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Contents

1.	Introduction	. 1
	Background: Objectives and Scope of the RBS	. 1
	RBS Enhancements and Stakeholder Consultation	. 2
2.	Methodology	. 3
	Summary of Core Model	. 3
	Summary of Proposed Changes: RBS1.0 to RBS2.0	. 4
3.	Update of RBS Core Data	. 5
	Data Collection, Analysis and Research	. 5
	Input of New Data, Revision and Review of Trends	. 7
4.	Enhancements: Stakeholder Feedback and Proposed Approaches	.9
	Introduction and process to develop enhancement options	. 9
	Consultation process	10
	Enhancement One: Power Demand by Time of Use Data	10
	Enhancement Two: Linkage with Weather Data	11
	Enhancement Three: Policy Scenario Testing	12
	Enhancement Four: Increased Data Granularity and Increased Data Output Options	14
5.	Detailed Enhancement Methodology and Approach	16
	Enhancement 1: Power demand by time	16
	Enhancement 2: Weather data linkage and additional regionalisation	19
	Enhancement 3: Policy Scenario Testing	21
	Enhancement 4: Increased Data Granularity and Increased Data Output Options	23
Ap	ppendix A: Underlying RBS1.0 Methodology	25
	Underlying Method	25
	Space Conditioning Method	28
	Peak Electricity Demand Method	30
	Model Architecture	32



1. Introduction

The Department has commissioned EnergyConsult to undertake an update of the first Residential Baseline Study (RBS), a study into energy use in the Australian and New Zealand Residential Sectors. The first RBS was conducted by EnergyConsult in 2015, and prior to that studies of 'Energy Use in the Australian Residential Sector' covering just Australia were published in 2008 and 1999.

This methodology report focuses on the need for enhancement of the RBS and the underlying methodology changes that will be used to expand the functions in the RBS. It describes the data and core RBS functional updates, and four areas of enhancement. Preliminary data gathering and assessment of the gaps to update the RBS is also described in this report

The potential enhancements to the RBS have been the subject of consultation with key RBS stakeholders, to ensure the enhancements would address their needs. The outcomes of this consultation, their feedback and the proposed methodology to address their needs is presented in the current report.

Background: Objectives and Scope of the RBS

The prime objective for the 2015 RBS was to develop a model of energy consumption that covers all categories of residential appliances/equipment and that provides projections of energy consumption until 2030. The study examined energy use in total, by end-use/products and by fuel. It also examined and modelled potential maximum residential electricity peak demand. The 2015 RBS was extended to include New Zealand. The modelling tool, the RBS model, is a bottom-up engineering, end-use energy model of the residential sector in Australia and New Zealand. 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. More specifically this involves estimating the energy use at the appliance (unit) level and then aggregating the energy use across all appliances and households to get the total energy use. The resulting RBS modelling enables the contribution of individual end-uses, product groups and products to national energy use to be examined and understood. See <u>2015 RBS</u> for more details.

The 2021 RBS has a number of objectives which remain consistent with those of the earlier 2015 RBS. These objectives and the prime requirements for the study include:

- Developing a model of energy consumption that covers all categories of residential appliances/equipment and that enables projection until 2040.
- Modelling potential residential electricity peak demand during extreme weather events, and potentially modelling average power demand by time of use as an enhancement to the RBS

- 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 integrated into the model
- Provide facilities so Department 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. This objective also relates to a potential enhancement of the RBS.

The RBS model is to continue to encompass:

- In Australia, the building classifications of Class 1a- detached dwellings, Class 1battached dwellings and Class 2- buildings containing two or more occupancy units
- Residential energy use of electricity, natural gas, liquid petroleum gas, and wood, and solar photovoltaic electricity generation
- Results and modelling at the jurisdictional level of Australian States and Territories, and at the national level.

RBS Enhancements and Stakeholder Consultation

There are four main enhancements which are to form part of the 2021 RBS. The broad requirements for these enhancements have been proposed by the Department as follows:

- Inclusion of Power Demand and Time of Use data
- Weather data linkages
- Policy scenario tool
- Increased data categories and outputs.

A key aspect of the workplan for updating the RBS is to consult with the Department and RBS users to refine the objectives for the enhancements proposed to be included. This consultation was undertaken by surveying the potential RBS users and seeking their feedback on the scope, usefulness and purpose of the proposed enhancements. This is described in section 4. Enhancements: Stakeholder Feedback and Proposed Approaches.

Another aspect of refining the objectives of the proposed enhancement was to research the availability of appropriate data to support the enhancements and the technical feasibility of modelling the enhancement. Feedback on this technical research was to inform the consultation with the Department.

The updated 2021 RBS is referred to as RBS2.0.



2. Methodology

The RBS2.0 model will be largely the same as the RBS1.0 model and will use fundamentally the same methodology, but with updates to data and some enhancements.

Summary of Core Model

The RBS model is a bottom-up engineering, end-use energy model of the residential sector in Australia and New Zealand. In essence, the RBS consists of a large database of information on all the different products that are in Australian and New Zealand homes, and on the number, size, efficiency and use characteristics. It is this underlying product data which is then combined using formulae relevant to each product to calculate how much energy each of the products uses annually. The results of the calculations are then extracted and can be reformatted in numerous ways to produce the modelling outputs in the form required by the RBS user.

An important implication of the RBS being a bottom-up model is that the accuracy of the RBS rests on the availability and accuracy of the underlying product and usage data. This is the strength of the RBS but also it has implications when developing enhancements to the RBS, as will be discussed later in the report.

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 and solar water heating.

In total 129 different appliances and products are currently modelled, but further product disaggregation being considered may increase this number. Appendix A: Underlying RBS1.0 Methodology describes in more detail the methods and approach used to estimate the energy use and demand of the different residential energy enduses in the RBS model, and the overall architecture of the RBS model. The Appendix describes:

- Underlying Method
- Space Conditioning Method
- Peak Load Method



• Model Architecture.

Summary of Proposed Changes: RBS1.0 to RBS2.0

The key areas of change between RBS1.0 and RBS2.0 are shown in Figure 1. As part of the update of the RBS, the core data will be updated to 2019 or 2020 and projections made to 2040. This includes obtaining and analysing data relating to the energy/technical characteristics of equipment, the sales/uptake of products from 2014 to 2019 (and projected trends post 2020), changes to the thermal efficiency of buildings and addition of new products.

Further enhancements for RBS2.0 relate to the estimation of average demand by time of day, linkages with weather, policy scenario functionality and additional outputs. These enhancements are described in detail in the following sections of this report.



Figure 1: Key areas of change for RBS2.0



3. Update of RBS Core Data

There are two main tasks in the updating of the RBS core data and modelling parameters, these being the data collection, analysis and research, plus the input of the new data, revision and review of trends.

Data Collection, Analysis and Research

Updating of the underlying data set will be a major part of the preparation of RBS 2.0 and will involve collection and preparation of appropriate data. The update will follow the same processes used in the creation of the RBS documented in the 2015 RBS – Technical Appendix — <u>PDF</u> | <u>Word</u>.

