IMPACT OF MINIMUM PERFORMANCE REQUIREMENTS FOR CLASS 1 BUILDINGS IN VICTORIA

AUSTRALIAN
Greenhouse
Office

The lead Commonwealth agency on greenhouse matters

SUSTAINABLE
ENERGY
AUTHORITY

ISBN 1 876536 44 6

For additional copies of this document, please contact the Australian Greenhouse Office Infoline on 1300 130 606.

This publication is also available on the Internet at the following address:
www.greenhouse.gov.au/energyefficiency/buildings

Acknowledgments

The information presented here has been provided by Energy Efficient Strategies for the Australian Greenhouse Office. While every effort has been made to ensure accuracy and completeness, no guarantee is given, nor responsibility taken by the Commonwealth for errors or omissions in the report, and the Commonwealth does not accept responsibility in respect of any information or advice given in relation to or as a consequence of anything contained here.

The Australian Greenhouse Office also wishes to acknowledge the support of the Sustainable Energy Authority of Victoria for co-funding *Impact of Minimum Energy Performance Requirements for Class 1 Buildings in Victoria.*

Design Wingrove Wingrove Design
Photos courtesy of the Housing Industry Association, Michael Shaw and Mirvac Lend Lease Village Consortium - Developers of Newington, the Sydney 2000 Olympic Village.
Background Image: courtesy of Robert Peck von Hartel Trethowan

CONTENTS

LIST OF FIGURES

LIST OF TABLES

ABBREVIATIONS

ABCB	Australian Building Codes Board
ABEC	Australian Building Energy council
ABM	Australian Bureau of Meteorology
ABS	Australian Bureau of Statistics
AGO	Australian Greenhouse Office
BAU	Business-as-Usual
BCA	Building Code of Australia
BCC	Building Control Commission, Victoria
DITR	Department of Industry, Technology and Resources
EES	Energy Efficient Strategies Proprietory Limited
EEV	Energy Efficiency Victoria (now known as SEA)
GFCV	Gas and Fuel Corporation of Victoria
GWA	George Wilkenfeld and Associates
HERS	House Energy Rating Scheme
LGA	Local Government Area
NatHERS	Nationwide House Energy Rating Scheme
NRE	Natural Resources and Environment, Victoria
SEA	Sustainable Energy Authority (formerly EEV)
SECV	State Electricity Commission of Victoria
VBR	Victorian Building Regulations
ISR	Commonwealth Department of Industry, Science and Resources

SECTION ONE
INTRODUCTION

SECTION 1 INTRODUCTION

1.1 Review of the Brief

1.1.1 Background

In his Statement of 20 November 1997, "Safeguarding the Future: Australia's Response to Climate Change", the Prime Minister announced a $180 million package of measures to reduce Australia's greenhouse gas emissions.

For the building sector, the Prime Minister's Statement specified:

> *"The Commonwealth will work with the States, Territories and key industry stakeholders to develop voluntary minimum energy performance standards for new and substantially refurbished commercial buildings on the basis of energy efficiency benchmarks. If after 12 months, the Government assesses that the voluntary approach is not achieving acceptable progress towards higher standards of energy efficiency for housing and commercial buildings, we will work with the States and industry to implement mandatory standards through amendment of the Building Code of Australia."*

The Prime Minister noted that this package of measures was designed both to ensure that Australia plays its part in the global effort required to reduce greenhouse gas emissions and to protect Australian jobs and industry. The Government is therefore seeking "realistic, cost-effective reductions in key sectors where emissions are high or growing strongly, while also fairly spreading the burden of action across the economy". The Prime Minister also noted that "[The Government is] prepared to ask industry to do more than they may otherwise be prepared to do, that is, to go beyond a "no regrets", minimal cost approach where this is sensible in order to achieve effective and meaningful outcomes".

Subsequent negotiations resulted in the Kyoto Protocol to the Framework Convention on Climate Change, under which Australia will have a target to reduce its rate of greenhouse gas emissions to 108% of its 1990 level by 2008-2012. This compares with a business-as-usual scenario prior to the Prime Minister's Statement of 28 per cent emissions growth for the economy as a whole, and around 50 per cent for energy-related emissions from buildings.

As a response to the Prime Minister's statement, members of the building industry formed the Australian Building Energy Council (ABEC), a peak body established to draw together views from a broad cross-section of building industry organisations (including architects, engineers, builders and property managers). On 16 December 1998 the ABEC Interim Board wrote to the Minister for the Environment and Heritage, Senator Robert Hill, supporting the need for a combination of mandatory and voluntary initiatives.

To assist in informing the process of selecting appropriate greenhouse gas abatement measures for implementation within the building industry, the AGO, again with cooperation from the building industry as well as the Australian Building Codes Board (ABCB), agreed to examine the impact and effectiveness of existing mandatory minimum energy performance measures, and in particular requirements within the Building Code of Australia (BCA) for Class 1 buildings in Victoria.

The Commonwealth Government, State and Territory Governments, ABCB, the building industry and the general public will have an opportunity to consider the outcome of this study in the context of overall greenhouse strategies.

1.1.2 Project Aims and Objectives

The overall objective of this study as stated in the brief is to examine the effectiveness of the legislation on the reduction of energy used to maintain building user comfort, and therefore its effect on the reduction of greenhouse gas emissions.

The study is designed to articulate, concisely and quantitatively, the impact of building energy performance legislation in Victoria for Class 1 buildings with respect to:

- the likely annual energy consumption
- the likely annual emissions of greenhouse gases
- the construction techniques and building materials
- the application of solar passive design

The study was also required to identify any factors, other than building energy performance legislation, that may have contributed to any change in energy and greenhouse performance of new Class 1 buildings in Victoria from 1990 to 2000.

1.1.3 Project Scope and Related Issues

The scope of this study is limited to building activity within the state of Victoria between the years 1990 and 1999 (or more precisely between the start of the 1989-90 financial year and the end of the 1998-99 financial year). The original scope (as included in the brief) contained a requirement to assess building activity in 1990, 1995 and 2000. It was agreed by the steering committee that in terms of trends in construction techniques, the time frame was relatively short and that resources would be better used by focusing the study on the first and last years only. By assessing two instead of three years it was possible to select a larger sample from each of those years and thereby improve the reliability of the results. As statistics on housing activity were only available up until the end of the 1998-99 financial year, an assessment of the position in the year 2000 was therefore not possible.

This report covers energy consumption and greenhouse gas emissions from the following building classifications as defined in the Building Code of Australia:

- Class 1a(i) – detached houses
- Class 1a(ii) – attached dwellings (including town houses, terrace houses and villas)

A third classification under Class 1 is Class 1b. This classification includes small boarding houses (for the accommodation of 12 or less persons). The most common form of small boarding house is likely to be in the form of bed and breakfast establishments which are often developed as renovations to existing houses, rather than as new purpose built developments. Neither the ABS nor the BCC (through its "Basis" Database) could provide any meaningful statistics on this sector of the market. This sector is known to account for only a very small portion of Class 1 buildings in Victoria and as such would be statistically insignificant. In consideration of the lack of data and the statistical insignificance of this sector it was decided, with steering committee approval, to exclude this building type from the study.

The brief for this study did not explicitly include alterations and additions to existing Class 1 buildings within the scope of this study. However, the inclusion of this sector of the market was considered by the steering committee as important. Under the provisions of the Building Code of Australia, additions to existing buildings must be constructed in accordance with the current provisions of the code including those provisions relating to thermal performance. Additions to existing housing constituted a significant proportion of the building activity in Victoria over the study period (estimated to account for approximately 20% of all floor area added per annum). Consequently the study of the impact of the Victorian legislation needed to include this sector of the market.

The brief for this project refers to the impacts of the Performance Provisions of the BCA in Victoria, which states that “A building must have an adequate level of thermal performance to ensure efficient use of energy for internal heating and cooling.”

Whilst a thermal performance requirement is specified in the code, in practice this method of compliance is rarely used (it is believed that less than 1% of approvals use this method of compliance). Overwhelmingly it is the alternative Acceptable Construction Practice prescriptive R level provisions of the code that have been adopted by industry in Victoria.

The analysis contained within this study is based upon these minimum insulation provisions rather than the thermal performance requirement (minimum star rating). Whilst the term "Deemed-to-Satisfy" is used in the code, it should be understood that the application of the Deemed-to-Satisfy minimum thermal insulation requirements would not necessarily equate to the performance requirements of the code (ie. minimum three stars) – part of the methodology for this study is to quantify the difference between "Deemed-to-Satisfy" minimum insulation measures and thermal performance requirements.

The initial budget for this project was augmented by Energy Efficiency Victoria (now the Sustainable Energy Authority of Victoria). This added contribution was used to expand the size of the 1999 sample and thereby improve the accuracy of the estimates for that year.

Greenhouse gas emissions embodied in construction materials and emissions associated with the construction, maintenance or demolition process are not covered in this report.

1.2 Approach to the Project

The primary method of analysis was based upon the selection and analysis of samples of Class 1 buildings constructed immediately prior to the introduction of thermal performance regulations in Victoria (1990) compared with a similar analysis of Class 1 buildings built in the latest calendar year (1999). The analysis also examined the secondary impact on energy performance of trends on design, materials and house size on energy efficiency.

An overview of the methodology adopted is described in Figure 1 below. Detailed descriptions of the methods adopted can be found in the sections noted adjacent to each task in the process diagram.

The first task involved the selection of a representative sample of Class 1 building plans from each era. ABS building activity data was used to identify local government areas (LGAs) with significant levels of building activity suitable for sampling. In addition to six LGAs within the Melbourne metropolitan area, two regional LGAs were included in the selection on the basis that they represented the only other climatic regions with significant levels of Class 1 building activity within the state apart from that of Melbourne's. A sample stratified into various construction types was then selected at random from the council records of each selected LGA.

Following sample selection, the selected plans were assessed for thermal performance using the *FirstRate* modelling software developed by SEA. The required input for the software was not always available from the sample plans. To deal with these short comings, a set of assumptions was developed for such cases.

Some of the assumptions made were based upon experience, some on findings of related studies, whilst others were based on surveys conducted specifically for this study. The groups surveyed specifically for this study included:

- council building surveyors regarding building practice and regulatory compliance
- insulation manufacturers regarding industry practice pre and post regulation
- window and glazing manufacturers regarding use of high performance glazing and frames

Apart from the BAU case as discerned from the sample and related research, plans were also modelled using a range of insulation options as well as a range of other performance cases as follows:

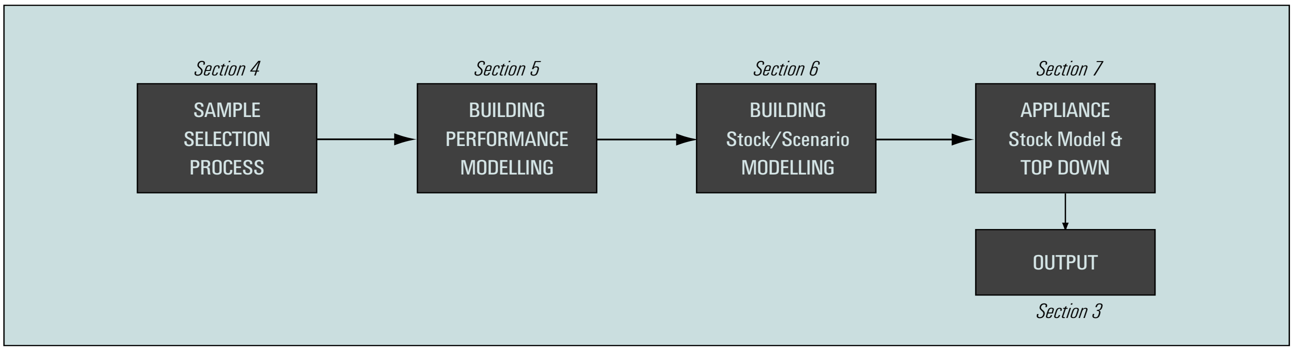
- no insulation
- insulation compliant with BCA minimum requirements (Base Case)
- insulation compliant with BCA minimum requirements post 1998 (Base Case post 1998 – see Section 2.1 for an explanation of the change post 1998)
- ceiling only insulation
- under compliant level of insulation
- over compliant level of insulation
- performance based housing design (ie. star rated)
- double glazing (low-e) combined with other options

Results from the performance modelling for the two sample years were then subjected to linear interpolation to determine performance levels in the intervening years based on the number and type of houses built in Victoria during that period. These results were also weighted to account for the changing proportions of houses built in the various climate zones over the study period.

The results of the performance modelling were then used as one of the inputs into a model of stock produced since 1990. The stock model consisted of two parallel models; one for detached housing accounting for approximately 90% of floor area produced and one for attached housing accounting for the remainder. The stock model for detached housing was developed from the level of construction type as follows:

- lightweight construction with a timber floor
- lightweight construction with a concrete floor
- brick Veneer construction with a timber floor
- brick Veneer construction with a concrete floor
- cavity Brick construction with a timber floor
- cavity Brick construction with a concrete floor

Figure 1 Overview of Study Methodology – Process Diagram



The stock model accounted for additions of new stock (ie. post regulation), alterations to existing stock and retirement of stock (ie. demolition of post regulation stock – assumed to be zero for buildings constructed in the past 10 years for the purposes of this project). The practice of retro fitting of insulation into ceiling spaces of post regulation stock was also modelled for that portion of the added stock that had no ceiling insulation fitted during construction[1]. The model estimated floor area at the level of construction type then multiplied this by the thermal efficiency estimates derived from the thermal performance modelling phase.

The output from the stock model was in the form of unconstrained heating and cooling estimates[2]. These estimates were then constrained by taking into account the following factors:

- the penetration of the various heating and cooling technologies
- the characteristics including average efficiency conversion factors associated with each technology
- user behaviour

Following the end use/constraint process, the model projected energy consumption at the end use level. Greenhouse gas emissions estimates were then made in line with the Australian Methodologies for the Estimation of Greenhouse Gas Emissions and Sinks with adjustments as necessary for changes in greenhouse gas intensity indices for major fuels such as electricity, gas and solid fuels.

Apart from the BAU case (known as "with regulations") a number of alternative scenarios were also modelled for comparative purposes. These alternative scenarios included:

- without Regulations
- star Rated (ranging from 1 to 5)
- higher Insulation scenario
- higher Insulation plus double glazing (low-e)
- with Regulations plus double glazing (low-e)
- without Regulations plus double glazing (low-e)

It must be stressed that none of the alternative scenarios noted above are advocated by this study. They were chosen simply as a basis for comparative evaluation with the BAU case and were not selected on the basis of any cost benefit analysis.

1.3 Project Team and Acknowledgments

This study was undertaken by Energy Efficient Strategies (Victoria), with assistance from Energy Partners (ACT) and George Wilkenfeld and Associates (NSW), for the Australian Greenhouse Office.

A number of organisations were contacted during the project and their cooperation and assistance is gratefully acknowledged. We would like to particularly thank staff of the following organisations:

Councils

- Ballarat
- Casey
- Mornington Peninsula
- Hume
- Kingston
- Monash
- Knox
- Greater Shepparton

Window and glazing organisations

- Pilkington (Australia) Limited
- MOEN Glass
- South West Aluminium and Glazing
- G. James Safety Glass Pty Ltd
- Boral Limited
- James Hardie Australia
- ANL Windows Pty Ltd
- Australian Window Association Inc.

Insulation manufacturers

- Bradford Insulation
- ACI Insulation and Packing Products
- Dow Construction Materials
- RMAX
- Fiberglass and Rockwool Insulation Manufacturers Association

1 This is most relevant to the "without regulations scenario"

2 The term "unconstrained" refers to the theoretical energy consumption required to maintain a house at comfortable conditions all year (assuming space heating and cooling equipment is installed). This "unconstrained" energy then has to be "constrained" to more accurately reflect actual energy used by typical households for heating and cooling. These terms are explained in more detail later in Section 2.3.

In addition to the above noted organisations, special mention is made of the following individuals:

- Mr Tony Isaacs and Mr Douglas McPherson of the Sustainable Energy Authority (Victoria) for provision of a specially formulated version of the *FirstRate* software for use in this study and advice on its use and the interpretation of results.
- Mr Peter Nassau of the BCC for supply of information from their "BASIS" Database as well as advice regarding changes in the BCA over the past 10 years.
- Ms Mia Ivanova and Ms Elizabeth Rea of the Australian Bureau of Statistics who supplied council construction approval data on sub-contract.

SECTION TWO
BACKGROUND AND CONCEPTS UNDERLYING THE STUDY

SECTION 2 BACKGROUND AND CONCEPTS UNDERLYING THE STUDY

2.1 Regulatory Controls on Thermal Performance

Regulations for insulation of new dwellings were recommended by a Victorian parliamentary committee as early as 1979. This was adopted as government policy following the recommendations of the Natural Resources and Environment Committee report on "Electricity Supply and Demand Beyond the Mid 1990's".

In 1986 the Department of Industry Technology and Resources (DITR) published a report on Thermal Insulation /Regulations for New Dwellings in Victoria. The report recommended that added insulation be installed in ceilings and external walls of new residential buildings.

Following this report, agreement was reached between the Minister for Planning and Environment and the Minister for Industry Technology and Resources to incorporate insulation requirements into the Victoria Building Regulations (VBR).

In 1990 a regulatory impact statement was prepared by the Department of Planning and Urban Growth. This study found that:

> *The regulations are justified as they will result in the conservation of valuable energy reserves, reduce supply infrastructure costs and reduce greenhouse emissions. The costs to the householder are more than offset by the resultant fuel savings.*

Regulations for insulation of new dwellings came into operation in Victoria through the Building Control Act on 18 March 1991. These regulations formed part of the VBRs and included Deemed-to-Satisfy provisions as seen in Table 1:

Table 1 Minimum Overall R Values (as prescribed in the VBRs – 1991)

Element	Option A	Option B
Roof or Ceiling	R2.2	R2.2
External Walls	R1.3	R1.7
Ground Floor	R1.0	R0.4

Various common construction types or elements that complied with the above requirements were also described in the regulation.

Since the introduction of these regulations, the Deemed-to-Satisfy requirements have remained largely unaltered.

Following are a list of changes to the regulations instigated since the introduction:

8 April 1991
BCA 1990 Amendment 1 Regulations incorporated into the Victoria additions to the Building Code of Australia (BCA). The BCA superseded VBRs.
30 September 1991 – 14 June 1993
BCA 1990 Amendments 2-5 Minor amendments and additions to the list of deemed R values for common elements.
1 November 1994
BCA 1990 Amendment 7 Provision under the performance requirements for compliance if the building achieves a House Energy Rating of at least 4 stars using Energy Victoria's House Energy Rating.
1996
Building Code of Australia 1996 supersedes BCA 1990. Amendment numbers recommence at 1.
1 August 1997
BCA 1996 Amendment 1 Reduction in the requirement under the House Energy Rating compliance method from 4 stars to 3 stars.
1 Jan 1999
BCA 1996 Amendment 4 The Ground floor requirement for option B (see Table 1 above) was increased from R0.4 to R0.7. This has little practical impact as the only common floor type that was deemed to be less than R0.7 (a timber framed floor with unenclosed perimeter – formerly deemed R0.4) was revised to a deemed level of R0.7.

A timber framed floor with an enclosed perimeter was revised in 1999 from being a deemed R0.7 to a deemed R1.0 construction. This would then allow the installation of reflective foil sarking only to the walls of a dwelling with an uninsulated suspended timber floor. Previously R1.5 insulation would have been required to have been fitted into these walls.

The nature of these amendments means that they will have had little or no impact on the results of the modelling over the study period. The only change of significance is the effective downgrading of the wall insulation requirements for houses built on enclosed suspended timber floors (estimated to be approximately 20% to 30% of all detached houses built in 1999). This change effects only the last six months of the study period but will be of greater significance for any projected energy and greenhouse gas emissions savings beyond the year 2000.

2.2 Building Stock and Building Activity

The total number of buildings in existence in any particular year is referred to as the "building stock". Stock profiles change over time as a result of three main contributing processes:

- addition of new stock (ie. the building of new houses)
- alterations to existing stock (including renovations alterations and conversions)
- retirement of existing stock (demolitions)

These processes are referred to as the "building activity". This study is concerned with the impact of thermal performance regulations on Class 1 buildings that have been built as a result of building activity undertaken since the introduction of those regulations in 1991. This sub set of the Victorian building stock shall be referred to in this study as the "post regulatory stock". Where reference is made to a "stock model" in this study it should be understood that "stock" in this context refers to the post regulatory component of the stock as described above.

2.3 Constraint of Performance Modelling Results

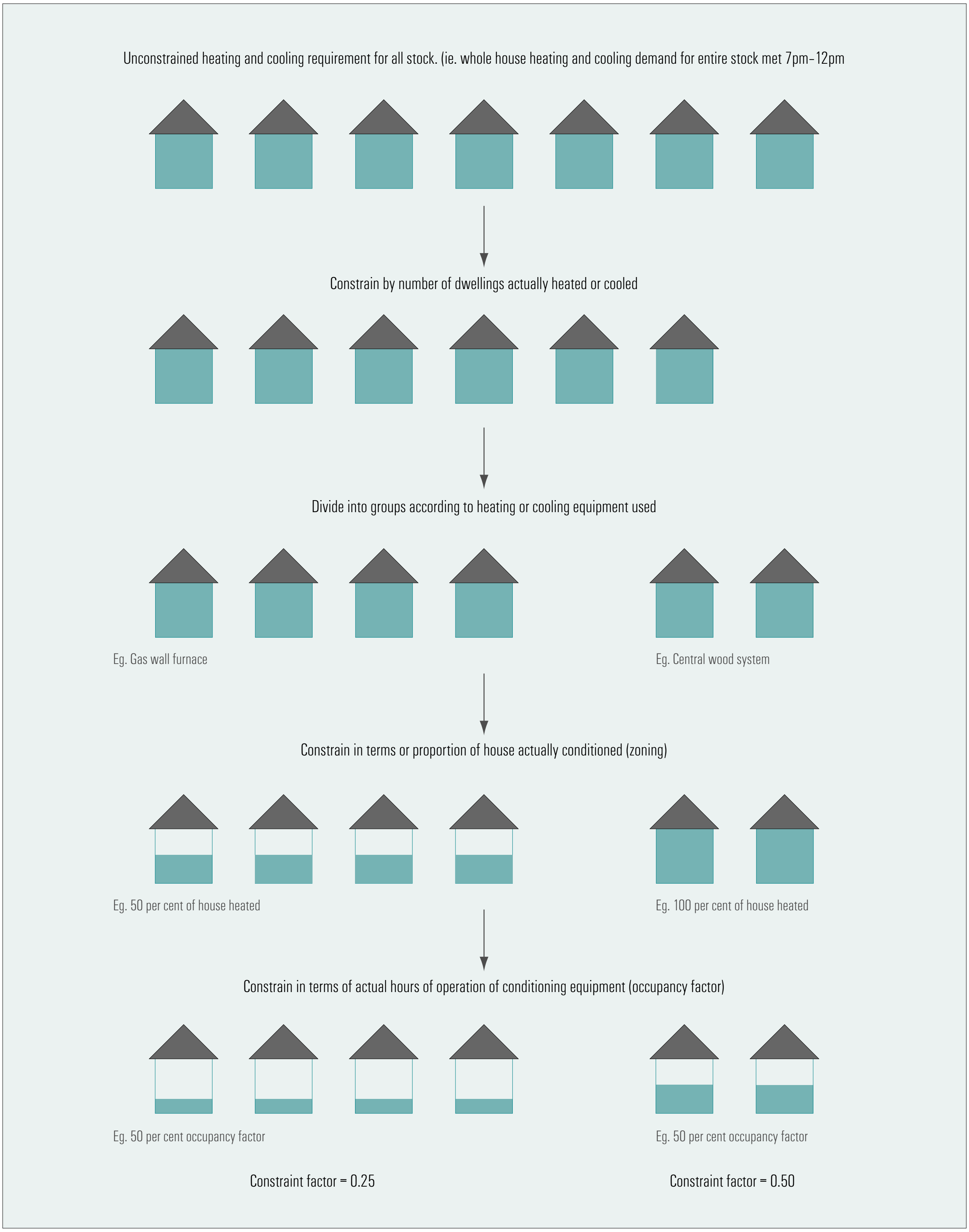
The following is an extract from a previous study by Energy Efficient Strategies entitled *Australian Residential Building Sector Greenhouse Gas Emissions 1990 – 2010* (EES 1999):

> The understanding of the concept of "constrained" and "unconstrained" heating and cooling is important to comprehending the analysis of the building shell model used for this report. The amount of energy required to satisfy the heating and cooling requirements of a house must, in part, be based upon a set of assumptions relating to user behaviour. Some of the main factors associated with user behaviour are as follows:
>
> ***Ownership of Conditioning Equipment***
>
> A potential heating or cooling demand can only be met if the user has installed equipment which can be used to meet that demand (ie. condition their home). This factor is most significant in respect of cooling. Whilst almost every house in Victoria has at least some potential demand for cooling (based upon accepted levels for thermal comfort), only about 45% of all houses in Victoria have air-conditioners of any type (including evaporative air conditioners). In the case of the other 55% of houses, most occupants will have decided to accept a less than optimal level of comfort during periods of high temperature.
>
> ***Occupancy Factor***
>
> This factor relates to the actual number of hours that a house is conditioned during the year. At various times of the day (eg during working hours) and at various times of the year (eg holidays) a house may be unoccupied. During these times, when excessively high or low internal temperatures may otherwise prompt an occupant to condition their home, it is common for users to switch off conditioning equipment. This behaviour has the effect of reducing the potential energy demand that would be required when compared with a house that is occupied 24 hours a day for 365 days a year.
>
> ***Zoning***
>
> Zoning refers to the tendency of many users in Australia to condition only part of their homes. For instance, a user may choose only to heat or cool their living areas and leave sleeping areas and service areas unconditioned. The level of zoning that a user will apply is dependant partly upon the space conditioning equipment installed. For instance, users with only a small electric radiator can practically only heat one or two rooms whereas users with a ducted gas central heating system could adopt whole house heating if desired (although some would choose not to do so).
>
> The NatHERS based program used for the purposes of modelling the space conditioning energy demands for this study makes a number of assumptions relating to the above user behaviour factors. The program assumes that the house has both heating and cooling equipment installed, that this equipment is used to heat and cool the entire house (excepting some minor service areas) to a high level of human comfort (this varies depending upon climate) continuously during the hours of 7 am to 12 midnight, 365 days a year.

The energy required to meet this level of demand is referred to as "the unconstrained heating and cooling demand". That is, unconstrained by the tendency of most users to reduce their potential demand through the various means outlined above. The initial output from the *FirstRate* modelling is in the form of unconstrained demand and therefore represents only the upper most limit of potential demand. To adjust this output to match reality the output needs to be "constrained" by the various behavioural factors.

The process of constraining is graphically described in Figure 2.

Figure 2 Diagrammatic Model of Constraint Process



SECTION THREE
PROJECT RESULTS

SECTION 3 PROJECT RESULTS

This section details the results from the modelling described in the proceeding sections of this report. The sub sections of this chapter cover in order the following aspects:

- a profile of the Class 1 building sector derived mainly from an analysis of the sample
- a profile of the thermal efficiency characteristics of the sample
- state wide energy and greenhouse gas estimates for the various scenarios examined as part of this study

3.1 Profile of Residential Building Sector 1990-99

Estimates of the impact of minimum energy performance requirements for Class 1 buildings in Victoria required the analysis of various aspects of the stock of Class 1 buildings produced during the study period. This section presents the findings of that analysis.

3.1.1 Number and Area

The rate of addition of new housing stock or more particularly the rate of addition of floor area will affect the magnitude of the impact of regulations designed to reduce energy consumption. The greater the floor area that is affected by the regulations the greater the impact of those regulations.

For this study, ABS data was used to determine both the number and the area of Class 1 buildings added to the stock between 1990 and 1999. Figure 3 details the number of Class 1 buildings constructed in each year of the study period. Typically, 25,000 to 30,000 Class 1 buildings are built each year. Fluctuations in activity do occur from year to year, this is thought to be a response mainly to economic drivers. There was a large amount of house construction activity commenced in 1999 in response to the government's announcement of the introduction of the GST in mid 2000.

The only trend of significance appears to be an increasing proportion of attached type housing. This has risen as a proportion of the total number of new dwellings from approximately 8% in 1990 to approximately 15% in 1999.

The trends in activity by floor area (Figure 4) mirrors trends in the number of dwellings. Subtle differences do exist, however, as a result of differing trends in average floor areas for detached houses as compared to attached houses (see Section 3.1.2). Figure 4 below also includes data on floor area added through additions to existing houses; this data is however less reliable than that for new housing (see Section 6.9).

Figure 3 Annual Building Activity By Number – Victoria (ABS)

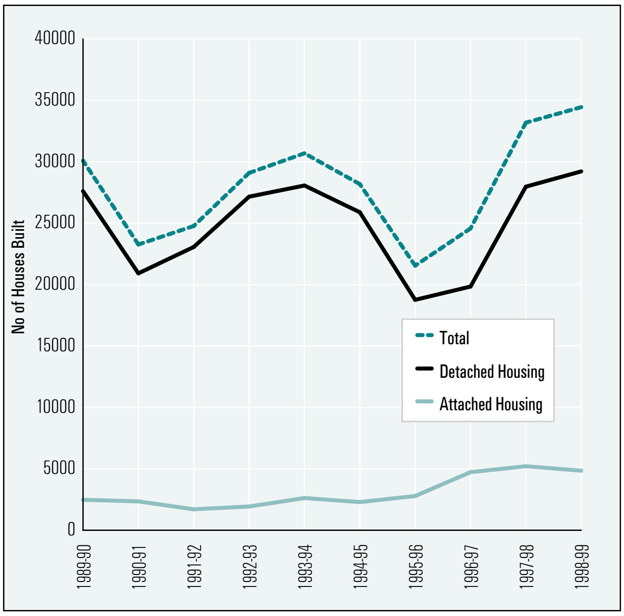
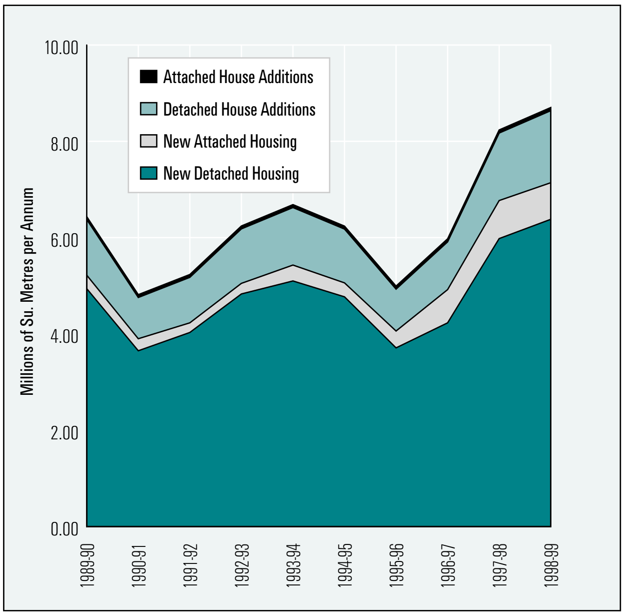


Figure 4 Annual Building Activity By Area – Victoria (ABS)



Minimum energy performance requirements have affected all class one housing built since 1991; this means that it is the cumulative number and area of houses built during the study period that is of importance when assessing impacts. Figure 5 below details the cumulative number of Class 1 buildings built since the introduction of regulations and Figure 6 details the cumulative floor area added during the same period.

