Energy Efficiency Forecasts: 2019 – 2041: Final Report

Prepared for: Australian Energy Market Operator

Date: July 2019

Revision History					
Rev No.	Description	Prepared by	Reviewed by	Authorised by	Date
00	Draft Report	PH	HS	PH	23/05/2019
00	Final Report	PH	HS, RF	PH	5/7/2019
01	Final Report (rev.)	PH	HS	PH	8/7/2019
02	Final Report (rev.)	PH	HS	PH	12/7/2019
03	Final Report (rev.)	PH	HS	PH	21/7/2019

Table of Contents

Figures

Tables

Abbreviations

Abbreviation	Full Term
ABS	Australian Bureau of Statistics
AC	Air Conditioning
AEEI	Autonomous Energy Efficiency Improvement (also referred to as Natural Energy Efficiency Improvement)
AEMO	Australian Energy Markets Operator
AES	Australian Energy Statistics
ANZSIC	Australian and New Zealand Standard Industrial Classification
BASIX	Building Sustainability Index (NSW)
BCA	Building Code of Australia
BCR	Benefit Cost Ratio
CBD	Commercial Building Disclosure
CFL	Compact Fluorescent Lamp
CLF	Conservation Load Factor
COP	Co-efficient of Performance
CRT	Cathode Ray Tube
CSIRO	Commonwealth Scientific and Industrial Research Organisation
CZ	Climate Zone
DEE	Department of the Environment and Energy (Australian Government)
DKIS	Darwin to Katherine Integrated System

Abbreviation	Full Term
E3	Equipment Energy Efficiency program
EEO	Energy Efficiency Opportunities program
EER	Energy Efficiency Rating
EES	Energy Efficient Strategies Pty Ltd
ESS	Energy Savings Scheme (NSW)
FTA	Free to Air
GEMS	Greenhouse and Energy Minimum Standards
GHG	Greenhouse Gas
GJ	Giga Joule
GLS	General Lighting Service (incandescent) lamps
GSP	Gross State Product
GWA	GeorgeWilkenfeld and Associates Pty Ltd
GWh	Giga Watt hours
HIP	Household Insulation Program
HVAC	Heating, ventilation and air conditioning
KPIs	Key Performance Indicators
kW	Kilo Watt
LCD	Liquid Crystal Display
LED	Light Emitting Diode
LFL	Linear Fluorescent Lamp

Abbreviation	Full Term
LV	Low Voltage
MB	Megabyte
MD	Maximum Demand
MEPS	Minimum Energy Performance Standards
MW	Mega Watt
MWh	Mega Watt hours
N/A	Not available
NABERS	National Australian Built Environment Rating Scheme
NatHERS	National House Energy Rating Scheme
NEPP	National Energy Productivity Plan
NCC	National Construction Code
NEM	National Energy Market
NWIS	North Western Integrated System
OEH	Office of Environment and Heritage (NSW)
OEM	Original Equipment Manufacturer
OLED	Organic Light Emitting Diode
RCP	Representative Concentration Pathway
REES	Retailer Energy Efficiency Scheme (SA)
RET	Renewable Energy Target (also known as nRET, the National Renewable Energy Target)
RIS	Regulation Impact Statement

Abbreviation	Full Term
RMY	Reference Meteorological Year
RSCMD	Residential Space Conditioning Maximum Demand model
SPR	Strategy Policy Research Pty Ltd
STB	Set Top Box
SWIS	South West Integrated System
TOU	Time of Use
US	United States
VEET	Victorian Energy Efficiency Target (now renamed VEU)
VENCORP	(former) Victorian Energy Corporation
VEU	Victorian Energy Upgrades (VIC)
WELS	Water Efficiency Labelling Scheme

Executive Summary

This report finds that energy efficiency policies and measures have a very significant impact in reducing both energy consumption and maximum demand in Australia.

Under Neutral scenario assumptions[1], for example, we find that by FY2041 efficiency policies are expected to generate annual electricity savings of some 64,600 GWh, comprising just under 30,400 GWh in the residential sector (a reduction of 34.7% relative to FY2001 'frozen efficiency'[2]), 27,900 GWh in the commercial sector (a reduction of 23.5% relative to FY2001 frozen efficiency), and just over 6300 GWh in the industrial sector[3], relative to the base year for this study of FY2001. In addition, and in the same Neutral scenario and year, the measures are estimated to avoid 35.5 PJ of gas consumption, again relative to the FY2001 base year. The residential sector gas savings represent a 9.3% reduction relative to frozen FY2001 efficiency, while the commercial sector gas savings represent just 2.1% savings on the same basis.

In terms of avoided peak load, the measures are estimated to reduce peaks in FY2041 by 11,500 MW in the residential sector (Neutral scenario); 9,700 MW in the commercial sector; and 1,400 MW in the industrial sector, again measured relative to FY2001.

Under Slow scenario assumptions, energy efficiency impacts are lower than in the Neutral case, but then consumption and demand would also be lower, reflecting slower growth in populations and gross state product. Under both Fast and Neutral Sensitivity assumptions, where we model the impact of potential strengthening of national energy efficiency policies in future, energy savings accumulate more rapidly.

To interpret the above savings values, it is important to note that all savings are expressed relative to a FY2001 base year. Savings in the historical period are already present in historical consumption and demand data. Therefore, the savings values shown in this report cannot simply be deducted from current or expected future consumption or demand. The incremental impact of energy efficiency savings on future demand and consumption can, however, be estimated by examining the *change* in the projected future efficiency savings trends[4], relative to those in the past. Where savings are expected to increase over time, relative to trend, then expected future consumption will be lower, and vice versa.

To summarise our analysis of other key research issues for this project:

- We cannot find evidence of existing policies, of any significant scale, that promote fuel switching from gas to electricity. Indeed, some existing policies, such as the hot water provisions for residential buildings in the Code, and some state energy savings schemes,

[1] See Section 2.1 for a description of AEMO's scenarios.
[2] Or the consumption that would have been expected in FY2041 had there been no improvement in energy efficiency since FY2001.
[3] No frozen efficiency projection has been made for the industrial sector – see Chapter 6 for details.
[4] Represented by the changing slope of the energy savings curves.

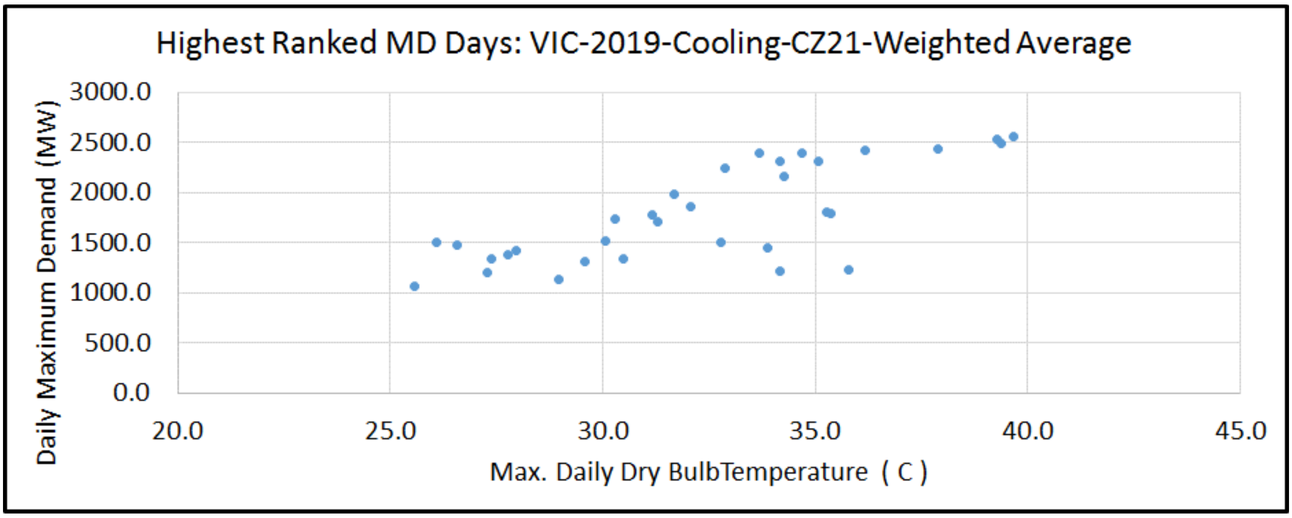
currently have the opposite effect. However, we are aware that some jurisdictions are exploring possible fuel-switching initiatives, so this should be reviewed again next year. Our models do take into account historical fuel switching, but the primary causes of this switching are market and technology factors rather than policy.

- Our analysis takes into account the changing population and housing trends by jurisdiction and climate zone. A sophisticated housing stock model has been developed that integrates AEMO's population projections with ABS Census, housing completion and family and household structural projections, on a unique basis for each state and territory and climate zone.
- We have included 'new' policies this year – in fact, these are the continuing or legacy effects of the Energy Efficiency Opportunities (EEO) program and the Household Insulation Program (HIP). Other potential inclusions were considered but generally not included due to their small scale and/or the difficulty of distinguishing program impacts from 'business as usual' market and technology impacts.
- Extensive provisions have been made to avoid double-counting of policy-induced energy efficiency savings. This include making allowances for autonomous or natural energy efficiency improvement, discounting the impact of certain programs to allow for diminishing returns over time and non-additionality (eg, NABERS and CBD), discounting Code impacts for potential non-compliance and 'performance gaps', and discounting or adjusting state scheme impacts for non-additionality to other policies and/or for 'business as usual' market and technology change, such as the widespread adoption of LED lighting.
    - At the same time, we note that to be confident of eliminating all double-counting, it would be necessary to first account for *total* energy efficiency change (by sector, fuel and jurisdiction, and then determine the shares that are policy-induced and market-/technology-based induced.
- Detailed results are provided in the body of the report and in accompanying workbooks of avoided energy consumption and peak demand for all states and territories, for electricity and gas, and for the residential, commercial and industrial sectors, over the period FY2002 – FY2041, relative to a FY2001 base.
- Advice for 'mapping' these results to AEMO's forecasts is summarised above and discussed in more detail in the chapters on each sector.

A specific and detailed analysis of potential saturation effects in heatwave conditions is contained in Chapter 4. A saturation effect can occur when demand fails to continue to increase as a function of rising temperature in heatwave conditions, for example because the installed air conditioning stock reaches it maximum cooling capacity (and therefore electrical demand). The extent to which this occurs is also likely to be dependent upon the thermal integrity of the dwelling's envelope, as well as the air conditioner's capacity. For a whole region, the mix of housing by energy efficiency and type, and the mix of air conditioning equipment, would be relevant.

While the scope of our analysis of this issue is limited in the current project, we find while there is some evidence of saturation effects on highest maximum demand days, at least in Victoria and for Class 1 dwellings, this effect is not particularly pronounced. See Figure 1, and Chapter 4 for further details.

Figure 1: Sample Output – Victoria 2019: Highest Ranked MD days



There are a number of risks and uncertainties associated with this analysis including:

- Data limitations – notably including that the ABS Building Activity series does not distinguish between apartments and townhouses, in the residential sector; provides no indication of the net change in floor area associated with the 'value of construction work done' in the non-residential sector, the type of work done (demolition, new construction, etc) or for which building classes
- The overall size of the non-residential building stock is (highly) uncertain, with estimates from different sources disagreeing by 100% or more. The Australian Government is expected to commission an updated Commercial Building Baseline Study that, along with advances in geospatial tools, may reduce this uncertainty in future.
- Energy consumption by non-residential building type is highly uncertain, particularly by climate zone or region, as energy consumption data is only published by ANZSIC code and by jurisdiction.
- Output from and the energy use of industrial enterprises is either not known or not published for confidentiality reasons, and this largely limits objective analysis of energy efficiency trends in this sector.

- The scope of our analysis of possible saturation effects has been limited – coverage of a representative sample of dwelling types and efficiencies in a range of climate zones is recommended for future studies, along with application of a more sophisticated representation of climate change impacts.

Given that energy efficiency generates avoided consumption and avoided demand – that it, it is not directly metered or measured expected in specific contexts (eg, upgrade projects that are monitored before and after), there is no ready methodology or data source available with which to check the accuracy of past, or indeed current, energy efficiency estimates. This study includes reconciliation of energy efficiency estimates with historical metered consumption – at least in the residential and commercial sectors – this is not feasible for the industrial sector as we do not model total energy consumption of this sector 'bottom up'.

However, the number of factors impacting on actual consumption is very large, and not all of those factors have been studied here. Price elasticity impacts during a period of very significant real price increases for energy, potential 'demand destruction' following the Global Financial Crisis, the impact of weather patterns and climate change, urban heat island effects, building and business cycles (other than GSP), specific changes in energy-using equipment, and many other relevant factors have not been studied here. However, our residential and commercial energy efficiency models enable consumption trends since FY2001 to be recreated without great deviation from reality in the historical period, and this increases confidence in the projection results.

1. Introduction

1.1 Purpose

This report sets out the key methodologies, assumptions, concepts and draft findings for energy efficiency forecasts to FY2041 by sector, jurisdiction, fuel and load segment.

AEMO's objectives in commissioning this work include to better understand:

- the expected impact of energy efficiency policies and measures on annual electricity and gas consumption (over the period to 2041, by state and territory, in the residential, commercial and industrial sectors)
- the expected impact of energy efficiency policies and measures on maximum demand for electricity and gas consumption over the period to 2041.

Additional objectives include understanding the extent to which the expected impact of energy efficiency measures on maximum demand may degrade, or reach saturation points, in heatwave conditions.

The report distinguishes energy efficiency changes that are attributable to specific policies and measures from those that may have occurred in any case. The latter are known as 'autonomous' or 'natural' energy efficiency changes, for example due to technology change or market forces. The scope, however, does not extend to a study of *total* energy efficiency change (the sum of policy-induced and autonomous efficiency change).

The report also details our approaches to managing the risks of double-counting savings from policies and measures that, in effect, target the same energy savings. We also make recommendations about the appropriate utilisation of the research findings, including a recommended methodology for integrating the efficiency forecasts into AEMO's wider demand and consumption forecasts.

The report also comments on the accuracy and reliability of the forecasts, and related data uncertainties. Where appropriate, we offer suggests for data improvement projects that could help to reduce uncertainties over time.

1.2 Methodology

1.2.1 Overview

The project requires assessments of the historical (back to FY2001) and expected future (to FY2041) impacts of energy efficiency policies and measures (inter alia). We therefore quantify the volume of energy consumption and demand avoided by each measure in each year of their actual historical and expected future operation. In effect, the methodology quantifies how much higher energy consumption and demand would have been in each year (and would be expected to be in each future year) if it were not for the presence of these particular policy interventions.

1.2.2 Application of Report Findings

To interpret and apply these results in the context of AEMO's forecasts, it is important to note that the historical impact of policy measures – in reducing consumption and demand – is *already present* in past actual values for consumption and demand. As a result, consumption and demand projections based on regressions of historical values will project into the future the past impact of efficiency policies.

However, regression-based projections analyses are generally blind to information about the specifics of policy and program design, existing legislation and government intent. Where these factors are expected to lead to either a slowing or an acceleration of the future rate of energy efficiency improvement – and examples of both are evidenced in this report – then regression-based projections are at risk of either under- or over-estimating future consumption and demand, potentially to significant degrees.

By way of illustration, Figure 2 illustrates a hypothetical example. The pre-2018 trend in energy efficiency is upwards (the blue curve) and this trend persists until 2022. However, the later period is best described by a downward trending curve (the red curve). The difference between these two trends quantifies the extent to which projections based on the first trend would over-estimate future efficiency savings. Forecasts would be improved by adding the difference between these two curves, after 2022, to expected future consumption.

Figure 2: Application of Energy Efficiency Forecasts to AEMO Forecasts

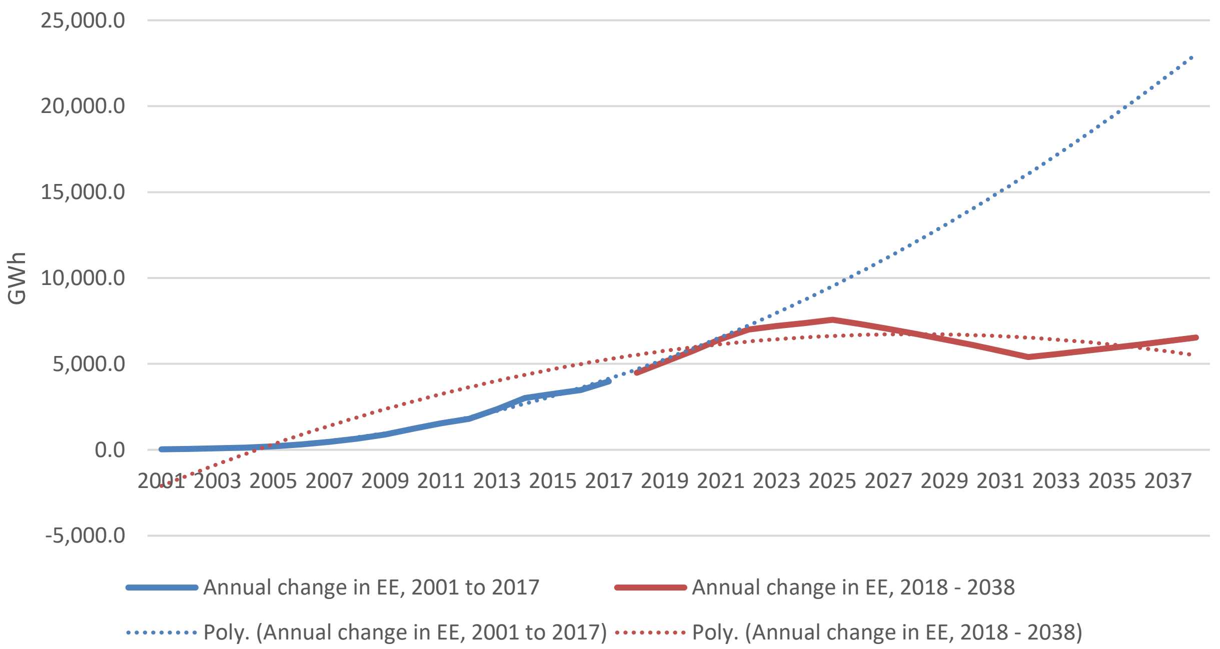
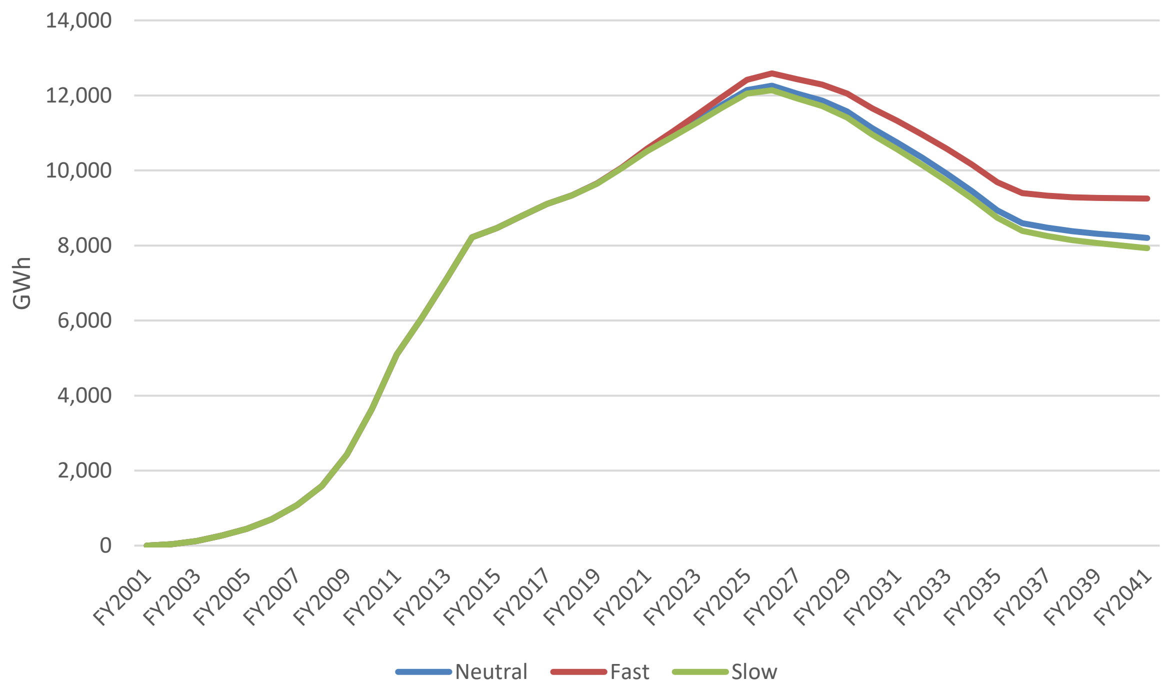


Figure 3 is not hypothetical, but rather shows the actual past and expected future trend of energy efficiency policy impacts in the industrial sector, aggregated to the whole-of-Australia level. Clearly, the trend is far from linear, reflecting specific changes, and future assumptions appropriate to each scenario, for specific policy measures. In this sector, the Greenhouse and Energy Minimum Standards (GEMS) program contributes energy savings that grow in a reasonably linear manner, but this is overlaid by the significant impact of the (former) Energy Efficiency Opportunities (EEO) program, first in pushing up savings after 2007, then in slowing savings after the program was abolished in 2014. In the latter years, the currently-legislated cessation dates for state energy savings schemes (only the NSW Energy Savings Scheme is relevant for the industrial sector) contribute to falling levels of policy-induced energy efficiency. It will be apparent that projections based on regression of pre-2019 values would risk over-estimating future policy-induced energy savings and, as a result, under-estimating future expected demand, and potentially by a large margin. The difference between the pre-2019 (historical trend), and future values based on our projections, can be used to make post-model adjustments to both consumption and demand, in order to incorporate the available information about efficiency policy trends.

Figure 3: Industrial Sector - Avoided Electricity Consumption by Scenario - Australia



1.3 Accuracy of Previous Forecasts

Since the methodology used in this study quantifies *avoided* consumption, there is no ready information source that can be used to check the accuracy of past projections. Potentially, a sophisticated model of energy consumption could be used to predict consumption in, say, FY2019, with/without the 2018 projections of energy efficiency for that year – utilised as described above – to quantify the extent to which inclusion of the efficiency projections better predicted actual consumption. However, this method would only be valid to the extent that the model accurately accounted for every other factor impacting on actual consumption, including weather, economic conditions, structural changes in the economy, business cycle, etc.

In some cases, new and more detailed information has been made available this year, for example on the energy savings impact of the NSW Energy Savings Scheme, and we acknowledge the assistance of the Office of Environment and Heritage in this regard. More generally, the latest information on program impacts has been sourced for every measure modelled, but in some cases, this relates to the 2017 financial or even calendar year (state energy savings schemes). Data on the GEMS program has been fully updated by George Wilkenfeld & Associates and accords with the current work program for this program.

1.4 Project Scope

1.4.1 Key Requirements

The core requirements include:

- Producing forecasts of energy efficiency policy impacts on an annual basis from FY2019 to FY2041 (MWh for electricity, GJ for gas)
    - For all states and territories
    - By AEMO Scenario
    - Separately for the residential, commercial and industrial sectors
- Producing historical efficiency savings estimates from FY2001 to FY2018 on the same frame as above
- Reviewing energy efficiency measures captured in AEMO's 2018 energy forecasts (published with the 2018 Electricity Statement of Opportunities)
- Updating the set of efficiency policy measures (as required) and include and consider any missing significant policies/regulations that are likely to affect energy efficiency forecasts
- Assessing, to the extent feasible, the accuracy of any previous energy efficiency forecasts that they have undertaken for AEMO
- Providing clear descriptions of the underlying assumptions, methodologies and approaches applied. This includes the avoidance of double counting between different programs, such

as building standards and codes, energy efficiency schemes, cooling/heating appliances, and natural energy efficiency activity

- Producing Assumptions Summary and Scenario Summary sheets in the workbooks
- Producing an Energy Efficiency Specifications document
- Producing a draft and then final report including:
    - A description of the method and approach
    - The annual forecasts and historical estimates
    - An analysis of risks and uncertainties associated with these forecasts, including those related to their accuracy/reliability
    - Summarising insights into the key themes and trends of efficiency, including the role of the National Energy Productivity Plan
    - Comparing 2019 and 2018 forecasts and explaining any significant differences, and commenting of the accuracy of 2018 forecasts.

A Final Report is expected to be produced by 7 June 2019.

1.4.2 New Elements for 2019

The 2019 study embodies a number of changes relative to the 2018 study. These include:

- The inclusion of industrial sector efficiency policy impacts
- Relatedly, the separation of efficiency forecasts into three sectors (and workbooks): residential, commercial and industrial
- Consideration of the accuracy of past efficiency forecasts
- The framing of AEMO's scenarios has changed, and this impacts on the efficiency forecasts by scenario
- Certain AEMO assumptions have been updated, such as the historical split between the heating- and cooling-shares of total electricity consumption by state
- The consideration of energy productivity measures such as policies that promote fuel-switching from gas to electricity
- Providing advice on a method for mapping energy efficiency changes onto annual expected changes in the NEM regional operational demand forecasts
- Providing advice on a method for mapping energy changes onto the NEM maximum demand half-hourly operational demand forecasts, including consideration of energy efficiency saturation points given weather conditions such as extreme temperature.

1.4.3 Scope Limitations

This study does not extend to a full examination of natural, or non-policy-induced, energy efficiency change in Australia, nor indeed total energy efficiency change. There would be considerable advantage in a study that first established the *total* change in energy efficiency, by sector/state/fuel, and then allocated that total change to policy-induced and non-policy-induced (or market and technology) effects. In particular, this approach would assist in ensuring that there is no double-counting of policy impacts, as the sum of changes from all measures plus market/technology effects could not exceed the estimated total. Relatedly, we note there is no recent research on rates of autonomous energy efficiency improvement in Australia in these sectors.

Also, the extent to which issues such as energy efficiency saturation points in heatwave conditions can be explored in this project is limited by the available time and budget. While Chapter 4 makes a solid start on this analysis, additional work would be required to fully document this phenomenon Australia-wide.

Demand management is outside the scope of this project.

1.5 Project Team

This project was delivered by Philip Harrington (SPR) and SPR Associate, Dr Hugh Saddler, in collaboration with Robert Foster and Lloyd Harrington (Energy Efficiency Strategies), and George Wilkenfeld and Associates.

2. Modelling Approaches

2.1 Scenarios

Forecasts are prepared for each of four scenarios:

1. Neutral: reference assumptions (from AEMO) for population growth and change in gross state product (GSP), 'business as usual' policy assumptions
2. Neutral Sensitivity: as per Neutral but with 'strong' efficiency policy settings
3. Fast Change: strong assumptions for population growth and growth in GSP, and with 'strong' efficiency policy settings
4. Slow Change: as per Neutral but with 'weak' population and GSP growth.

These scenarios are summarised in Table 1.

Table 1: Summary of Scenario Parameters

Scenario/ sensitivity	Neutral	Neutral sensitivity	Fast change	Slow change
Demand settings				
Economic growth	Neutral	Neutral	Strong	Weak
Population	Neutral	Neutral	Strong	Weak
Connections	Neutral	Neutral	Strong	Weak
Policy settings				
Energy efficiency improvements	Neutral	Strong	Strong	Weak

Source: AEMO

2.1.1 Modelling the Scenarios

The differentiation between the three primary scenarios (neutral, fast change, slow change) is as follows:

- **Residential**: net annual growth in the dwelling stock is modelled as proportional to growth in the underlying population, although – as explained in Chapter 3 – this is complicated by the changing composition of the dwelling stock over time.[5] These are modelled taking into account perspectives from the Australian Bureau of Statistics Census, and also Household and Family Projections.[6]
- **Commercial**: net annual growth in the non-residential building stock (floor area) is modelled as a percentage of the growth in Gross State Product each year and for each jurisdiction, reflecting historical relationships between these variables, but discounted in future years to reflect trends such as increasing productivity in the use of non-residential buildings,

[5] Note that we also model stock turnover – including demolitions, replacements, major refurbishments and extensions/additions – which is one factor that accounts for a higher impact for National Construction Code energy performance requirements than would otherwise be expected. The requirements apply to all 'new building work' and not only to the net growth in the stock annually.
[6] ABS 3236.0 – House and Family Projections, Australia, 2016 – 2041.

increasing work-from-home, and possible impacts on retail floor area associated with online retailing. GSP is assumed to vary in future between scenarios as indicated in Table 1.

- **Industrial**: industrial sector output and energy use in Australia is significantly influenced by sector- and even project-specific decisions. These will primarily reflect opportunities for export or import substitution. AEMO's primary approach to forecasting energy consumption and demand in this sector is to survey major industrial enterprises, to update expectations. Our methodology to estimating efficiency savings for this sector is based on program-specific data, and this introduces a modest degree of differentiation between scenarios.

For the Fast and Neutral Sensitivity scenarios, we model the impact of plausible future changes to key efficiency policies, including:

- For the National Construction Code (NCC), higher but cost-effective energy performance requirements, as anticipated in the COAG Energy Council's Code Trajectory and underpinning modelling[7,8]
- For GEMS, inclusion of the full set of 'possible future' and 'suspended' measures as mapped by George Wilkenfeld (refer to Chapter 3).

2.2 Modelling Efficiency Policy Impacts on Annual Energy Consumption

2.2.1 Overview

The impacts attributable to specific (and major) policy interventions at national and state/territory level are quantified drawing on:

- Program data and reporting
- Independent studies such as regulation impact statement benefit cost analyses
- Other data sources relevant to particular policy measures – such as building stock growth and turnover data for estimating impacts associated with building code energy performance requirements
- Scenario attributes such as differential rates of change in Gross State Product, connections and population.

Impacts are estimated annually for the historical period (FY2001 – FY2018), with forecast prepared annually from FY2019 to FY2041. Energy savings are distinguished by:

- Fuel (electricity and gas)
- State and territory (for national measures)

[7] COAG Energy Council, *Trajectory for low energy buildings*, December 2018.
[8] Delivered by SPR and Energy Action, for non-residential buildings, and AECOM for residential.

- Temperature-sensitive and non-temperature-sensitive portions (see also Section 2.3 on maximum demand impacts), specifically:
    - Heating load savings[9]
    - Cooling load savings
    - Baseload (temperature insensitive)
    - Hot water (not significantly temperature-sensitive but considered separately as this is often a controlled load).
- Residential, commercial and industrial sectors.

AEMO has provided estimates of historical energy consumption linked to heating and cooling loads and baseload, generated using regression techniques, as an input to this study. These are discussed further below.

In terms of defining the scope of energy use by sector, AEMO has specified the following definitions:

- Residential – as per AEMO and Australian Energy Statistics
- Commercial – remaining ANZSIC Divisions, not elsewhere classified (this includes commercial and services (ANZSIC divisions F, G, H, J, K, L, M, N, O, P, Q, R and S); agriculture; transport, postal and warehousing; construction)
- Industrial – Division B (mining) excluding coal mining and coal seam gas production; Division C (manufacturing) excluding aluminium production; and Division D (electricity, gas, water & waste) but excluding electricity supply.

2.2.2 Management of Additionality/Avoiding Double-Counting

The data sources noted above that help to inform the impacts of particular policy measures are rarely suitable for inclusion 'as-is', but rather requires additional analysis to control for a number of effects.

First, program-specific data often emerge from program KPIs, or what is reported to program managers. However, such KPIs may be selected to show the program impacts in the best possible light, with no account of the extent to which the KPIs noted are attributable to the program in question. Since NABERS and CBD rate the (changing*) total* energy performance of larger offices (and other buildings in the case of NABERS), for example, they provide extremely valuable insights into how the *overall* efficiency of these building segments is changing over time. However, they capture

[9] Note that the electricity sector uses the term 'load' to indicate instantaneous electrical (or energy) demand, whereas building simulation modellers use the terms 'load' or 'thermal load' to indicate the degree of transmission of heat energy through a building envelope. In the case of buildings, the significant difference between thermal load and electrical (or other energy) load is the type and efficiency (co-efficient of performance or COP) of the space conditioning devices used to ameliorate thermal loads on building structures. For clarity, we will use 'electrical load' in the former sense only, and 'thermal load' in the latter sense only.

all efficiency change *regardless of the cause or attribution*, including changes that are attributable to technology and/or market changes, and those attributable to other policies and programs that impact on the same building classes. For example, this could include the NCC, where an office undergoes a major refurbishment to current Code standards; CitySwitch (where whole building ratings are assessed); CBD (which uses NABERS ratings as a key program output); GEMS (where new equipment/appliances covered by GEMS impact on an overall rating) and state energy savings schemes (some of which credit NABERS upgrades). NABERS usefully publishes the number of Energy Savings Certificates created annually using the NABERS upgrade method, which implicitly acknowledges the risk of double-counting between the measures, but also enables this (specific) risk to be managed.

Broadly, our approach is to commence with program data, but then progressively allocate the total changes noted to different effects or causes. Where two measures target the same energy savings, allocation rules are required. Generally, we assume that mandatory measures 'crowd out' voluntary ones (so, CBD savings directly reduce NABERS savings – but not to zero). In circumstances where two or more measures provided financial support for the same actions, then the relative sizes of the incentives are likely to be indicative of the relative attribution of overall savings to the measures. Adjustments can include an allowance for autonomous or natural energy efficiency change, which is intended to ensure that savings estimates are additional to 'business as usual' efficiency change.

For savings estimates that draw benefit-cost analyses or regulation impact assessments (such as those attributable to the GEMS program, for example, but also NCC changes), the methodology required of studies is such that only incremental savings, additional to those expected to have occurred under BAU conditions, are estimated. Therefore, these savings estimates are not adjusted for BAU impacts a second time in our modelling. They are, however, estimations, often based on engineering or thermal modelling studies and also then-existing assumptions about stock growth, turnover and other factors. In reality, and despite the best efforts of analysts, many of these factors will deviate from those which were anticipated at a point in time. Generally, adjustments for such impacts must be based on professional judgement, including examination of the significance of changes that might have occurred, and an awareness of the assumptions built into RIS documents.

Further details on specific strategies used to manage double-counting risks associated with individual measures are noted in the context of specific measures in the Chapter 3 – 6 below.

2.2.3 Selection of Energy Efficiency Policies and Measures

There have been since FY2001, and are today, large numbers of government interventions at all levels – from national to local – that may have some impact on the efficiency of energy use in Australia. However, the incremental impact of more minor interventions – such as providing advice, information and encouraging behaviour change – is difficult to separate from business-as-usual trends, particularly with internet and social media providing ever-greater access to information for consumers, and also difficult to separate from price-elasticity responses, particularly in the period 2007 – 2015 when real prices rose strongly. Also, seeking to capture the incremental impact of smaller efficiency measures offers diminishing returns to considerable analytical effort. We therefore confine the analysis to larger and more significant policy interventions.

2.2.3.1 Measures included in past years

The set of measures included in past studies and again in 2019 is as follows:

Residential

1. Residential building energy performance requirements (including lighting and hot water provisions) (National Construction Code), noting that we model each Code energy performance increment separately.[10]
   a. Performance requirements have not changed since 2018
   b. Code electricity savings estimates are discounted by 10% (for all Classes) to reflect ongoing uncertainty about the extent to which there is full compliance with the requirements.
2. BASIX in NSW (a Code Variation for that State)
   a. Slightly higher targets have applied since July 2017, but these were already included in the 2018 study
3. State-based schemes (Energy Savings Scheme (ESS, NSW), VEET/Victorian Energy Upgrades (VIC), Retailer Energy Efficiency Scheme (REES, SA)
   a. Some have changed 'activities' – for example, commenced phase out for support for LED lighting.[11] While this will not change overall targets or saving, the distribution of savings may change, with consequences for peak demand, for example
   b. The NSW Department of Planning, Industry & Environment provided detailed program impact data by sector and method, which has enabled more detailed and accurate analysis to be performed
4. Residential portion of the Greenhouse and Energy Minimum Standards (GEMS) program (also known as the E3 or Equipment Energy Efficiency program), including labelling
   a. Generally, the reduction in the impact of this important program continues, with further delays in implementation of previously-expected measures. At the same time, the overall significance of this program remains high
   b. George Wilkenfeld & Associates has updated savings estimates for all elements of this program, including taking into account GEMS' expected future work program.

[10] The brief also refers to analysing the changing mix of dwellings in different states – such as an overall trend towards apartments and townhouses and away from detached houses; and changing house sizes. This effect was captured in the 2018 study, but updated data has been used in the present study.
[11] At least NSW ESS and Vic VEU have amended 'activities' to reduce the assumed degree of additional savings attributable to LED lighting refits.

Commercial

1. Non-residential building energy performance requirements (National Construction Code, also known as 'Section J' requirements) – noting that we separately analyse BCA2006, BCA2010 and NCC2019
    a. NCC2019 changes are updated for lower-than-expected stringency and delayed implementation. Estimates are discounted for possible non-compliance and other contributors to the so-called 'performance gap' (refer to Chapter 5 for details)
2. NABERS – this measure is modelled (jointly with CBD) drawing on the latest online annual report data
3. Commercial Building Disclosure (CBD)
    a. This scope of this program was expanded from July 2017, but this change was already captured in the 2018 study. The measure is analysed drawing on the comprehensive database of lifetime program statistics that is available online.[12]
4. Commercial portion of the GEMS/E3 program
    a. These have been impacted by program implementation delays, with measure-by-measure analysis updated by George Wilkenfeld & Associates
5. Commercial portion of state-based schemes (ESS, REES, VEU).

2.2.3.2 Additional measures not included in past years

Energy Efficiency Opportunities (EEO) program

Many programs – including significant ones such as the *Energy Efficiency Opportunities* program (one of the few efficiency policy interventions in the industrial sector) – have operated for a time but since closed down (in 2014, in EEO's case). EEO required (mandatory) analysis and reporting (including public reporting of summary findings) of energy efficiency opportunities (by payback range) by companies that used at least 0.5 PJ of energy annually, but it did not require (but did encourage) uptake or implementation of those opportunities. No financial reward (or penalty) was offered by the program, but arguably there were reputational outcomes for participating companies, with Board engagement a key strategy utilised by the program.

Past assessments of EEO discount reported savings for 'BAU' effects (for example, most opportunities with paybacks of less than 2 years should be realised in the normal course of events, assuming that the companies would have been aware of these opportunities, while savings (realised) with paybacks of 4 years or more may be additional). Despite this, savings estimates were significant (noting these are energy-intensive businesses). We note that this program was not included in past studies as the industrial sector (the primary focus of EEO) was out of scope.

[12] http://www.cbd.gov.au/registers/cbd-downloadable-data-set

Household Insulation Program

The Household Insulation Program (HIP) is another example of a significant but closed program, in this case in the residential sector. HIP led to over 1 million homes being retrofitted with insulation, and the effects of this change will persist for decades. Therefore, we have included this measure in the 2019 study, drawing on detailed analysis by Energy Efficient Strategies. This does, however, represent a discontinuity with the 2018 forecasts.

Other State and Territory Programs

We examined the case for including other measures, including at the state and territory level. For example, the ACT's retailer obligation scheme (the Energy Efficiency Improvement Scheme) is similar in design to the NSW, VIC and SA energy savings schemes; however, its smaller scale means that we have not included it in this study.

National Energy Productivity Plan

The National Energy Productivity Plan (NEPP) is an overarching framework or work program, which covers or references all the existing measures noted above. In that sense, we do not attribute additional energy efficiency impacts arise beyond those already noted.

Fuel Switching

A new requirement for this study is that the impacts of any *policy measures* that target fuel switching, eg, from gas to electricity, should be included. While we understand that several jurisdictions are exploring such policy options, we are not aware than any measures are in place at present. Indeed, elements of the existing energy efficiency policy framework – such as the hot water provisions for new residential dwellings – tend to encourage gas over electricity consumption.

At the same time, historical fuel switching is captured in our analysis, not because it has been caused by energy efficiency impacts, for the most part, but rather to ensure that our model balances with actual historical consumption data. We do allow for some continued (modest) fuel switching in all sectors, depending upon the scenario, but this is overwhelmingly attributable to market/technology drivers rather than policy. A full study of the trend towards the use of reverse cycle air conditioning for space heating, rather than gas heating, would be required to quantify this effect reliably, but again, this is likely to be occurring for market/technology reasons rather than policy.

2.3 Efficiency Policy Impacts on Maximum Demand

This study follows the same methodology as the 2018 Energy Efficiency Forecast study – with the addition of a substantial new analysis of the saturation effects, as described in Section 2.5 below, with detailed analysis presented in Chapter 4.

The peak demand avoided by the energy efficiency measures noted above are estimated using the conservation load factor (CLF) methodology, as developed in Australia by the Institute for Sustainable Futures and Energetics, and documented in a report prepared for the Department of

Climate Change and Energy Efficiency.[13] Input values including CLFs were informed by two additional references by Oakley Greenwood/Marchment Hill[14] and SKM MMA.[15] The reduction in peak demand that is attributable to avoided electricity consumption is calculated using the following formula:

$$\text{Peak demand reduction}^{i}_{\text{Summer, Winter}} = \frac{\dfrac{\text{Annual energy usage reduction}^{i}_{\text{jurisdiction}}}{8{,}760\ \text{h}}}{\text{CLF}^{i}_{\text{Summer, Winter}}}$$

Rearranging the formula, the CLF for a specific energy saving technology is defined as "…its average reduction in load divided by its peak reduction in load (annual energy savings in MWh divided by number of hours per year divided by system co-incident peak reduction (in MW)".[16]

Additional details of the methodologies and assumptions for individual measures and sectors are contained in Chapters 3 (residential), 5 (commercial) and 6 (industrial).

2.4 Potential Saturation Effects in Heatwave Conditions

A new task for 2019 was to examine the potential for 'energy efficiency saturation points' given weather conditions such as extreme temperature. Summer peak loads, in particular, are an important consideration for AEMO and the NEM, as peak loads drive investment in both generation and transmission infrastructure. Previous investigations by Energy Efficient Strategies for VENCORP in Victoria (2005) showed summer peak demand during extreme weather events is overwhelmingly dominated by residential air conditioning loads. For this study, Energy Efficient Strategies has updated past work and produced a dedicated estimation tool. The methodology, tool and key results are described in Chapter 4 and Appendices A and B.

[13] Institute for Sustainable Future and Energetics, *Building our savings: Reduced infrastructure costs from improving building energy efficiency*, report prepared for the Department of Climate Change and Energy Efficiency, July 2010.
[14] Oakley Greenwood/Marchment Hill, *Stocktake and Assessment of Energy Efficiency Policies and Programs that Impact or Seek to Integrate with the NEM: Stage 2 Report*, August 2012.
[15] SKM/MMA, *Energy Market Modelling of National Energy Savings Initiative Scheme – Assumptions Report*, December 2011.
[16] Oakley Greenwood/Marchment Hill (2012), p. 41.

3. Residential Sector – Results and Analysis

3.1 Introduction

As noted in Chapter 2, our methodology estimates the annual electricity and gas and peak demand savings in all states and territories that are attributable to the major energy efficiency measures in Australia including, for the residential sector:

- The GEMS program (minimum energy performance standards and labelling for certain appliances and equipment)
- Energy performance requirements within the NCC, including state and territory variations
- State-based energy savings targets and programs in NSW, Vic and SA
- The Household Insulation Program (HIP).

Energy savings are separated into baseload, heating load and cooling load components, to facilitate analysis of the impacts on measures on summer peak load, in addition to impacts on energy consumption.

In line with AEMO's requirements, we select a FY2001 base year, as this year predates most if not all of the energy efficiency measures analysed. Energy savings are estimated for the FY2001 – FY2018 historical period, and projected for the FY 2019 – FY2041 period, relative to the FY2001 'frozen efficiency' baseline.

The savings estimates can best be interpreted as indicating the extent to which energy demand (and consumption) would have been higher, in each of the historical and projection years, if not for the presence of the policy measures analysed.

The analysis accounts for at least major risks of double counting of energy savings. Key examples include:

- National Construction Code provisions relating to hot water and lighting, where MEPS and labelling programs also exist
- Different increments to energy efficiency performance standards (appliances, equipment, buildings) over time.

Further details of the key aspects of the methodology are provided below, while more detailed figures for savings by sector, measure, fuel and jurisdiction are set out in Appendix D.

3.2 Stock Modelling

An entirely new, and much more sophisticated residential stock projection model has been built for the 2019 efficiency savings estimations. The new model explicitly models the likely future changes in the mix of the three dwelling types – detached/separate houses (NCC Class 1A1), terrace/townhouses (NCC Class 1A2), and apartments (NCC Class 2) – on the basis of the observed propensity of different types of households to occupy each of the three dwelling types, and the projected future mix of household types.

The foundations for this new residential building stock model are two ABS publication. The first, used for the first time this year, is the March 2019 release of the ABS publication Household and Family Projections Australia, 2016 to 2041, Cat. No. 3236.0. This publication classifies households into six categories: couple families with children, couple families without children, one parent families, other families, lone person households, and group households. This publication contains three different projections for each state and major city, based on different assumptions about living arrangement propensities. The model described here uses projection Series II. The second ABS source is the various Census tables of household type by dwelling type. These tables use a slightly different mix of household types from Cat.no. 3236.0. To achieve alignment between the two ABS sources, the categories other families and group households, in Cat. No. 3236.0, were combined. The steps in building the new stock model are set out below.

1. *Align population levels underlying the ABS household projections with AEMO population projections*

The ABS household projections are based on projection Series B of Population Projections, Australia, 2017 (base) – 2066, Cat. No. 3222.0. This set of population projections differs slightly from the AEMO population projections. Therefore the ABS household projections were multiplied by an adjustment factor, calculated as the ratio of AEMO population to ABS population for each state in each year, to ensure that all the household projections were consistent with the AEMO population projections. Separate sets of adjustment factors were calculated for the Neutral, Slow and Fast scenarios.

2. *Use Census data to calculate propensities of the five different household types to occupy the three different types of dwelling*

For each of the past three Censuses (2006, 2011 and 2016), tables have been compiled and published by ABS showing household type by dwelling type. The allocation of each household type to dwelling types was calculated as the shares of each household type in each dwelling type in each Census year. This analysis was undertaken for each state capital major urban region and the rest of the state, except for Queensland, where the Gold Coast and Sunshine Coast urban regions were combined with Brisbane. As expected, most of the allocations show a shift away from Class 1A dwellings and towards Class 1B and 2 dwellings in the major urban areas. They also show much higher proportions of Class 1A2 and Class 2 dwellings in major urban areas than in the rest of each state. Approximate annual rates of change in these allocation shares over the period 2006 to 2016 were calculated from these data, and the revealed trends were assumed to continue over the projection period.

This Census data showed some apparently anomalous trends, such as a sharp rise in the share of a particular household type in a particular dwelling type between 2006 and 2011, followed by an almost identical sharp fall between 2011 and 2016. There was no clear pattern in these anomalous results, as could perhaps have been explained by some definitional changes between Censuses. It was therefore necessary, in some cases, to exercise professional judgment in defining a trend. That said, this approach represents a significant improvement on the approach used in 2018, which simply applied the shares of dwelling type is 2016 to all future years. The mix of dwelling types has a major bearing on energy consumption for space heating and cooling, and the mix has changed quite dramatically in many parts of Australia over the past ten or so years. The new housing stock model provides a firm basis for projecting these changes forward in a non-arbitrary manner. It also allows changes in the key assumptions affecting the future dwelling type mix to be applied, should that be desired, in a straightforward and transparent manner.

3. *Allocate base year (2016) stock to NCC Climate Zones*

The initial procedure followed was the same as the procedure developed for the 2018 model, using Census data for a number of regional urban areas in each state and assumptions about the number and mix of dwelling types in the remaining parts of each Climate Zone in each state. A major difficulty encountered in constructing this base was that the total number of households in 2016, as estimated for ABS cat. no. 3236.0, are larger than the 2016 Census count of households, because estimated total population numbers used to estimate household numbers are also larger. The ABS explains that this difference is caused by "a combination of dwelling undercount and dwelling misclassification in the Census and persons that were temporarily overseas on Census night" (Explanatory Note 15). The Census based estimates of the distribution of dwellings by type and Climate Zone were therefore scaled up to conform with the higher population figures forming the base for the household number projections.

4. *Allocate ABS household number projections to each Climate Zone in each state*

In each state except Tasmania there are several Climate Zones. However, in each state except NSW, the major urban centre is covered by a single Climate Zone: 6 for Melbourne, 5 for Adelaide and Perth and 2 for Brisbane plus the Gold and Sunshine Coasts. In Tasmania the whole state falls into Climate Zone 7. Eastern Sydney falls into Climate Zone 5 and western Sydney into Climate Zone 6. Estimates of future household numbers of each type in these Climate Zones are made by applying the ABS household number growth rates for the respective metropolitan areas to the applicable base year household numbers. The rates of household number growth in the other Climate Zones in each state are then calculating as the difference between ABS state totals and the projected metropolitan area numbers.

5. *Estimate projected numbers of each dwelling type in each Climate Zone in each state forward to 2041*

The projected dwelling type shares by household type, as calculated in Step (2), were applied to projected household numbers, as calculated at Step (4) to estimate future dwelling numbers of each type in each Climate Zone in each state. In a few cases of Climate Zones with small populations this process resulted in an absolute fall in dwelling numbers of a particular type in the Climate Zone.

This was judged to be highly improbable, given that total household numbers are growing in all areas. Small adjustments to the projections of propensities estimated at Step 2 were made to ensure that all dwelling types increase throughout in all Climate Zone in all states, albeit only very slowly in some cases.

6. *Estimate gross additions to and removals from dwelling stock*

The outcome of Step (5) is estimates of numbers of each dwelling type in each Climate Zone in each state. The next step was to estimate gross additions to and removals from the stock in each year. In 2018 this was done by simple linear extrapolation, scaled to total stock numbers, of the additions and removals calculated for 2016 and 2017. A different approach was used this year.

Initially, an attempt was made to establish the trend historic relationship between net additions, gross additions and gross removals by applying ABS dwelling completion figures, contained in the ABS publication Building Activity, Australia, Dec 2018, cat. no. 8752.0, to the historic dwelling stock figures as calculated for the successive 2006, 2011 and 2016 Censuses. In theory, this approach should enable estimates to be made of both gross additions and, by subtraction, gross removals (being the difference between gross and net additions). (Note that comprehensive figures for dwelling removals in each year are not collected.) Unfortunately, however, the two data sets do not reconcile at all well, and therefore provide a very inadequate basis for projecting the relationships between net stock increase, gross additions to stock and gross removals for stock. It was therefore necessary to apply an assumed relationship.

It was assumed that for Class 1A dwellings gross additions are equal to net additions multiplied by 1.2 and net removals are therefore 0.2 multiplied by net additions in each Climate Zone in each state in each year. For Class 1B and Class 2 dwellings, however, it was assumed that gross stock additions are equal to net additions, i.e. that there are no net removals. It is recognised that both these assumptions are gross simplifications, but, in the absence of better data, such simplifying assumptions are unavoidable.

That said, we consider that the approach used this year is an improvement, albeit minor, on the approach used in 2018, in that the assumptions are fully transparent and any changes can be easily applied to as few or as many Climate Zone and state combinations as may be desired.

Outcome

This modelling process was repeated for the two other population growth Scenarios (Fast and Slow). The Sensitivity Scenario uses the Neutral population projections.

The outcome is a set of three projections of annual dwelling stock in each Climate Zone in each state, plus the areas covered by the SWIS in WA and Darwin (representing the great majority of dwellings supplied through the DKIS) in the NT. . This is a total of nineteen stock projections: five for NSW including the ACT (Zones 2, 4, 5, 6 and 7), three for Victoria (Zones 4, 6 and 7), four for Queensland (Zones 1, 2, 3 and 5), three for SA (Zones 4, 5 and 6), one for Tasmania (Zone 7), three for the SWIS (Zones 4, 5 and 6), and one for the DKIS (Zone 1). In each state the underlying population growth on which the stock numbers are based are those specified by AEMO for the three different growth scenarios. For every Zone in each state the underlying population growth rate is the same. However, the household composition mix to which these population growth rates give rise differs between metropolitan and non-metropolitan areas in each state. Moreover, the mix of dwelling types, and the rates of change of this mix, differ in each Climate Zone, because they depend also on the existing mix of dwelling types and the rates at which that mix has changed since 2006.

Relationship between dwelling numbers and connection numbers

In each state the total number of households in each state in 2017, as reported in ABS cat. No. 3236.0, is less than the number of residential connections specified by AEMO, even though, as explained above, the ABS numbers are larger by several percent than the numbers reported in the Census results. This means that, in every projection year in every state, total dwelling numbers are also less than total connection numbers. However, as also explained, underlying population growth rates are identical with those specified by AEMO.

3.3 Energy Efficiency Measures

The 2019 estimates model the impact of the same energy efficiency policies and programs as were modelled in 2018, with two exceptions.

First, energy consumption savings from the lighting energy efficiency requirements of the NCC were assumed to be zero, on the grounds that they are not additional to savings initially realised through GEMS and state/territory programs in NSW, Victoria, SA and the ACT from around 2008. More recently, the dramatic fall in the cost of LEDs, and their near universal use in many residential lighting applications, have made use of high efficiency lamps standard practice. Coupled with the short operational lifespan of old lamp types, use of high efficiency lamps has not been confined to new and upgraded dwellings, but has spread rapidly through almost the entire housing stock.

Second, we include the (closed) Household Insulation Program (HIP) for the first time – see Section 3.3.3.

3.3.1 Residential Building Code Energy Performance Requirements

The approach to modelling building code energy performance requirements is based on the average annual thermal energy load required to maintain comfortable living conditions for dwelling occupants, as defined by the National House Energy Rating Scheme (NatHERS), separated into heating load and cooling load. These loads are different for each Climate Zone and decrease with increasing star rating. Note that NatHERS defines a total of 69 climate zones covering the 7 Climate Zones defined in the NCC. For each of the NCC Climate Zones a representative pair of load values was chosen from the larger NatHERS set. In the case of Climate Zone 5, which covers, among other areas, the eastern half of Sydney, the whole of Adelaide and the whole of Perth, different NatHERS zones were chosen as representative for the three cities.

Other key parameters include the following:

- the share of all dwellings using electric heating,
- the share of all dwellings using gas heating,
- the share of electric heating supplied by RCAC systems,
- the average CoP of RCAC systems (by implication, the efficiency of electric resistance heating is assumed to be 100%), and the average efficiency of gas heating,
- the share of electric heating and cooling and gas heating supplied through ducted systems, and
- ducting loss factors.

All these factors are assumed to change over time in new dwellings. In the Slow and Neutral scenarios, the current 6-star thermal performance standard (and state variations) is assumed to apply through to F2Y041. Higher star ratings are assumed to apply from 2022 in the Fast and Neutral sensitivity scenarios, specifically 6.5 star in 2022, 7 star in 2025 and 7.5 in 2028. Actual performance requirements for at least 2022 will be determined by COAG Energy Council in the lead-up to 2022 through a Regulation Impact Assessment process. On 1 February 2019, COAG Energy Ministers agreed *Trajectory for Low Energy Buildings* (The Trajectory).[17] This is a national plan that sets a trajectory towards zero energy (and carbon) ready buildings for Australia. The Trajectory notes that the starting point for analysis should begin at 7 stars for colder climates such as Melbourne, and it will include the concept of a whole of house energy budget (that is, covering potentially all energy end-uses).[18]

Both the absolute levels and the rates of change of these factors vary between each Climate Zone in each state, and both differ between the three dwelling types. In general, the share of dwellings using electric heating increases over time, i.e. space heating shifts away from gas, other or none, and towards electricity from 2001 onward, as does the share of ducted systems, while RCAC efficiency increases and ducting losses decrease. These trends based on data in the triennial ABS household energy survey, Cat. No. 4602.0.55.001. Regrettably, as explained below, this data source is no longer available.

Application of these factors allowed NatHERS based annual electricity consumption for heating and average annual gas consumption per dwelling, and similarly average annual electricity consumption for cooling, to be calculated, in dwellings with active cooling for each Climate Zone in each state and territory. Note that this calculation approach allows for the average to include dwellings with no active space heating and/or cooling. The shares of electricity and gas consumption for heating differ

[17] COAG Energy Council, *Trajectory for low energy buildings*, December 2018.
[18] The detailed supporting paper, COAG Energy Council, *Report for Achieving Low Energy Homes*, December, 2018, notes that cost effective 2022 star rating targets might range between 6 and 7 stars, depending upon the climate zone (pp 23 – 26) and with some difference by building class. This report assumes 6.5 stars as the mid-point of the range. The Trajectory report does not name star rating target for later periods (2025 and beyond), but notes that “additional cost effective changes to building energy efficiency provisions in the NCC should be assessed as part of a RIS process” (p. 7).

markedly between states, with Victoria, in particular, using a much large share of gas for space heating than other states. Consequently, there some differences between states in average annual electricity consumption per dwelling in a given Climate Zone, as Climate Zones often extend across state boundaries.

The shares of electricity and gas heating in the various Climate Zones and states also reflect the actual availability of reticulated gas supply to households. In general, widespread supply of gas to households is restricted to major metropolitan areas. The exceptions are Climate Zone 7 in NSW (which includes the ACT) and 7 in Victoria, and Climate Zone 6 in SA. Further, household gas supply in Queensland is used almost exclusively for water heating and cooking, and it was therefore assumed that space heating gas consumption savings from enhanced dwelling energy afficiency are zero in Queensland. Savings were also assumed to be zero in Tasmania, where the share of dwellings with gas supply remains very low. Key assumptions are set out below by dwelling type, fuel type and jurisdiction in Table 2 to Table 9.