The update will involve identifying and extracting product and housing data, relating to the annual installation/sales of products; usage, energy efficiency and capacity (size) characteristics and trends. The following sources will be utilised:

- Latest Australian (2016) and NZ (2018) census data
- Latest ABS/Stats NZ housing and population forecasts
- Regulatory Impact Statement (RIS) reports
- GEMS registration database
- Clean Energy Regulator Small-scale Renewable Energy Scheme data
- AEMO Distributed Energy Resource Register and Login
- Recent market studies (including <u>Cold Hard Facts 2019</u>)
- Market research (GfK, BIS Oxford Economics)
- EECA NZ/Department programs and data
- CSIRO National Energy Analytics Research (NEAR) Program
- Department/E3 and NSW DPIE purchased commercial data
- Industry stakeholders
- Industry stakeholder publications

Table 1 provides an initial assessment of some of the data available for updating the RBS. This table will continue to be updated as further information is obtained on data sources and the update of the RBS core data proceeds.



Appliance Category/ RBS Module	Sales Data	Efficiency/Size data	Usage data	New Products/ Classifications	Other considerations
Whitegoods	GfK 2016, 2017, 2018	GEMS Registration matched with GFK	Review	Classify motors vs VSD power electronics (if supported by data)	GfK updated to 2015, Align with Refrigerator RIS
Space Conditioning	GfK 2016, 2017, 2018	GEMS Registration matched with GFK	Review	Classify motors vs VSD power electronics	GfK updated to 2015, Align with AC RIS
Home Entertainment and ICT	GfK 2014,2016 2017, 2018	GEMS Registration matched with GFK	Review, possible new data from Nielsen	New products – voice assistants, TVs screen technology (OLED, etc), , casting devices, connected IoT (from IEA work)	Check with E3 TV RIS work, need GfK from 2015 onwards
Lighting	Lighting RIS, State programs	Lighting RIS	E3 lighting Survey in 2016	Connected lights, possible new product	Align with Lighting RIS
Other Equipment	GfK 2014, 2016 2017, 2018. Pool Pump RIS. CER	Pool Pump RIS	Review	Battery Storage Systems, CER/AEMO now has registry. Consider electric vehicles	Align with AEMO forecasts
Cooking	Some GfK data coverage	Limited data, some GfK, BIS Oxford reports	Review	Examine induction cookers	Fuel by product is already classified
Photovoltaics Generation	CER, by state and zone to 2020	CER	Solar Analytics, PVOutput.org	Battery storage might fit here, or placed in the other equipment	Need to update model structure to account for NET generation.
Building data	Update from ABS Census, ABS projections (3236. 2016), and from Stats NZ, BRANZ and MBIE for NZ.	Building Code RIS, Trajectory work	Not applicable	Align with Enhancement 3 and chosen disaggregation by climate zones	Review impacts of building code changes, COAG decisions, align and check household projections with Dept buildings team

Table 1: RBS Core update data sources and considerations

The update of the core RBS modules requires significant sourcing, processing and analysis of multiple data sources.

All recent product and housing data identified will be analysed and compared to other data sources to check the validity of the data. Conflicting or inconsistent data will be reviewed and modified to be consistent with macro trends and alternative data sources when required. Research will also be conducted on the impact of new variables affecting product usage, e.g. impacts of movie streaming on television use etc. At this stage, the long to medium-term impacts of the COVID-19 pandemic will not be incorporated, as research will need to establish if behaviours, working locations and other household attributes are changed into the future.

A review of any new research concerning the impacts of building shell efficiency on space conditioning usage will be undertaken, and the RBS modelling of building shell impacts will be reviewed if required. The more recent work completed by the Department and the Australian Building Codes Board (ABCB) for the residential National Construction Code (NCC) 2022 update may provide additional information in this area.

After processing and analysis, data will be formatted in preparation to be input into the RBS.

Data Gaps

During the review of data sources, gaps in recent data availability will be considered, and methods of developing estimates undertaken when required or impacts on the validity of the RBS noted. Preliminary data gaps are noted below.

Firstly, there is data used in the original RBS that is no longer available. Reliable longitudinal product ownership data is important for the validation of RBS stock estimates. The ABS 4602 product ownership survey ceased in 2014 and alternative estimates of product penetration may need to be used. These surveys were conducted by the ABS since the 1990s (approximately every 3 years) and have tracked trends in the ownership and fuel types of space heaters, water heaters and many appliance types by state/territory, and in some surveys they provided usage information.

Secondly, a significant data gap has also been identified that impacts how the changes in average product efficiency are estimated. Product sales data (by model) has been purchased by the Department from GfK over the last two decades, however GfK stopped collecting this data from the start of 2019. This GfK model specific sales data is matched to the GEMS model registration database, and sales weighted technical characteristics (efficiency, capacity and product sub-type) are developed for many of the key residential products, such as refrigerators, air conditioners, washing machines, TVs etc. For the current update of the RBS, the impact of this data gap will be small, as only the 2019 year is missing, however, for the next RBS update, this will create a critical gap in the available data and reduce the accuracy of the RBS using the same methodology. Alternative mechanisms may need to be considered in the future, such as requiring manufacturers/suppliers to submit the sales of models annually as is done in New Zealand under their energy efficiency regulations¹.

Input of New Data, Revision and Review of Trends

The new data will be progressively input into the RBS modules as the work proceeds. Once the data has been inputted, it is examined to identify sales and stock trends.

¹ See <u>https://www.eeca.govt.nz/assets/EECA-Resources/Product-regulations/Sales-data-tool-user-guide.pdf</u>

Trends for the 2014 to 2019 period will be 'sanity checked' to ensure the trends are realistic, in terms of market and physical boundaries. Such checks include ensuring:

- Stock levels meet but do not exceed physical requirements. For example, water heater stock numbers should not be substantially less or more than residential building numbers (Note: stock numbers may not equal housing numbers as shared water heating in apartments could reduce stock numbers, and more than one water heater may be used in very large houses)
- Stock levels are consistent with market or penetration surveys. For example, the trends in the ABS 4602, BIS Oxford and the Queensland Household Energy Survey.
- Trends in product characteristics are realistic and consistent with policy changes and previous market trends (e.g. rapid changes in average physical characteristic not induced by a policy change would be investigated).

Sales and stock forecast trends post 2019 will be developed based on the trends in recent years derived from input data. Such forecast trends are largely projections of recent sales, and resulting stock. The trends will be 'sanity checked' to ensure they are realistic, and compared against industry forecasts and commentary where available.

Forecast trends for product technical characteristics will be based on the trends in recent years, modified for any GEMS regulated changes or changes which have been formally announced, e.g. changes to air conditioning, lighting, refrigerators and pool pumps. Assumptions concerning these GEMS policy changes, the timing and impact on the market will be sourced from the published RIS, consultant Cost Benefit Analysis/stock models and discussed with the Department.

The impacts from energy efficiency programs on recent and projected sales, the forecasting of product trends, as well as the technical characteristics of relevant products will be considered. For example, in Victoria, the Victorian Energy Upgrades program has rapidly increased the ownership of LED lighting. The impact of other State programs will also be considered if legislated, e.g. Victorian plans to phase out open-flue gas space heaters.