Figure 5 Cumulative Number of Houses Built Since 1989-90

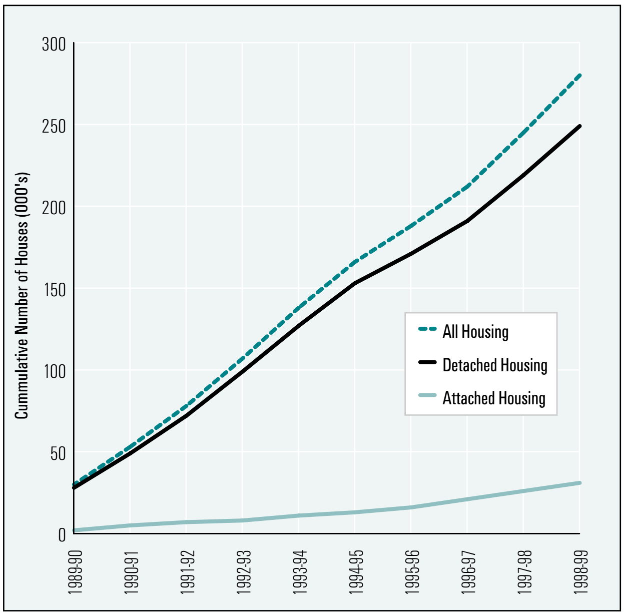
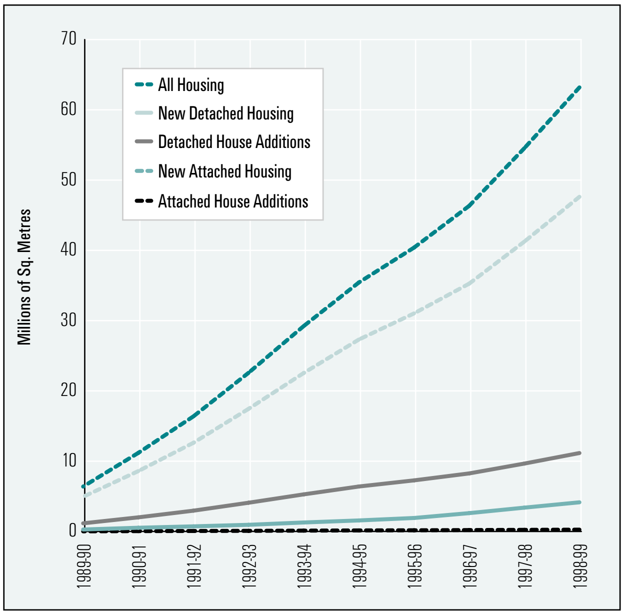


Figure 6 Cumulative Floor Area Added Since 1989-90



Between the end of 1990-91 (ie. the start of regulation) to the end of 1998-99 a total of 200,000 detached houses, and 26,000 attached houses were added to the stock. The total addition of new houses built during the regulatory period was 226,000.

The new stock added 39 million square metres of detached housing and 3.6 million square metres of attached housing. In addition, 9.1 million square metres was added through renovations to detached dwellings and 0.2 million square metres for attached dwellings. In total it is estimated that 52 million square metres of floor area has been added to the stock since the introduction of legislation until the end of the 1998-99 financial year.

3.1.2 Floor Areas – Averages and Frequency Distributions

From 1990 until 1999 there has been a continuing trend towards the construction of houses with increased floor area. This is true for both detached and attached type housing. Average floor areas for detached housing has risen by 43m^2 (175m^2 to 218m^2) or 25% and average floor areas for attached housing has risen by 35m^2 (116m^2 to 151m^2) or 31%. These trends are illustrated in Figure 7.

Added floor area associated with additions to existing detached houses varied between an average of 60m^2 and 80m^2 over the study period. The average for the entire period was 65m^2 with a trend towards larger additions in the last few years of the study. No meaningful data on the added floor area associated with additions to existing attached houses was

Figure 7 Trends in Average Floor Areas

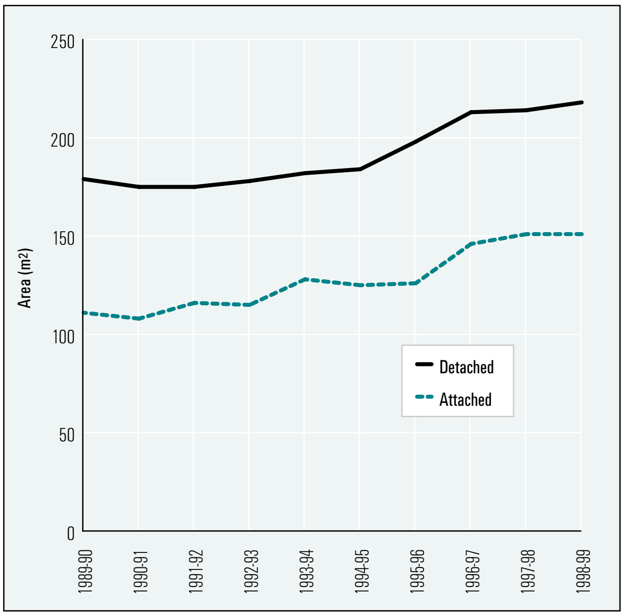


Figure 8 Distribution of Floor Areas – Detached Housing

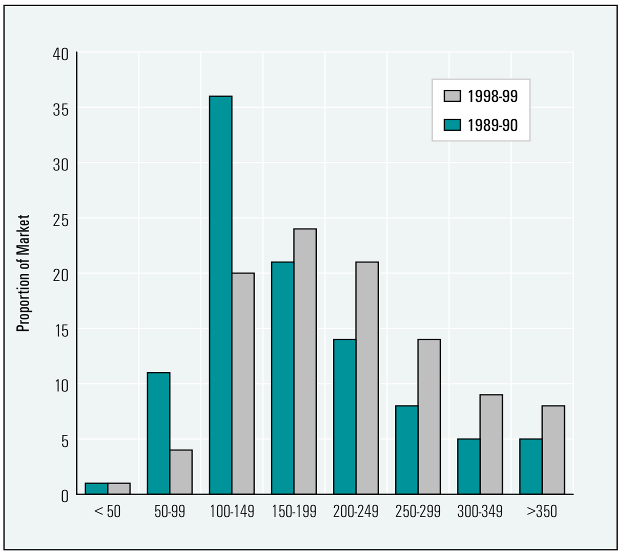
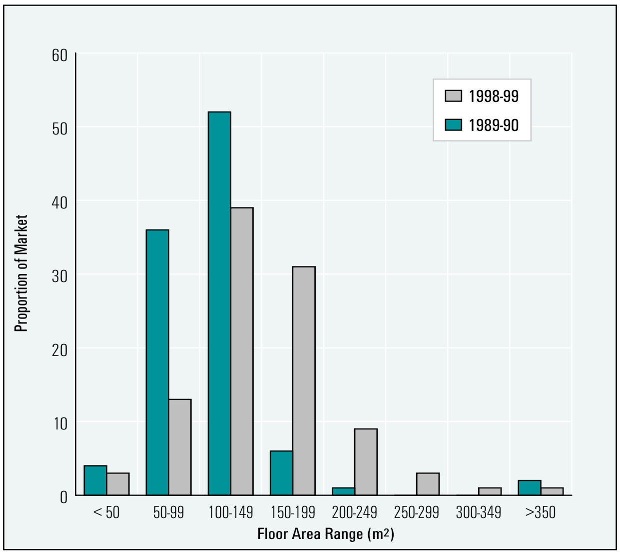


Figure 9 Distribution of Floor Areas – Attached Housing



available (see Section 6.9). ABS statistics report added area by project (groups or blocks constructed at the same time by the same builder) rather than by housing unit: they do not report number of units renovated per project.

The distribution of new dwelling floor areas as reported by the ABS was also analysed for this study. The analysis for both detached (Figure 8) and attached (Figure 9) show a marked shift in the distribution curves between the years 1989-90 and 1998-99.

It is known that increased floor area is usually associated with an increase in the floor area to wall area ratio. Analysis of the sample (see Figure 10) shows that the floor area to wall area ratio has increased by approximately 10% between 1989-90 and 1998-99. Such an increase will improve the thermal efficiency of the dwelling due to a reduced rate of heat exchange through the walls per unit area of floor, all other things being equal. There is no definitive quantitative study on the effect of increasing floor area to wall area ratios on thermal efficiency, but it is certain that this trend will have accounted for part of the 6% improvement in thermal efficiency that has arisen independently of the insulation regulations (see Section 3.2.1). Quantification of the impact of dwelling size on performance rating is beyond the scope of this study, but is worth considering as a follow up task to this project.

3.1.3 Attached/Detached Split

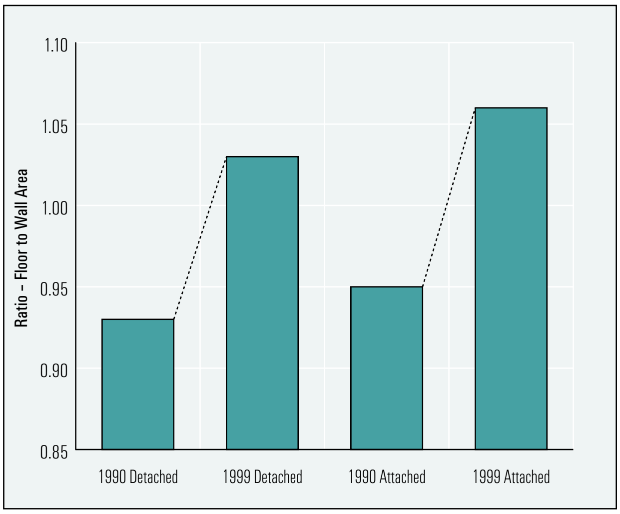
Figure 11 shows a general trend toward an increasing proportion (of floor area) of attached housing type over the study period. This has risen as a proportion of the total from approximately 4% in 1990 to approximately 9% in 1999.

The average thermal efficiency levels of the sample of attached housing was found to be 11%[3] better than that of detached housing (average of 275 MJ/m^2 as compared to 310 MJ/m^2)[4]. On this basis this shift of 5% is estimated to account for approximately 0.6% improvement in thermal efficiency of the whole building stock (post regulatory component).

3.1.4 Floor Construction

Data from the ABS indicates that between the introduction of legislation (1991) and 1998-99 there has been a gradual trend towards greater use of concrete slab on ground floor construction for Class 1 detached housing (see Figure 12). The use of concrete floors over this period has increased by 5% at the expense of timber floor construction.

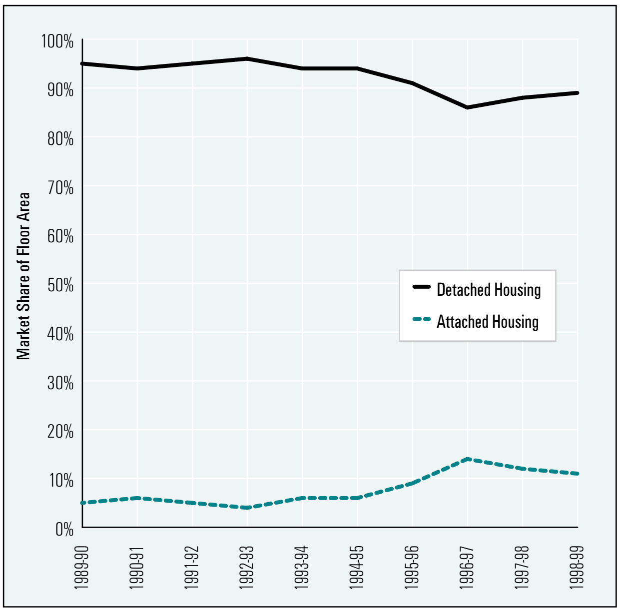
Figure 10 Floor Area to Wall Ratios



3 Note: Attached housing in this study only includes Class 1 attached housing ie. housing that shares one or more common walls. This does not include "flats" that may share walls and floors and ceilings with adjoining properties. These types of dwellings would be expected to show a greater percentage improvement in performance compared to detached housing to that exhibited by the attached dwellings that were the subject of this study.

4 The effect of insulation has been normalised in this analysis by setting all housing to the same level of insulation (compliant with BCA settings).

Figure 11 Market Share of Floor Area Built – Attached and Detached Housing



The average thermal efficiency levels (as assessed using *FirstRate*) of the sample of housing with concrete floors was found to be 14% better than that of housing with suspended timber floors (average of 289 MJ/m^2 as compared to 337 MJ/m^2)4. Whilst other factors apart from the greater use of concrete floors may be driving this improvement, the net effect is estimated to account for approximately 0.7% improvement in thermal efficiency of the building stock constructed since the introduction of the legislation.

ABS data for floor type is only available for detached type housing, but as this represents more than 90% of the floor area added during the study period, analysis of the whole sector based on these statistics is considered reasonably valid.

3.1.5 Wall Construction

Data from the ABS indicates that whilst there has been some fluctuation over the study period in the choice of each of the main wall types used in detached housing (see Figure 13), the proportions of each type at the start and the end of the study period are almost identical. By far the predominant wall construction type has been brick veneer, consistently accounting for at least 85% of the detached housing market.

A lack of any definitive trend in wall type over the study period means that this aspect of building construction is unlikely to have had any impact on the average thermal efficiency of Class 1 buildings.

ABS data for wall type is only available for detached housing. Any trend that may exist in attached housing (eg possible greater use of lightweight construction) cannot be determined, nevertheless the impact of such a trend on the entire sector, if it existed, would be very small.

Figure 12 Market Share of Floor Construction Type 89-90 to 98-99 (Detached Housing)

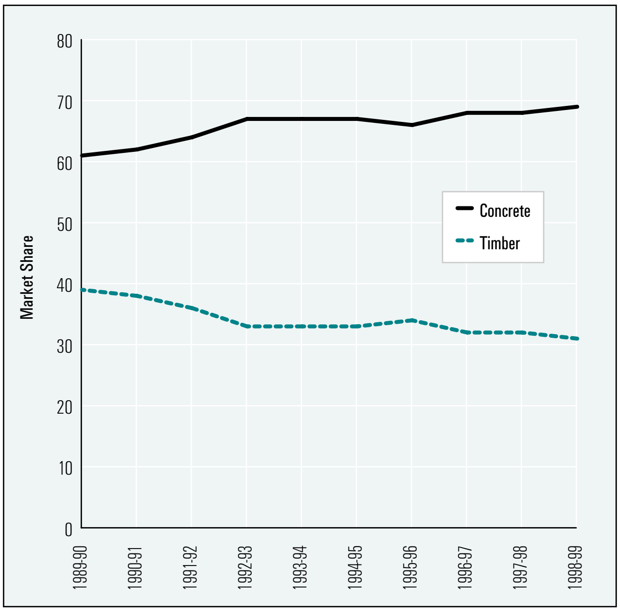
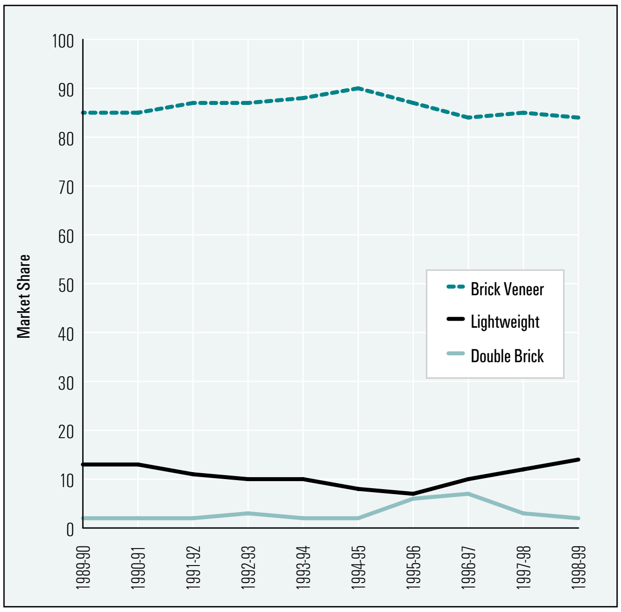


Figure 13 Market Share of Wall Construction Type 89-90 to 98-99 (Detached Housing)



3.1.6 Glazing Type and Area

Analysis of the sample revealed that the area of windows per house had increased from an average of 40.5m^2 in 1990 to 47.2m^2 in 1999 – an increase of 17%.

Over the same period the average net conditioned floor area[5] increased by 34%. The net result of these two factors has been to reduce the average window to net conditioned floor area ratio from 31% to 27%. It should be noted that individual houses in the sample varied significantly from the average, ranging from as low as 11% to as high as 50%.

Trends for detached houses were significantly different from those for attached houses. The glazed area of attached houses actually declined marginally over the study period from 31.4 m^2 to 30.3m^2 compared to detached housing where the area rose from 41.1 m^2 to 50.2 m^2 . The average window to net conditioned floor area ratio for detached housing declined from 31% to 27% and the average window to net conditioned floor area ratio for attached housing declined from 29% to 25%. The increase in net conditioned floor area over the study period for detached housing (40%) was significantly greater than that for attached housing (14%). This disparity is thought to be a result of a trend towards a greater proportion of floor space in attached dwellings being allocated to "service" areas such as bathrooms[6].

Glazing types identified in the sample were either single glazed or not stated (assumed to be single glazed). Information sourced from industry (see Section 8.5) confirms that the penetration of higher performance glazing is low (less than 5% and probably less than 2%). ABS data gives a stock penetration of 2% in 1999, however much of this may be retro-fitted (ie. not fitted during construction) and confined to alpine regions (not well covered in the sample).

When used as part of a passive solar design strategy, increased glazed areas can in certain circumstances have a beneficial effect on thermal efficiency. However, in the case of non passive solar designs, which are by far the predominant type in the sample (see Section 3.2.4) the reverse will normally be true. The thermal resistance offered by glazing, even high performance glazing, is substantially less than most wall systems that comply with the minimum insulation requirements of the BCA. This means that the reduction in glazed area to conditioned floor area ratios over the study period is likely to have resulted in a net improvement in thermal efficiency.

This contention is supported by the analysis contained in Section 3.2.3. However, because of the complex relationships between window size, window placement, window shading and incident solar radiation it is difficult to quantify the impact on performance arising from this reduction in glazed area to conditioned wall area ratios.

3.1.7 Insulation

Studies by the ABS and the former Gas and Fuel Corporation of Victoria provide data on insulation type and penetration for the stock of all housing. This is of limited use however as our primary focus is on the insulation practices during construction for those houses built over the past 10 years, not of the entire stock. Industry surveys were conducted (see Section 8.3) in an attempt to ascertain these practices. The results are summarised below:

Insulation Practices – Pre-legislation

- 40% – 60% of houses fitted with ceiling insulation – R2.0 to R2.5
- 10% – 50% of houses fitted with wall insulation – R1.5 or reflective foil
- negligible use of floor insulation

Insulation Practices – Post-legislation

- 80% of houses compliant with BCA insulation requirements.
- 10% of houses over compliant – R3.5 in ceiling and or R2.0 in walls.
- 10% of houses under compliant – ie. insulation installed but at an effective level less than that prescribed in the regulations – typically as a result of poor installation practices.
- Possibly 1%–2% non compliant, ie. either wall or ceiling insulation not installed.

These changes in insulation practices following the introduction of the legislation were used in constructing both the BAU scenario (ie. with regulations) and the "without regulations" scenario. Comparing the average thermal efficiency results of these scenarios in 1998-99, a 34% improvement in the average thermal efficiency is noted (with regulations 388 MJ/m^2, without regulations 585 MJ/m^2). It is estimated (in Section 3.2) that 6% of this improvement is attributable to factors other than increased levels of insulation; this means that an approximate 28% improvement can be attributed to the increased rates of insulation that resulted from the introduction of the regulations for insulation of new dwellings in Victoria. It should be remembered that this is not a comparison of insulated dwellings against non insulated dwellings (in such a case the improvements would be more significant) but of dwellings insulated to the levels that existed post regulation compared to those insulated to levels that existed pre-regulation.

5 The net conditioned floor area is the area of floor assumed by the FirstRate software to be space conditioned. This includes all rooms except bathrooms, laundries, garages and other similar utility areas but does include en-suites and walk in robes. Whilst this may be analogous to total floor area, any changes over time in the areas of these 'utility' rooms as a proportion of the total floor area will tend to distort the results slightly compared to results that could be obtained from an analysis of window to total floor area ratios.

6 Service areas such as bathrooms are not normally counted as part of the net conditioned floor area in FirstRate.

3.1.8 Prevalence of Multi Storey Housing

Only limited data was available on the prevalence of multi storey housing. Data available from the ABS covered detached housing in 1998-99. No data was available on detached housing at the beginning of the study period and no data at all was available for attached housing. The ABS data for detached housing is graphically represented in Figure 14 below.

In general it would be expected that multi storey housing would perform better thermally than single storey housing, all other factors being equal. The internalised upper floor/lower ceiling of a multi storey dwelling generally suffers no heat loss or gain (assuming that the space below and above the floor are conditioned spaces). The floor area exposed to the exterior (ground floor only) and the ceiling area exposed to an external roof area (upper floor only) will be significantly reduced compared to a single storey dwelling of comparable total floor area. This equates to reduced heat transfers in a multistorey dwelling basically as a result of reduced external surface area.

The average thermal efficiency levels of the sample of multi storey housing was found to be 14% better than that of single storey housing (average of 275 MJ/m^2 as compared to 318 MJ/m^2). On this basis the assumed shift of 9% towards multi storey housing (see Section 4.5.2) is estimated to account for approximately 1.3% improvement in thermal efficiency of the stock (post regulatory component).

3.1.9 Orientation of Glazing

The sample houses were analysed to determine the average area of glazing to be found on each facade of the house. The analysis was carried out for both detached housing and attached housing and the results for the 1990 sample were compared to those for the1999 sample.

Figure 15 illustrates the results for the detached housing sample. Whilst a bias clearly exists for the ordinal points of the compass (no doubt a reflection of the tendency especially in Melbourne to align streets north-south or east-west), there is little bias shown towards any one of these points.

The most glazed facade in 1990 (14% of all glazing) and 1999 (16% of all glazing) was the southern facade. This was closely followed by the northern facade (13% of all glazing in 1990 and 14% in 1999) and the eastern facade (12% of all glazing in 1990 and 14% in 1999). The western facade had marginally less glazing again (10% of all glazing in 1990 and 12% in 1999).

There appears to be no identifiable trend emerging over the study period in terms of the proportion of glazing placed on each facade of detached housing. For the majority of houses in the sample it would appear that little or no consideration is given to improving thermal efficiency through optimisation of glazing orientation. If this were the case, it would be expected that a bias towards the northerly orientations would be evident; clearly this is not the case.

Figure 14 Market Share of Multi Storey Housing 98-99 (Detached Housing)

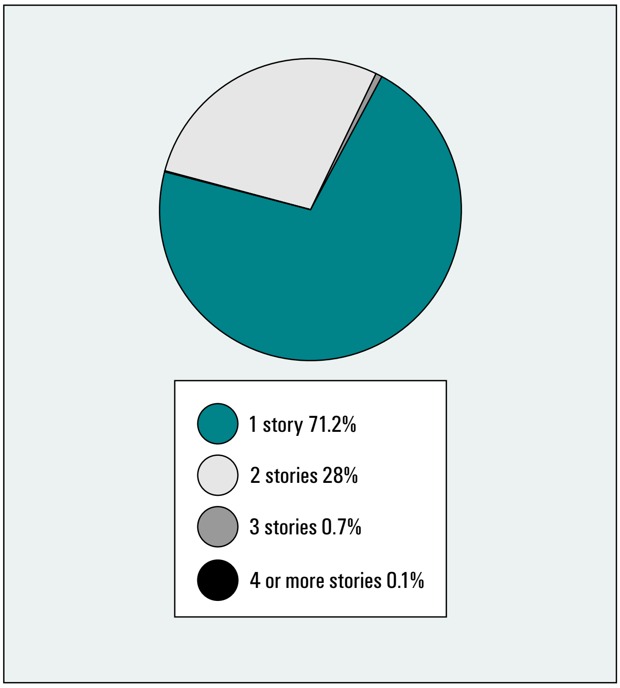


Figure 15 Average Area of Glazing By Orientation 1990 and 1999 (m^2) – Detached Housing

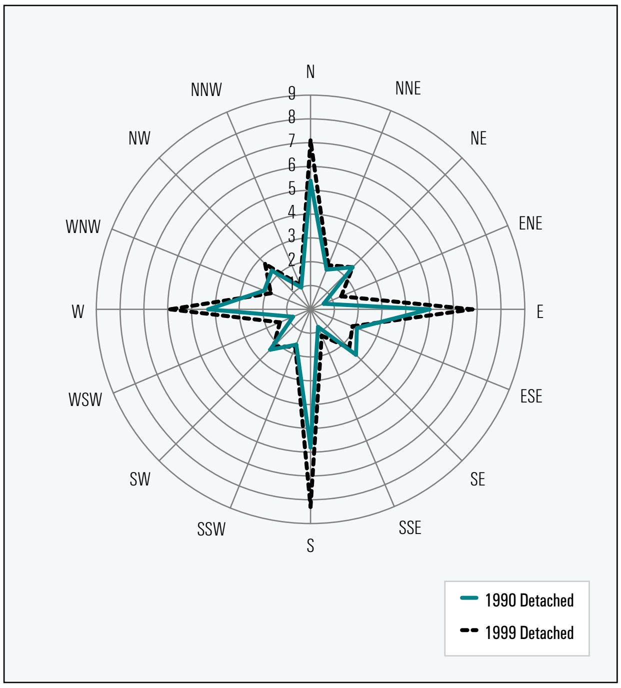


Figure 16 Average Area of Glazing By Orientation 1990 and 1999 (m^2) – Attached Housing

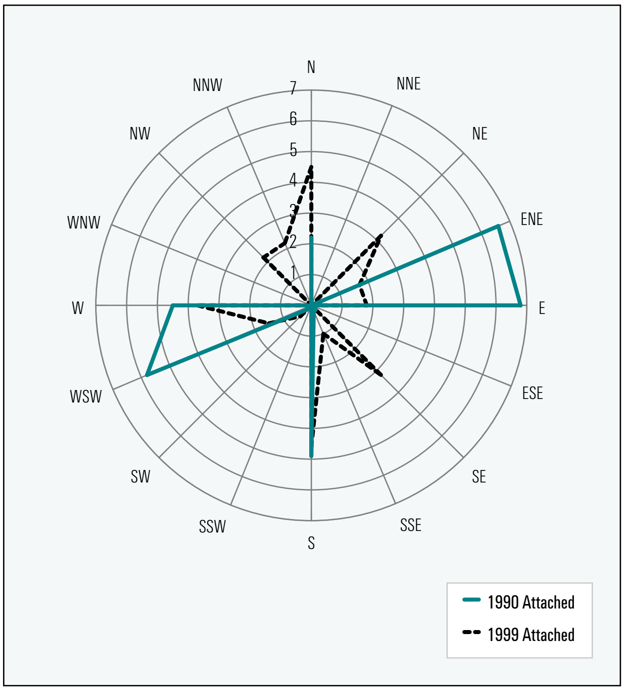


Figure 16 illustrates the results for the attached housing sample. Whilst the 1990 sample appears to show a greater asymmetry compared to that for detached housing, these results can not be considered representative. The 1990 sample of attached housing included only 7 houses, this is clearly too few to provide a representative distribution of the stock of new attached houses built in that year.

The sample for 1999 (34 houses) is more reliable than that for 1990. In this sample (dotted line), as with the detached housing sample, there is no evidence of a bias towards any one orientation. The attached housing sample does show a greater proportion of glazing to orientations other than the ordinal points than for the detached housing sample but this is not significant. Like the detached sample it would appear that little or no consideration is given to improving thermal efficiency through optimisation of glazing orientation.

3.1.10 Housing Activity by Climate Region

NatHERS and *FirstRate* distinguish 28 different climatic zones throughout Australia. Victoria contains five of these zones, only 3 of which are significant in terms of building activity.

Figure 17 (detached housing) and Figure 18 (attached housing) detail the number of houses built in each of these climate zones in 1991-92 and 1998-99. The Melbourne climate zone is clearly the dominant zone in terms of proportion of houses built; this is especially true in the case of attached housing. The average proportion of detached houses built in the Melbourne climate zone during the study period was 83% and the average for attached housing was 94%.

Since the introduction of the legislation in 1991 there has been a shift towards a greater proportion of houses being built in the Melbourne (MEL 21) climate zone. This has been at the expense of activity in the more severe Ballarat (CAN 24) and Bendigo (WAG 20) climate zones. Over this period, the proportion of all Class 1 houses built in the milder Melbourne climate zone has risen from 80% to 85%.

The average *FirstRate* performance levels (modelled with compliant levels of insulation) of the sample of housing in each of the 3 main climate zones was found to be:

Melbourne Climate Zone – MEL 21	285 MJ/m^2	2.4 stars
Ballarat Climate Zone – CAN 24	406 MJ/m^2	2.4 stars
Bendigo Climate Zone – WAG 20	370 MJ/m^2	2.6 stars

On this basis, the shift of 5% towards the Melbourne climate zone is estimated to account for approximately 1.8% improvement in thermal efficiency of the stock (post regulatory component).