Table 2: Assumed shares of Class 1A1 dwellings using electric heating

State and NCC Climate Zone	Base 2 and 3 star dwellings	New from 2004 to 2006	New from 2007to 2021	New from 2022 to 2024	New from 2025
1 Qld	0%	0%	0%	0%	0%
1 Darwin	0%	0%	0%	0%	0%
2	45%	55%	55%	55%	55%
3	30%	40%	40%	40%	40%
4	70%	75%	80%	80%	80%
5 Sydney E	55%	55%	65%	70%	80%
5 Adelaide	45%	45%	65%	70%	80%
5 Perth	25%	30%	35%	35%	50%
6 Vic	20%	20%	20%	30%	60%
6 NSW/SA	60%	70%	70%	80%	85%
7 NSW/Vic	65%	60%	60%	70%	85%
7 Tas	60%	95%	95%	95%	95%

Note: Shares calculated inclusive of households using fuels other than electricity/gas, or which do not heat

Table 3: Assumed shares of Class 1A2 and 1B dwellings using electric heating

State and NCC Climate Zone	Base 2 and 3 star dwellings	New from 2007 to 2010	New from 2011 on
1 Qld	0%	0%	0%
1 Darwin	0%	0%	0%
2	70%	70%	70%
3	30%	40%	60%
4	60%	70%	80%
5 Sydney E	65%	75%	80%
5 Adelaide	65%	90%	95%
5 Perth	60%	70%	80%
6 Vic	60%	80%	90%
6 NSW/SA	80%	90%	95%
7 NSW/Vic	75%	90%	95%
7 Tas	95%	100%	100%

Note: Shares calculated inclusive of households using fuels other than electricity/gas, or which do not heat

Table 4: Assumed shares of Class 1A1 dwellings with electric heating which use RCAC for space heating

State and NCC Climate Zone	All dwellings to 2006	New from 2007 to 2010	New from 2011 on
3	0%	0%	0%
4	30%	40%	60%
5 Sydney E	30%	40%	60%
5 Adelaide	30%	40%	90%
5 Perth	30%	40%	80%
6 Vic	30%	40%	95%
6 NSW/SA	30%	40%	95%
7 NSW/Vic	30%	40%	95%
7 Tas	30%	40%	95%

Table 5: Assumed shares of Class 1A2 and 1B dwellings with electric heating which use RCAC for space heating

State and NCC Climate Zone	Base year 2 star dwellings	Base year 3 star dwellings	New from 2007 to 2011	New from 2011 on
3	0%	0%	0%	0%
4	30%	50%	60%	60%
5 Sydney E	30%	50%	60%	60%
5 Adelaide	30%	50%	60%	90%
5 Perth	30%	50%	60%	80%
6 Vic	30%	50%	60%	95%
6 NSW/SA	30%	50%	60%	95%
7 NSW/Vic	30%	50%	60%	95%
7 Tas	30%	50%	60%	95%

Table 6: Assumed shares of Class 1A1 dwellings with electric heating which use air conditioning

State and NCC Climate Zone	All dwellings to 2006	New from 2007 on
1 Qld	95%	100%
1 Darwin	95%	100%
2	90%	95%
3	90%	95%
4	90%	95%
5 Sydney E	70%	85%
5 Adelaide	90%	95%
5 Perth	90%	95%
6 Vic	80%	90%
6 NSW/SA	85%	90%
7 NSW/Vic	60%	75%
7 Tas	20%	40%

Table 7: Assumed shares of Class 1A2 and 1B dwellings with electric heating which use air conditioning

State and NCC Climate Zone	All dwellings to 2006	New from 2007 to 2024	New from 20025 on
1 Qld	95%	100%	100%
1 Darwin	95%	100%	100%
2	90%	95%	100%
3	90%	95%	100%
4	90%	95%	100%
5 Sydney E	70%	85%	100%
5 Adelaide	90%	95%	100%
5 Perth	90%	95%	100%
6 Vic	80%	90%	100%
6 NSW/SA	85%	90%	100%
7 NSW/Vic	60%	75%	90%
7 Tas	20%	40%	60%

Table 8: Assumed shares of Class 1A1 dwellings using gas heating

State and Climate Zone	Base 2 and 3 star dwellings	New from 2004 to 2006	New from 2007to 2010	New from 2025
2	5%	5%	5%	5%
3	0%	0%	0%	0%
4	10%	10%	5%	5%
5 Sydney E	25%	30%	30%	30%
5 Adelaide	40%	40%	35%	30%
5 Perth	60%	50%	40%	35%
6 Vic	75%	75%	70%	65%
6 NSW/SA	25%	25%	20%	20%
7 NSW/Vic	35%	35%	30%	30%
7 Tas	0%	2%	3%	5%

Note: Shares calculated inclusive of households using fuels other than electricity/gas, or which do not heat

Table 9: Assumed shares of Class 1A2 and 1B dwellings using gas heating

State and Climate Zone	All dwellings to 2006	New from 2007 on
2	0%	0%
3	0%	0%
4	10%	0%
5 Sydney E	20%	15%
5 Adelaide	20%	5%
5 Perth	20%	5%
6 Vic	30%	10%
6 NSW/SA	10%	5%
7 NSW/Vic	20%	5%
7 Tas	0%	0%

Note: Shares calculated inclusive of households using fuels other than electricity/gas, or which do not heat

Finally, a 50% constraint factor was applied to all the calculated values to obtain final estimates of average electricity consumption per dwelling for heating and cooling. This constraint factor is a rule of thumb, based on considerable expert experience, which adjusts for the facts that NatHERS modelling assumes that all dwellings are occupied 24/7 and that the entire floor area of a dwelling is thermally conditioned. A larger discount is applied to gas heating savings, especially in the milder Climate Zones (Climate Zones 4 to 6), to reflect the fact that many households with gas heaters use single room heaters, rather than central heating.

All the parameter values used are unchanged from those used in 2018. There was, unfortunately, no empirical basis for making any changes because there is no comprehensive relevant recent data. The major source of comprehensive data on how energy is used within residential dwellings is the (formerly) triennial ABS publication *Environmental Issues: Energy Use and Conservation, cat. no. 4602.0.* The ABS discontinued this very important series after completion of the 2014 survey.

By appropriately combining the factors described above, estimates were prepared of average electricity consumption per dwelling for space heating and space cooling for each type of dwelling in each Climate Zone in each state. Separate values were calculated for each NatHERS star band rating from 2 to 6. For the sensitivity scenario, values for additionally more stringent ratings of 6.5, 7 and 7.5 were also calculated.

As explained at the outset, energy consumption savings are assumed to arise over time from two processes.

Firstly, under a counter-factual 2001 base business as usual, all new dwellings would have had, and would continue to have, the same star rating as an average new dwelling built in that year. This reference level rating is assumed to be 3 stars. Note that this assumption represents a change from the 2018 report, in which the average reference level rating was assumed to be 2 stars. It follows that, for each average new dwelling built, the energy saved against a 2001 reference base is the difference between the applicable calculated consumption if the building were 4 stars and the smaller consumption assuming that the new dwelling is compliant with the minimum rating applicable in the year concerned. In 2003 a minimum rating of 4 stars was introduced for new detached houses. In 2007 the minimum for houses was increased to 5 stars, and this requirement was also applied to townhouses and apartments, which had not previously been subject to minimum energy performance regulation. In 2011 the minimum performance of all types of dwelling was increased to 6 stars. As a final step in the calculation, the annual per dwelling energy savings calculated in this way are downgraded by 10% to allow for non-compliance with the minimum energy performance requirements. Note that this procedure automatically ensures that the average savings per new dwelling take account not only of the higher EER level, but also the differing mixes of energy type, equipment type and equipment efficiency between the hypothetical 2001 reference and the actual year in which a new dwelling is built.

Secondly, as previously explained, the dwelling stock projections include estimates of the numbers of detached houses removed (demolished) each year. It is assumed that the great majority of these houses will be older than 2001 and will have an average star rating of 2, and corresponding equipment type and efficiency. Energy savings result simply from the fact that these dwellings are removed from the stock.

All the energy consumption savings calculated in this way are assumed to persist throughout the entire projection period to 2041. Consequently, total annual savings, relative to the 2001 base, increase steadily over the entire projection period.

Efficiency Changes Not Accounted For

The methodology described here does not take account of two potentially important trends affecting residential electricity consumption for heating and cooling. Both omissions are an unavoidable consequence of the lack of comprehensive and up to date national data on energy consumption in residential buildings.

The first omission, which was discussed in the 2018 report, relates to the shift away from gas heating and towards RCAC in many cooler parts of Australia with extensive gas reticulation networks. Anecdotally, this shift is important in parts of Sydney, Canberra and Adelaide, but possibly less so in Melbourne. This change is largely being driven by recent reductions in the cost and increase in the performance of RCAC, and the fact that RCAC can provide both heating and cooling from a single piece of equipment. This is an important consideration for householders in some Climate Zone 6 and 7 areas where significant space heating is essential for thermal comfort in winter, but where some very hot days are also experienced in summer. This change is also economically attractive for many households with rooftop solar generation. It should be noted, however, that in some areas there is an opposite trend affecting water heating, largely driven by a change in the NCC, which prevents the installation of large electric resistance storage water heaters in new dwellings. Many builders and owners, in areas with gas reticulation, are choosing to use instantaneous gas water heaters as the alternative. This is an attractive option for builders because instantaneous gas water heaters have a lower capital cost than any other type of water heater.

The second omission, not discussed in any detail in the 2018 report, concerns the impact of changes to older existing dwellings. The most important changes are of two types.

Firstly, the operational life of space heating equipment is typically less than the operational life of a house, meaning that the equipment is replaced/upgraded one or more times over the life of the house. Over the past several decades, many such upgrades, particularly in Climate Zones 6 and 7, have taken the form of a shift from individual room heating to whole house central heating, with consequent increase in annual energy consumption. Other upgrades have taken the form of a shift from gas to RCAC heating, as discussed above, but for existing dwellings as well as new dwellings. On the other hand, other upgrades have involved the adoption of more efficient versions of the same types of equipment.

Secondly, various forms of building thermal performance upgrades have become a well-recognised trend over recent years, in many cases supported and/or encouraged by government programs. Probably the largest, and certainly the most well-known, albeit controversial, of such program was the Rudd Government's HIP. Despite the criticisms and controversy surrounding it, this Program did in fact result in significant improvements in the thermal performance of a large number of houses. A detailed analysis of the ongoing energy consumption savings, both electricity and gas, resulting from this Program was undertaken by Robert Foster, and his estimates have been included in the 2019 residential model. A brief description of these figures is provided below.

However, individual house owners were upgrading the ceiling insulation in their houses for many years before this Program and continue to do so today. Many, particularly in colder climates, are also retrofitting cavity wall insulation and making other improvements, such as window shading or, in some cases, double glazing. Many of the more far-reaching upgrades are linked to large house renovations and extensions. Often such larger upgrades are triggered by the NCC requirement that renovations/extensions above a specified minimum size must comply with the prevailing energy performance requirements, which are obviously more stringent than the requirements (mostly non-existent) at the time the house was originally built. The ABS does not compile comprehensive national data on housing stock upgrades and there is no other source of data which could be used to estimate the extent and impact of these upgrades. Clearly, however, they must, on balance, be contributing to reduce average per dwelling consumption of electricity and gas for heating and cooling.

We note that for the Fast and Neutral Sensitivity scenarios, we assume that NatHERS star rating minimum requirements are increased to 6.5 stars in 2022, 7 stars in 2025 and 7.5 stars in 2028.[19] For our analysis of the avoided peak demand attributable to the residential energy efficiency measures, assumption for Code related energy performance requirements are set out in Section 3.4, while GEMS-related CLF assumptions are set out below.

[19] This scenario is broadly based on the COAG Energy Council Low Energy Trajectory, but specific star ratings will not be determined until additional benefit cost/regulation impact assessment is undertaken, in the lead up to each regulatory 'window', so strictly these are SPR assumptions.

3.3.2 Greenhouse and Energy Minimum Standards (GEMS)

Background

The Equipment Energy Efficiency (E3) program comprises a range of energy labelling and minimum energy performance standards (MEPS) measures, legislated under the *Commonwealth Greenhouse and Energy Minimum Standards (GEMS) Act 2012*. Many of the measures were implemented under state legislation decades before the GEMS Act. For example, the energy labelling of refrigerators and freezers started in NSW in 1986.

The E3 program is managed under an agreement between the Commonwealth, State, Territory and New Zealand governments. After many departmental changes, it is currently administered by the Commonwealth Department of the Environment and Energy (DEE).

From time to time the E3 program has published projections of the energy savings expected from measures already implemented and those planned (E3 2009a). The latest report was prepared by George Wilkenfeld and Associates (GWA) for the E3 Committee during 2012 and 2013 and published in early 2014 (E3 2014a).

For this report, GWA has updated those projections, based on the following information:

- The publication of actual GEMS determinations, which mark the implementation of a program (although the impacts may only commence a year or two later, since most determinations take effect after a lead time);
- E3 program priorities published from time to time (the latest was E3 (2017a));
- The publication of Product Profiles, which represent the first stage of detailed development of measures;
- The publication of Regulation Impact Statements (RISs, usually prepared for E3 by external consultants), which represent the best estimates of projected impacts at the time COAG Energy Ministers approve a measure;
- GWA's knowledge of work under way within DEE.

Some 50 distinct programs are covered in the E3 projections, as summarised in Table 10. The Program numbers refer to an identifier in the source spreadsheets. The Category classifications have the following meanings:

A: MEPS & labelling regulations in place (already implemented);

C: MEPS & labelling projects in train (where details are settled and they are in the process of implementation);

D: Possible projects – identified as high priority but not yet fully developed;

EF: Projects that have been on the E3 work program in the past, are currently suspended, but could be reactivated.

For this report, Categories A and C measures are considered as base case measures and included in the Neutral and Slow Change scenarios. All classifications are included in the Neutral Sensitivity and Fast Change scenarios. Each program has an impact on a particular product and then are then grouped into the end-uses shown. In some cases, the same product is used in both the residential and business sector, so the energy impacts are distributed across sectors based on the best available sector split. The sector impacts are classified as follows: R = Residential, C = Commercial, I = Industrial, HW: Hot water, T = Transformer. Transformer savings are distributed across all end uses but are allocated to industrial for this study. [20] Commercial and industrial are classified as business for this study. Hot water is classified as primarily residential for this study, but there will be minor effects in the business sector.

More detailed analysis of GEMS impacts, including by measure and sector, can be found in Appendix D.

[20] AEMO excludes Division D 'energy supply' (which includes distribution transformers) from its forecasts. As a result, the estimated impact of distribution transformer standards on industrial consumption and demand should be transferred to Division D projections.

Table 10: List of GEMS/E3 Programs

Program #	Category	End-Use	Sector	Program Description	Status
1	A	Refrigeration	R	Household Refrigerators & Freezers - Labelling 1986 to MEPS 2005	Implemented
2A	A	Water heating	HW	Large electric water heaters	Implemented
2B	A	Water heating	HW	Small electric storage water heaters	Implemented
3	A	Washers/ Dryers	R	Clothes washers, dishwashers, clothes dryers (Plug loads only)	Implemented
4	A	Heating/ Cooling	C	Close Control ACs - MEPS 2009	Implemented
5	A	Heating/ Cooling	C	AC Chillers - MEPS 2009	Implemented
6	A	Lifestyle/ Electronics	R	Televisions - labelling & MEPS 2009	Implemented
7	A	Lifestyle/ Electronics	R	Set Top Boxes - MEPS	Implemented
8A	A	Lifestyle/ Electronics	R	External Power Supplies MEPS (Residential)	Implemented
8B	A	Lifestyle/ Electronics	C	External Power Supplies MEPS (Non-Res)	Implemented
9	A	Refrigeration	C	Refrigerated Display Cabinets MEPS	Implemented
10A	A	Lighting	R	Lamp efficacy, (Res use)	Implemented
10B	A	Lighting	C	Lamp efficacy, (Commercial use)	Implemented
11A	A	Lighting	R	Ballast MEPS (Res use)	Implemented
11B	A	Lighting	C	Ballast MEPS (Commercial use)	Implemented
12	A	Lighting	C	Tri-Phosphor Lamps (Commercial use)	Implemented
13	A	Motors/ Pumps	I	Motors - MEPS 2001, 2006	Implemented
14	A	Transformers	T	Distribution Transformers (2004 MEPS)	Implemented
15	A	Water heating	R	WELS Impacts	Implemented
15	A	Water heating	C	WELS Impacts	Implemented
15	A	Water heating	I	WELS Impacts	Implemented
22	D	Water heating	HW	Heat Pump Water Heaters	Possible
22	D	Water heating	HW	Electric, solar & other electric storage water heaters - heat loss MEPS	Possible
23	D	Water heating	HW	Solar-electric water heaters - all measures other than heat loss	Possible
24	A	Heating/ Cooling	R	Air conditioners - Res MEPS 2004-2010	Implemented
24A	A	Heating/ Cooling	R	Air conditioners - Res MEPS 2011	Implemented

Program #	Category	End-Use	Sector	Program Description	Status
25	A	Heating/ Cooling	C	Air conditioners - Non-Res MEPS 2001-2007	Implemented
25A	A	Heating/ Cooling	C	Air conditioners - Non-Res MEPS 2011	Implemented
26	EF	Transformers	T	Distribution Transformers (2017 MEPS)	Suspended
27	EF	Lifestyle/ Electronics	R	Standby - range of products	Suspended
30	C	Motors/ Pumps	R	Swimming pool pump-units labelling + MEPS	In train
33A	A	Lifestyle/ Electronics	C	PCs and Monitors (Business Use)	Implemented
33B	A	Lifestyle/ Electronics	R	PCs and Monitors (Residential Use)	Implemented
34	C	Heating/ Cooling	C	AC Chillers - MEPS 2017	Possible
35A	C	Heating/ Cooling	R	Air conditioners (Residential - fixed) - MEPS 2017	In train
35B	EF	Lifestyle/ Electronics	R	Battery Chargers (Small consumer)	Suspended
35C	A	Heating/ Cooling	C	Air conditioners (Non-residential) - MEPS 2017	In train
36	C	Lighting	C	LED MEPS (Commercial use – replaces ballasts)	In train
37	C	Lighting	R	LED MEPS (Residential use – replaces Linear fluorescent lamps)	In train
38	EF	Motors/ Pumps	I	Motors - MEPS 2017	In train
39	EF	Refrigeration	R	Household Refrigerators & Freezers - MEPS 2021	In train
40	A	Lifestyle/ Electronics	R	Televisions - labelling upgrade & MEPS – 2013	Implemented
42	C	Refrigeration	C	Commercial refrigeration - MEPS 2015	In train
47	C	Heating/ Cooling	R	Portable air conditioners (impacts now included with 35A)	In train
42A	EF	Refrigeration	C	Commercial Refrigeration Compressor MEPS	Suspended
42B	EF	Refrigeration	C	Self-contained food-service	Suspended
47-55	EF	Refrigeration	C	Additional Commercial Refrigeration equipment	Suspended
56-59	C	Other	I	Process & Industrial Equipment (Fans)	In train
63-65	EF	Refrigeration	C	Commercial Catering Equipment	Suspended
63-65	EF	Lighting	R	Phase-out of halogen lamps	In train

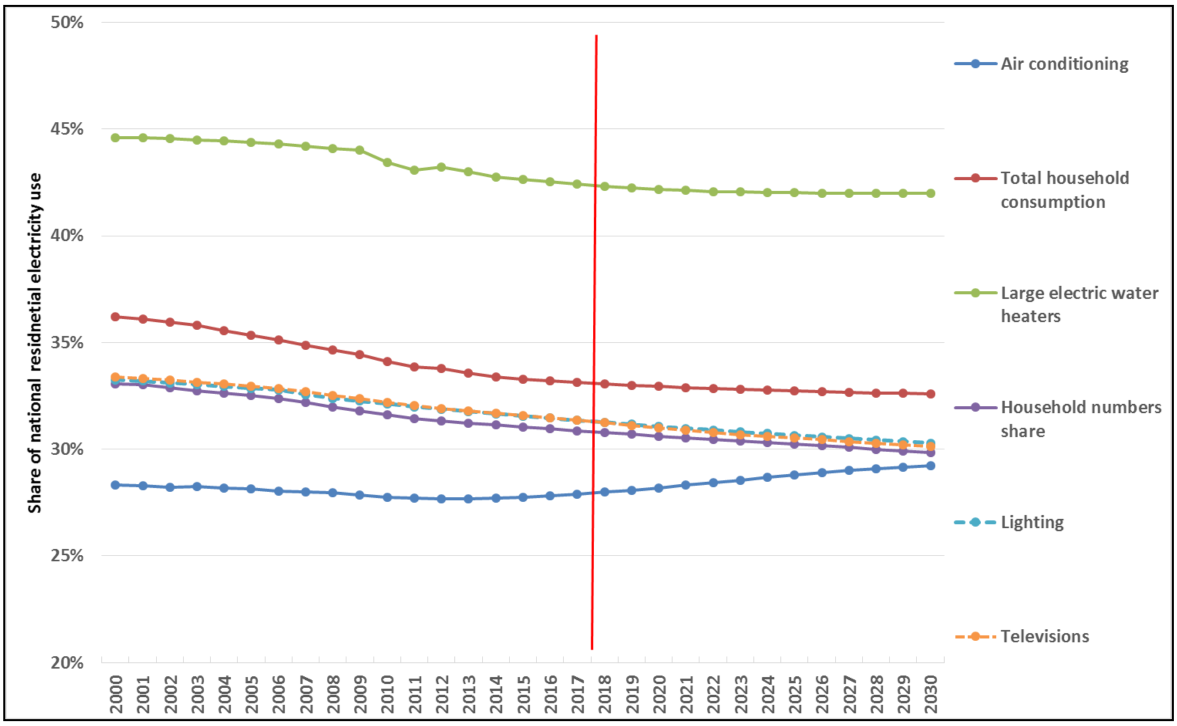
Table notes: The year nominated for each program was as originally proposed by E3, actual implementation dates may have changed for programs in the process of implementation. Sectors are R = Residential, C = Commercial, I = Industrial, HW: Hot water, T = Transformer. See text for more detailed explanation of category and sector. Cells in grey indicate change of program status since 2018.

3.3.3 Allocation and Extension of National Projections

This section reviews the factors used to allocate the national E3 impact projections to the states and territories, using NSW and the ACT as an example of the approach used for all states and territories. The share of total households is a poor proxy for allocation. The NSW share of national households was about 31% in 2018, and it is projected to fall to just below 30% by 2030 (Australian Bureau of Statistics 2015). However, the share of end use energy allocated to NSW depends on the pattern of appliance ownership. For example, electric storage water heating is more common in NSW than in some other states, where gas water heating is more common. Therefore, the energy savings of E3 measures impacting electric storage water heaters will flow disproportionately to NSW.

The latest projections of household electricity use published by E3 (EnergyConsult 2015) break down national electricity use by end use and by State and Territory for each year of the projections. These shares have been used to allocate projected energy savings to NSW, on the assumption that the impact of E3 measures in each jurisdiction is proportional to the energy use in that jurisdiction by the targeted products. The allocation percentages for the key end uses are illustrated in Figure 4.

Figure 4: NSW allocation shares for residential electricity use and key end uses



The end use where NSW has the highest share of national household electricity use is large electric water heaters. The end use where NSW has the lowest share is air conditioners, but this is projected to rise over time. Figure 4 also shows that the NSW share of national household electricity is projected to keep falling, from about 36% in 2000 to less than 33% 2030, more or less in parallel to the population share.

We have investigated the latest Australian Energy Statistics published by the Department of Industry, Innovation and Science (see Table F in the FY2017 data set) (Office of the Chief Economist 2018). Although the department no longer publishes detailed projections of energy end use, the historical data are broken down by economic sector and State/Territory and this provides a basis for allocating non-residential emissions. The latest data (for 2014-15) are summarised in Table 11 and Table 12.

Table 11: Electricity use by main sectors, Australia 2014-15

	NSW+ACT	VIC	QLD	SA	WA	Tas	NT	Aust
Mining	4671	493	7045	1699	13422	443	869	28643
Manufacturing	18143	11560	16317	2456	6562	6342	0	61380
Commercial	19917	16867	14611	4108	5437	1975	1379	64295
Residential	21773	10939	12324	4756	6834	2290	357	59273
Other	9127	10178	10218	2681	5298	872	392	38765
Total	73632	50036	60516	15700	37553	11923	2997	252356
Share of total	29.2%	19.8%	24.0%	6.2%	14.9%	4.7%	1.2%	100.0%

Source: Office of the Chief Economist (2018)

Table 12: Electricity use by industrial and commercial sectors, Australia 2014-15

	NSW+ACT	VIC	QLD	SA	WA	Tas	NT	Aust
Industrial	22814	12053	23363	4155	19984	6785	869	90023
(Mining + Mfr)	25.3%	13.4%	26.0%	4.6%	22.2%	7.5%	1.0%	100.0%
Commercial	19917	16867	14611	4108	5437	1975	1379	64295
	31.0%	26.2%	22.7%	6.4%	8.5%	3.1%	2.1%	100.0%

Source: Office of the Chief Economist (2018)

3.3.4 Peak Demand

Analysis of E3 programs generally focuses on energy reductions as a result of energy efficiency measures. There has been little analysis by E3 of the likely peak load impact of energy efficiency programs. However, there is no doubt that increased energy efficiency of appliances and equipment will reduce peak load demands during system peaks because the whole load curve is reduced as a result of efficiency measures, including during peak periods. For most appliances and equipment covered by E3 programs, the usage profile of the energy service is not greatly influenced by the weather. Equipment such as lighting, motors, industrial equipment, electronics, home entertainment and conventional hot water will not be directly affected by temperature, so are assumed to have a constant average load pattern each day.

Large air conditioning systems (chillers, close control air conditioners) generally service buildings that are conditioned at all times, so the thermal inertia of the structure dampens load variations. Household and commercial refrigeration may experience a small increase in energy consumption during more extreme weather (up to 20% higher demand) when compared to a typical average daily load profile.

The most significant weather sensitive load is smaller air conditioners during summer, which are often switched on in the afternoon, after the building is already heated up. Analysis in several states found that household and small business air conditioners drive system peaks substantially (Energy Efficient Strategies 2004). These appliances may generate peak loads during system peaks that are two the three times higher than would occur on an average day. As air conditioners become the preferred mode of electric heating, displacing resistance heaters, air conditioner energy efficiency is also starting to exert a greater impact on winter peak loads.

As noted in Section 2.4, the Conservation Load Factor or CLF method is used to estimate peak load reductions associated with the energy consumption savings induced by efficiency measures, and this includes for GEMS. The CLF values noted below in Table 13 below draw on values established in relevant RISs, and are the same values used in the 2018 study.

Table 13: Conservation Load Factors for GEMS

Program Description	CLFs
Large electric water heaters	2.00
Small electric storage water heaters	2.00
Close Control ACs - MEPS 2009	1.00
AC Chillers - MEPS 2009	0.40
Televisions - labelling & MEPS	1.50
Set Top Boxes - MEPS	1.00
External Power Supplies MEPS (Residential)	1.00
External Power Supplies MEPS (Non-Res)	1.00
Refrigerated Dispaly Cabinets MEPS	0.50
Lamp efficacy, (Res use)	3.00
Lamp efficacy, (Comm use)	0.50
Ballast MEPS (Res use)	3.00
Ballast MEPS (Comm use)	0.50
Tri-Phosphor Lamps (Comm use)	0.50
Motors - MEPS 2001, 2006	0.70
Distribution Transformers (2004 MEPS)	1.00
WELS Impacts	2.00
Heat Pump Water Heaters	2.00
Solar-electric water heaters - all measures other than heat loss	2.00
Air conditioners - Res MEPS 2004-2010	0.15
Air conditioners - Res MEPS 2011	0.15

Program Description	CLFs
Air conditioners - Non-Res MEPS 2001-2007	0.40
Air conditioners - Non-Res MEPS 2011	0.40
Distribution Transformers (2017 MEPS)	1.00
Standby - range of products	1.00
Swimming pool pump-units labelling+MEPS	1.50
PCs and Monitors (Business Use)	0.50
PCs and Monitors (Residential Use)	1.50
AC Chillers - MEPS 2017	0.40
Air conditioners (Residential - fixed) - MEPS 2017	0.15
Battery Chargers (Small consumer)	1.50
Air conditioners (Non-residential) - MEPS 2017	0.40
LED MEPS - Res	3.00
LED MEPS - Comm	0.50
Motors - MEPS 2017	0.70
Household Refrigerators & Freezers - MEPS 2017	0.70
Televisions - labelling upgrade & MEPS - 2013	1.50
Commercial refrigeration - MEPS 2015	0.50
Portable air conditioners (Now included in 35A)	0.15
Commercial Refrigeration (Compressor MEPS)	0.50
Self-contained food-service	0.50
Commercial Refigeration (Quantified)	0.50
Process & Industrial Equipment (Quantified) - Fan-units	0.50
Commercial Catering (Quantified) - ELEC	0.50
Halogens phaseout	3.00

For the Code changes, a Conservation Load Factor (CLF) of 0.15 was assumed for winter and summer, as per the 2018 energy efficiency forecasts, reflecting the expectation that reverse cycle air conditioning will be the dominant load for summer cooling and, to degrees which vary by state (as described in Section 3.3.1), for winter heating as well.

3.3.5 Household Insulation Program (HIP)

As noted, estimates of ongoing annual electrical energy savings arising in each state from the Household Insulation Program were provide by Energy Efficient Strategies. These estimates follow a similar approach to that described above for the estimation of savings from new building stock. They take account of climate, state and regional differences in the fuel mix used for space heating, and the annual heating/cooling split for electrical energy use. They also include a uniform discount factor of 70% to allow for non-compliant of incomplete installation.

All the installations are assumed to occur in 2008-09 and 2009-10. The results provided extend out to 2019-20, gradually changing over that period to account for assumed heating and cooling equipment and fuel mix changes in insulated houses over that period. In some cases, that results in gradual increases in annual savings and in other gradual decreases. We have extended savings out to 2041, by reducing annual savings each year by a rate equal to the annual removal of Class 1A1 dwellings (houses), as generated by our housing stock model for each state. Total savings are quite small, relative to some of the other savings modelled, reaching maxima in 2019-20 of 370 GWh electric heating and 260 GWh for cooling, and 4.7 PJ for gas.

3.3.6 State Energy Savings Schemes

We model savings associated with the three larger state-based energy savings targets and schemes, in NSW (Energy Savings Scheme or ESS), VIC (Victorian Energy Upgrades (VEU) – also known as the Victorian Energy Efficiency Target or VEET) and SA (Retailer Energy Efficiency Scheme or REES). Generally, our methodology is to work from published annual reports and other performance reporting for these schemes – or other data where available – making allowances for the fact that reported savings for a given year are generally total 'deemed' savings over a specified number of future years. Therefore, we spread these deemed savings out over a period of 10 - 12 years, depending upon the program. The split of savings between electricity and gas, and between the residential and commercial sectors, also reflects program-specific data. For future expected savings, we assume that currently-announced targets and timelines will be met, and programs will cease as currently provided for (where that is clear). For all of the state schemes, it appears that the majority if not all savings are of a baseload nature, and this is assumed for the purposes of estimating the impact of these schemes on maximum demand (see Section 3.4 below).

NSW Energy Savings Scheme

In the case of ESS, a nominal target of 8.5% of electricity sales has been announced for 2019 and 2020, equivalent to 7.5% after deductions for the energy-intensive, trade-exposed sector. As the scheme's duration is currently limited to 2025, and no targets have yet been announced for the post-2020 period, we assume that the target remains at 8.5% of expected NSW consumption over the period to 2025, and then no further targets are assumed. A statutory review of the scheme is due in 2019-20. Note that since targets are specified relative to expected consumption, they are responsive to AEMO's slow, neutral and fast scenarios – the same target is assumed, but post-2018 consumption varies.

The NSW Department of Planning, Industry & Environment kindly made available detailed program performance data. This data excluded any savings attributable to the aluminium and coal mining sectors (which are not included in AEMO's definition of 'commercial'), and also provided data (from FY2015 onwards, and summary data for the pre-2015 period) by sector and activity type/methodology. This enabled more accurate conversion of savings as report in the program's Annual Report to estimated annual savings, by applying differentiated deeming rules. We assume that savings reported under metered baseline methods have an economic life of 20 years. As data was provided by method, we were able to exclude savings attributed to the NABERS method, to avoid double-counting. For this reason, ESS savings were not further discounted for non-additionality.

SA Retailer Energy Efficiency Scheme

Annual targets for REES are set as an absolute value in GJ. As a result, energy savings do not vary by AEMO scenario. Other targets and requirements apply under the scheme that affect the distribution of savings by end-user, but not the overall target. Targets for both 2019 and 2020 are 2.3 million GJ, and a review is also underway regarding possible future targets and scheme extension. However, since the scheme will end after FY2020 on current policy settings, the scheme is currently assumed to terminate at that point.

Energy savings are based on those reported in the 2017 Annual Report, with an average deeming life of 10 years assumed. The sectoral shares of savings are revealed in the online data set and vary from 100% residential in Phase 1 (to 2014), to an estimated 77% commercial in 2018. We assume this share continues in later years. The fuel mix of savings is also estimated from the online workbook data. While there is some variation by year, electricity accounts for at least 80% of the savings in most years, and 95% of savings in 2017 (and, we assume, later years). Given that fluorescent and, more recently, LED lighting dominates total savings, the extent of savings that are additional to those that would otherwise have been expected to occur is, as with all the state schemes, difficult to assess. However, we apply a 50% discount to electricity savings, but no discount to the smaller gas savings, to avoid over-estimating actual savings.

VIC Victorian Energy Upgrades

VEU is currently legislated to run until 2030, but targets have only been set to 2020. We assume that the 2020 target of 6.5 Mt CO2-e is continued through to 2030 and then ceases. As with the other state programs, a review is currently underway that will recommend post-2020 targets. Given the manner is which targets are set, savings are not modelled to vary as a function of AEMO scenarios. Also, there appear to be no savings attributable to the industrial sector. Noting that targets are set in emissions units, some program outcomes have included increases in gas consumption in the historical period. Overall, we model around 102% of reported total savings are electricity savings, offset by a 2% increase in gas consumption, based on historical impacts. We note that changing emissions factors in future may change the past tendency to encourage gas consumption.

For the historical period, we model savings as a function of the quantity of VEECs registered each year, as reported in the VEET Performance Report 2017 (September 2018), taking into account that the number of certificates created varies from the target considerably in most years, and also that not all certificates created are eventually registered. Also, we note that the emissions factor that converts CO2 savings to energy savings varies by year. Savings are modelled to have an average deeming period of 12 years. This is higher than the value of 7 years modelled in 2018, reflecting advice from program managers.

As with other schemes, the sectoral composition of savings has changed over time, from a predominance of residential savings in the early years to an estimated 89% of commercial sector savings in 2017. As with REES, we apply a discount of 50% to the estimated electricity savings, noting that 94% of VEU certificates created in 2017 were for lighting, and it is likely that a significant number of these lighting savings would have occurred in any case.

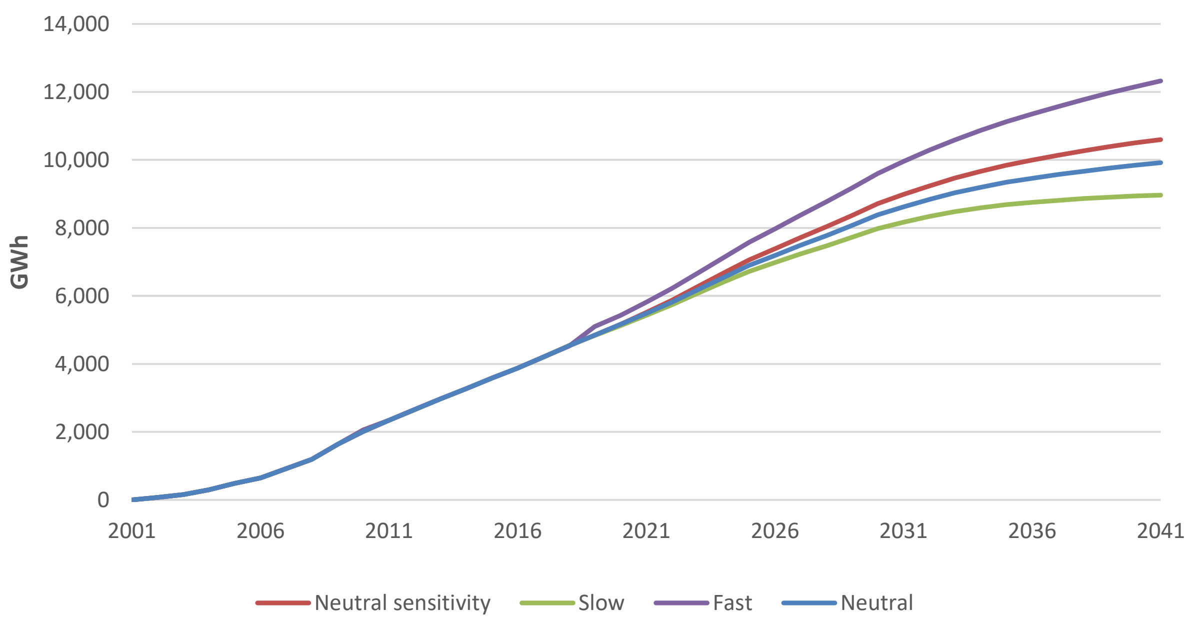
3.4 Efficiency Forecasts by Jurisdiction and Scenario

Given the unique housing profile and fuel mix in each jurisdiction, energy efficiency forecasts are presented by jurisdiction. Note that WA and NT forecasts relate to the SWIS and DKIS respectively, as no reliable data on the share of dwellings off grid, or their energy consumption, is available, and the residential load on NWIS is very small. Electricity are presented immediately below, with gas results in Section 3.5.11.

3.4.1 New South Wales and the Australia Capital Territory

Figure 5 shows the forecast electricity savings for NSW/ACT. Savings increase in a reasonably linear manner in the historical period but taper off in the forecast period, due primarily to the assumed plateauing or cessation of state energy savings schemes over the 2020 – 2030 period.

Figure 5: NSW/ACT Energy Efficiency Forecast by Scenario – Residential Sector



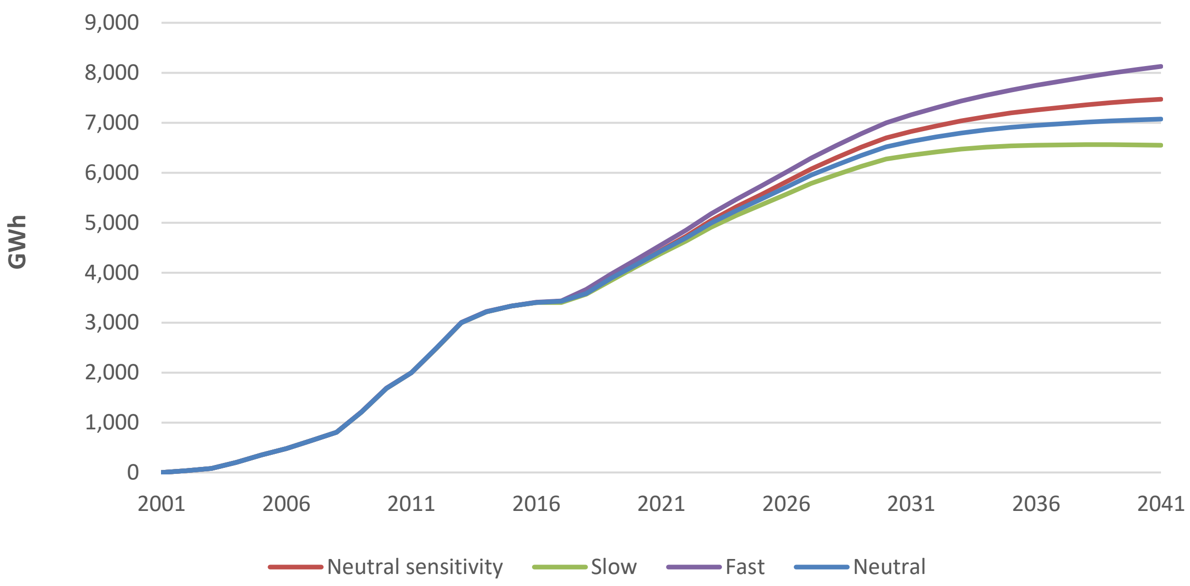
For NSW/ACT, and indeed for the other jurisdictions below, the general pattern is for declining energy efficiency savings from the second half of the 2020s, with this delayed under Fast (and Neutral Sensitivity) assumptions.

3.4.2 Victoria

Figure 6 shows the energy efficiency forecasts for Victoria. The overall pattern is similar to NSW/ACT, and for similar reasons. As noted, VEU is assumed to have constant targets from 2020 through to its currently-scheduled cessation in 2030. The irregular shape of the annual savings curve is a result of the changes made to the VEU, which took effect from around 2012-13. Up until that time the program had focussed on residential savings measures, such as lamp replacements and stand-by power control devices, which could be rolled out very quickly, but had short deemed operational lives. After that, the emphasis switched to the commercial sector, and also to residential sector measures with longer operational lives which took longer to roll out. This meant that growth in annual savings in the residential sector slowed for several years, before moving onto a longer-term growth path.

Changes in the scope of ESS in NSW, and also of REES in SA, had somewhat similar, though less pronounced effects on incremental annual gas energy savings in those two states.

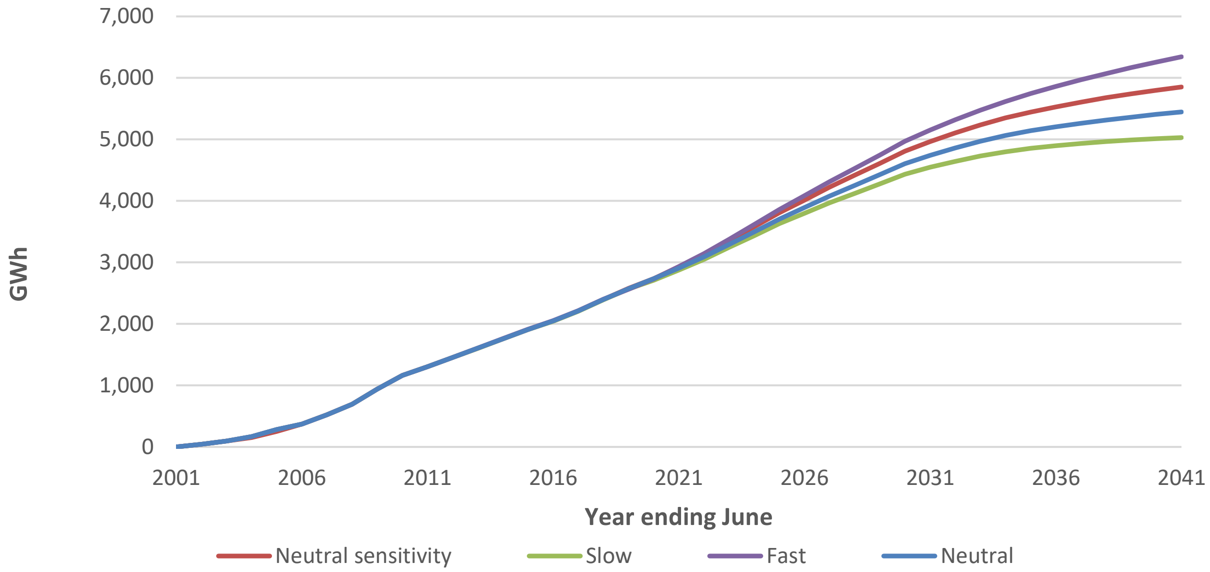
Figure 6: Victorian Energy Efficiency Forecast by Scenario – Residential Sector



3.4.3 Queensland

Figure 7 shows the residential energy efficiency forecast for Queensland by scenario. Savings are relatively smaller than those in NSW or Victoria, noting the absence of a state energy savings scheme. In addition, total space heating requirements in Queensland are negligible, while cooling requirements per dwelling are larger than in either NSW or Victoria, by much less than would be needed to offset the absence of heating requirements. This is particularly the case for Climate Zone 2, covering south east Queensland, where the majority of dwellings are located.

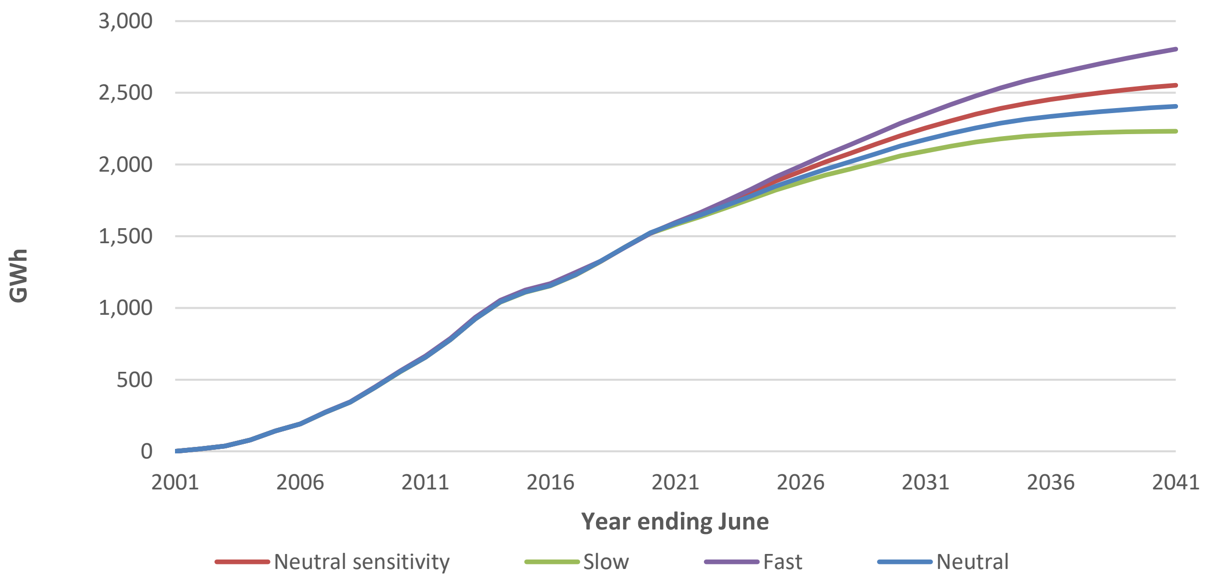
Figure 7: Queensland Energy Efficiency Forecast by Scenario – Residential Sector



3.4.4 South Australia

Figure 8 includes the effect of South Australia's Retailer Energy Efficiency Scheme (REES), in addition to national measures, in generating energy efficiency savings over time, relative to the FY2001 base year. As discussed above, however, state scheme savings, including in South Australia, are weighted towards to the commercial sector (and industrial in NSW only).

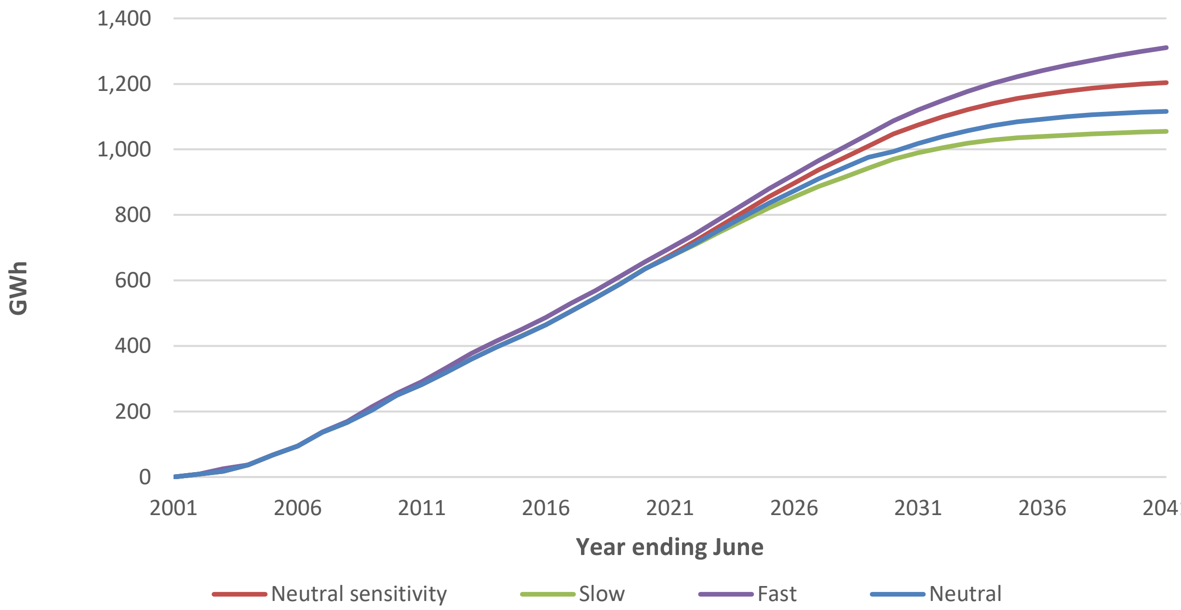
Figure 8: South Australian Energy Efficiency Forecast by Scenario – Residential Sector



3.4.5 Tasmania

The energy efficiency savings shown in Figure 9 for Tasmania are more modest, due both to lower total consumption, relative to other states, and the fact that only national policy measures apply.[21] Savings are nevertheless higher than those estimated in the 2018 study, and this reflects stronger GSP and population growth, particularly in recent years, and also forecast for at least the next five years. In addition, almost all dwellings in Tasmania use electricity for space heating and heating load per average dwelling is higher, because of the colder climate (climate Zone 7). This means that electricity saving from more efficient housing is relatively large, despite the almost complete absence of cooling requirements.

Figure 9: Tasmanian Energy Efficiency Forecast by Scenario – Residential Sector

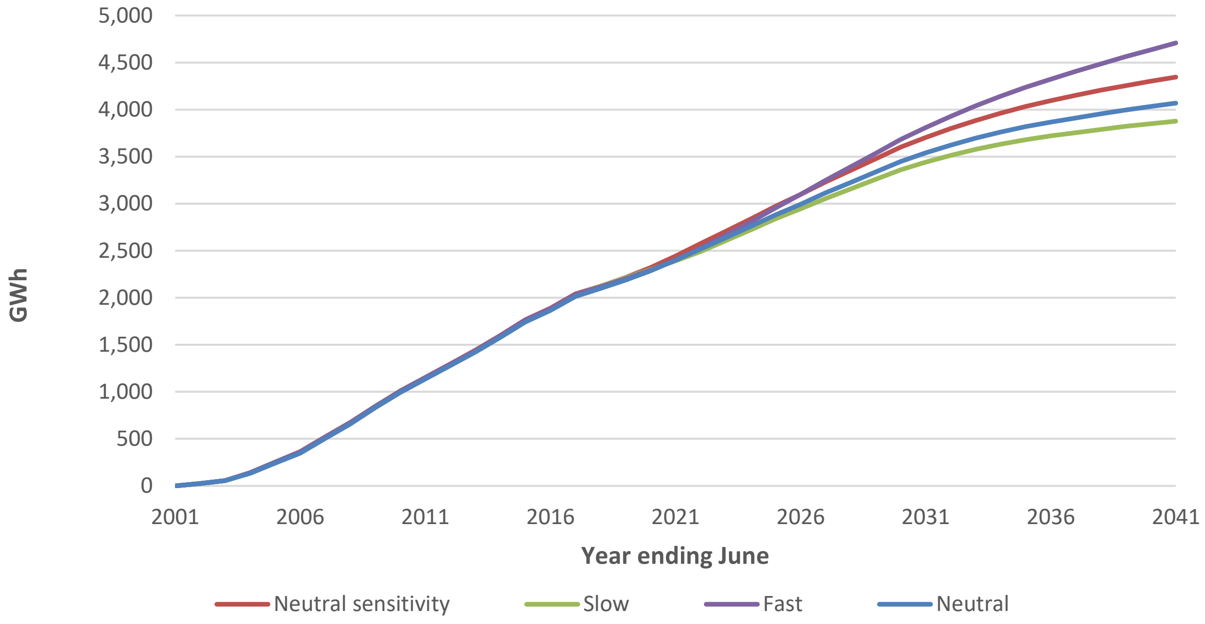


3.4.6 Western Australia (SWIS)

Figure 10 shows the electrical efficiency forecast for Western Australia limited, as noted above, to the South Western Interconnected System or SWIS, due to poor data on the residential stock and energy consumption outside the SWIS.

[21] The recent Tasmania Energy Efficiency Loans Scheme (TEELS) was not included due to a lack of data on the energy savings impact of this scheme.

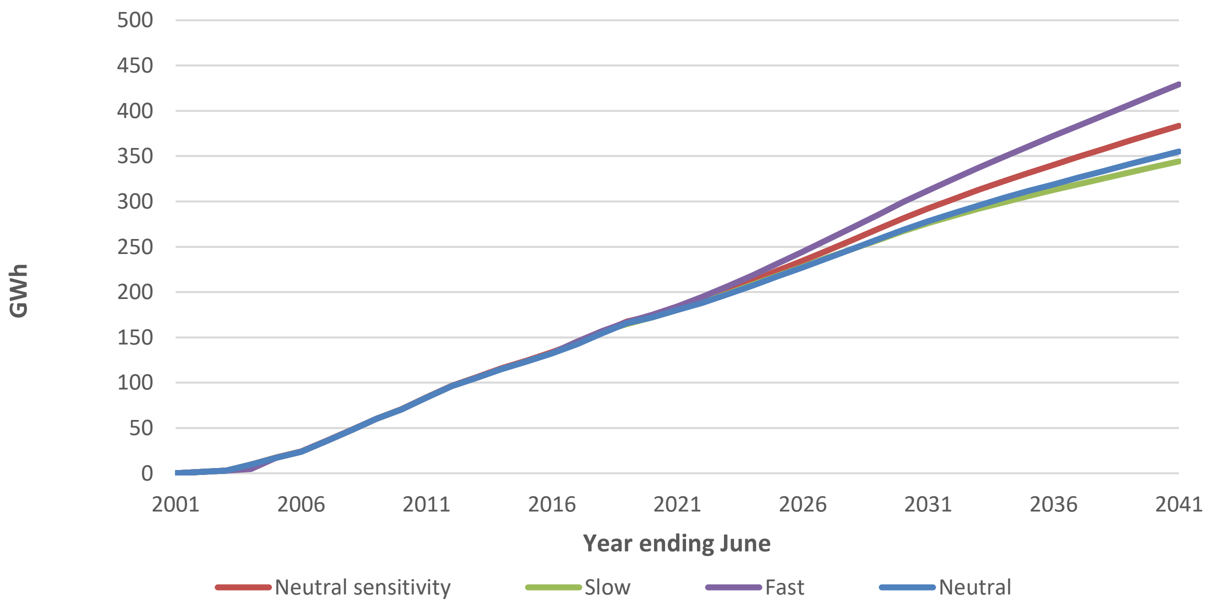
Figure 10: Western Australian Energy Efficiency Forecast by Scenario – Residential Sector (SWIS)



3.4.7 Northern Territory (DKIS)

Figure 11 shows the Neutral scenario energy efficiency forecast for the residential sector in the Northern Territory. As with WA, the analysis is limited to the main Darwin-Katherine Interconnected System due to data limitations relating to the energy use and number of dwellings off-grid.

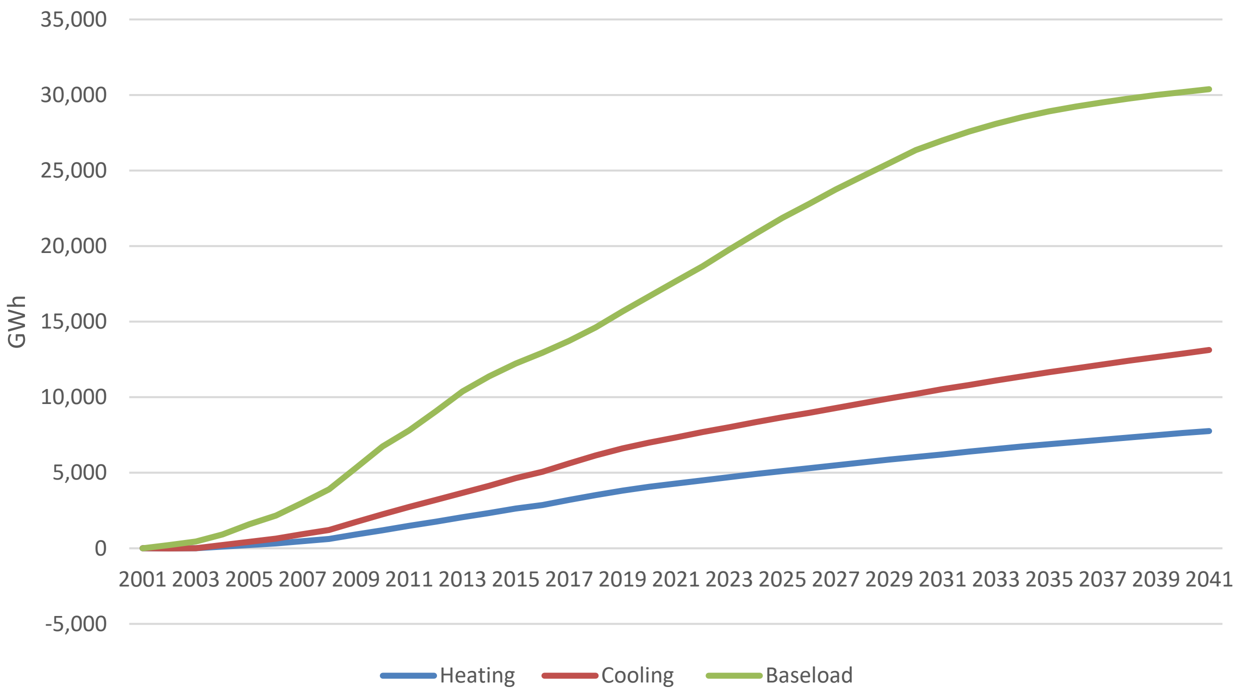
Figure 11: Northern Territory Energy Efficiency Forecast by Scenario – Residential Sector (DKIS)



3.4.8 Total Electricity Savings by Load Segment

Figure 12 shows the total neutral scenario energy efficiency savings, including broken down by load segment. Across all jurisdictions, the total savings, relative to the FY2001 base year, are projected to reach just over 30,000 GWh by FY2041 in the Neutral scenario. This exceeds expected commercial sector savings in the same year and scenario, of 27,900 GWh, and is significantly higher than the 6,300 GWh of electricity savings in the industrial sector in the same year and scenario.