New data may be available for Class 2 buildings. Information provided by the Department suggests that improved energy use information of Class 2 buildings disaggregated by common services, hot water and space conditioning may be used to improve the estimates used in RBS1.0. Discussions are continuing with the Department to assess how this information can be used. However, it is not possible to segment all Class 2 energy consumption without replicating the RBS and separately modelling Class 1 and Class 2 buildings.

Top-down checking of RBS energy consumption outputs against national and state data on energy consumption by fuel will be undertaken to confirm the consistency of the model with network level data. The Department has agreed to assist with the sourcing of this distributor level data for each of the states and territories.



4. Enhancements: Stakeholder Feedback and Proposed Approaches

Introduction and process to develop enhancement options

RBS2.0 is to include a number of enhancements designed to improve the ability of the RBS to meet potential users' needs. The proposed enhancements include:

- 1. inclusion of power demand/time of use data with associated outputs/reports
- incorporation of annual weather data, linked to energy use, with presentation of data at the Local Government Area (LGA) level of detail (subject to data availability, to be discussed with the Department if data is not available)
- 3. inclusion of functionality for users to test different policy scenarios
- 4. inclusion of greater data/product categorisation and data output features.

In order to ensure that these enhancements best satisfy the needs of RBS stakeholders and future users, consultation with the stakeholders and the Department formed part of the process of developing this Draft Methodology Report.

Following this consultation, the needs of users were examined by EnergyConsult and options for enhancing the RBS to address these needs were developed. These options were then reviewed considering the data they required and what was available, and whether it was feasible to modify the RBS to provide the enhancement options. This process enabled proposed enhancements to be refined and the resulting enhancements are presented below, together with the key findings of the consultation process.



Consultation process

The consultation process involved the development of a survey which asked stakeholders to provide feedback on their previous use, and intended future use of the RBS and of the enhancements. The survey included questions on their extent of interest in each enhancement, in how they use/would use the RBS with regard to the enhancement, what features they required regarding the enhancement and on whether they were aware of or had access to data which would support the enhancements. The Department identified and contacted relevant stakeholders. A copy of the questionnaire is available from the Department

Stakeholders, including the Department, EECA, AEMO, and the relevant energy areas in the States were sent copies of the survey and asked to provide written responses to it. Responses were received from the Department, EECA, AEMO, NSW, Victoria, Queensland, South Australia and Western Australia. Teleconferences were then conducted with the Department, AEMO, and EECA to obtain further data regarding their responses and needs. Further discussions with the States will be conducted as the RBS is updated.

The feedback from the survey and the teleconferences was combined and summarised. These summaries are presented for each enhancement in the sections below, along with the proposed scope of the enhancement.

Enhancement One: Power Demand by Time of Use Data

Feedback

The inclusion of power demand by time of use (ToU) data and outputs in the RBS was supported by the majority of stakeholders, though only a few stakeholders appeared to have a strong understanding of how this feature in the RBS might be useful to them. The key demand for the power demand /ToU enhancement was as an input to other analysis/forecasting models or for policy analysis of other changes, e.g. increased energy efficiency or introduction of demand responses.

The strongest preference for power demand /ToU outputs was expressed in obtaining RBS outputs of average or typical demand on an hourly basis for weekdays and weekend, and for summer, winter and shoulder² seasons. There was also interest in obtaining summer and winter peak demand outputs.

The geographic focus of stakeholders' interest in RBS analysis varied but the strongest interest was in national and/or State based analysis, followed by a regional or network regions focus.

² Spring and autumn

Proposed Enhancement One

EnergyConsult propose to provide an enhancement that provide RBS outputs of <u>average or typical demand</u> on an hourly³ basis for weekdays and weekend, and for summer, winter and shoulder season. This functionality is most consistent with stakeholder preferences, the functionality of the RBS, and data known to be available.

The proposed enhancement should also enable the impact of policy interventions, such as energy efficiency improvements or changes to the uptake of appliances on demand profile, to be explored as policy scenarios.

Forecasts of maximum peak demand will continue in their current form.

Enhancement Two: Linkage with Weather Data

Feedback

There was minimal interest by stakeholders in the RBS undertaking analysis or producing outputs at the LGA level. The only significant support for this level of analysis was to provide outputs which could be then used for regional, network area or climate zone analysis. The majority of stakeholders were interested in the national and/or State based analysis. Analysis at the network regional level or regional level (not defined) has some support and there was some interest in analysis of differences between climate regions (zones).

There was strong interest in including weather data and analysis in the RBS, but no consistency about the nature of weather effect/analysis to be included. Interest ranged from analysis of the impacts on energy use/demand of day to day (24 hour) weather variation, of annual variations in heating/cooling degree days, and of annual variations in extreme event days. A minority were interested in long term changes in climate but there was greater interest in weather variation impacts.

Proposed Enhancement Two

Given the minimal interest in providing RBS analysis at the LGA level, and the lack of product sales and ownership data at this level, an LGA analysis is not expected to be useful or accurate. EnergyConsult recommend that an LGA level of analysis not be provided as an enhancement but instead propose analysis, within States, at the climate zone level.

The proposed climate zone approach will make use of data on population or dwelling distributions by climate zone within States (or New Zealand) and differences in space

³ Note: It is recognised that interval meters operate in 30-minute increments and some stakeholders have expressed interest in ½ hour profiles but there is insufficient increase in accuracy to move to ½ hourly profiles. See the discussion in Detailed Enhancement Methodology and Approach on page 17.



conditioning use between climate zones to reallocate RBS energy outputs (and potentially average demand) outputs for a State across their climate zones. This will enable an understanding of how the differences in climate across the State affect energy use, which may also help in long term climate change forecasting.

The strong interest in weather impacts being incorporated into the RBS unfortunately is not matched by the availability of data on weather's relationship with energy demand or consumption. Without such data on the relationships the RBS cannot at this stage forecast energy consumption or demand impacts associated with changes in weather. However, the RBS can be modified to anticipate that data on the weather's relationship with energy will become available, or that some users may have data for their localities.

EnergyConsult propose that functionality to support weather impacts on energy use be included in the RBS, but that it will be up to the RBS user to define the relationship between weather and energy use that they will use in their analysis. The proposed weather enhancement would enable the input of weather data, e.g. annual Cooling Degree Days (CDD) and Heating Degree Days (HDD), to modify annual energy consumption by space conditioning in the State, with the user specifying the relationship between the weather variables and hours of use of space conditioning products. As further data on these relationships becomes known, the accuracy of weather impact analyses will improve and can be refined by the RBS user.

Enhancement Three: Policy Scenario Testing

Feedback

All stakeholders expressed an interest in using the RBS for policy scenario testing and they wanted it for testing a broad range of policy scenarios. The scenarios to be explored include changes to the sale/uptake of high efficiency appliances, impact of MEPS changes, changes to water heater charging times, impacts of demand management/response initiatives, building shell changes, efficiency program impacts, building code changes, and various fuel switching alternatives. There was also interest in including start and finish dates to a scenario being tested and interest in the RBS producing outputs of the BAU case and the scenario.

In discussions with stakeholders, they were asked whether enhancements to the RBS that made it easier to use the RBS as part of their policy analysis would be useful to them, if the RBS on its own could not do all of the analysis. Stakeholders agreed that enhancements making it easier to use the RBS for policy analysis would be useful.

