detached and duplex dwellings from the pre-1978 (insulated and uninsulated), and for the three regulatory periods. Modelling was done for all six climate zones as identified by EECA, these being Auckland, Hamilton, Nelson/Marlborough, Wellington, Christchurch and Queenstown Lakes.

Typical designs and a typical range of construction types were researched and chosen. This resulted in around 128 variations of each design in each climate zone being modelled, for each regulatory period. This meant a total of 2,688 design/climate variations were modelled. Within each region and regulatory periods, the average energy loads results across design variations were calculated. These energy loads were then weighted by dwelling numbers in each region to produce national weighted average space condition energy loads for each regulatory period and for insulated/uninsulated for pre-1978 housing.

As for Australia, the Usage Adjustment Factor for a given year was then calculated from the ratio of the predicted space conditioning energy load compared to that in the base year, 2012. The Demand Adjustment Factor was defined as equalling the Usage Adjustment Factor.

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