Figure 12: Total Electricity Savings by Load Segment - Neutral Scenario

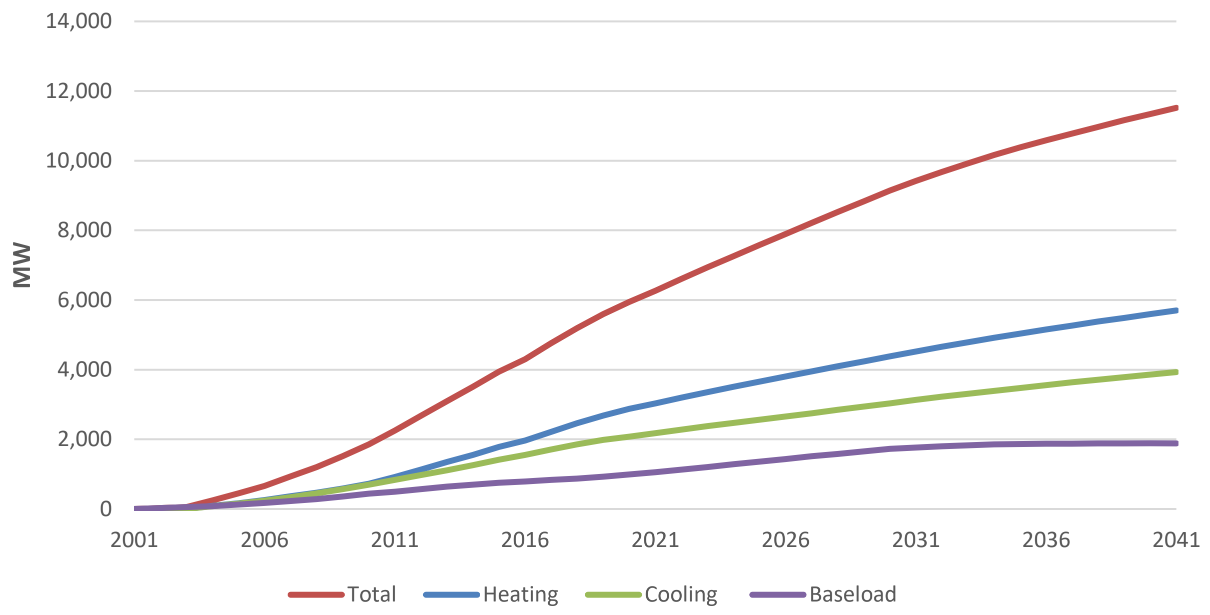


In terms of the load segments, and as discussed in Section 2.4 above, AEMO has adopted a revised set of assumptions regarding the temperature-responsive portions of the load ('heating' and 'cooling' for this study. The net result is that the baseload share of total savings is estimated to be proportionately higher than in previous studies, offset by smaller heating and cooling shares. When the residential sector results are compared to commercial or industrial (Chapters 5 and 6), it may be noted that both the temperature-responsive portions of the load are relatively larger for residential than for the other sectors. This reflects a combination of the inherent thermo-dynamics of smaller buildings (their higher surface to volume ratio makes their internal environment inherently more sensitive temperature and other changes in the external environment), together with the typical (but changing) occupancy pattern whereby many houses are unoccupied and not space-conditioned during the weekdays, but therefore can experience *relatively* larger peaks before and after working hours.

3.4.9 Maximum Demand

The assumptions underpinning the analysis of avoided peak demand, including the conservation load factors used, are set out in Section 3.4 above, and summarised in Table 13. Figure 13 shows the resulting avoided peak demand in MW for the Neutral Scenario, including in total and for each load segment.

Figure 13: Avoided Peak Demand by Load Segment and Total: Neutral Scenario: Residential Sector: Australia



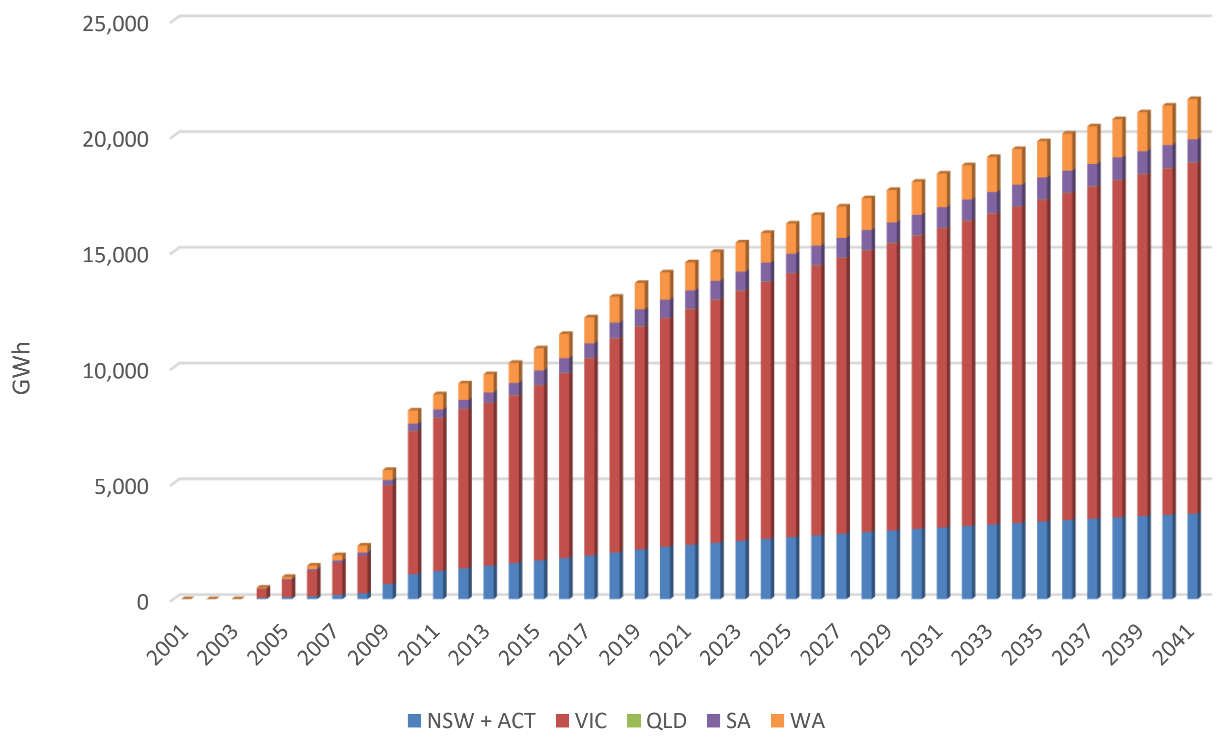
Since the CLF values used to derive the avoided peak demand values already take into account, for each end-use, the degree of coincidence between the expected time of avoided energy consumption and system peaks, it is the total avoided peak demand that is most relevant. Note that, as with energy consumption values, these avoided peak values are measured relative to a FY2001 baseline. Second, the avoided peak consumption shown for the historical period is already fully incorporated within historical demand values. For this reason, projections based on regressions of historical values will also include a projection of the future impact of past and existing energy efficiency policies on peak demand. As noted elsewhere, the appropriate application of this data, then, is to adjust demand expectations based on the changing *rate* of growth in avoided peak demand over time. In the case shown in Figure 13, the slowing trend of avoided peak demand in this scenario would mean that forecasts would risk to over-estimate the extent of avoided peak demand and therefore under-estimate expected peaks.

3.4.10 Gas Savings

Figure 14 summarises the expected gas savings in the Neutral scenario for the residential sector. Overall savings are modest but step up following the introduction of the Household Insulation

Program in 2009, which led to over 1 million houses being retrofitted with insulation. With Victoria being the largest user of residential gas, and primarily for space heating purposes, Victoria dominates the overall gas savings results. Gross gas savings in gas consumption are somewhat larger than net savings, because one component of the VEU scheme supports substitution of gas for electricity. Victoria is also the only state where the effect on electricity and gas consumption of residential water heating measures in the NCC is (modestly) additional to the effect of other measures, meaning that there is a further small increase in gas consumption because of fuel switching from electricity to gas for water heating.

Figure 14: Residential Gas Savings – Neutral Scenario – Relevant Jurisdictions



Gas savings in the Slow scenario are smaller, and larger in the Fast scenario, by round ±10% by the end of the projection period in Vic, SA and WA, and somewhat more in NSW. The differences between states are affected by quite complex interactions between a number of factors, including the current shares of gas space heating in the different climate zones and different dwelling types, and how these shares are projected to change over the projection period, together with the size of the heating thermal load, as determined by differing climate zones.

3.5 Conclusions

Overall, the pattern of projected energy efficiency savings under Slow and Neutral scenarios is consistent with modest savings arising in a more or less linear manner from the GEMS program. Savings estimates for GEMS have been scaled back annually for a number of years now, given ongoing delays in implementation of anticipated measures. In addition, there are ongoing annual savings from the 6 star standard that took effect (to varying degrees by jurisdiction) from 2011 or 2012. This measure continues to accumulate savings as a function of with net growth in the housing stock, and also as older, pre-energy-efficiency-regulation houses are demolished and replaced with 6 star ones (with some conversion to apartments or townhouses, but still at 6 star in most jurisdictions). At the same time, state energy savings schemes are currently scheduled to terminate between 2020 and 2030 and, for the time being, post-2020 targets are not set, and therefore we model the continuation of 2020 targets through to the currently-scheduled end of these schemes. As a result, efficiency savings begin to fall away, particularly after 2030. If instead these schemes are extended in time, and/or have higher targets set, then additional energy savings than shown above would be expected. Also, growth in dwelling numbers slows down slightly towards the end of the projection period, in line with the population projections, and this marginally slows the accumulation of energy savings.

In the Fast and Neutral Sensitivity scenarios, an expanded GEMS program and progressively higher thermal performance requirements for new housing under the National Construction Code are assumed to take effect from 2022 onwards, generating significant additional energy savings.

There are some results that stand out and require interpretation. Notably, there are relatively large cooling-related energy savings in WA. This arises from the combined impact of a number of factors: the high cooling load in Zone 5, rapid population growth in Perth (projected by AEMO to be faster than in any other state), higher mix of Class 1A1 dwellings in Perth than in Brisbane and Sydney. Also, as noted above, gas savings are largely concentrated in Victoria. This reflects the facts that, firstly, the gas share of residential space heating is much higher than in any other state and, secondly, that there are many more dwellings in the cooler Climate Zones 6 and 7 in Victoria than in any other state. Population growth in Victoria is also projected to be faster than in NSW, though not as fast as in either Queensland or WA.

The results also highlight the importance of stock turnover in determining the size of savings from enhanced energy efficiency, and we note that a general uncertainty in this regard is the demolition rate for existing housing, which appears not to be tracked in any statistical collection.

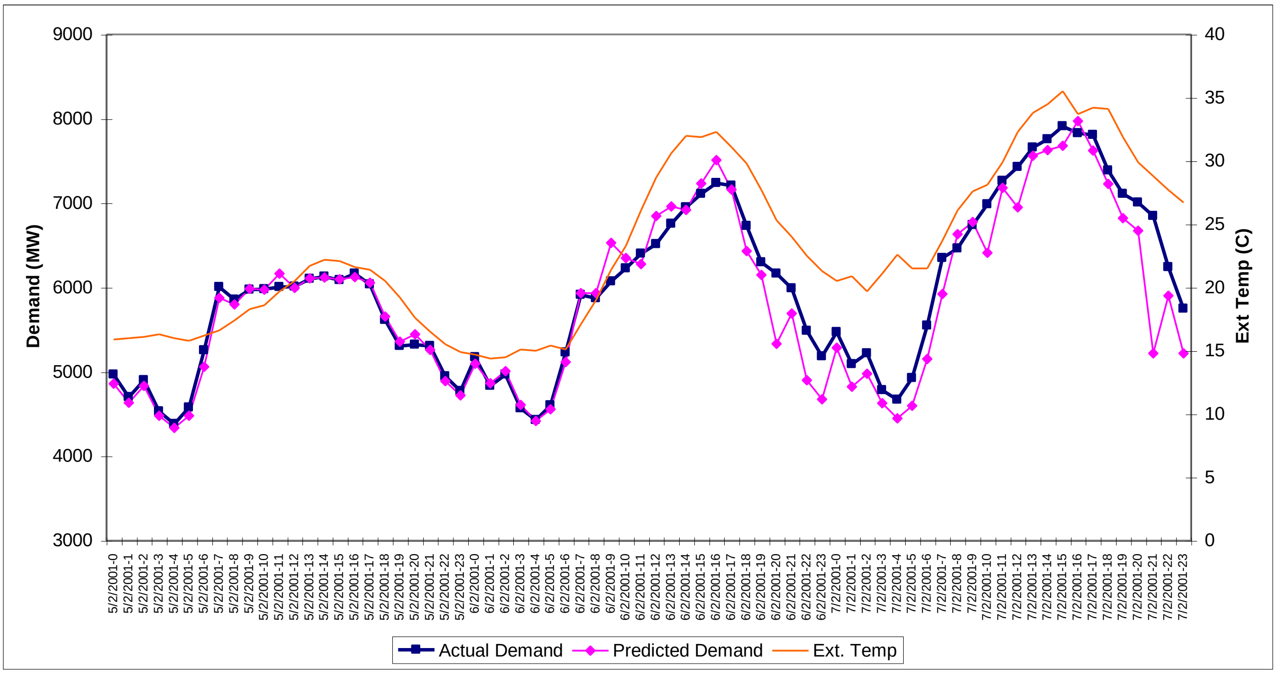
4. Residential Sector – Saturation Effects in Heatwave Conditions

4.1 Introduction

A new focus for this study is to providing advice on a method for mapping energy changes onto the NEM maximum demand half-hourly operational demand forecasts, including consideration of energy efficiency saturation points given weather conditions such as extreme temperature.

Summer peak loads are an important consideration for AEMO and the NEM, as peak loads drive investment in both generation and transmission infrastructure. Previous investigations by Energy Efficient Strategies for VENCORP in Victoria (2005) showed summer peak demand during extreme weather events is overwhelmingly dominated by residential air conditioning loads. The VENCORP study examined hourly state loads from 1999 to 2004 and showed through bottom up modelling that residential air conditioners were the main temperature sensitive load component and that bottom up modelling results closely matched system wide loads recorded by VENCORP.

Figure 15: Sample simulation model output – 5/2/2001 to 7/2/2001 Victoria (VENCORP report) – Source EES



When projecting impacts over the medium term (to FY2041 in this case), there are a range of factors that will impact on residential air conditioning loads. Given the complex interactions between these elements, the net effect is not intuitively obvious. The main factors that appear to be driving residential air conditioning loads are:

- An increase in air conditioner ownership over time

- An increase in the efficiency of air conditioners over time
- Changes in the installed capacity of air conditioners (generally this is stable or declining)
- Improved building shell performance for new homes through mandatory requirement under the NCC
- Changes in floor areas for new Class 1a dwellings (stand-alone houses), although this has largely stabilised in the past 5 years
- Increasing use of whole house ducted air conditioning, and other changes to zoning behaviours (change preferences, work from home)
- A higher proportion of Class 2 dwellings (apartments) in major cities
- Changes in occupancy (more people working at home or retired)
- More extreme hot weather events in summer as a result of climate change.

The interaction of these elements is quite complex and the net effects over the medium to long term was explored using a bottom up model in order to quantify likely future impacts.

The detailed methodology that underpins the findings in this Chapter may be found in Appendix A.

4.2 Summary of Key Findings

The Residential Space Conditioning Maximum Demand (RSCMD) model developed for this project[22] is a pilot model only, based on a limited set of representative dwellings types that form a basic housing stock model. These are modelled using selected weather files, occupancy profiles and thermostat setting assumptions to derive cooling and heating loads that are then processed through a basic appliance stock model covering historical and future trends in ownership, capacity and efficiency.

The model is capable of making comparisons of likely maximum demand across a wide range of parameters including:

- Jurisdiction/Climate Zone (three at present – New South Wales, Victoria, Queensland)
- Year of analysis (present until 2041)
- Climate change impacts (turned on or off)
- Building shell efficiency
- Impacts of differing occupancy schedules and day of week impacts
- Space conditioning equipment ownership impacts
- Space conditioning equipment efficiency impacts.

[22] See Appendix A and Appendix B for further details.

Multiple parameters as noted above can be varied simultaneously in the model which means that a huge number of permutations are possible to model. Whilst it is not possible to document the breadth of possible options available within the tool, below is some sample output for the state of Victoria, showing maximum demand from the residential sector in 2019 using state weighted average housing stock, space cooling equipment stock and state weighted occupancy profiling.

Figure 16 shows the relationship between daily residential cooling maximum demand in Victoria and the maximum dry bulb temperature on that day. Whilst the maximum demand does tend to plateau off above 36ºC, as can be seen, the relationship between dry bulb temperature and maximum demand is not particularly strong.

Figure 16: Sample Output – Victoria 2019: Highest Ranked MD days

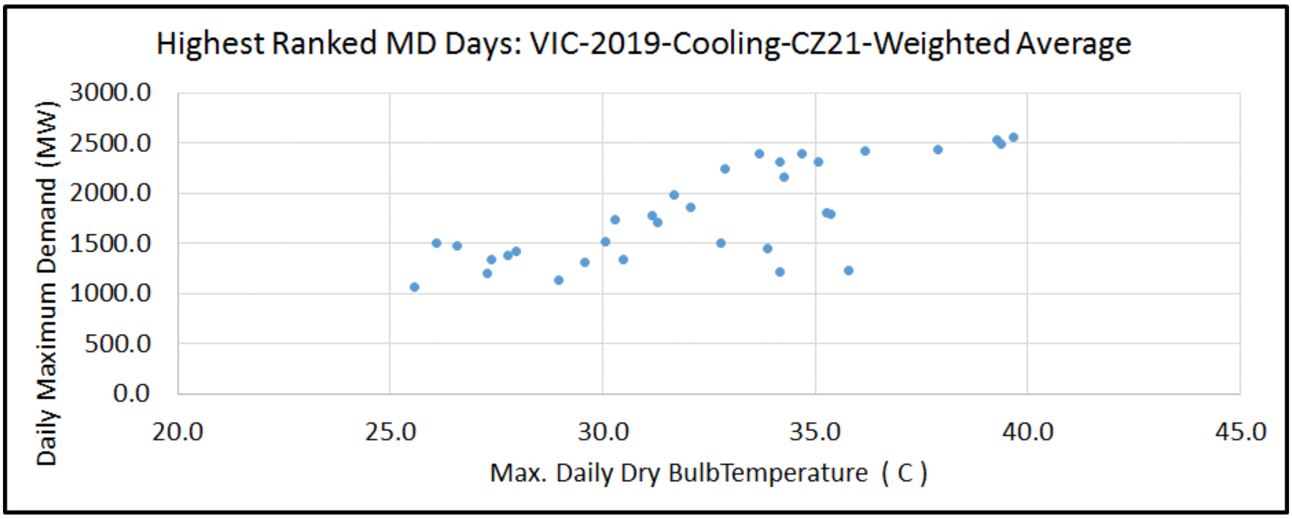
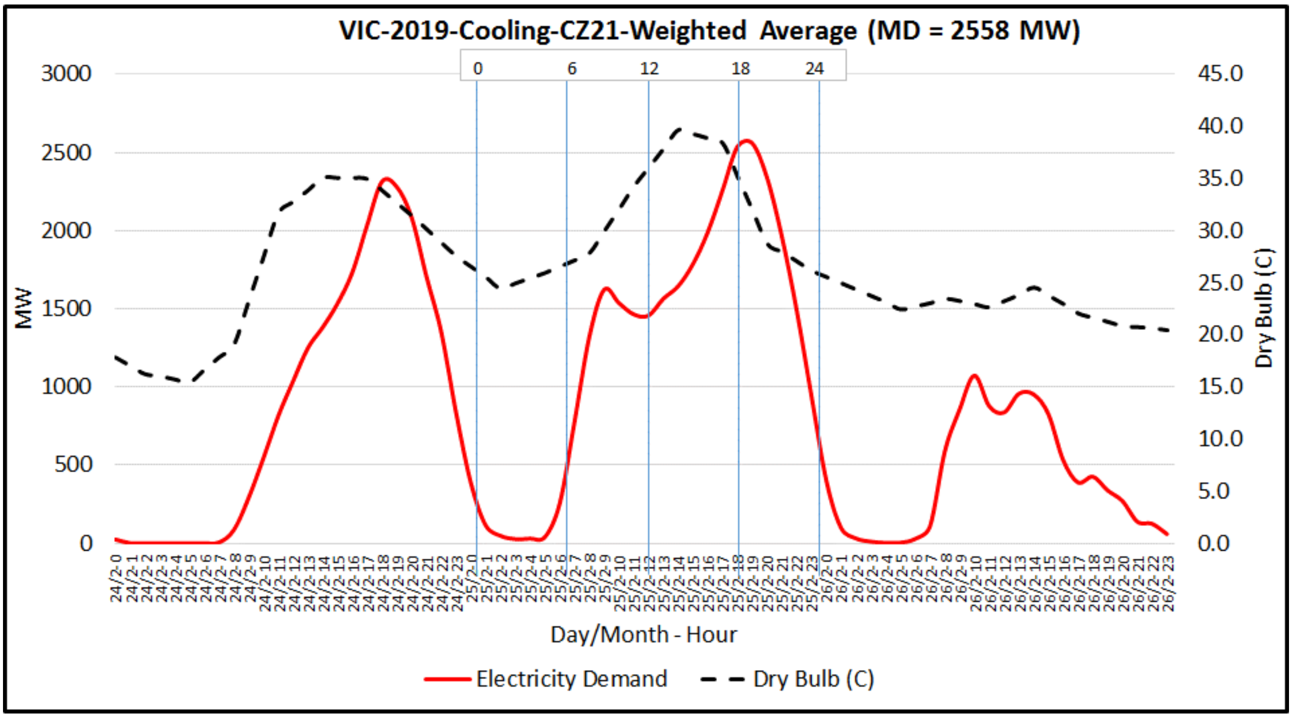


Figure 17 shows an hourly trace of the residential cooling demand over a 3-day period centred on the number one ranked day of maximum demand (25 February). Plotted against this is the corresponding dry bulb temperature (black dotted line) for each hour. The model provides options to also plot; moisture content (humidity ratio), wind speed, cloud cover, direct and indirect solar radiation. Analysis using this model has shown that, whilst dry bulb temperature is the most important predictor of maximum demand, direct solar radiation is also a particularly important determinant. Days of relatively high temperature but relatively low maximum demand often have high levels of cloud cover and reduced levels of direct solar radiation. The parameter of humidity ratio (sometimes called absolute humidity), is not generally a useful measure when assessing human comfort, so conversion to relative humidity may provide a more useful assessment of this parameter, especially in Queensland.

Figure 17: Sample Output – Victoria 2019: 3 day trace of No.1 ranked day of maximum demand

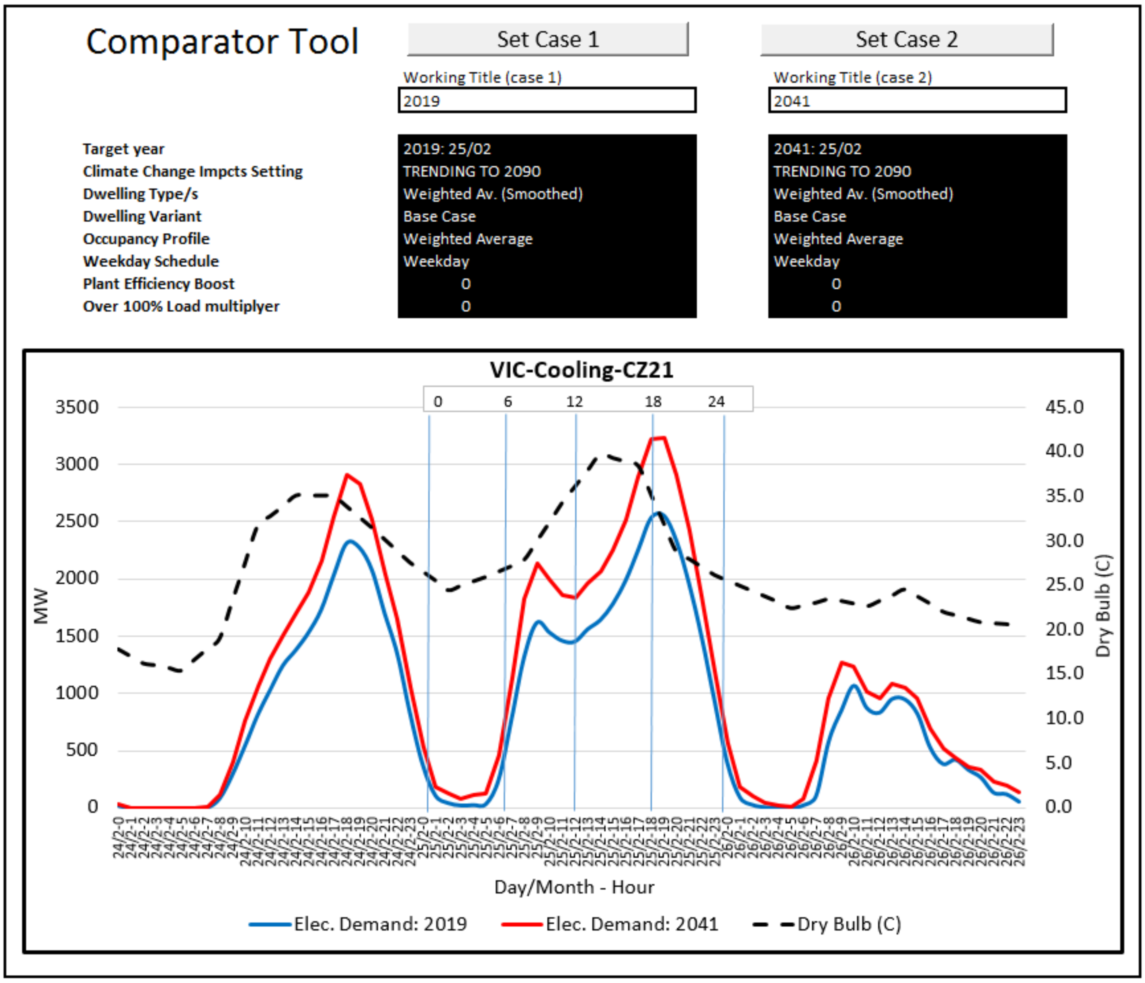


In addition to a three-day trace at state level, a similar trace at household level (state average) is also available as an output from the model.

Finally, the model also includes a "comparator tool" that allows the user to compare two different cases simultaneously. In Figure 18, the residential cooling demand over a 3-day period centred on the number one ranked day of maximum demand for both 2019 and 2041 are compared. This comparison takes into account such aspects as:

- Changes in the housing stock numbers (increasing)
- Changes in the housing stock efficiency (increasing)
- Changes in the ownership of space cooling equipment (modest increase)
- Changes in space cooling equipment efficiency (increasing)
- Changes in climate (increasing dry bulb temperature).

Figure 18: Sample Output Comparator Tool – Victoria 2019 V 2041: 3 day trace of No.1 ranked day of maximum demand



This tool offers the facility to enhance understanding of the drivers and trends in relation to residential cooling maximum demand. However, significantly more analysis using the tool is required before such an appreciation can be gained.

In terms of future analysis that would enhance the accuracy of the tool, the following is recommended:

- Comparison of model outputs using real weather data with actual maximum demand
- Expanded weather file usage to provide a more comprehensive picture of state-level maximum demands
- Further refinement of occupancy profiles so as to better mimic actual demand curves
- Expanded scope of dwelling types modelled including specific modifications such as the addition of shading devices.

4.3 Future Research

The bottom-up residential cooling peak load modelling undertaken for this project has demonstrated a proof of concept of how detailed building shell models can quantify likely peak electricity peak loads from residential air conditioner use. This work builds on two previous studies undertaken by Energy Efficient Strategies for Victoria and South Australia, prior to the creation of AEMO and the NEM.

While this project and the associated tool provide unique insights into the current and future drivers of residential peak demand in Australia, the data use for this iteration has some limitations. Firstly, the weather files used for Melbourne, Sydney and Brisbane were provided by the Department of the Environment and Energy for a representative mean year (RMY) of 2016. These weather files are a composite of month by month weather data from a number of previous years (typically 1995 to 2015), so while they are thought to be very useful representations of current "typical" weather patterns, they may not necessarily give the best indication of future climatic changes. At this stage only three climate zones have been examined. Future modelling may be improved by including a larger number of climate zones to better cover the NEM on a population weighted basis.

There are several areas of key interest for AEMO in terms of peak demand that cannot be readily addressed by the input data to this study as it currently stands. It is well understood that magnitude of peak demand from extreme weather events is strongly influenced by the underlying demand, which is determined in part by the day of the week. Weekends typically exhibit a much lower underlying demand across all sectors. The summer holiday period (Christmas to mid-January) is a period where underlying demand is also usually quite low (due to industry shut-downs) but where hot weather events are common. These factors will result in an overstatement of the prevalence and magnitude of system peak demands where these would normally occur during a weekend (somewhat a random aspect of timing, two out of seven) or during the holiday break period because the TMY weather files cannot be mapped to day-of-the-week.

The other topic of interest to AEMO is the amelioration of total system peak load impacts due to the diversification of more extreme weather events across the whole geographical NEM region. For example, the most extreme weather event in South Australia is probably not likely to occur on the same day or at the same time as the most extreme weather event in Queensland. As all of the TMY weather files are independently compiled from historical data for each month, data for say, January, will almost certainly be selected from different years in each climate, so these cannot be compared directly.

Both of these shortcomings can be addressed to a fair degree by the use of real weather files in ACDB format for building simulations. The use of real weather files will allow the bottom up modelling data to be matched with historical total system demand across the NEM (or even at a state level). A review of five to eight years of real weather data up to the present could also identify series of weather events of interest, which would allow fine tuning of the model outputs, especially when correcting for changes in non-temperature sensitive underlying demand (on weekends). Real weather data matched to AEMO demand data will also allow a more detailed exploration of other factors (in addition to sensible air temperature) that may impact on user demand for air conditioners (e.g. humidity, cloud cover).

In the case of regional diversification of weather, the use of actual weather files for all regions of interest over several years will allow the bottom up peak demand to be simulated in parallel. This can then be matched with actual NEM demand in different parts of the system to see how the regional diversity in bottom up estimates of peak demand matches the actual NEM system demand. Anecdotally it is known that more extreme hot weather events start in Adelaide and progress through Melbourne and then on to New South Wales over a period of several days. Hot weather events in Queensland can be impacted from the South but are often unrelated to the larger weather systems that travel across southern Australia over the summer periods. This type of detailed analysis using real parallel weather files will provide clear quantification of the impacts of geographical diversity. Real weather files are prepared by or for the NatHERS Administrator as part of the process of generating new TMY files for each region. So real weather files to 2015 should already exist, but it is unclear whether these can be readily accessed. It would be possible to construct real weather files from data purchased from BOM, but this would be a time-consuming process.

5. Commercial Sector – Analysis and Results

5.1 Introduction

We model stock growth and turnover (demolition and replacement, major refurbishment) in order to estimate the quantity of building floor area that is built to Code annually by building type and state and territory. However, as discussed in more detail elsewhere,[23] there is very considerable uncertainty about all key parameters regarding commercial building stock growth and turnover in Australia, due essentially to inadequate statistical collections.

While the nature and turnover of the residential stock is reasonably well illuminated by completions data (numbers, floor area, by dwelling type), and the Census, and also informed by other statistical observations relating to households and population demographics, no similar data exists for non-residential buildings. The ABS *Building Activity* series quantifies the 'value of construction work done' as a single value for each state each quarter, without revealing the productivity of this expenditure in terms of net floor area created, or indeed the share of this activity that relates to demolitions, refurbishment or new construction, or which building class. The total size of the commercial building stock is unknown, and estimates vary widely.

The stock assumptions employed here are mostly derived from the 2012 Commercial Building Baseline Study.[24] A stock model created for that project – with input from BIS Shrapnel in particular – has been updated and expanded to include all non-residential building classes (and Class 2 or apartment building common areas, as the energy performance of these areas is regulated by Volume 1 of the NCC).

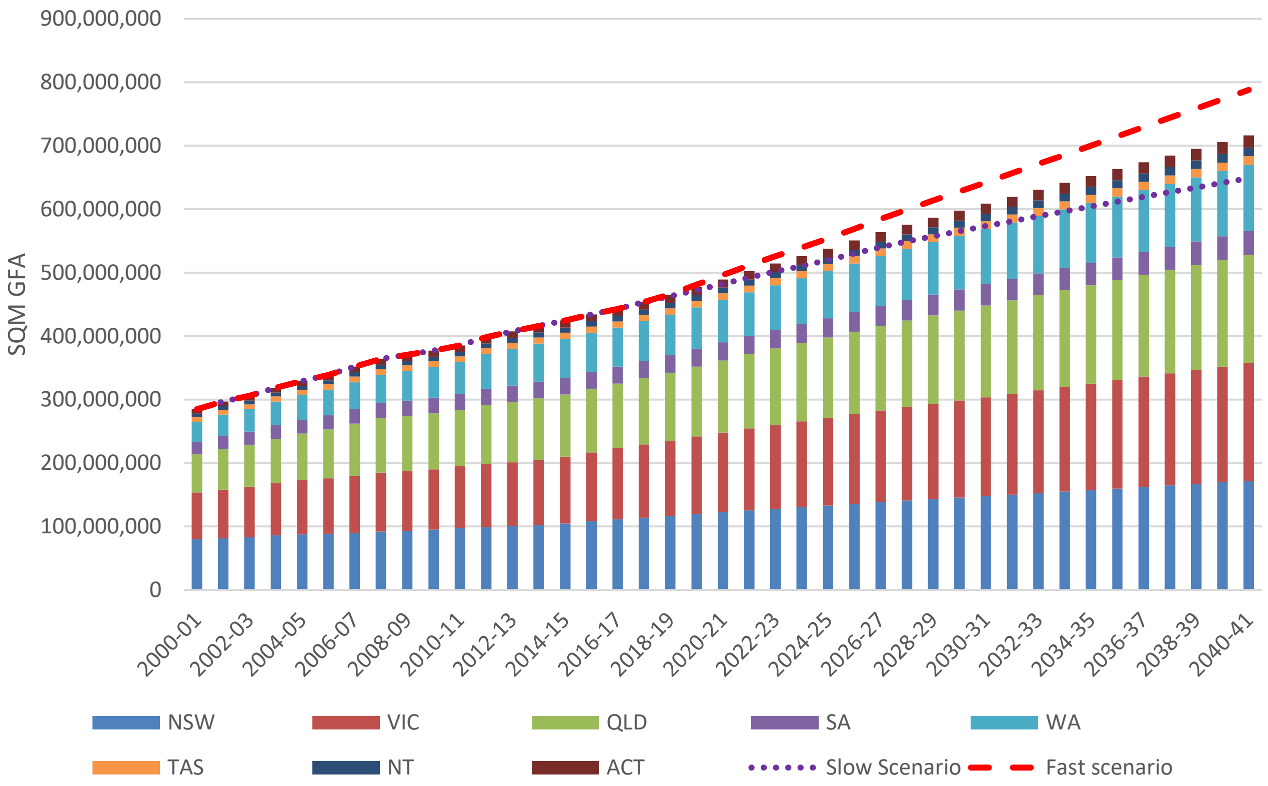
With respect to stock growth over time, we make the assumption that stock growth is responsive to the rate of growth in Gross State Product over time, but progressively moderated by factors such as the increasing productivity of at least office space in Australia (a greater number of persons per floor, or smaller number of sqm of floor area per person), and newer trends such as a greater prevalence of work-from-home and online retailing. We note that an update to the Baseline Study is expected to be undertaken in FY2020, and this study may be able to reduce at least some the uncertainties discussed here.

Setting these uncertainties to one side for now, Figure 19 indicates our estimate of the total non-residential stock by state, measured in square metres of gross floor area. The neutral scenario is represented by the bars, while the dotted lines indicate the range of total floor expected under slow and fast scenarios. Our model also represents the stock by building type and by NCC climate zone, as these are required for modelling different types of policy interventions. As a gross average, our stock model indicates that there is a net increase of around 12 million sqm of non-residential floor

[23] See, for example, Energy Action/SPR, *Achieving Low Energy Commercial Buildings in Australia*, December 2012, pp 27 – 29.
[24] COAG National Strategy on Energy Efficiency, *Baseline Energy Consumption and Greenhouse Gas Emissions in Commercial Buildings in Australia – Part 1*, November 2012, prepared by pitt&sherry et al.

area annually, over an estimated total floor area of around 450 million sqm of total non-residential floor area in FY2018. This includes an assumption that an area of around 10% of net annual increase, or around 1.2 million sqm annually, is demolished and replaced, or substantially refurbished (to the point where the current NCC performance requirements are triggered) annually. This estimate is likely to be overly conservative, but the data to test this thesis is not readily available. We note that 'conversion' of an existing building from one Class to another (eg, from office to hotel or vice versa) also, in principle, triggers the application of the Code. However, there is again very poor data available about the extent and specific nature of building conversion activity in Australia and also about the extent to which such buildings do, in fact, comply with the Code.

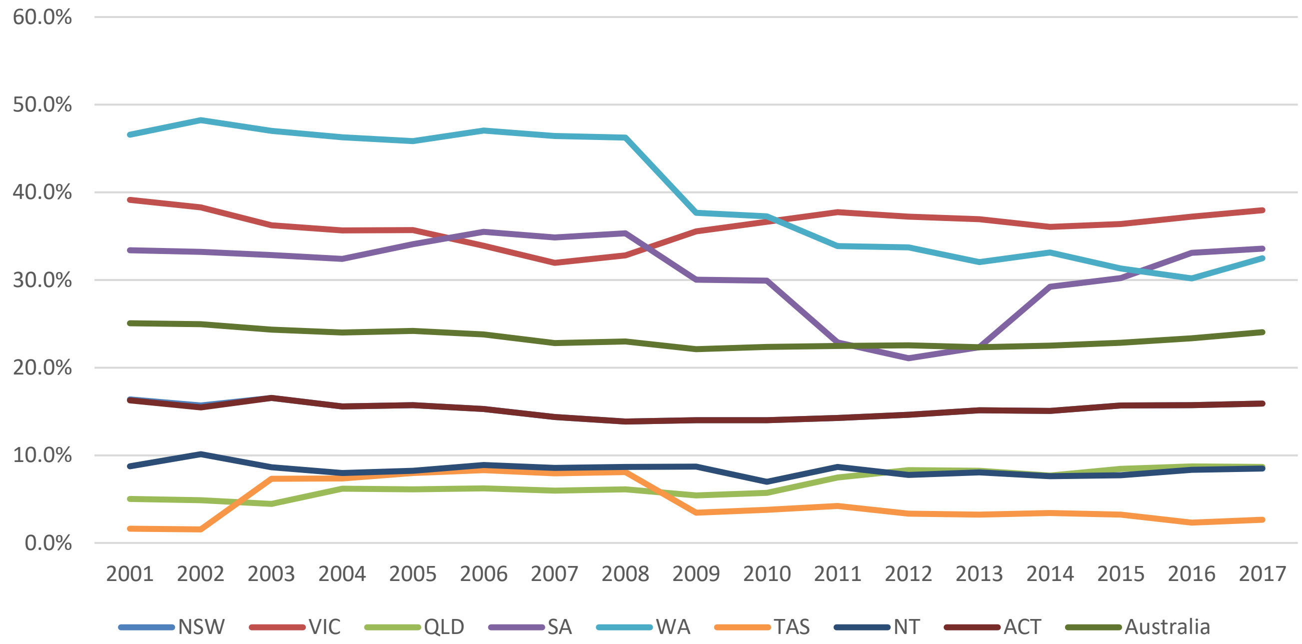
Figure 19: Non-Residential Building Stock – Neutral Scenario



5.2 Key Assumptions

The mix of fuels saved under specific measures, and particularly the NCC's energy performance requirements, must be estimated. Figure 20 indicates that, overall, there has been a modest reduction in the gas share of total energy use in the commercial and services sector in the period since 2001.

Figure 20: Historical Gas Shares of Total (Stationary) Energy Consumption, Commercial & Services



Source: Australian Energy Statistics, Table F, 2018[25]

We adjust our model of past energy consumption to reflect these historical fuel mix changes. Looking forward, there is considerable uncertainty about the future fuel mix. In addition to market considerations such as relative prices, technology trends and policy influences will also bear on the outcome. Noting that the rate of uptake of renewable electricity is a key factor in AEMO's scenarios, we assume modest differentiation in the future fuel mix for the commercial sector as set out in Table 14. Values also vary by jurisdiction reflecting the diversity of existing fuel mix patterns, as indicated in Figure 20.

Table 14: Fuel Mix Assumptions from FY2019

Jurisdiction	Neutral Scenario annual reduction in gas share	Fast Scenario annual reduction in gas share	Slow Scenario annual reduction in gas share
NSW	0.10%	0.20%	0.05%
VIC	0.20%	0.30%	0.05%
QLD	0.00%	0.10%	0.05%
SA	0.10%	0.20%	0.05%
WA	0.20%	0.30%	0.05%
TAS	0.10%	0.20%	0.05%
NT	0.10%	0.20%	0.05%
ACT	0.10%	0.20%	0.05%

[25] Australian Government, Department of the Environment and Energy, Australian Energy Statistics, Table F, August 2018.

Note that the fuel mix for individual building classes, as modelled for various RISs, also varies, and this variation is carried through into our models. The diversity of typical building class fuel mix profiles is revealed in the Baseline Study.

5.3 Energy Efficiency Measures

As noted in Chapter 2, we model the following energy efficiency measures for the commercial sector:

1. NCC energy performance requirements
2. NABERS
3. The CBD program
4. Commercial portion of the GEMS/E3 program
5. Commercial portion of state energy savings schemes.

5.3.1 National Construction Code Energy Performance Requirements

Energy performance requirements for non-residential buildings were first introduced in 2006, updated in 2010, and then not further updated until changes announced by COAG Energy Council in February 2019. These will take effect from May 2019, but only become mandatory from May 2020. Noting lags associated with the building cycle, we model savings from the latter only from FY2021, and then at 50% of the expected annual total, with the full savings impact from FY2022 onwards.

Generally, specific energy consumption changes (in MJ/sqm.a by fuel type) are modelled, drawing on values noted in the relevant RISs. However, the quality and completeness of these RISs has varied over time. The 2006 RIS, in particular, is widely believed to have over-estimated actual savings, particularly of gas, and particularly in some states/territories/climate zones. Also, the agreement between specific energy savings values by state and territory, on the one hand, and by climate zone on the other, is difficult to explain. We use the values noted by climate zone, as they appear far more conservative.

In addition, we increase our allowance for non-compliance or non-realisation of modelled savings from 10% in last year's study to 25% in this year's. This reflects analysis by The Centre for International Economics undertaken in the context of the 2019 NCC changes, which suggests that up to 25% of modelling savings may not in fact be realised due to a combination of poor Code enforcement, poor or missing commissioning of buildings, and possible modelling errors or over-estimation of 'real world' expected savings.[26] We note that there is a lack of objective evidence

[26] ABCB/The CIE, *Decision Regulation Impact Statement: energy efficiency of commercial buildings*, November 2018, Appendix D.

regarding the extent of this phenomenon in Australia, including a lack of any published compliance audits in any state or territory. Victoria is currently conducting compliance audits for residential buildings, but not for non-residential buildings. For NCC2019, we select the 'medium realisation scenario' values, which are discounted by 25% from those that would apply if modelled savings were fully realised.

Since Code changes apply to new construction work, and the volume of new construction work is assumed to be sensitive to GSP changes over time (see Section 5.2), the energy savings attributable to the Code are sensitive to AEMO's scenarios.

5.3.2 Greenhouse and Energy Minimum Standards (GEMS)

The general approach to modelling GEMS impacts is described in detail in Section 3.3.2 and not repeated here. For the commercial, we select the savings attributed (by George Wilkenfeld & Associates) to the commercial sector, with 'implemented' and 'on track' measures assumed to apply in the slow and neutral scenarios, and 'possible' and 'suspended' measures added in for the fast and neutral sensitivity scenarios. In addition, savings are assumed to be responsive to AEMO's population growth assumptions - as a proxy for energy consumption - with a discount applied to the Slow scenario relative to the Neutral scenario, reflecting slower expected population growth, and a loading applied to the Fast scenario relative to Neutral on the same basis.

5.3.3 NABERS and Commercial Building Disclosure (CDB)

NABERS is a voluntary building rating tool that has operated since 2001, and Commercial Building Disclosure is a mandatory rating and disclosure scheme that commenced in 2011, applying then to offices over 2,000 sqm. That threshold was reduced to 1,000 sqm from July 2017. CBD's Building Energy Efficiency Certificates (BEECs) are derived using NABERS, therefore energy savings from the two programs are strictly non-additional. Given the extensive overlap between the two measures, we model NABERS and CBD in parallel, using a convention that mandatory measures 'crowd out' voluntary ones. As a result, the savings attributable to the two programs are increasingly weighted towards CBD over time. For AEMO's purposes, the split between the two programs is less material than their joint savings impact, but savings attributions are nevertheless estimated.

In addition to the inter-twining of the two schemes, a second key challenge in modelling the additional energy savings attributable to them is that their key performance indicators are derived from the actual energy consumption of buildings over time. This is both a strength – in that the data are likely to provide a highly accurate picture of *total* energy savings, or energy intensity change, particularly for larger offices – but also a weakness, because the KPI includes efficiency changes regardless of their causation. Therefore there is a significant risk that savings claimed, or at least reported, by both NABERS and CBD will double-count those attributable to the National Construction Code (for new/substantially refurbished buildings), Energy Savings Scheme in NSW (which rewards NABERS upgrades of at least one star), GEMS (because lighting and equipment efficiency gains may also affect ratings, including indirectly through their impacts on HVAC energy consumption), and possibly other measures including state office procurement policies (not assessed in this study) and the Australian Government's Emissions Reductions Fund (also not assessed in this study – as the vast majority of savings are attributed to land use changes, while the share specifically attributable to NABERS (if any) is not revealed in program reporting).

In the case of ESS, the NSW Office of Environment and Heritage provided detailed data which enabled us to avoid counting savings under the NABERS method. Other state schemes are also discounted for non-additionality with other programs, including NABERS, while the approach to modelling NABERS, described below, has been designed specifically to counter the double-counting risks.

For this study we examine only office-related savings, due both to the overlap with CBD, but also reflecting the facts that a) non-office buildings covered by NABERS represent voluntary ratings only, and b) there are much lower numbers of non-office buildings rated than offices (energy ratings). For example, there were 148 shopping centre (base buildings) certified in FY2018, 12 data centres and just 3 hotels, as compared to 1,743 offices.[27] While this may slightly under-estimate the impact of NABERS, we do not have sufficient data to determine the extent to which average energy intensity of non-office buildings rated differs from those not rated. In addition, we would need to determine whether any such differences reflected a 'selection bias' (that is, buildings voluntarily rated may well be poorly representative of average energy efficiency, but rather reflect the efficiency of the 'better' end of the building stock. Practically these uncertainties mean that a much more detailed study would be needed to determine the extent of additional energy savings attributable to these non-office buildings.

Offices

Noting the extensive double-counting risks, our approach to estimating the additional or incremental energy savings attributable to NABERS and CBD is to work backwards from the 'headline' NABERS savings, discounting them as appropriate for saturation effects (see below), then determining the share of the total savings attributable to CBD, and then attributing the residual to NABERS.

The NABERS Annual Report 2017-18 indicates that the take-up of NABERS energy ratings had reached an impressive 86% of the national office market in that year. That is, 86% of the national office stock had been rated at least once by the end of FY2018. We assume that take-up plateaus at around 90% by around 2041, due to offices less than 1,000 sqm remaining outside CBD, and many of those (the so-called 'mid-tier' offices) may not be rated voluntarily either.

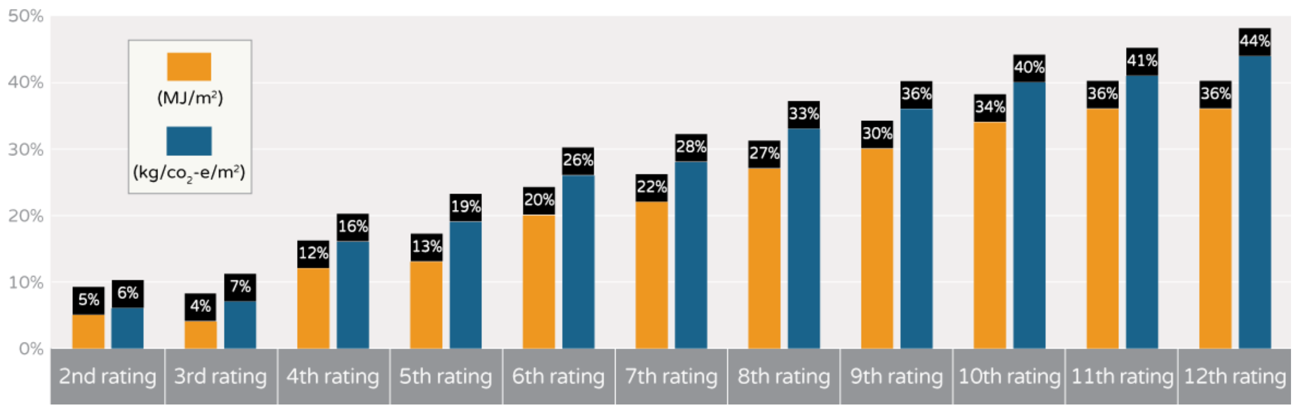
NABERS reports average reductions in energy use (base and whole buildings) in MJ/sqm.a as a function of the number of times specific offices have been rated – see Figure 21. Headline savings of 36% energy savings for offices rated 12 times appear impressive. However, this is problematic as a metric because it does not indicate over what time-period these multiple ratings have occurred.

---

[27] https://nabers.info/annual-report/2017-2018/office-energy.html

By way of background, many property trusts and institutions have internal policies that call for annual ratings of the offices that they own. At a minimum, then, we could assume that an office rated 12 times is being measured over *at least* 12 years. Also, for any given year, the share of offices rated for the first time, second time, or nth time that year is not revealed. Therefore, the annual 'headline' energy savings claimed by NABERS is not clear, even before attribution questions are addressed. For modelling purposes, then, we assume values over time for the share of offices rated multiple times, and therefore expected to be achieving the maximum or headline savings, in each year. These values generally increase over time, with some 'resets' for program discontinuities (such as the beginning of CBD, and the change in the CBD threshold), and by the mid-2020s are approaching 100%.

Figure 21: Average Reduction in Office Energy Use After Multiple Ratings



Source: NABERS online annual report 2017-18[28]

However, we cannot assume that offices rated not 12, but perhaps 20, times by the mid-2020s, let alone by 2041, will achieve the same *annual* energy efficiency improvement as those rated fewer times. The policy mechanism is simply information disclosure. Initial disclosures inform both the owner and tenant about the relative energy efficiency of an office, and that in turn provides an incentive for tenants to select more efficient offices and, therefore, for owners to ensure that their offices are efficient enough to be competitive. However, the amount of *new* information revealed by a second, third and nth rating is likely to be progressively more and more modest. Rational building owners will take advantage of the most cost-effective savings opportunities first, with the result that, over time, the residual opportunity set will be increasingly less cost-effective.[29] Therefore, the additional savings attributable to the disclosure (as distinct from those attributable to other efficiency changes occurring in any case) is projected to saturate over time. This saturation effect works against the effect noted above of both an increasing total share of offices covered by

[28] https://nabers.info/annual-report/2017-2018/life-of-program-statistics.html, viewed 4/7/2019.
[29] Technology and/or market changes will create new savings opportunities over time, but these are not attributable to NABERS, but (by definition) would have occurred in any case.

the scheme over time, and an increasing share that is likely to have been rated multiple times as each year passes.

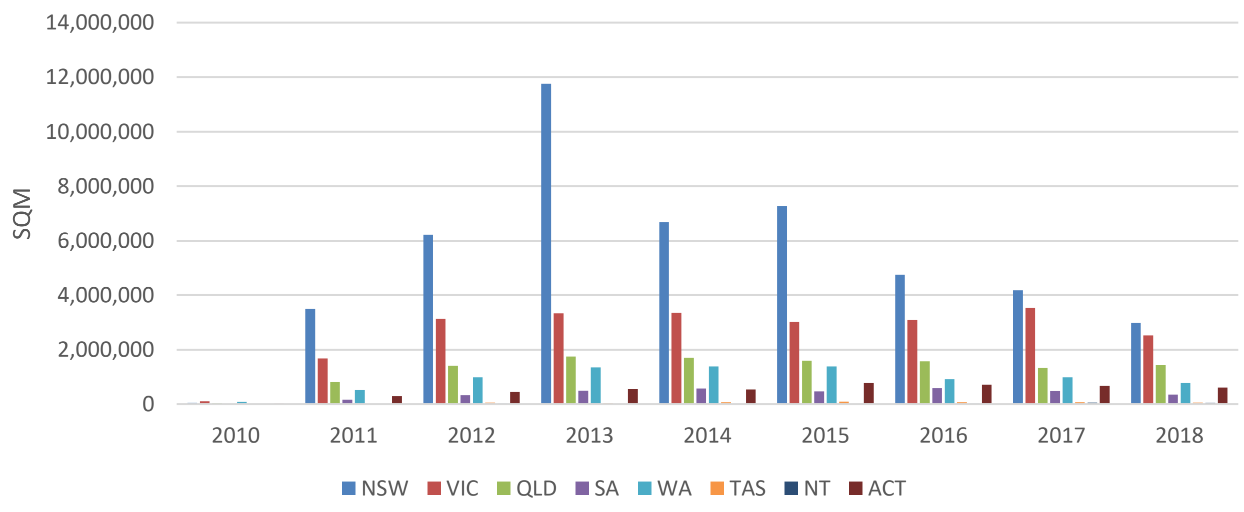
For modelling purposes, we assume that the saturation effect increases as function of the average number of times an office has been rated. A weighted average savings rate for each year is calculated as a function of a) the headline or maximum savings rate for buildings rated multiple times, b) the estimated share of buildings rated each year that have been rated multiple times (sufficient to achieve the headline savings rate), and c) a saturation effect that increases progressively over time, again with discontinuities attributable to changes in the program's operating environment. The building stock model described in Section 5.2 is used as the basis for estimating the floor area impacted by NABERS annually. By FY2018, the floor area affected by NABERS is estimated at some 81 million sqm nationally, with this figure expected to reach at least 136 million sqm by FY2041.

Noting that data provided by OEH for the NSW Energy Savings Scheme enabled us to exclude ESCs attributable to the NABERS method, there was no need to adjust NABERS savings for this potential double-counting risk. However, both NABERS and CBD savings are discounted by 25% to account for the likelihood of other non-additionalities, as noted above, including possible risks that new office savings (attributable to NCC) and equipment savings (attributable to GEMS) are also being counted as savings under these schemes.

Commercial Building Disclosure

The annual floor area rated/disclosed under CBD is revealed in downloadable program statistics that cover the whole of the program life.

Figure 22: CBD Floor Area Rated Annually by Jurisdiction



Source: derived from CBD downloadable program statistics[30]

[30] http://www.cbd.gov.au/registers/cbd-downloadable-data-set, viewed 4/7/2019.

We assume that the energy savings per unit of floor area attributable to CBD are the same as those attributable to NABERS, as the disclosure mechanism is the same – the difference, of the mandatory application of CBD, affects the uptake of the measure, but not the efficiency outcomes. Both NABERS and CBD are non-prescriptive measures; that is, it is left to the discretion of the parties involved (tenants, prospective tenants, owners, prospective owners) to determine what if any action to take in response to the information provided/disclosed. Therefore, the joint estimated savings of the two measures – discounted as noted above – are then shared between the two schemes on the basis of floor area.

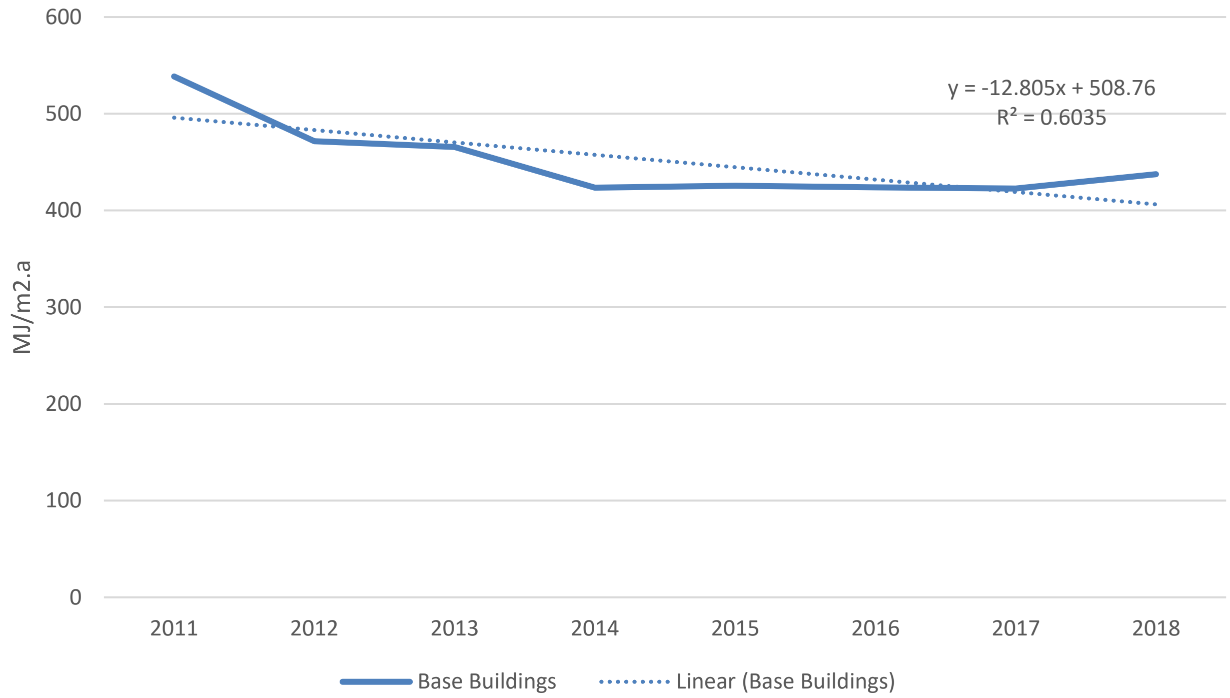
On a cumulative basis, the data shown in Figure 18 indicates that, by the end of FY2018, some 64.9 million sqm of office floor area had been rated/disclosed under CBD at least once.[31] This can be compared with the estimate above of around 81 million sqm rated under NABERS.