Fuel switching scenarios were of interest to most stakeholders, with the main interest being in gas to electric scenarios. There was also some interest in various other fuel switching scenarios, e.g. electric to gas, wood to electric, LPG to natural gas etc.

Despite the interest in scenario testing, the majority of respondents did not appear to have had exposure to using the RBS for policy scenario testing or to have a detailed



appreciation of what that could involve, partially because many did not have access to the full RBS model. Most stakeholders wanted to use the RBS for very specific scenarios, but to forecast the impact of these scenarios would involve detailed analyses which are impossible to anticipate and therefore include in the RBS.

Proposed Enhancement Three

The RBS enhancement would provide a scenario control module which the user could operate to input the starting and finishing years of a scenario change, the RBS variable/s that would be affected by the scenario, and the scenario RBS inputs derived from the scenario specific analyses. The scenario RBS input variables that could be input by the user would include a percentage change of the product's average energy efficiency values, sales change for alternative products (for fuel switching or incentives) and usage impacts from building shell efficiency measures. The scenario control module would also produce a BAU base-case RBS output, which the scenario output could be compared to.

These proposed enhancements to the RBS will make it easier to input or alter RBS variables developed from anticipated scenario specific analyses, so the RBS can be used to model and forecast the energy use and demand impacts of the scenarios. Anticipated scenarios impacting on specific products which the RBS could support include MEPS level changes, energy efficiency program impacts (e.g. labelling), and to a limited extent fuel switching⁴. Building shell efficiency change scenarios could also be supported.

The RBS enhancement will not, however, undertake the external scenario specific analyses and research that each scenario will require. Such research and analysis are unique to each specific scenario being explored and will need to be undertaken independently of the RBS. The results of this work will then form inputs into the RBS for the scenario modelling.

For example, a typical scenario to be tested may be to analyse the impact of a change in a MEPS level on a product's energy use. The external research and analysis for such a scenario may involve developing an estimate of the sales-weighted average energy efficiency of the product for each year in the years following the introduction of the new MEPS level. This in turn could involve researching the product's market, the current distribution of the energy efficiency of models in the market and forecasting their future distribution, and then forecasting the average energy efficiency of the product for each year in the relevant years. The forecast average energy efficiency values could then form an input for the RBS, which could model the resulting energy usage over relevant years.

⁴ Fuel switching scenarios are complicated to model accurately if the alternative products have differing operating lives. If the lives are similar, e.g. 10 and 12 years, then RBS scenario forecasts will be accurate for about half the shortest operating life, but increasingly inaccurate after that.

EnergyConsult do not propose including an enhancement enabling the users to test demand changes, such as by input different time-of-use profiles for specific products, due to technical constraints of the RBS model. It is appreciated that some users are very interested in demand-change scenarios, but the calculation and support requirements needed to support a user-inputted demand profile function will be too great to include in the RBS model.

Every product in the RBS requires between 72 and 288 time-of-use profiles to be developed. For many products which operate in a variety of modes, the different types of profiles will interact and need to be reconciled. Profiles need to also be reconciled with total energy use and demand, to ensure profiles used are realistic. Some of this reconciliation and adjustment of profiles can be automated but other aspects will need a more detailed understanding of the product functioning and manual adjustment. At present it is proposed that these profiles will be developed and tested external to the RBS model and then 'hard-wired' into the RBS model once they are finalised.

For users to test demand changes would require the development of functions in the RBS which would support the automatic reconciliation of user input product profiles across all product modes and reconciliation with total energy results. Without such automatic profile reconciliation functions, the RBS results are likely to be erroneous. At present it is considered unlikely that such automatic profile development functions can be developed, meaning the RBS 2.0 will not support users testing demand changes.

It is possible that once the RBS 2.0 is completed and its power demand functions established, methods could be developed to input user developed, and separately reconciled, product time-of-use profiles into the RBS to test demand scenarios. However, it is not possible guarantee this at this time, or to estimate the work involved in developing functions to support user testing of product time-of-use profiles.

Enhancement Four: Increased Data Granularity and Increased Data Output Options

Feedback

Around half of respondents were interested in increasing the granularity of the RBS data, which effectively means they wanted further sub-divisions of a few product categories, or wanted some products to include fuel type information. The main request for the further breakdown of products however appears to come from RBS users who did not have access to the complete RBS. The request for breakdown of products by fuel type can be ignored as the RBS already contains this information.

This leaves the requests for further breakdown of products as follows:

- Refrigerators, by those with and without inverters
- Air conditioners, by those with and without inverters
- Air conditioner energy outputs results can be identified for cooling versus heating

• Electric water heaters by power source (e.g. PV, PV & battery, grid & battery, grid).

There was a request for breakdown of new products including batteries by technology, EV chargers by type and home energy management systems.

The lack of access to the full RBS has also been a factor influencing users' requests for increases in data output and report options. The RBS can already output an enormous variety of data formations and reports, and in discussions with stakeholders it became apparent they either did not have access to this facility in their version of the RBS or did not know about it. The feedback therefore did not justify a need to greatly change the RBS output facilities, but there were a few enhancements that stakeholders sought which would be additions to the RBS, these being:

- Providing some commonly used report types to assist users in producing reports
- Providing scenario testing reports that present the BAU forecast as well as the scenario being tested

Proposed Enhancement Four

The main enhancements involve additional product categories being added to the RBS, or sub-dividing existing categories. After reviewing the data available EnergyConsult propose adding the following product categories, or making outputs available for the following categories:

- Refrigerators by those with, without inverters (only now being recorded by GEMS)
- Air conditioners, providing outputs for those with, without inverters

The inclusion of refrigerators with/without inverters is possible as the underlying data is now available and refrigerators with inverters is a reasonably new market change, so including these will not alter historic (pre-2015) RBS data. This is not the case for air conditioners though, as inverter air conditioners have been around for years and the majority of models now sold have inverters.

Dividing air conditioners by those with/without inverters as products in the RBS would mean re-researching and analysing all the historic information on air conditioners, plus altering all the existing air conditioner product data. It is unclear if the data is available that would support such an analysis and the result would be that pre 2015 outputs of RBS 1.0 and 2.0 could not be accurately compared.

In comparison, making additional RBS outputs available for air conditioners with/without inverters is possible without adding additional product categories. This will involve the air conditioner RBS output being reanalysed and additional attributes of categories created, then specially outputting the RBS results with the additional information included, e.g. with the output for inverter/non-inverter separately shown.

EnergyConsult will also provide the output enhancements that stakeholders sought:

- Providing some commonly used report types to assist users in producing reports
- Providing scenario testing reports that present the BAU forecast as well as the scenario being tested.



5. Detailed Enhancement Methodology and Approach

Enhancement 1: Power demand by time

The requirement is to provide typical (average) electrical power demand on an hourly basis for weekdays and weekend, and for summer, winter and shoulder season.

The following disaggregation of power demand outputs from the RBS are proposed to be provided:

- By type of day and season
- By state/territory
- By end use, category, group and product

This level of disaggregation will enable the reporting of almost any level or be aggregated to a higher level (average by state).

To enable the calculation of these outputs, the shoulder season will be split into sub seasons; those with/without day light savings, for States where that is applicable.