Figure 17 Detached Building Activity by Climate Zone

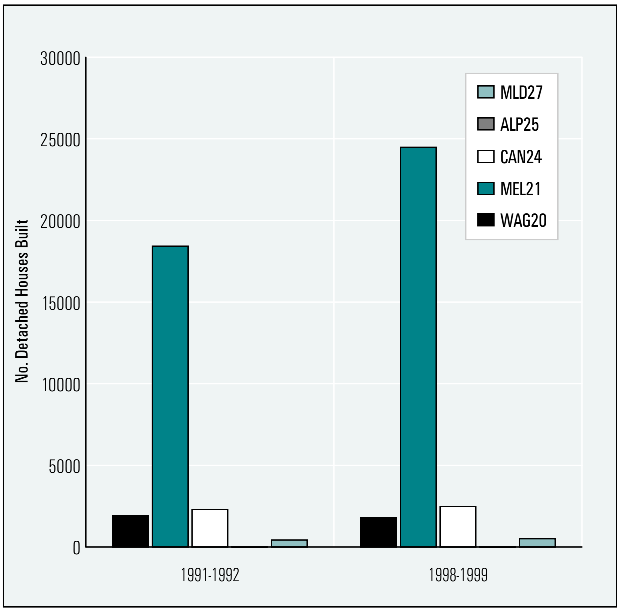
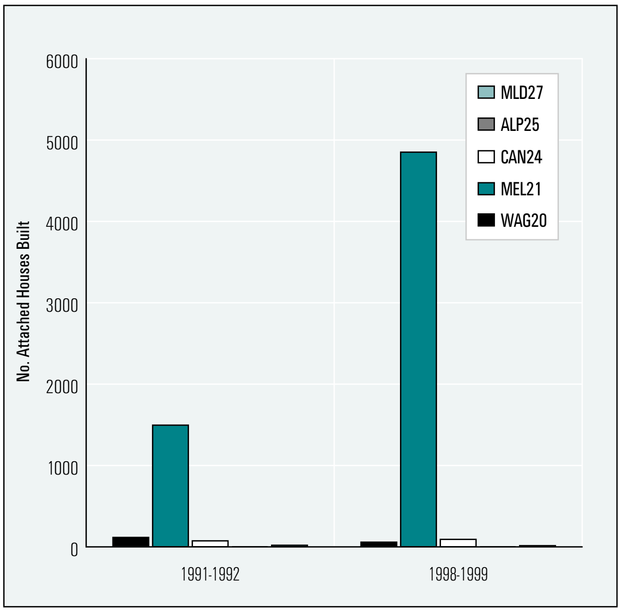


Figure 18 Attached Building Activity by Climate Zone



3.1.11 Summary – Typical house 1990 and 1999

In Table 2 (detached housing) and Table 3 (attached housing) is a summary of the profile analysis for a "typical" house in 1990 and 1999. These typical house specifications are made up of averages and predominant construction types as derived from the analysis above. The averages are state averages only, individual dwellings will show a distribution about these mean values.

Table 2 Summary – Typical Detached House Profile

Factor	1990	1999
Proportion of Class 1 Housing	96%	91%
Number of Storeys	Single (predominant, % unknown)	Single (71%)
Location (climate Zone)	Melbourne (MEL 21)	Melbourne (MEL 21)
Floor Area	175 m^2	218 m^2
Net Conditioned Floor Area to Wall Area Ratio	0.93	1.03
Floor Construction	Concrete 60%	Concrete 70%
Wall Construction	Brick Veneer 85%	Brick Veneer 85%
Window Area	41.1 m^2	50.2 m^2
Window to Net Conditioned Floor Area Ratio	31%	27%
Glazing Type	Single clear	Single clear
Ceiling Insulation	R2.0 – R2.5 (60%)	R2.5
Wall Insulation	None (80%)	Reflective Foil or R1.5
Floor Insulation	None	None

Table 3 Summary – Typical Attached House Profile

Factor	1990	1999
Proportion of Class 1 Housing	4%	9%
Number of Storeys	Unknown	Unknown
Location (climate Zone)	Melbourne (MEL 21)	Melbourne (MEL 21)
Floor Area	116 m^2	151 m^2
Net Conditioned Floor Area to Wall Area Ratio	0.95	1.06
Floor Construction	Unknown (probably concrete)	Unknown (probably concrete)
Wall Construction	Unknown	Unknown
Window Area	31.4 m^2	30.3 m^2
Window to Net Conditioned Floor Area	29%	25%
Glazing Type	Single clear	Single clear
Ceiling Insulation	R2.0 – R2.5 (60%)	R2.5
Wall Insulation	None	Reflective foil or R1.5
Floor Insulation	None	None

3.2 Thermal Efficiency Profile of the Sample

3.2.1 Thermal Efficiency Improvements Over the Study Period

The thermal efficiency of the stock built in 1989-90 and 1998-99 was determined using the methodology as described in Section 5 and 6. The results are shown in Table 4 below. The Figures in this table represent the average *FirstRate* thermal efficiency level for all Class 1 floor area added in the noted years, including floor area added through the construction of new dwellings and also by addition to existing dwellings as reported by the ABS.

The improvement in average thermal efficiency over the study period was in the order of 40%. Almost all of this improvement (36%) was realised immediately following the introduction of the legislation in 1991.

Improvements in average thermal efficiency since the introduction of legislation have been very modest. Figure 19 tracks the change in thermal efficiency of Class 1 floor area added each year since the introduction of the legislation.

Since 1991-92 there has only been a total of 6% improvement in thermal efficiency. This weak trend has levelled off to practically zero over the last few years of the study period.

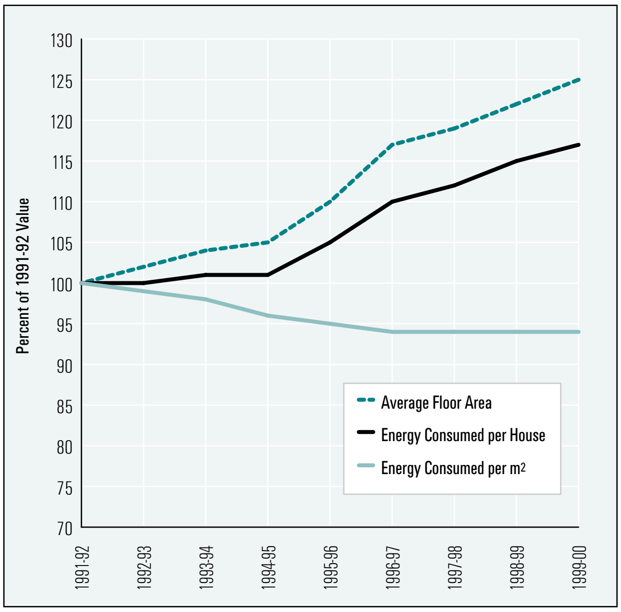
This 6% is an improvement above and beyond improvements resulting from the introduction of thermal performance regulations in Victoria in 1991. This improvement is likely to be as a result of some or all of the following factors previously detailed in Section 3.1:

- an increase in average floor area
- an increase in the ratio of floor area to wall area
- an increase in the proportion of attached type housing
- an increase in the use of concrete slab on ground construction
- a decrease in the glass to floor area ratio
- an increase in the proportion of multi storey housing
- an increase in the proportion of building activity to the milder Melbourne climate zones

Table 4 Average *FirstRate* Thermal Efficiency Levels – All Class 1 Building Activities

Housing Type	1989-90 Pre-regulation	1991-1992 Immediately Post Regulation	1998-99 End of Study Period
Detached Dwellings	647 MJ/m^2	414 MJ/m^2	395 MJ/m^2
Attached Dwellings	538 MJ/m^2	353 MJ/m^2	315 MJ/m^2
All Dwellings	642 MJ/m^2	411 MJ/m^2	388 MJ/m^2

Figure 19 Changes in Thermal Performance Efficiency of New Housing 1991-92 to 1998-99



Those factors that have been quantified are summarised in Table 5. These quantified factors account for just over two thirds of the improvement. In addition, factors such as increased average floor area[7] and reductions in window to net conditioned floor area ratios would no doubt account for all the remainder of the improvement and probably more.

It is clear from this analysis that:

> *Apart from improvements gained as a result of the implementation of the regulations it is apparent that improvements in thermal efficiency in other areas of building design are almost non existent. The meagre improvements that have occurred appear to have resulted from unrelated shifts in building practices.*

3.2.2 Thermal Efficiency Distributions in the Sample

In addition to the analysis of changes to average levels of thermal efficiency of the stock of Class 1 building floor area it was possible to analyse the thermal efficiency of the new housing constructed in 1999 in more detail.

The majority of the new housing stock produced in 1999 was compliant with the insulation levels prescribed in the BCA regulations. A small percentage had higher levels of insulation (over compliant) and a similar small percentage had lower levels of insulation (under compliant). For the purpose of gauging the approximate distribution of new house thermal efficiency levels, the 1999 sample was modelled with insulation levels set at those prescribed in the BCA[8].

Figure 20 (star bands for all climate zones) and Figure 21 (efficiency levels for the Melbourne climate zone only) detail the distribution of thermal efficiency of the 240 sample houses built in 1999. In addition to the distributions, Figure 21 also shows the threshold points for the star rating bands for *FirstRate* in terms of MJ per square metre.

Table 5 Factors other than insulation assumed to be affecting themal efficiency

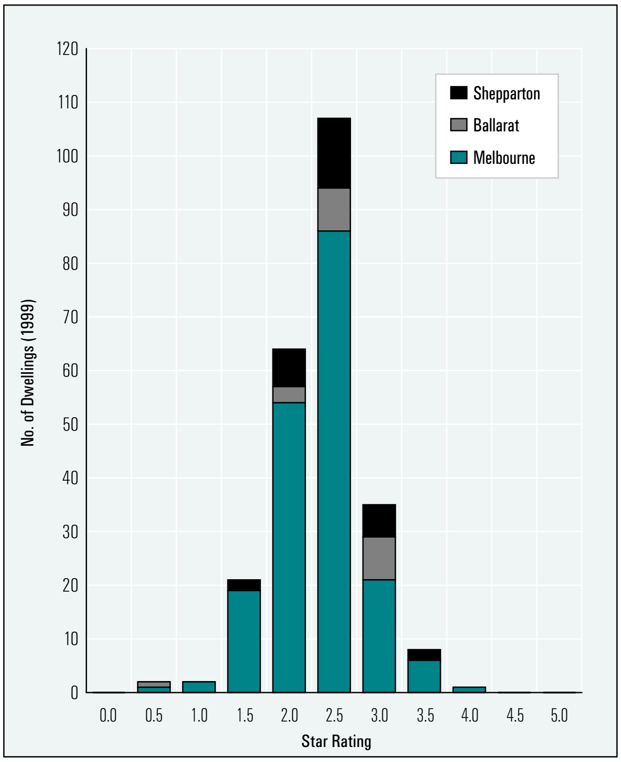
Factor	Estimated impact on efficiency since 1991
Shift towards a greater proportion of attached housing	0.6% improvement
Shift towards a greater proportion of multi storey housing	1.3% improvement
Shift towards more housing in the milder Melbourne climate zone	1.8% improvement
Shift towards a greater use of concrete floors*	0.7% improvement*
Total (quantified)	**4.4% improvement**

* The impact is estimated from analysis of the sample using *FirstRate*. It should be understood that other factors apart from the greater use of concrete floors may be driving this improvement, this Figure represents a net effect.

7 It is not the increased floor area per se that is significant but the consequent increased floor area to wall area ratio usually associated with increased floor area that will effect an improvement in thermal performance, measured as MJ per square metre.

8 A similar analysis of the 1990 sample is more problematical. Insulation levels were rarely marked on plans, therefore it is not possible to determine which houses in the sample would have been fitted with ceiling insulation, or wall insulation or both. Furthermore, the small size of the 1990 attached housing sample meant that no meaningful distribution data could be extracted for this sector. For this reason performance distribution charts are not provided for the 1990 sample. However, it would be reasonable to assume that if the 1990 sample were modelled with insulation compliant with the BCA (post 1991), then the distribution of performance would be very similar to that determined for the 1999 sample.

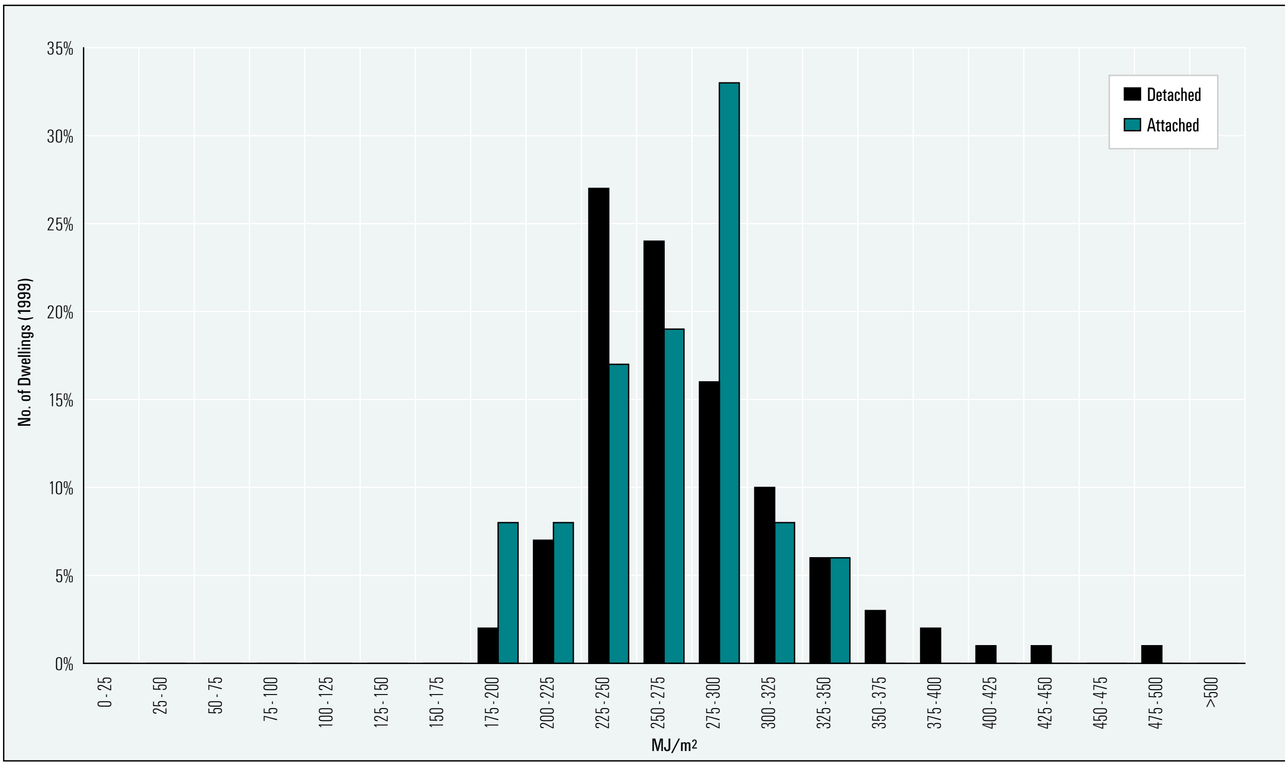
Figure 20 Thermal Efficiency Distribution By Star Rating of the 1999 Sample Housing



A number of important conclusions can be drawn from these distribution charts:

> *A relatively wide distribution of thermal efficiency levels was found to exist in the sample, especially in the case of detached housing, where it ranged from less than 200MJ/m^2 to as high as 500MJ/m^2.*
>
> *It seems that the Deemed-to-Satisfy insulation provisions have produced an average thermal efficiency result somewhat below the performance target of 3 stars. The average thermal efficiency of both the attached housing sample and detached housing sample in 1999 falls short of this mark.*
>
> *Despite the introduction of mandatory minimum insulation requirements, a significant number of poorly performing houses are produced each year. For detached housing almost half of the sample performs at or below the 2 star level; many opportunities for energy savings appear to have been missed.*

Figure 21 Thermal Efficiency Distribution by MJ/m^2 of 1999 sample – Melbourne climate zone



3.2.3 Correlation Between Housing Characteristics And Thermal Efficiency

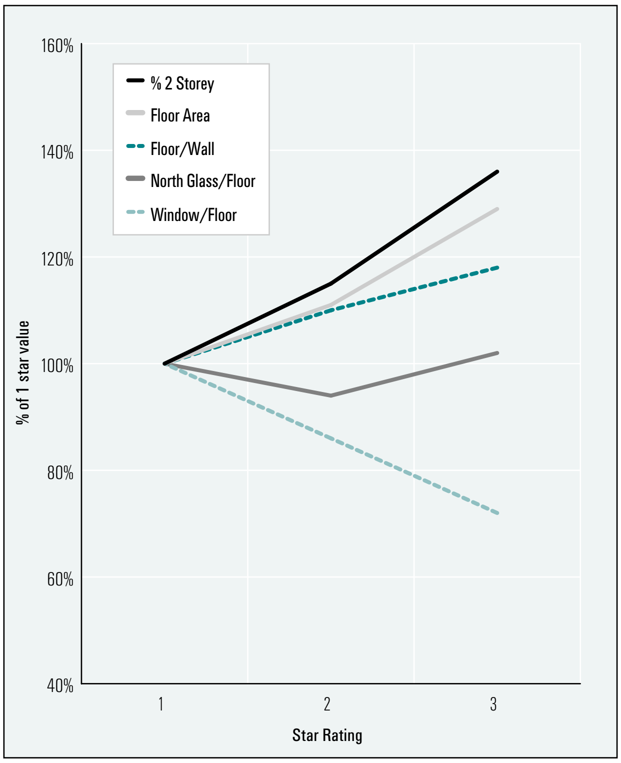
A further analysis was carried out to determine what if any correlation existed between key construction characteristics and building thermal efficiency as measured by star rating. Using the data interrogation facilities provided in *FirstRate* it was possible to analyse the correlation between star rating and the following factors:

- the proportion of multi storey houses
- the average net conditioned floor area
- the ratio of net conditioned floor area to wall area
- the ratio of glazed area to net conditioned floor area
- the proportion of glazing facing north

Analysis was only possible between the range of 1 star and 3 star rated houses. Houses of 0, 4 or 5 stars were too few in number to provide any useful comparison. Figure 22 shows the correlation between these factors and the star rating for the entire sample of Class 1 buildings studied.

The effect of insulation has been normalised in this analysis by setting all housing to the same level of insulation (compliant with BCA settings). Even so, in consideration of the number of variables involved and their complex interactions, the results shown in Figure 22 should be considered as qualitative only and not used for quantitative purposes.

Figure 22 Correlation between Various Factors and Building Shell Thermal Efficiency



The Figure suggests a correlation between improved thermal efficiency level and increasing floor area, increasing floor to wall area ratio and increasing proportion of multi storey housing. Decreasing ratios of window to floor areas are also associated with improved thermal efficiency levels. The thermal efficiency level was found to be fairly insensitive to the ratio of north glazing to floor area. This insensitivity is believed to be a consequence of the almost total lack of application of passive solar design principles in the sample of housing. This aspect is studied in more detail in Section 3.2.4. Floor area and floor to wall area are inherently strongly correlated and it is also likely that floor area and window to floor area are inherently inversely correlated, so these effects should not be considered independent of each other.

3.2.4 Sensitivity to Orientation and Application of Solar Passive Design Principles

Using a special batch facility in *FirstRate* it was possible to model each of the sample houses through the complete range of available orientations (16 orientations at 22.50 intervals). The effect of insulation was normalised by setting all housing to the same level of insulation (compliant with BCA settings).

By comparing the thermal efficiency results for each of the orientations, the sensitivity of the sample to change in orientation could be assessed. The results of this analysis are summarised in point form below:

- On average, the thermal efficiency of a house in the sample will vary by 12% from most to least favourable orientation. This suggests that the sample houses have a low thermal efficiency sensitivity to orientation change. Modelling undertaken for Residential Buildings Study (EES 1999) showed that a passive solar house in Melbourne showed a 30%+ variation in thermal efficiency from most to least favourable orientation.
- Both the 1990 sample and the 1999 sample showed the same sensitivity of thermal efficiency to orientation. This suggests virtually no shift towards the application of passive solar design principle over the study period.
- Attached housing showed a significantly higher sensitivity of thermal efficiency to orientation (18% average range) compared to detached housing (11% average range). This is to be expected given the fact that designers of attached housing will often only have the opportunity to place glazing on two opposite facades.

- Comparing the actual thermal efficiency levels of the sample houses (ie. as per the orientations marked on their site plans) to their levels when optimally oriented, the 1990 sample was found to average 7% lower thermal efficiency than optimal compared to the 1999 sample that showed a 5% lower thermal efficiency than optimal.

Prevalence of Passive Solar Design

Passive solar design involves the improvement in thermal efficiency by the moderation of solar radiation gains (and storage of energy) through building design. Passive solar design requires, amongst other things, the effective use of glazing, shading, insulation, thermal mass and air movement. There is no accepted measure of what divides passive solar design from non passive solar design, rather, it is more of a continuum.

For the purposes of this study it was necessary to set some criteria by which the application of passive solar design was to be judged. As a basic measure three criteria were selected:

- The house must achieve a minimum 3.5 star rating (this is considered the absolute bottom end for passive solar design performance).
- The house must have a reasonably high thermal efficiency sensitivity to change in orientation (this is a key indicator for passive solar design), a thermal efficiency range of 20% or more from most to least favourable orientation of the house was adopted for this criteria.
- Given a 20% range of possible thermal efficiency levels (depending upon orientation) it is important that the house is in fact favourably oriented (essential qualification for passive solar design). An as-sited thermal efficiency that is within 5% of the houses optimal thermal efficiency was adopted for this criteria.

Using these criteria to filter the sample for passive solar designs, a total of 7 houses were found to meet the criteria: three attached houses and four detached houses. This means that passive solar designed houses[9] represent 2% of the sample. Interestingly, none of the passive solar designed houses came from the 1990 sample. This tends to indicate a slight trend towards increasing numbers of passive solar designed houses over the study period, but may also be a function of the smaller sample size for that year.

3.3 State wide Energy and Greenhouse Gas Estimates

3.3.1 Total Stock Perspective

In 1990 the estimated total state residential heating and cooling energy consumption was 59.0 PJ (this is a constrained actual state wide energy consumption for all households). By the year 2000 it is estimated that, in the absence of the minimum energy performance requirements for Class 1 buildings in Victoria (introduced in 1991), energy consumption would have risen to 82.6 PJ. The impact of the regulations has been to limit this consumption to 75PJ in 2000, a reduction of 7.6 PJ (9%).

In terms of greenhouse gas emissions it is estimated that in 1990, total state residential heating and cooling greenhouse gas emissions was 4.0 Mt. By the year 2000 it is estimated that, in the absence of the minimum energy performance requirements, this would have risen to 5.5 Mt. The impact of the regulations has been to limit these emissions to 5.0 Mt in 2000, a reduction of 0.5Mt (9%).

Figure 23 (energy) and Figure 24 (greenhouse gas emissions) detail the total state heating and cooling energy consumption and greenhouse gas emissions over the study period (1990 – 2000) for various scenarios. The major conclusions that can be drawn from these Figures are:

- In the absence of the regulations, the energy efficiency (energy and greenhouse gas) of the Class 1 buildings constructed between 1991 and 2000 would have been equivalent to all housing being constructed to less than a 1 star performance level.
- The performance of the Class 1 buildings constructed between 1991 and 2000 with current regulations applied was equivalent to an average performance level of 2.2 stars.
- If in 1991 a requirement for a state average 3 star performance level had been adopted instead of the current regulations, the impact on total state residential heating and cooling energy consumption would have been an estimated reduction in consumption of 10.5 PJ or 13% compared to the no regulation scenario. This would equate to a greenhouse emissions reduction of 0.7Mt (13%) compared to the no regulations scenario.
- If in 1991 a requirement that was equivalent to a state average 5 star performance level had been adopted instead of the current regulations, the impact on total state residential heating and cooling energy consumption would have been an estimated reduction in consumption of 14 PJ or 17% compared to the no regulation scenario. This would equate to a greenhouse emissions reduction of 0.9 Mt (17%) compared to the no regulations scenario.

9 Based upon the adopted criteria for passive solar design

3.3.2 Post Regulatory Stock Perspective

This section looks at only that stock affected by the regulations (ie. stock produced post March 1991).

For each scenario studied, Figure 25 compares the space conditioning greenhouse gas emissions generated by the post regulatory stock. The results are expressed relative to the BAU case (with regulations). From this analysis the following conclusions are drawn regarding the post regulatory stock only.

- The post regulatory stock would have generated 38% more space conditioning related greenhouse gas emissions compared to the case where regulations had not been introduced in 1991.
- If double glazing (low-e) had been mandated instead of insulation, the emissions would have been 22% worse than the result achieved.
- If higher insulation levels were mandated in 1991, only a 7% improvement in emissions would have been realised.
- If higher insulation levels plus double glazing (low-e) had been mandated in 1991, the emissions are estimated to have been equivalent to a state average 4 star performance level from 1991.
- If a requirement that was equivalent to a state average 5 star performance level had been adopted in 1991 instead of the current regulations, a 31% improvement in emissions would have been realised.

Figure 23 Total State Heating and Cooling Energy – Various Scenarios

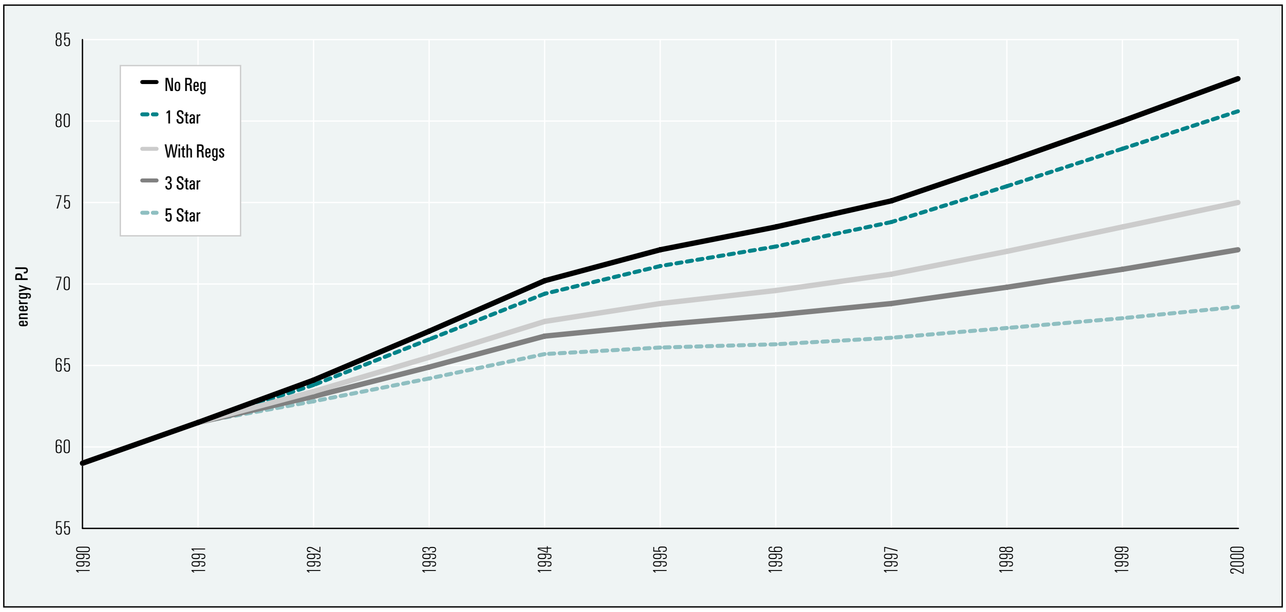
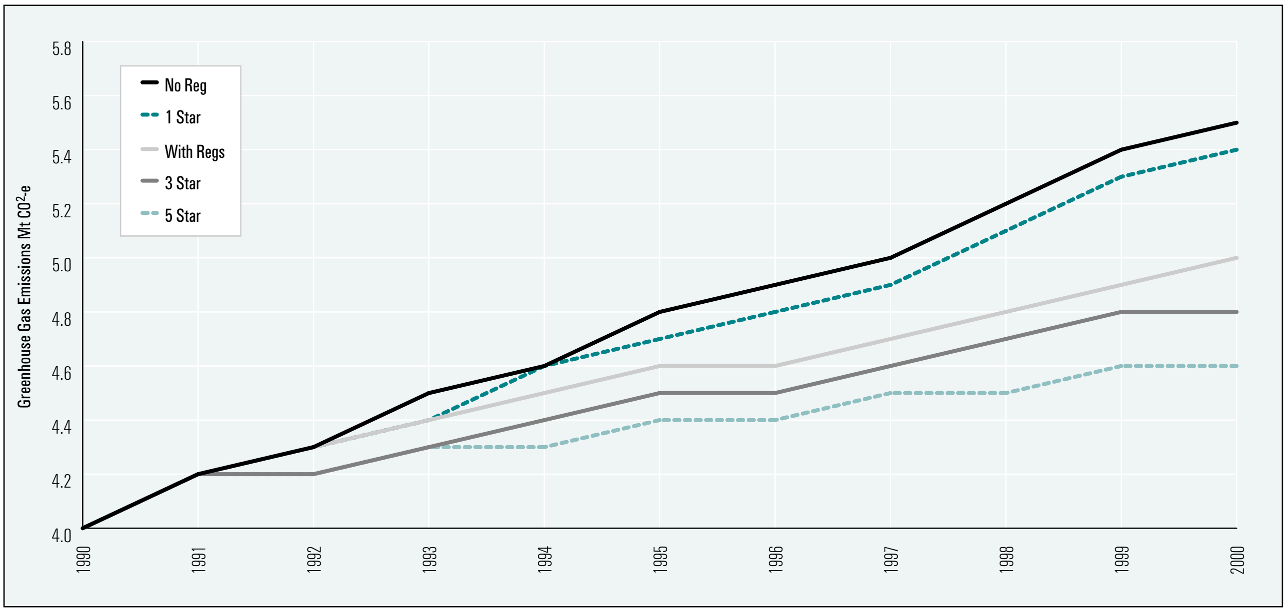


Figure 24 Total State Heating and Cooling Greenhouse Gas Emissions – Various Scenarios



3.3.3 Kyoto Perspective

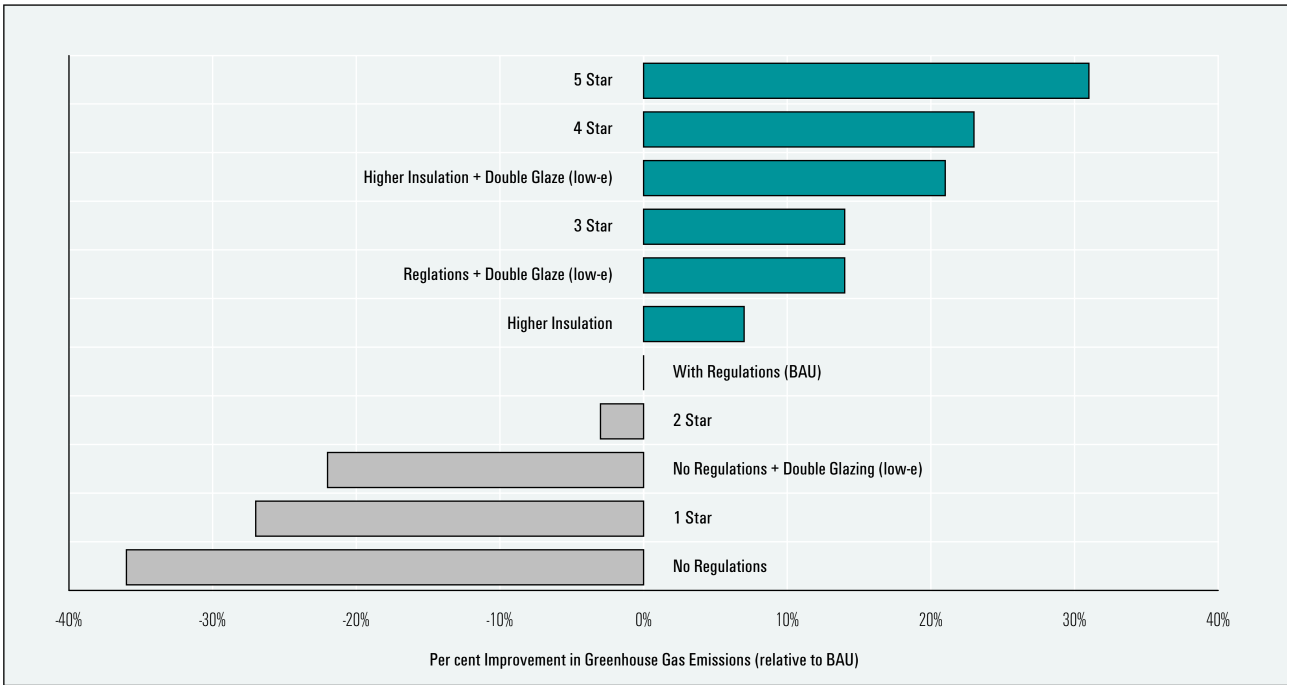
Figure 26 plots the trends in greenhouse gas emissions for the various scenarios relative to the level of emissions in 1990. This type of comparison is consistent with the type of analysis needed to assess compliance with commitments to national targets under the Kyoto Protocol. The increase in emissions from the sector has been reduced from 137% of 1990 levels in 2000 for the "without regulations" scenario to a 125% increase for the "with regulations" or BAU case. The best result would have been achieved by the 5 star rated (average equivalent) scenario, where emissions are limited to 114% of 1990 levels. The 5 star result is still 6% higher than the 108% Kyoto target (assuming a uniform target across sectors and end uses), and this has to be met in 2010 rather than 2000.