The future floor area expected to be rated under CBD is extrapolated from the 2018 figures, assuming 1% growth in floor area per year – although we note that the annual uptake of this measure appears to have hit a peak in 2013 – most likely representing a backlog of offices rated for the first time. Generally, we should expect floor area treated under the scheme to increase over time until a saturation point is reached. We assume that CBD uptake is capped at 90% of the total office floor area rated under NABERS, to allow for the possibility that smaller properties (eg, below the 1,000 sqm threshold of CBD) may be rated voluntarily under NABERS – although, as noted above, some of these smaller offices may sit in market niches that reduce this likelihood. In any case, as noted, this assumption affects only the *distribution* of savings between CBD and NABERS, and not the total savings. On this basis, NABERS captures 100% of the pre-2011 savings, but this share falls to around 10% of the total by the early 1990s, with the balance attributed to CBD.

The CBD program statistics enable analysis of the average change in efficiency (again, regardless of causation, as per NABERS) of rated offices. As described above, we do not use this data directly to estimate program savings, but it is presented in any case as the base building data (85% of CBD ratings are base, rather than whole, buildings) appear to show a saturation effect already at work, within the context of an overall downward trend (of a 2% efficiency improvement per year) – see Figure 23. Note that this figure is based on a sample of 5,942 unique buildings.

[31] We examined data for the set of unique buildings, but it is also possible to examine data per building over time, or all building floor area, regardless of the number of times rated.

Figure 23: NABERS Base Building Office Energy Average Energy Intensity Trends, 2011 - 2018 (CBD sub-set) – Australia



5.3.4 State Energy Savings Schemes

The analysis of state energy savings schemes is described in Section 3.3.4 above. Each of the NSW, VIC and SA schemes include commercial savings and, in recent years, these savings are indeed weighted towards the commercial sector.

More detailed figures for savings by sector, measure, fuel and jurisdiction are in Appendix D.

5.4 Efficiency Forecasts by Scenario

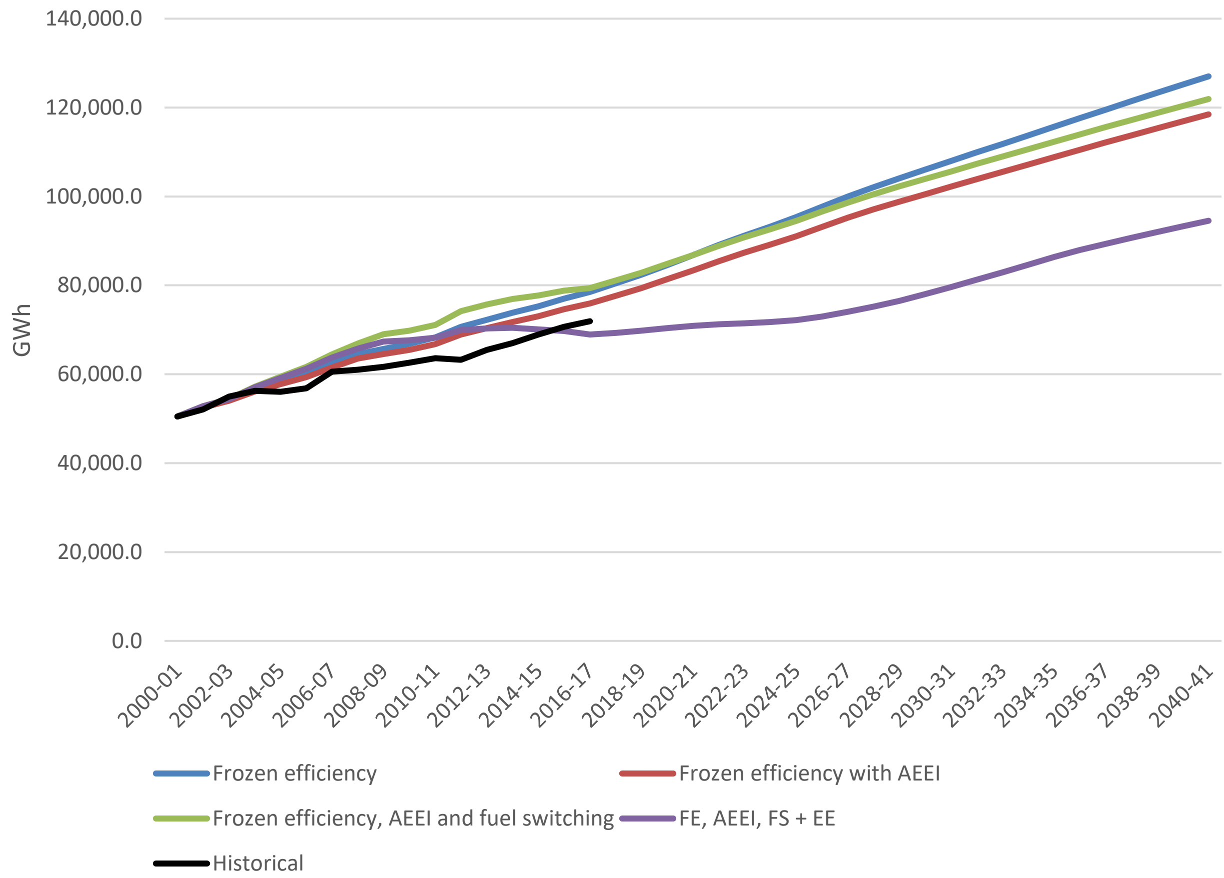
5.4.1 Neutral Scenario

Figure 24 provides an overview of the Neutral scenario results and their derivation. The top, blue line is a counter-factual projection of commercial energy consumption if energy efficiency were frozen at FY2001 levels. In order of calculation, the red line comes next, showing the estimated impact of autonomous or natural energy efficiency improvement (AEEI) on the frozen efficiency projection.[32] Next, the green line shows the impact of fuel switching. As noted above, the overall impact, across all jurisdictions, is to increase electricity consumption (and reduce gas consumption), which explains why this line lies above the red one. Finally, the lowest, purple-coloured line represents expected commercial electricity consumption, deducting modelling policy-induced

[32] A value of 0.25% per year is estimated. We have been unable to identify relevant Australian literature regarding AEEI rates in the commercial sector. This is not a critical assumption, however. It is employed here for the purpose of estimating the degree to which savings attributable to efficiency policy, and those attributable to other effects, agree with historical consumption data.

energy efficiency savings from the fuel switching line. That is, the purple line represents frozen efficiency adjusted for autonomous energy efficiency improvement, historical fuel switching and energy efficiency policies and programs. The black line indicates historical consumption as revealed in *Australian Energy Statistics*.

Figure 24: Energy Efficiency Forecast – Commercial Sector – Neutral Scenario – Australia (electricity)

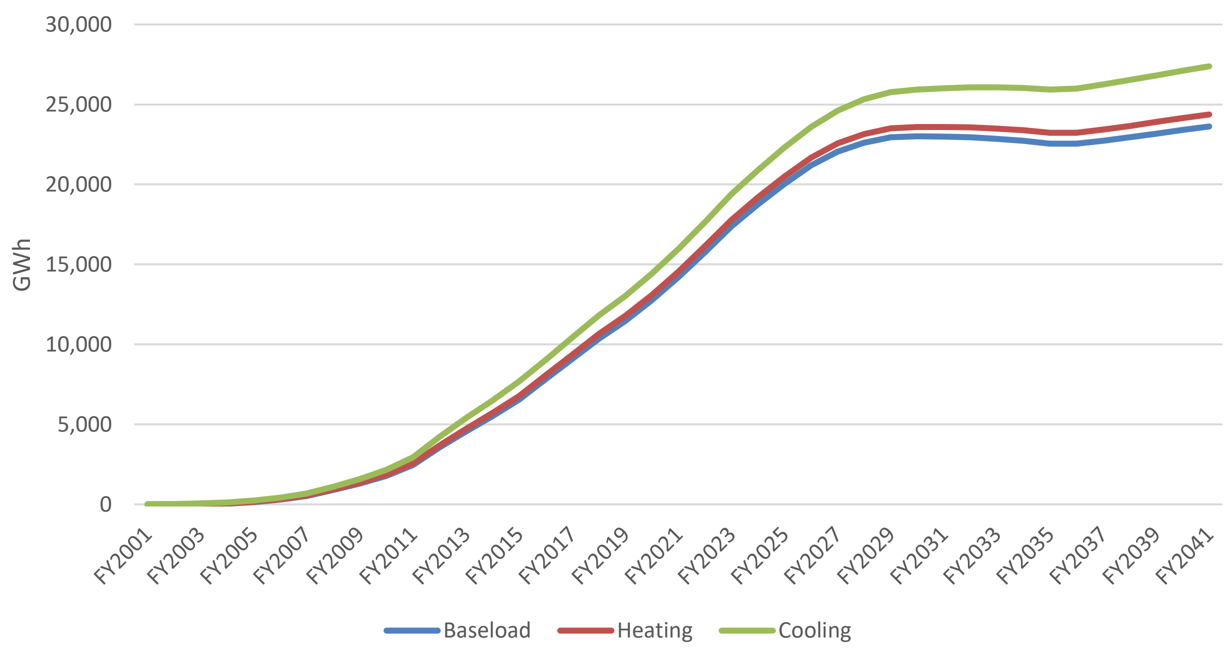


Despite the discounts for non-additionality and other factors, the modelled savings appear too small to fully explain the slow growth in actual consumption over the 2007 – 2012 period, and then appear to generate savings that are larger than those actually experienced in the 2013 – 2017 period. We note that this analysis does not represent a complete backcast or forecast of commercial electricity consumption, as numerous factors that will be modelled by AEMO are not modelled here, including effects related to relative fuel prices and impacts associated with the Global Financial Crisis. This would merit further investigation, as it may suggest that the energy savings attributable to certain measures remain over-stated, or non-additionalities between measures are still not sufficiently accounted for, although it is possible that other effects may also explain these results, such as the uncertainty about the actual rate of growth in the building stock.

Another perspective on the Neutral scenario is offered in Figure 25. Here the annual energy savings are shown as measured; that is, relative to the 2001 base year. In the first instance, it may be noted that policy-induced efficiency savings accelerate from around the mid-2000s through to around 2011/2012, and then remain relatively linear over the historical period, and projected through to the mid-2020s. There is then a marked slow-down projected, which primarily reflects the assumptions made with respect to the state energy savings schemes. Also, under BAU conditions, only modest additional savings are assumed to arise from GEMS while, as noted above, NABERS and CBD savings are expected to saturate and begin to fall (slowly) from around 2026.

Figure 25 also highlights that the majority of policy-induced energy efficiency savings are expected to occur in the baseload, or non-temperature-responsive, load segment. As discussed in Section 2.2 above, a methodology change is embodied in AEMO's 2019 scenarios when compared to previous studies. Based on historical analysis of actual NEM outcomes, AEMO assigns a lower proportion of total commercial electricity consumption to a temperature-invariant, or 'baseload', category. Previous studies implicitly assumed that the share of commercial building electricity use attributable to heating, ventilation and air-conditioning (HVAC) is temperature-responsive; that is, representing either heating or cooling load. However, commercial building HVAC systems use energy even with moderate external temperatures, partly for ventilation and partly to extract internally-generated heat. HVAC systems may also simultaneously heat some parts of a building while cooling others, depending upon factors such as solar gain and shading. AEMO analysis of these issues has led to a revised set of assumptions for the heating and cooling shares of the total load which are considerably lower than last year, and this is reflected in Figure 25 *inter alia* (also in the maximum demand calculations – see Section 5.5.5).

Figure 25: Commercial Sector - Avoided Electricity Consumption by Load Segment - Neutral Scenario - Australia



For comparison with other scenarios, we estimate that FY2041 commercial and services electricity consumption will be around 94,500 GWh on the Neutral scenario, which includes around 27,400 GWh of avoided consumption attributable to energy efficiency policy interventions. That is, if not for energy efficiency policy, electricity consumption in FY2041 would have been 28% higher than it is expected to be. These estimates allow for and are additional to autonomous or natural energy efficiency improvement, as noted, and also include significant reductions in modelled savings to allow for double-counting risks. We recall that the neutral (and slow) scenarios represent 'frozen policy'. Therefore, if policy settings were to be strengthened in future – for example, higher and/or extended state energy savings scheme targets, and expanded GEMS program, or lifted energy performance requirements in future versions of the NCC, then energy savings will be higher than shown above.

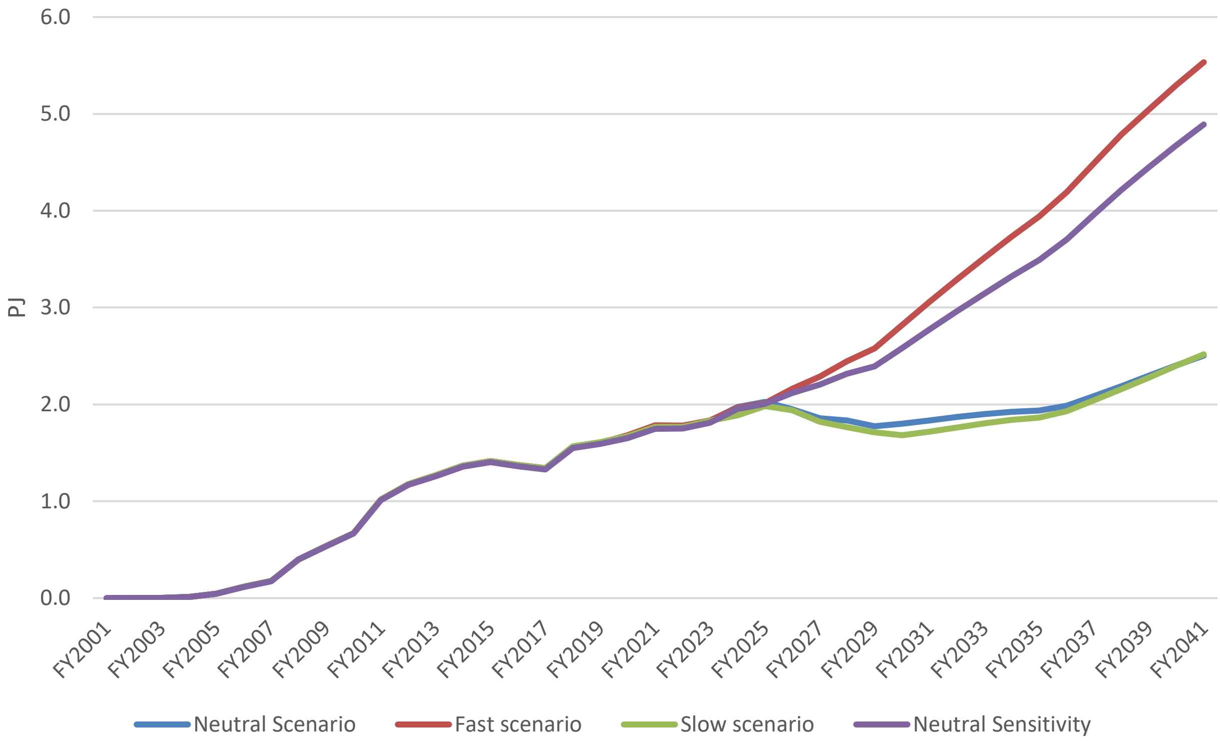
Gas Savings

By comparison with policy-induced electricity savings, policy-induced gas savings are very small – although somewhat larger in the fast and also neutral sensitivity scenarios. The general explanation for the low overall level of gas savings is:

- Gas is a relatively small share of commercial sector stationary energy consumption, at less than 16% in 2017 (refer to Figure 20)
- GEMS does not cover gas
- There has been fuel switching away from gas in the historical period, and we assume this will continue at a modest rate in future, depending upon the scenario
- State energy schemes predominantly avoid electricity (particularly for lighting), with little impact on gas, while VEU encourages gas use (modestly)[33]
- Energy performance requirements in BCA2010 and NCC2019 in some cases have the effect of leading to negative gas savings, or increased gas use
- Technical and economic opportunities for gas energy efficiency savings are relatively small, when compared to electrical efficiency savings, and also potentially less economic (since gas savings have a lower unit value than electricity savings). Therefore, non-prescriptive policy measures (Code, CBD, NABERS, etc) are less likely to encourage gas savings and more likely to encourage electricity savings.

[33] As noted, this effect may diminish in future years.

Figure 26: Commercial Sector Gas Savings by Scenario



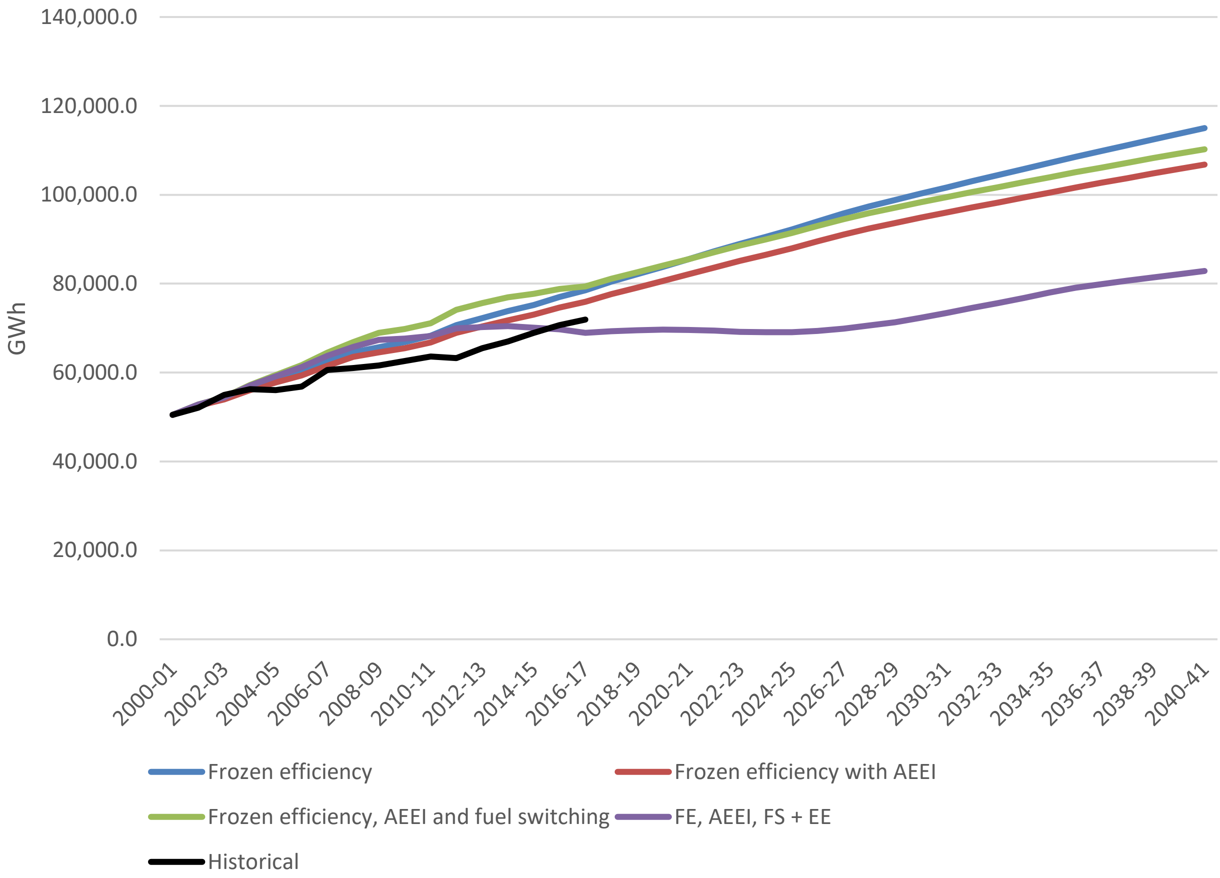
As discussed further below, the Fast and Neutral Sensitivity scenarios differ significantly from the others in that national policies are allowed to change. The significant increase in gas savings in the Fast and Neutral Sensitivity scenarios is entirely attributable to the assumption that significantly higher, but still cost-effective, energy performance requirements are put in place (progressively over the next 15 years) via the NCC. These are modelled to drive large additional energy savings of both electricity (predominantly) and also gas. This is discussed further in Sections 5.5.3 and 5.5.4 below.

5.4.2 Slow Scenario

The Slow scenario results differ from those in the Neutral scenario due to slower assumed rates of growth in population and GSP post 2018. The slower rate of growth in GSP translates into a slower accumulation of floor area in the built environment, while the slower rate of growth of population applies an effective discount to the savings expected under the GEMS program under Neutral growth assumptions.

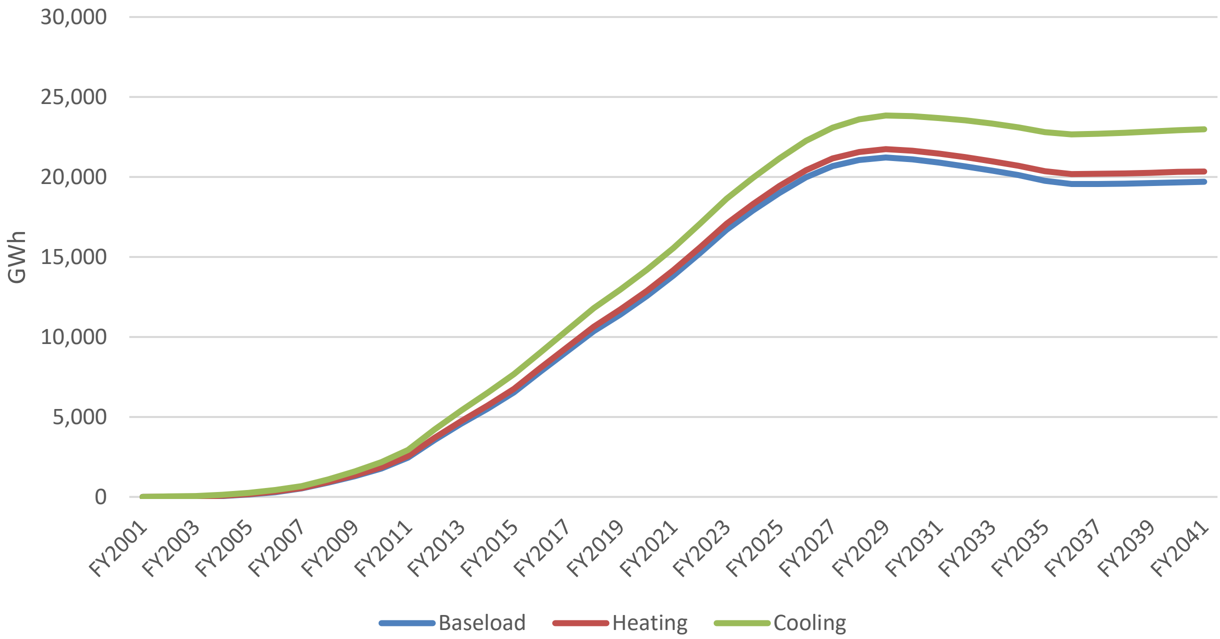
Excepting these factors, the Slow scenario results show broadly parallel patterns to those of the Neutral scenario. Figure 27 highlights that, under frozen efficiency assumptions, total commercial electricity consumption would have reached around 115,000 GWh in FY2041 as compared to 127,000 GWh in the Neutral scenario.

Figure 27: Energy Efficiency Forecast: Commercial Sector – Slow Scenario – Electricity - Australia



Even though the quantum of energy efficiency savings is lower in the Slow scenario than in the Neutral scenario – because energy-using stock growth and turnover is lower – FY2041 consumption after policy-induced and autonomous energy efficiency improvements and fuel switching is still lower at around 83,000 GWh as compared to 94,500 GWh in the Neutral scenario. This reflects the lower consumption drivers of GSP and population. Avoided consumption is shown to plateau from the late 2020s at about 25,000 GWh per year (relative to the 2001 base year); that is, there is no additional policy-induced energy efficiency gains (for electricity) from around 2028 onwards. This reflects BAU policy assumptions, including no lift in building code energy performance standards (after NCC2019), no expansion of the GEMS program, and no new state energy savings targets.

Figure 28: Commercial Sector - Avoided Electricity Consumption by Load Segment - Slow Scenario - Australia



As noted above, gas savings in the slow scenario differ little from the Neutral scenario, due primarily to the low share of gas savings in total energy savings, which generates small absolute changes in gas consumption between the two scenarios.

5.4.3 Fast Scenario

The fast scenario differs from the previous two not only in faster GSP and population growth rates, but also assumes more ambitious national efficiency policies, as a contribution towards cost-effective achievement of a 45% greenhouse gas abatement target by 2030. In addition to the measures modelled for the previous scenarios, we add the expected impact of:

- For the NCC, higher but cost-effective energy performance requirements, as anticipated in the COAG Energy Council's *Code Trajectory*[34] and underpinning modelling[35]
- For GEMS, inclusion of the full set of 'possible future' and 'suspended' measures as mapped by George Wilkenfeld.

Both of these measures would add <u>significant</u> additional energy savings. These savings would be mostly electricity – recalling that GEMS only covers electricity – but also in this case, more significant gas savings than in other scenarios due to higher commercial building energy performance requirements. Also, given that both are regulatory measures, and based on existing benefit cost analyses and regulation impact statements, and also the knowledge that any new measures would be subject to further regulation impact assessment in future, we know that both sets of measures would be highly cost-effective. For example, the scenario modelled here for future building code

[34] COAG Energy Council, *Trajectory for low energy buildings*, February 2019; see also Energy Action/SPR, *Achieving Low Energy Commercial Buildings in Australia*, December 2018.

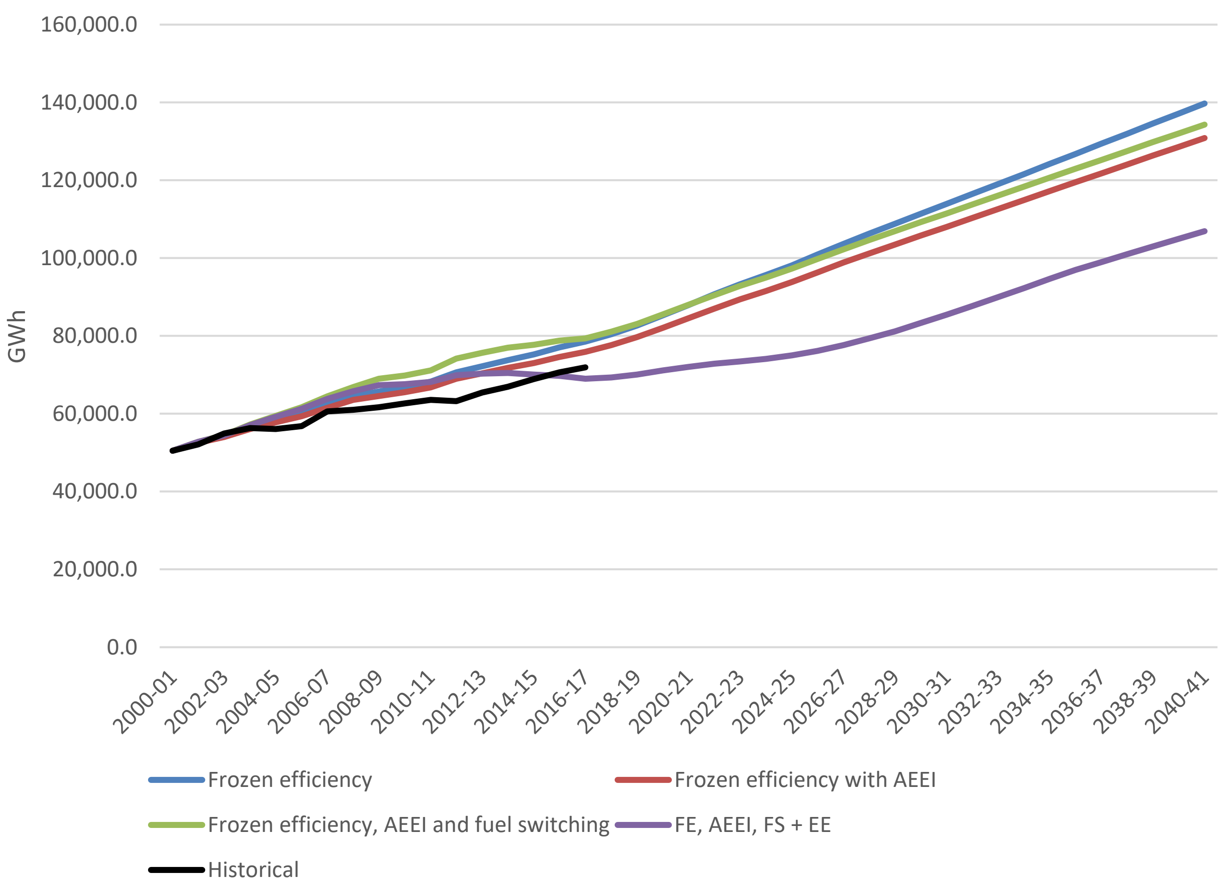
[35] Delivered by SPR and Energy Action, for non-residential buildings, and AECOM for residential.

energy performance requirements (described, in the reference cited, as the '2025 scenario') is associated with a net present value of $21.3 billion at a 7% real discount rate, with a benefit cost ratio of 2.1.[36]

Note that the Code scenario modelled has been subject to wide consultation, including with all states and territories and the Australian Government, and has been published by COAG. The GEMS scenario reflects detailed work by George Wilkenfeld & Associates, and others, who have been instrumental in identifying and quantifying the net benefits associated with GEMS regulatory proposals.

Figure 29 shows that the Fast scenario drivers would have been associated with electricity consumption in FY2041 of around 140,000 GWh. However, after taking autonomous and policy-induced energy efficiency into account, and historical fuel switching, actual consumption is here projected at around 107,000 GWh.

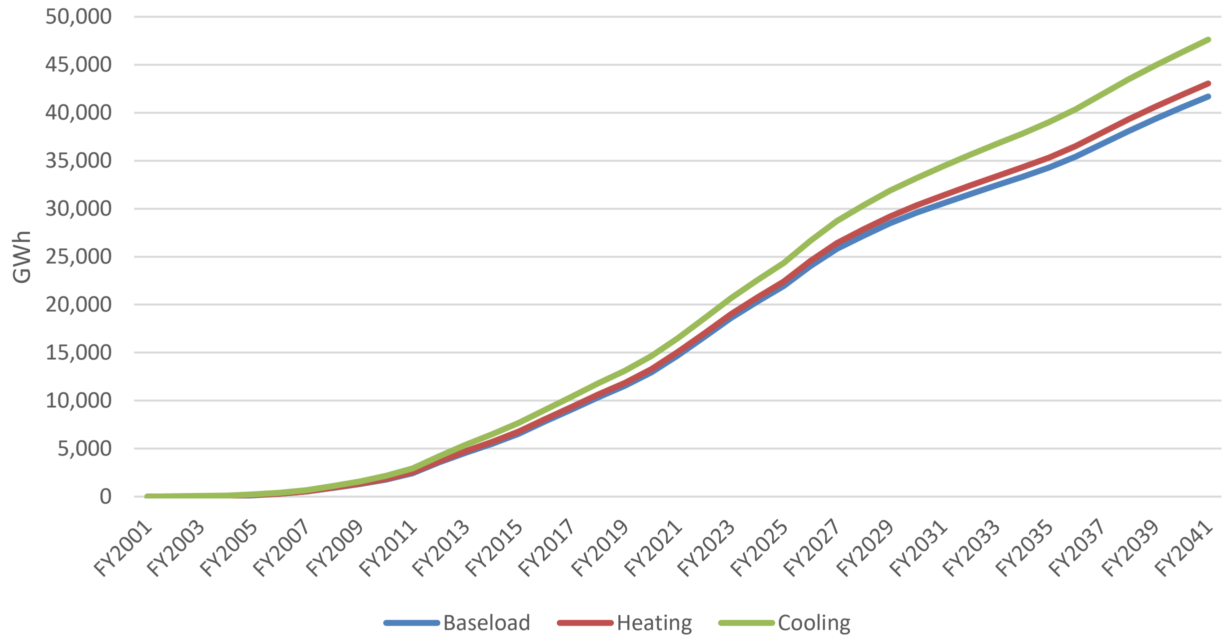
Figure 29: Energy Efficiency Forecasts - Commercial Sector – Electricity – Fast Scenario - Australia



36 Energy Action/SPR (2018).

The contribution of policy-induced energy efficiency to the outcome above is shown in Figure 30 below. It may be noted that avoided electricity consumption in FY2041 is around 47,600 GWh, compared with 27,400 GWh in the Neutral scenario and 23,000 in the Slow. Also, because the new measures would take effect from FY2020 – FY2022, with uptake proportional to stock turnover and consumption, the shape of these curves is very different from those for the Neutral and Slow scenarios. Energy efficiency is shown to accelerate, rather than slow, through the 2020s, and then continue in a largely linear fashion through to at least FY2041.

Figure 30: Energy Efficiency Forecast - Commercial Sector - Avoided Electricity Consumption by Load Segment - Fast Scenario - Australia



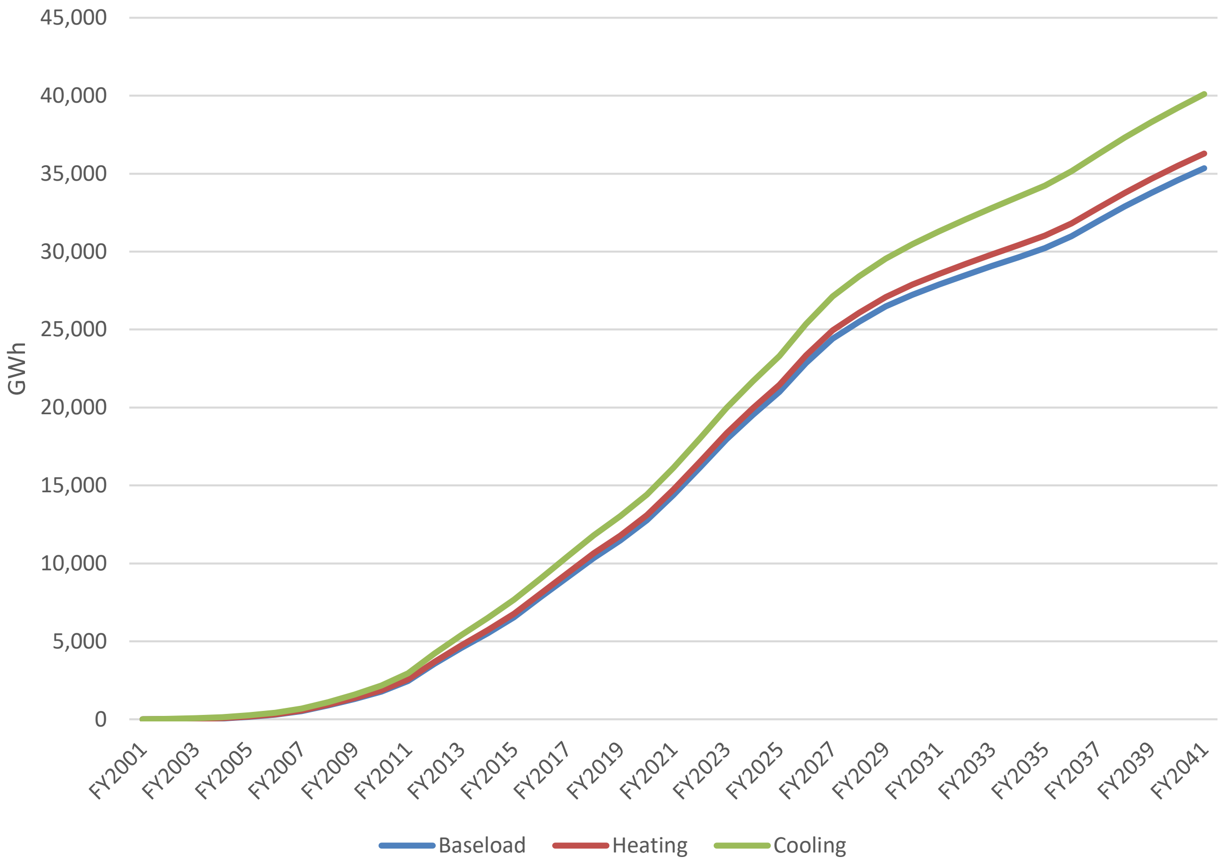
Gas savings in this scenario are described in Section 5.5.1 above and depicted in Figure 26. The gas savings are more significant in this scenario because significantly higher energy performance requirements are modelled for non-residential buildings under the National Construction Code. Technical measures – for example – like improved air-tightness, improved thermal performance of glazing and facades, and others, could enable reduced gas consumption in new commercial buildings. This should be kept in perspective, however. This scenario would see a little over 8 PJ of gas savings by FY2041, as compared to around 206 PJ of electricity savings.

5.4.4 Neutral Sensitivity Scenario

Figure 31 shows that this scenario is similar to the Fast scenario above, thanks to the additional policy measures as described above. However, total energy efficiency savings are somewhat lower, reaching just over 40,000 GWh rather than 47,600 GWh in the Fast scenario, but this against a lower consumption baseline than in the Fast scenario.

In common with the Fast scenario, gas savings are also higher than in the Neutral scenario, but somewhat less than in the Fast scenario (by a little less than 1 PJ in FY2014) due to the Neutral scenario's lower GSP and population growth assumptions – see Figure 26 above.

Figure 31: Commercial Sector - Avoided Electricity Consumption by Load Segment - Neutral Sensitivity Scenario - Australia



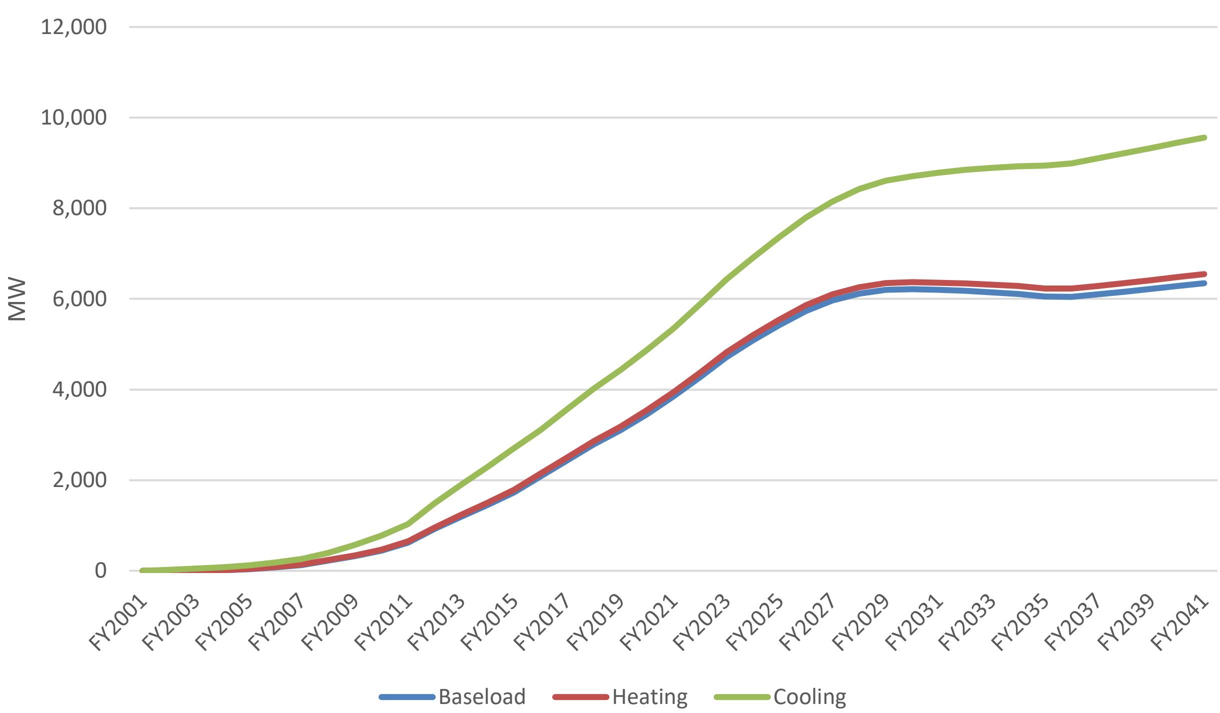
5.4.5 Avoided Maximum Demand

As introduced in Chapter 3, we utilise the Conservation Load Factor (CLF) method to estimate the avoided peak demands induced by the energy efficiency policy measures described above for each scenario. As per the 2018 study, and in line with the references cited in Chapter 3, we assume an average CLF of 0.4 for the commercial sector.

Neutral Scenario

Avoided peak demand in this scenario reaches just under 10,000 MW by FY2041, relative to the 2001 base year. This figure is a little lower than the value in the 2018 study, reflecting policy delays in GEMS and NCC2019, in particular, and higher discounts applied to the Code and state schemes. As discussed in Chapter 2 and elsewhere, the distribution of the avoided peak is indicated to be different from 2018, due to AEMO's changed assumptions regarding temperature-sensitive vs temperature-insensitive load segments. In our view, however, the relevant value is the top line below (which shows the *sum* of baseload, heating and cooling), as conservation load factor values already take into account the degree of co-incidence between avoided energy consumption in a given end-use and the system peak. Indeed, that is their essential purpose. Therefore, in our view, the values shown below for the avoided peak attributable to individual load segments are not material, but only the total.

Figure 32: Avoided maximum demand (relative to FY2001) - commercial sector - neutral scenario - Australia



It is important to note that, as with avoided energy consumption, the avoided peak demand in the historical period shown above is, by definition, *already included* in historical values for peak demand. Therefore, the *future* impact of existing energy efficiency measures in reducing peak demand will be contained, in some way, in forecasts of peak demand that are based on linear regressions of past values. It may be noted in Figure 32 that from around FY2012 to FY2028, the annual increase in avoided peak demand is quite linear. Therefore, projections of future avoided demand based on regressions over this period are likely to be reasonable accurate and require no post-model adjustments in order to incorporate the effects of energy efficiency policies.

However, as with avoided energy consumption, avoided peak demand in this Neutral scenario almost flattens after FY2029, due to the assumed cessation or weakening of impacts of the current efficiency policy set by that time.[37] Therefore, projections of avoided peak demand in this period based on regressions of values in the historical period would *over*-estimate the future impact of

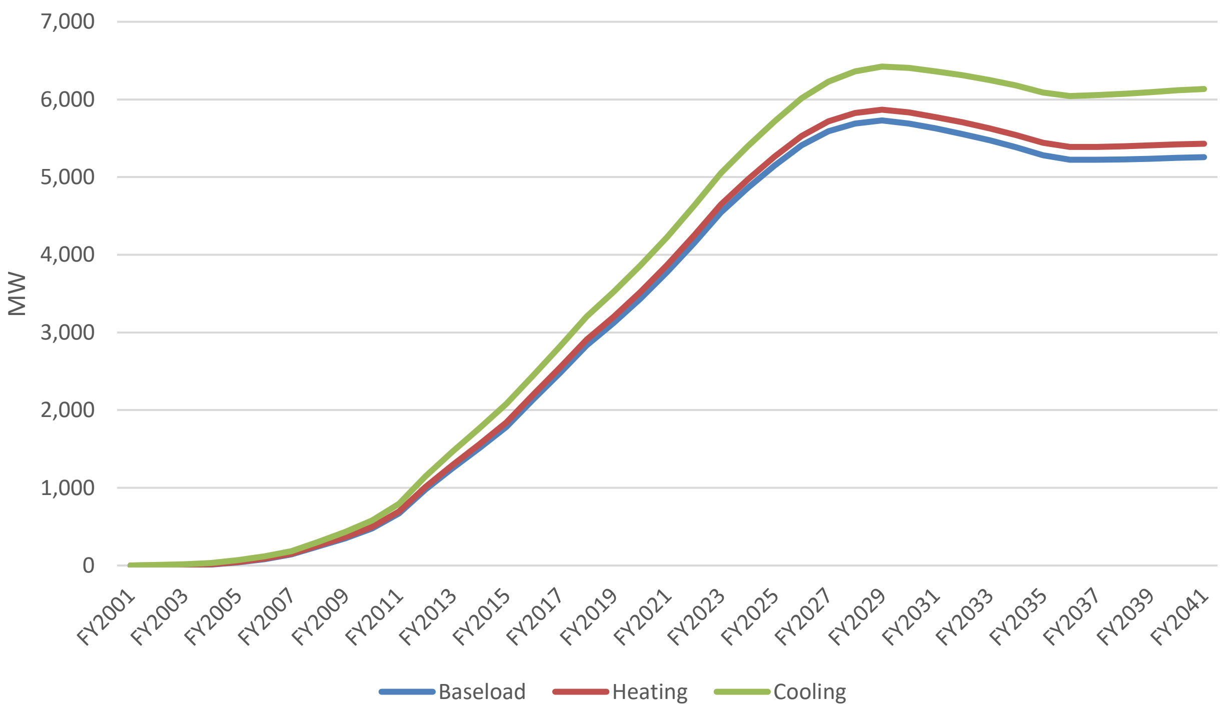
[37] Recalling that the Neutral scenario assumes no future changes to current efficiency policy settings.

policies in reducing peak demand, and therefore *under*-estimate expected peak demand in this sector and scenario. As discussed in Section 1.2.3, we propose that this analysis may be used by AEMO to make post-model adjustments based on the changing slope of the avoided consumption and avoided demand curves.

Slow Scenario

Figure 33 shows the expected avoided peak demand for the commercial sector in the Slow scenario. It indicates that almost 4,000 MW *less* peak demand would be avoided than in the Neutral scenario above. The change in the trend pre- and post-around FY2020 is even more marked than in the Neutral scenario, reflecting the reduction in absolute energy efficiency savings (shown in Figure 28) in these later years. For this scenario, then, the risk of over-estimating future peak demand avoided by energy efficiency policies is particularly acute.

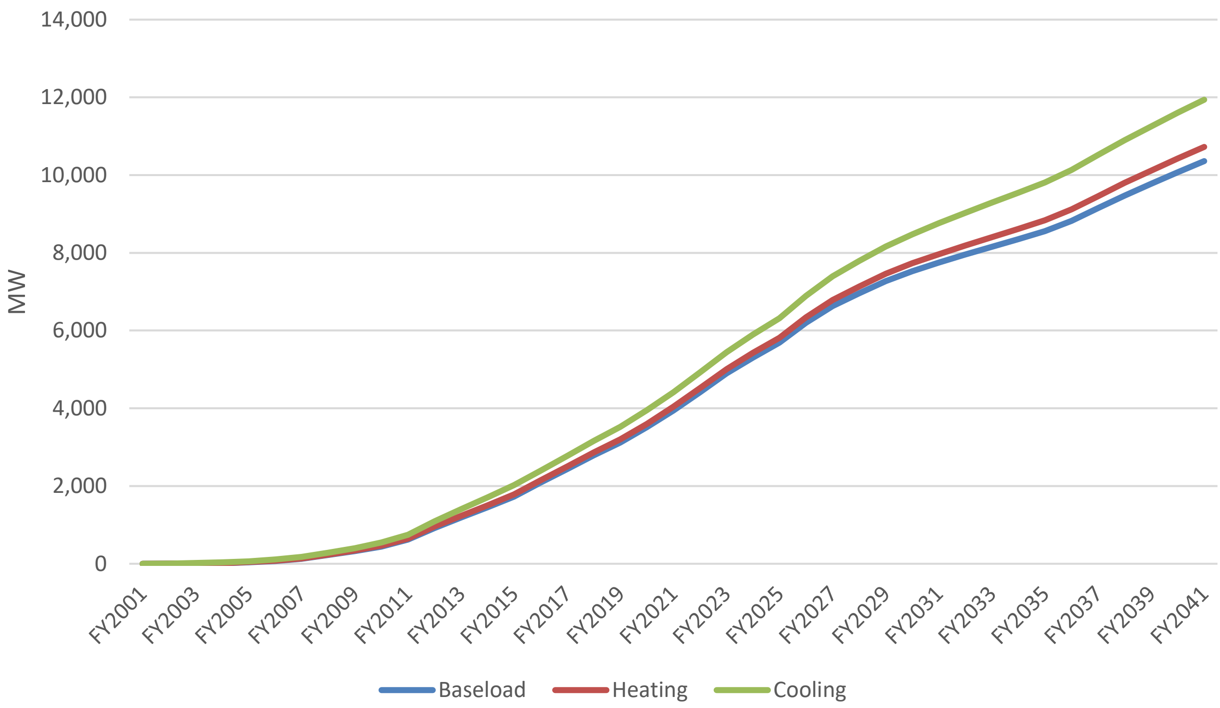
Figure 33: Avoided maximum demand (relative to FY2001) - commercial sector - slow scenario - Australia



Fast Scenario

Figure 34 shows that avoided peak demand would be *significantly* higher if national energy efficiency policies were strengthened as assumed in this scenario. Avoided peak demand would reach around 12,000 MW in this scenario. Also, consistent with the energy consumption savings in this scenario, the annual rate of increase in avoided peak demand in this scenario tends to increase over the period from early 2020s to early 2030s, rather than decrease, as in the Neutral and Slow scenarios. As a result, projections of future avoided peak demand based on linear regressions over the historical period would tend to *under*-estimate future avoided peak demand attributable to efficiency policy, and therefore *over*-estimate future peaks. The fact that this scenario is the reverse of the Neutral and Slow in this regard (where future peaks would risk to be under-estimated) highlights the importance of modelling energy efficiency separately and bottom-up, and not relying exclusively on linear regressions.

Figure 34: Avoided maximum electricity demand (relative to FY2001) - commercial sector - fast scenario - Australia



Avoided peak demands were not calculated for the Neutral Sensitivity scenario but, in line with energy consumption results above, would more closely approximate Figure 34 than Figure 33 or Figure 32.

5.5 Model Agreement in the Historical Period

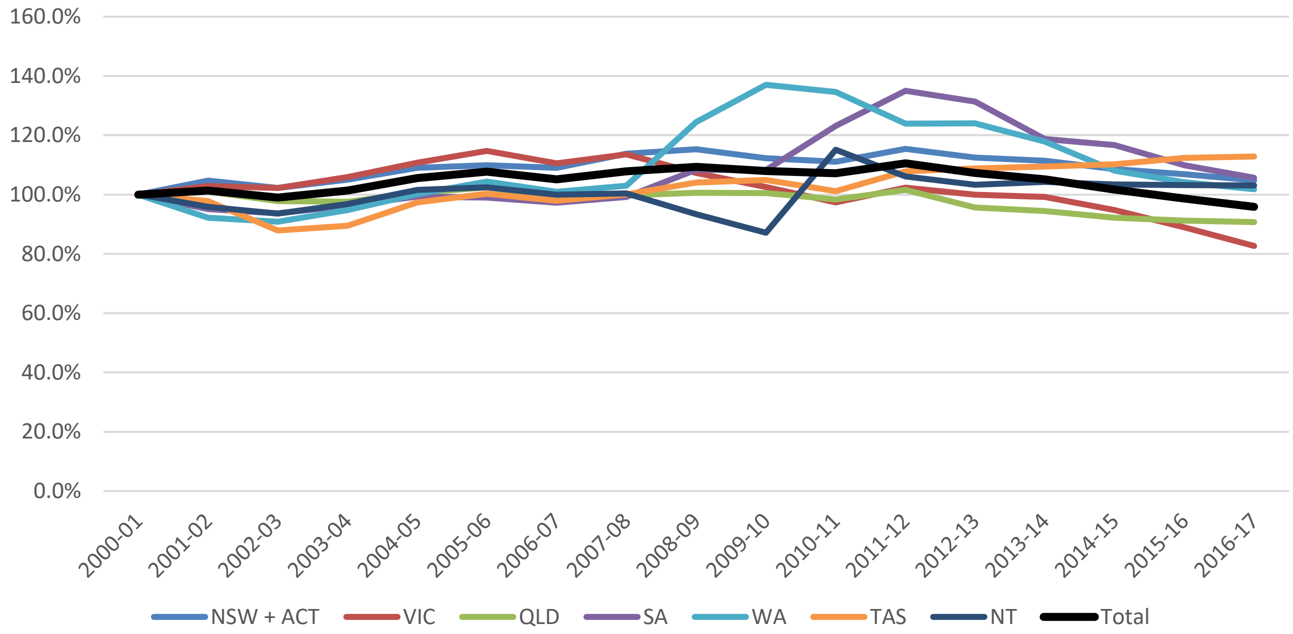
The brief for this study requests that we seek to ascertain the accuracy of past efficiency estimates. As discussed in Chapter 1, this is not feasible in any direct manner, since our estimates are counter-factual, representing avoided consumption and demand. By definition, these are not metered or measured directly. Also, there are known and significant uncertainties in key values drawn upon for this study (summarised in Section 5.7) that relate to the nature of program reporting and statistical collections over which we have no control.

However, *some* indication is provided by the extent to which past estimates of energy efficiency policy impacts agrees with historical consumption data. Of course, the limitation is that very many effects impact on actual consumption that are not measured as part of this study. These include:

- Weather effects
- Climate change/urban heat island effects (but see Chapter 4)
- Price elasticity effects
- Behavioural effects not attributable to policy measures
- Other market impacts such as business closures, building and investment cycles
- The exact nature of fuel switching behaviours

Many of these effects would also vary significantly from jurisdiction to jurisdiction annually, and also, in some cases, between regions within a given jurisdiction.

Figure 35: Model Agreement with Australian Energy Statistics – Historical Period



In total (the thicker black line in Figure 35), the model replicates commercial sector energy consumption[38] in *Australian Energy Statistics* reasonably well, although the model is over-estimating actual consumption (ie, greater than 100% of AES) from around 2008 – 2014. Our expectation that this is unlikely be related to energy efficiency policy impacts, but rather to price elasticity effect (or to what one stakeholder described as "demand destruction" effects) attributable

[38] Note that we sum (where appropriate by jurisdiction) commercial and services LPG, natural gas and town gas into a single 'gas' value; we add natural gas and electricity from transport, postal and warehousing (but not LPG as this may be used for vehicles); we add a small allowance of 0.5% of residential electricity consumption to allow for the consumption of Class 2 common areas; and we have corrected – in consultation with the Office of the Chief Economist – for a discontinuity in AES data between FY2002 and FY2003 which relates to a change in the treatment of embedded generation.

to *combined* impacts of the Global Financial Crisis and the record increases in real electricity and gas prices in Australia that occurred in this same period. An investigation of the quantitative impacts of these effects is, however, outside the scope of this study.

Second, it is apparent that the model is less reliably tracking actual energy consumption at the level of individual states and territories. It is likely that the primary contributor to this is the poor statistical understanding of the rate of actual change in commercial floor area and utilisation at the state level. Our model is sensitive to changes in GSP by jurisdiction, but actual changes in commercial floor area and utilisation, and related energy consumption, will in reality reflect many additional factors, including local business and building cycles, vacancy rates and others that are not modelled here.

5.6 Conclusions

Overall, the commercial sector energy efficiency forecasts:

1. Confirm that the strength of energy efficiency policy measures in Australia makes a material difference to both annual electricity consumption and peak electrical demand.
2. Show that, by contrast, energy efficiency policy impacts in reducing gas consumption are small, and indeed some measures tend to (marginally) increase gas consumption.
3. There is a significant risk that electricity demand and consumption forecasts based on linear regressions of historical values will poorly represent *expected* future values. This is because rates of policy-induced energy efficiency are shown to be quite variable over time, being the net result of changing policy settings, across all jurisdictions, over time.
4. The greater the difference between the historical and expected future trends in energy efficiency improvement, and regardless of the direction of the change (weakening or strengthening), the greater the risk that forecasts of consumption and demand will be under-estimated (weakening policy) or over-estimated (strengthening policy).
5. The bottom-up analysis in this report would enable AEMO to make post-model adjustments for future demand and consumption by applying the *differences* (for each scenario) between future energy savings estimates shown in this report and those implicitly carried by regression-based forecasts, which are based on past trends.

We have noted that there are significant uncertainties associated with key values in the commercial sector analysis – greater than for the residential sector and, mostly likely, for the industrial sector as well. This is because the nature of stock formation and change over time in the commercial sector, as well as the absolute size of the stock, is poorly represented in national statistical collections. Energy consumption is tracked by ANZSIC code in *Australian Energy Statistics*, but this is difficult to correlate with individual building types or classes, and yet most efficiency measures in this sector are specific to individual building types. We note that an updated Commercial Building

Baseline Study is planned for FY2020, and this may assist – but potentially only in a one-off manner – in deepening our collective understanding of the commercial sector.

The ABS does not publish detailed information on the physical nature or productivity of 'building activity' for non-residential buildings, and notably less information than it does for residential buildings. It would be particularly valuable if the ABS published, in its quarterly *Building Activity* series:

- The number of projects per state that are included within the 'value of work done' in each period
- The type of project – including new construction, demolition, major refurbishment or conversion (from which class to which class)
- The net change in floor area attributable to each project (or total additions each quarter, total removals, and total conversions (from which class to which class)).

As noted, many energy efficiency program impact statistics published in Australia require significant interpretation and adjustment in order to avoid double-counting of savings (and, in some cases, risks of under-counting). There would be many opportunities for program managers to change or add to the indicators they publish to limit these risks. To name some examples:

- States and territory governments could take steps, such as compliance audits, to ascertain the extent to which Code energy performance requirements for non-residential buildings are being complied with, and how material, in terms of energy performance, are any non-compliances found.
- NABERS could publish results data by annual building cohort, and statistics on the share of buildings that are rated each year that have been rated n times before. It could also survey users of the scheme to seek to ascertain causality or, at a minimum, request information on the causes of changes in star ratings for particular buildings over time.
- The above comments may also be applied to CBD. In addition, CBD could publish the fuel intensity of buildings in addition to or instead of their overall energy intensity.
- For GEMS, and indeed other programs, there would be considerable value in retrospective assessments that compared expected outcomes, as observed in relevant RISs, with real world outcomes and, to the extent there are differences, quantifying the relevant effects in terms of their material significance.
- State energy savings schemes could publish – using a consistent methodology – estimates of actual changes in energy consumption, by fuel and sector, attributable to their programs, abstracting from the deeming methodologies used for different activities, and taking into account double-counting risks.

In terms of the likely accuracy of the commercial energy efficiency forecasts (and historical estimates) presented here, we note that there is reasonable agreement between our modelled and actual energy demand in the historical period. In fact, our model tends to over-estimate consumption in the 2008 – 2015 period.