The time-of-use profiles (i.e. the proportion of annual energy consumed by the product used in a given period) which will drive the RBS model will be developed for the following breakdowns:

- By type of day and season
- By state/territory
- By end use, category, group (although it will be possible to input the proportion of time by demand data at the product level, the group will be the lowest resolution in the majority of cases)
- By mode (Operation 1, Operation 2, Auxiliary and Standby)

The time-of-use profiles will not change by year as it is unlikely that data is available to support variations to the profiles by year.

Data sources and research

The key data sources to support the development of load profiles are as follows:

- CSIRO household monitoring study (2012-2017)
- Solar Analytics data set (still to be determined if there is sufficient data and resources for the analysis)
- Sustainability Victoria Residential energy measurement

These data sources are being investigated to determine if it will be possible to estimate proportions of energy demand by hour for a range of products. The CSIRO has already



estimated the daily energy consumption by house type and season for Melbourne, Adelaide and Brisbane.

Methodology Approach

The RBS determines energy consumption for each product by mode on an annual basis. This is effectively the same result as if the average hourly energy use was determined and multiplied by the number of hours in the year. So the average electrical energy use (kWh) is equal to the average power demand (kW) over an hour. Therefore, the RBS as it currently functions can be used to estimate the average power demand over the whole year. However, in practice power demand varies with time for many equipment types due to usage or the characteristics of the equipment and relationship with seasonal (or monthly) climate conditions. This is the variation that needs to be integrated into the RBS.

The proposed methodology to be utilised is to estimate the proportion of average power demand for each product (by group) by each hour of a typical day. The Annual Energy Consumption (AEC) is proportioned to each typical day type (by season and week/end day), and then proportioned over the 24 hour period. The basic calculation is shown in the equation:

$$AEC_{R,G,M} = \sum_{s=1,d=1,h=1}^{s=x,d=y,h=24} P_{s,d,h} \times Pwr$$

Where:

AEC $_{R,G,M}$ is the annual energy consumption for mode M, product G in region R *P* is the proportion of energy consumption in:

- *s* season⁵, from 1 and 4 (numbers represent summer, winter, shoulder daylight saving, shoulder non-daylight savings)
- d day type, from 1 and 2 (representing weekday and weekend day)
- h hour of the day, from 1 to 24, representing the hours of the day

Pwr is the average energy consumption over one hour, expressed as kWh/h or kW

Default proportions to derive average daily energy consumption are shown below:

Season	Proportion			Days	
Day Туре	Season	Weekday	Weekend	Weekday	Weekend
Summer	0.247	0.71429	0.28571	64.3	25.7
Winter	0.252	0.71429	0.28571	65.7	26.3
Shoulder- Daylight Savings (DS)	0.251	0.71429	0.28571	65,4	26.2
Shoulder-Non Daylight Savings (NDS)	0.250	0.71429	0.28571	65.3	26.1

⁵ Instead of season, month may be used and aggregated to the season



For instance, the daily weekday summer average energy consumption for a particular product, in region (R) and mode (M) is:

AEC x 0.247 x 0.71429 / 64.3

Proportions of energy use and the 24-hour profiles will be developed by review and assessment of the analysis of the CSIRO data and the Solar Analytics data. Where suitable profiles for products or groups cannot be determined, approximate profiles and seasonal/day type proportions will be developed based on assumptions about product use. The source information of the profile will be indicated in the module.

The daily proportional load profile by hour (which sums to 1.0 over 24 hour periods) would then be multiplied by this daily consumption to provide the estimated average hourly demand (kW) by hour of the day.

The total number of profiles of 24 hourly demand proportions required is based on the following:

- Seasons x 4 (summer, winter, shoulder DS, shoulder NDS autumn and spring are assumed to be the same).
- Weekdays + Weekend days
- Each mode with electricity energy consumption (depending on which modes are applicable; operation 1, operation 2, auxiliary and standby)
- For each of the Regions (9 = 8 x AU + 1 x NZ)

The number of profiles needed to allow for variations across day types, seasons etc, means the total number of time-of-use profiles needed by the RBS is substantial. There are 120 products in the RBS and in addition some require separate profiles for different operating modes, which means that 178 profiles are needed just to cover the average annual profiles for these products. The number is multiplied by 4 for the seasons, then multiplied by 2 for the day-types and then is multiplied by 9 for the eight states/territories and New Zealand. (i.e. $178 \times 4 \times 2 \times 9 = 12,816$ profiles). Many of these would be the same (for instance the refrigeration products would use the same profile, potentially for each region), but the result is a large number of profiles need to be researched, generated and reconciled with total energy demand data. Each separate product will need to have between 72 and 288 profiles developed.

The demand proportions and average demand profiles will be entered into a new, separate module in the RBS model to reduce the computational resources required of PCs running the RBS. Depending on the size of this demand module, it may also contain the output values of average demand by season and day type by region (for a selected year).

There have been suggestions that this enhancement to the RBS model should use ½ hourly resolution for the profiles. That approach to profiles, however, will result in a doubling of the complexity of the time-of-use profiles and in power demand result outputs. This will place further computational drain on the PCs running the RBS model for minimal gain in accuracy. The difference in accuracy is likely to be minimal based

on Victorian data for total house demand. Figure 2 shows less than 8 % difference between the average power of the 30 min interval compared to the 1-hour interval, for a typical winter weekday. Half-hourly profiles could be included later, and if supported. AEMO requested hourly profiles in their feedback.



Figure 2: Average power for Victorian households, Winter. Comparing ½ hour and one-hour average values

Enhancement 2: Weather data linkage and additional regionalisation

The requirement is to provide functionality to support analysis of weather impacts on energy use in the RBS. It will be up to the RBS user to define the relationship between weather and energy use. The proposed weather enhancement will enable the input of changes to weather data, such as increased or decreased cooling or heating degree days, and link this to the usage variable in the model for space conditioning equipment.

The second part of this requirement is to enable the reporting of space conditioning energy and potentially average power demand outputs by <u>ABCB</u> climate zone.

For the weather data linkage, the input adjustments will be segmented into the following:

- By region (state/territory)
- By space conditioning category and group (although it will be possible to input adjustments at the product level, the group is the most likely lowest resolution)
- By mode (Operation 1 heating, Operation 2 cooling and Aux)
- By year (starting and ending year of change)



Data sources and research

As noted earlier, there is not sufficient research and data available to develop the relationship between weather and the adjustment to usage for the space conditioning for every region. This research will be undertaken by the RBS user, who will input the relationship that drives the changes to usage. The key data sources to support the development of RBS outputs by climate zone are as follows:

- <u>Australian Building Codes Board Climate Zone Map</u> and <u>NatHERS Climate Zone</u>
 <u>Postcodes</u>
- ABS Census of Population and Housing 2016 (Census TableBuilder)
- ABS 3222.0 Population projections, Australia, 2017
- ABS 4671.0 Household Energy Consumption Survey, 2012

The ABS 4671 data will be analysed to derive usage by climate zone. Similar data for NZ will be sought.

Methodology Approach

The RBS Space Conditioning module will be modified to specifically include a weather data linkage input sheet, which will enable the user to enter a Usage Adjustment Factor (called UAF3) for each product's usage. This UAF is a factor (which increases or decreased the amount of usage of a product) and will be applied separately to the AEC calculation for each mode of each product by region.