3.3.4 Conclusions

- There appears to have been no significant improvement in the thermal efficiency of new Class 1 buildings since the introduction of regulations in 1991 – in fact increases in average size are driving up total energy consumption at a significant rate.
- Whilst the present policy of mandatory insulation has and will continue to deliver a significant level of savings in energy consumption and greenhouse gas emissions (compared to the situation without regulations), the policy offers little scope to go beyond this level of improvement.
- Further increases in the mandatory level of insulation will only result in marginal improvements in energy consumption. A policy of increasing insulation levels would also suffer from diminishing returns on investment.
- Mandatory double glazing (low-e) requirements, if they had been introduced along with the mandatory insulation requirements, would have reduced total residential heating and cooling emissions by a further 5.4 % in 2000 (9.9% in 2010). For the stock constructed since 1990, this equates to a 21% reduction in heating and cooling emissions in 2000 compared to the BAU case.
- The potential for improvement would have been greatest if a mandatory minimum energy performance standard (such as a minimum star rating) had been introduced instead of the current regulations. Even a 3 star minimum requirement would have resulted in a significant improvement over the current regulations. The greatest impact would have been achieved by the introduction of a 5 star requirement.
- Given the long life of residential dwellings, any decisions regarding insulation or performance requirements have very long term impacts although the impacts on the total stock of dwellings is gradual.

Projecting further ahead to 2010, the expected situation is shown in Figure 27. All scenarios examined are presented in this projected estimate of the situation in 2010.

Figure 25 GHG Emission Reductions: New stock from 1991 and 1999 – Various Scenarios



10 *Based upon the methodology adopted by EES (1999).*

Figure 26 Heating and Cooling Greenhouse Gas Emissions Relative to 1990 – Various Scenarios

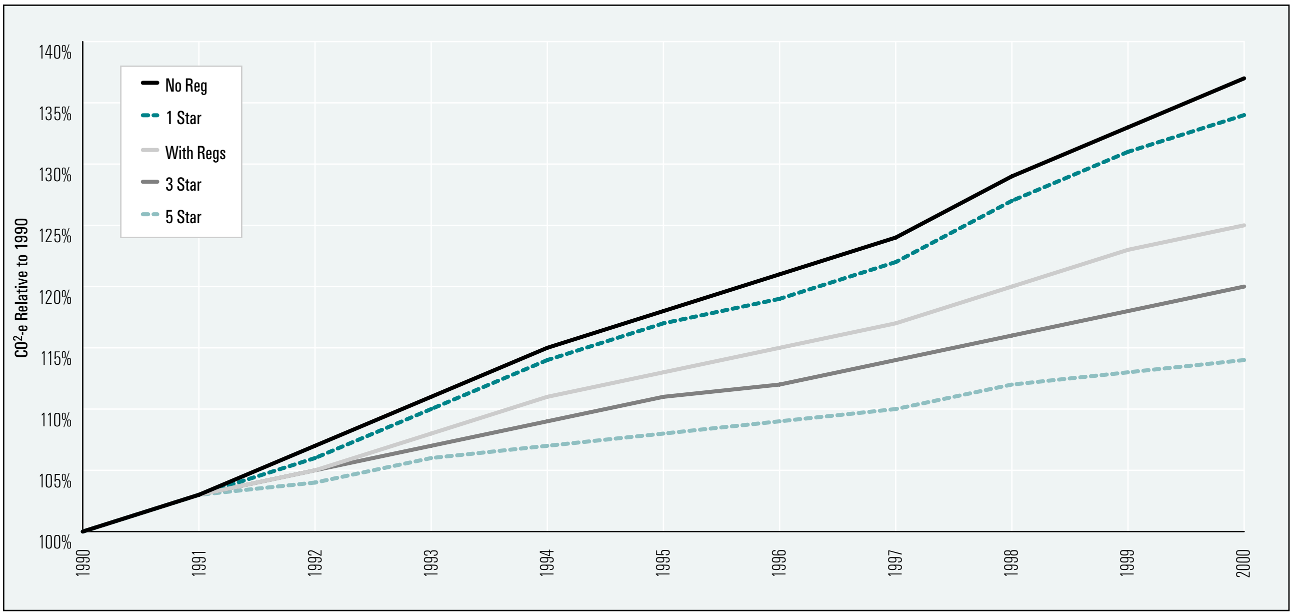
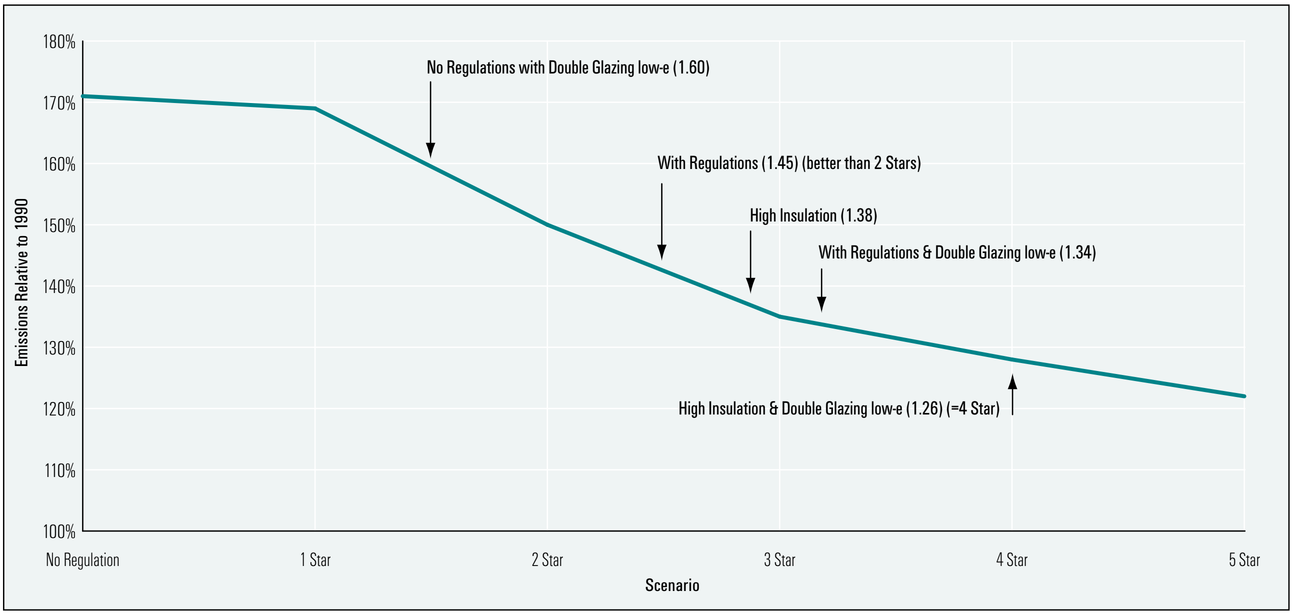


Figure 27 Greenhouse Gas Emissions For Various Scenarios in 2010 (all stock)



SECTION FOUR
SAMPLE SELECTION

SECTION 4 SAMPLE SELECTION

4.1 Overview

The methodology applied for selecting the sample for the study involved several steps which are also illustrated in Figure 28. Briefly, the process involved:

1. Finalising the sample size for the study.

For 1990, 105 homes were to be rated, 240 homes were to be rated for 1999. The increased sample size for 1999 was funded by the Sustainable Energy Authority of Victoria (formerly EEV). The authors undertook an additional 5 home ratings for the 1990 period making a total of 110 for 1990 and 350 overall.

2. Acquiring data from the ABS on councils with the greatest amount of construction activity.

Building data for all Victorian councils were obtained from ABS from 1991 to 1999 including data on numbers of approvals, construction type and floor area by council. A final list of eleven councils was compiled based on the ABS data and the Councils were approached through the AGO to seek participation in the study. Consideration was also given to ensuring that councils represented the various NatHERS climate zones within Victoria.

3. Determining housing construction types to be used as the basis for the strata in the sample.

Four housing construction types were chosen including: brick veneer and concrete floor construction, brick veneer and timber floor construction, lightweight construction and double brick construction types[11]. These were based on data supplied by ABS for the whole of Victoria at LGA level.

4. Approaching councils to obtain agreement to supply building plans for each of the study years.

Eight councils representing metropolitan and regional Victoria agreed to participate in the study.

5. Obtaining photocopies of building plans from the councils.

Each randomly selected set of building plans had identifying information such as site address concealed. Plans were then copied by council staff and handed to the research team.

6. Categorising and compiling council plans to be used for performance analysis.

Plans were categorised by year, council, construction type, housing type and number of storeys. They were assigned identification codes (see appendix) ready for rating.

7. Weighting the sample appropriately according to NatHERS climate zones and number of storeys.

Unavoidable distortions in the sample in terms of climate zone and multi storey representativeness were normalised on the basis of state level data.

A summary of each house that makes up the sample is contained in the appendix to this report.

4.2 Sample Size, Error Margins and Confidence Limits

The original scope of work allowed for a sample size of 105 houses in each year of the study – 1990 and 1999. However, with participation from SEA in the study, the scope expanded to include 240 houses in the year 1999.

The extra number of houses modelled in 1999 improved the sample accuracy in that year enabling comparisons within that year to be made with greater precision in the results. At a 95% confidence interval, the sampling error for the 1999 sample was reduced from ±10% (original sampling error for a sample of 105) to ±6%. However, it should be noted that while the extra numbers of houses sampled in 1999 are useful for gaining a greater insight into the efficiency of housing construction in that year, the increased numbers in 1999 do not improve the sample accuracy when comparing 1990 to 1999.

The sample size of 110 in 1990 and 240 in 1999 allows for a sampling error of ±10% at a 95% confidence interval. Put simply, we are 95% certain that the results achieved lie within ±10% of the actual population. The final sample achieved within each construction type is shown in Table 6 below. The construction types are described in detail in the section "Stratification of the Sample".

All building plans were obtained from councils within country and metropolitan regions throughout the state. The selection of councils for inclusion in the study is described below.

11 Refer to Section 6.3 for details of ABS construction categories aggregated under each of these headings.

Figure 28 Overview of Sample Selection Methodology

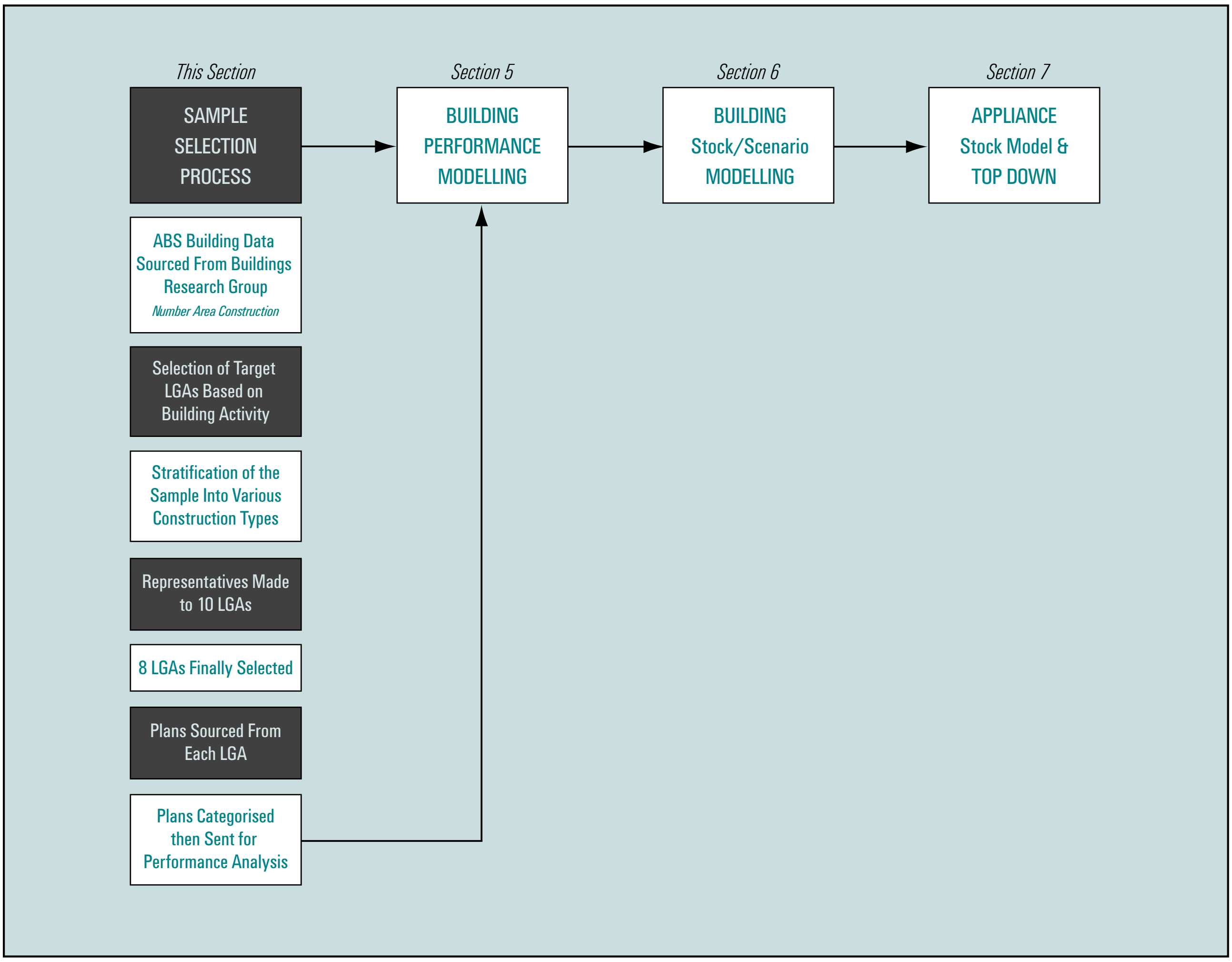


Table 6 Sample Details by Construction Type

Group	Number Obtained 1990	Number Obtained 1999
Attached Houses:	7	36
Total	7	36
Detached Houses:		
Light weight	6	19
Brick veneer and timber floor	35	57
Brick veneer and concrete floor	61	126
Double brick	1	2
Total	103	204
Grand Total	110	240

4.3 LGA Selection Process

Councils were chosen based on the level of new housing activity in the years 1991/92[12] and 1998/99. The ABS was approached to provide data on the number of new houses built in these years within each (LGA)[13]. The data was provided for detached houses and non-detached houses.

Data collected in the respective years was sorted and ranked based on the number of new dwellings built. A combined score based on the individual rankings was used to select the top eleven councils to be approached in the study.

In summary, LGAs were selected using the following criteria:

- ranking LGAs based on the number of detached and non-detached dwellings built in the years 1991/92 and 1998/99
- Those LGAs with a high ranking of detached and non-detached dwellings built were selected
- LGAs within the "hotter" climate zone (Zone 20) and "cooler" climate zone (Zone 24) were also selected to ensure adequate representation of the three main climate types encountered in Victoria. These LGAs were also selected according to their ranking and representation of detached and non-detached housing types

The LGAs within these climate zones were also rural LGAs. The LGAs selected initially for sampling included:

- Casey (on rural fringe 35km east of Melbourne)
- Ballarat (rural city 100km west of Melbourne)
- Mornington Peninsula (on Port Philip Bay, SE of Melbourne)
- Hume (northern suburban area of Melbourne)
- Greater Geelong (regional city on Corio Bay, 60km SW of Melbourne)
- Kingston (south eastern suburbs of Melbourne)
- Hobson's Bay (western suburban area of Melbourne within 10km of GPO)
- Monash (south eastern suburbs of Melbourne)
- Knox (heartland of Melbourne's eastern suburbs)
- Wodonga (regional city in Victoria's north east, 300km from Melbourne)
- Greater Shepparton (regional city in Victoria's north east)

The above councils were subsequently approached through the AGO to ascertain their willingness to cooperate in the study. Of the 11 councils approached, the 8 listed in Table 7 agreed to provide plans.

Table 8 details the Class 1 building activity in each of the selected councils as a proportion of the state total. councils selected in the study account for approximately 30% of Class 1 building activity in the state during the study periods of 1990 and 1999. It should be noted that participating councils were asked to provide building plans based on state level data for construction type and detached/attached dwellings to ensure that representativeness at the state level was achieved in the sample. Therefore, although the councils selected represent 30% of Victoria in terms of building activity, housing construction types are generally reflective of construction activity at the state level.

Table 7 Selected LGAs That Provided Samples for the Study

Selected LGAs	Postcode (indicative)	FirstRate Climate Zone (NatHERS)
Ballarat – code B	3350	24 Ballarat (Canberra)
Casey – code C	3000	21 Melbourne
Hume – code H	3000	21 Melbourne
Kingston – code I	3000	21 Melbourne
Knox – code K	3000	21 Melbourne
Monash – code M	3000	21 Melbourne
Mornington Peninsula – code P	3000	21 Melbourne
Greater Shepparton – code S	3630	20 Bendigo (Wagga Wagga)

12 Note that the activity level in 1991/2 was used as the basis of selection of local councils (about the year of introduction of the regulations) but the plans obtained from councils were actually from 1990. This was because electronic records on building activity prior to 1991 were not readily available from ABS.

13 Note over the study period LGA boundaries were substantially altered due to widespread council amalgamations. All data sourced for this study was resolved into the current LGA boundaries. This process was complicated and was not possible to carry this out prior to 1991/92. As a result the sample selection for the 1990 year was based upon data relating to building activity in 1991/2.

Table 8 Building Activity by Selected LGA as % State Activity

LGA	91-92			98-99		
	Detached	Attached	Total	Detached	Attached	Total
Ballarat	2%	1%	2%	2%	1%	2%
Casey	9%	4%	8%	8%	2%	7%
Hume	6%	4%	6%	4%	1%	4%
Kingston	2%	5%	3%	2%	6%	3%
Knox	3%	1%	3%	4%	3%	4%
Monash	1%	3%	1%	3%	4%	3%
Mornington Peninsula	5%	3%	5%	6%	3%	5%
Greater Shepparton (C)	1%	1%	1%	1%	0%	1%
Sample Coverage	29%	22%	29%	31%	20%	29%

4.4 Stratification of the Sample

A stratified random sampling technique was used in the study, with construction type used as the basis for the strata. This sampling approach was chosen for its randomness and hence its ability to reduce sample bias. It also ensured that the sample was representative of the actual distribution of key building types in Victoria.

Statistical data from the ABS on housing activity by LGA was used to select councils for inclusion in the study based on their high level of new housing activity, as described earlier. A state-wide comparison of housing construction types was also obtained from the ABS. This was used as the basis for creating the strata of housing construction types which councils would use to select building plans for use in the study.

Table 9 Housing Activities by Construction Type (ABS)

Construction Type	1989/90	1998/99
Lightweight	13%	13%
Brick Veneer and Timber or Other Floor	27%	24%
Brick Veneer and Concrete Floor	58%	62%
Double Brick	2%	2%
Total	**100%**	**100%**

4.4.1 Detached Housing Sample Frame

Based on the state wide data collected in the first round of data from ABS, the following sampling strata for detached housing types were developed:

- lightweight (includes construction in fibre cement, timber, aluminium, steel or curtain glass) and timber or other floor
- brick veneer and timber or other floor
- brick veneer and concrete floor
- double brick and concrete or timber floor

Table 9 shows the proportions of housing types in the years 1989/90 and 1998/99 as sourced from the ABS. These proportions formed the strata within the sample. In reality the actual proportions of each strata returned by councils varied slightly from the target strata proportions. The only notable variation between target and actual levels was in the case of lightweight construction where the strata proved difficult to source. In the 1990 sample only 6% was lightweight and in 1999 it was 9%, compared to a target of 13% in both years. This means that the performance estimates for this category of construction are likely to be less accurate than the target accuracy as described in Section 4.2.

It should be noted that the actual construction type data showed a small proportion of "other" construction type materials (probably attributed to mud brick, rammed earth, tilt slab and aerated concrete block construction types). In 1989/90 "other" construction types constituted 2% of the new houses built in Victoria and in 1998/99 it constituted 14% of new houses built.

The 1998/99 data for other was considered erroneous for the following reasons:

- The proportion of “other” housing construction types such as mud brick would most likely be smaller than the reported 14% for all new detached dwellings built. It is unlikely that there would have been a shift of 12% to other construction types in such a short time span (10 years).
- Discussions with the main producer of aerated concrete blocks and panels – Hebel Pty Ltd, revealed that industry estimates of the market penetration of these products is less than 2%.
- On closer inspection of construction types in council specific data, it seemed that only a small proportion of councils (two of the ten chosen in the sample) recorded more than 13% of "other" construction types. All other councils reported less than 3%. This suggested that the data was incorrectly recorded by ABS.

Due to the potential inaccuracies and associated difficulties in collecting data from councils that contained "other" construction types, these houses were excluded from the sampling frame provided to each council. Whilst the actual proportion of these "other" construction types cannot be known with any certainty, it is likely that even if they did constitute more than 2-3% of the market, in many cases their performance characteristic especially in terms of overall wall R values would not be dissimilar to those of the predominant construction types. For example, mud brick or rammed earth construction (typically un-insulated) would provide similar performance characteristics to cavity brick construction (also typically un-insulated).

4.4.2 Attached Housing Sample Frame

The attached housing sample frame was more simplified than the detached sample frame in that only a small proportion of housing construction was attached housing. Table 10 shows the proportion of attached housing in the 1989/90 and 1998/99 years.

Table 10 Attached Housing Sample Proportion of Total

1989/90	1998/99
7%	15%

The attached housing types were not broken into construction type strata as with the detached housing for two reasons. Firstly there was no reliable data available on the market share of each construction types used (this data is not recorded by ABS) and secondly, the small size of the required sample meant that stratification would have been difficult to achieve in practice (finding examples of any attached housing amongst council records represented a significant challenge in itself). Instead, reliance was made on the randomly selected sample of attached housing being representative of the proportions of the various construction types actually used.

4.5 Sample Weighting

While all necessary steps were chosen to ensure sample representativeness in the sampling procedure, some weighting of the sample was required to correct for over representation of some councils according to the NatHERS/*FirstRate* climate zones and number of storeys.

Table 11 Representative and Actual Sample Sizes by Climate Zones

Climate	Representative Target Sample size		Actual Sample Size	
	1990	1999	1990	1999
WAG 20 (Shepparton)	9	13	11	30
MEL 21 (Melbourne Suburbs)	84	205	87	190
CAN 24 (Ballarat)	10	18	12	20
ALP 25 (Nil)	0	0	0	0
MLD 27 (Nil)	2	4	0	0
Total	**105**	**240**	**110**	**240**

4.5.1 Weighting for NatHERS Climate Zones

The sampling strategy aimed to cover the major climate types in Victoria according to NatHERS/*FirstRate*, however, over representation of the Shepparton Council, particularly in 1999, meant that results for plans rated in Shepparton had to be weighted down accordingly. Some slight weighting adjustments were made to the remaining sample as shown in Table 12 which indicates the representative sample size and the actual sample size obtained.

The discrepancies noted in Table 11 were adjusted by weighting the *FirstRate* runs accordingly. See also Section 5.5 for details of the weighting process.

4.5.2 Weighting for Multi Storey

On average multi storey houses were found to use about 14% less space conditioning energy compared to single storey houses. The sample was weighted to correct for houses with two or more levels as the sample collected under represented multi storey houses in the 1990 sample and over represented multi storey houses in the 1999 sample[14]. Table 12 shows the sample sizes collected and the actual population data as obtained from the ABS on the number of levels within residential dwellings.

Table 12 Sample Proportions for Multi Storey Housing

	1989/90	1998/99
Representative sample size	20%[1]	29%
Actual sample size	12%	30%

Note 1: This Figure is an estimate only. For 1990 the number of storeys was not reported in available ABS data. The Figure for 1990 was assumed to be lower than the 1999 Figure due to the recent proliferation of two storey dwellings in the new housing market. A sensitivity analysis of the potential error associated with this estimate gives a 1.0% error in the total energy estimates for each +/- 7% shift in this estimate (ie. between a range of 13% and 27% for the proportion of multi storey housing in 1990).

14 *Weighting for multistorey was only practical for the sample from the MEL 21 climate zone. Samples from the other two (regional councils) climate zones were too small to allow a reliable weighting for multi-storey housing.*

SECTION FIVE
BUILDING PERFORMANCE MODELLING

SECTION 5 BUILDING PERFORMANCE MODELLING

5.1 Overview

Following sample selection, the selected plans were assessed for thermal performance using the *FirstRate* modelling software developed by SEA. The analysis of performance required the modelling of a series of performance cases using a set of specially developed assumptions. The output had various weightings applied to deal with particular shortcomings within the sample and interpolations were made between the two years from which the sample was drawn. The process is summarised in Figure 29 below.

5.2 Performance Modelling Tool

The thermal performance modelling tool adopted for use in this study was the *FirstRate* software. *FirstRate* is an accredited tool for use in Victoria in the Nationwide HER scheme and its use was approved by the Project Steering Committee.

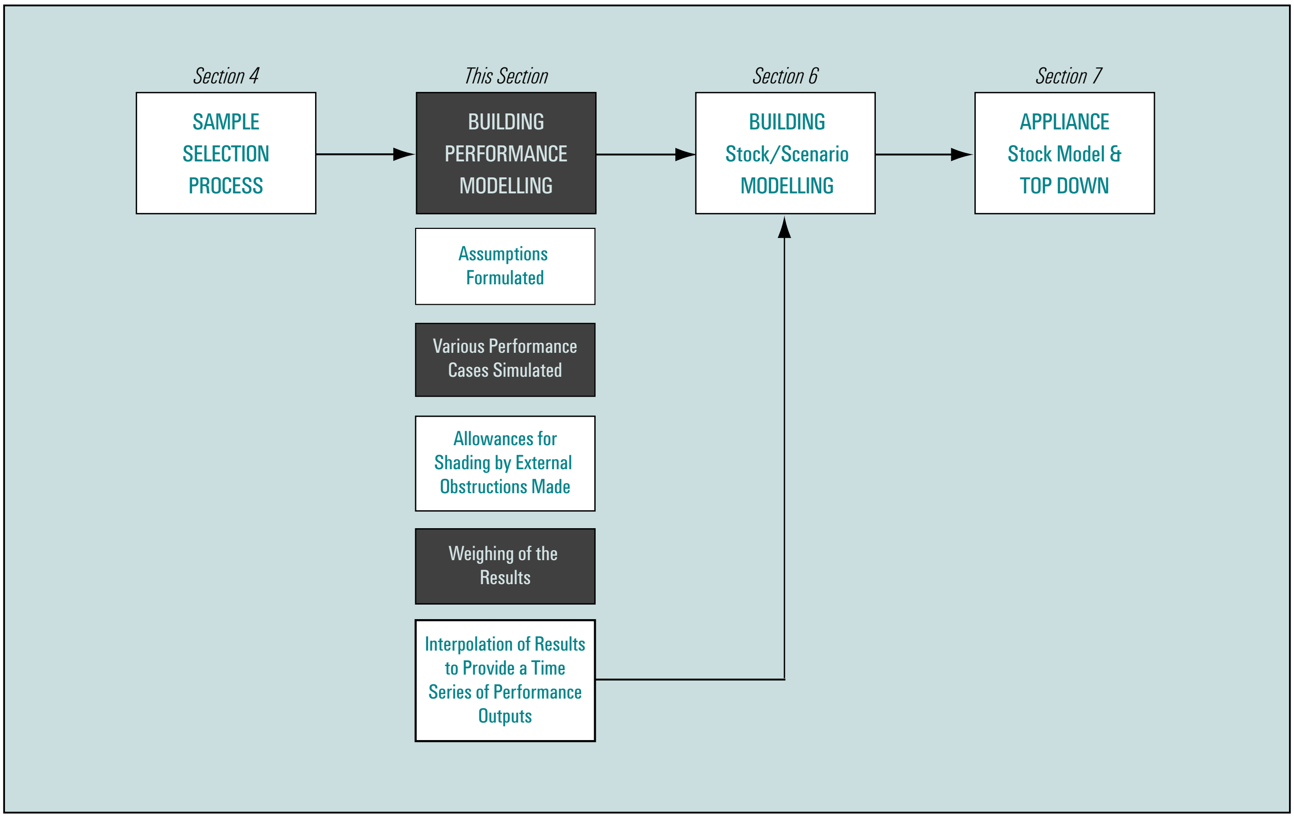
The CSIRO's Nationwide House Energy Rating Software (NatHERS) is a building thermal performance simulation software package which underpins the Nationwide House Energy Rating scheme throughout Australia. It has been tested against the best international software and found to be quite accurate. SEA has used this software to develop a correlation between building element properties and NatHERS simulated energy use. These correlations are expressed as the point scores in the *FirstRate* software.