Risks of double-counting or over-estimation of savings have been managed for each program, as described in the relevant sections of this chapter. Given the data limitations noted, our view is that the best ‘double-check’ on bottom-up estimates of energy efficiency policy/program impacts would be to complete a careful top-down study of *total* energy efficiency change over time, by jurisdiction, sector and fuel. This would then enable the bottom-up estimates of policy impacts to be reconciled with the total, actual change. At a minimum, this would significantly reduce risks of over-estimating policy impacts. Second, it would allow for a considered and transparent process of allocating effects for particular end-uses, fuels and technologies to market/technology vs policy impacts, without any risk that the total of the two effects would be over-estimated. Third, it would help to address the research void that applies to studies of autonomous or natural energy efficiency change in Australia. We have observed that there are almost no relevant studies in the Australian literature, while the few that do exist are either limited to very specific sectors (eg, heavy industry) and/or use methodologies that do not, in fact, capture or estimate ‘autonomous’ energy efficiency, even if they claim to. Some capture *total* energy efficiency and assume that 100% of this is natural or autonomous. Such a conclusion is at least as erroneous as attributing 100% of energy efficiency change to policy impacts. The reality lies somewhere in between the two extremes. Others use metrics such as energy productivity rather than energy efficiency, but these are poor proxy for energy efficiency, as they are influenced by unit-price effects, exchange rate effects and other factors that are poorly visible in national statistics.

In this context, we note that technology and/or market-driven changes in energy efficiency are highly specific to certain sectors, calling for analysis of this kind to be done at the end-use level within sectors (and by fuel). For example, the efficiency changes driven by LED lighting cannot easily be compared with the electrical efficiency changes resulting from incremental improvements in the efficiency of motor drive systems, chillers, computers or other electricity-using devices. Each is on a unique trajectory that is largely determined by the nature of the global research effort – including as driven by the policies of major countries from which we import technologies (US, Japan, China, Korea, etc). Similarly, the share of total electricity consumption attributable to lighting (to extend the example) will vary considerably from sector to sector, and so the impact of a given technology trend will also vary by sector.

A final observation about the accuracy of the energy efficiency estimates presented in this chapter and report is that, for the purposes of AEMO’s forecasting of future demand and consumption, the absolute value of savings relative to a fixed point in time (FY2001 in this study) is not perhaps the key indicator required – because a) historical consumption data by definition includes the past impact of energy efficiency policies (without any risk of double-counting or omissions!), and b) forecasts based on that historical data already include some information about future energy efficiency policy impacts. The key issue is that regression-based projections risk to fail to capture information that is available that indicates a *change* in expected energy efficiency impacts in future.

It is these changes – generally attributable to the specific provisions of individual energy efficiency policy interventions – that give rise to the risk that forecasts may under- or over-estimate future consumption and demand. These risks can be managed (within the limits of the information available) by adjusting forecasts based the changing efficiency trends, or slope of the curve, over time, by sector and fuel. These trends and resulting forecast adjustments are not likely to be greatly impacted by the precision with which the level of energy efficiency savings induced by specific policy measures is able to be estimated, but moreso by overall trend formed by the sum of all policy interventions (for each fuel, jurisdiction and sector) and how this is changing over time.

6. Industrial Sector – Analysis and Results

6.1 Methodology

The methodology for estimating the policy-induced energy efficiency savings in the industrial sector differs from the residential and commercial sectors in that is not feasible for us to model industrial output and energy consumption bottom-up. This is because:

- The energy use of industrial enterprises is primarily a function of the quantity of production or output (for a given energy-using process) in a year. In Australia, and in many cases, demand for industrial sector outputs is largely from international markets, and changes in demand may depend upon factors such as the exchange rate and changes in relative production costs in different countries
- Output from the industrial sector (eg, tonnes or litres of product), including from specific enterprises, is not published in national statistics, and indeed is generally considered confidential
- Energy use by the industrial sector and specific enterprises is often not published in national statistics except in a highly-aggregated manner, again to manage the risk of identification of individual enterprises' consumption).

Given that energy efficiency is energy use per unit output, and with both unknown for the industrial sector (in a statistical sense), then observing overall change in energy efficiency is not feasible using such a method.

AEMO overcomes these limitations by directly surveying large enterprises about their energy use and future production plans. The former Energy Efficiency Opportunities (EEO) program, discussed further below, was enabled by legislation that required reporting of energy use, inter alia, by enterprises using at least 0.5 PJ of energy annually.

In short, we are able to draw on program-specific data – for the GEMS program, EEO and the NSW ESS – to estimate total energy savings. AEMO will be able to draw on its survey-work inter alia to forecast future energy consumption, taking into account our bottom-up energy efficiency estimates.

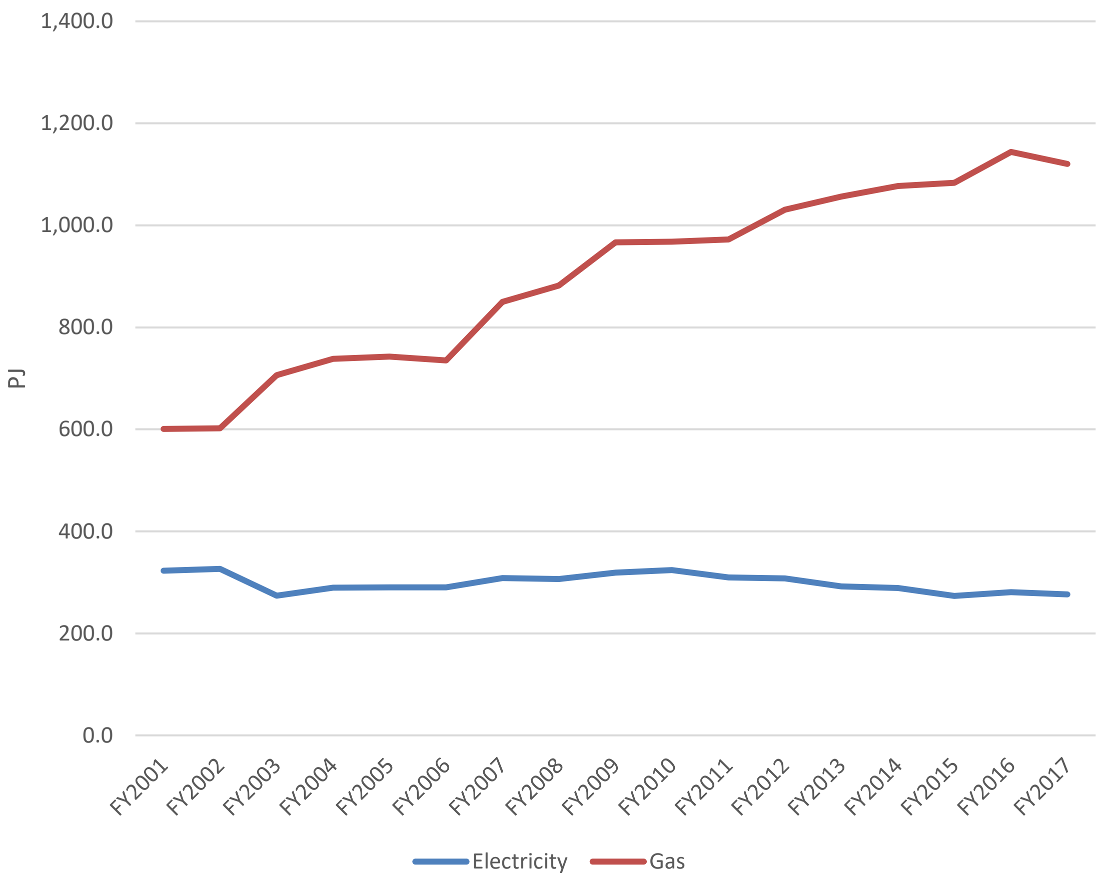
6.2 Energy Use

For the purposes of this study, AEMO defined 'industrial' as referring to:

- Division B Mining, but excluding coal mining and coal seam gas production
- Division C Manufacturing, but excluding aluminium
- Division D Electricity, Gas, Water and Waste, but excluding electricity supply.

Australian Energy Statistics and AEMO data have been drawn upon to estimate electricity and gas consumption by jurisdiction on this basis, and national totals are shown in Figure 36. It may be noted that gas consumption is far more significant than electricity consumption. Use of other fuels in the industrial sector, such as diesel, is not shown.

Figure 36: Historical Electricity and Gas Consumption: Industrial Sector: Australia



Sources: Australian Energy Statistics, AEMO

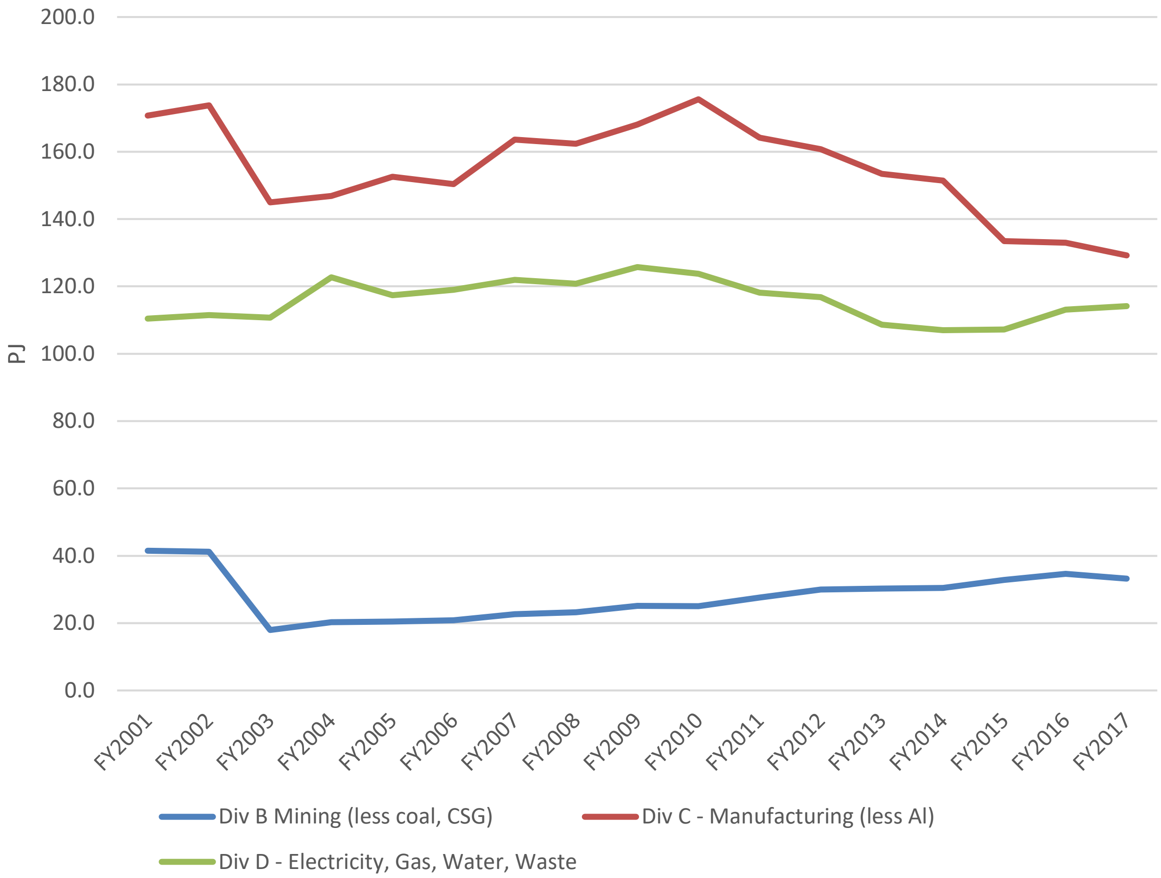
Figure 37 indicates that gas consumption in the rose rapidly in Division D (Electricity, Gas, Water & Waste), but also significantly in Division B (Mining) in more recent years. The likely explanations are power generation, in the first instance, and consumption of gas in LNG production, in the second. Gas consumption in manufacturing rose modestly in the 2000s before falling from FY2013. Gas consumption in the manufacturing sector was lower in FY2017 than in FY2001, with a reduction in manufacturing sector activity and output in Australia the most likely cause.

Figure 37: Industrial Sector Gas Consumption by Division - Australia

Source: Australian Energy Statistics, AEMO. NB: values are not 'stacked' but relate to individual Divisions.

Electricity consumption by Division in the industrial sector is shown in Figure 38. We note that data between FY2002 and FY2003 may be affected by a discontinuity relating to the changed treatment of embedded generation in *Australia Energy Statistics* at this time.

Figure 38: Industrial Sector Electricity Consumption by Division - Australia



Source: Australian Energy Statistics, AEMO. NB: values are not 'stacked' but relate to individual Divisions.

6.3 Energy Efficiency Measures

There are very few energy efficiency policy measures in Australia that target the industrial sector. The most significant intervention, the EEO program, noted above, was discontinued in 2014. We nevertheless model the historical and likely 'legacy' impacts of this scheme based on past program reporting and evaluations. A portion of the GEMS program covers products used in the industrial sector; specifically, electric motors/pumps, distribution transformers, industrial water heaters. An increasing share of the NSW ESS scheme is attributable to the industrial sector, excluding coal and aluminium. This share was 24.3% of electricity savings (but 0% of gas savings) in 2009, rising to 31.9% in 2018. Recalling that GEMS only targets electricity savings, then only the former EEO program targeted gas energy efficiency improvement in the industrial sector.

Note that more detailed figures for savings by sector, measure, fuel and jurisdiction are set out in Appendix D.

6.3.1 Energy Efficiency Opportunities (EEO) Program

EEO was a national program that operated under enabling legislation between 2007 and 2014. It required public reporting of energy use, but also of energy savings opportunities, categorised by payback period. The program mechanism was disclosure, with the rationale being to overcome market barriers relating not only the information failures, but also to barriers related to the decision-making structures within covered enterprises. The public disclosure, along with the program's considerable efforts to engage corporate CEOs and Board members, along with Government Ministers, deliberate sought to create 'high profile' attention to energy efficiency – a topic more normally considered by site engineers, if at all. The program was generally popular – although some did not welcome the reporting burden – and appears to have been highly successful. Because many of the energy efficiency savings implemented and reported by companies under the program were highly cost effective (eg, in the 0 – 2 year payback range), it may be said that the savings, or some portion of them, were 'business as usual'. However, an evaluation of the program in 2013 found compelling evidence that such savings were not, in fact, routinely being captured prior to EEO, and that EEO was responsible for at least doubling the rate of energy efficiency improvement in covered enterprises.[39]

To model program savings, we assume that 50% of the reported savings are attributable to EEO, as above. Specifically, the program reported savings in categories such as 'identified', 'commenced', 'implemented' and 'approved but not yet implemented'. We capture, or estimate as required (since the program reporting currently available does not cover all the years that the program operated), only the 'implemented' savings (discounted by 50%) during the program's life. We estimate these 'additional' savings as 1 PJ in FY2007, rising to around 44 PJ in FY2014.

The 'legacy' or ongoing impacts of the program are difficult to estimate, following the program's closure, as reporting ceased at that date. However, since the program's mechanism was to raise awareness of the extent of highly cost-effective savings opportunities in this energy-intensive sector, it is unlikely that this 'learning' would be rapidly reversed. In principle, industrial companies have a strong incentive to capture cost-effective energy efficiency opportunities – particularly post-EEO. Even at time of plant replacement, it is likely that many of the changes to corporate decision-making and internal reporting systems, advocated and 'trained' by EEO, will remain in place and continue to influence future decisions. At the same time, there is likely to be some loss of corporate memory, corporate process/ownership changes, and new entrants to the sector. Therefore, we apply an annual discount of 2% of the estimated savings post-2014, to represent the impact of these effects.

The breakdown of savings by sector and fuel is based on program reporting – noting that this reporting covers 'the first five years'.[40] Gas was estimated to comprise 48.3% of savings, electricity 17.2%, and savings attributable to other fuels are not counted.[41] The state breakdown of savings

[39] ACIL Tasman, *EEO Program Review*, 2013.
[40] Australian Government, *EEO – The First Five Years – 2006-2011*, 2013.
[41] Ibid, p. 18.

was not reported by the program and has been estimated using the same methodology as for the GEMS program industrial savings; that is, in proportion to the states' total industrial energy use. Given that EEO is closed, we do not differentiate future or legacy impacts by AEMO scenario.

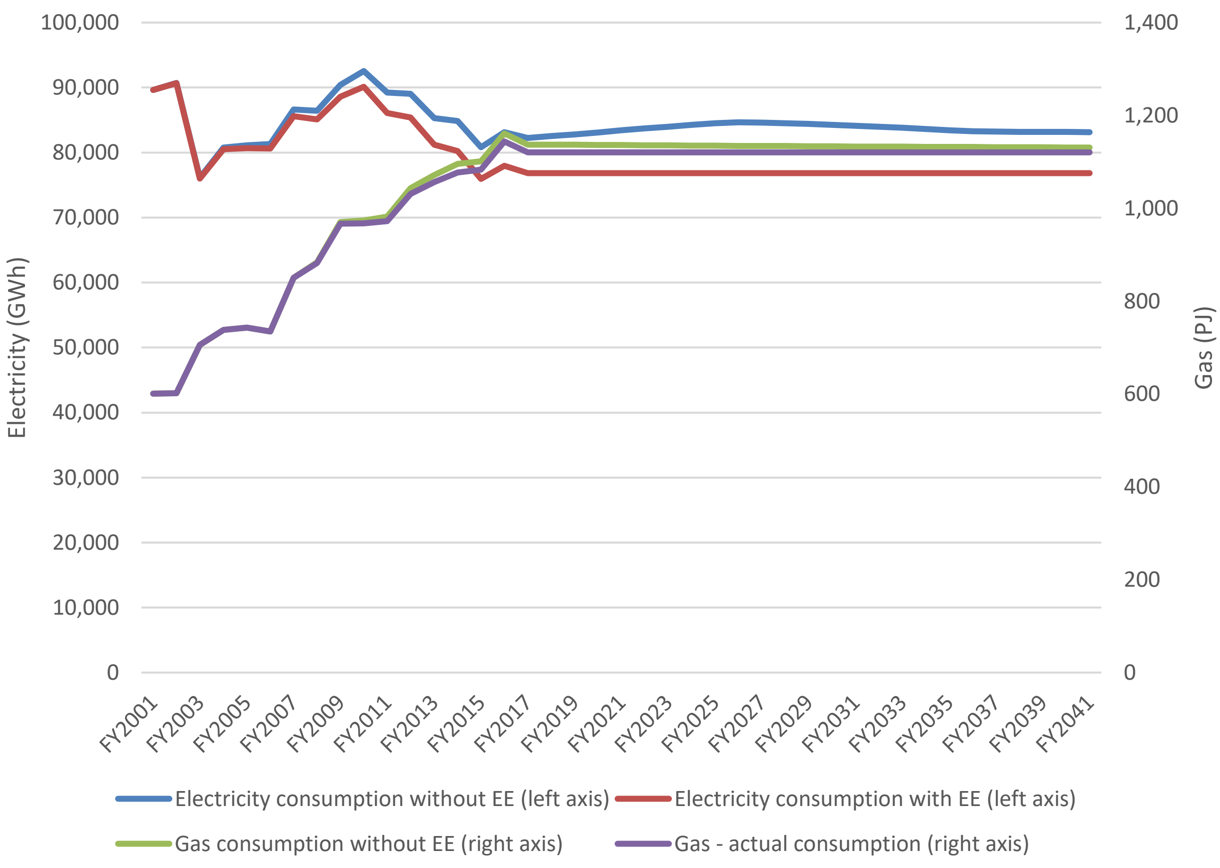
6.3.2 Other Measures

GEMS and ESS are described in detail in Chapter 3.

6.3.3 Historical Impact of Measures

Figure 39 shows the estimated historical impact of energy efficiency measures on industrial sector electricity and gas consumption in Australia. As noted above, the savings are weighted towards electricity, despite gas being the more prominent fuel in this sector. Overall, the efficiency savings are modest relative to the total level of energy consumption: around 9,300 GWh of electricity and 17 PJ of gas by FY2018, relative to the FY2001 base year.

Figure 39: Industrial Energy Efficiency Program Impacts by Fuel, Australia



6.4 Efficiency Forecasts by Scenario

6.4.1 Primary Scenarios

Electricity Savings

Figure 40 indicates that there is modest differentiation in policy-induced energy efficiency savings between the Neutral, Slow and Fast scenarios, primarily because EEO, the largest source of savings, is not differentiated by scenario. As with other sectors, the Fast scenario in the industrial sector includes new policy measures that would be likely to be implemented if a national target of 45% greenhouse gas abatement were set for 2030. We assume that 'possible' and 'suspended' GEMS savings would be implemented, but do not model other potential policy models, as none are known to be under active consideration at the national level.

Figure 40: Industrial Sector - Avoided Electricity Consumption by Scenario - Australia

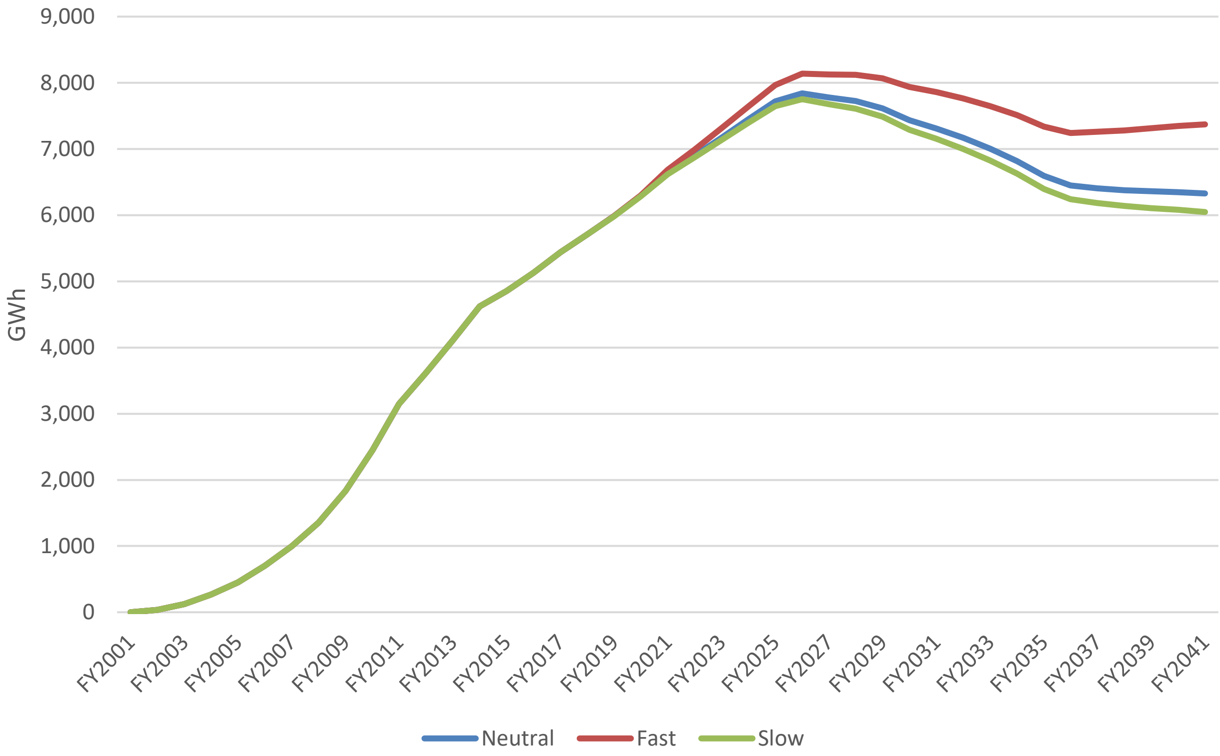
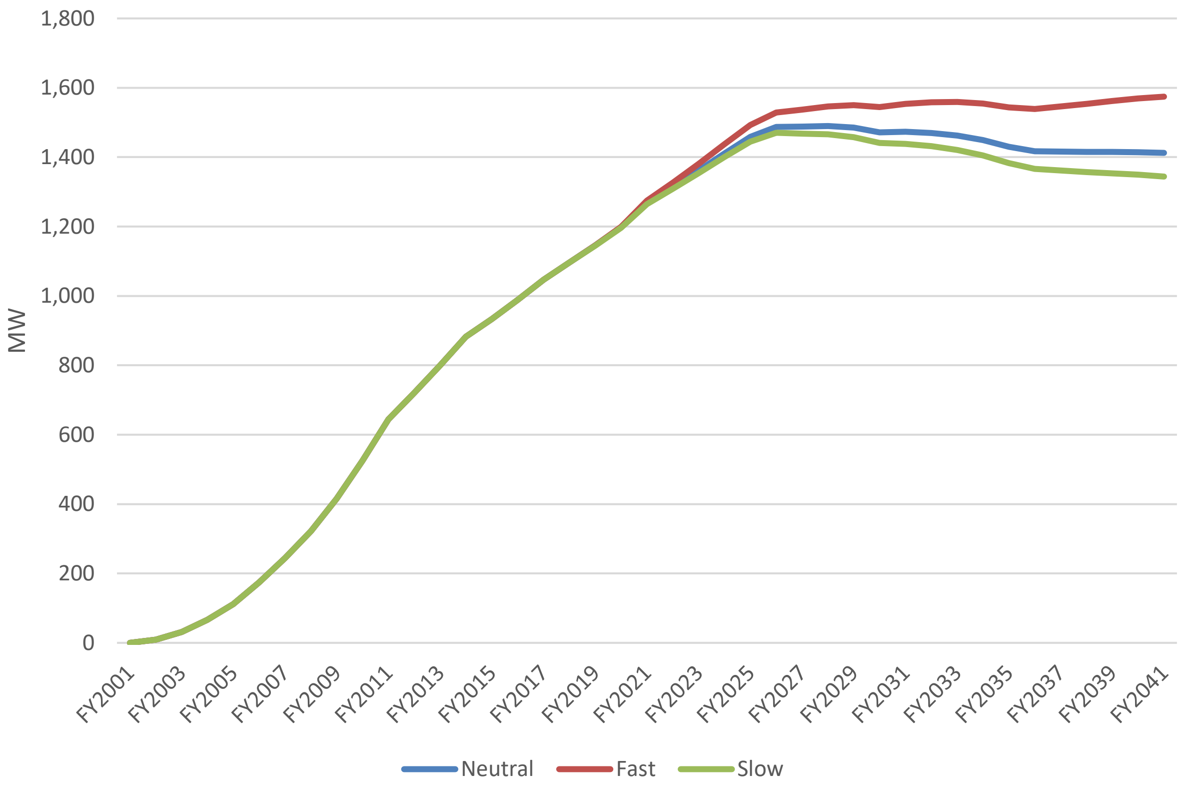


Figure 40 shows changes in trend energy efficiency gains that are readily associated with policy/program changes. GEMS savings accumulate in a reasonably progressive manner over the whole period, while EEO savings cause the acceleration that can be noted to FY2014. ESS savings begin to fall after FY2025 due to the progressive expiry of the economic lives of investments made in the industrial sector over the program's life, recalling that the program is currently legislated to cease in that year. The differentiation between scenarios over the period to FY2041 is driven primarily by the scope for additional GEMS savings, assuming strengthened policy settings, with some contribution from GEMS, which is responsive to changes in total electricity consumption through to 2025, which in turn is responsive to GSP assumptions to that point.

Avoided Peak Demand

Figure 41 shows the avoided maximum electrical demand attributable to the energy efficiency policy measures. As this is derived using the conservation load factor method, the overall shape of these curves matches those for changes in underlying electricity consumption. Differentiation between scenarios is again modest, for the reasons discussed above. CLFs for GEMS products in the sector range between 0.7 for electric motors and pumps to 2.0 for water heating. Other electrical savings – EEO and ESS – are assumed to have a CLF of 1.0; that is, to follow the overall load shape for the sector.

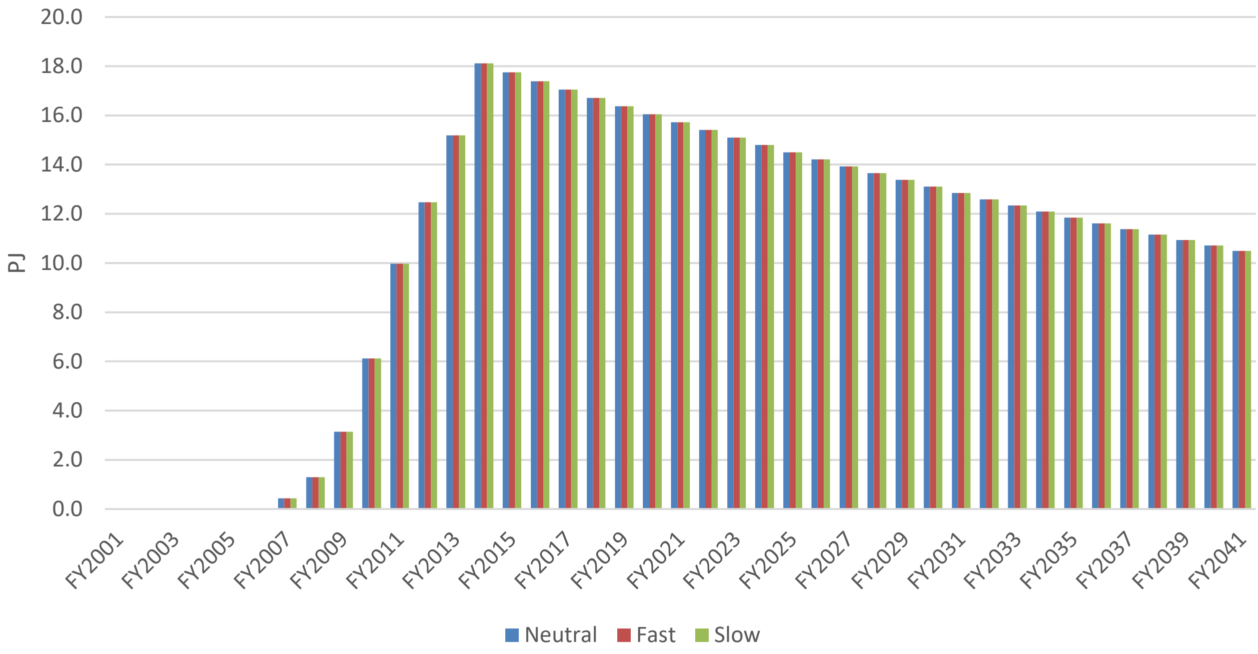
Figure 41: Avoided maximum demand - industrial sector - electricity - by scenario



Gas Savings

Figure 42 shows the estimates of avoided industrial sector gas consumption due to energy efficiency policies in Australia. As may be noted, there is almost no differentiation between scenarios, as GEMS does not cover gas, and EEO is closed and not differentiated by scenario. ESS savings do vary marginally due to the Fast scenario's higher consumption and therefore targeted savings over the period to FY2025. Overall, savings begin to fall after FY2014 due to the closure of EEO.

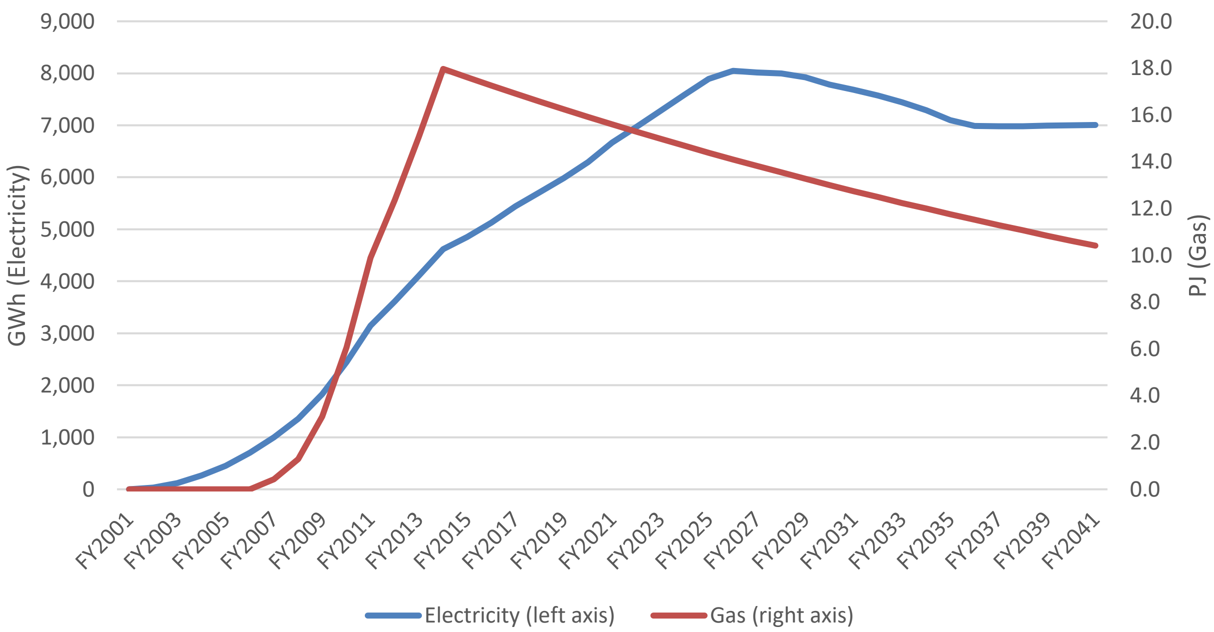
Figure 42: Industrial Sector - Avoided Gas Consumption by Scenario - Australia



6.4.2 Neutral Sensitivity Scenario

Figure 43 shows the expected policy-induced electricity and gas energy efficiency savings, aggregated to the national level, under the Neutral Sensitivity scenario. As with the Fast scenario above, this scenario assumes more ambitious GEMS settings, but Neutral scenario growth drivers (GSP and population). As a result, saving are somewhat lower than for the Fast scenario.

Figure 43: Industrial Sector Electricity and Gas Savings – Neutral Sensitivity Scenario - Australia



6.5 Application of the Findings

As with the commercial sector, the application of these findings to AEMO's forecasting for the sector should be to correct existing assumptions about the future impact of efficiency policies, that were based on historical values, by applying the modelled *differences* between the historical trend and future expectations, which take into account known policy settings and impacts, to make post-model adjustments to expected consumption and demand (see below). In particular, given that (policy-induced) energy efficiency impacts are expected to fall away over time, there is a risk that forecasts would *under*-estimate future consumption and demand.

6.6 Conclusions

Overall, energy efficiency policy impacts in the industrial sector are modest. This more reflects a lack of policy than a lack of cost-effective opportunities in the sector. Since industrial enterprises tend to be larger than those in other sectors, and also larger energy users, there is a temptation to assume that rational company owners will capture cost effective savings in the normal course of business. The EEO program, however, demonstrated that this is far from the case.

Given the program-specific methodologies used, and the fact that detailed data on ESS savings was provided by OEH, the estimates provided above are likely to be reasonably accurate. However, as with other sectors, it is not possible to directly observe 'avoided' consumption and, also as with other sectors, the historical savings shown are already present in historical actual consumption and demand data. Therefore, these past savings will be projected forward in forecasts based on regressions of past values. In this case, such regressions are likely to fail to 'see' the expected reduction in energy efficiency savings in future, and therefore to under-estimate future consumption and demand, albeit modestly relative to the scale of the sector's overall energy use.

In terms of potential data improvement opportunities, there are few, given the paucity of policy interventions. However, if a program similar to EEO were recommenced in future, or potentially under existing reporting schemes such as NGERS (the National Greenhouse and Energy Reporting Scheme), it would be possible to (again) capture data on energy use, including by end-use and fuel, directly from enterprises. In addition, and unlike in the past, it would be possible to capture data on output, in order to enable quantitative analysis of energy efficiency and productivity trends. Such data would be considered confidential but could be analysed and then published in more aggregated forms to protect confidentiality.

7. References

Australian Bureau of Statistics 2014, Environmental Issues: Energy Use and Conservation, Canberra, Australia.

E3 (2018) Policy framework for hot water systems in Australia and New Zealand, 2018

E3 (2018a) Decision regulation impact statement: Air conditioners, December 2018 retrieved from

http://www.energyrating.gov.au/document/decision-ris-air-conditioners

E3 (2018b) Decision regulation impact statement: Swimming pool pumps, September 2018

Energy Efficient Strategies 2008, Energy Use in the Australian Residential Sector 1986 – 2020, for the Department of the Environment, Water Heritage and the Arts, Canberra, Australia, retrieved from http://www.energyrating.gov.au/document/report-energy-use-australian-residential-sector-1986-2020

Energy Efficient Strategies 2016, Whitegoods Efficiency Trends in Australia 1993-2014, Department of Innovation, Industry and Science, Canberra, Australia, retrieved from http://www.energyrating.gov.au/document/whitegoods-efficiency-trends-1993-2014

Cushman-Roisin, Benoit, ENGS 44 Sustainable Design: In search of indoor comfort, syllabus for Dartmouth College, UK, 4 April 2019, see

http://www.dartmouth.edu/~cushman/courses/engs44/comfort.pdf

Energy Efficient Strategies et al (2018) Impact of energy efficiency programs on electricity consumption in NSW and the ACT, Energy Efficient Strategies for Transgrid, June 2018

GEMS (2018) Market Surveillance Results: July 2017 To June 2018, GEMS Regulator

GEMS (2018a), Commercial refrigeration – refrigerated display and storage cabinets, Greenhouse and Energy Minimum Standards Regulator, August 2018

GEMS (2018b) Greenhouse and Energy Minimum Standards (Household Refrigerating Appliances) Determination Exposure Draft September 2018

GEMS (2018c) Greenhouse and Energy Minimum Standards (Refrigerated Cabinets) Determination Exposure Draft November 2018

GEMS (2018d) Greenhouse and Energy Minimum Standards (Three Phase Cage Induction Motors) Determination Exposure Draft November 2018

GEMS (2019) Greenhouse and Energy Minimum Standards (Air Conditioners up to 65kW) Determination 2019

Appendix A: Saturation Effects in Heatwave Conditions: Detailed Methodology

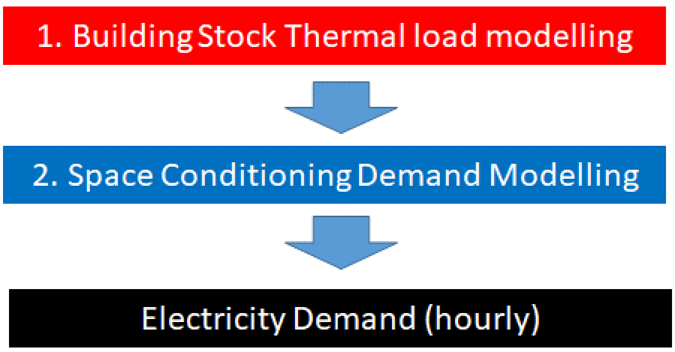
Overview

Modelling of maximum demand attributable to the space cooling load attributable to the residential sector encompassed both Class 1 (detached and semi-detached housing) and Class 2 (flats and apartments) dwelling types, as defined in the NCC.

Modelling was undertaken for three jurisdictions only; New South Wales, Victoria and Queensland. Whilst the Residential Space Conditioning Maximum Demand model (RSCMD – model) in this initial build only had cooling load analysis applied, the model is also capable of undertaking heating load analysis with additional data.

The model consists of two main components; an (external) building stock thermal load model that provides simulated hourly heating and cooling load, which is then input into a space conditioning demand model (see Figure 44) to simulate the use of specific space conditioning equipment in order to estimate the associated electricity demand.

Figure 44: ***Key Components of the Residential Space conditioning Maximum Demand Model***



The output from the model is hourly electricity demand (at a state or household level) required to meet the householders' requirement for space cooling (or heating) over a given year of weather data in the nominated jurisdiction.

A schematic of the Building Stock Thermal Load module can be found in Figure 45. At the heart of this module is a NatHERS approved building shell thermal simulation tool. In this case CSIRO's AccuRate ® was used (V 2.3.3.13 SP4). Into this simulation tool three main inputs were needed:

- Full dimensional and construction details of a range of sample housing types selected to be representative of the dwelling types found within the housing stock of each jurisdiction. The representative housing types (class 1 and class 2) included dwellings with a range of building shell efficiencies, from older stock with relatively poor efficiency to newer stock with relatively good efficiency (these types are detailed later in this section).

- Weather data for selected (representative) climates within each state modelled. The weather data is a composite file from various years to provide a representative set of values. The input file includes a wide range of variables including dry bulb temperature, humidity, wind speed, direct and indirect solar radiation etc. These hourly weather inputs are used by AccuRate to calculate heat flows into and out of each dwelling type.
- User behaviour data, which is also used as an input into AccuRate, to calculate heat flows into and out of each dwelling type. User behaviour includes occupancy patterns, thermostat settings and zoning strategies (primarily, is the dwelling centrally-conditioned or is space conditioning limited to main living areas).

The output from this module is in the form of hourly cooling and heating loads by climate zone, dwelling type and occupancy profile. These hourly load values are then weighted in the RSCMD model according to the selections made by the user. Apart from being able to select a particular dwelling type or a particular occupancy profile etc. the user can also choose to select stock weighted values for all key variables. Stock weighted settings are intended to mimic actual demand characteristics of the system wide residential space cooling loads. The Space Conditioning Demand module (see Figure 45) takes the weighted hourly cooling (or heating) load values from the Building Stock Thermal Load module and passes those loads through a stock model of space cooling equipment.

The Space Conditioning Demand module includes a range of commonly utilized space conditioning plant types and for each type it applies three characteristics:

- Ownership i.e. how many units of each type are in the stock of housing
- Plant Capacity i.e. the rated output of each type of unit. Generally for each type of unit the plant capacity is divided into three sub-categories, small, medium and large.
- Plant Efficiency i.e. Cooling capacity divided by input electrical power

The output from this second process is an hourly system electrical demand imposed by the particular modelled/installed space conditioning equipment that is needed to meet the cooling (or heating) load applied by the modelled housing stock, weather conditions and user behaviour.

Figure 45: *Key Components of the Building Stock Thermal Load Module*

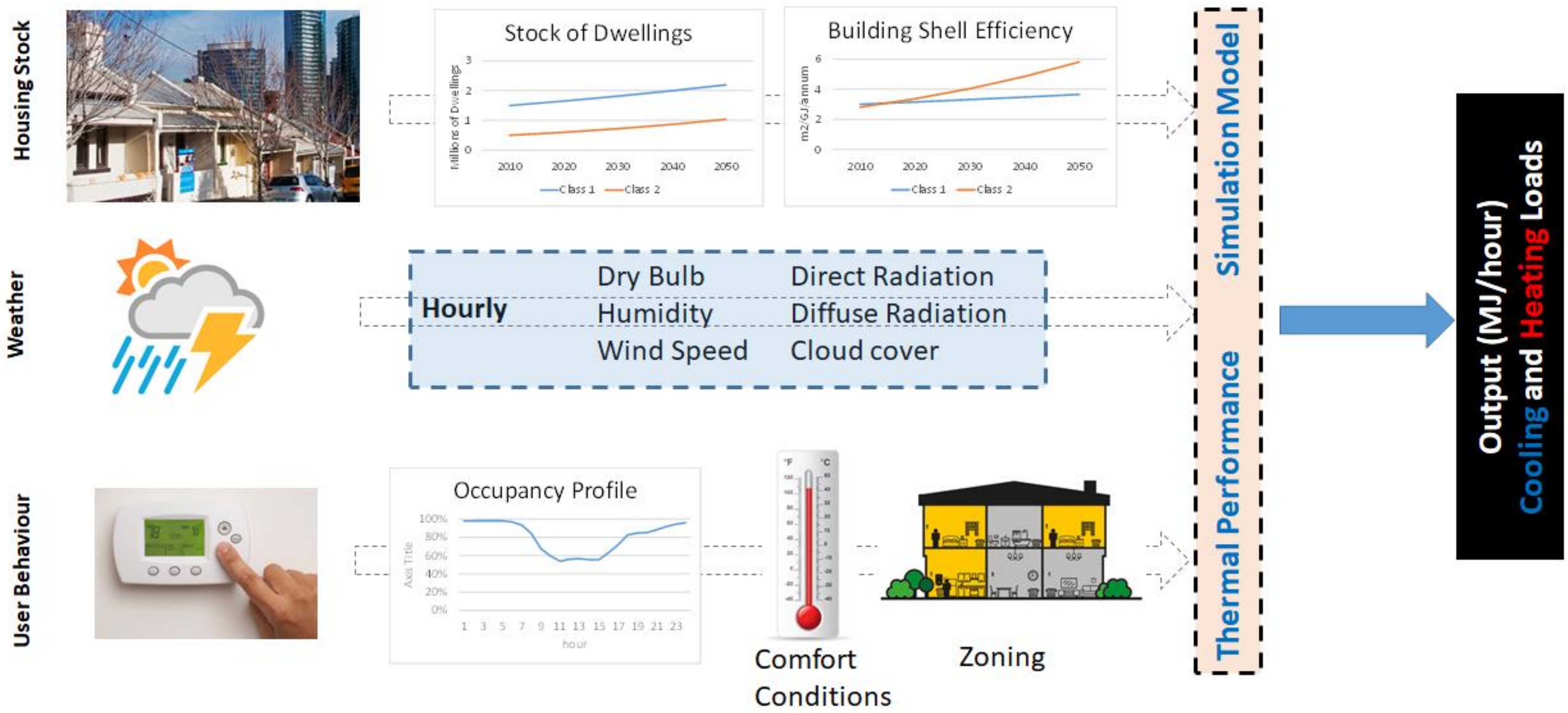
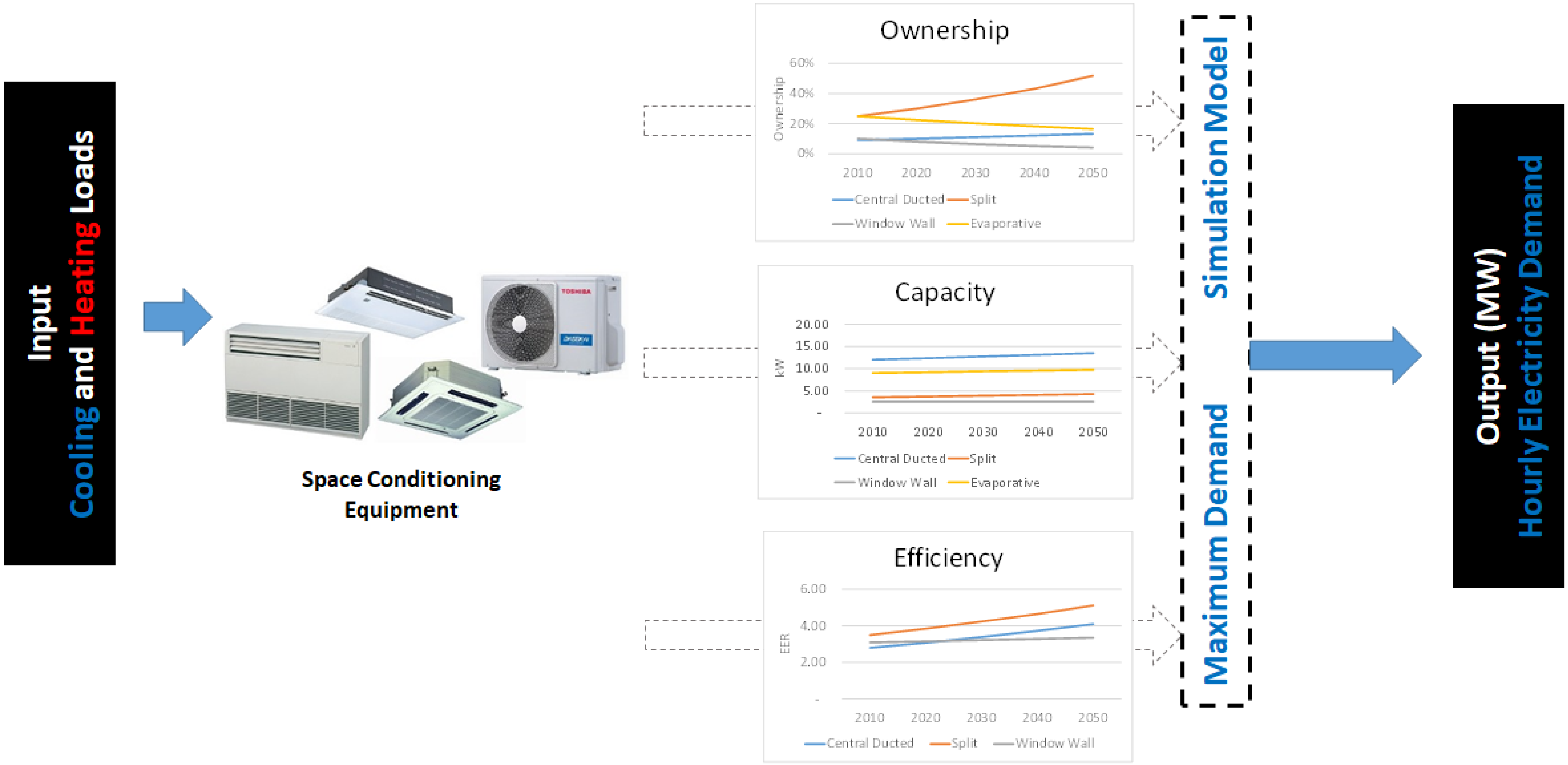


Figure 46: ***Key Components of the Space Conditioning Demand Module***



As noted, the model estimates the imposed cooling load in each hour of the year. If that load is less than the maximum capacity of the installed space conditioning equipment then the load is simply applied. If, however, the load exceeds the capacity of the installed equipment, then the model effectively truncates the load to match the capacity of the installed space conditioning equipment (this is most likely to occur in housing with an inefficient building shell i.e. a 2 star NatHERS rated building rather than a 6 star NatHERS rated building). The model does have a feature that will allow the user to let the model allow a load exceeding the capacity of the installed unit to be met (e.g. by say 10%). This feature is intended to allow analysis of inverter driven heat pumps (most common type) that generally have facility to run at over-capacity for at least short periods of time.

This study did not explore the impact of demand response or thermostat set points on peak demand from residential air conditioning, but this methodology could be used to assess that in more detail using bottom up simulations.

Modelling Methodology – Dwellings Profile

Time and resources available for this project did not allow for the development of an elaborate stock model of representative housing types. Consequently a total of 5 representative dwelling types only were modelled. These included:

- Three Class 1 dwellings (stand-alone houses)
- Two Class 2 dwellings (apartments)

The class 1 dwellings were divided into three groupings as follows:

1. Older housing (pre 1990s) with a typical NatHERS rating in the range of between 1 and 3 stars were represented by a dwelling that rated approximately 2 stars. These dwellings are assumed to have suspended timber floors, no floor or wall insulation and only nominal ceiling insulation (if any)
2. Newer (and upgraded older) housing circa 1990 – 2010 with a typical NatHERS rating in the range of 3 to 5 stars were represented by a dwelling that rated approximately 4 stars. These dwellings are assumed to have concrete floors, wall insulation of approximately R1.5 and ceiling insulation of at least R2.5 (no double glazing)
3. New dwellings built post 2010 that meet the 6 star NatHERS standard. These are similar to type 2, but with higher levels of insulation and some (limited) double glazing. Note: in Queensland, regulatory dispensations for certain features such as “outdoor living areas” and or PV installations mean that on average Queensland dwellings are somewhat less than the 6 star standard, consequently a 5.5 star standard was applied in Queensland.

The class 2 dwellings were divided into two groupings as follows:

1. Older flats, pre 2010 with an average NatHERS rating of between 3 to 5 stars. These dwellings are assumed to have concrete floors, but little or no insulation or any double glazing.

2. New flats built post 2010 that meet the 6 star NatHERS standard, or in the case of Queensland, the NatHERS 5 star standard. These are similar to type 1 but with wall and ceiling insulation (top floor only) and some (limited) double glazing.

While this study did not include a comprehensive housing stock model, the use of these five standardised dwelling types of different efficiencies means that these can be weighted differently over time to better reflect the mix of dwelling types in the stock and thereby provide a proxy stock weighted average efficiency. This approach allows a bottom-up estimate of residential peak cooling loads to be developed over the forecast period.

Modelling Methodology – Thermal simulation Process

MODELLING TOOLS

Thermal simulation modelling of the representative dwelling types was carried out using CSIRO AccuRate software (V 2.3.3.13 SP4). To assist in the process of modelling, a batching tool, also developed by CSIRO called AccuBatch, was also used.

The AccuBatch utility allows a number of rating files to be run sequentially in any climate or set of climates. AccuBatch also allows the user the flexibility to set occupancy profiles and thermostat settings that vary from the default values used in AccuRate in normal rating mode (this is discussed in more detail in the section below on "Occupancy profiles and thermostat setting"). Finally, Accubatch allows the user to apply some rudimentary levels of zoning, either whole of house cooling/heating (as would be applicable to central coolers/heaters) or living zone only cooling/heating (as would be applicable to room or space conditioners).

In terms of its output, AccuBatch also allows the user to output hourly load data for each conditioned zone within the modelled dwelling. A separate compiling tool was developed to sum the loads from each zone into a single household hourly load profile (one for cooling and one for heating) for each dwelling. These hourly cooling/heating loads formed a key input into the RSCMD model.

CLIMATE ZONES AND WEATHER FILES

As a rating tool, AccuRate comes pre-loaded with a complete set of weather files representative of a range of 69 climates across Australia. These files are, however, quite dated and represent weather conditions typical of the early 1990s. These files are currently being updated by the Commonwealth Department of Energy and Environment (DEE). The updated files are claimed to be representative of 2016 weather conditions. DEE was able to furnish us with these 2016 representative mean year (RMY) weather files and, with agreement from AEMO, these files were used in the thermal simulation modelling process. A set of "Future" climate files were also developed for use in this project; these are discussed later in the sub-section entitled "Modelling Methodology – Accounting for Climate change"

As noted, modelling was undertaken for three states, New South Wales, Victoria and Queensland. Each state contains multiple NatHERS climate zones (more than 10 zones in each). Available time and resources would not allow for the modelling of more than one representative climate zone for each state. Consequently a single representative climate zone was selected for modelling in each state (generally based on the zone with the largest number of households). The selected climate zones (with agreement from AEMO) were as follows:

- New South Wales – Climate Zone 56 (Mascot)
- Victoria – Climate Zone 21 (Melbourne)
- Queensland – Climate Zone 10 (Brisbane).

OCCUPANCY PROFILES AND THERMOSTAT SETTINGS

Thermal simulation models, such as AccuRate, rely in part on various inputs relating to user behaviour. The most critical of these behaviour factors in terms of estimates of heating and cooling loads are; the comfort conditions required by the occupants (primarily in the form of assumed thermostat settings) and the actual hours of occupancy of the building.

Occupancy profiles

It is generally assumed that use of space conditioning equipment correlates closely with hours of occupancy, or more precisely that space heating and cooling are generally only invoked when the building is actually occupied by one or more occupants. The actual occupancy profile for a given building is therefore likely to significantly impact on both the hourly loads and the total annual space conditioning energy consumption.

To provide a consistent basis for making comparative ratings of the thermal performance of buildings, simulation models such as AccuRate make assumptions regarding, amongst other things, the occupancy profile for households in Australia. In the case of AccuRate the assumed occupancy is 24 hours a day (although not all zones within the dwelling are assumed to be continuously occupied). For the purposes of making a comparative assessment between different house designs the use of this relatively high occupancy factor is considered valid, even desirable from the point of view of amplifying the differences in performance between different designs.

While the use of a single (high) occupancy factor for the purposes of making comparative assessments of building thermal performance may be valid, for those who wish to simulate actual consumption and time of use profiles for a real population of households, a different approach is necessary. What is required for this later form of assessment is an occupancy profile (or set of profiles) that are representative of the behaviour of the occupants of the actual population of households under investigation.

A set of residential occupancy profiles was developed by EES for the study *Energy Use in the Australian Residential Sector 1986-2020* (EES 2008). These profiles were based upon an analysis of an ABS survey entitled "How Australians use their time" (Time Use Survey) ABS4153. This study was undertaken by the ABS to obtain information about the way people allocate time to different activities. It was conducted in both 1992 and 1997 over 4 periods during each year so as to balance seasonal influences which might affect time use patterns (no subsequent surveys of this type have been undertaken by the ABS). In these studies, each household member was required to record where they were and what they were doing for each hour of the day. Of particular interest, was when they were at home and when they were not at home.

For each hour of the day the number of households (weighted values) where at least one respondent was home was tabulated. The data was then disaggregated by hour of day and day of week.

Results for 1992 and 1997 showed very little difference with no significant trends so these two years were combined to provide a single set of profiles. These profiles are presented in Figure 47.

Occupancy levels noted in this figure represent the percentage of households in the sample that had one or more residents in occupancy during all or part of the noted hour. Also, because the profiles for Monday to Friday were almost identical, these were combined into a single "Weekday" profile thereby leaving just 3 profiles, "Weekday", "Saturday" and "Sunday".

The AccuRate simulation software does not allow the user to set a percentage occupancy rate for each hour of operation. Rather, a dwelling or zone within that dwelling is either set as occupied or unoccupied at any given hour. This means that to be able to mimic the occupancy profiles represented in Figure 47 it is necessary to create a set of profiles that when combined will match (as closely as practical) the observed occupancy profiles.

To this end a detailed analysis of the available data was undertaken to determine an appropriate set of AccuRate profiles that when combined in specified proportions would match the observed profiles. The developed profiles are as shown in Table 15.