The proposed formula (simplified by removing year) will operate as follows:

AEC = UEC x Stock x Usage x UAF1 x UAF2 x UAF3

Where

AEC is the annual energy consumption in year y UEC is the unit energy consumption for each product in year y Stock is the cohort of products operating in year y UAF1 is the usage adjustment factor related to occupancy UAF2 is the usage adjustment factor related to thermal performance of the dwelling stock in year y UAF3 is the new usage adjustment factor related to weather in year y

And

UAF3 will default to 1.0 if this function is not used in the model. A default function will enable a percentage change in UAF3 from year (start) to year (finish) with a linear change between these years. The user can change this relationship depending on the outcome of their research.

The proposed function will ignore the decrease/increase in standby energy due to the increased/decrease usage of the product to reduce the number of inputs.

To create output energy use and typical power demand by climate zone, the following modifications will be made to the model:



- Space conditioning module outputs in the Aggregator module⁶ will be proportioned according to the following:
 - Household numbers in each climate zone by state/territory (or NZ)
 - Usage by climate zone (from ABS 4671 or similar in NZ)
- Outputs will be summed to obtain energy consumption by climate zone

The proportioning of power demand by climate zone will be investigated during the development of enhancement one (power demand by time). This may require the development of separate load profiles, which would need to be supported by data that is not yet available. It would also increase the number of profiles and inputs by season/day types. A simplification may be possible that will reduce the research required and complexity, such as assigning state/territory load profile inputs to specific climate zones.

Enhancement 3: Policy Scenario Testing

The requirement is to provide functionality to support policy analysis within the RBS, such as changes to the average efficiency of products due to increase/decrease of higher efficiency products. It will be up to the RBS user to define the relationship between the policy initiative and what changes will be made to the various input variables. The proposed policy scenario enhancement will enable the input of changes to the following variables, and potentially related policy initiatives:

- Sales weighted efficiency of products installed by year
 - MEPS, energy rating labels, energy efficiency certificate schemes
- Sales/installation of products by year
 - MEPS, energy rating labels, energy efficiency certificate schemes
 - Fuel switching policy interventions (building codes, incentives)
- Average stock weighted building shell thermal efficiency of all buildings
 - Building codes

The inputs affecting the products will be specified for the following:

- By product
- By specific region(s) (state/territory) or whole country (default)
- By mode (Operation 1, Operation 2, Aux and standby)
- By year (starting and ending year of change)

For building shell thermal efficiency, the inputs will be specified by region(s) (state/territory) and year, and input as stock-weighted average NatHERs star ratings.

⁶ See Appendix A: Underlying RBS1.0 Methodology for explanation of Aggregator role

Data sources and research

No data sources are required for this enhancement.

Methodology Approach

The principal changes that will be made to the RBS are algorithmic and structural as follows:

- BAU scenario will be output and identified in the Aggregator module
- Scenario name will be entered into the scenario control sheet in each module and propagated throughout the model outputs in the Aggregator module when the scenario is exported
- Each end-use module will be modified to enable the variables to be easily modified in scenario control sheets
- The space conditioning module will have an additional scenario control sheet for building shell thermal efficiency inputs/changes

A master scenario control sheet will be created for each module that contains the principal controls and names:

- Scenario name, description and start year
- Variables chosen to change (sales weighted efficiency, sales and/or building thermal shell)
- region(s) (state/territory) impacted

Two separate scenario control sheets will be introduced to each module that enable the inputs of the BAU values to be overridden directly or modified by a formula from a particular year. These are:

- Sales weighted average efficiency inputs by product, mode and year
 - Efficiency can be changed by a % amount from start to end year, with BAU efficiency changes to continue follow the change. For instance, a MEPS would be modelled as a step change in one (or two) years, while a label might impact over a longer period of time
 - Efficiency values can be overridden directly by the user
- Sales inputs by product and year
 - Sales can be changed by a % amount or number from start to end year, with BAU sales growth to continue follow the change. For instance, a building code change would increase the % sales of a particular product and decrease the sales of an alternative product over a set period. Incentives might also be modelled in a similar way.
 - Sales values can be overridden directly by the user

The RBS Space Conditioning module will be modified to specifically include a building thermal shell change input sheet, which will enable the user to enter a scenario value for the Usage Adjustment Factor (named UAF2) that is applied to space conditioning product usage. This will be applied separately to the AEC calculation for each mode of

each product by region. Standby energy consumption could be modified separately if the impacts are significant (in terms of reducing operational time), but initially will be ignored to reduce complexity.

To create output energy use and typical power demand by scenario compared to BAU, the Aggregator module will be modified to provide several commonly required template report outputs, such as:

- Total energy consumption by year for selected end-use, category or group
- Energy consumption by fuel by year for selected end-use, category or group
- Stock by year for selected end-use, category or group

The use of pivot tables will enable any outputs that are currently generated in the Aggregator module to be provided by adding scenario to the row or column. This may also enable multiple scenarios to be compared.

The impacts of the scenario changes on average power demand by season, day type and region will also be available to the user to view in the demand module. However, scenario-based changes to the demand profiles are not proposed due to the enormous variations that would need to be considered.

Enhancement 4: Increased Data Granularity and Increased Data Output Options

The requirement is to provide additional outputs and increased granularity for particular product types and outputs. The requested additional data outputs are available in the Aggregator module, with users able to construct almost any output table or chart with the pivot tables. Additional tables will be provided to cover sample report items in consultation with the Department and users.

The main focus of this enhancement will be to:

- Provide more instructions on how to construct tables with pivot tables in the Aggregator. Specific changes will be made to:
 - Output the heating and cooling energy consumption separately for space conditioning products
- Disaggregate the outputs of energy, stock and connected power load for:
 - Air conditioners by those with, and without inverters
 - Refrigerators by those with, and without inverters

Data sources and research

The data sources required for the further disaggregation of the refrigeration and air conditioning products or analysis outputs include:

- RIS and CBA model for the air conditioners Zone Energy Rating Label + MEPS 2017
- RIS and CBA model for household refrigerators MEPS 2017



• GEMS registry information matched to the GfK sales data

No other data sources are required for increasing the RBS output options.

Methodology Approach

The approach for this enhancement is elaborate and extend the reporting templates for the RBS in the Aggregator module. The Aggregator contains a flat file database of all the key RBS outputs that is queried by pivot tables and charts. Further templates and instructions will be provided in consultation with the Department.

For the disaggregation of heating and cooling mode energy consumption, the Aggregator outputs will be supplemented to include this field so that heating and cooling energy consumption is explicitly identified (they are currently identified as Operation 1 and Operation 2). Standby and Aux energy consumption could be proportioned to the heating and cooling energy consumption to ensure that it is a complete value.

The disaggregation of refrigerators to those with/without inverter compressors will be implemented by adding an additional product. This will be possible as sales of inverter refrigerators are more recent (post 2015) and will not impact on the historical product types.

The disaggregation of air conditioners will be addressed in the aggregator module, with a separate sheet(s) to calculate the stock, energy and connected power for these products, as the vast majority of stock of non-ducted air conditioners are now inverter driven. The alternative of creating specific product types for these will not be possible in the RBS as the historical (pre 2014) values would need to be revised.