5.3 Assumptions

In order that performance assessments may be carried out on sample houses it was necessary for a number of assumptions to be made about various aspects of the houses construction and operation.

Some of these assumptions, such as those relating to user behaviour, are built into the software and are derived from the assumptions used in NatHERS. Other assumptions relate to

Figure 29 Overview of Building Performance Modelling Methodology



required modelling data inputs that may not be readily discernible from the documentation obtained from local government records. For instance, few of the sample plans contained detailed information regarding floor coverings. In these circumstances a set of assumptions was developed based on known common practices.

The following sub sections detail the thermal performance modelling assumptions adopted for this study. With the exception of assumptions relating to user behaviour, the assumptions noted are based upon the most common practices associated with the BAU case (ie. with current regulations). Other cases involving different settings for selected assumptions were also modelled as part of this study, these are described in Section 5.4.

5.3.1 Floors

Floor coverings were assumed to be carpet throughout the house except in kitchen/ family areas where it was assumed that vinyl was used and in wet areas where it was assumed that ceramic tiles were used.

It was assumed in all cases that for the purpose of area measurement that floor areas extend to the outer edge of walls adjoining utility rooms, garages or neighbours as in the case of party walls.

Floor were assumed to be uninsulated unless noted otherwise. The practice of floor insulation is most uncommon in Victoria (see Section 8). Under the current BCA provisions one option is to insulate a timber floor thereby negating the need for anything other than foil insulation in the wall (for framed construction). In practice however this option is rarely taken up as the insulation of floors is seen as a less attractive option by the building industry than using R1.5 insulation in the walls (ie. the alternative compliance solution offered in the BCA).

The *FirstRate* software makes no provision for the input of data relating to slab edge insulation. In circumstances where edge insulation of floor slabs was indicated on drawings or specifications it was assumed that such a practice would provide a similar level of thermal performance enhancement to that of full floor area insulation of R-value equivalent to half that of the actual edge insulation. Unlike slab edge insulation this deemed equivalent alternative could be input as data into the program.

5.3.2 Walls

For the 1998-99 sample houses it was assumed that wall insulation consisted of R1.5 for framed construction with a timber floor and R1.0 for framed construction with a concrete slab floor. These assumptions are based upon the minimum requirements as set out in the Building Code of Australia. Interviews with building surveyors and industry representatives (see Section 8) suggest that minimum insulation levels are overwhelmingly the normal practice.

A further consideration relating to walls was how walls joined to garages should be handled. The enclosed space of a garage offers additional insulative properties to what is otherwise considered an external wall. In these cases such walls were input as "Weatherboard" if of framed construction and as "Concrete 100mm Int." if of solid construction while adding notional insulation of an additional R0.5 if the garage is fully enclosed.

5.3.3 Roofs / Ceilings

Unless noted otherwise it was assumed that houses built pre-regulation were not fitted with ceiling insulation. In fact, it is thought that approximately half the housing built during this period now has ceiling insulation installed at a similar level (R rating) to that required under the current regulations. This has been accounted for by forming the pre-regulation profile from a blend of performance (insulation) cases – see Section 6.5.

For the 1999 sample, ceiling insulation was assumed to be R 2.5. In fact industry surveys (see Section 8) indicate that the actual case consists of a combination of R2.0 ceiling insulation with reflective foil under the roof or R2.5 ceiling insulation alone. Whilst these two alternatives will provide slightly different performances on a seasonal basis, the difference is not significant and would be more than outweighed by the uncertainty regarding the market penetration of each of the insulation options.

5.3.4 Windows and Pergolas

Unless otherwise noted on the plans, window frames were assumed to be standard aluminium. Timber frames and high performance metal frames are less common but will provide a small improvement in overall building shell thermal efficiency. This assumption is likely to result in a slight over estimate of energy consumption.

Window coverings were assumed to be vertical blinds. Vertical blinds will provide a moderate level of performance improvement, better than no coverings at all but not as good as heavy drapes.

Pergolas where they are indicated on plans are expected to support some form of vegetation – typically deciduous. An assumption was made that pergolas are 50% covered in summer and 20% covered in winter.

5.3.5 Infiltration

The level of infiltration is measured by the number of air-changes per hour. This is mainly affected by the following factors:

- whether or not wall vents are present
- how well windows and doors are sealed
- whether or not there are vented skylights and or down lights
- whether open fire places are sealable or not
- the degree of site exposure.

Houses built in the past ten years typically have no wall vents fitted. Windows and doors are reasonably tight fitting but seals are usually fairly basic or in some cases absent (especially on doors). Down lights are typically vented (for heat dissipation purposes). Skylights typically have some fixed ventilation as standard (to comply with health and safety requirements contained in the BCA). Fire places are typically of the insert type which come standard with a flue damper.

Based on these professional judgements regarding the housing market in Victoria the following *FirstRate* settings were selected:

Table 13 Default "Air Leakage" settings adopted for *FirstRate* simulations

Option	*FirstRate* Setting
Door and window gap size	Medium
Down lights	Vented
Skylights	Vented
Chimneys	Sealed
Site Exposure	Suburban except where it is ascertained from the plans that the setting is rural

In addition to the above assumptions it was decided that external doors in utility rooms be counted as external doors.

5.3.6 Climate

Whilst modelling is carried out at a State level based on data derived at the LGA level, in terms of predicting thermal efficiency characteristics of building shells it is not these boundaries that are relevant but "climatic zones". *FirstRate* distinguishes 28 different climatic zones throughout Australia. Victoria contains five of these zones, only 3 of which are significant in terms of building activity (see Figure 30 and Figure 31). Samples were derived from each of these three significant climate zones and *FirstRate* modelling was set to the appropriate climate zone for the particular sample selected as noted in Table 7.

5.3.7 User Behaviour

In addition to the thermostat set points and times of occupation and the operation of ventilation and shading options in response to weather conditions set out under the relevant headings below, other factors are entrenched in the *FirstRate* / NatHERS internal settings which do not necessarily reflect common household patterns:

1. No allowance for part house heating and/or cooling.
2. No allowance for vacation absences at any time.
3. No differentiation between weekdays and weekends or public holidays.
4. Preset patterns of lighting and internal appliance efficiency and use.

Factors 1 and 2 will both result in overestimation of actual energy consumption for real households while factor 3 may result in a lesser or greater overestimation of energy consumption depending on the actual "normal" and "holiday" occupancy patterns of the household concerned. Factor 4 is probably neutral in terms of current practice but will not account well for predicted improvements in appliance and lighting efficiencies and user diligence. In terms of forecast energy consumption, this may overestimate cooling energy and underestimate heating energy due to the lower amounts of "internal loads" that we would anticipate in future households.

These indicated corrections are implicit in the adjustment to the constrained demand case as described in Section 7.

5.3.8 Thermostat Set Points And Hours of Operation

The thermostat set points and hours of operation shown in Table 14 are incorporated in *FirstRate* / NatHERS although, at the time of writing, they are still under state-by-state consideration. They form the basis of the simulations done for this study but are yet to be confirmed by all the jurisdictions (eg, Wilrath 1998).

This assumed "unconstrained"[15] pattern of heating and cooling is not directly related to population behaviour but rather to the house if its occupants were considered "always" comfortable (in the absence of cooling air movement). This is well known to give energy consumption results which exceed the known average demand and this is why we have used such results cautiously – constraining them in the light of actual energy consumption data.

15 "Unconstrained" by economic factors, a concern for the environment or other competing benefits like silence versus coolness at night.

Table 14 *FirstRate* / NatHERS Assumptions by Climate Code

Location	Climate Code	Living Hours[1]	Rooms Temps	Bed Hours[1]	Rooms Temps
Ballarat	WAG 20	07-24	21°-26°C	07-24	21°-26°C
Melbourne	MEL 21	07-24	21°-26°C	07-24	21°-26°C
Shepparton	CAN 24	07-24	21°-26°C	07-24	21°-26°C

Note 1: Hours relate to assumed hours of space conditioning use as adopted by the NBEECC working party rather than hours of actual occupancy.

5.3.9 Beneficial shading and Ventilation

Default shading and ventilation settings for *FirstRate* are based upon the settings used in NatHERS. The NatHERS Users' Manual (CSIRO, 1998) says:

External Blinds

The blinds are drawn if

- at a given hour the outdoor temperature exceeds a preset value
- at a given hour the incident direct solar radiation on the window (allowing for overhangs and pergolas) exceeds a preset value.

The temperatures and solar radiation values for these operations are predefined and cannot be changed by the user. The shading factor is the proportion of total solar radiation that reaches the window when the blind is drawn.

Internal Window Coverings

The curtains or blinds are assumed to be drawn overnight, and may also be drawn during the day under certain conditions. These conditions are:

- if there are no external blinds for that window, or the external blinds are not to be drawn
- if at a given hour the outdoor temperature exceeds a preset value
- if at a given hour the incident direct solar radiation on that window (allowing for overhangs and pergolas) exceeds a preset value.

The times, temperatures and solar radiation values for these operations are predefined and cannot be changed by the user. Window coverings reduce heat conduction through the windows and incoming solar radiation. The window covering also affects the overall window U-value when they are closed. The added resistance depends on which window coverings were selected

For external blinds, awnings and the like, the activation temperature is at (or about, pending consensus) the mid-point of the heat and cool thermostat settings and the direct irradiation activation value is 75 W/m^2. This represents a very active use of these devices which is a reasonable way of handling the more common strategy of setting them for the summer and rarely retracting them. For internal blinds, the activation temperature is at (or about, pending consensus) the upper thermostat set point and the direct irradiation activation value is 200 W/m^2. This represents a much less active use regime and is reflective of the common occupant preference of not visually "closing up" the house for only modest efficiency gains.

Both values conform with our view of prudent and likely average user behaviour. Objections that this will allow many (and sometimes protracted) instances of the cooling device being on with the sun shining (weakly) through the window are accurate observations. Such behaviour obviously falls short of economically ideal occupant action. We do not, however, believe that occupants will generally shut themselves off from the outside world in the absence of strong sun penetrating the window and hence regard this as a suitable simulation of actual household action.

Ventilation

The house is assumed to be able to be cooled using outside air when favourable conditions exist. The windows are opened for ventilation at any time of the day if the zone temperature is too high for comfort and the temperature outside is lower than inside. When the house is cool enough the windows are assumed to be closed again. If the house can be kept comfortable using ventilation only, the air conditioning is not activated. If ventilation is not able to maintain comfort conditions, the windows are assumed to be closed and the air conditioning started.

The ventilation rate is varied in proportion to the square root of the local wind speed, and also depends on the question about cross-flow ventilation in the "Design Features" Section of *FirstRate*. If the local wind speed is greater than 1.0 m/s then:

Ventilation rate (Air Changes per Hour) = A + B where A and B are constants.

Local Wind Speed (m/s) = Wind speed x Terrain Factor.

If the local wind speed is less than 1.0 m/s then

Ventilation rate (Air Changes per Hour) = A + B x Local Wind Speed.

These temperature conditions and ventilation values conform with our view of prudent and likely average user behaviour (except for their failure to adjust upward the thermostat limit temperature in response to internal air movement generated by the ventilation). Accordingly we expect that the *FirstRate* results will be an overestimate of cooling energy demand but this overestimation is corrected by the application of "constraint" factors.

5.3.10 Glazing

Double glazing currently has an insignificant market share except in the Alpine climate zone (NatHERS ALP25), which represents only a small portion of Victorian Class 1 building activity (less than 1%) . Houses were assumed to have clear single glazing only unless noted otherwise on the plans. ABS surveys indicate that total stock market share of double glazing in 1999 was 2.2% (ABS 4602.0 1999).

In addition to the base case assumption regarding glazing noted above, a hypothetical scenario was modelled using the sample houses fitted with double glazing. The results of this modelling is covered in Section 6.

5.3.11 Allowing For Shading By External Obstructions

Overshadowing of windows either by features on the house itself (self shading) or features external to the house (external obstructions) will have the effect of reducing solar heat gains. Consequently, shading will tend to increase heating demand in the cooler seasons and reduce cooling demand in the warmer seasons.

Whilst features that will result in self shading are normally evident from the plans, external obstructions that will cause overshadowing generally are not. Most houses would be expected to be affected to some extent by overshadowing from external obstructions such as plants, trees, fences, carports, out-buildings adjacent houses, etc. To make allowance for shading by external obstructions, the following assumptions were made.

Self Shading

Overshadowing (self-shading) only occurs for windows facing a northerly direction or where the shading wall/roof is on the northerly side of a window facing east or west.

Overshadowing By External Obstructions

For detached housing external obstructions, if any, that were shown on the site plans were ignored, instead a shading factor was applied based on the assumption that solar irradiation of windows is discounted to 60% of the unobstructed value in winter and 80% in summer. This "suburbia factor" is a professional judgment as no definitive research in this field is known. The most recent "Environmental Issues" study by the ABS found that 61% of respondents in Victoria reported "significant" shading out of winter sunlight to their windows.

For the purposes of this study it is not so much the assumed degree of shading that is critical[16] but whether or not shading has tended to increase or decrease over the study period. In the same ABS study an assessment was made of the number of rooms that received winter sunlight in both 1999 and 1994. Whilst the results cannot be considered a perfect indicator of shading, differences over the range of rooms assessed ranged from only a 1% to a maximum of a 3% increase in 1999 as compared to 1994. This difference was considered insignificant and suggests that the final result will not be sensitive to the shading factor adopted provided that a similar factor is applied over the entire study period.

For attached housing, external obstruction caused by neighbouring buildings on the same site was accounted for directly (as is the convention in NatHERS rating in NSW). The "suburbia factor" was then applied to the result to allow for the other obstructions as described for detached housing above.

Based on research work carried out by the authors for the *Australian Residential Sector Greenhouse Gas Emissions 1990 – 2010* (EES 1999), on average for detached housing this assumption translates into:

- a 30% increase in unconstrained heating energy consumption compared to the unshaded case
- a 20% decrease in unconstrained cooling energy consumption compared to the unshaded case

These factors were applied to the *FirstRate* output for all scenarios including the star rated options. This makes for a fair comparison, as star rating does not account for many of the obstructions likely to affect a house over its lifetime. For instance, it will never address the tendency of many home owners to plant trees, erect carports, outbuildings and verandahs that will effect thermal performance.

5.4 Formulation of Output

The samples from 1990 and 1999 were modelled separately such that outputs for each era could be fed into the stock model. As noted in Section 4.4 the sample houses were also stratified into detached and attached housing and into various construction types. Results from samples within each strata were averaged to provide estimated average thermal efficiency levels for each construction type.

As modelling was conducted on two years of sample houses only (1990 and 1999) it was necessary to interpolate the thermal efficiency levels for the intervening years. This was carried out as a linear interpolation at the level of construction type.

16 Shading factors are applied to the estimates of unconstrained heating and cooling demand. These results are subsequently constrained to match top down data relating to total state residential energy consumption by fuel type for the whole sector. The adoption of a lesser shading factor would for instance only result in an increase in the level of constraint necessary to match the top down estimates. The net effect of shading is to alter the balance between heating and cooling energy rather than change total energy consumption to any significant extent, as ultimately the model parameters are adjusted so that predicted energy closely matches top down energy records for the period 1986 to 1999.

5.5 Weighting for Variations in Building Activity by Climate Zone

State average housing thermal efficiency levels vary over time as a result of changes in construction and design; this has been accounted for as noted in Section 5.4 above. Variations will also occur as a result of changes in the proportion of houses built in the various (NatHERS) climate zones within Victoria. For example, a shift towards a greater proportion of houses being built in the more "extreme" climate zones within the state would result in an overall increase in state average housing space conditioning energy demands, all other factors being equal.

As noted in Section 5.3.6 there are a total of five NatHERS climate zones found in Victoria, only three of which are significant in terms of building activity. To adjust the modelling output to account for the differing proportions of building activity within each climate zone, the activity as reported at an LGA level by the ABS needed firstly to be mapped into the various NatHERS climate zones. Once the proportions of building activity were known in the target years of 1991-92 and 1998-99 (see Figure 30 & Figure 31), a simple linear interpolation could then be applied to determine the levels in the intervening years. These levels were then used to weight the *FirstRate* outputs.

Process of Mapping Building Activity into NatHERS Climate Zones

Building activity by LGA in terms of numbers of detached and attached houses built in the target years were evenly distributed amongst the postcode regions that were known to exist within that LGA. The actual postcodes that exist within each LGA was determined from ABS postcode to LGA concordance data. Postcode regions that were only partially located within an LGA were given a pro rata share of the building activity within that LGA. This calculated building activity in each postcode region was then attributed to the dominant NatHERS climate zone found in that region based upon NatHERS postcode/climate zone concordance data available from the NatHERS base files. The results of this analysis are reproduced in full in the appendix to this report.

Activity in postcode areas within common climate zones were then aggregated to provide state level activity Figures by climate zones.

The process of postcode to climate zone mapping relied upon a number of assumptions.

- Assumption 1: That where there are a number of postcode regions within a single LGA it is assumed that the building activity known to occur in that LGA is evenly spread over those postcode regions. This assumption is usually of little significance given that in the majority of cases all postcodes within a single LGA map into a single climate zone.
- Assumption 2: That when dealing with postcode areas that are split over LGA boundaries the housing numbers in postcode regions in adjoining LGAs are of a similar size. This assumption is usually of little significance given that in the majority of cases adjoining LGAs usually share a common climate zone.
- Assumption 3: That postcodes not covered by the NatHERS system are assumed to be in climate zones that are the dominant type found in the LGA in which the postcode region is located. The "missing" postcodes were listed in the ABS concordance:

Postcode	Indicative Location	Assumed Climate Zone
3283	Koroit roadside delivery	21
3312	Ardno	20
3402	Horsham PB	20
3586	Bulga	27
3656	Located in Mitchell shire	24
3838	Located in Latrobe shire	21
3864	Delvine	21
3866	Located in East Gippsland shire	21
3889	Bellbird Creek	21

None of the sample houses for 1990 or 1999 were located in these missing postcodes.

- Assumption 4: Where NatHERS identifies more than one climate zone present within a single postcode district, an assessment was made through reference to a state map as to the likely dominant climate zone within that postcode region. Generally it was a case of assuming that lowland/coastal areas dominated over highland areas. One exception to this rule was applied in the case of Omeo where it was assumed that the dominate climate type was Alpine (ALP25).

The results of the mapping are illustrated below in Figure 30 & Figure 31. The most significant change in building activity patterns between the years of 1991-92 and 1998-99 is the increase in activity within the Melbourne climate zone from 80% to 85%. This increase is matched by a commensurate decrease in the Ballarat and Bendigo climate zones. The shift of activity to the Melbourne climate zone is most noticeable in the attached housing market where the proportion has increased from 88% to 97%.

Figure 30 Proportion of Building Activity by NatHERS Climate Zone 1991-92

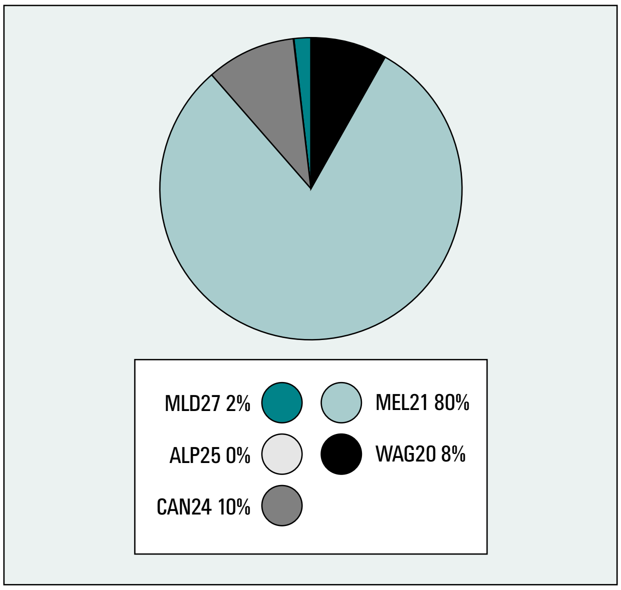
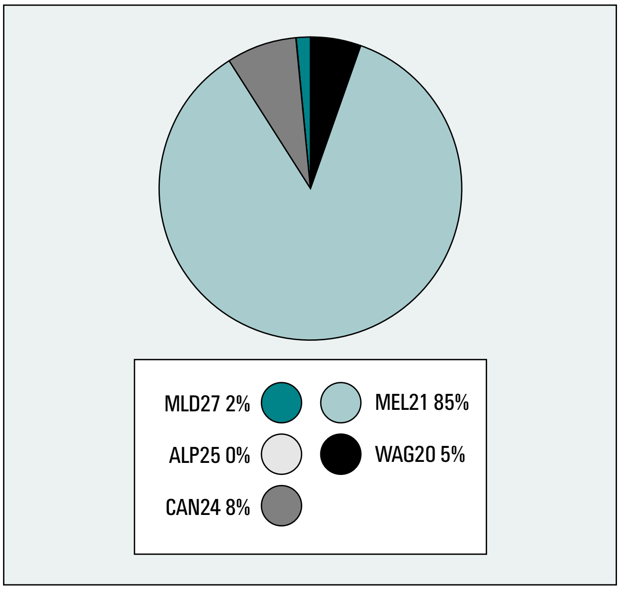


Figure 31 Proportion of Building Activity by NatHERS Climate Zone 1991-92



5.6 Alternative Performance Cases Modelled

In addition to the base case modelling, each house within the sample was remodelled using selectively modified sets of assumptions. The purpose of this was to allow for the modelling of a range of scenarios that could be made up of a blend of different housing performance profiles. For instance, in 1998-99 the most common practice was to comply with the minimum insulation requirements. However, a proportion of houses would exceed the minimum requirements and a very small number would be non compliant. A truly representative stock profile would therefore consist of a blend of these performance cases. Some hypothetical performance cases were also modelled such as star rated scenarios or scenarios including double glazing to all housing for instance.

The performance cases that were modelled were as follows:

1. No Insulation.
2. Insulation compliant with BCA minimum requirements (Base Case).
3. Insulation compliant with BCA minimum requirements post 1998 (Base Case post 1998 – see Section 2.1 for an explanation of the change post 1998).
4. Ceiling only insulation.
5. Under compliant level of insulation.
6. Over compliant level of insulation.
7. Performance based housing design (ie. star rated).
8. Double glazing (low-e)combined with cases 1 to 6 above.

The applied settings for cases 1 to 5 above were as noted in Table 15.

Table 15 Deemed R Values of Applied Insulation for Various Perfromance Options

Insulation Performance Option	Deemed R Value[4] Floor	Walls: Light weight	Walls: BV on Timber Floor	Walls: BV on Concrete Floor	Walls: Cavity Brick	Ceiling
No Insulation	0	0	0	0	0	0
Compliant with Regulations	0	1.5	1.5	1	0	2.5[1]
Compliant with Regs post 1998[2]	0	1.5	1	1	0	2.5[1]
Ceiling Only Insulation	0	0	0	0	0	2.5[1]
Under Compliant	0	1	1	0.5	0	1.5
Over Compliant	0.5	2	2	2	1[3]	3.5

Notes:
1. Bulk ceiling insulation only i.e. no reflective foil.
2. See Section 2.1 for details of changes to the regulations.
3. Assumed to be nominal 25mm polystyrene foam.
4. Deemed R value is the incremental increase in R value in addition to the R value of the stated material.

The star bands noted are the latest as formulated by SEA for use with *FirstRate* and NatHERS for those climate zones applicable to Victoria – see Table 16. These interim star bands have received in principle approval from the various jurisdictions responsible for NatHERS and are expected to be incorporated into the next release of NatHERS. The star bands have been set such that on average the star rating received using the *FirstRate* software will be equivalent to a rating that would have been achieved using the former Energy Victoria's HERS software in conjunction with the former star band settings[17]. This means that the results of this study can be reasonably compared to the performance targets set down in the BCA which were originally based upon ratings using Energy Victoria's (now SEA) HERS software.

The NatHERS star bands prescribe a total maximum energy consumption (summation of both heating and cooling), but this does not differentiate between heating and cooling energy. To allow for end use stock modelling of both heating and cooling appliances it was necessary to split these Figures into heating and cooling components. This split was based on the *FirstRate* modelled energy consumption ratio for heating and cooling found in the sample analysed and equated to 76% heating[18] and 24% cooling (reflecting the fact that Melbourne has a heating dominated climate).

Table 16 NatHERS Star Bands for Victorian Climates MJ/m^2

STAR RATING	Bendigo WAG20	Melbourne MEL21	Ballarat CAN24	Alpine ALP25*	Mildura MLD27*
1	610	460	580	1650	550
1.5	515	386	515	1382	430
2	441	328	460	1114	430
2.5	379	276	404	846	360
3	329	233	352	578	360
3.5	294	206	317	495	300
4	265	185	287	413	300
4.5	234	162	255	330	250
5	205	143	233	248	250

Note *: Revised values still to be obtained from SEA

State level average star rated performance scenarios were weighted to account for the changing pattern of building activity within the state using a similar process to that described in Section 5.5 i.e. the shift towards a greater proportion of the states houses being built in the MEL21 climate zone.

5.7 Interrogation Process Used on Sample

An output interrogation facility for the *FirstRate* modelling software was used to evaluate a number of characteristics of the sample other than thermal efficiency. The data retrieved included:

- conditioned floor areas
- conditioned external wall area
- conditioned floor area to conditioned external wall area ratio
- window areas by orientation
- window area to conditioned floor area ratio

An analysis of the outputs from this process can be found in the "Project Results" section of this report in Section 3.

17 Advice from SEA who have carried out over 1000 comparisons between the old and the new software is that for more than 70% of the cases tested the difference between the old software and the current software is less than half a star. However, compared to the old software, the new software does provide a slight bias for houses with concrete slab on ground floors compared to houses with suspended timber floors. In terms of this study this will result in the estimates for houses with timber floors appearing to be slightly worse when compared to the original BCA target performance level and the result for houses with concrete slab on ground floors appearing to be slightly better. Overall the comparison is expected to be valid.

18 A similar analysis conducted by SEA on their files produced an average Figure of 71% heating and 29% cooling. It was decided to use the Figure derived from the analysis of the sample associated with this study, as it was considered that this study's sample would be more representative than SEA's.

SECTION SIX
BUILDING STOCK/SCENARIO MODELLING

SECTION 6 BUILDING STOCK/SCENARIO MODELLING

6.1 Methodology Overview

The process of stock modelling of the building stock is outlined in Figure 32. The model was developed as two separate models; one that accounted for detached housing and one that accounted for attached housing. The outputs from each of these parts were then combined at the end of the stock modelling process.

In order that different scenarios examining the application of thermal efficiency improvement measures could be gauged, model variants were developed by blending various proportions of the performance options noted in Section 5.6. The scenarios modelled for comparison included:

- with regulations (ie. BAU)
- without regulations
- star rated
- higher insulation
- without regulations plus double glazing (low-e)

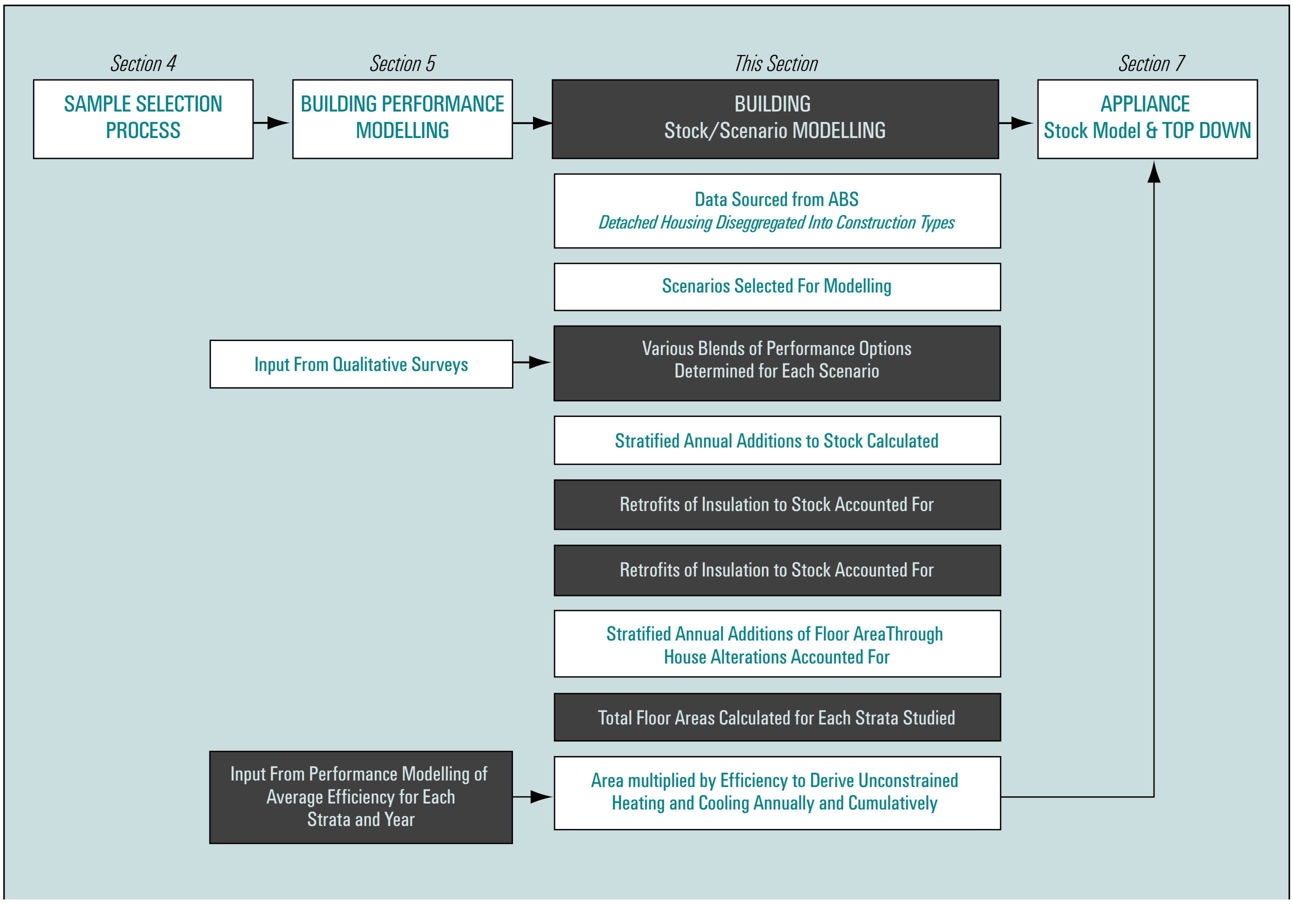
The stock model was designed to account for the following:

- new additions to stock
- retrofits of ceiling insulation to the stock produced during the study period
- alterations and additions to existing stock

Floor area data for the stock model was primarily derived from ABS data on building activity in Victoria. This was augmented with qualitative data gathered specifically for this study. The stock model of floor area was then combined with the thermal efficiency data derived from the *FirstRate* modelling of the sample houses (see Section 5) to derive unconstrained heating and cooling estimates for the study period.