Figure 47: *Residential Occupancy Profiles – Australia (EES 2008)*

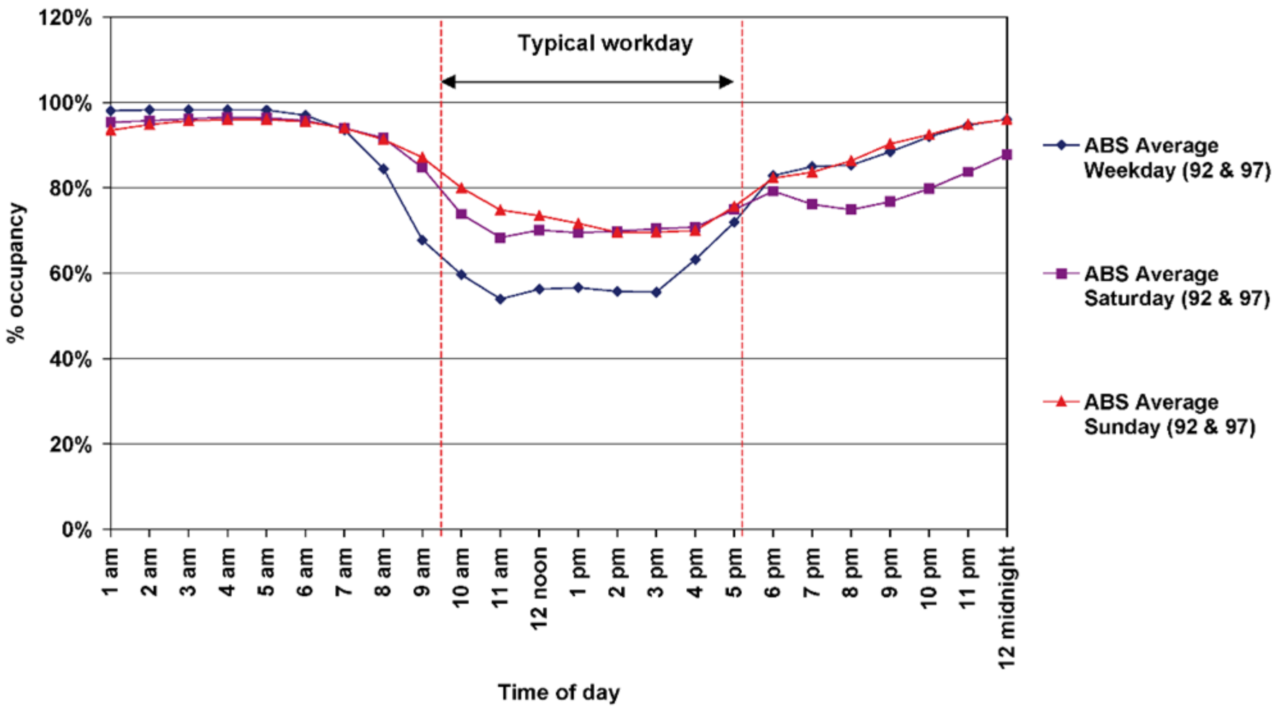


Table 15: Summary of occupancy profiles and their proportions by day of the week

Code	Profile Name	Weekday	Saturday	Sunday
P01	Home all day	55.6%	70.4%	69.6%
P02	Depart 7am Return 4 pm	7.6%	0.4%	0.3%
P03	Depart 8am Return 5 pm	8.7%	4.0%	5.6%
P04	Depart 9am Return 6 pm	11.0%	4.4%	6.6%
P05	Depart 10am Return 7-11 pm	13.2%	8.6%	13.8%

Note: A small proportion of dwellings surveyed were simply unoccupied for the entire 24 hours of a given day. These are factored in as "Unoccupied" and assumed to have no heating or cooling loads. Consequently, the sum of the proportion of each profile in the table below adds up to slightly less than 100%,

The "Home All Day" profile assumes at least one person in the household is in occupancy throughout the 24-hour period. This type of profile is likely to be applicable to; retirees, stay at home parents, the infirm, unemployed, those that operate from home offices etc.

The other four profiles (Codes P02 – P05) are "At Work" type profiles where at least one person in the household is in occupancy throughout the 24-hour period except for the period somewhere between 7 am and 11 pm when the dwelling is unoccupied. This type of profile is likely to be applicable to "dual income no kids", dual or single income with school age children or children in day care, single employed person households, university students etc.

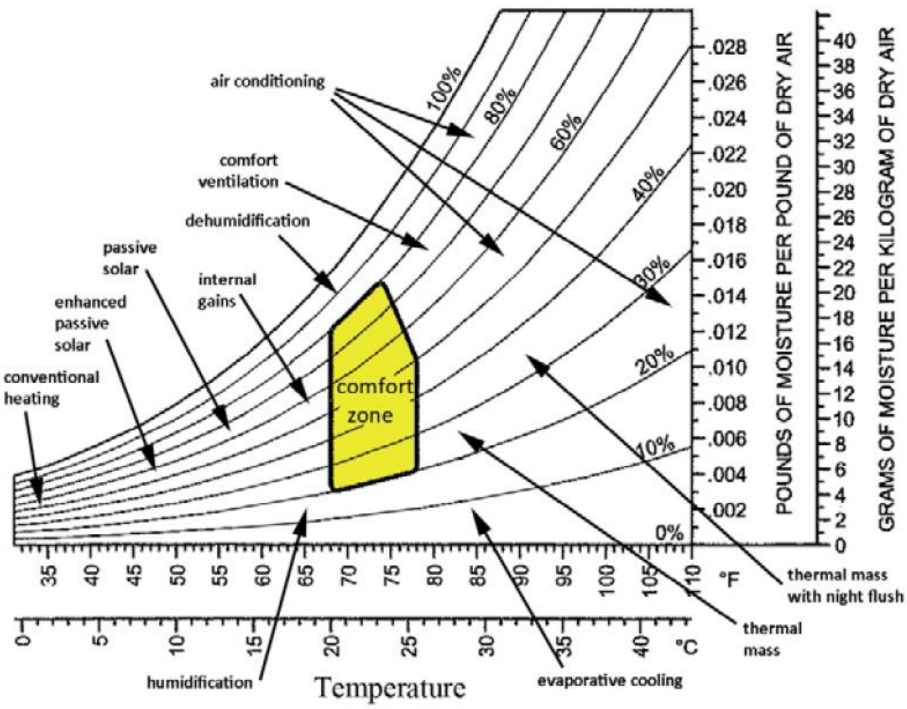
These "at work" profiles are important in the context of this project, as large peaks in cooling demand occur when a householder returns home in the evening of a hot day and turns on their air-conditioner, which then must run at or near full capacity to deal with the heat load that has built up during the daytime.

Thermostat settings

The Accurate simulation software applies heating or cooling to each zone within the dwelling during the specified hours of occupancy for that zone. Space conditioning is not, however, invoked unless required. The invoking of space conditioning depends upon an hourly assessment of the internal environmental conditions compared with an assumed comfort requirement that takes into account the dry bulb temperature and to a lesser degree the humidity and the degree of air movement within the zone. An illustration of the "comfort zone" in terms of temperature and humidity and method to achieve this are illustrated in Figure 48.

The exact process for invoking space conditioning that is described below is an extract from the AccuRate help file and is reproduced in the following Box.

Figure 48: Various methods and technologies to bring indoor air conditions into the "comfort zone"



Source: Sustainable Design: In search of indoor comfort, Benoit Cushman-Roisin, 4 April 2019

Heating

Heating is applied if the zone temperature at the end of the hour without heating is below the heating thermostat setting. Enough heat is supplied so that the zone temperature at the end of the hour is equal to the thermostat setting.

Cooling

1. If at the end of the hour the zone condition (i.e. temperature and moisture content) without cooling or ventilation is within the comfort region on the psychometric chart, cooling is not invoked. The comfort region is a parallelepiped, the boundaries of which are:

- **Top: Absolute moisture content = 12 g/kg**
- **Bottom: Absolute moisture content = 0 g/kg (normally it is 4 g/kg but AccuRate will not invoke cooling merely because the air is too dry)**
- **Right: Environmental Temperature line passing through the point corresponding to (Cooling Thermostat + 2.5) degrees and 50% RH**
- **Left: Not relevant**

2. If at the end of the hour the zone condition without cooling or ventilation is outside the comfort region, ventilation is switched on (i.e. windows and other controlled openings in this zone are opened) provided that the zone temperature is greater than the outdoor air temperature less 4 degrees Celcius. The new zone temperature is calculated and an indoor air speed is estimated. If the indoor air speed is above 0.2 m/s, the comfort region described above is extended in two ways: the top boundary becomes the 90% RH line, and the right boundary becomes an ET* line passing through the point corresponding to (Cooling Thermostat + 2.5 + dT) and 50% RH, where:

$$dT = 6*(v - 0.2) - 1.6*(v - 0.2)^2,$$

where v is the indoor air speed (m/s). An upper limit of 1.5 m/s is imposed on the indoor air speed.

If the zone condition with natural ventilation is within the extended comfort region, cooling is not invoked.

3. If the zone condition with natural ventilation remains outside the extended comfort region, and ceiling fans are available in that zone, the indoor air speed calculated from natural ventilation is replaced by an indoor air speed appropriate to the number of fans and zone floor area (based on the cooling benefit of ceiling fans - see Zone details). If the zone condition with ceiling fans and natural ventilation is within the extended comfort region, cooling is not invoked.

4. If the zone condition with ceiling fans and natural ventilation is still outside the extended comfort region, the zone openings are closed, ceiling fans (if any) are switched off, and sufficient cooling is applied so that the zone temperature at the end of the hour is the cooling thermostat setting.

The cooling thermostat setting adopted in AccuRate (known as the summer neutral temperature Tn) is calculated using the "de Dear's adaptive comfort model", as adopted by ASHRAE see - *Developing an Adaptive Model of Thermal Comfort and Preference – Final Report*, ASHRAE RP- 884, (Richard de Dear et al).

The relevant algorithm used for setting of the AccuRate summer neutral temperatures based on de Dear's work is as follows:

Tn = 17.8 + 0.31*Tout,

where

Tn = The cooling thermostat adopted in AccuRate rounded to the nearest 0.5 degrees

Tout = The mean January temperature for the weather data file used by AccuRate

The de Dear model adopted in AccuRate is designed for "free running" buildings (i.e. those that do not utilise space heating or cooling equipment). The premise underpinning de Dears model is that "building occupants' thermal ideals are influenced by their thermal experiences both indoors and outdoors" (Richard de Dear et al 1997 p. xi). In a free running building this equates to a relatively steep slope in the linear regression comparing neutral indoor temperature with outdoor temperature and this is reflected in the relatively wide range of AccuRate thermostat settings from cool to hot climate zones across Australia (22.5°C to 27.5°C).

By contrast, for constantly conditioned buildings de Dear found that the acceptable range for summer neutral was narrow, 22-23°C irrespective of outside air temperature i.e. occupants of fully conditioned buildings are likely to expect homogeneity in their thermal environment (Richard de Dear et. al. 1997).

Residential buildings with space conditioning (i.e. the focus of this study) are neither constantly conditioned nor permanently free running - so the operation of space cooling becomes more complex. For the purposes of this study it was assumed that, up until the point when cooling is invoked, occupants will tend to act more like the building is in free running mode and the default summer neutral temperatures in AccuRate can reasonably be applied. However, once cooling is invoked, occupants are assumed to act as if the building is one that is constantly-conditioned and the acceptable comfort region will be within a narrow band (about 22°C - 23°C) irrespective of external thermal experiences.

Consequently, for heating operation the NatHERS defaults are generally used (20°C generally and 18°C in bedrooms). For Cooling, 23°C is used. This is slightly lower than generally used in NatHERS, but is based on field studies of user behaviour see *Energy Use in the Australian Residential Sector 1986-2020* (EES 2008).

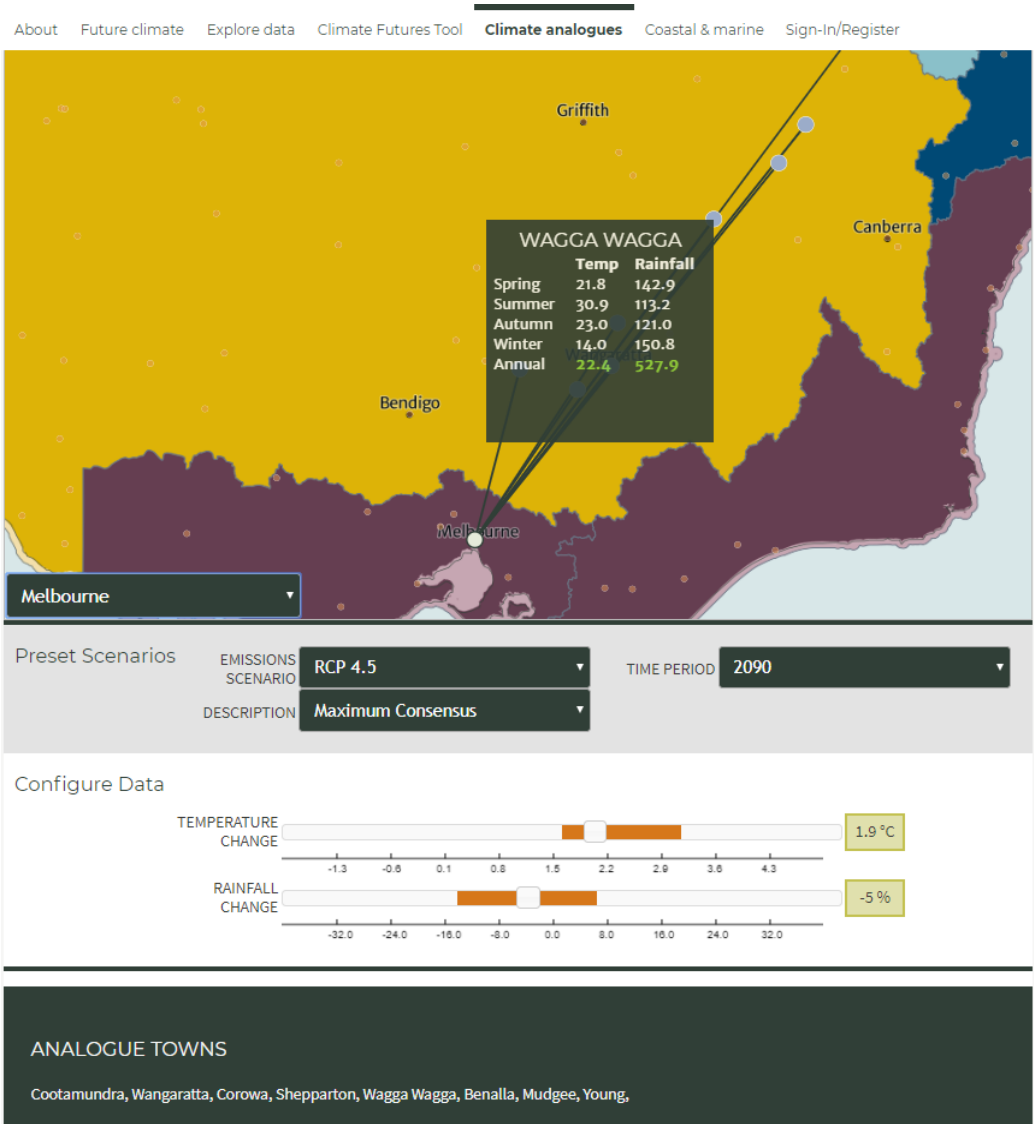
Modelling Methodology – Accounting for Climate change

Due to global warming, climate conditions are now understood to be dynamic over relatively short timeframes (decades). To make accurate estimates of heating and cooling loads into the future, it is therefore necessary to take account of expected changes in climate.

It was beyond the scope of this project to develop actual future weather files for the selected locations in New South Wales, Victoria and Queensland, instead reference was made to CSIRO's future weather analogues as the basis of future climates (CSIRO and Bureau of Meteorology, Climate Change in Australia website (http://www.climatechangeinaustralia.gov.au/). The CSIRO climate analogue tool matches the proposed future climate of a region of interest with the current climate experienced in another region using annual average rainfall and maximum temperature (within set tolerances). The CSIRO climate analogue tool allows the user to select an emissions scenario or "Representative Concentration Pathway" (RCP). The options available as used in the Intergovernmental Panel on Climate Change Fifth Assessment Report (2013) are RCP2.5, RCP4.5 and RCP8.5. At the direction of AEMO an RCP of 4.5 was used.

The depiction below in Figure 49 is an example provided by CSIRO that shows that Melbourne's future climate in 2090 would, on average, be 1.9°C warmer than at present (emissions scenario RCP = 4.5) and is expected to be similar to the present-day climate in Shepparton or Wagga Wagga.

Figure 49: CSIRO Climate Analogue: Melbourne 2090 RCP = 4.5



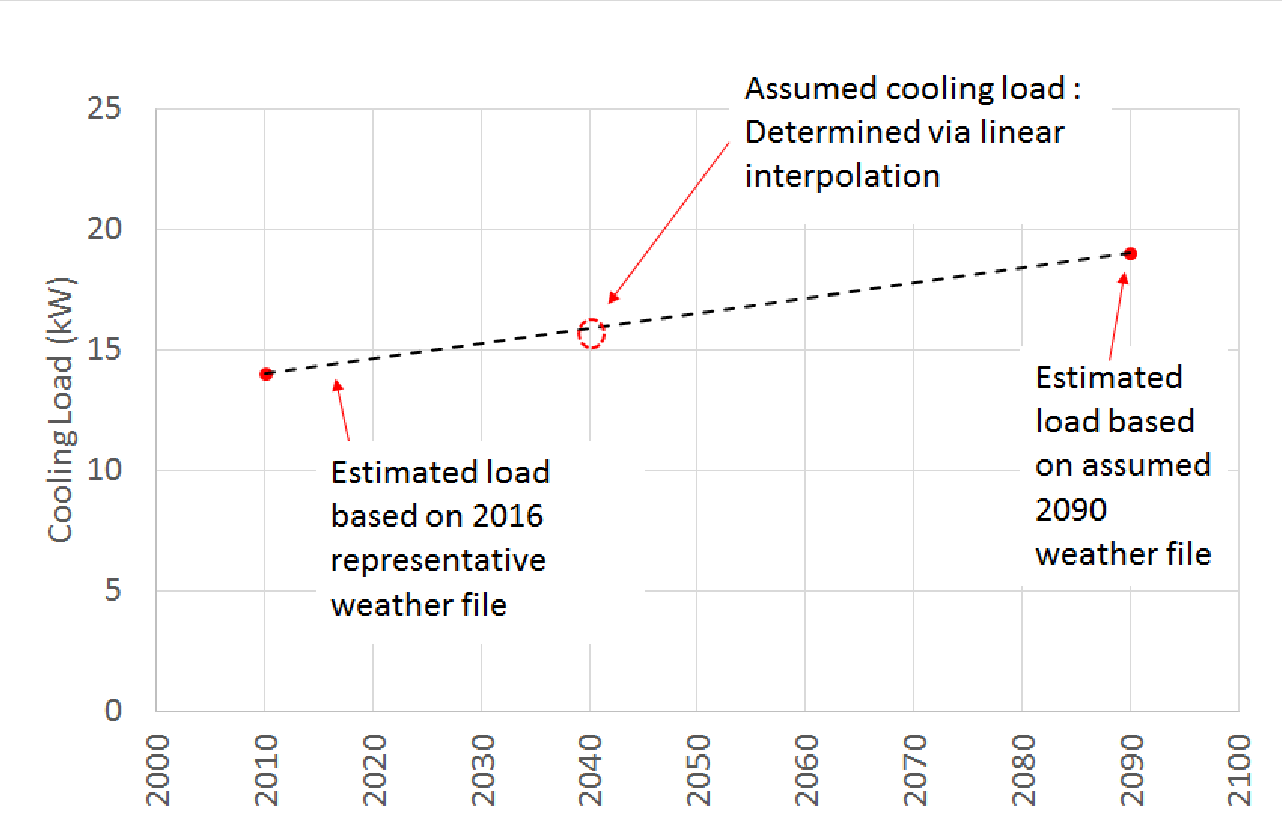
Using an RCP of 4.5 for the climate zones selected for use in this study the following increases in average dry bulb temperature were determined from the CSIRO future climate tool:

- New South Wales – Climate Zone 56 (Mascot) + 2.1°C
- Victoria – Climate Zone 21 (Melbourne) + 1.9°C
- Queensland – Climate Zone 10 (Brisbane) + 2.1°C

As an approximation only, future climate files (2090) were created by simply adding the increase in average dry bulb temperature noted above to the current hourly dry bulb temperatures in the 2016 RMY weather files for the same climates. It is recognised that this is only a rough approximation of future weather, accounting only for changes in dry bulb temperatures (and even then the accounting process is very rudimentary). However, using this approach means that the weather events in both 2016 and 2090 are effectively matched events in terms of hourly sequence throughout the year. This makes it possible to use interpolation between the load results for 2016 and 2090 to determine the likely cooling/heating load in any of the intervening years.

This interpolation process is graphically illustrated in Figure 50 below.

Figure 50: Graphical illustration: Future Climate Interpolation Process



Modelling Methodology – Space Cooling Equipment Profile

An appliance stock model was developed to define the key attributes (ownership and performance) of space cooling equipment expected to be present in the stock of residential housing. This data was then used to convert the weather-related loads from the building shell model to electricity demand. At this stage, the model covered Victoria, New South Wales and Queensland. Some limited data is available for capital city versus rest of state, but this is not consistently available over the years, so state-wide ownership was used for this study. The data documented in this report draws on the best available sales and attribute data for new products (e.g. product registration data for regulated products, publicly available data sets for other new product attributes). The product efficiency attributes for new products are then converted to an expected stock average efficiency over time using a generic stock model conversion process.

For space cooling equipment, equipment was broken into a substantial number of sub-types in order to provide a more granular level of data for modelling purposes. Available information on the penetration of each type of equipment was compiled from several sources, mainly ABS4602, which tracks the stock of equipment from 1994 to 2014. This data was then projected on trend to 2030. Other data sources were also used where available, such as the BIS Shrapnel report on heating and cooling equipment in new homes in 2011. It is important to note that ABS are no longer collecting appliance ownership data for households in Australia, with the last data collection from 2014, so tracking historical data and making sensible projections will become increasingly difficult in the future.

Data on the efficiency of average new equipment by year and type was estimated primarily from registration data for air conditioners (only cooling mode was examined for this report, but many products are also capable of heating). As little sales weighted data has been published (partly because sales data is scrappy and incomplete), a model weighted average by appliance type and size has been used. Given the very large number of air conditioners that are registered each year (of the order of around 700 new registrations per year), this is considered to be quite accurate when used to calculate new attributes of particular types of products (e.g. heating efficiency of single split systems in the range 8kW to 12kW output). More details on the expected penetration and efficiency by product type over the period of interest are shown in the following sections.

Product Types

The following product types were examined for this project, as set out in Table 16.

Table 16: Cooling product types for this study

Product category	Description and notes	Class 1 size share by type	Class 2 size share by type
No Cooling	No cooling system	N/A	N/A
Central Ducted - Small	Ducted 10-18kW	10%	60%
Central Ducted - Medium	Ducted 18-28kW	50%	30%
Central Ducted - Large	Ducted >28kW	40%	10%
Central Non Ducted - Small	Non-ducted Multi-split 5-11kW	10%	60%
Central Non Ducted - Medium	Non-ducted Multi-split 11-18kW	50%	30%
Central Non Ducted - Large	Non-ducted Multi-split >18kW	40%	10%
Evaporative - Small	Fan and pump power only	Portable	Portable
Evaporative - Medium	Fan and pump power only	30%	80%
Evaporative - Large	Fan and pump power only	70%	20%
Split - Small	Non-ducted single split 2-4.5kW	10%	60%
Split - Medium	Non-ducted single split 4.5-8kW	40%	30%
Split - Large	Non-ducted single split >8kW	50%	10%
Window/Wall - Small	Window wall <3kW	30%	50%
Window/Wall - Medium	Window wall 3-5kW	40%	30%
Window/Wall - Large	Window wall >5kW	30%	20%

Table notes: Share of each type (e.g. central ducted) adds to 100% within each building Class.

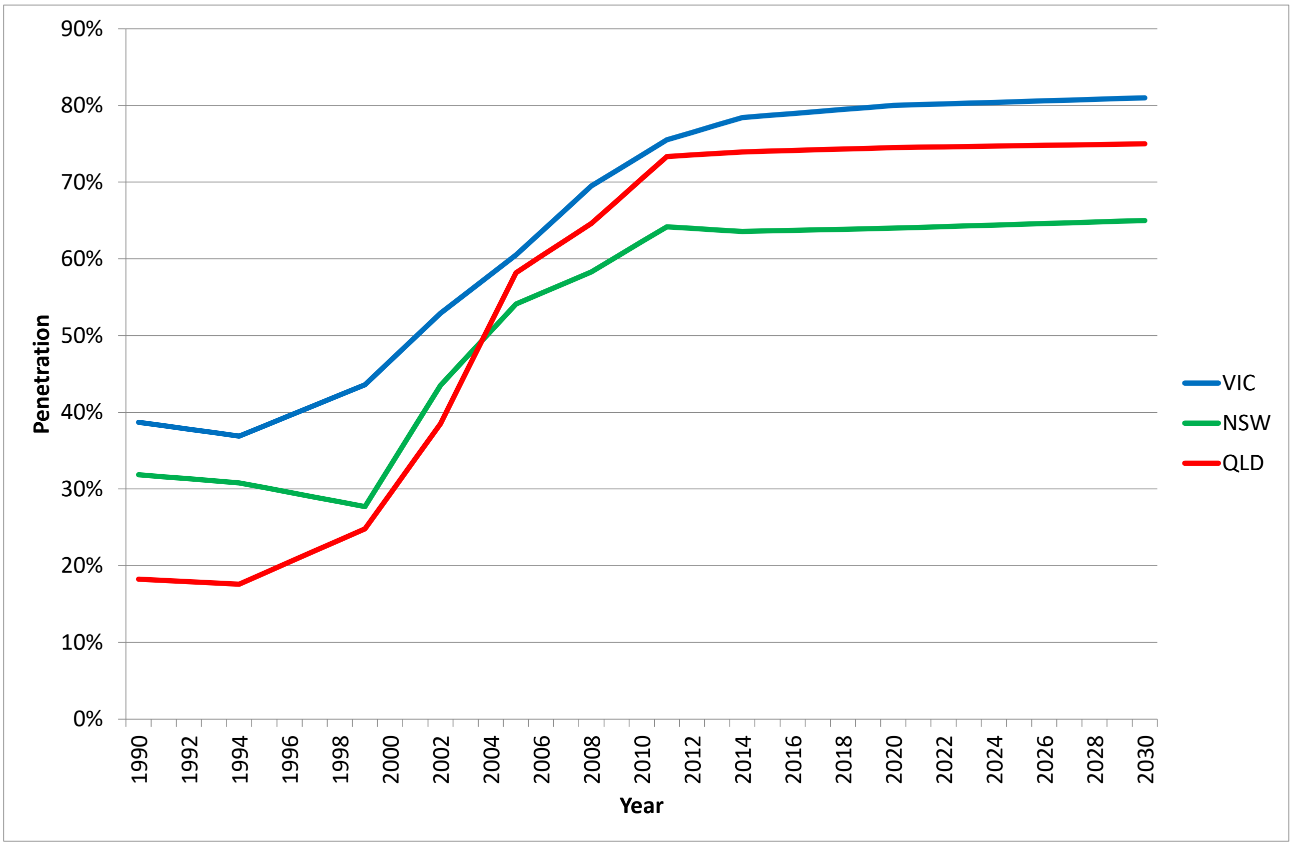
The same product categories were used for both Class 1 dwellings (separate houses) and Class 2 dwellings (flats). As Class 2 dwellings are typically much smaller, the share of small, medium and large systems in Table 2 were altered for Class 1 and Class 2 as shown to reflect the average capacity of equipment installed. For example, in Class 1 dwellings the share of small, medium and large split systems is estimated to be 10%, 40% and 50% respectively, while the share for these systems in Class 2 dwellings is estimated to be 60%, 30% and 10% respectively. This is based on typical distributions of floor area, zoning requirements and historical equipment sizing practices by builders and installers.

Penetration

ABS have published almost no data on the separate penetration of appliances in Class 1 versus Class 2 dwellings. There is also limited data on differences in penetration between capital city and the rest of the state. It would be possible to commission ABS to prepare some private cross-tabs of data for the states and cities of interest, but this is expensive and slow and was not feasible for this project within the given time frame. In any case, the most recent data collection was 2014, so this is now rather out of date and of diminishing value.

However, despite the shortcomings of the available data, the historical data series from 1990 to 2014 does provide some very interesting insights, which allows us to make reasonable projections on the likely overall penetration in each state to 2030. Firstly, the overall penetration of air conditioners is shown in Figure 51. The overall trends are quite similar by state. Queensland started with the lowest penetration in the 1990s but is now comparable to Victoria. Note that ownership does not provide any indication of likely usage levels. All states appeared to have a surge in penetration after 2000. This is mainly due to the increased availability of low-cost products from China, which increased demand dramatically.

Figure 51: Penetration of air conditioners by state



The share of all conditioners in the stock by type from 1990 to 2030 for each state is shown in Figure 52 to Figure 54. Note that the share values always add to 100% in each year. Note that values from 2015 to 2030 are projections based on the actual trend to 2014.

Figure 52: Historical and projected trends in stock share of air conditioners by type for Victoria

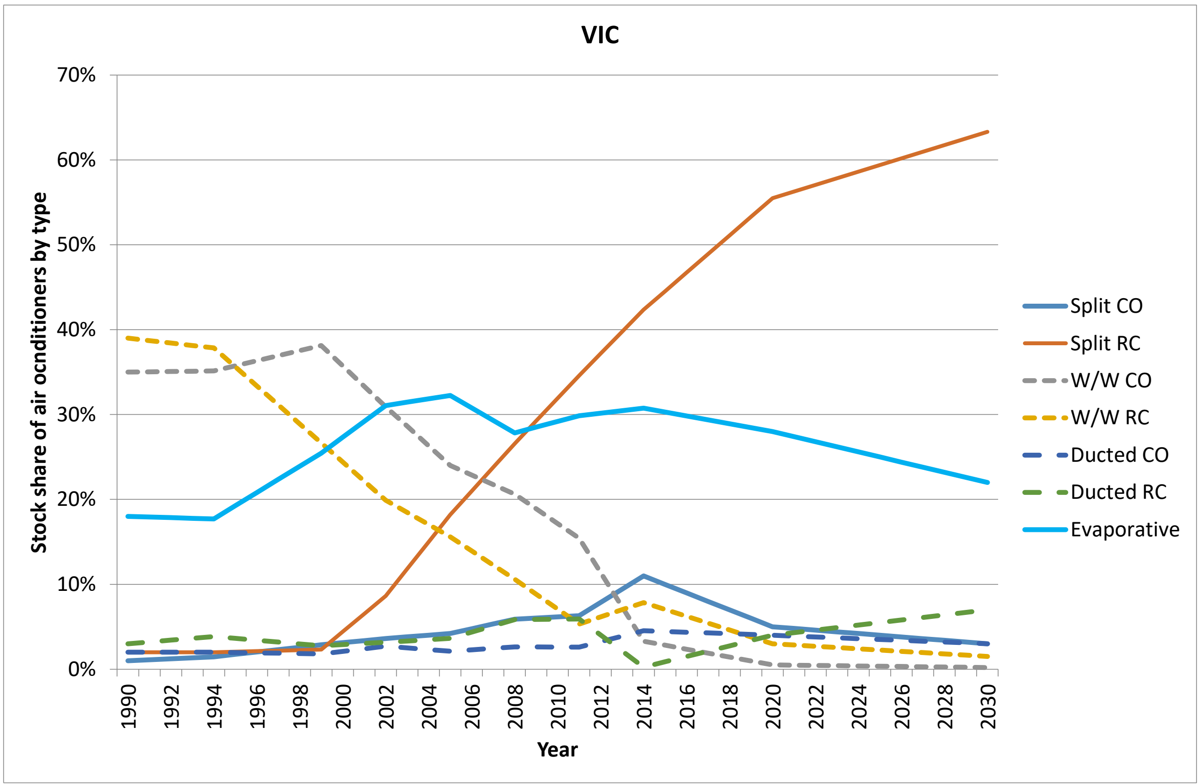


Figure 53: Historical and projected trends in stock share of air conditioners by type for New South Wales

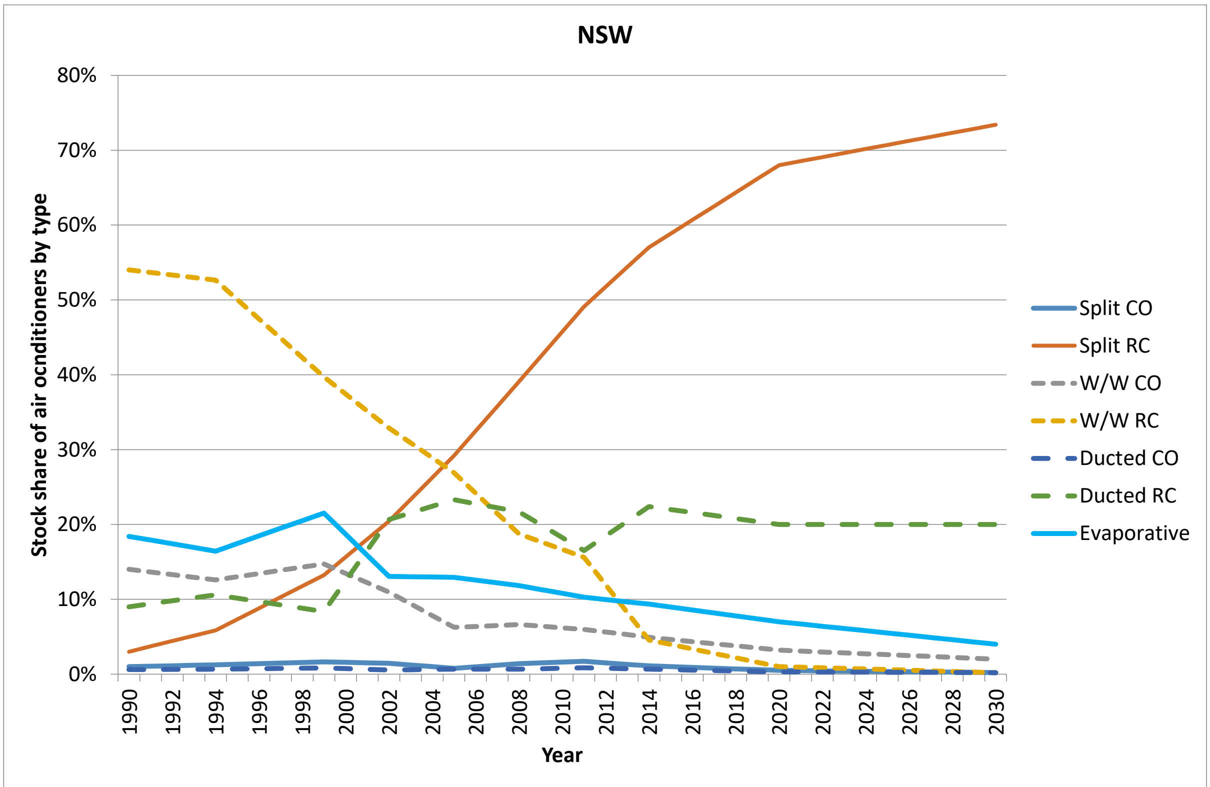
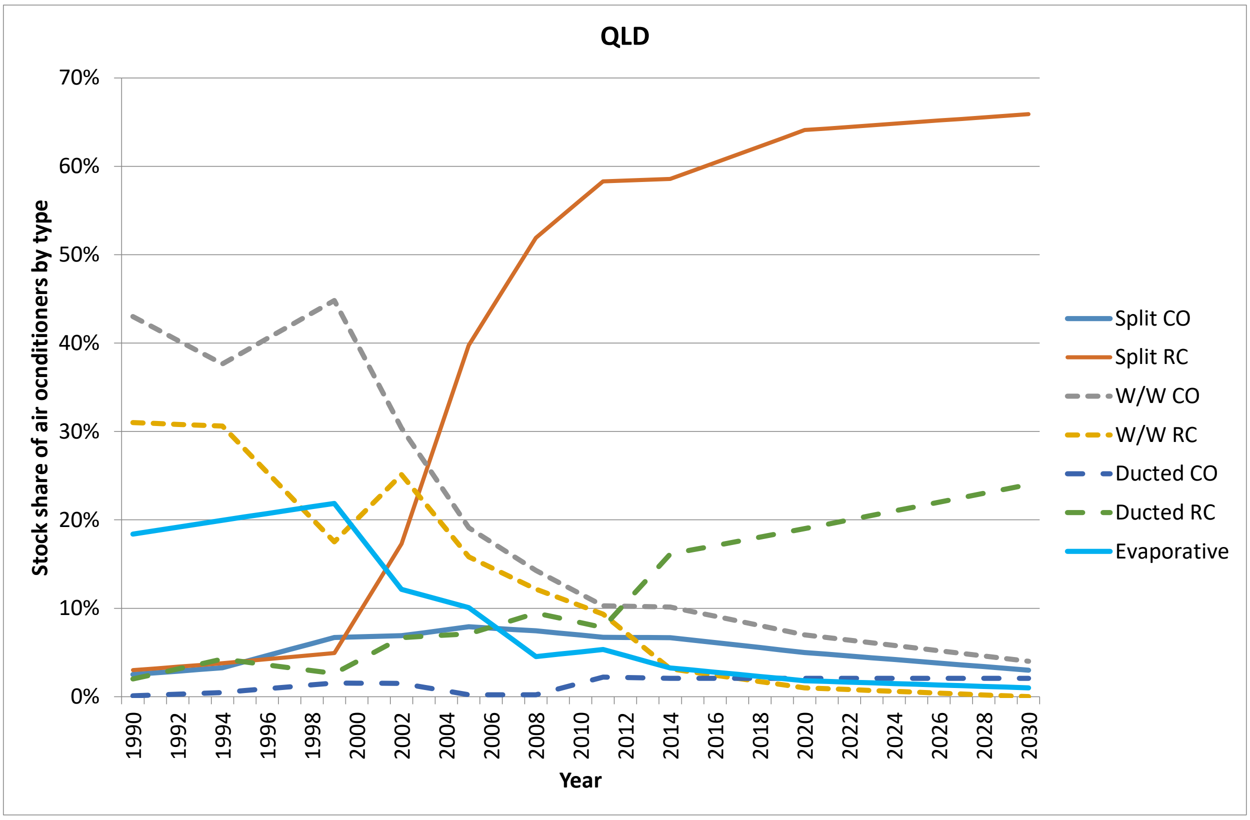


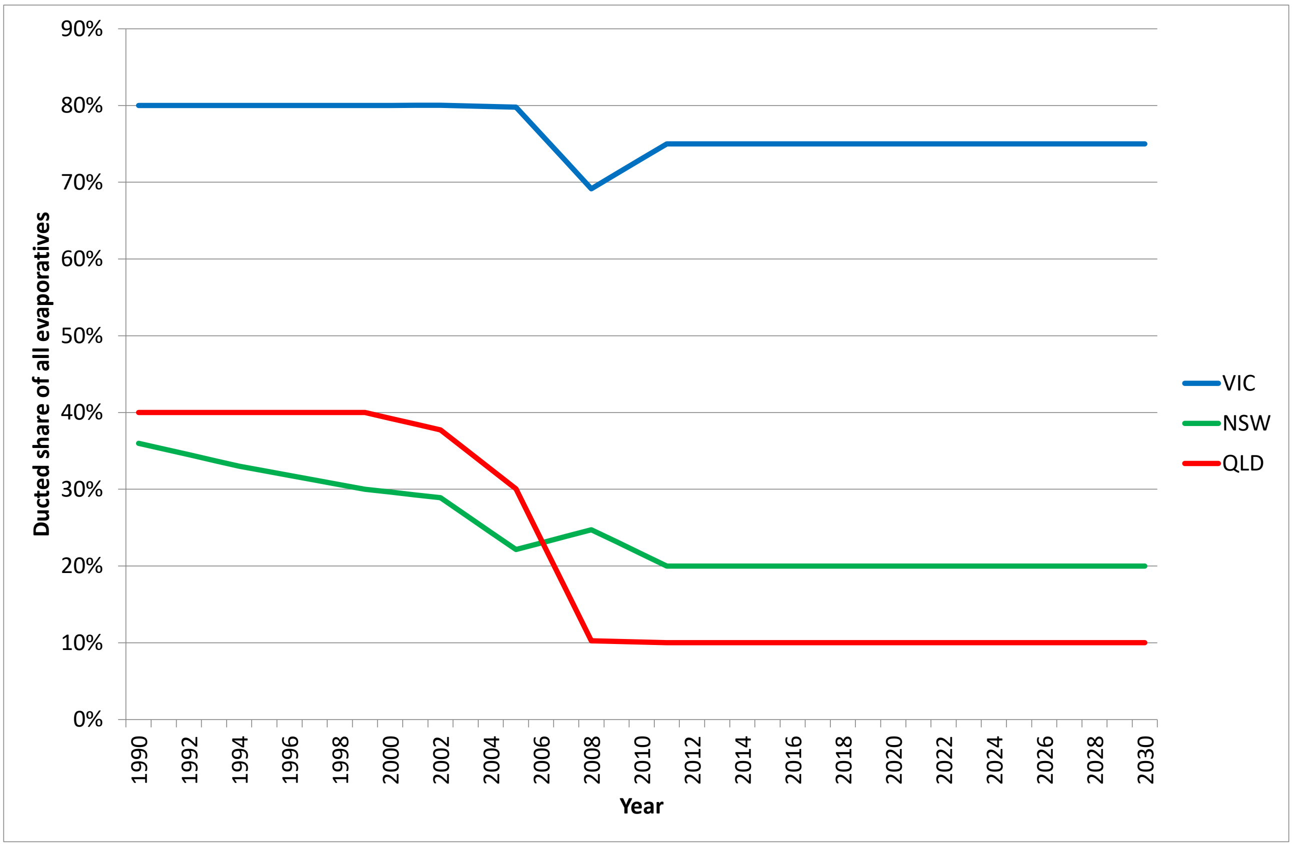
Figure 54: Historical and projected trends in stock share of air conditioners by type for Queensland



While there are some significant differences between states, window wall systems are disappearing quickly (as may be expected) and most are expected to disappear by 2020. The trends appear to indicate window/wall cooling only systems in Queensland (which are sometimes used in mining villages in remote centres) persisting beyond 2020. Overall penetration of split systems is reaching very high levels in all states. Central ducted systems appear to increase in popularity from South to North. Evaporative systems appear to decrease in popularity from South to North. The presence of cooling only versus reverse cycle is partly affected by the availability of natural gas for heating. However, gas penetration for heating, even in Victoria, is declining and it appears that reverse cycle systems are taking their place.

Another piece of information required for projections is the share ducted evaporative systems as a share of all evaporative systems. This data was reported spasmodically in ABS surveys over the years and the available data has been compiled to form a trend estimate to 2030 as shown in Figure 55.

Figure 55: Trends in the share of ducted evaporative systems as a share of all evaporative systems



As the share of reverse cycle air conditioners increases, limited data from industry has indicated that medium to large central non-ducted systems (multi-splits and larger Variable Refrigerant Volume (VRF) systems) are starting to gain some market share. These are likely to be replacing ducted systems, mostly in newer housing developments. The prevalence of these systems was very low prior to 2010 and they were only regulated for efficiency for the first time in 2014. However, by 2020 they are expected to make up around 6% of split system sales and could be as much as 10% by 2030. These systems tend to be a bit larger than single split systems and are more versatile in the operation and coverage in the home, typically having 3 to 5 indoor heads. They can also compete with ducted systems and do not suffer the same energy losses through ducts. Ducted systems often have poor energy performance through low levels of insulation in the duct work and air leakages at joins. They also require maintenance and cleaning. So it is understandable that central non-ducted systems are increasing in popularity.

Using these trends by product type and the share of product type by size and building Class in Table 16, it is possible to generate detailed penetration values over time for all product types defined for this study for each state for the period 1990 to 2030.

In terms of modelling beyond 2030, the penetration in 2030 is assumed to remain constant for years 2031 to 2090.

Strategy. Policy. Research. Making the business case for sustainability

Product efficiency and capacity characteristics

The primary source of data for refrigerative air conditioners (using the vapour compression cycle) was national energy labelling and MEPS register for new products. Energy labelling of room air conditioners commenced in Australia in 1987, so for many products types, there is an extensive time series of capacity and efficiency data available from the registration databases. There is little published sales weighted data on air conditioner efficiency as the market is highly fragmented and there is no central sales data source. GfK, for example, cover less than 40% of split system sales and less than 10% of ducted sales. Some limited sales weighted data was published in the recent air conditioner regulatory impact statement (E3, 2018).

As noted in the introduction, there are around 700 new model air conditioner registrations each year, with data commencing in 1986. This provides an excellent time series to explore the changes in new product characteristics over time. Detailed work undertaken on whitegoods has illustrated that, where there are a large number of models registered each year, then sales weighted and model weighted characteristics are generally very close, especially when examining specific types on products within the appliance (Energy Efficient Strategies 2016). Model weighted data was generally confirmed against the limited published sales weighted data wherever possible. So there is a good degree of confidence in the analysis undertaken for this report.

As set out in Table 16, air conditioners were broken up into a series of sub-categories by type of product and size. This allowed trends in capacity and efficiency of new products registered over the period of interest to be examined to 2019 and then projected to 2030 for each of these sub-categories. The attributes of the selected types and size range over all available years were analysed, based on the year of registration. This results in capacity values that are relatively steady over the period, as expected (e.g. the average output of small non-ducted single split systems is based on all products in the range 2 to 4.5 kW, so the average is typically around 3kW, although this does vary slightly by year). It is important to note that the average efficiency and capacity results by size range are for exactly the same units in each year, so the capacity and efficiency values are linked. The trends for each of the major product types are illustrated in Figure 56 to Figure 63. For air conditioners, the output is the total sensible and latent cooling of the system in kW (sensible only in heating mode), while the input is the electrical consumption in kW to deliver that output under defined operating conditions. The efficiency of an air conditioner is defined as the output over the input and is called the Energy Efficiency Ratio (EER) for cooling and the Coefficient of Performance (COP) for heating. Refer to the standard ISO5151 *Non-ducted airconditioners and heat pumps—Testing and rating for performance* for technical details on how this is determined. Usually the efficiency of an air conditioner is quoted at its rated capacity (nominal maximum persistent output). Under part load conditions (milder weather or different indoor set points), which are common during normal use, the efficiency of a fixed speed compressor system will remain fairly constant. For inverter driven products (which now dominate the market), the efficiency usually increases significantly under part load conditions, although this is probably less true of the more extreme conditions that are the focus of this report.

Figure 56: Trends in central ducted air conditioner capacity by size range to 2030

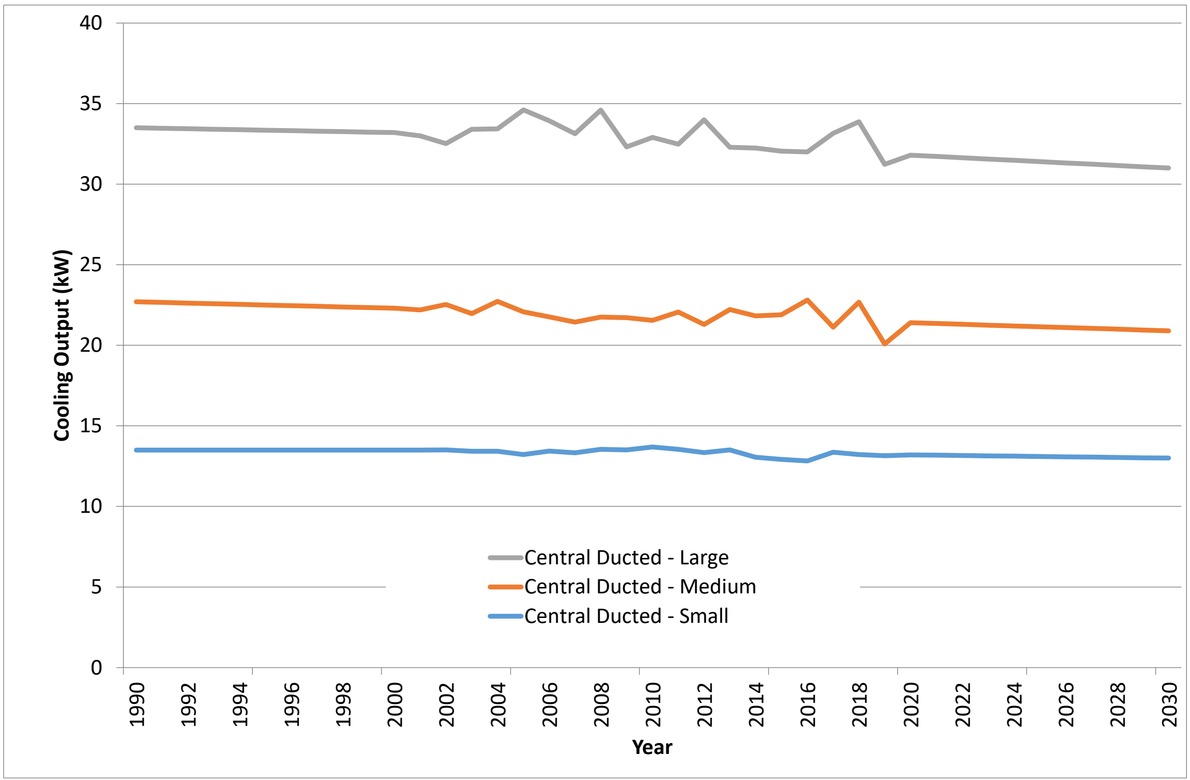


Figure 57: Trends in central ducted air conditioner efficiency (EER) by size range to 2030

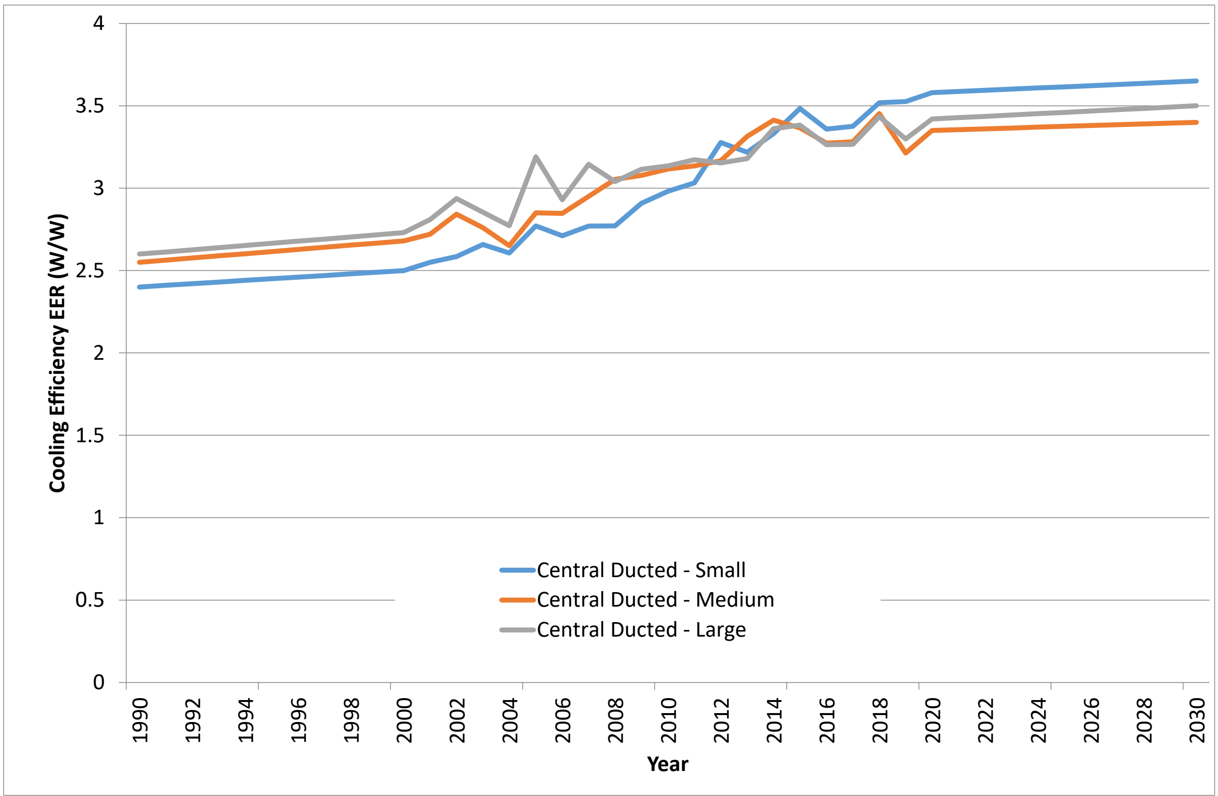


Figure 58: Trends in central non-ducted air conditioner capacity by size range to 2030

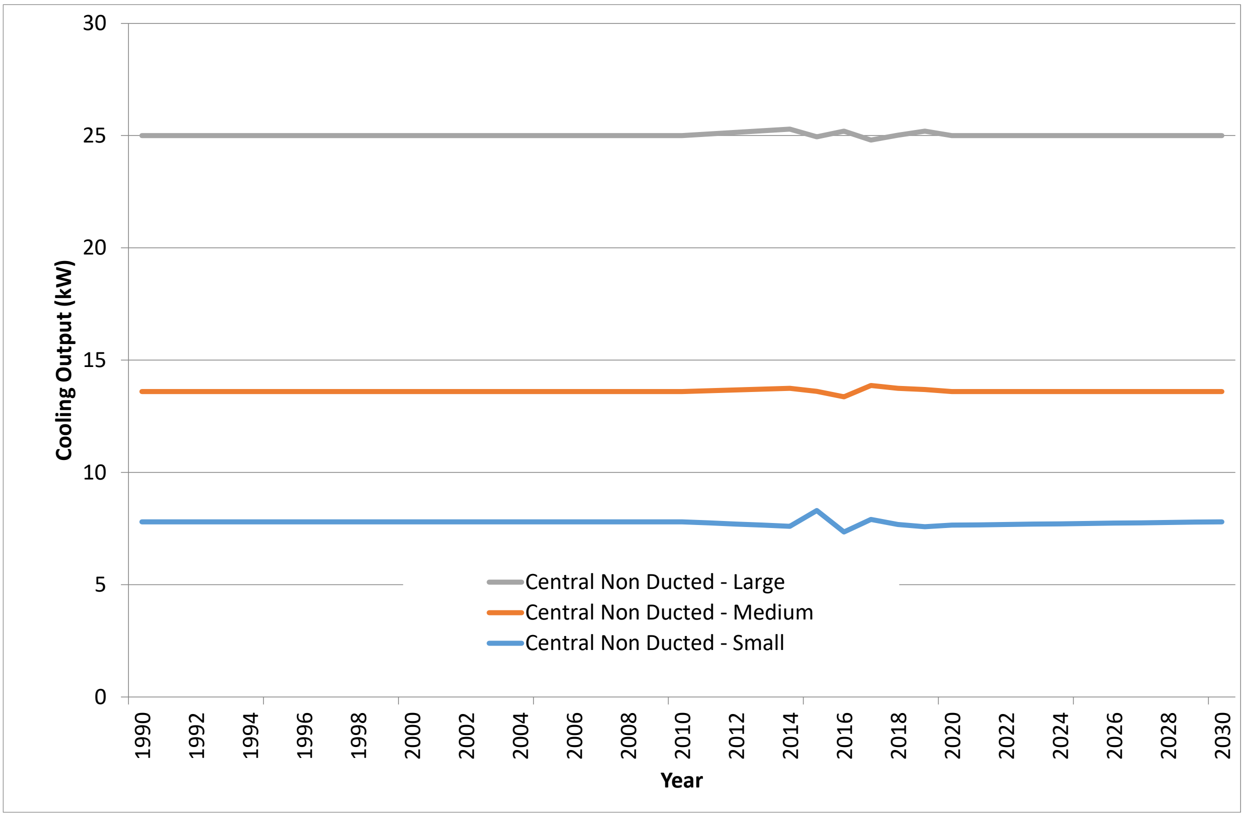


Figure 59: Trends in central ducted air conditioner efficiency (EER) by size range to 2030