Appendix A: Underlying RBS1.0 Methodology

This Appendix describes the RBS1.0 methodology, and where appropriate notes where there are differences or enhancements due to the proposed scope of the RBS2.0 update. The text is taken from the RBS1.0 report, with modifications where necessary.

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). This method remains unaltered in RBS 2.0. 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.⁷ More specifically this involves estimating the energy use at the appliance (unit) level and 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:

Annual Energy Consumed (AEC) = Stock Numbers * Unit Energy Consumption (UEC).

Likewise for energy demand in principle:

Total Power Demand = Stock Numbers * Unit Power Demand (UPD)⁸.

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 numbers 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 3 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

⁷ 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.

⁸ 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.

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 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. This stock modelling is done at the national level and at the State/Territory level.

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 = Hours of usage * Unit Energy Input, or



UEC = Hours of usage⁹ * Unit Capacity * 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 different measurement and usage metrics (such as wet appliances where UEC is a function of the use 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. Although there are several different modes of operation found in appliances these have been condensed to the modes shown in Table 2.

Mode	Description
Operation 1	Main operation mode - heating mode in space conditioning equipment.
Operation 2	Main operation mode - 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.

Table 2: Modes of operation used in the RBS

Unit Power Demand (UPD) is currently 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 = Proportion of equipment operating * Unit Power Input.

Consequently UPD is estimated for peak (maximum) demand periods during a year. This means information on the usage behaviour for the equipment during the peak 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.

In the RBS2.0, average power demand during specific time periods will be calculated using a different method, and this is the subject of one of the potential enhancements discussed in this Methodology report (see section 5. Detailed Enhancement Methodology and Approach). This method will derive average UPD for a given hour from stock-weighted average UEC, with the proportion of UEC determined using the product's time of use profile and seasonal/day type proportion of energy use. This calculation approach will be used as stock-weighted average UEC incorporates average unit efficiency and usage, and hence recognises that many products do not always operate at their Unit Power Input level.

⁹ 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.

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 is relatively limited data available to use measurement/metering based approaches. What data there is available is based on small and/or localised residential samples, which makes extrapolating this data to the general population problematic. The building thermal modelling, using AccuRate software developed by CSIRO, and engineering algorithm approaches however have both been used and are accepted methods for predicting energy use and demand.

Thermal modelling involves the modelling of the energy requirements of a building to achieve specified internal thermal comfort 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 dwelling design in different climate zones to meet specified interior comfort conditions.

However, on its own, thermal modelling cannot meet the requirements of the RBS to determine the energy used in Australia 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 with information 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 use data.

This combined thermal modelling/engineering algorithm approach is what was used in the previous RBS (RBS 2015) and in the older 'Energy Use in the Australian Residential Sector' (EES 2008) and this combined approach will again be used in the current RBS.

The two key components of the current modelling approach are:

- <u>Engineering algorithm modelling</u> 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 is 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 in States 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 is a percentage increase or decrease in estimated energy required compared to a base year¹⁰. 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:

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 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).

A further complication for the model was that Hours of Usage¹¹ does not directly equate to the number of hours that each unit is operating at its Unit Capacity (i.e. 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^{12.}
- Reverse Cycle Use: Reverse cycle air conditioning equipment introduces another modelling issue in that the proportion of equipment used for heating and/or

¹² 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.



¹⁰ The base year was 2012, chosen as it was the year where the most recent and accurate space conditioning usage data was available.

¹¹ 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.

cooling varies between climate zones. So only 5% of AC units may be used for heating in the Northern Territory, but 95% may be used for heating in Tasmania.

- 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) have 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.

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

UEC = Hours of usage * Usage Adjustment Factor * Unit Capacity * 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. This approach is unchanged in the RBS2.0.

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 general energy efficiency. The model was designed to estimate the trends in potential maximum peak demand in each State, 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 periods 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 Demand = units * kW/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.¹³

Implementing the engineering algorithm approach in RBS1.0 involved obtaining data on the number and characteristics of all residential appliances and equipment potentially operating during system 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 State and nationally for each year of the study period.

For RBS2.0, the same approach will be used for calculating peak demand but it is anticipated that the availability of additional time of use data and research, such as the CSIRO NEAR studies and Solar Analytics monitoring data, will enhance the accuracy of the underlying factors data driving the analysis.

The impact of building shell efficiency changes was integrated into the demand model in a similar way to the manner 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

¹³ Further explanation of the calculation of potential maximum demand and of these terms is provided in the Technical Appendix.

overall annual energy consumption (i.e. 0.92 for detached housing and 0.94 for semidetached). 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, 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.

Model Architecture

The RBS energy end-use model was developed to meet the requirements of the 2015 study of residential energy use and the same architecture, with a few additions, will be used in the RBS2.0. 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 4. Examples of the types of input data are



also shown. This model does not include any variations that may be required to implement the potential enhancements discussed later in the report.



Figure 4: 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)
- Demand Aggregator (which is not shown in the diagram, but will be added with the RBS2.0 enhancement).

A schematic of the end-use model is provided in Figure 5 below.





Figure 5: 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, product category and end-use as appropriate. The calculations were undertaken on a jurisdictional basis (state/territory/country) and by relevant climate zone where this was applicable (solar 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 <u>Technical Appendix</u>.

The model processed data and provided results on the energy end-uses, product categories, groups and products that are listed in Table 3.

End Use	Category	Group	Product
Space conditioning	Combined space heating and space cooling equipment	AC ducted	AC ducted
	Combined space heating and space cooling equipment	AC non-ducted (split and WW)	AC non-ducted
	Combined space heating and space cooling equipment	AC non-ducted (split and WW)	AC Portable
	Combined space heating and space cooling equipment	AC non-ducted (split and WW)	AC Window Wall
	Space cooling equipment	Evaporative (mostly central)	Evaporative (mostly central)
	Heating Equipment	Electric resistive	Electric Resistive-Main
	Heating Equipment	Electric resistive	Electric Floor Heating

Table 3: List of Products, by Group, Category and End-Use included in RBS1.0 & 2.0 Model