The output of the building stock model was then used as in input to the appliance and space heating models. The results for space heating were constrained using a process as described in Section 7 so that total top energy for each fuel was equal to the modelled energy consumption for the state.

Figure 32 Overview of Stock Scenario Modelling Methodology



6.2 Building Activity and Related Data

Data on building activity over the study period was sourced from the ABS. This data formed the basis of the stock model developed for this project.

Data was obtained as follows.

- Number of detached houses built in each financial year from 1989-90 to 1998-99 at the state level.
- Average floor areas and floor area distributions of detached houses built in each financial year from 1989-90 to 1998-99 at the state level.
- Number of detached houses built in each LGA by number of storeys 1991-92 and 1998-99.
- Number of attached houses built in each financial year from 1989-90 to 1998-99 at the state level.
- Average floor areas and floor area distributions of attached houses built in each financial year from 1989-90 to 1998-99 at the state level.
- Number of attached houses built in each LGA 1991-92 and 1998-99. Note that data relating to number of storeys for attached housing was not available.
- Number of house alterations (detached and attached) undertaken in each financial year from 1989-90 to 1998-99 at the state level.
- Average area of house alterations (detached and attached) undertaken in each financial year from 1989-90 to 1998-99 at the state level. Where area was not reported these records were excluded from the calculation of average area.
- Construction details by wall and floor type for detached houses built in each financial year from 1989-90 to 1998-99 at the state level. Note that similar data for attached housing was not available.
- ABS postcode to LGA concordance data – see Section 5.5.

6.3 Disaggregation into Detached and Attached Types

Stock was divided into two broad types known to exhibit differing performance characteristics and differing trends in terms of stock numbers (see Figure 3 on page 15).

The two main types were:

- detached houses
- attached houses, ie. houses that share either common walls or floors or both.

It should be noted that attached houses for the purposes of this study do not include "flats"[19]. Flats do not come under the Class 1 building classification in the BCA and are therefore not subject to the thermal performance regulations under review. Flats represent a significant and growing proportion of the attached housing type. By excluding flats from the study the attached housing type accounts for less than 10% of the building activity in terms of floor area produced each year.

6.4 Disaggregation into Construction Types

The construction type of the floor, walls and to a lesser degree the roof affects both the insulating characteristics and the thermal mass of the shell. It is known from ABS data that the penetrations of the various construction types available will vary from year to year thus affecting average thermal efficiency characteristics. For the purposes of modelling, a set of the most common floor/wall/roof combinations were selected to represent the range of major construction types. In carrying out this process regard was given only to those factors that were likely to significantly affect thermal efficiency.

The selected combinations are noted in Table 17. Variations in roof material were not included as generally speaking roof material (as distinct from roof insulation) has a comparatively small effect upon thermal efficiency. Available ABS data provided splits into concrete and timber floor types for all wall construction types. However, due to the very small sample size of the cavity brick types and the lightweight wall types

Table 17 Housing Construction Types

Basic Construction Type	Description
Lightweight	Timber or metal framed walls with sheet cladding and suspended timber floor
Brick Veneer/Timber floor	Brick or block veneer walls, internal timber or metal wall frame and a suspended timber floor. Category also Includes precast concrete walls with internal framing
Brick Veneer/Concrete floor	Brick or block veneer walls, internal timber or metal wall frame and a concrete raft slab floor. Category also includes precast concrete walls with internal framing
Cavity Brick/Timber floor	Cavity Brick or block and suspended timber floor
Cavity Brick/Concrete floor	Cavity Brick or block and a concrete raft slab floor

19 Referred to in the BCA as "Sole occupancy units".

20 The relevant regulations came into force in mid March 1991 not at the start of the 91-92 financial year as adopted. In practice the first houses to be commenced under the new regulations would not in fact have begun to become operational until about July 1991.

with concrete floors, activity numbers for lightweight and cavity brick were aggregated without regard for floor type.

In order that the ABS data could be reconciled into the various construction types noted above the following assumptions were made regarding reported wall types:

- construction noted as "stone" has been aggregated with cavity brick construction
- constructions noted as "fibre cement", "timber", "curtain glass", "steel" and "aluminium" have all been classified as "lightweight"
- construction noted as "other" and "not stated" have been proportionally distributed amongst the other wall construction types

No separate data was available for attached construction types. Instead of attempting to disaggregate the attached housing into different construction types as was done with detached housing, reliance was made on the randomly selected sample of attached housing being representative of the proportions of the various construction types actually used. Only the sample in 1999 was large enough to provide a representative picture of the distribution of construction types.

6.5 Scenarios Modelled

The stock model was constructed in a manner that would allow for the modelling of scenarios that differed from the BAU case, otherwise known as the "with regulations" case. Basically the model was designed to allow for the blending of houses that exhibited the various performance options as detailed in Section 5.6. By blending different proportions of these performance types the following stock scenarios were modelled.

With Regulations

This is the "BAU" case. Starting in the 1991-92[20] financial year, the majority of housing complied with the minimum insulation standards as prescribed in the BCA. Apart from those houses that belonged to this dominant category, other minor performance categories that were represented were:

- no insulation
- ceiling only insulation (ie. wall insulation omitted)
- under compliant insulation (ie. insulation installed but to a lower standard)
- over compliant insulation (ie. insulation installed but to a higher standard)

The various proportions of each of the above types noted above are detailed in Table 18 below and are based upon findings derived from Section 8.

Without Regulations

This is a scenario that assumes that the minimum energy performance provisions of the BCA were not implemented. The scenario utilises the same performance types as the "with regulations" scenario (excluding the under compliant type) but in very different proportions – see Table 18.

Table 18 Penetrations of Performance Types Adopted for Each Scenario Modelled

SCENARIO	Penetration of Performance Types						2nd Level Performance Options
	No Insulation	Compliant with BCA2	Ceiling Only Insulation	Over compliant	Under Compliant	Star Rated	Double Glazed low-e
With Regulations (BAU)	0.01	0.77	0.02	0.10	0.10	0.00	NO + YES
Without Regulations1	0.40	0.20	0.40	0.00	0.00	0.00	NO + YES
Higher Insulation	0.01	0.00	0.02	0.87	0.10	0.00	NO + YES
Star Rated	0.01	0.00	0.02	0.00	0.10	0.87	NO

1. Note that the values used for the various insulation options differ significantly from those found in the pre-regulation sample (1990). This is because there is believed to be a significant incidence of non documentation of insulation actually installed in the period prior to regulation. The incidence of insulation reported on plans used in the 1990 sample was as follows: ceiling only = 10%, wall and ceiling = 14%, none = 76%. The Figures noted above are based instead upon the findings from Section 8.

2. Note that for 1999 onwards the performance settings for the BAU case were adjusted to account for changes to the governing regulations as detailed in Section 2.1.

Star Rated

This scenario assumes that in place of the thermal performance regulations implemented in 1991 a regulation was enacted that required that compliance be only through the attainment of an average star rating as prescribed under NatHERS (see Table 16). Note that this is an average performance target, not a minimum performance level. This scenario assumes the same level of non-compliance and under compliance as that assumed for the "with regulations" scenario. All whole star bands from 1 star to 5 stars were modelled.

Higher Insulation scenario

This scenario is basically the same as the "with regulations" scenario except that a higher proportion of insulation is assumed to have been mandated. The level of insulation is as noted in Table 15.

With Regulations plus double glazing (low-e)

This scenario is the same as the "with regulations" scenario except that a requirement to install double glazed low-e glazing throughout is assumed to have been mandated in addition to the mandatory insulation requirements.

It must be stressed that none of the alternative scenarios noted above are being advocated by this study. They were chosen simply as a basis for comparative evaluation against the BAU case and were not selected on the basis of any cost benefit analysis.

6.6 New Additions to Stock

Data available from the ABS indicates that additions of new stock during the period in which the thermal performance regulations have been in force were occurring at a rate of between 25,000 and 35,000 new Class 1 buildings per annum. This increase is not static and varies as a result of a number of factors, the most significant one being the state of the economy – see Figure 3. There was a surge in activity in the late 1990's in an attempt to beat cost rises associated with the GST.

A total of 226,324 new dwellings were recorded as having been built between the years of 1991-92 and 1998-99 inclusive. The numbers of detached and attached houses built in each of the years of the study period were fed into the detached and attached stock models respectively.

6.7 Removals from Stock – Demolitions

In a standard stock model, account is usually made of the number of houses that would be removed from the stock each year. However, as the stock model for this study only deals with dwellings constructed over the past nine years, it is considered unlikely that any of this post regulatory stock will have been removed[21] (demolished). Consequently the stock model developed for this study makes no allowance for removals from stock.

6.8 Insulation Retrofit

Stock numbers for the "No Insulation" performance type (most prevalent in the "Without Regulations" scenario) were adjusted to account for the practice of retro-fitting insulation into their roof spaces. This process in effect shifts a proportion of the stock each year from the "No Insulation" performance type to the "Ceiling Only Insulation" performance type, however it does not affect the total number or area of the stock.

The adopted rate for retrofitting was 1.7% per annum which is above the estimated national average of 1.2% (EES 1999). This Figure was derived from an analysis of various data sources as described in Section 8.4 and summarised in Section 8.6.

When calculating the retro-fit numbers from the cumulative stock numbers the cumulative stock was adjusted annually to account for the number of houses previously retro-fitted. That is, previously retro-fitted houses are deducted from the cumulative stock numbers against which retro-fit rates are applied.

6.9 Renovations to Existing Stock

Extensions to existing stock through renovation post regulation in Victoria would have been subject to the same regulatory controls on thermal performance as the new stock. However, unlike the new stock, augmentation to the floor area of the stock through renovation affects the entire stock and not just the stock constructed post regulation. The profile of the construction types used for renovations is therefore likely to be quite different from those of the new stock[22].

A time series of penetrations for each construction type were derived for the total Victorian stock levels as estimated in the study – *Australian Residential Sector Greenhouse Gas Emissions 1990 – 2010* (EES 1999).

These penetrations were then multiplied by average floor areas of alterations and additions as reported by the ABS in each of the studied years. Not all ABS records of alterations and additions report floor area so the average floor area of additions was estimated from those records that did report

21 A handful of houses will have been destroyed by fire but these will be rebuilt to similar standards.

22 Assuming that in general the construction type of the renovation typically matches that of the original construction – although this is not always the case.

floor area; this was then multiplied by the total number of reported alterations and additions to provide an estimate of total area of alterations and additions for the state.

Whilst this methodology was appropriate for detached housing, a different approach was required for attached housing. For attached housing the ABS reporting rates for added floor area were very low (typically less than 10% and as low as 3% in some years, and the results in those years were erratic). Instead a percentage rate extrapolated from the available data was applied to the total stock of attached housing as derived from the study *Australian Residential Building Sector Greenhouse Gas Emissions 1990 – 2010* (EES 1999). Whilst these estimates for attached housing are not highly reliable, the sector represents only a very small portion of the total additions (approximately half a percent only of total Class 1 floor area added per annum).

Note that renovations/additions that exceed 50% of the original building size are required by regulation to have their existing structure upgraded to the current standard, including the standard for thermal performance. However, in practice this is rarely done. Existing walls are difficult to insulate and usually ceiling only insulation to the existing part is required by the building surveyor. This practice is accounted for in the retrofitting provisions as noted in Section 6.8.

6.10 Total Stock Area

The total stock area is calculated at the construction type level for each performance case by multiplying the new additions to stock suitably adjusted for retrofitting by the average floor area applicable to each year studied as reported by the ABS. Added to this, is the floor area resulting from extensions to existing stock.

6.11 Unconstrained Heating and Cooling Calculation

The unconstrained heating and cooling demand is calculated by multiplying the floor area at the level of construction type for each performance case by the thermal efficiency level applicable to that construction type and performance case as derived from the analysis of the stratified sample using the *FirstRate* modelling software.

SECTION SEVEN
APPLIANCE STOCK MODELLING

SECTION 7 APPLIANCE STOCK MODELLING

7.1 Overview

This section summarises the stock modelling process that was used to compile the building shell modelling data and reconcile this with appliance data and state level actual energy consumption data. Actual data from the years 1986 to 1998 have been compared with the model outputs for the BAU case to ensure a high degree of certainty regarding the results. This then provides a firm basis from which to examine the energy impact of a range of building shell scenarios that have been developed in the previous section. This section also provide data on households and projects trends in ownership of all appliances (including heating and cooling appliances) and trends in use of appliances.

7.2 Reconciliation of Top Down and Modelled Energy Data

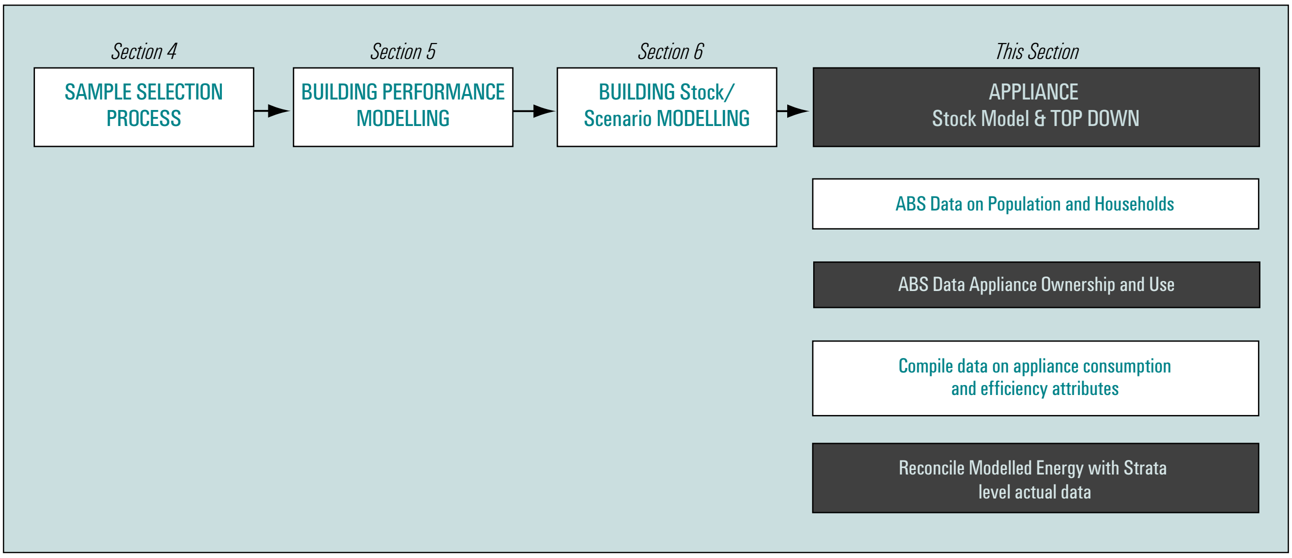
7.2.1 Overview of the Approach

It is possible to calculate theoretical heating and cooling energy demand required to maintain any Australian dwelling at standard comfort conditions, given its location, size, orientation, insulation and construction materials. Indeed, this is the basis of the NatHERS and other building shell thermal performance modelling software such as *FirstRate*, which has been used for this project. It is also possible to use the same approach to calculate an aggregated heating and cooling demand for all dwellings, and to estimate the energy consumption that would result if the existing stock of heating and cooling appliances were used to meet the demand. However, the energy consumption estimated in this way is typically several times the actual energy used for heating and cooling. For example, in 1990 the unconstrained[23] heating and cooling demand for Victoria was 98 PJ (before conversion efficiency of end use devices) approximately 81% of the total residential energy consumption for Victoria for all end uses and fuels (ie. around 121 PJ) – whereas space heating and cooling in Victoria is estimated in this study to be only 50% of total delivered energy consumption.

For this study, the baseline energy consumption of Victorian households has been modelled using the following iterative approach:

1. For each energy form, consumption for purposes other than heating (and, in the case of electricity, cooling) was modelled first, as there is a reasonable degree of certainty regarding the magnitude of these end uses. This is called the BAU with measures (BAU+) Scenario (refer to EES 1999 for details). This scenario includes those program measures introduced or finalised for introduction during the period from 1990 to November 1997 (the time of the Prime Minister's statement). These include MEPS for refrigerators, freezers and electric storage water heaters.

Figure 33 Overview of The Constraint Process



23 *"Unconstrained" refers to the energy demand required to maintain an entire dwelling at a high level of human comfort continuously during normal waking hours 365 days a year. In reality such demand is usually "constrained" by various user behaviours including, reducing the hours of heating and or cooling operation (occupancy levels), conditioning of only part of their homes (zoning) and acceptance of lower comfort levels (thermostat settings).*

An intermediate population and household forecast has been used for the BAU+ projections (based on ABS population Series II);

2. The building stock for Victoria was characterised into a number of main categories of construction as outlined in previous sections. Separate and attached dwellings were separately modelled by construction type. Data was based on various surveys by ABS and data on the characteristics of new dwellings from 1986 and other sources.
3. The aggregate heating and cooling demand (unconstrained) was then calculated using the *FirstRate* building shell modelling program. Actual sample designs for both detached and non detached housing types were used. These were modelled through the range of scenarios as outlined in previous sections.
4. The heating (and cooling) demand was adjusted to be a proportion of the unconstrained demand for each state, on the basis of reduced hours of occupancy (in comparison with the *FirstRate* model) and zoned heating and cooling within a household (only part of the house is typically climate controlled). Occupancy was generally set assuming that the house was only heated or cooled for 50% of the total hours of space conditioning assumed under *FirstRate*, for all technologies in all years. Zoning factors were adjusted by energy type to ensure that the total consumption of each energy form, as recorded by the Australian Bureau of Agricultural and Resource Economics (ABARE), were broadly consistent at the state level for the period 1986 to 1997. The modelling outputs with the selected zoning and occupancy factors for heating and cooling also broadly matched available end use monitoring data for Victoria (or adjusted values from other states).
5. The heating and cooling energy was checked for fit with the stock of heating and cooling equipment, and information about hours of use and direct metering data by end use where this was available. Third party sources such as this were used to check all end use energy estimates wherever possible, or to calibrate end use energy consumption where this is known with some certainty. (Note that available data for Victoria is limited – end use data for some other states are much more extensive and the results from other states have been applied to Victoria in a consistent manner, as applicable).

The approach is simplest for wood, for which it has been assumed that all consumption is for space heating (the small amount of wood use for cooking and water heating has been ignored for this study). The ABARE estimates of wood consumption have been examined, although these are subject to considerable uncertainty since wood use is not metered, and a part of it is self-gathered rather than supplied by merchants. Wood consumption estimated by this study is substantially less than that estimated by ABARE. Two classes of wood heating technology – open and closed combustion – have been modelled separately, since they have quite different efficiency and greenhouse emissions characteristics. However, little firm data on the market share for these types is available at this stage (Mogg 1999). The average energy efficiency of each equipment class has been varied over time.

At the other extreme is electricity, where total consumption is accurately recorded, but a relatively small share of it is used for heating or cooling. Electricity is the preferred form of heating energy in the warmer parts of Australia but is relatively rare in Victoria, so dwelling thermal characteristics are often of limited use in predicting consumption. Furthermore, the heating energy share needs to be further divided between two main classes of heating technology – heat pump and resistance – and two classes of cooling technology – heat pump and evaporative. Again, the average energy efficiency of each equipment class has been varied over time based on known market data.

Natural gas and LPG are used almost entirely for water heating, space heating and cooking. (There is a small amount of gas used for purposes such as pool heating, clothes drying and novelty lighting, and LPG is used for recreational purposes and some portable appliances (eg BBQs), but these uses have been ignored for this study). There is a high degree of correlation between space heating demand and mains gas consumption. Space heating accounts for the majority of natural gas use in Victoria and most of the space heating demand is met by natural gas.

The consumption of the minor fuels – briquettes, coal, kerosene, heating oil, automotive diesel oil and town gas – has not been explicitly modelled for this project. Together these accounted for only a few percent of energy and greenhouse gas emissions and are forecast by ABARE to decrease.

ABARE calculates the contribution of solar energy to the household sector in terms of equivalent fossil energy displaced. The appliance model developed for this project also explicitly estimates solar contribution of installed solar water heaters, but this is treated as a negative heat loss for the electric water heating load (as almost all installed solar water heaters are electric boosted). The solar contribution estimated by the end use model correlates reasonably closely with the ABARE estimates.

The contribution of passive solar energy to space heating through optimally designed orientation and glazing is captured by the decrease in the heating required to maintain standard heating comfort conditions. This contribution is not counted explicitly by ABARE or for this project, but the net impact is captured in the building shell performance monitoring.

23 "Unconstrained" refers to the energy demand required to maintain an entire dwelling at a high level of human comfort continuously during normal waking hours 365 days a year. In reality such demand is usually "constrained" by various user behaviours including, reducing the hours of heating and or cooling operation (occupancy levels), conditioning of only part of their homes (zoning) and acceptance of lower comfort levels (thermostat settings).

7.2.2 Constraining Process

The first task was to develop a model of appliance stock and use within each energy form that matched the residential sector energy use reported by ABARE over the period 1986 to 1997.

An unconstrained heating/cooling model was developed to calculate what the heating and cooling demand would be in Victoria given the distribution of housing types and climatic zones, if all dwellings maintained the standard comfort conditions embodied in the *FirstRate* program in terms of continuity of heating/cooling, target internal temperatures, proportion of dwelling heated/cooled and a high level of occupancy. For all technology types, the actual estimated energy consumption for heating and cooling was significantly lower than the unconstrained demand would suggest. Figure 34 shows the "constraint ratio" adopted for each heating and cooling technology. Constraint factors in the model are broken into two parts: the first being that average houses are occupied less than assumed in the *FirstRate* model (called occupancy level), eg heating is turned down/off when at work or when away, and second, that in many cases only part of the house is thermally controlled (called zoning). The overall constraint factors are shown in Figure 34.

7.2.3 Summary of Model Results vs Top Down Data

Figure 35 shows the modelled EES and ABARE estimates of actual electricity and gas consumption for the same periods for Victoria.

The model provides a very close fit of electricity data for the 12 year period examined and therefore provides a fair degree of confidence of accuracy. The gas data results warrant closer examination as there is clearly significant variation in consumption from year to year. Figure 36 shows that while the data on average is a reasonable fit, that weather appears to have a substantial impact. Energy modelling suggests that space heating accounts for about 71% of gas consumption in Victorian households in 1990 and this share appears to be increasing slowly.

Figure 37 shows that the weather over the period 1986 to 1997 appears to have a significant impact on gas consumption in Victoria. Data on daily temperatures has been analysed for Melbourne for the period 1986 and 1997 (ABM 1998) to derive an estimate of heating degree days (HDD) based on total degree-hours below 18°C annually. The precise impact is difficult to determine because of the rapidly increasing total demand for gas, but warmer years 1988, 1989, 1991 and 1994 all seem to be associated with lower total gas consumption in Victoria. The effect of these warmer years also appears to be present on electricity consumption (refer Figure 35), although the total impact is smaller.

When the gas data and the heating degree days are normalised, the impact is clearer, as shown in Figure 38. This Figure shows the ratio of actual energy to EES modelled energy by year as well as the actual HDD versus the average HDD for the same period. Actual impact correlation appears to vary a little from year (possibly due to factors such as solar radiation and wind in those years), but the trend is quite distinct. Most importantly, the EES modelled energy consumption for gas is approximately equal to the actual gas consumption for those years where the HDD are close to average for Melbourne.

Figure 34 Constraint Factors for Heating and Cooling by Technology

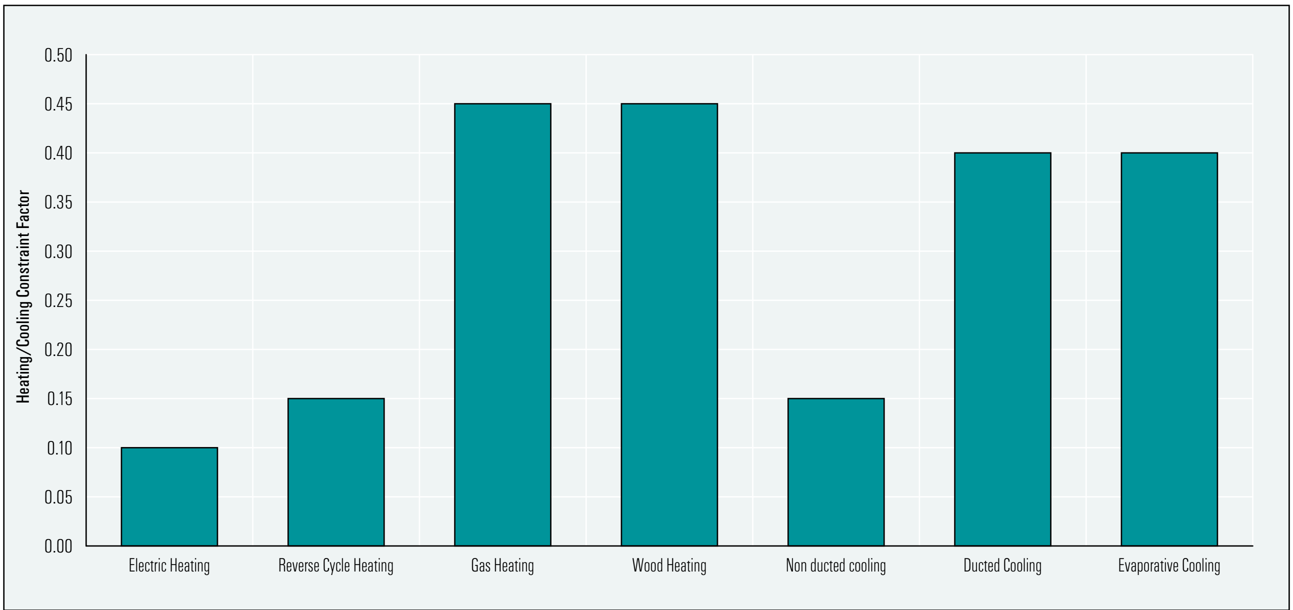


Figure 35 Actual versus EES Modelled Energy Consumption, Victoria 1986-1997

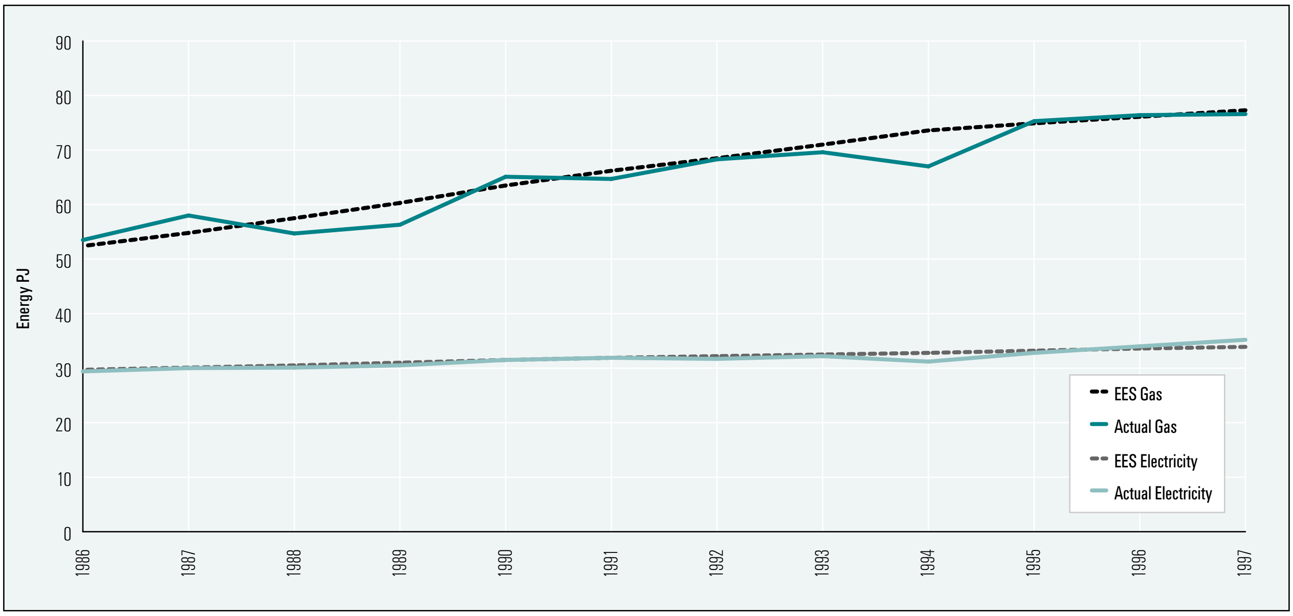


Figure 36 Victorian Gas Energy Consumption 1986-1997 (actual vs modelled)