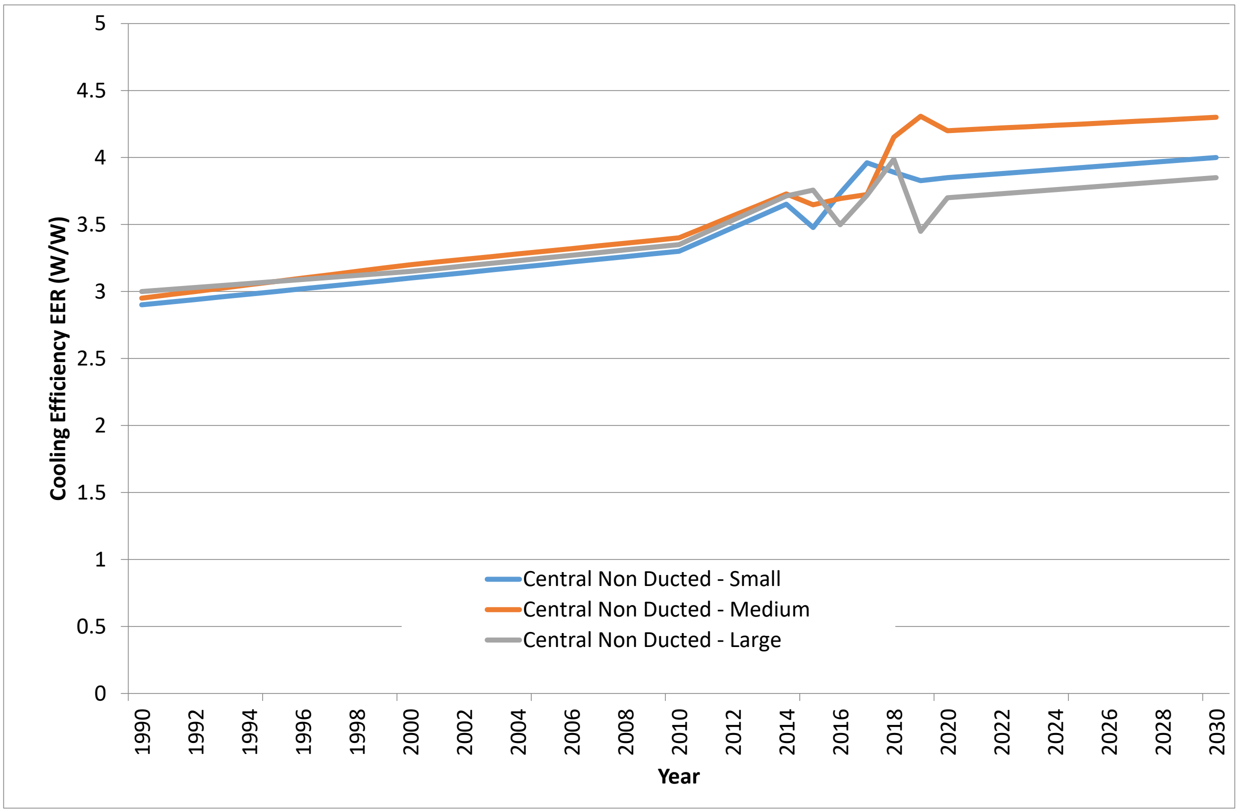


Figure 60: Trends in single split air conditioner capacity by size range to 2030

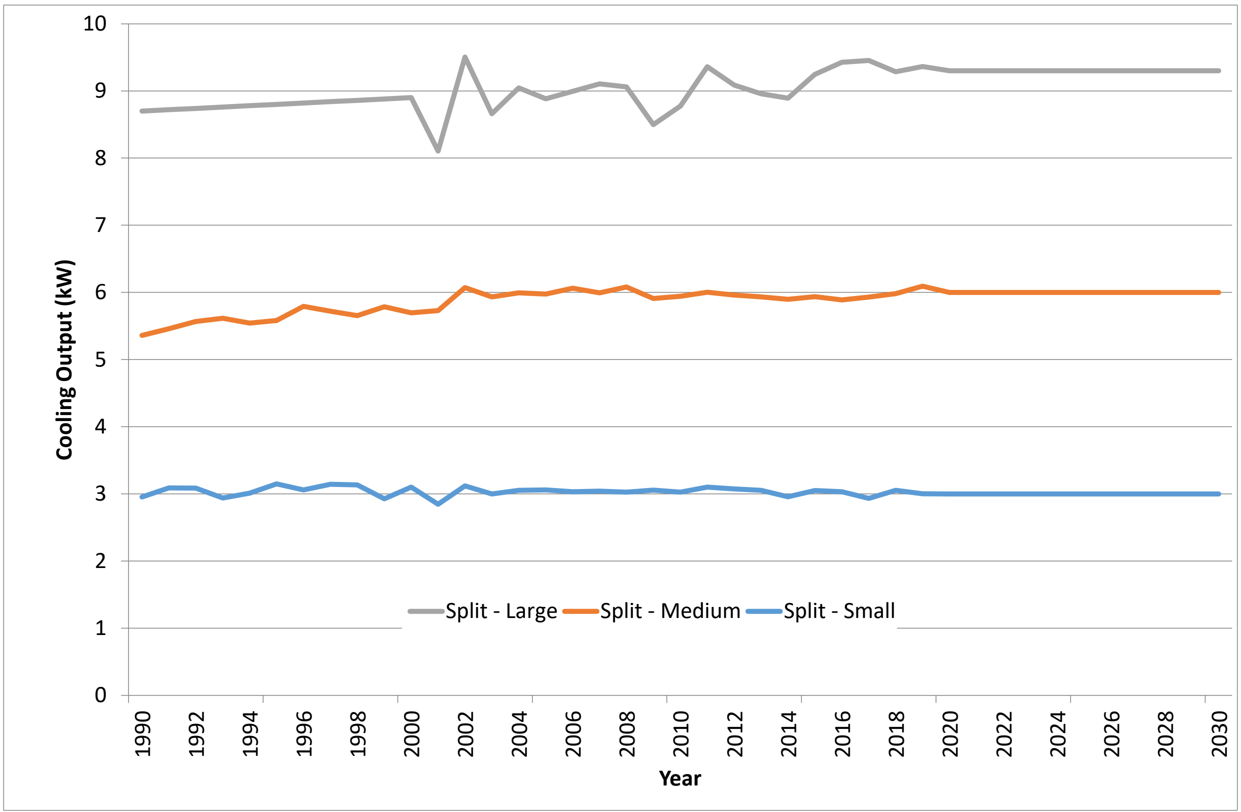


Figure 61: Trends in single split air conditioner efficiency (EER) by size range to 2030

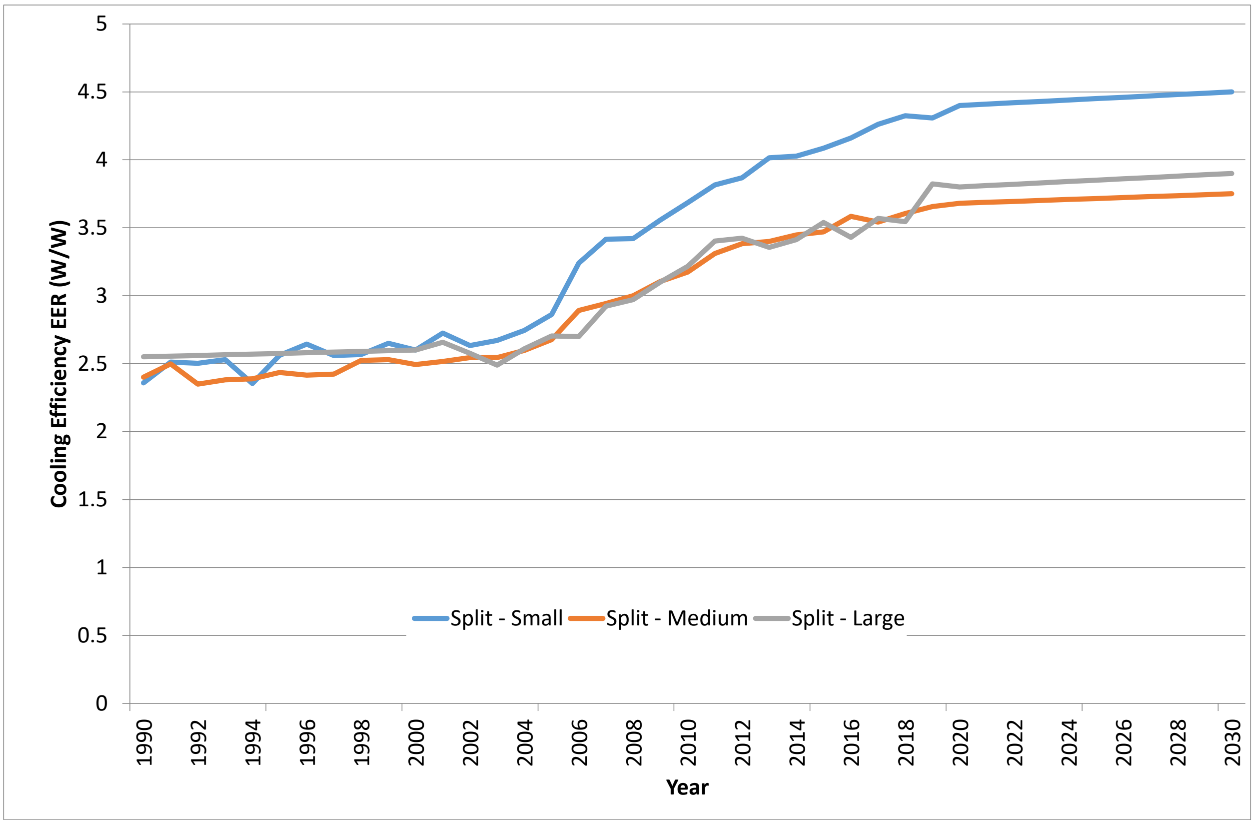


Figure 62: Trends in window wall air conditioner capacity by size range to 2030

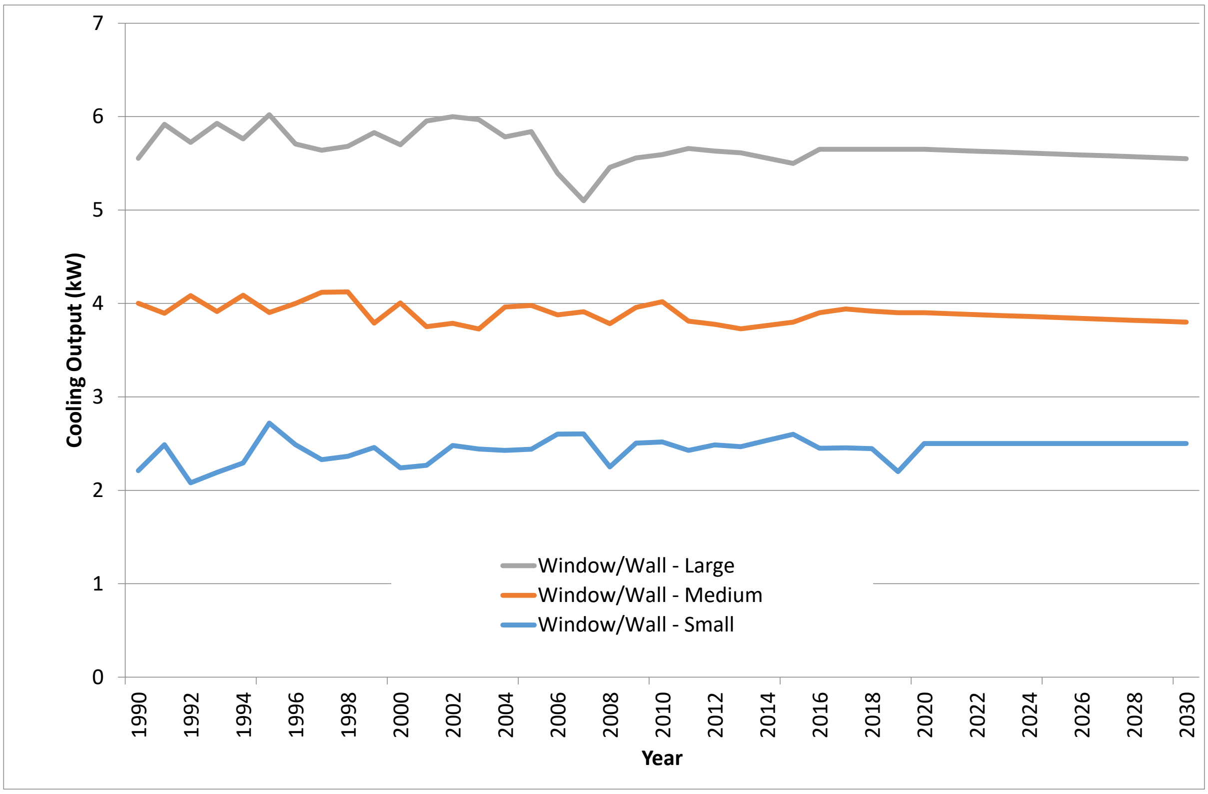
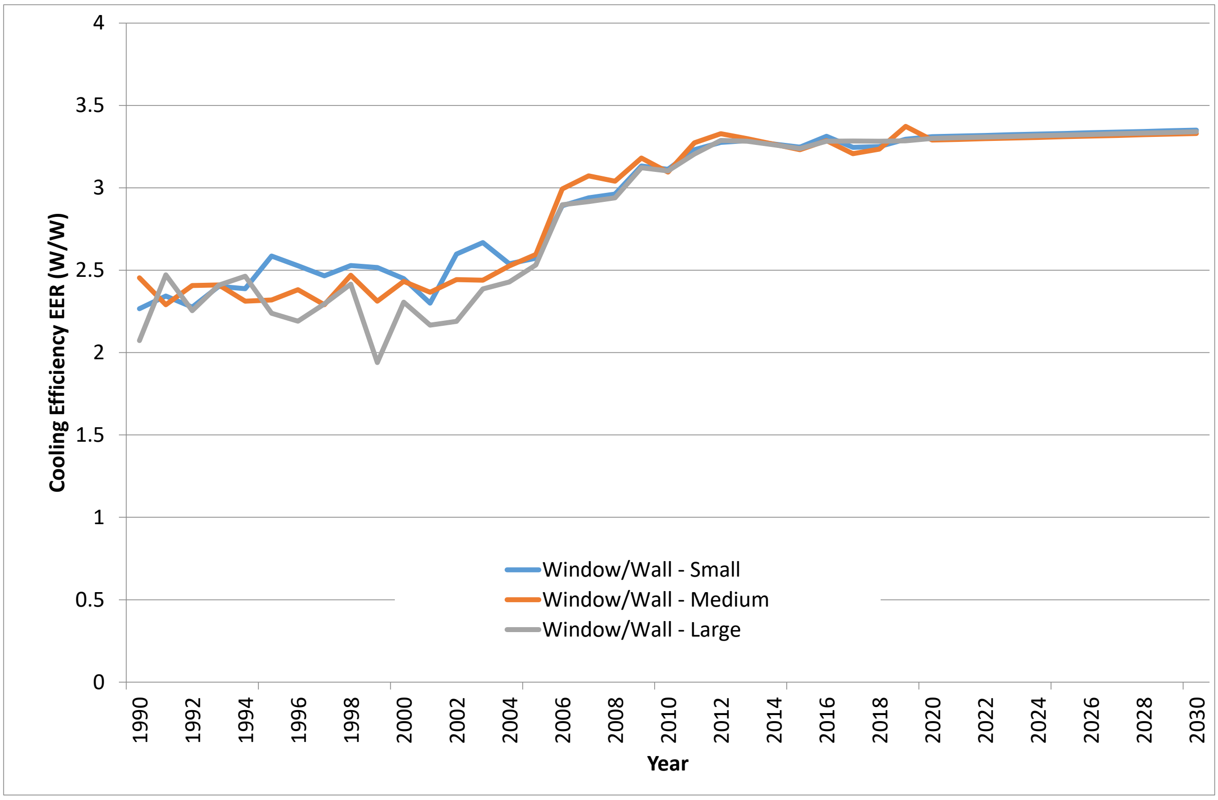


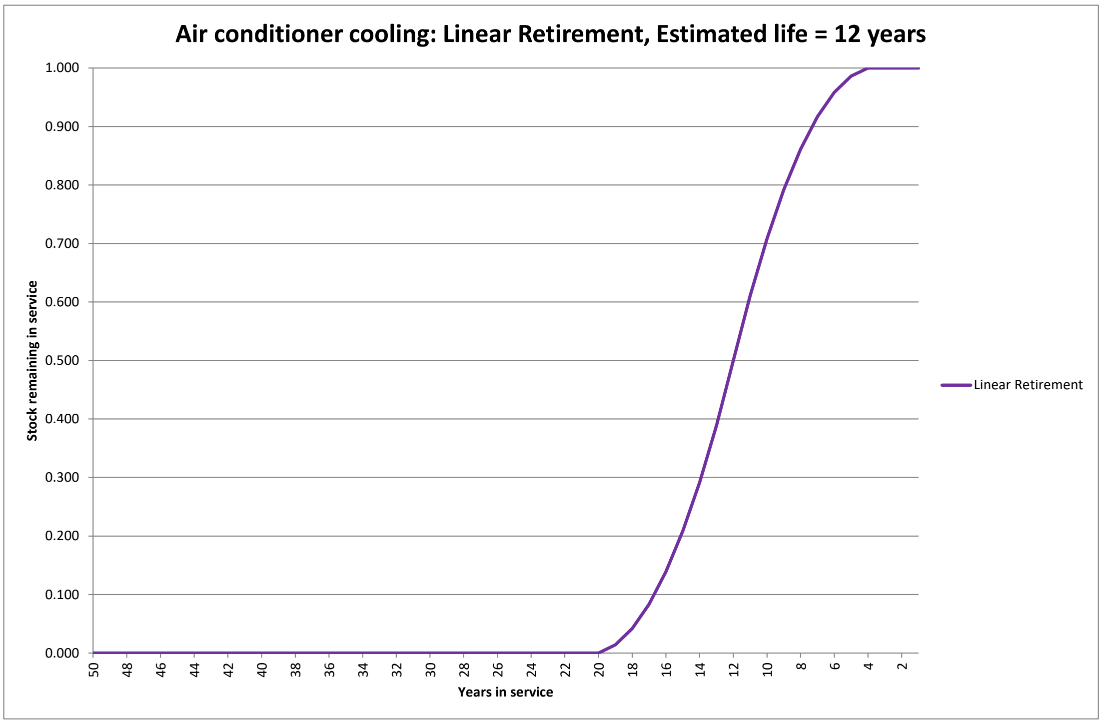
Figure 63: Trends in window wall air conditioner efficiency (EER) by size range to 2030



The capacity of small, medium and large sizes within each sub-category are relatively constant over the years, but the efficiency (EER) does increase significantly from 2004 to 2012 for all product types. This is primarily due to MEPS forcing out less efficient models, which are replaced by more efficient ones. The absolute efficiency of different product types does vary by year, product size and product sub-category. Central non-ducted systems are expected to increase in efficiency over time. Single split systems vary significantly in efficiency by size. This is because MEPS levels are much more stringent for split systems that are less than 4 kW. This is a global trend and was initially driven by the Japanese Top Runner program and the widespread availability of small, highly efficient inverter driven compressors.

The parameters shown in the previous charts are for new appliances that are entering the stock each year. For this project, we are more interested in the stock average attributes of all appliances installed in households. The stock of air conditioners operating today is made up of units installed this year plus units installed in previous years, less older units that are retired from the stock. To calculate the stock average values of capacity and efficiency for the study period, a generic stock model was used. This effectively added new stock each year and retired older stock in accordance with the selected retirement function. For air conditioners, an average lifetime of 12 years was selected. The retirement function assumed a normal distribution of retirement with a mean of 12 years and a standard deviation of 3 years. This resulted in a retirement function (stock remaining) that is illustrated inFigure 64. This shows that some air conditioners will start to be retired as early as 5 years, while the longest-lived products are expected to last for around 20 years.

Figure 64: Proportion of the stock remaining by years of service



Once the new appliance attributes were run through the stock model, a set of smoothed output parameters were generated. The stock model generates stock average capacity and efficiency values from 1990 to 2055. These parameters were then assumed to be constant from 2056 to 2090. These stock average capacity and efficiency figures were subsequently used in the building shell model the generate peak loads. For sub-categories where the efficiency improvement of new products past 2020 is zero or small, then the stock average efficiency tends to reach its peak and stabilise by 2030. For sub-categories where the efficiency of new products is expected to improve up to 2030, then the stock average efficiency tends to continue to slowly increase until around 2045.

Evaporative coolers

Evaporative cooling systems can provide a low energy method of cooling. They draw in outside air and pass this through a series of wet membranes to evaporate water and produce a cooling effect. The phase transition of liquid water to water vapour (called latent cooling) is a very effective way of cooling dry air because water has a large enthalpy of vaporisation when it evaporates. For evaporative cooling to work effectively, the relative humidity of the incoming outside fresh air has to be low. Evaporative cooling is widely used in southern states (Victoria, South Australia and the southern parts of Western Australia) where there are hot and dry summers. It is used less frequently in New South Wales (mainly west of the Great Dividing Range) and it is uncommon in Queensland (mainly inland rural areas well away from the coast). Evaporative cooling is usually configured as a direct cooling system which relies on large air flows through the building, so users have to have windows partly open to allow incoming air from the evaporative system to exit the building. Direct cooling evaporative systems also significantly increase indoor humidity, which can reduce human comfort (humid hot air is less comfortable than dry hot air at the same temperature). Indirect systems are possible (where cooled moist air does not enter the building where heat exchangers are used to transfer heat), but these are not common in Australia.

There is relatively poor data on the energy service provided by evaporative cooling systems. While these can provide a low energy method of cooling a residential building (with relatively low peak demand), they can consume significant quantities of water. They are also only suitable for a limited number of climate zones (hotter drier regions). A technical review of the performance of evaporative systems, with a particular reference to new technologies that can reduce fan and pump loads as well as water consumption while maintaining performance, should be undertaken.

Inclusion of evaporative systems in a building shell model is a somewhat vexed issue, as the energy service provided by a refrigerative and evaporative systems is quite different. Based on published data from a range of manufacturers, an "equivalent" energy efficiency rating (EER) value was calculated. Equivalence in this sense relates to the relative energy consumption of these systems, rather than the energy service which is delivered or its quality. An equivalent EER of 12 has been used as this is representative of central ducted models which make up the majority of medium and large systems (Energy Efficient Strategies 2008). A lower equivalent EER (of the order of five to eight) would apply to smaller room systems, so an equivalent EER of 8 has been selected for the small system in this study. The water consumption of these systems is significant but this has not been quantified for this study.

Appendix B: Using the Saturation Effects Model

This section briefly describes the use of the RSCMD Model.

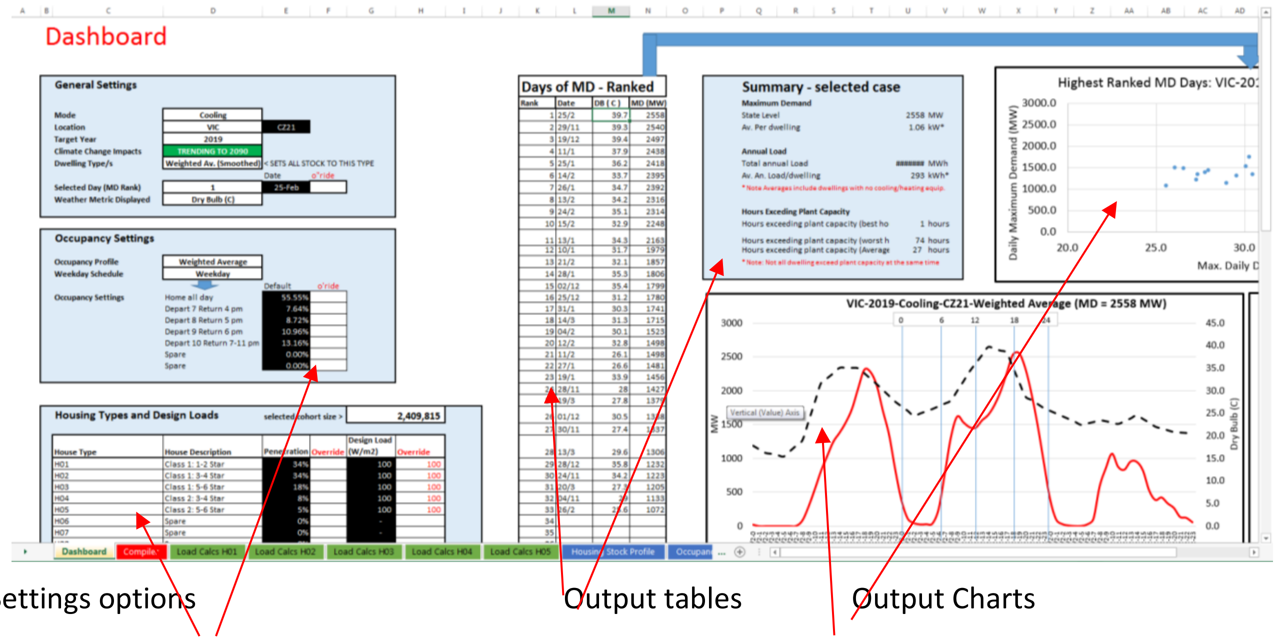
The model is constructed within a single MS-Excel workbook. The workbook is quite large (approximately 60 MB) and as such it can take some time to open and one or two seconds to complete a calculation.

The model is divided into 6 functional sections. The key sections are:

Sheet Name	Sheet description
Dashboard	This is the main control panel for the model where a user makes modelling selections and adjusts various settings. Some key outputs in the form of charts are also provided directly to the right of the control panel section.
Compiler	The compiler sheets compiles data sets from the calculation models ("calcs" modules) and generates output tables and charts for delivery to the dashboard.
Calcs	There is one calculation module for each representative dwelling type. The calculation modules assemble the 8760 hours of load data, determines the capacity requirement needed to meet that load then applies data from the space conditioning stock model profile in order to calculate hourly electrical loads
Profiles	A range of assumed profiles are stored in these tabs including: • Housing Stock • Occupancy • Climate • Cooling Equipment • Heating Equipment (yet to be completed)
Data	Various data sets used in the model are stored in these tabs, including: • Housing typology • Design Equipment loads • Weather data (from the RMY files) • Hourly load data imported from the thermal simulation process
Picklists	Common headings and picklists used in other worksheets plus default values used in the various settings
About	History of amendments to this tool

The dashboard tab is where the user interacts with the model. The dashboard basically includes a set a range of settings options on the left-hand side and a range of output types on the right-hand side (see Figure 65).

Figure 65: The RSCMD Model Dashboard (part)



The key setting controls are shown in Figure 66.

Figure 66: Example setting controls in the RSCMD model

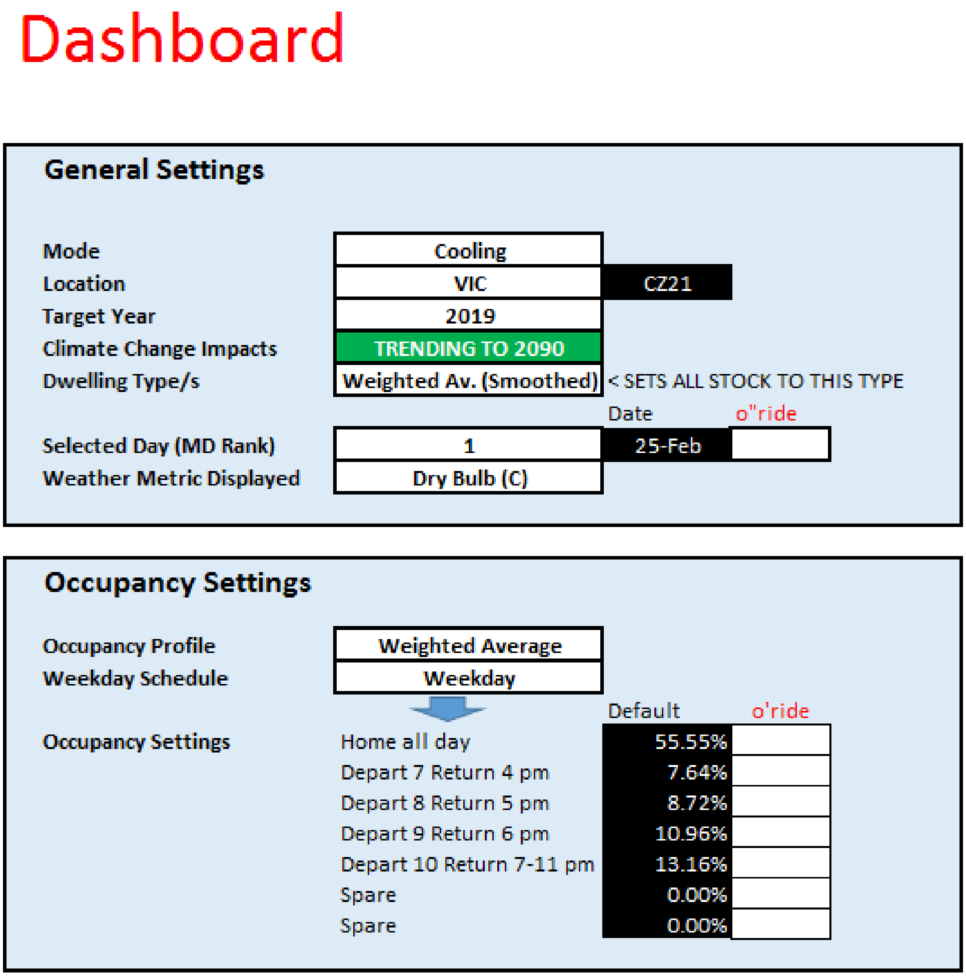


Table 17: Description of key controls in the RSCMD model

Mode Selection	Allows the user to select either cooling load analysis or heating load analysis (future option)
Location	Allows the user to select the desired location for analysis (NSW,Vic or Qld)
Target Year	Allows the user to select a particular year for analysis, changing the year affects many parameters including: • The housing stock profile • The space conditioning stock profile • The degree of climate change
Climate change impacts	The user can select one of three options: • Impacts Off – turns off any impacts of climate change and returns loads based on current (2016) weather data • Trending to 2090 – loads in any selected target year are based on an assumed linear trend between the 2016 weather files and the 2090 future weather file • 100% Impacts – Irrespective of target year selected the full impact of climate change by 2090 is applied.

Dwelling Types	The user can either select the weighted average of all dwelling type efficiencies modelled or they can apply a particular dwelling type across the entire stock
Selected Day (MD Rank)	Use this to select a particular day of interest for charting of results. A user can either select by rank in terms of maximum demand or alternatively specify a particular date of interest.
Weather Metric Displayed	Use this to select a particular weather metric of interest for charting against the hourly electrical load. The options are: • Dry bulb temperature • Moisture content • Wind speed • Oktas (cloud cover) • Direct solar radiation • Diffuse solar radiation
Occupancy Profile	Select either a weighted average of all profiles or alternatively a particular profile to apply, either: • Weighted Average • Home all day • Depart 7 Return 4 pm • Depart 8 Return 5 pm • Depart 9 Return 6 pm • Depart 10 Return 7-11 pm
Weekday Schedule	Occupancy profiles vary according to the day of the week. Use this control to select a particular day, either: • Weekday • Saturday • Sunday
Occupancy Settings	Use this table to vary the default assumptions (shown in the black cells) if required by overriding the default values by inserting new values in the cells to the right of the default values. Note: The default values will vary according to the occupancy profile and the weekday schedule selected.

Figure 67: Illustration of housing types and design load in the RSCMD model

Housing Types and Design Loads selected cohort size > **2,409,815**

House Type	House Description	Penetration	Override	Design Load (W/m2)	Override
H01	Class 1: 1-2 Star	34%		100	100
H02	Class 1: 3-4 Star	34%		100	100
H03	Class 1: 5-6 Star	18%		100	100
H04	Class 2: 3-4 Star	8%		100	100
H05	Class 2: 5-6 Star	5%		100	100
H06	Spare	0%		-	
H07	Spare	0%		-	
H08	Spare	0%		-	
H09	Spare	0%		-	
H10	Spare	0%		-	

The housing types and design loads (see Figure 67) shows the default penetration of each housing type (left-hand set of black cells) which is governed by the selections made in the **Location**, **Target Year** and **Dwelling types** fields in the dashboard general settings section (see Figure 66). Also shown Figure 67 are the default assumed plant design loads (either heating or cooling as selected). Any of the values can be overridden by inserting alternative values in the fields immediately to the right of the black fields.

Figure 68: Cooling plant ownership and specifications in the RSCMD model

Cooling Plant - Ownership and Specifications

Boost Default Plant Efficiency by > 0%

Class 1	Penetration	Override	Capacity	Override	Plant Efficiency	Override	Losses	Override
No Cooling	20.3%		-		100%		0%	
Central Ducted - Small	0.6%		11.28		324%		20%	
Central Ducted - Medium	3.0%		18.49		323%		20%	
Central Ducted - Large	2.4%		27.84		324%		20%	
Central Non Ducted - Small	0.3%		6.58		359%		0%	
Central Non Ducted - Medium	1.4%		11.61		370%		0%	
Central Non Ducted - Large	1.1%		21.31		357%		0%	
Evaporative - Small	5.7%		7.65		1500%		20%	
Evaporative - Medium	5.1%		11.48		1500%		20%	
Evaporative - Large	11.9%		15.30		1500%		20%	
Split - Small	4.5%		2.57		395%		0%	
Split - Medium	17.8%		5.07		338%		0%	
Split - Large	22.3%		7.78		339%		0%	
Window/Wall - Small	1.1%		2.08		320%		0%	
Window/Wall - Medium	1.5%		3.28		322%		0%	
Window/Wall - Large	1.1%		4.75		319%		0%	
Spare	0.0%		-		100%		0%	
Spare	0.0%		-		100%		0%	
Spare	0.0%		-		100%		0%	
Spare	0.0%		-		100%		0%	
Spare	0.0%		-		100%		0%	

Default Capacity Adjustment Factor 85%

Class 2	Penetration	Override	Capacity	Override	Plant Efficiency	Override	Losses	Override
No Cooling	20.3%		-		100%		0%	
Central Ducted - Small	3.6%		11.28		324%		20%	
Central Ducted - Medium	1.8%		18.49		323%		20%	

The cooling plant ownership and specifications (see Figure 68) shows the following defaults for each cooling equipment type:

- Penetration
- Rated capacity
- Plant efficiency
- System losses.

These values are all drawn from the data within the cooling equipment profile tab in the model, but can be overridden by inserting alternative values in the fields immediately to the right of the black fields.

At the bottom of the table is a "Capacity Adjustment Factor" field for application to the Default capacity values in the table. By altering this value, the assumed capacities for all cooling appliances can be scaled up or down as may be required.

There are separate tables that cover both class 1 and class 2 type dwellings and future versions of the model may also include similar tables for heating equipment.

Appendix C: Energy Savings by Sector, Measure, Jurisdiction and Fuel

Residential Sector

Figure 69: Residential Sector Electricity Savings - National Construction Code Energy Performance Requirements (Neutral Scenario)

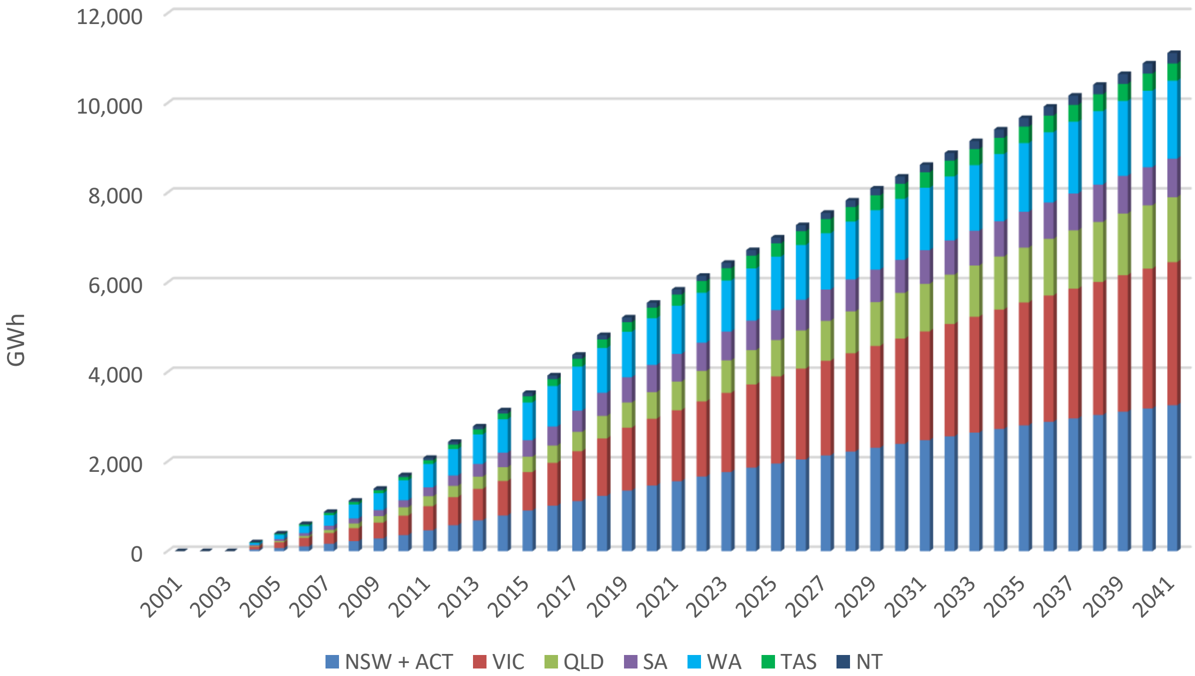


Figure 70: Residential Sector Gas Savings - National Construction Code Energy Performance Requirements (Neutral Scenario)

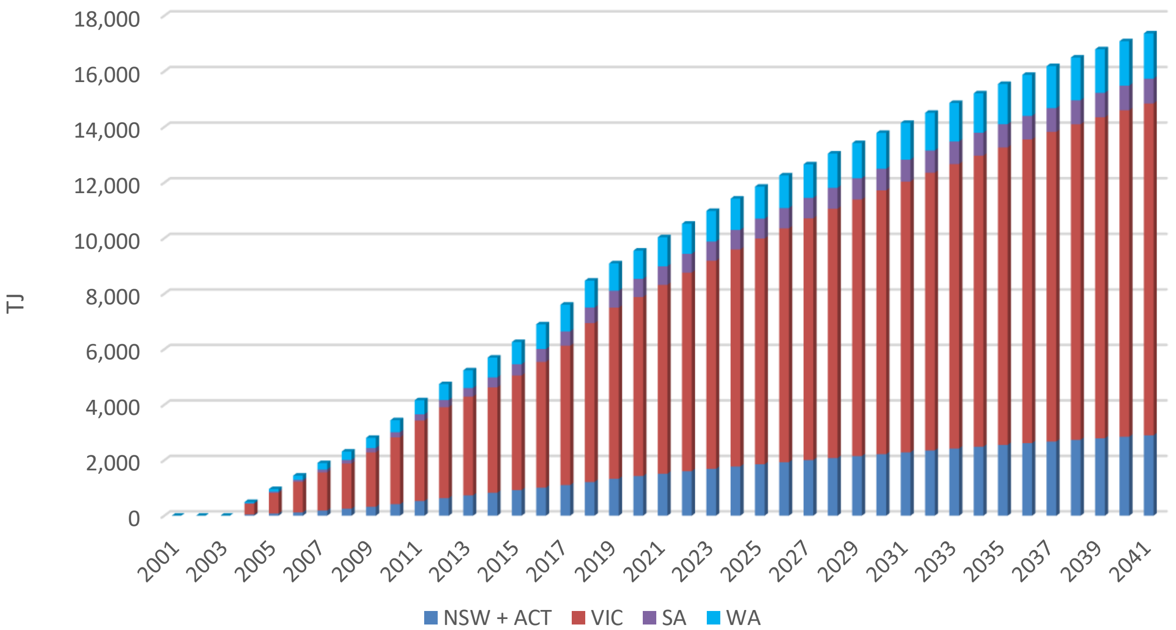


Figure 71: Residential Sector Electricity Savings - Greenhouse and Energy Minimum Standards (Neutral Scenario)

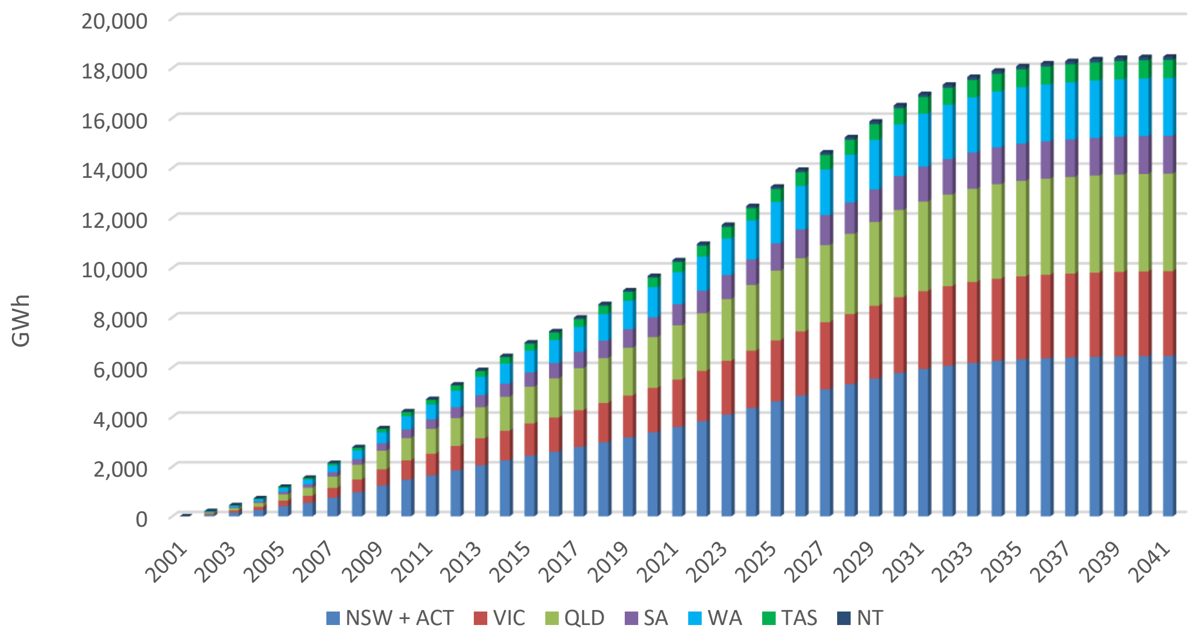


Figure 72: Residential Sector Electricity Savings - Home Insulation Program (Neutral Scenario)

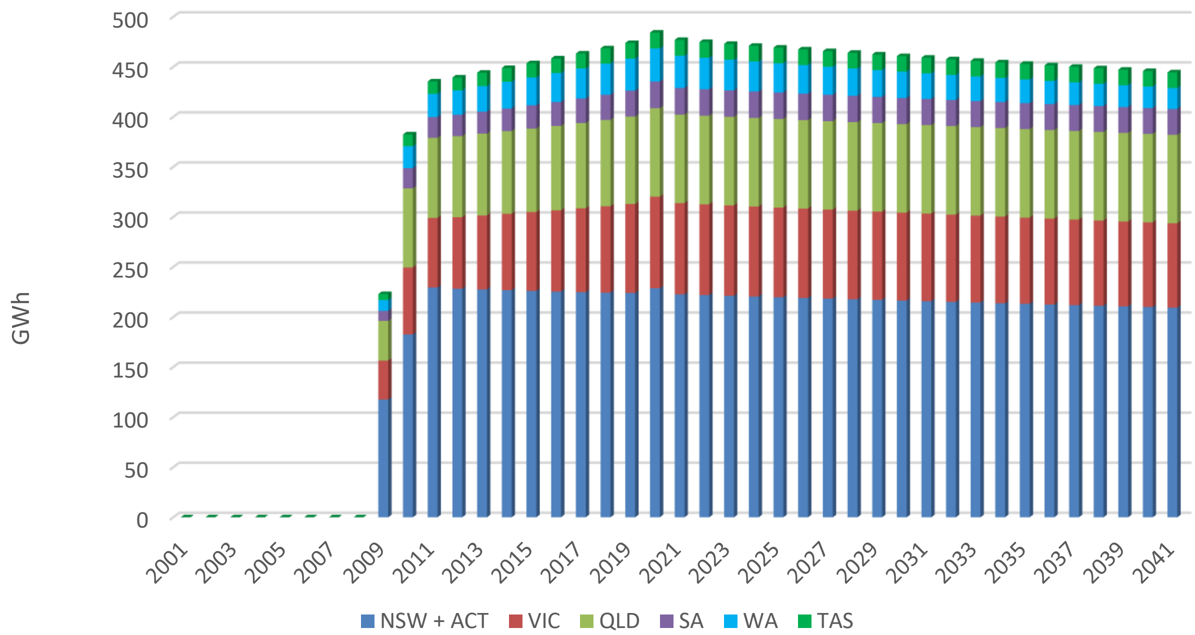


Figure 73: Residential Sector Gas Savings - Home Insulation Program (Neutral Scenario)

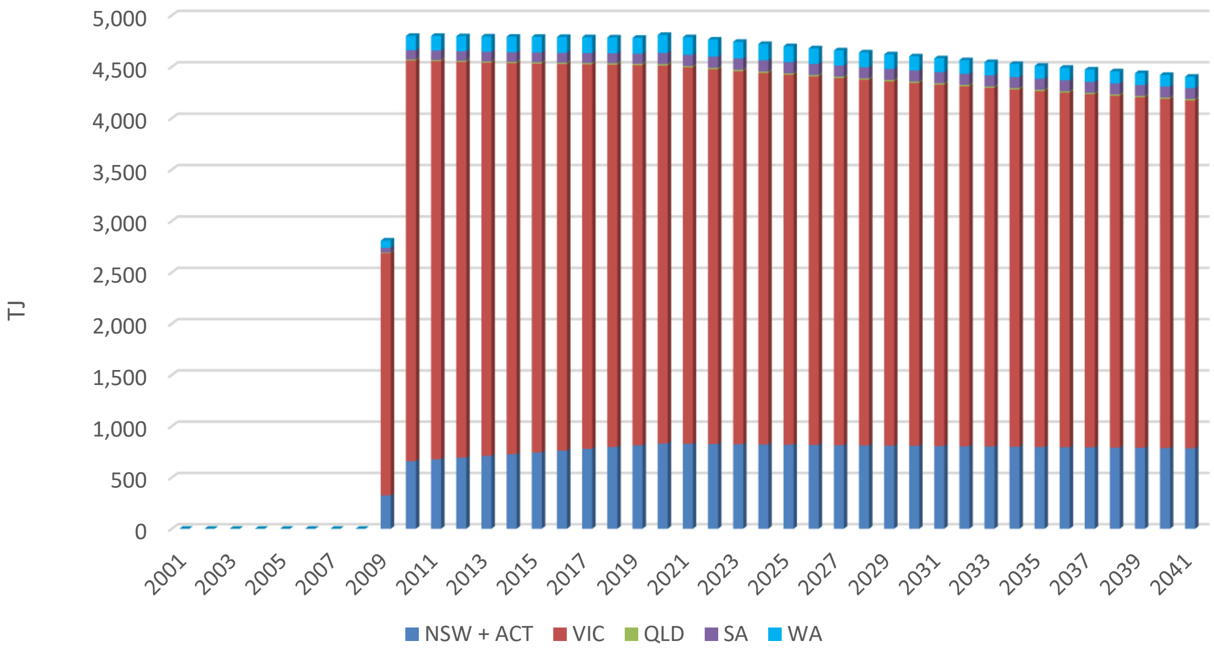
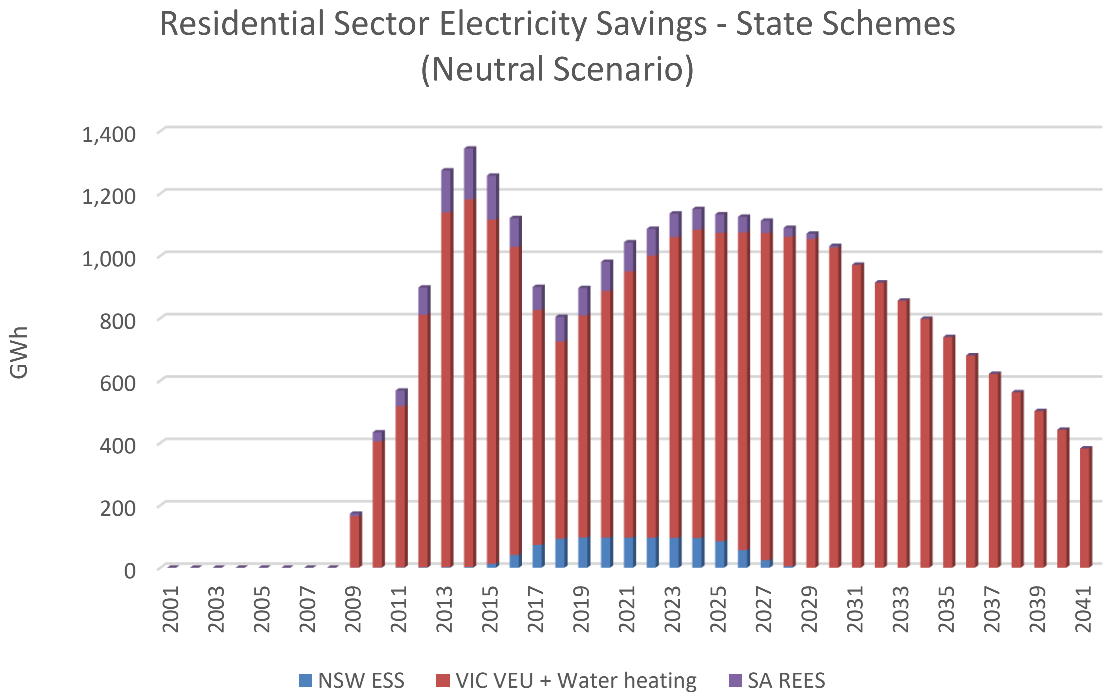


Figure 74: Residential Sector Electricity Savings - State Schemes (Neutral Scenario)



Commercial Sector

Figure 75: Commercial Sector Electricity Savings - National Construction Code Energy Performance Requirements (Neutral Scenario)

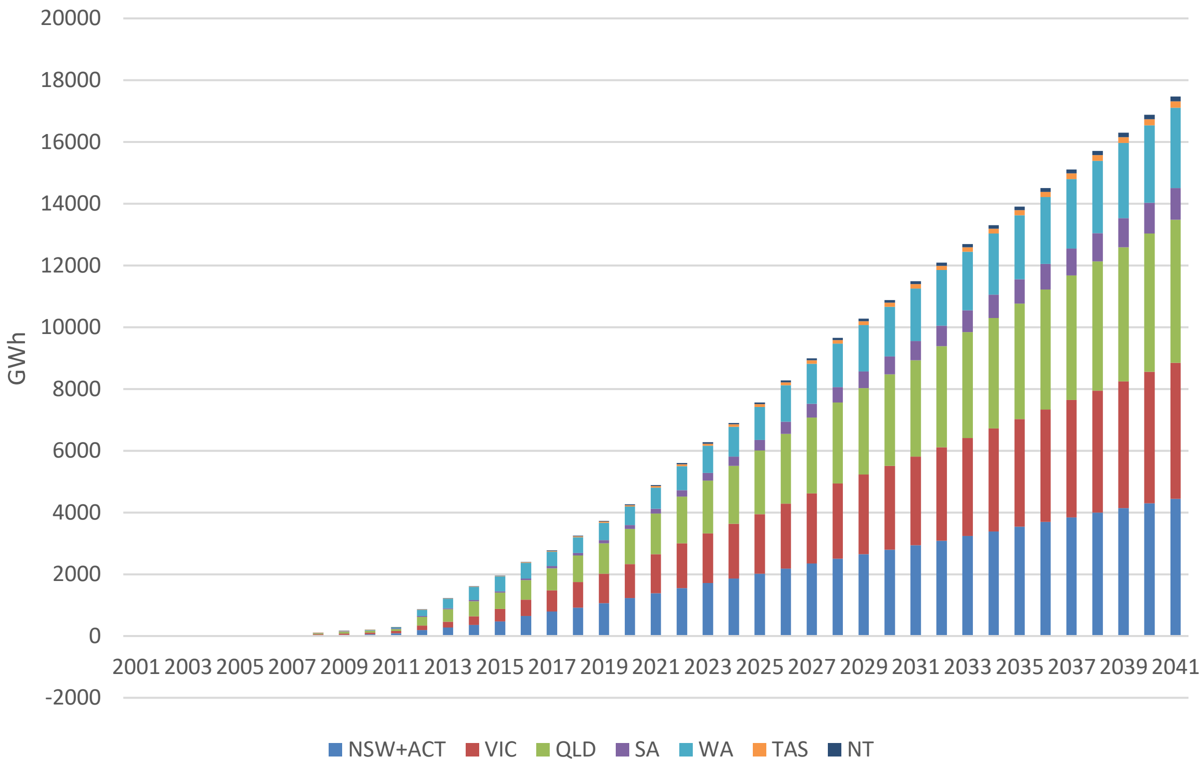


Figure 76: Commercial Sector Gas Savings - National Construction Code Energy Performance Requirements (Neutral Scenario)

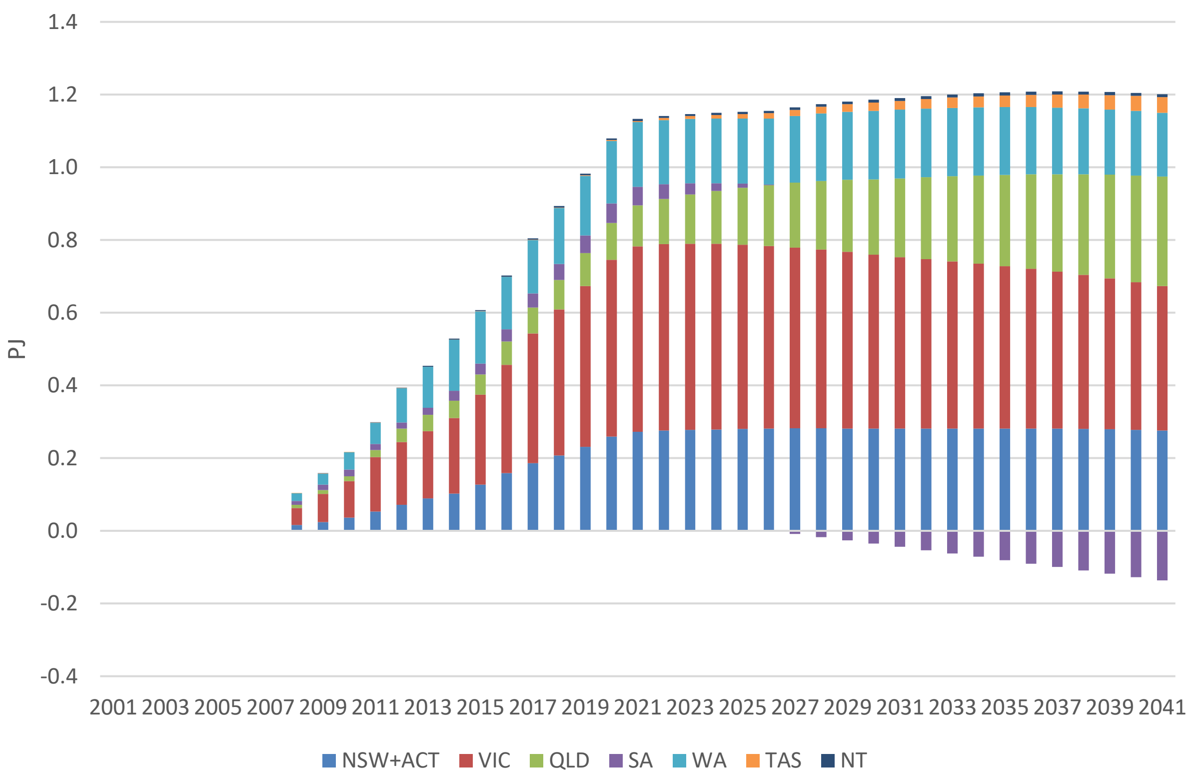


Figure 77: GEMS Electricity Savings by State (Neutral Scenario)

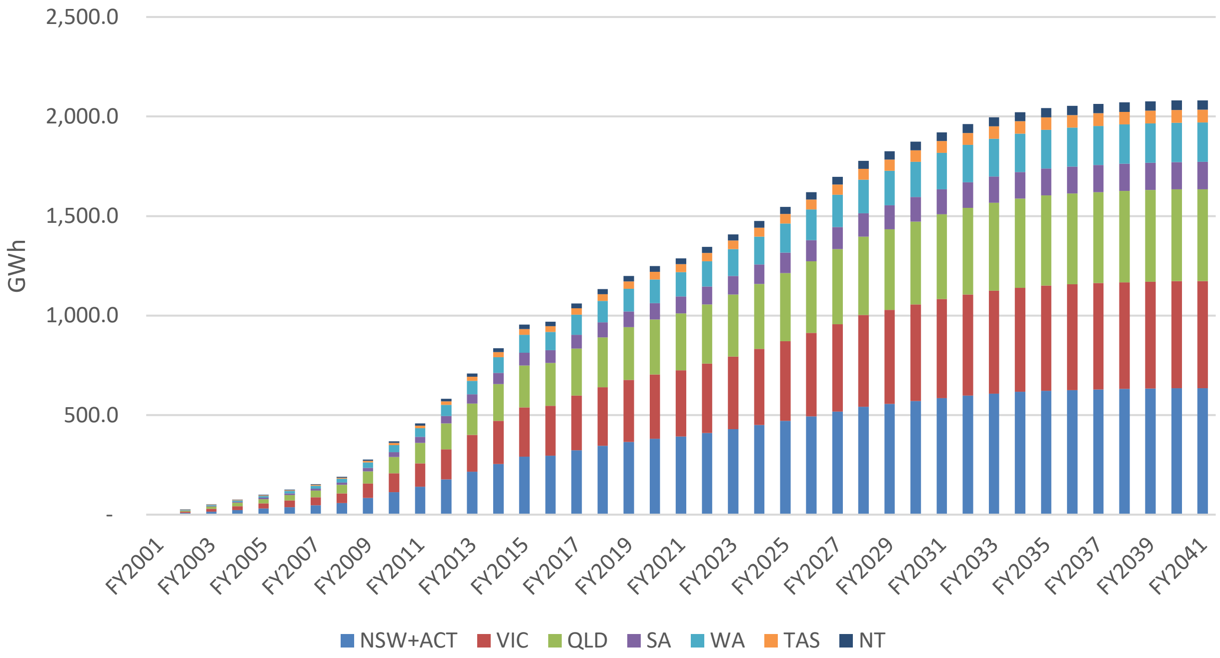


Figure 78: Commercial Building Disclosure Electricity Savings by Jurisdiction (Neutral Scenario)

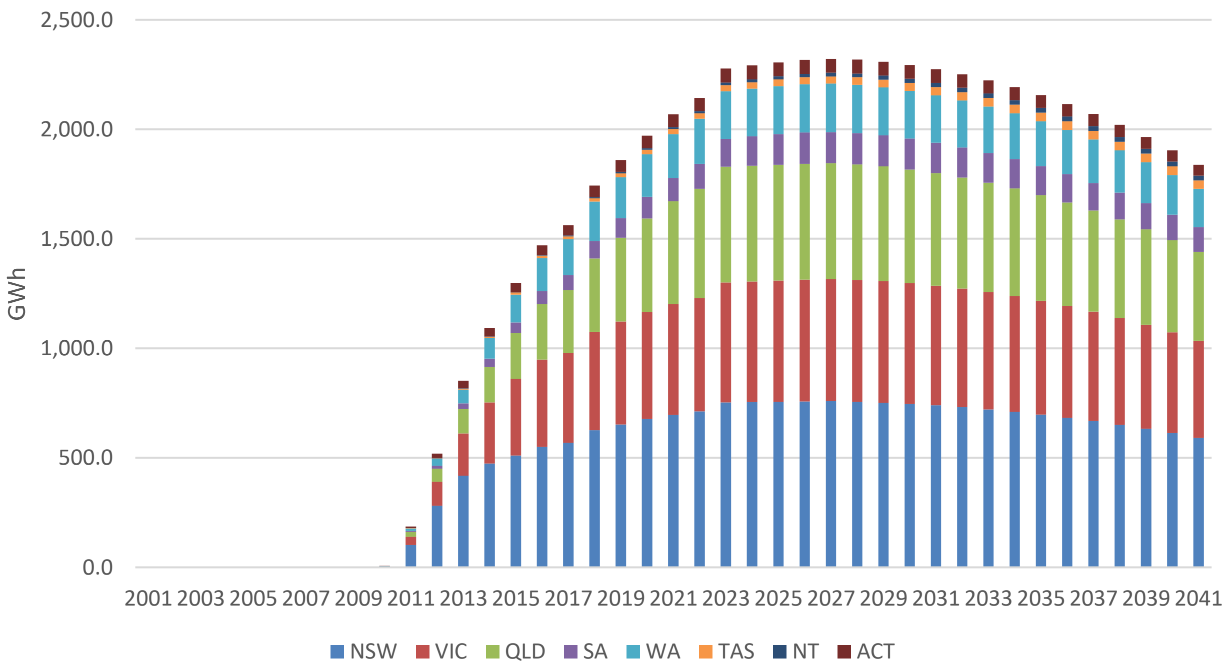


Figure 79: Commercial Building Disclosure Gas Savings by Jurisdiction (Neutral Scenario)