End Use	Category	Group	Product
	Heating Equipment	Mains gas non-ducted	Gas Space: Flued-NG
	Heating Equipment	Mains gas non-ducted	Gas Space: Unflued-NG
	Heating Equipment	Mains gas ducted	Gas Ducted-NG
	Heating Equipment	LPG gas non-ducted	Gas Space: Flued -LPG
	Heating Equipment	LPG gas non-ducted	Gas Space: Unflued -LPG
	Heating Equipment	Wood Heaters	Wood-Combustion
	Heating Equipment	Wood Heaters	Wood-Open fire
	Space cooling equipment	Fans	Fans
	Heating Equipment	Electric resistive	Electric Resistive-Secondary
Appliances	White goods	Refrigerators	RF1
	White goods	Refrigerators	RF2
	White goods	Refrigerators	RF3
	White goods	Refrigerators	RF4
	White goods	Refrigerators	RF5
	White goods	Refrigerators	RF5B
	White goods	Refrigerators	RF5S
	White goods	Refrigerators	RF5T
	White goods	Freezers	RF6C
	White goods	Freezers	RF6U
	White goods	Freezers	RF7
	White goods	Dishwashers	DW
	White goods	Clothes washers	CW-F
	White goods	Clothes washers	CW-T
	White goods	Clothes dryers	CD
	White goods	Refrigerators	RF-Drink
	White goods	Refrigerators	RF-Wine
Lighting	Lighting	MV incandescent	MV incandescent
	Lighting	MV halogen	MV halogen
	Lighting	ELV halogen	ELV halogen
	Lighting	CFL	CFL
	Lighting	Linear fluorescent	Linear fluorescent
	Lighting	LED	LED
Cooking	Cooking Products	Uprights	Upright - Elec
	Cooking Products	Cooktops	Cooktop - Elec
	Cooking Products	Ovens	Oven - Elec
	Cooking Products	Uprights	Upright - NG
	Cooking Products	Cooktops	Cooktop - NG
	Cooking Products	Ovens	Oven - NG
	Cooking Products	Uprights	Upright - LPG
	Cooking Products	Cooktops	Cooktop - LPG
	Cooking Products	Ovens	Oven - LPG
	Cooking Products	Microwave	Microwave
Water heating	Hot water heaters	Electric Water - Small	ESWH Small



End Use	Category	Group	Product
	Hot water heaters	Electric Water - Med/Large	ESWH Med
	Hot water heaters	Electric Water - Med/Large	ESWH Large
	Hot water heaters	Electric Water - Small	EIWH
	Hot water heaters	Gas storage (mains)	GSWH - NG
	Hot water heaters	Gas storage (LPG)	GSWH - LPG
	Hot water heaters	Gas instant (mains)	GIWH - NG
	Hot water heaters	Gas instant (LPG)	GIWH - LPG
	Hot water heaters	Solar electric	SEWH Z1
	Hot water heaters	Solar electric	SEWH Z2
	Hot water heaters	Solar electric	SEWH Z3
	Hot water heaters	Solar electric	SEWH Z4
	Hot water heaters	Heat pump	HPWH Z1
	Hot water heaters	Heat pump	HPWH Z2
	Hot water heaters	Heat pump	HPWH Z3
	Hot water heaters	Heat pump	HPWH Z4
	Hot water heaters	Heat pump	HPWH Z5
	Hot water heaters	Solar gas	SGWH Z1 - NG
	Hot water heaters	Solar gas	SGWH Z2 - NG
	Hot water heaters	Solar gas	SGWH Z3 - NG
	Hot water heaters	Solar gas	SGWH Z4 - NG
	Hot water heaters	Solar gas	SGWH Z1 - LPG
	Hot water heaters	Solar gas	SGWH Z2 - LPG
	Hot water heaters	Solar gas	SGWH Z3 - LPG
	Hot water heaters	Solar gas	SGWH Z4 - LPG
	Hot water heaters	Wood	Wetbacks
	Hot water heaters	Electric Water - Small	ESWH Small NZ
	Hot water heaters	Electric Water - Med/Large	ESWH Med NZ
	Hot water heaters	Electric Water - Med/Large	ESWH Large NZ
Appliances	Other Equipment	Pool Equipment - Elec	Pool Pump
	Other Equipment	Pool Equipment - Elec	Pool Heating-HP
	Other Equipment	Pool Equipment - NG	Pool Heating-Gas
	Other Equipment	Pool Equipment - Elec	Pool Heating-Solar (pumps)
	Other Equipment	Pool Equipment - Elec	Spa-Elec
	Other Equipment	Pool Equipment - NG	Spa-Gas
	Other Equipment	Pool Equipment - Elec	Pool Chlorine Cells
	Other Equipment	Pumps	Water Pumps
	Other Equipment	Battery chargers	Battery chargers-mobility
	Other Equipment	Battery chargers	Battery chargers
	Other Equipment	Miscellaneous	Kitchen Appliances
	Other Equipment	Miscellaneous	Other miscellaneous
	Other Equipment	Miscellaneous	Other standby
	Other Equipment	Class 2 Common Areas	Class 2 Common Areas
Appliances	IT&HE	Television - composite average	TV-CRT



End Use	Category	Group	Product
	IT&HE	Television - composite average	TV-LCD
	IT&HE	Television - composite average	TV-OLED
	IT&HE	Television - composite average	TV-Plasma
	IT&HE	Television - composite average	TV-Projection
	IT&HE	Set-top box - free-to-air	STB - FTA
	IT&HE	Set-top box - subscription	STB - STV
	IT&HE	Video players and media	DVD/Blu-ray players
	-	recorders	
	IT&HE	Video players and media	VCRs
	IT&HE	Video players and media	HDD Video Recorders &
	-	recorders	Media Players
	IT&HE	Home entertainment - other (mostly audio equipment)	Audio/Home Theatre
	IT&HE	Game consoles	Game consoles
	IT&HE	Home entertainment - other	Misc HE
		(mostly audio equipment)	
	IT&HE	Computers - desktop	PC - Separate Monitor
	IT&HE	Computers - desktop	PC - Integrated Monitor
	IT&HE	Computers - laptop	PC - Notebook
	IT&HE	Monitors (used with desktop computers)	Monitors
	IT&HE	Wireless/Wired networked device	Routers, Access Points, Modems, Switches, etc
	IT&HE	Miscellaneous IT equipment	Drives, other
	IT&HE	Miscellaneous IT equipment	Printers/MFDs, Fax
	IT&HE	Wireless/Wired networked	Broadband Terminal
	IT&HE	Home entertainment - other (mostly audio equipment)	Smart Speaker/Display
Generation	PV	PV 2kW	PV 2kW - Z1
	PV	PV 2kW	PV 2kW - Z2
	PV	PV 2kW	PV 2kW - Z3
	PV	PV 2kW	PV 2kW - Z4
	PV	PV 4kW	PV 4kW - Z1
	PV	PV 4kW	PV 4kW - Z2
	PV	PV 4kW	PV 4kW - Z3
	PV	PV 4kW	PV 4kW - Z4
-	PV	PV 6kW	PV 6kW - Z1
	PV	PV 6kW	PV 6kW - Z2
	PV	PV 6kW	PV 6kW - Z3
	PV	PV 6kW	PV 6kW - Z4
	PV	PV 10kW	PV 10kW - Z1
	PV	PV 10kW	PV 10kW - Z2
	PV	PV 10kW	PV 10kW - 73
	PV	PV 10kW	PV 10kW - 74
	PV	PV >10kW	PV >10kW - 71
	PV	PV >10kW	PV >10kW - 72



End Use	Category	Group	Product
	PV	PV >10kW	PV >10kW - Z3
	PV	PV >10kW	PV >10kW - Z4
	PV	PV NZ	PV - NZ1
	PV	PV NZ	PV - NZ2
	BSS	Batt Storage	BS - Retrofit - S1
	BSS	Batt Storage	BS - Retrofit - S2
	BSS	Batt Storage	BS - Integrated - S1
	BSS	Batt Storage	BS - Integrated - S2
Transport	Electric vehicle	EV	Electric vehicle

Note: New products, groups categories and end-uses for RBS 2.0 are shown in blue