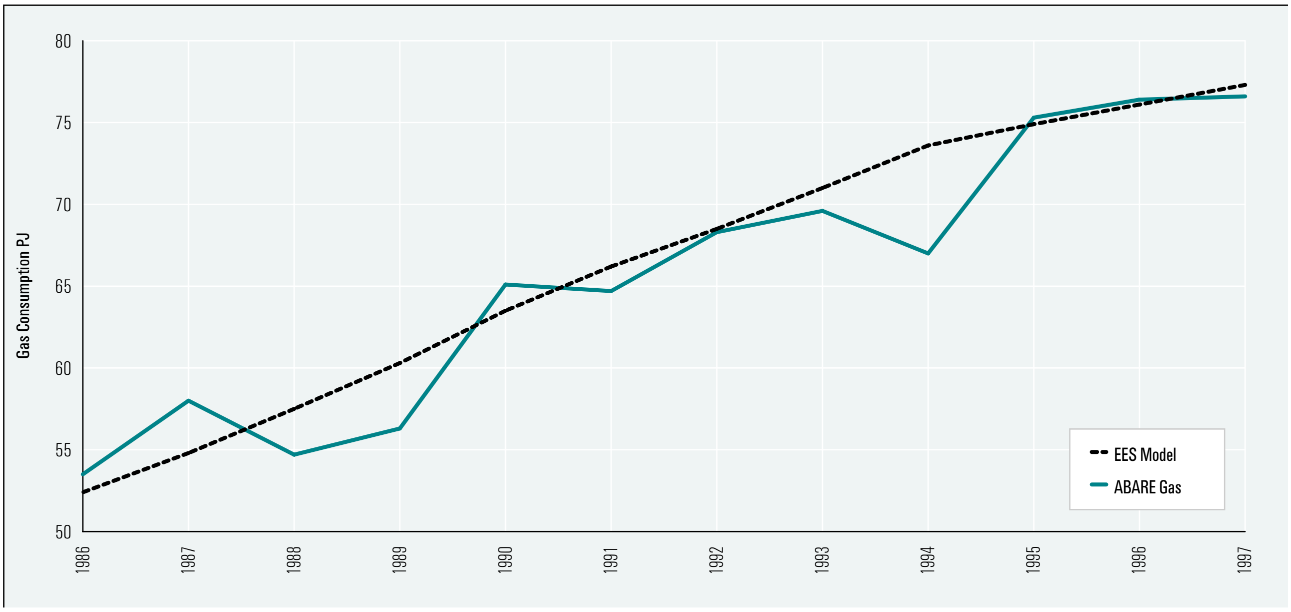


Figure 37 Actual Gas Consumption (Victoria) vs Heating Degree Days (Melbourne)

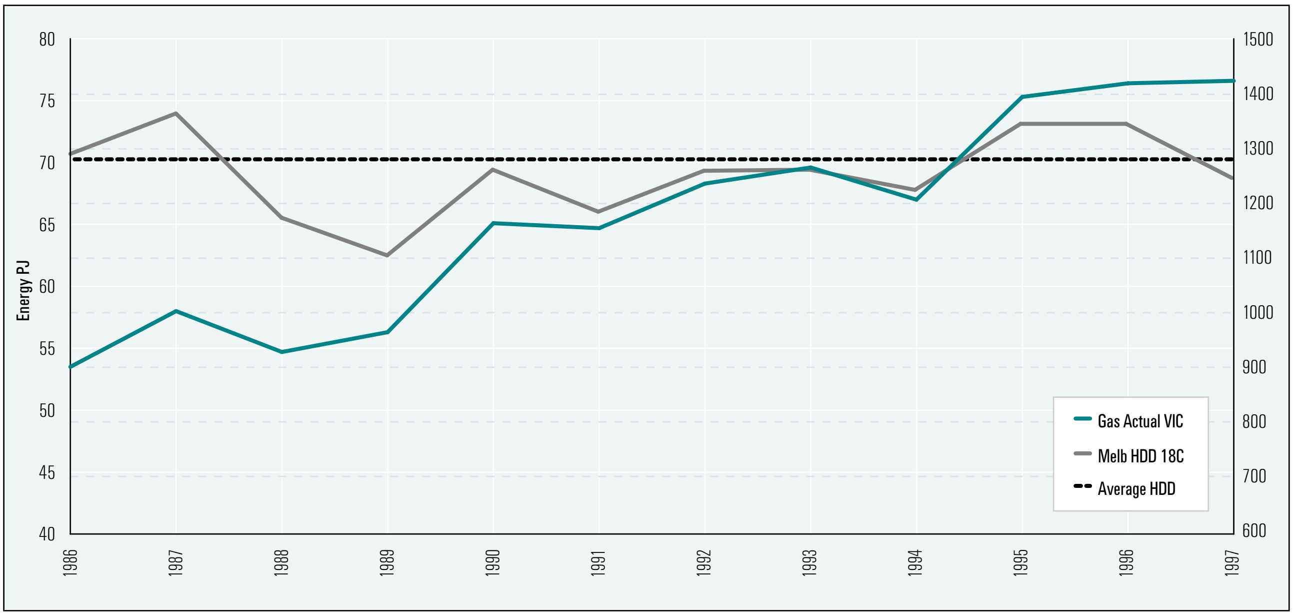
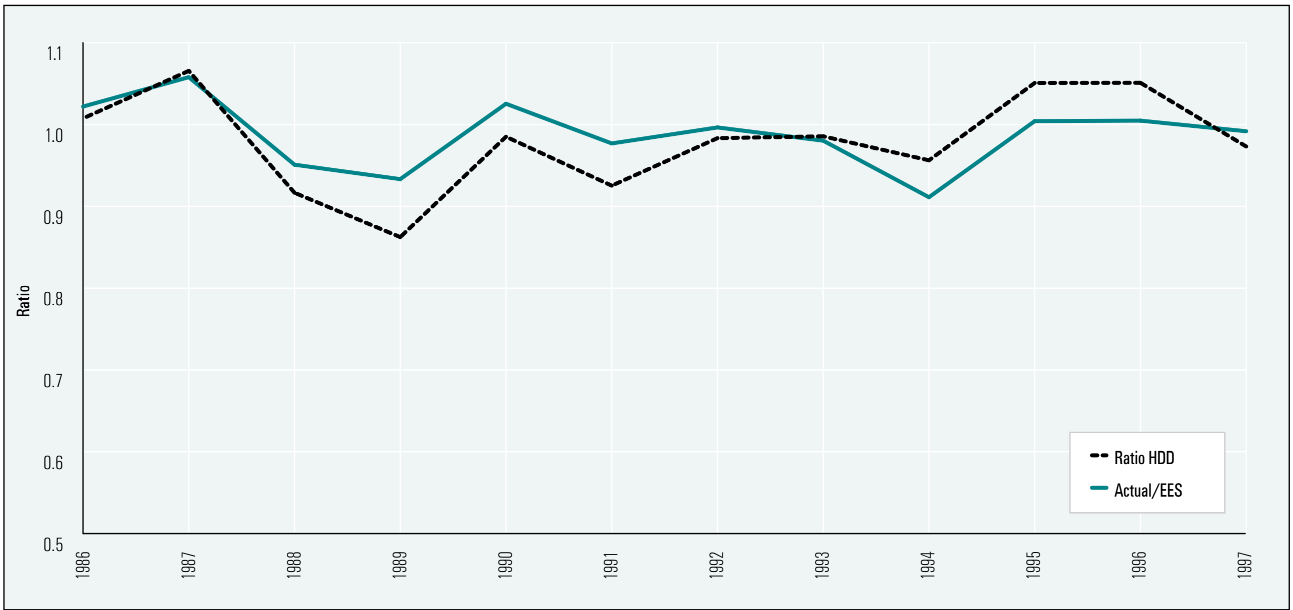


Figure 38 Actual/EES Gas Consumption vs Heating Degree Days, Victoria



It is important to bear in mind that the *FirstRate* building shell model uses an "average" or "typical" year for modelling purposes so is unable to capture the impact of weather. While it is technically possible to model the impact of actual weather if a data set for the same period was available (1986 to 1997), this appears not be the case at present and in itself would represent a substantial computational exercise.

Annual LPG consumption in Victoria is small and is typically of the order of 2.5 PJ. Data modelled by EES is slightly lower than that reported by ABARE for most years, but this is expected given the alternative recreational uses for LPG such as portable appliances (lighting and refrigeration) and BBQs which are not included in the EES model.

ABARE estimates for wood energy consumption for Victoria are substantially larger than estimated from the modelled data (22.2 PJ in 1990 compared with the EES modelled value of 7.2 PJ). This discrepancy for wood energy was noted in the Residential Buildings Study (EES 1999) and is thought to be related to ABARE's estimation methodology rather than an actual discrepancy. As outlined above, there are considerable uncertainties associated with the collection and use of wood for residential purposes. In any case, wood energy consumption has little impact on greenhouse emissions as outlined above, so no further investigations have been undertaken.

7.3 Population and Households

The Australian Bureau of Statistics has conducted a Census of Population and Housing at 5 yearly intervals since 1961 and at ad hoc intervals prior to 1961. Population reported in the census excludes temporary visitors from overseas. Note that the census records the population where they are found on census night (not necessarily in their usual residence) and does not include Australian residents who are temporarily overseas. All censuses have occurred on or about 30 June of the year of the census, except for 1996 which was held in August.

Estimated Resident Population (ERP) are estimates of the Australian population obtained by adding to the estimated population at the beginning of a period the components of natural increase (on a usual residence basis) and net overseas migration. For states and territories, account is also taken of estimated interstate movements involving a change of usual residence. After each census, estimates for the preceding inter-censal period are revised by incorporating additional data obtained from the new census. Estimates of ERP are based on adjusted census counts (which tend to under enumerate population) by place of usual residence, to which the number of Australian residents estimated to be temporarily overseas at the time of census. The concept of ERP links people to a place of usual residence within Australia. Usual residence is that place where each person has lived or intends to live for six months or more in the reference year. Estimates of ERP are available from 1971 in ABS 3102.0.

The detailed methodology for the projection of household numbers is outlined in Section 4 of EES (1999) and is not reproduced here. The population series used for modelling is the median projection used by the ABS (Series 2) in ABS 3222.0. A summary of the data for Victoria is shown in Table 19 and Table 20.

7.4 Appliance Ownership Data

This section provides an overview of the primary elements of input data which are required for the stock model and the data sources used to provide each of the estimates. In summary these are:

- appliance penetration and ownership estimates (number in use)
- appliance technical attributes (eg efficiency, losses)
- discretionary usage factors (eg frequency and duration of use, wash temperatures)
- climate and physical data
- overview of energy end use measurements (direct measurements or estimates) by technology type

The data and methodology summarised in this section is reported in more detail in Residential Building Study (EES 1999), but the ownership data has been updated with the release of the 1999 survey on appliance ownership (ABS4602.0) which was published in early 2000. Only data for Victoria are reported for this study.

7.4.1 Concepts and Definitions

Each household has a number of appliances which convert the energy purchased to the desired energy services of space conditioning, water heating, lighting etc. For this report, the following terms are used.

- Penetration – the proportion of households in which a particular appliance type is present (irrespective of the number of units of that appliance in the household). This value is usually given as a percentage.

Table 19 ABS Series 2 – Estimated Resident Population – Victoria

Year	Population
1966	3149035
1971	3481370
1976	3799937
1981	3931159
1986	4140430
1991	4401563
1996	4570535
2001	4748600
2006	4892500
2011	5015000

Table 20 ABS Series 2 – Actual and Estimated Households – Victoria

Year	Households
1966	879598
1971	1008887
1976	1120474
1981	1237483
1986	1355173
1991	1475393
1996	1591657
2001	1687141
2006	1773454
2011	1854656

Note: Values for 1996 to 2011 have been estimated by authors for this project

- Stock – the total number of a particular appliance type in use within households. This value is given as an integer (usually thousands or millions). The stock refers to the number in regular use, or a proxy for the number in regular use.
- Ownership – the ratio of stock to the total number of households. This value is usually given as a decimal number.
- Saturation – the average number of appliances per household for those households with the appliance.

Where each household owns a single appliance of a particular type, ownership is equal to penetration. Where some households own more than one of a particular appliance type, ownership is greater than penetration (penetration x saturation = ownership). The main appliances in Victoria where the ownership is significantly higher than the penetration are as follows:

- refrigerator
- freezers
- air conditioners
- video Cassette Recorders (VCR)
- televisions

Lighting is treated as a single end use even though there are a number of appliances within a house which provide the energy service. Similarly, standby losses are also aggregated from a number of appliances.

7.4.2 Primary Data Sources

The only national data sets for ownership and penetration of appliances in Australia have been the ABS national energy surveys conducted in November 1980, June 1983 and (nominally January) 1986 (ABS 8212.0 and 8213.0) and an environmental issues surveys ABS 4602.0 in June 1994 and March 1999. These surveys collected primarily penetration data, but there is some limited ownership data for some appliances for some years, namely refrigerators, freezers and air conditioners.

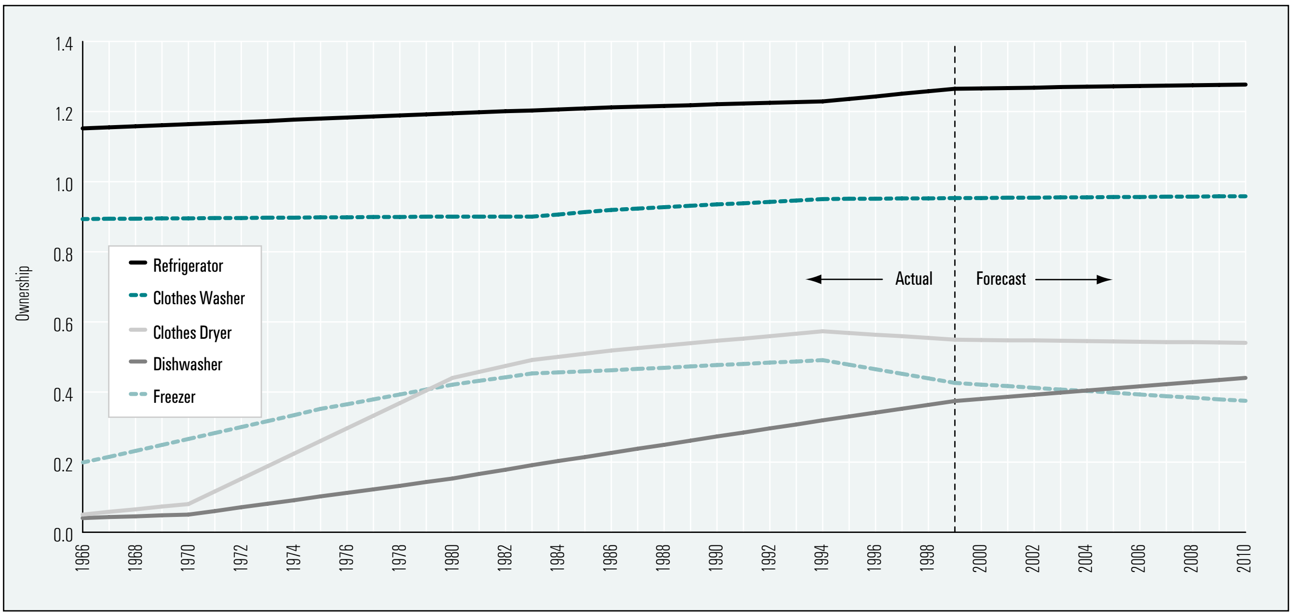
The other major early data source is the 1976 census which collected data for all households regarding the main fuel used for lighting, hot water, space heating and cooking (ABS 2409.0 to 2417.0 1976) which have been obtained from ABS for this project.

We have also used our knowledge of the appliance market plus selected interviews with manufacturers to estimate early trends within some market segments.

This project has developed only a single scenario for future ownership and penetration trends. However, the modelling approach developed for this project could easily accommodate alternative ownership and penetration forecasts, such as high penetration gas or wood scenarios, should this be required after the completion of this project.

While specific issues for each appliance are discussed below, it should be noted most appliances were assumed to have a saturation of 1.0 except were otherwise noted. There are always some households with additional appliances (apart from those with known high levels of saturation listed above), but in most cases these additional units are rarely used. Fuel

Figure 39 Ownership of White Goods, Victoria



share projections for large energy end uses such as space heating and hot water took account of the natural gas supply system and the likely saturation of gas appliances.

For multi-fuel end uses such as main space heating, cooking and hot water, saturation was assumed to be 1.0 and penetration 100%. Totals were reconciled for every year to add to 100% for all fuel types (where no appliance was present, this was counted as a separate fuel type for these types of appliances to ensure consistency). Some secondary heating appliances (portable electric heaters) are also known to exist, although the level of data on the ownership and their patterns of use are quite poor. Therefore these appliances have not been specifically modelled in this project. This means that some miscellaneous electricity consumption will in fact be associated with space heating, but data is too poor to separate this end use any further.

Generally speaking, reference to "gas" means natural gas (or mains gas) plus LPG.

7.4.3 Ownership and Penetration – White Goods and Other Appliances

The ownership of various major appliances for Victoria is summarised in Figure 39. Key trends include:

- Ownership of refrigerators increased over the period 1994 to 1999, mainly due to increased retention of second refrigerators (this trend is evident nationally and is more pronounced in most other states).
- Separate freezer ownership appears to be declining.
- Clothes washer ownership is saturated at 95%.
- Clothes dryer ownership also appears to be saturated at 55%, with a small decline between 1994 and 1999.
- Dishwasher ownership is steadily increasing.

Details for these and other appliances by year are shown in the appendix.

7.4.4 Ownership and Penetration – Space Conditioning Equipment

The ownership of space heating and air conditioning equipment for Victoria is summarised in Figure 40. Key trends for space heating include:

- Nearing saturation of gas space heating at about 72%.
- A small and slowly declining use of electric space heating (includes reverse cycle air conditioning). Many Victorian households with reverse cycle air conditioners report that they use another type of main heating.
- Steady and slightly increasing use of wood for space heating.
- Negligible use of oil for space heating since 1990.
- Negligible households with no space heating in Victoria.

The share of air conditioners by type is shown in Figure 41. Key trends for air conditioners include:

- A substantial increase in ownership of air conditioners from 1994 to 1999 to an average of 0.505 air conditioners per household in 2000 (penetration in 2000 was 43.8%);
- A small but steady increase in ducted reverse cycle systems (share 5.9% in 2000);
- A small but steady increase in ducted cooling only systems (share 3.1% in 2000);
- A rapid decline in non-ducted reverse cycle systems (share 25.2% in 2000);
- A small but steady increase in non-ducted cooling only systems (share 40.1% in 2000);
- A steady increase in ducted evaporative systems and non-ducted evaporative systems (share 25.7% in 2000).

Details by year are shown in the appendix.

Figure 40 Ownership of Space Conditioning Equipment, Victoria

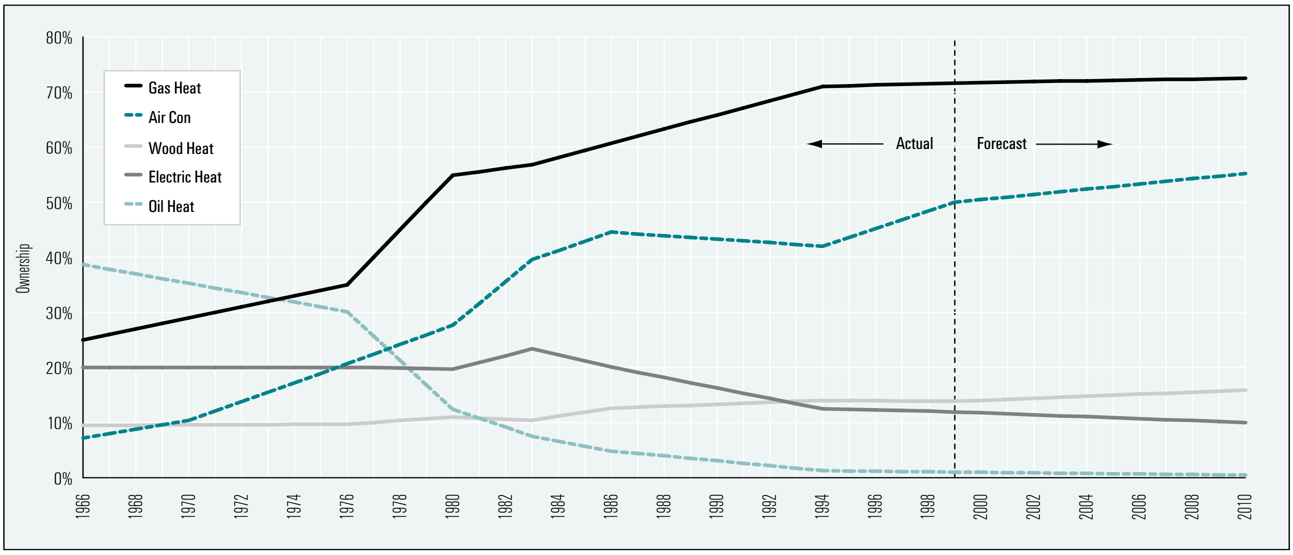
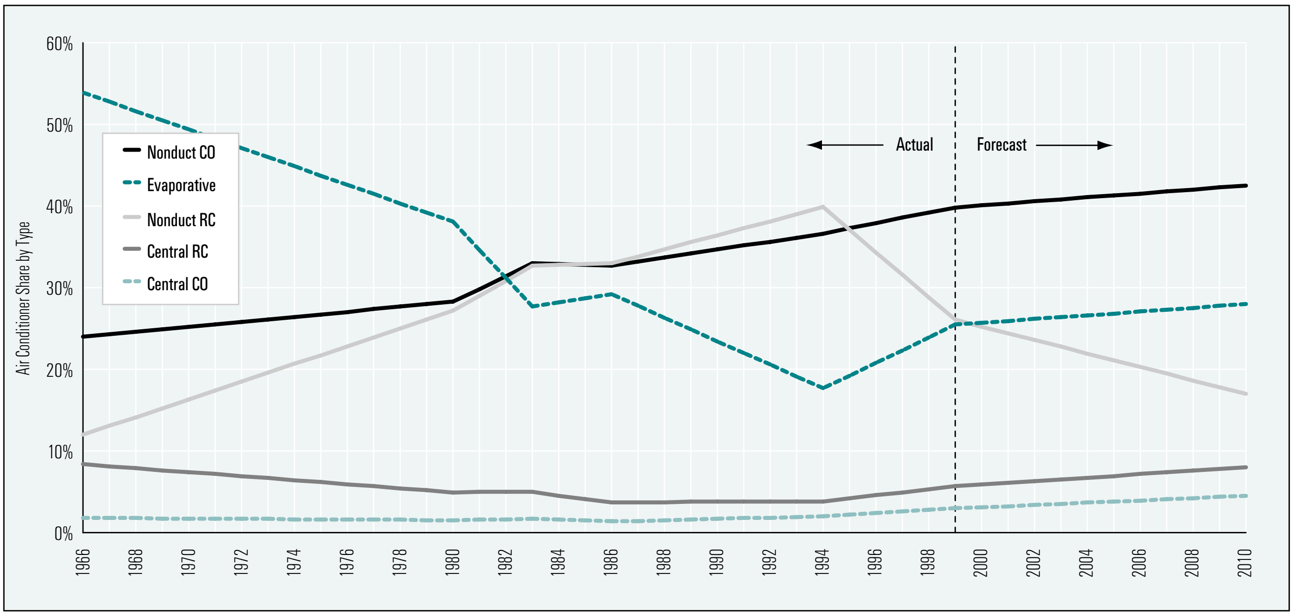


Figure 41 Share of Air Conditioner Equipment by Type, Victoria



7.5 Appliance Attribute Data

Energy consumption is influenced significantly by the appliance "attributes". Attributes of each appliance are those factors which determine energy consumption independently of how the user operates the appliance. Attributes are primarily energy efficiency related (capacity, unit efficiency or losses), although some factors are required to derive the requirements for secondary appliances (eg hot water consumption of clothes washers will affect total hot water requirements, spin performance of clothes washers will affect dryer energy consumption) and are usually determined under standardised conditions24. Where necessary, values determined under standardised conditions have been varied to reflect actual conditions eg colder air and water temperatures in Victoria result in higher heat losses and energy consumption for water heaters. The values for these attributes can be varied from year to year and reflect the average value of new appliances sold in that year. Attributes include:

- average size (eg litres) or capacity (eg kg of clothes)
- energy consumption of certain components in the appliance (eg pumps and motors per load) or of the whole appliance (eg refrigerators and freezers under standard conditions)
- standby losses (electronic controls) or standing heat losses (eg water heaters)
- intrinsic energy efficiency, eg kWh per kg water removed for clothes dryers, coefficient of performance for air conditioners, burner efficiency for gas appliances, lumens per Watt for lighting appliances
- intrinsic water efficiency, eg total and hot litres per wash under standard conditions
- spin performance for clothes washers
- for dishwashers, the proportion connected to hot only, cold only and both

The appliance attributes are derived from a range of sources. These include the analysis of GfK retail appliance sales data for refrigerators, freezers, clothes washers, clothes dryers and dishwashers from 1993 to 1997 (EES 1997), energy labelling registers, Australian Gas Association data on energy labelling of gas appliances (Australian Gas Association 1997), various Choice Magazine test results over the years, George Wilkenfeld and Associates (1991a) and interviews with various manufacturers over the years.

The appliance attributes used for modelling in this report are documented in the Residential Buildings Study (EES 1999). Details by appliance type can be found in the appendix of this report. Detail is not provided here as appliances are not a key area of interest for this report.

7.6 Appliance Discretionary Use Data

Discretionary use factors are those applicable to the whole stock of appliances in use in any particular year, regardless of the appliance age. This includes frequency and duration of use and climatic related factors (such as average water and air temperatures) which affect the performance of an appliance. Discretionary factors include:

- frequency of use, eg loads per week, hours of use of an appliance such as a heater or cooker, hours of television viewing etc.

24 Standardised in this sense refers to those conditions set out in a test procedure, such as an industry or Australian Standard.

- overall energy adjustment factors to account for climate (eg refrigerators, heat losses for water heaters) and cold water temperatures for water heaters

The discretionary factors can also be varied from year to year (ie. a gradual increase in hours of TV viewing, increase in loads of washing per year), but the model is so constructed that all units in operation in that year are equally affected. This is consistent with the fact that most trends in appliance-using behaviour affect all households equally, not just those households which happen to purchase appliances in a given year. An example of this is the trend to lower clothes washing temperatures which is occurring independently of the turnover of the clothes washer stock.

The discretionary use factors used for this report are the same as for the Residential Buildings Study (EES 1999), so details should be referenced from that report. The only exception is that the clothes washer wash temperature profiles have been updated based on the reported values in ABS 4602.0 (1999). The actual wash temperature profiles used for this report are shown in Table 21 below.

Table 21 Clothes Washer Temperature Profiles for Victoria

Year	Cold Washes	Warm Washes	Hot Wash/yr
1985	25.0%	65.0%	10.0%
1986	27.9%	62.4%	9.7%
1987	30.8%	59.7%	9.5%
1988	33.8%	57.1%	9.2%
1989	36.7%	54.4%	8.9%
1990	39.6%	51.8%	8.6%
1991	42.5%	49.1%	8.4%
1992	45.4%	46.5%	8.1%
1993	48.4%	43.8%	7.8%
1994	51.3%	41.2%	7.5%
1995	52.9%	39.9%	7.2%
1996	54.5%	38.7%	6.8%
1997	56.1%	37.5%	6.4%
1998	57.8%	36.2%	6.0%
1999	59.4%	35.0%	5.7%
2000	59.9%	34.6%	5.5%

7.7 Third Party End Use Energy Estimates for Appliances

A wide range of third party estimates of energy consumption are reviewed in the Residential Buildings Study (EES 1999). Where data was available for Victoria, these were used to confirm the modelling estimates in this report. Where data was available for other states, indirect confirmation could sometimes be obtained through direct comparisons or through adjustments in accordance with known differences in operation or climate.

7.8 Stock Model

7.8.1 Overview of the Stock Model

The stock of each appliance type in service in each state and in each year of the study period (1990 to 2000) is calculated in the following way:

1. The number of households in the state is estimated.
2. The stock of each appliance type in use is calculated as the product of the number of households and the historical or projected ownership rate.
3. The number of units retiring from the stock is estimated, using a stock sub-model for each appliance.
4. The number of new units added to the stock in each year is calculated as the sum of the increase in the total stock and the number retiring in that year.

The number of units retiring from the stock in each year is a function of the number installed in previous years and their expected service life. In practice the service life of appliances installed in a particular year (a "cohort") follows a decay curve. There is no research data on average service life and/or decay curves for Australian appliances, but US data suggests that only a proportion – perhaps even a minority – actually fail at the average service life (ie. total years of service divided by total stock). The function used in this study is the simplified decay curve developed by Lawrence Berkeley Laboratory (LBL) in the USA, which was also used in the MEPS study (GWA 1993a) and for EES (1995). The assumptions are:

- all appliances in a cohort survive for 1/3 of the average service life
- there is a linear decay such that 50% of the cohort survive to the average service life, and the last appliance in the cohort retires at 5/3 of the average service life

A graphical depiction of the units remaining in service is shown in Figure 42.

If the average service life for a particular appliance type is set at 15 years, for example, the oldest appliance leaving service in 1995 will have been installed in 1970 (5L/3 = 25 years). Therefore it is necessary to estimate the numbers and energy characteristics of units installed in 1970 and in every subsequent year in order to calculate the impact of their retirement on the energy consumption of the total stock in 1995. The model has been designed to accommodate average appliance service lives up to about 21 years (even though the earliest data is currently for 1966 – the model assumes constant characteristics before this date, if required). The appliance life entered in the model must be an integer.

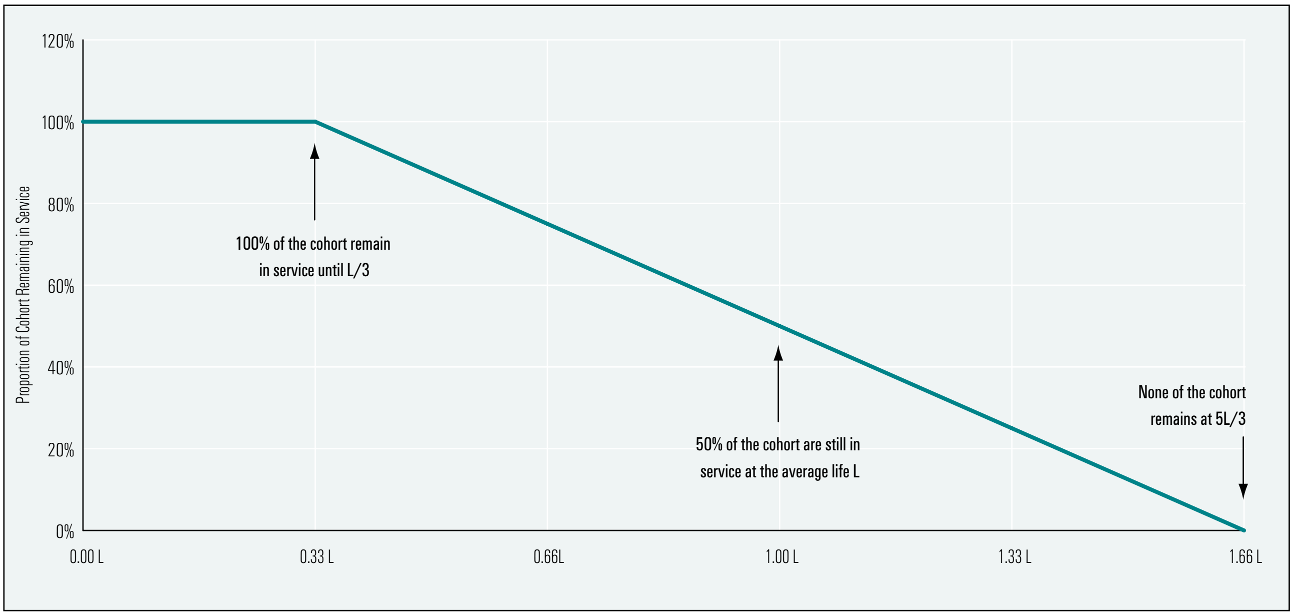
The historical, current and projected ownership estimates for each appliance type are contained in the ownership module. This series goes back to 1966. All state total estimates have been cross checked and adjusted to be internally consistent for all years. The stock of each appliance for each year and each state from 1966 to 2010 is determined by combining the ownership values with the household numbers.