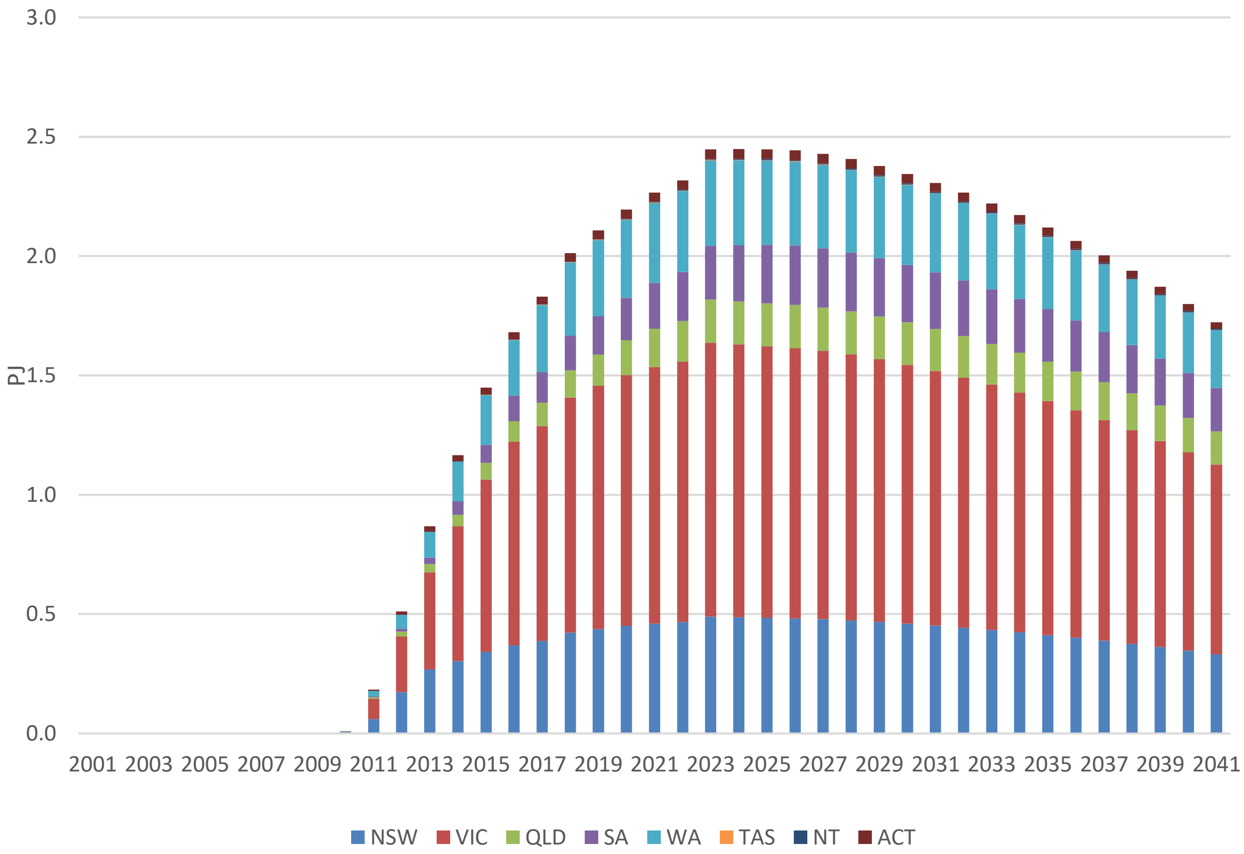


Figure 80: NABERS Electricity Savings by Jurisdiction (Neutral Scenario)

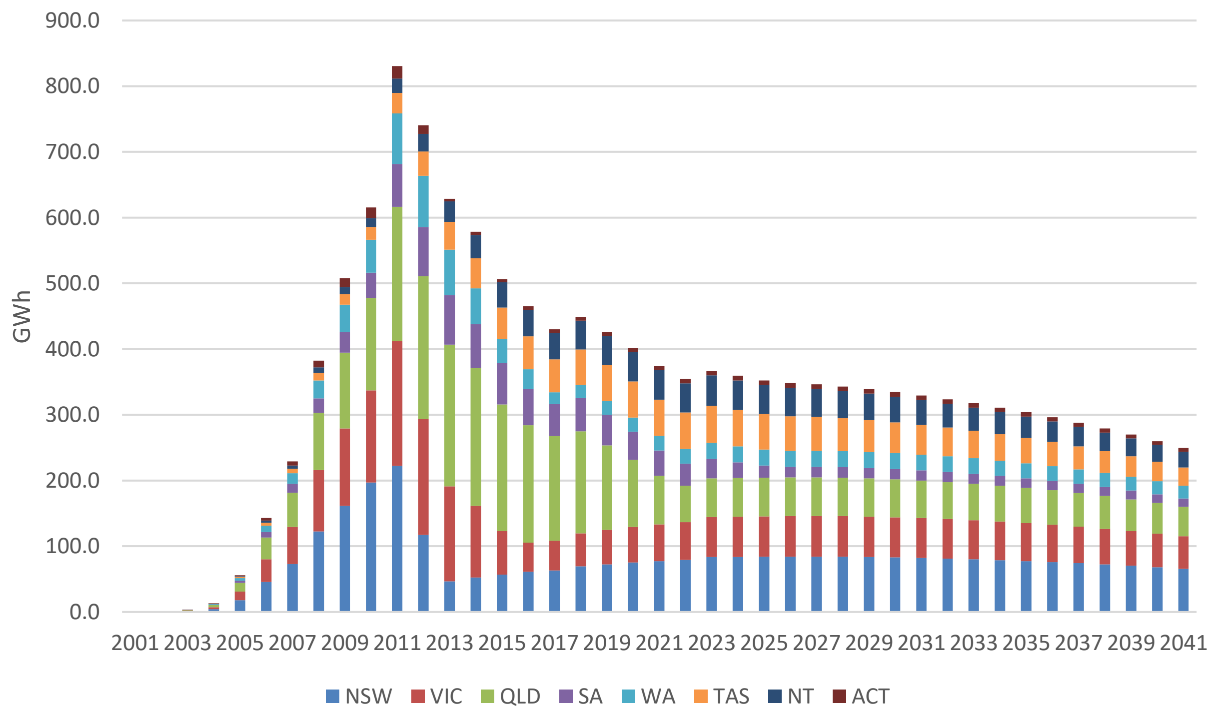


Figure 81: NABERS Gas Savings by Jurisdiction (Neutral Scenario)

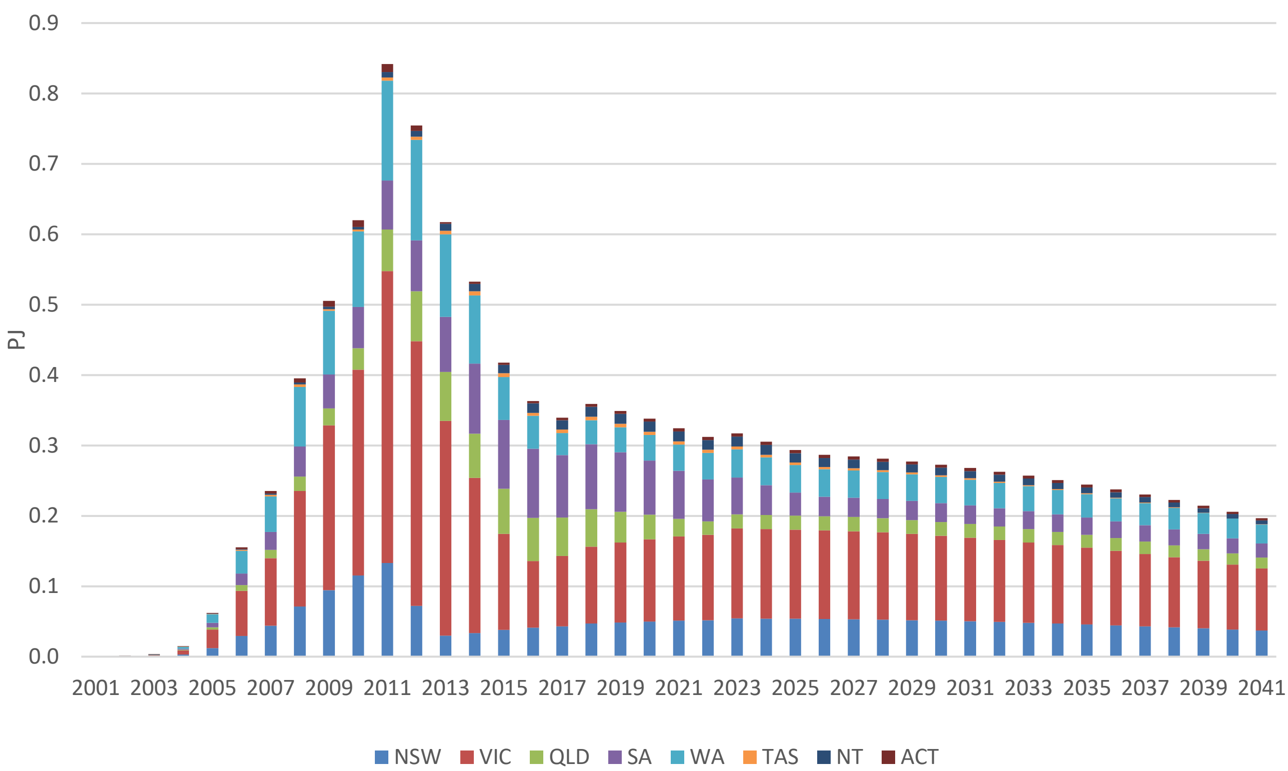


Figure 82: State Energy Savings Targets Electricity Savings (Neutral Scenario)

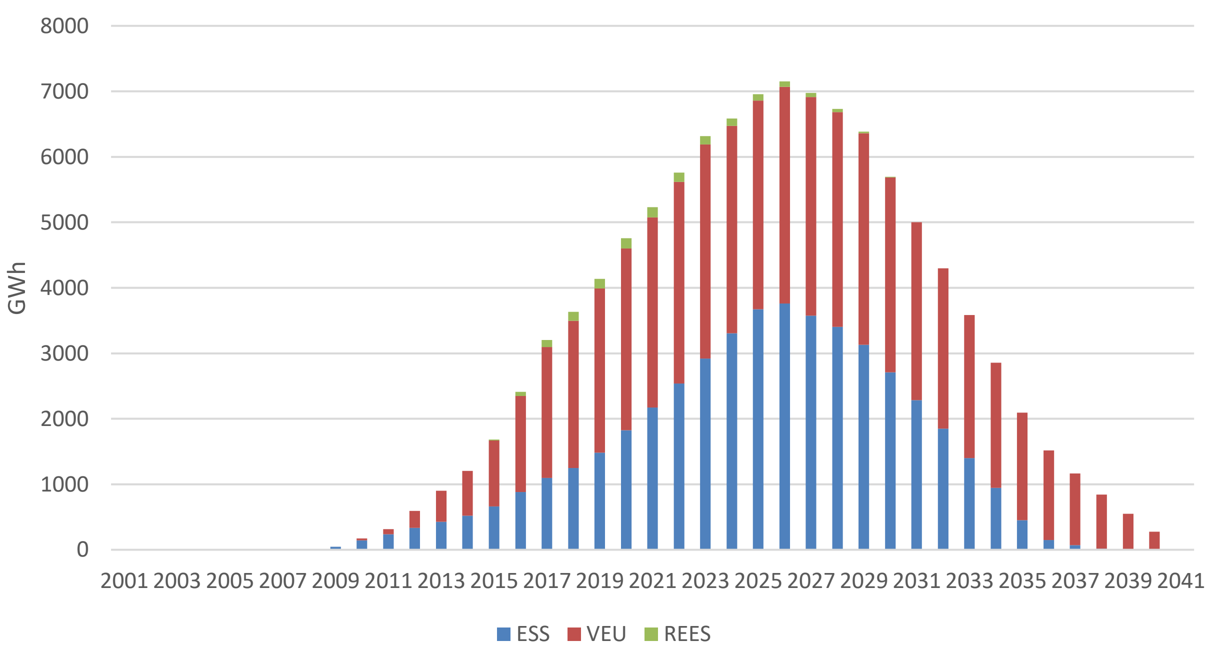
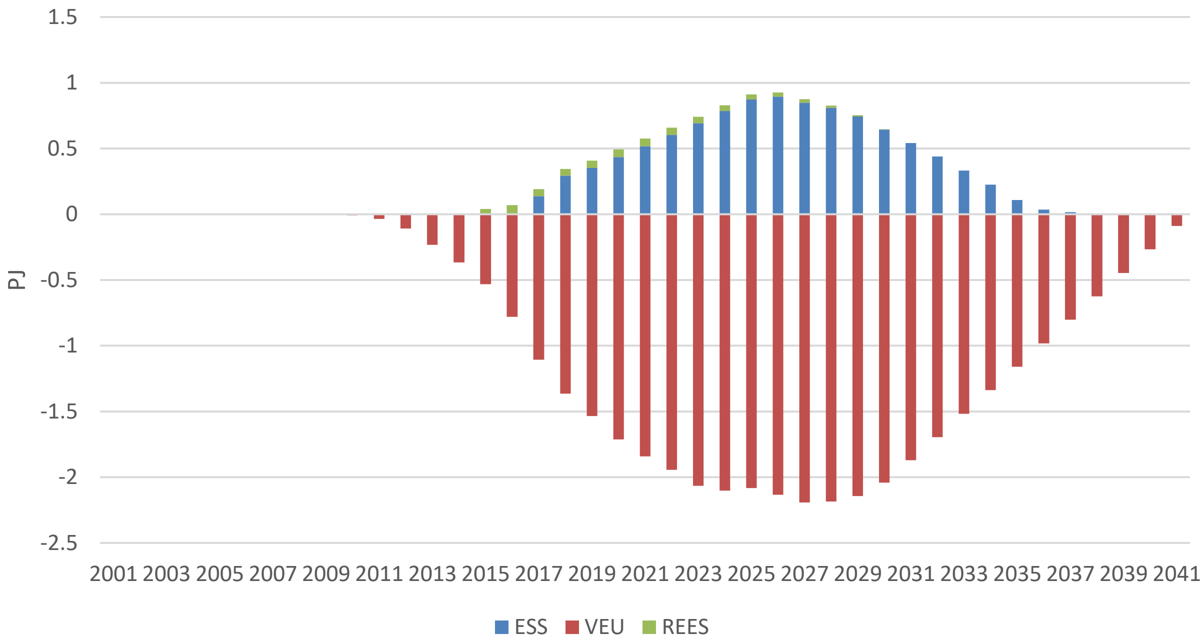


Figure 83: State Energy Savings Targets Gas Savings (Neutral Scenario)[42]



[42] As noted in Chapter 3, VEU's historical encouragement of gas consumption may not continue into the future.

Industrial Sector

Figure 84: GEMS Industrial Sector Electricity Savings (Neutral Scenario)

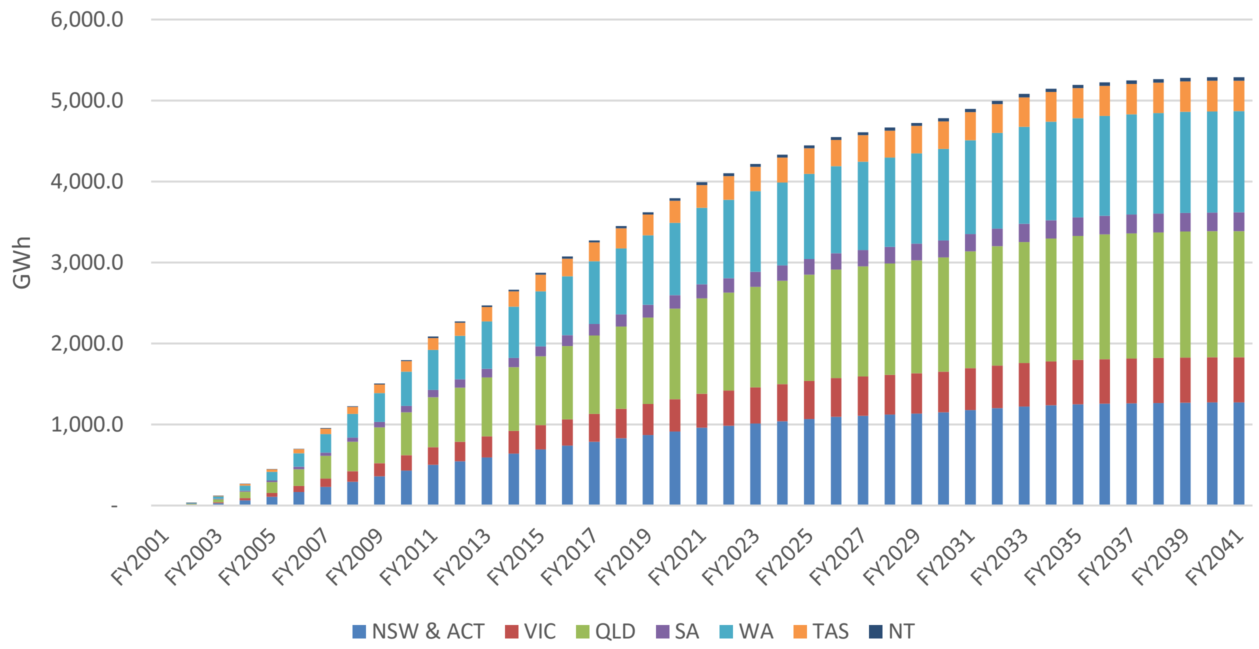


Figure 85: Energy Savings Scheme Industrial Sector Savings (excl. coal and aluminium) (Neutral Scenario)

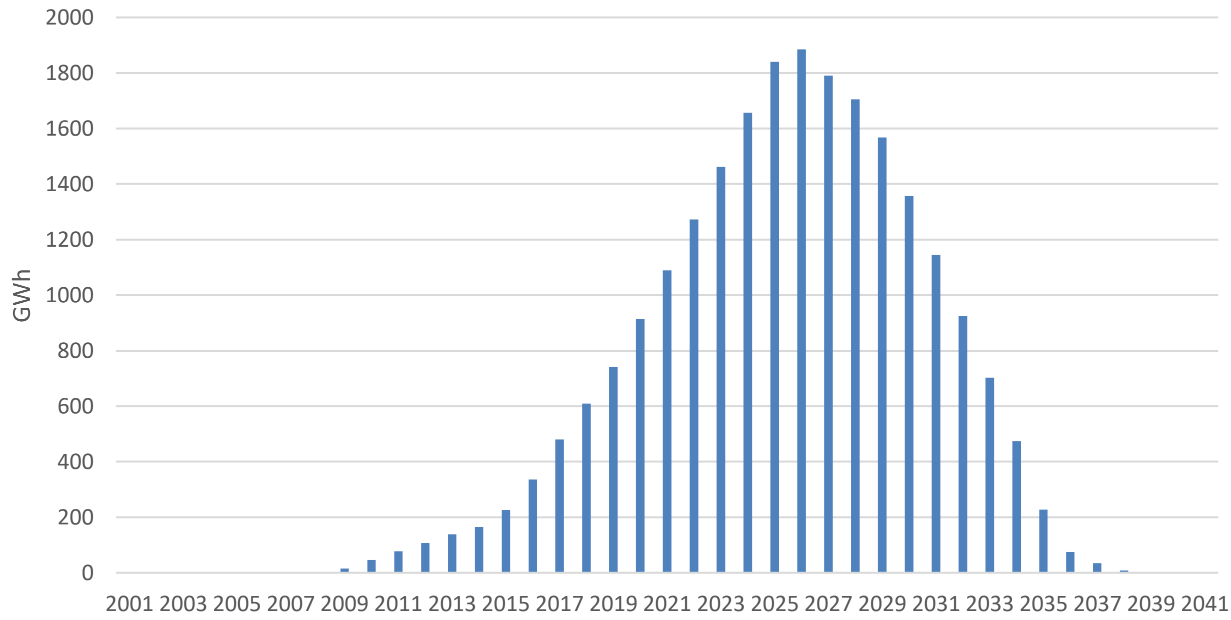


Figure 86: Energy Efficiency Opportunities Program Industrial Sector Electricity Savings (Neutral Scenario)

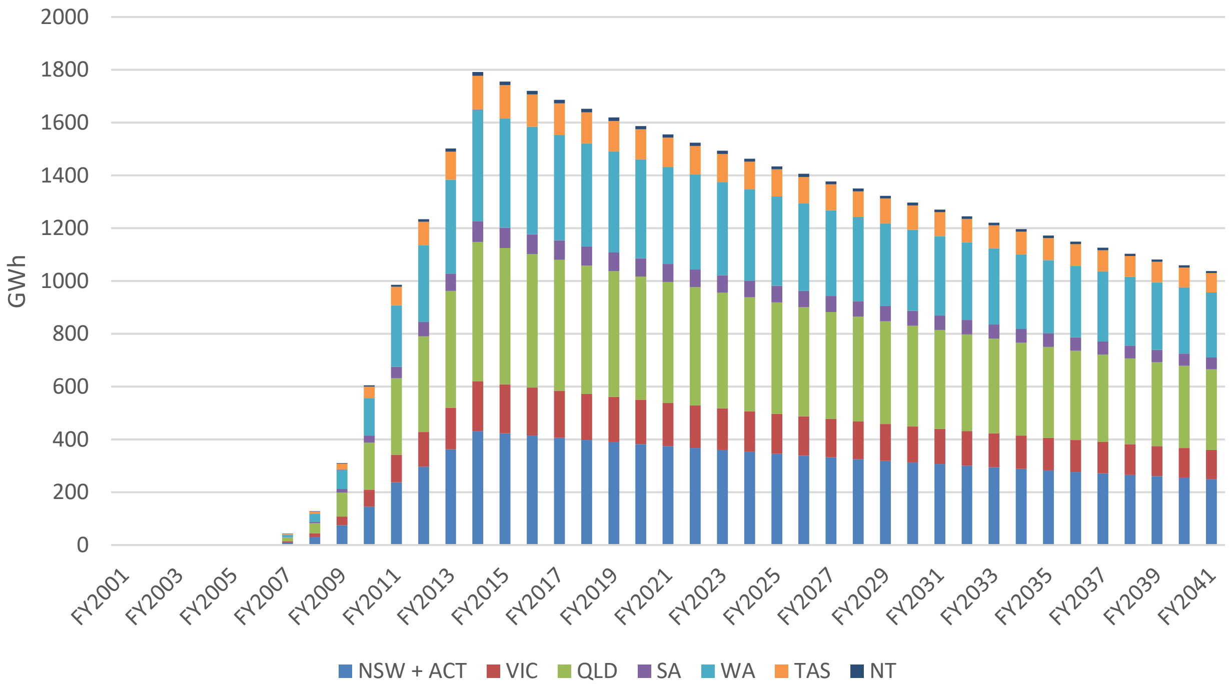
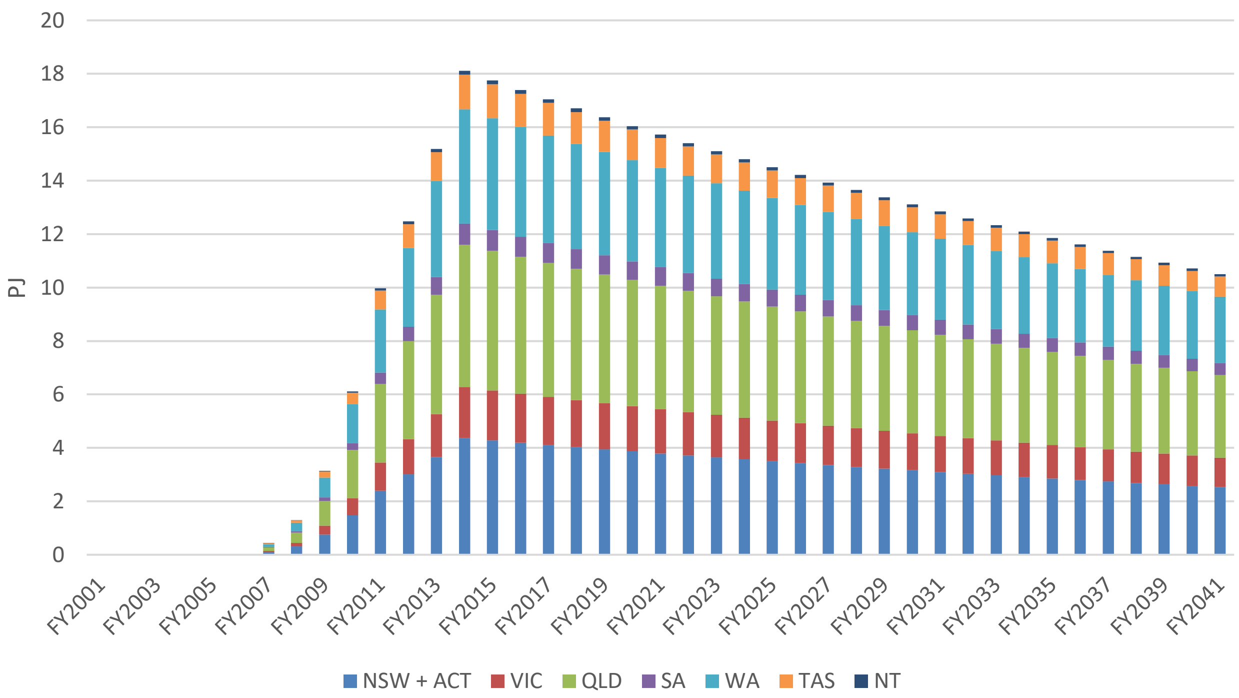


Figure 87: Energy Efficiency Opportunities Program Industrial Sector Gas Savings (Neutral Scenario)



Appendix D: Greenhouse and Energy Minimum Standards – Detailed Analysis

Changes in past year

The impact estimates for the programs in Table 18 have changed since last year. The adjustments have been downwards, with the exception of Program 30, and most have related to programs that are in train or possible. However, the impact of the air conditioner MEPS implemented in 2011 has also been revised downward. The reasons for the changes are covered in the following sections.

Table 18: Programs with Impact Estimates Changed over the Past Year

Program #	Program Description	Adjustment
22-23	Electric, solar-electric and heat pump water heaters	Reduce impacts
24A	Air conditioners – Res MEPS 2011	Reduce impacts
25A	Air conditioners – Non-Res MEPS 2011	Reduce impacts
30	Swimming pool pump-units labelling and MEPS (now projected to start FY 2021)	Increase impacts
34	AC Chillers – MEPS 2017 (now no start date)	Change status from In train to Possible; delay impact
35A	Air conditioners – Res MEPS 2017 (now MEPS 2021) (a)	Delay and reduce impacts
35C	Air conditioners – Non-Res MEPS 2017 (now MEPS 2022) (a)	Change status from Implemented to In train; Delay and reduce impacts
38	Motors – MEPS 2017	Change status from Suspended to In train
42	Commercial refrigeration – MEPS 2015 (now MEPS 2021) (a)	Delay impacts
56-59	Process & Industrial Equipment Fan-units	Delay impacts

Post-implementation indicators

Full impact evaluations of E3 measures after they have been in place for some years, as distinct from projections, are rare. Only two have been done, for refrigerators and freezers (Harrington & Lane 2010) and for residential air conditioners (EnergyConsult 2010). These indicated that the prior impact estimates were conservative, which lead to the subsequent upward revision of impact estimates (E3 2011).

However, one indicator of program effectiveness is compliance by suppliers. If suppliers do not register products, there is no way of checking whether they comply with the required MEPS. In addition, if a significant share of products remains unlabelled, consumers will find it harder to exercise preference for more efficient models.

Table 19 summarises the share of residential product models found to be unregistered in random store surveys. Non-registration rates were consistently low for whitegoods, televisions and air conditioners, and somewhat higher for computer monitors. However, the only data point for lamps (2013) showed a high rate of non-registration.

Table 19: Registration non-compliance rates, selected products

Products	% of models without valid registration						
	2009	**2011**	**2013**	**2015-16**	**2016-17**	**2017**	**2017-18**
Refrigerators & freezers	NSR	NS	NS	3.0%	3.2%	2.6%	2.4%
Clothes washers (a)	NSR	NS	NS	0.8%	1.7%	3.9%	1.1%
Clothes dryers	NSR	NS	NS	0.8%	1.0%	0%	0.6%
Dishwashers	NSR	NS	NS	5.2%	1.9%	2.7%	2.1%
Whitegoods (all of above)	0.6%	NS	NS	2.4%	2.2%	2.6%	1.8%
Televisions	NS	1.8%	NS	0%	1.7%	1.2%	2.8%
Computer monitors	NS	NS	NS	16.7%	13.7%	4.2%	7.3%
Air conditioners	1.1%	NS	NS	3.2%	7.0%	0%	2.8%
Compact fluorescent lamps	NS	NS	22.4%	NA	NA	NA	NA
Linear fluorescent lamps	NS	NS	16.0%	NA	NA	NA	NA
Incandescent lamps	NS	NS	26.8%	NA	NA	NA	NA
Number of units examined	27,966	5,140	1,203	2,768	3,591	416	4,337

Sources: Australian Refrigeration Council (2009), E3 (2013a), Department of the Environment and Energy (2016, 2018a, 2018b), GEMS (2018). Notes: NS = Not surveyed this year. NSR = Not separately reported. (a) Includes washer-dryers.

Table 20 shows the share of displayed products that were correctly labelled. The ratio is consistently around 90% for whitegoods and seems be improving for computer monitors (with the caution that the latest survey had much smaller sample sizes). However, the "correct labelling" ratio seems stubbornly low for televisions. Apparently, the main cause is the understandable desire of sales staff and customers to see an unobstructed screen in the showroom, so labels adhered to the screen are removed. Although the labelling rules permit labels to be presented as swing tags or fixed by their edge, the trend in television design is to minimise the dimensions of edges and frames around the screen, so there is less and less non-screen surface for label attachment. This would indicate that labelling has less of an impact on the television market, and this has been taken into account by modifying the energy impact projections for televisions.

Table 20: Labelling compliance rates, selected products

Products	% of models correctly labelled		
	2015-16	**2016-17**	**2017**
Refrigerators & freezers	95%	86%	90%
Clothes washers (a)	97%	94%	85%
Clothes dryers	95%	88%	94%
Dishwashers	92%	83%	77%
Whitegoods (all of above)	92%	87%	88%
Televisions	61%	48%	55%

Products	% of models correctly labelled		
Computer monitors	35%	37%	83%
Air conditioners	93%	74%	82%
Number of units examined	2,347	3,367	423

Televisions and image processing

Televisions were first subject to energy labelling in 2009 and MEPS in 2010 (Program 6). Products are tested and labelled in accordance with AS/NZS 62087. This was the first use of the additional 7 to 10 star 'super-efficient coronet' option on the label. The rate of increase in efficiency was so rapid (most likely due to underestimates of technical developments already under way) that the scheme was revised in 2013 (Program 40). The label scales were changed so that a product with the same level of efficiency scored three fewer stars, and the MEPS levels were made more stringent (the so-called 'Tier 2' MEPS, equal to the original 4 star line).

TVs fall into distinct efficiency groups:

- Cathode ray tube (CRT) televisions, which are the least efficient. These disappeared from the market after 2014;
- Liquid crystal display (LCD) televisions, which used about 40% less energy per cm2 of screen area than CRT models in 2014. These have since improved so they now have less than half the energy intensity of 4 years ago, although some of this is due to larger average screen sizes (see Figure 1 and Figure 2);
- LCD with light emitting diode backlighting (LCD/LED models). These are now the most common types, and also the most energy-efficient;
- LCD with organic LEDs (LCD/OLED models). These use 10-20% more energy than LCD/LED for a similar screen size;
- Plasma models, which use 30-50% more energy than LCD/LED for a similar screen size. Plasmas were the first technology to offer large screen areas with high brightness, but these attributes can now be met by LCD/LED types, so the number of plasma models on the market has fallen sharply. No plasma TVs have been registered since 2014, so this technology can now be regarded as obsolete.

The introduction of MEPS and energy labelling coincided with major changes in the TV market:

- The phase-out of CRT models in favour of flat screen technologies, hastened by the end of analogue broadcasting, a fall in new model costs due to the high Australian dollar and sustained growth in household disposable incomes;
- The trend toward the most efficient category of flat screen products (i.e. LCD/LED), which increased from 55% to 85% of models listed;
- Lower standby power consumption;

- The availability of alternative screens (e.g. tablets, computer screens and games consoles) for some forms of home entertainment, possibly reducing the viewing hours for televisions;
- The trend to larger screen sizes, which partly counteracted the energy savings from the other factors. Between 2014 and 2018, the average screen size of the models on the market (i.e. all models on the register in those years, irrespective of year of registration) increased by 22% while energy intensity (W per cm2) fell by 41%.

Figure 88: Average screen size by year of registration for televisions

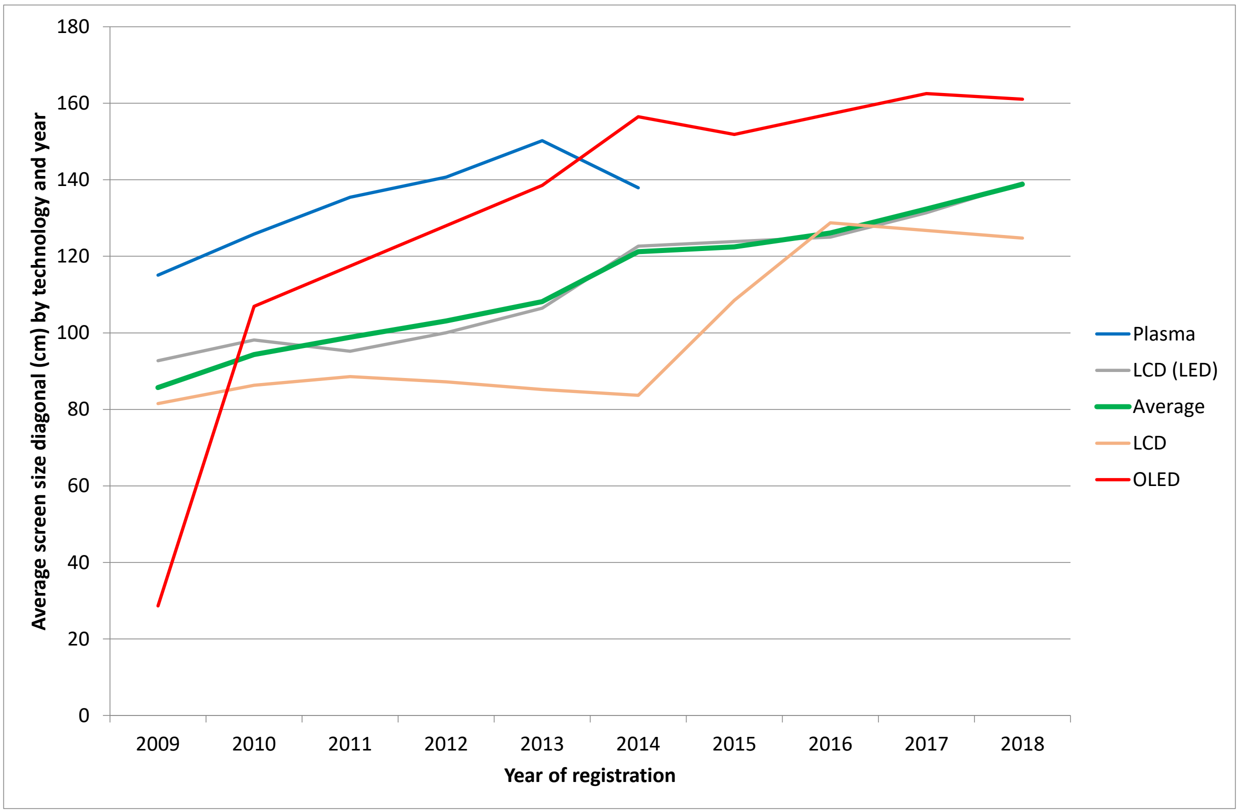
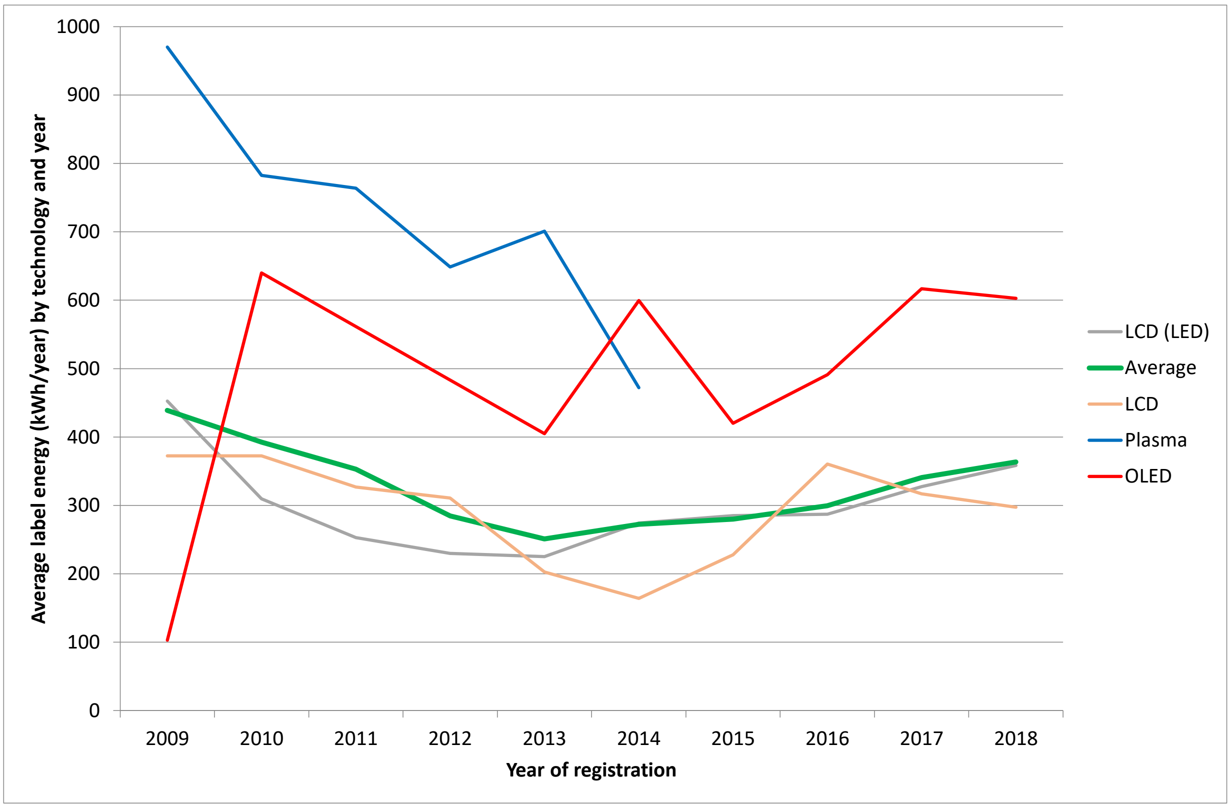


Figure 89: Average label energy by year of registration for televisions



Source: Energy labelling and MEPS registration database

Some of the apparent increase in efficiency would have been due to the increase in screen size (since the fixed energy of tuners etc. is distributed across a greater screen area) and some to technical improvement. Most of the improvement in efficiency has been taken up in greater screen size and the transition to higher definition image quality – the model-weighted energy use (on the label cycle) fell by only 8.5%, from 317 to 290 kWh/year.

The extent to which the MEPS and labelling programs accelerated the reduction in average energy use per TV is uncertain, given these factors. All televisions are imported, so technical improvements under way in the global market would most likely have found their way to Australia in any case. The extent to which the process was accelerated by the impact of E3 programs on suppliers (who would have been motivated to import more efficient products than otherwise) and on consumers (who would have been motivated to prefer the more efficient of what was on the market) is uncertain.

It was widely acknowledged that the energy saving projections in the original estimates (E3 2009b) were significantly over-estimated, and the later E3 projections (E3 2014a) use significantly lower impact projections than in the RIS. The relatively low compliance rates for television energy labelling Figure 89 indicates that the assumptions of a reduced impact were justified and are now also extended to the post-2014 impacts.

The trend to larger screen sizes may saturate, since viewing distance from the screen is partly limited by room dimensions. The average floor area of new houses appears to have reached a limit and more households are living in apartments. On the other hand, higher screen resolution technologies such as 4K, require more energy, so if take-up increases, then the rate of energy growth may be steeper. Whether this could be counteracted by increasing MEPS and raising the effectiveness of energy labelling is a matter for government. Many new televisions have automatic brightness control (ABC) which changes the screen brightness according to illuminance levels on the room. This can reduce energy consumption by as much as 50% during the evening in normal use. However, the test method to assess this technology for energy labelling has not yet been implemented and no energy saving estimates for ABC have been included in this report.

The traditional image transmission pathways are free-to-air broadcast (terrestrial and satellite), subscription (cable and satellite) and image recording and play back media (videotapes and then DVDs). These involve other devices connected to the television, each with its own energy demand.

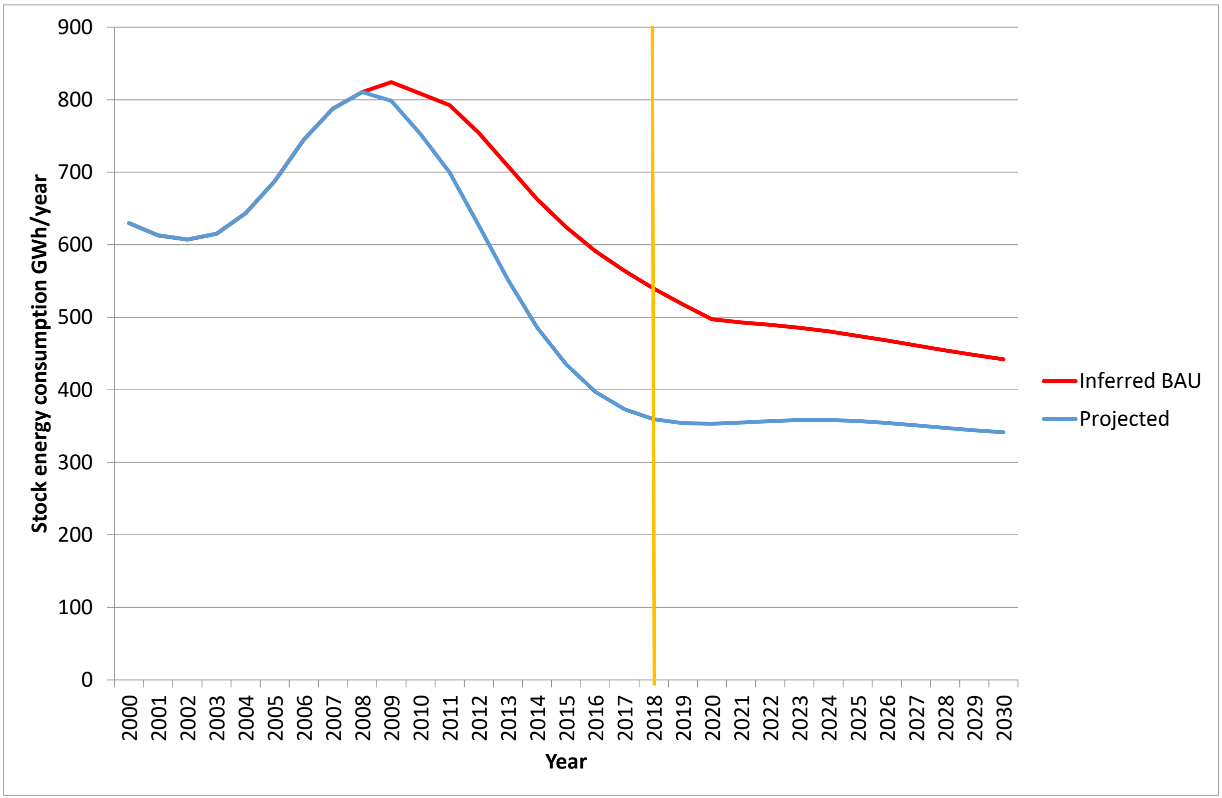
Ownership of image recording and playback devices (video cassette recorders and DVD players) is nearly universal, but actual use has fallen away with the collapse of the video rental and sales industry (although most homes retain them to play legacy collections of media). Subscription services provide users with subscription set top boxes (SSTBs) which process and decode the provider's signals (whether delivered by coaxial cable, copper or satellite) and also have a program storage and playback capability. The number of subscribers to the largest remaining service (Foxtel) peaked in 2016 at around 2.8 million and is now declining slowly. Estimates of the number of Netflix subscribers in Australia vary from about 4 million to 7.6 million.

Foxtel's subscriber numbers are likely to be maintained by its retention of rights to live sporting events. Although some of the content is now delivered to consumers by video streaming over internet rather than through dedicated cable, Foxtel still requires the installation of a separate proprietary SSTB. Netflix and the free to air (FTA) channel video on demand services use the home Wifi router.

Free-to-air set top boxes (FTA STBs) were introduced in 2010 to enable older televisions with analogue signal tuners to receive digital signals during the transition to digital-only broadcasting. The last analogue signal was switched off at the end of 2013. The changeover was accompanied by the introduction of flat-screen televisions with integrated digital tuners, so the number of FTA STBs in use is falling as old CRT televisions are replaced.

E3 introduced MEPS for STBs of both types in 2009 (Program 7). Figure 90 illustrates the projected energy use without and with the impact of STB MEPS. Energy use would have declined, even without the E3 measures, due to the retirement of image recorders and FTA STBs. The sharp decline in STB energy between 2008 and 2017 corresponds to the retirement of FTA STBs as consumers acquired new digital-capable televisions. The flattened trend after 2017 assumes that SSTB use will remain more or less constant. For the present, this is supported by steady cable service subscriber numbers, but could drop if more live sports events migrate to general as distinct from proprietary video streaming delivery.

Figure 90: Electricity use by set top boxes and image recorders, Australia



Residential air conditioners

Air conditioners have been energy labelled since 1987. The first MEPS were phased in between October 2004 and increased between April 2006 and October 2007 (different product types on different dates). The energy label was regraded in 2010 and MEPS were applied to the heating function (E3 2008a, 2009c) and expanded to non-operating (standby) energy. The energy label scale was also changed to permit up to 10 stars to be displayed (E3 2011). Between April 2010 and October 2011, MEPS were increased again in several steps.

Another group of changes was proposed in 2016 (E3 2016a). These included:

- Basing MEPS for products up to 30kW cooling capacity on Seasonal Energy Efficiency Ratings (SEER) rather than on fixed rating points
- Replacing the existing energy label design with a climate-zoned energy label
- Including portable units in the scheme for the first time
- Extending the scheme to air conditioners of greater than 65kW cooling capacity

- Increasing the MEPS levels for chillers and adding smaller chillers (<350 kW) to the scheme.

These measures were delayed pending further consultations with industry. A set of revised proposals was published in late 2016 (E3 2016b), and a Decision RIS was published in 2018 (E3 2018a). The Decision RIS also included lower estimates of the impacts of the 2011 MEPS. The final proposals modified the original proposals in a number of ways:

- Mandatory physical energy labels will only be required for products that must be energy labelled at present (the original proposal would have expanded the scope somewhat). Other products must have their rating shown on the website;
- A new "zoned" label format will be introduced. This will indicate energy efficiency in tropical, temperate and cold climate zones separately, using a linear 10-star scale (as distinct from the current arched 6-plus-4 star scale);
- For portable air conditioners, the proposed MEPS levels is reduced from an energy efficiency ratio (EER) of 2.6 to 2.5;
- Chillers were removed from the proposal, pending further consultations.

A GEMS Determination has now been published (GEMS 2019). Given the lead times implementation, the measures will first impact on the market in 2021 (for residential air conditioners) and FY 2022 (for commercial units).

Lighting

The first E3 lighting programs targeted fluorescent lighting technologies. MEPS for ballasts were introduced in 2001 (E3 2001) and efficacy standards for linear fluorescent lamps (LFLs) were implemented in 2004. The latter led to the exclusion of all LFLs other than tri-phosphor types. The energy saving estimates assume that some of the initial benefits of higher efficacy LFLs were taken as greater light output, because when existing fittings are re-lamped, a brighter LFL is substituted for another of the same wattage. As new lighting installations are installed over time, the luminaire spacing can be increased, so reducing the energy density per unit of floor area.

The second round of lighting programs targeted single-socket GLS lamps, with the aim of phasing out tungsten filament lamps (E3 2008b). Part of this strategy was based on encouraging the adoption of compact fluorescent lamps (CFLs), which were also heavily promoted by State programs. As the effects of these drivers are difficult to disaggregate, the impacts of are covered together in Chapter 3, together with the introduction of MEPS for low voltage (LV) transformers under AS/NZS4879.2. The impact of this program has been included in Chapter 3 and is likely to be declining rapidly as mains voltage LED downlights substitute for LV halogens.

The following policy options for commercial lighting were set out in a broad proposal for commercial lighting MEPS (E3 2015):

- Update fluorescent lamp ballast test methods and MEPS levels;

- Increase LFL efficacy levels;
- Introduce standards for circular fluorescent lamps;
- Introduce MEPS for luminaires.

In the latest policy update (E3 2017b), there are no measures targeting fluorescent lamp technologies, probably because suppliers have switched development efforts to LEDs, which are coming to dominate the commercial lighting market even more than the residential. The ballasts market has largely changed from ferromagnetic to electronic designs, which are inherently more energy efficient.

Household refrigerators

Energy labelling for refrigerators and freezers was introduced in NSW and Victoria in 1986 and nationally in 1992. Revisions of the energy labelling algorithm led to re-scaling of the labels in 2000 and again in 2010. MEPS were first introduced in October 1999 and made more stringent again in 2005, to match US 2001 MEPS levels. Program 1 covers all measures from 1986 to 2005. The MEPS definitions were adjusted in 2010, but this did not increase their stringency.

By 2017, the average energy consumption (kWh per year) of refrigerators and freezers was about 52% of the 1993 levels (E3 2017c). Given that average volumes had increased, the average energy efficiency (kWh per adjusted litre) had increased by over 80% (Energy Efficient Strategies 2016). Nearly all of this improvement occurred between 1996 and 2005, coinciding with MEPS changes.

Proposals to increase Australian MEPS levels again, to match those announced for the US in 2014, were first discussed by E3 in 2011, with the aim of introducing them in 2015 (Harrington & Brown 2012). The planned implementation (Program 39) was later delayed to 2017. In 2017 E3 published a Consultation RIS (E3 2017d) and then a Decision RIS (E3 2017c), which COAG Energy Council accepted. The target implementation date is now January 2021. However, the Decision RIS, which used the latest data, found that Australian suppliers responded to the 2012 announcement and that average efficiency was already increasing at the same rate as if implementation had occurred in 2015 as originally planned.

A draft GEMS Determination has now been published (GEMS 2018b), indicating the implementation timetable is on track.

Commercial refrigeration

Australia and New Zealand introduced MEPS and high efficiency performance standards (HEPS) for refrigerated display cabinets in 2004, as specified in AS1731. The potential for further measures was investigated by the E3 Committee in 2009, in 2013 (E3 2013b) and then again in 2017 (E3 2017e). The options included more stringent MEPS levels and alignment of the AS1731 test standards with ISO23953, which were in draft at the time (this was published in 2015, so removing one potential barrier to implementing new measures).

A guide to the proposals published in 2018 (GEMS 2018a) confirmed that they were essentially unchanged, and a draft GEMS Determination has now been published (GEMS 2018c), indicating that implementation is on track to take effect in FY 2021.

Swimming Pool Pumps

In households with a pool, the pump-unit typically uses 1,500 to 1,800 kWh/year, making it the largest single consumer of electricity after the electric water heater (where one is present). A test and labelling standard for pool pump-units, AS5102, developed at the request of E3, was published in 2009. There are three main technology groups on the market – single-speed, dual/multi-speed and variable-speed. Variable speed pumps as a group are the most energy-efficient, since they can adapt flow rates as required and use the lowest pump speed for each situation. However, single-speed pumps are much cheaper to buy and are preferred by price-sensitive buyers, even if their lifetime costs are higher. There is a range in efficiency within each pump type, so it is not necessary to force buyers to a more expensive type to make energy savings.

In April 2010, E3 introduced a voluntary energy labelling scheme in order to motivate buyers to prefer more efficient models. This was only a limited success, since suppliers chose to label only their most efficient models. There is a 10 star rating scale (the basic 6 plus up to 4 more for a 'super-efficient' model). At present there are 54 models registered for voluntary labelling – 1 model at 10 stars, 8 models at 9 stars, 28 models at 8 stars, 7 models at 7 stars, 7 models at 6 stars and 3 models at 5.5 stars. This is clearly unrepresentative of the efficiency distribution of all the models on the market, which is typically 2 to 3 stars.

The DEE estimates that the models registered for the voluntary labelling scheme make up about a quarter of all pump-units sold (E3 2016c)(p 23). This leaves the majority of the market untouched by energy efficiency measures. E3 first proposed MEPS and mandatory energy labelling for pumps in 2010, but the project was shelved in 2013. It has now been revived, with the publication of Consultation RIS in late 2016 (E3 2016c). Following nearly a year of industry consultations, it now appears that the scheme will be implemented in 2020 (E3 2017f).

The RIS estimated the impacts of various options – mandatory labelling alone, and with three levels of MEPS: low-level (with products rating less than 2 stars excluded), medium-level (4 stars) and high-level (5.5 stars, so eliminating single-speed pumps). The Decision RIS published in 2018 recommended starting with labelling and low-level MEPS in FY 2021, moving to mid-level MEPS after two years (E3 2018b). The modelling in the Decision RIS projected higher energy savings than in the Consultation RIS.

Water Heating

E3 has not implemented any new measures for water heaters using electricity since 2005, when the MEPS recommended for small water heaters in 1996 were finally implemented and heat exchange systems were included in the scope. There was some activity in 2013, with the publication of Consultation RISs proposing MEPS for heat pump water heaters (E3 2013c) and more stringent heat loss MEPS for all tanks used in electric systems (E3 2013d). In 2014, E3 published a product profile raising the possibility of MEPS or labelling for solar water heaters, covering the efficiency of collectors and circulation pumps (E3 2014b).

These programs were all suspended following the change of federal government in 2013. In 2018 however, E3 published a ''Policy Framework'' (E3 2018) for water heaters. This introduced a set of "principles, including:

- Moving all water heater types to a "new method of testing that is technology neutral, to enable direct and fair comparisons between technologies, and to make it possible to develop a technology neutral MEPS in future"
- Implementing energy efficiency measures (MEPS and labelling) across all hot water technologies.

The Policy Framework includes some preliminary impact estimates, which are less than half the estimates included for new water heater measures (programs 22 and 23 in Table 1). These have been adjusted downward accordingly. The first feasible year of impact would be FY 2021.

The Federal government operates the Small-scale Renewable Energy Scheme, which allows users to earn Small Scale Technology Certificates (STCs, also called Renewable Energy Certificates or RECs) when a solar water heater or heat pump water heater is installed. RECs are a tradeable item that can be sold. This is part of the national Renewable Energy Target (RET). ACT and NSW have requirements under their local regulations (BASIX in NSW and BCA in the ACT) that restrict the type of water heater that can be installed in a new residential dwelling, so RECs are not always additional relative to the base case. The operation of these schemes is factored into the base case for water heating.

Fan-Units

A fan-unit is the combination of an electric motor and a fan or impeller, intended for the purpose of moving air. There is a vast range of sizes and capacities on the market, from a few watts (e.g. for circulating cold air in domestic frost-free refrigerators) to hundreds of kW (e.g. for moving air through the HVAC ducts of large buildings).

The energy efficiency of a fan-unit is the ratio of the power output from the fan to the electrical power input of the motor driving the fan. The energy efficiency of a fan-unit varies over its operating range, defined by the air pressure against which the fan operates and the air flow rate.

As with electric motors, fan-units are a basic component of many types of industrial equipment and domestic appliances. This complicates the supply chain, as the fan-unit manufacturer or importer may supply to either an original equipment manufacturer (OEM), an installer, an assembler or (more rarely) direct to the end user.

If the fan-unit is powered by a 3-phase cage-induction electric motor with output in the range 0.73 kW to 185 kW, then the motor is already subject to MEPS. However, this does not guarantee the performance of the fan-unit as a whole if the fan and its housing are poorly designed. Conversely, many fan-units are installed in products that are themselves subject to MEPS, such as packaged air conditioners.

Fans-units are the first product in the category "process and industrial equipment" (program 56-59 in Table 1) to be fully analysed (E3 2017g). The current proposal is:

- No energy efficiency regulation for fan-units incorporated into products whose overall performance is subject to MEPS (currently, only air conditioners are in this category);
- Fan-units incorporated into all other products (except gas ducted heaters) would be subject to MEPS (provided the motor has an output power of 0.125 to 185 kW);
- Fan-units sold as individual units would not be subject to MEPS;
- MEPS would not be applied to fan-units incorporated into gas ducted heaters. These products would be required to carry an electrical energy rating label. The electricity consumption reported on the label, and used to derive the rating, is largely determined by the energy use of the main air circulation fan.

There would some energy savings impact on the residential sector through MEPS for fan-units in evaporative coolers, and energy labelling (not MEPS) for fan-units in ducted gas heaters. There would also be some use of larger fans in manufacturing, mining and other industrial applications. However, the great majority of the impact is expected to be in the commercial sector (building HVAC and cold storage).

There is no new information on this program, but given the passage of time the earliest feasible implementation date has slipped a year to FY2021.

Electric Motors

The proposed changes in MEPS levels (program 38) were previously classified as suspended, but with the publication of a draft GEMS determination (GEMS 2018d) they have been reclassified as in train. given the passage of time the earliest feasible implementation date has slipped a year to FY 2021.

Contact

Philip Harrington

philip_harrington@strategypolicyresearch.com.au

0419 106 449

Strategy. Policy. Research. Pty Ltd

ABN 38 615 039 864

www.strategypolicyresearch.com.au