The stock model also imports the appliance attributes for each year for each appliance from 1966 to 2010 from the attributes module. It is assumed that appliance attributes are uniform for each year.

It is important to note that for all years, the actual historical and projected stock values are always used to generate the energy consumption for the particular end use. The stock model is really only a calculation engine which is used to determine average attributes (eg energy efficiency) of all units remaining in operation in a particular year given particular installation and retirement profiles. These average characteristics estimated by the stock model are then applied to the actual stock in each year. The stock model carries a profile for each appliance for each year.

The appliance life assumed in the model is not particularly critical when estimating appliance attributes and energy consumption projections. Underestimating the life means that estimated sales are higher than actual sales and therefore new appliances influence the stock average slightly more quickly than in reality. Similarly, if the appliance life is overestimated, the influence of new appliances will be slower than in reality. This is really only critical where the attributes of new units are substantially different from the average stock value (ie. where change is rapid), which is relatively uncommon. An exception here is the introduction of MEPS for electric storage water heaters, where a 30% improvement is expected to occur in 1999.

Figure 42 Appliance Retirement Function



7.8.2 Assumed Appliance Lives

The only published data relating to appliance life in Australia is reported in BIS Shrapnel surveys of customers purchasing new appliances (BIS 1998a). Recent purchasers of new appliances were asked to estimate the age of the appliance which they were replacing. Since the data was based on consumer recall during a telephone interview, it was not likely to be highly reliable (there tends to be a high incidence of responses at 5, 10 and 15 years, for example, although recent changes to the questionnaire are aimed at overcoming this problem). Furthermore, only about 25% to 50% of replaced appliances were reported as actually leaving the stock (ie. being scrapped). The rest were either retained by the household, sold or handed down, and so possibly remained in service (noting that many of the retained units will not be used). While some of these units may not in fact be used regularly, these movements will mean that the effective service life of appliances is longer than the estimated ages reported in BIS Shrapnel (1998a) and reported in GWA (1993). Consequently longer service lives are assumed in this study (see Table 22). If improved information on appliance life were available, the stock model could be adjusted to accurately reflect this data.

In general terms, the appliance lives have been set so that the sales generated by the model broadly match total appliance sales where these are known.

Table 22 Assumed and Reported Average Appliance Lives

Appliance	Assumed Life for this Study	Reported Age of Replaced Appliance
Refrigerator	17	13.1
Freezer *	21	13.0
Clothes washer	14	11.9
Dishwasher	12	11.7
Clothes dryer	16	11.8
AC – non ducted	10	11.5
AC – ducted	10	7.2
Portable heaters	10	7.4
Gas heaters	10	11.1
Hot water systems	12	12.7
Cooking appliances	15	N/A
Televisions	10	N/A
VCRs	12	N/A
Generic standby	8	N/A

Source: BIS Schrapnel (1998)

* Sales for freezers are still too high given penetration data, so life may be >21 years.

SECTION EIGHT
RELATED RESEARCH DATA – THERMAL PERFORMANCE

SECTION 8 RELATED RESEARCH DATA – THERMAL PERFORMANCE

8.1 Overview

In an attempt to improve our understanding of some key factors that are likely to affect the thermal performance of Victorian Class 1 buildings, a range of primary and secondary research was undertaken for this study. The data sought was intended to fill gaps in the information that was obtained through the sample plans sourced from councils. Both qualitative and quantitative data was gathered.

The main issues covered were:

- the prevalence of new homes built with insulation installed that exceeded minimum compliance levels
- the rate of non compliance with thermal performance regulations
- insulation practices prior to the introduction of regulation
- the extent to which building construction had changed in the past five to ten years that has led to an improvement in building thermal efficiency, (qualitative only)
- rates of insulation retro-fitting
- the penetration of double glazed and thermally advanced windows

The primary research consisted of a number of surveys conducted amongst various stakeholders in the building industry. This included surveys of selected building surveyors, insulation manufacturers and window and glazing manufacturers.

Secondary research consisted of a review of related surveys undertaken by various groups including the Australian Bureau of Statistics and the former Gas and Fuel Corporation of Victoria.

This data was primarily used to assist in determining appropriate stock blend proportions (penetrations) for the various performance options noted in Section 5.6.

The following sections cover each of the data sources, some of the data sources cover more than one of the areas of interest noted above. In some circumstances the information obtained from one data source was found to be at variance with that from another. A summary of the conclusions drawn from all these related data sources can be found in the last Section 8.2.5.

8.2 Survey of Council Building Inspectors

This section provides a summary of the in-person interviews conducted with council representatives on changes to building practices since 1990. In person interviews were conducted with representatives from six councils who participated in the study. All of the respondents were council Building Surveyors and the majority had been employed by their council for longer than ten years and were therefore able to comment on building practices prior to the introduction of the insulation regulations.

8.2.1 Exceeding Minimum Requirements

Respondents were asked several questions about the prevalence of new homes built with insulation installed that exceeded minimum compliance levels. All respondents mentioned that overall very few (less than 5%) of new homes would install insulation that exceeded minimum requirements. However, there was a definite distinction made between builders and owner builders on the performance of the insulation installed. Most respondents mentioned that a higher proportion of owner builders (one respondent mentioned up to 30%) would install insulation that exceeded the minimum requirements. Only occasionally is this "over specification" of insulation installation documented in the building plan.

Ballarat was the only council that keeps records on the R value and type of wall and ceiling insulation installed in new homes. This information is collected from the home owner at the final inspection. Monash City Council requires that builders provide a certificate which confirms that insulation was installed in the premises.

8.2.2 Non Compliance with Regulations

Issues of non compliance with insulation regulations were raised with respondents and the degree to which it occurs in new developments. Non compliance is not an issue according to the respondents interviewed for this study as all stated that all builders/owner builders complied with the minimum standards on insulation. However, all respondents also mentioned that there had been instances of non compliance which had occurred on only one or two occasions. Instances of non compliance were generally found by the home owner post occupancy but instances were so seldom that it was not considered to be of any concern. However, it should be borne in mind that questions regarding insulation compliance could be construed by building inspectors as questioning their ability to carry out their job competently, so this issue was handled sensitively by the project team during interviews. This situation could result in an overly optimistic view of non compliance by building inspectors, so a judgement was made by the project team regarding this data.

8.2.3 Insulation Practices Pre-Regulation

Several questions were asked which aimed to determine the extent to which builders/home owners insulated houses prior to regulations on insulation being introduced. Three of the respondents interviewed agreed that more than 50% of houses had insulation installed in the ceiling prior to the introduction of regulations. One of these respondents mentioned that approximately 80% of new homes had ceiling insulation. These three respondents represented councils within the Melbourne region.

According to respondents, of those new homes built with insulation installed in the ceiling, the majority matched the minimum requirements as outlined in the regulations before their introduction. Only one council was the exception in that only 25% of new homes within that municipality reportedly matched the minimum requirements set out in the insulation regulations. Table 23 shows the results:

Table 23 Pre-Regulatory Insulation Practices – Estimates by Building Surveyors

Percent of houses estimatedto have been fitted with ceiling insulation	Percent of those houses with insulation that matched the present minimum insulation requirements
20%	100%
40%	80%
>50%	>80%
50 to 60%	25%
80%	90%
Don't know	Don't know

The majority of respondents agreed that the incidence of insulation installation that exceeded the minimum requirements was very low (if at all in some councils), although some home owners were known to install or upgrade insulation installed after building completion.

Insulation in walls was far less common prior to the introduction of regulations, with only the minority of houses (less than 25% in one council but generally less than 10%) having insulation in the walls. The type of insulation used in these cases was nearly always reflective foil with only a limited number of houses using bulk insulation in the walls.

Floor insulation was considered non-existent in 1990 according to five of the six councils surveyed. The most inner suburban council (Monash) mentioned that less than five percent of houses had suspended floor insulation which was usually bulk insulation. Interestingly, floor insulation was nearly as uncommon in 1999 according to all the respondents interviewed. Only two respondents representing Melbourne councils reported any use of floor insulation, which was believed to be prevalent in less than ten percent of houses and consisted of either reflective foil or bulk insulation.

8.2.4 Improvements in Design

Respondents were asked to what extent building construction had changed in the past five to ten years which had led to an improvement in building thermal efficiency. Interestingly, all respondents either reported that there had been no improvement or only a marginal improvement in thermal efficiency. Some of the comments included:

> *"There has been no real shift in housing design since 1990. Any benefits in terms of energy efficiency are a result of design elements that unintentionally improve thermal performance, such as larger windows on a north facing aspect."*

> *"Most houses built here are "speculative" or project homes and builders are not putting in any extra effort to improve efficiency. Windows capture the views regardless of the aspect. Even larger, owner builder homes are not taking advantage of energy efficiency principles."*

> *"'Production' builders don't pay attention to energy efficiency. Orientation is sometimes considered but owner builders are definitely more mindful of energy efficiency and good design."*

> *"Home owners and designers' awareness of how to make use of a northerly aspect has increased but fundamentally there has been no improvement in building construction. Builders are still placing standard designs on blocks and showing no flexibility in design options without a significant increase in price."*

> *"Sometimes it relates to the subdivision and how it is set out. The home owner can be stuck with what's there. Some project homes don't consider energy efficiency."*

The comments suggest that there is a greater likelihood for owner builders to consider energy efficiency in design compared to volume builders.

Table 24 below provides a summary of the types of improvements to building thermal efficiency that have been implemented among new homes in the councils interviewed. As the table indicates, measures are either not implemented at all or only implemented in a minority of cases. Interestingly, in many of these cases, improvements to design were not for the purposes of maximising energy efficiency, (such as in building orientation/window placement or window size) but rather for capturing views.

8.2.5 Summary

It appears that the majority of new homes built in Victoria in recent years are not taking any extra measures than those legislated to improve the thermal efficiency of the dwelling. While the regulations on insulation have been effective in forcing compliance on the degree of insulation installed, there is little else in terms of building design, orientation or materials used that is improving the thermal efficiency of new homes.

8.3 Survey of Insulation Manufacturers

Telephone interviews were held with the two key market players in the bulk insulation and reflective foil insulation industry, as well as some other minor players. The results of these surveys are detailed in the following sections.

8.3.1 Ceiling Insulation Practices – Pre Regulation

Prior to the introduction of regulations the market penetration of ceiling insulation was estimated by the respondents to be somewhere between 40% to 60%. Most respondents opted for the higher 60% value. There was general agreement that bulk ceiling insulation immediately prior to the regulations was typically rated R2.0 to R2.5. One respondent considered that whilst R2.0 was more popular in the early 1980's by the late 1980's R2.5 was dominant and that it rarely if ever exceeded this level. It was also agreed that at the time glass fibre and cellulose fibre insulation each held about 50% of the market. The respondents agreed that pre regulation the use of reflective foil under roofs was of the order of 10% for houses with tiled roofs and 30% for houses with metal roofs.

8.3.2 Wall Insulation Practices – Pre Regulation

Prior to the introduction of regulations the market penetration of wall insulation was estimated by the respondents to be anywhere between 20% to 50%, although the lower Figure was generally favoured. There was general agreement that bulk wall insulation immediately prior to the regulations was typically rated R1.5 and rarely if ever exceeded this level. It was also agreed that at the time, bulk wall insulation held an equal or slightly higher share of the market compared to reflective foil.

8.3.3 Floor Insulation Practices – Pre Regulation

All respondents agreed that the use of floor insulation of any form was negligible in the period prior to the introduction of regulations.

8.3.4 Ceiling Insulation Practices – Post Regulation

There was general agreement that the rate of over compliance was at least 10% but could often be higher for fibreglass insulation especially at times of specials (typically offers for R3.3 or R3.5 insulation at the same price as R2.5). One supplier estimated that at the time of such specials, over compliance was as high as 70%. There was general agreement that over compliance typically meant the use of R3.3 or R 3.5 bulk ceiling insulation.

Table 24 Improvements to Housing Thermal Efficiency – Estimates by Building Surveyors

Improvements	Implemented in Majority of Houses	Implemented in Minority of Houses	Implemented in no Houses at all
Insulation levels	✔✔✔✔✔✔		
Zoning		✔✔	✔✔✔✔
Building Orientation / Window Placement		✔✔✔✔✔	✔
Consideration of Shading (i.e. by trees, adjacent buildings)		✔✔✔	✔✔✔
Use of thermal mass		✔✔✔✔	✔✔
High Performance Glazing.		✔✔✔✔✔	✔
Window size (small in south, large to north, etc.)		✔✔✔✔	✔✔
Draft control measures		✔	✔✔✔✔✔
Other – Internal blinds/curtains		✔ *	

✔ = positive response from an interviewee. * Only one response received to this question

Under compliance was considered to be reasonably common. There was agreement that this would often occur in cathedral ceiling applications where R1.0 blankets were typically used. Also, some inadequate spray installations were thought to occur where post occupancy settlement would result in diminished performance. Improper and incomplete installations were also cited. Overall, under compliance levels for ceiling insulation was thought to be in the order of 10% – 20% with an estimate of non compliance (ie. insulation omitted) at between 1% to 3%.

The respondents agreed that at present the use of reflective foil under roofs was of the order of 15% to 25% for houses with tiled roofs and 30% to as high as 80% for houses with metal roofs.

8.3.5 Wall Insulation Practices – Post Regulation

For wall types other than cavity brick, the rate of over compliance for wall insulation was variously reported to be between 5% to as high as 20%. There was general agreement that over compliance typically meant the use of either R2.0 or R 1.5 bulk insulation in combination with reflective foil.

For cavity brick construction the rate of over compliance (ie. the use of any insulation – typically R1.0 styro-foam) was thought to be less than 2%.

As with ceiling insulation, under compliance was considered to be reasonably common. There was agreement that this would often occur as a result of improper and or incomplete installations – damage to reflective foil during installation was considered common. Overall, under compliance levels for wall insulation was thought to be in the order of 10% – 20% with an estimate of non compliance (ie. insulation omitted) between 1% and 15%.

8.3.6 Floor Insulation Practices – Post Regulation

There was general agreement that the rate of over compliance was only about 1% for concrete floors and 5% or less for suspended timber floors. There was general agreement that over compliance typically meant the use of reflective foil or bulk insulation between floor joists or the use of foam insulation for slab edge applications. Slab edges were rarely insulated except in the case of floor slabs that incorporated slab heating.

Under or non compliance was not considered to be an issue, especially given the fact that it is only ever mandated in the rare circumstances involving suspended timber floors associated with walls fitted only with reflective foil.

8.4 Insulation Study by the Former Gas And Fuel Corporation

In 1990 the former Gas and Fuel Corporation of Victoria published a report entitled "*Home Insulation Penetration and Gas Savings in Victoria*". The study was based upon joint GFCV/SECV biennial fuel and appliance surveys with samples of approximately 3000 households across the state.

Whilst the study was primarily concerned with analysis of the stock as distinct from recent building activity (as is the focus of this study), nonetheless it provides some useful data at a point in time immediately prior to the introduction of regulations.

In 1989 the study estimated that the rates for insulation in the Melbourne metropolitan area was as shown in Table 25.

Table 25 Proportion of Dwellings (Stock) with Insulation (GFCV 1990)

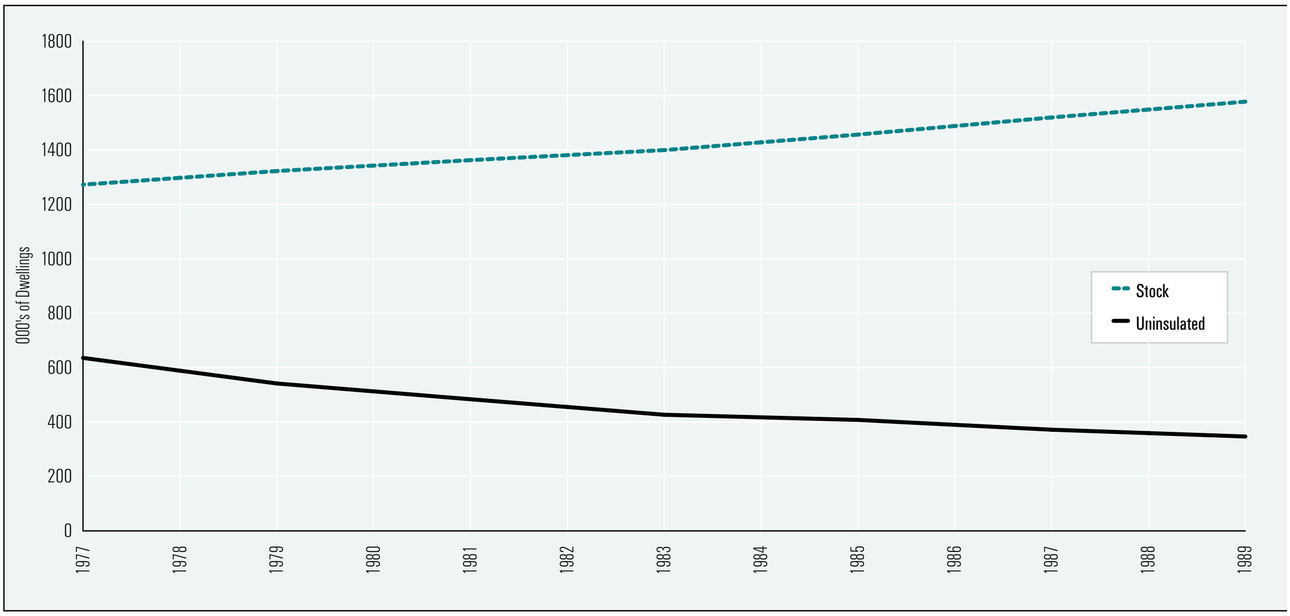
Insulation Installed	% of Dwellings
Ceiling Only	56.4%
Walls Only	1.9%
Ceilings and Walls	17.8%
Total Insulated	76.1%
Total Not Insulated	23.9%

The rates for insulation noted in Table 25 broadly support the levels of insulation estimated by the insulation manufacturers to have been installed into new dwellings of the era. The level of ceiling insulation estimated in the GFVC study for 1990 was 74.2% this compares favourably with an ABS estimate of 74.4% for 1986 (71% if foil insulation only is excluded). Clearly the level of ceiling insulation for the stock is higher than that estimated to be installed in new dwellings pre-regulation. This may be explained by a relatively high level of ceiling insulation retro-fitting soon after occupancy.

Between 1985 and 1989 the study estimated that the stock of housing increased by some 106,000 units whilst the stock of uninsulated houses declined by some 61,000 units (see Figure 43). Assuming that the insulation rate (either wall or ceiling or both) for new houses was in the order of 60% this would indicate that the number of new houses that came onto the market during that period without insulation was in the order of 42,000 units. The total number of houses retro-fitted with insulation (almost exclusively ceiling insulation) over this four year period must have therefore been the sum of these two Figures – approximately 103,000[25] units or approximately 26,000 units per annum.

25 These estimates take into account the effect of demolition of existing stock estimated to be approximately 0.2% per annum based upon Figures published in the BASIS publication.

Figure 43 Housing Stock Total and Uninsulated 1977 – 1989 (GFCV 1990)



This number of retro-fits is equivalent to a rate of 1.7% of stock retro-fitted per annum. This Figure may be compared to a national Figure estimated to be 1.2% EES (1999); this estimate by EES was based upon data from BIS Shrapnel (1994). Whilst the national average is less than the estimate for Victoria, it is considered likely to be accurate given that the practice of retro-fitting of insulation is likely to be more popular in the cooler climate zones of Australia, where central heating has shown a significant increase in popularity.

8.5 Survey of Window and Glazing Manufacturers

Telephone interviews were held with a total of seven key market players in the glass and window manufacturing industry, four representing double glazing manufacturers and three representing window manufacturers. Companies included:

- Pilkington (Australia) Limited
- MOEN Glass
- South West Aluminium and Glazing
- G. James Safety Glass Pty Ltd
- Boral Limited
- James Hardie Australia
- ANL Windows P/L
- Australian Window Association Inc.

A telephone interview was also held with a representative from the Australian Window Association.

8.5.1 Penetration of Double Glazed and Thermally Advanced Windows

All of the respondents mentioned that the proportion of homes with double glazing or that have installed windows that are thermally advanced in terms of frame or glass design is very small. Pilkington Australia Ltd suggest that the proportion of homes with double glazed window units is less than 1.5% in Victoria. Most of the window manufacturers spoken to noted that the proportion of double glazed units sold compared to conventional units sold was very small (less than 5%) or less than 10%.

ABS 4602.0 (1999) estimates that the penetration of double glazing in Victorian housing stock is 2.2%. A significant proportion of this percentage is likely to be a result of retrofitting rather than as a result of installation during construction, which is the focus of this study. Whilst these statistics do not provide any definitive data on the rate of installations into new housing it does suggest that the rate is likely to be very low – probably in the order of the Pilkington's estimate of less than 1.5%.

8.5.2 Marketing of Double Glazed and Thermally Advanced Windows

Very few of the companies spoken to are conducting any serious marketing effort of double glazed or thermally advanced windows. While various reasons were noted, it seems that the potential market is perceived to be small and as such little promotion is carried out. Several respondents noted that their marketing efforts targeted home owners and certainly not builders who were perceived to be highly price driven and unlikely to change to more efficient window products.

Marketing activities largely promote the energy performance of the product as opposed to acoustic or other benefits of double glazed or thermally advanced window units. All respondents agreed that while acoustic properties of windows were sometimes important in the past, higher energy Efficiency is the primary reason for installation in new homes of today. One respondent mentioned that marketing activities had "missed the point" of the benefits of double glazed windows in that the "comfort factor" in terms of maintaining a constant temperature in the home should be a more heavily promoted aspect of double glazing.

The double glazed, high performance window unit market is perceived to be at the "upper end" of new homes built in Victoria. Respondents noted that second or third home owners were more likely to consider thermally efficient windows and that such home owners were not included in the budget driven end of the new home market.

8.5.3 Types of Frames Manufactured and Glass Technologies Used

Mixed results were obtained on the types of frames used in Victoria. One window manufacturer believed that twenty to thirty per cent of frames in Victoria would be timber while another mentioned that the majority of houses would install windows with timber frames (although they manufacture 50% of windows with timber frames). Aluminium frames were considered to constitute the bulk of the remaining market with a smaller proportion attributed to thermally improved aluminium frames.

Respondents were asked to give an estimate of the percent of sales of various glazing types. Table 26 shows that sales are very minimal and generally below five percent. It should be noted that respondents were not able to provide exact estimates of the types of glazing installed in the residential market so the table below is only very arbitrary in the information it contains.

Table 26 Estimated Sales of Glazing Types

Glazing Types	% of Sales
Low e	Very minimal (less than 5%)
Reflective	Almost nil in Victoria (more common in Queensland)
Body tinted	Almost nil
Double Glazed standard/clear	Small, but greater than Low e, reflective or body tinted
Double Glazed plus Low e	Very small (less than 5%)
Double Glazed plus reflective	Very small (less than 5%)
Double Glazed plus body tinted	Very small (less than 5%)
Thermally enhanced frames	Small
WERS rated windows	Small

8.5.4 Trends

All respondent agreed that the proportion of new homes with double glazed windows now compared to say, ten years ago, had increased. However, as mentioned earlier, this trend is considered evident in the upper market houses and is having little or no effect in the first home buyer market.

While cost was considered the primary factor prohibiting the installation of double glazed or thermally efficient windows, a lack of awareness of new technologies in the glass industry was also considered to be an important factor prohibiting installation of efficient window units.

There was a perception among some respondents that the area of glass in proportion to the floor area had increased since 1990. However, not all respondents felt that this was the case and certainly no respondents were able to support their opinions with any substantive evidence such as sales Figures.

8.5.5 Summary

Overall, it appears that while the market for double glazed or thermally enhanced windows may be growing, the market remains very small. High cost and a general lack of awareness of window technologies are the most significant barriers to their installation and use in new homes. New glazing and window frame technologies have the potential to capture a larger market share provided the benefits of efficient window technologies are promoted and encouraged to new home owners and builders alike.

8.6 Summary of Findings from the Related Data Sources

The prevalence of new homes built with insulation installed that exceeded minimum compliance levels.

The view of the Building Surveyors surveyed suggested that over compliance with the insulation requirements was quite rare (less than 5%). This contrasts
with the view of the insulation manufacturers who put the Figure at around 10% with occasional increases above this level in response to sales specials. In this instance it was decided to accept the base level as suggested by the manufacturers (10%), given that they have access to actual sales data whereas the building surveyors with the exception of Ballarat's do not record actual R values as installed.

The prevalence of new homes built with insulation installed below minimum compliance levels (under compliant).

The view of the Insulation manufacturers
was that under compliance was in the order of 10% – 20%. The building surveyors considered that under compliance was

"not a problem" but did concede that it did occur. The authors own experience suggests that poor installation practices are an issue, and are likely to result in effective insulation levels below those required in the code. For the purposes of this study the lower level of non compliance as suggested by the manufacturers (10%) was adopted.

The rate of non compliance with thermal performance regulations.

The view of the Insulation manufacturers was that non compliance was in the order of 1% – 3% for ceilings and 1% – 15% for walls. The building surveyors considered that non compliance was "not a problem" but did concede that it did occur very rarely. It was decided to adopt the lower levels nominated by the manufacturers except that in the case of wall insulation a level of 2% rather than 1%. This was adopted in consideration of the fact that wall insulation is permanently concealed (unlike most ceiling insulation) and is therefore more likely to be omitted by opportunistic builders seeking to save on construction costs than ceiling insulation.

Insulation practices prior to the introduction of regulation.

Based upon the information provided, mainly from the insulation manufacturers and FARIMA, the following pre regulation levels were adopted for use in the modelling:

- ceilings – 40% market penetration – new housing in 1990
- ceiling and Walls – 20% market penetration – new housing in 1990
- floor Insulation – 0% market penetration – new housing in 1990
- R values – broadly as per regulation – new housing in 1990

The extent to which building construction had changed in the past five to ten years that has led to an improvement in building thermal efficiency. (Qualitative only)

With the exception of the improvements associated with the introduction of the insulation regulations respondents believe that there have been no changes in building construction that have led to the improvement in building thermal efficiency.

Rates of insulation retro-fitting.

From the data available it would appear reasonable to assume that the rate of retro-fit of ceiling insulation was of the order of 1.7% immediately prior to the introduction of regulations. Predicting trends in this rate (in the absence of regulations) is more problematical. The GFCV study suggests that whilst the trend towards more attached housing and more rental housing would have been likely to have reduced this rate, the trend towards a greater use of central heating would have been likely to have increased this rate. For the purposes of this study it will be assumed that this rate would have remained static over the study period. This assumption is supported by advice received from FARIMA as reported in the Study of greenhouse gas emissions from the Australian residential (EES 1999).

A sensitivity analysis was conducted to gauge the effect of a ±0.5% shift in this rate on the "without regulations scenario" which will be the most sensitive to this variable. The results are shown in Table 27. From this analysis the potential error in the energy estimates associated with this assumption is likely to be limited to less than ±0.5%.

The penetration of double glazing and thermally advanced window frames.

Analysis of the data gathered in this area suggests that the penetration of double glazing in new Victorian housing is less than 2% and possibly closer to 1%. On this basis it was decided that all glazing in the sample would be considered to be single glazing unless specifically noted otherwise in the drawings. In fact no houses in the sample were found to have double glazing or thermally advanced window frames specified.

Table 27 Sensitivity Analysis on Insulation Retro-fit Rate

Insulation Retro-fit Rate	Unconstrained Cumulative Energy Consumption in 1999	% Variation in Result
1.2% (ie. -0.5%)	38.44	+0.44%
1.7% (ie. adopted rate)	38.27	0.00%
2.2% (ie. +0.5%)	38.11	-0.42%

SECTION NINE
GREENHOUSE GAS INTENSITY

SECTION 9 GREENHOUSE GAS INTENSITY

This section is partly reproduced from the Australian Greenhouse Office Australian Residential Building Sector Greenhouse Gas Emissions 1990-2010 (EES 1999). Since that publication, greenhouse gas emission estimates for electricity have been revised based on the latest projections as at mid 2000. The latest Figures presented below are derived from Electricity Greenhouse Gas Coefficient Projections, 1997/98 to 2019/20 by George Wilkenfeld and Associates (GWA 2000).

Table 28 summarises the emissions per unit of electricity delivered to users in Victoria, and Table 29 summarises emissions per unit of natural gas delivered (and burned). Combustion emissions are the emissions from the power stations or gas appliances themselves. The CO2-equivalent values are slightly higher than the CO2 value because of the global warming impact of the small amounts of CH4 (methane) and N2O (nitrous oxide) emitted during combustion.

Full fuel cycle emissions also include the combustion and fugitive emissions associated with the production, processing and transport of the fuel. For example, there are fugitive CH4 emissions associated with the production of the brown coal used in generating electricity, and naturally occurring CO2 is vented at the wellhead in gas production[26].

Emissions per unit of electricity delivered change over time with the following factors:

Table 28 Greenhouse gas emissions per kWh electricity delivered – Victoria

1990(a)	1995(a)	1998
1.367	1.357	1.421

All values kg CO2-e/kWh delivered.

Source: GWA 2000

Table 29 Greenhouse gas emissions per GJ natural gas delivered, 1995 0 Victoria

kg/GJ Delivered and burned	
CO2	CO2-e
63.6	68.7

Source: GWA 1998

- the share of electricity generated from fossil fuels and from renewable energy: the higher the renewable component, the lower the emissions intensity
- the fossil fuel mix: coal for example has higher emissions per PJ burned than does natural gas
- the efficiency of thermal power stations: the higher the efficiency the lower the emissions intensity, all else being equal

In November 1997 the Prime Minister announced a number of greenhouse gas reduction policies including the objective of increasing the renewable energy share of electricity generation by 2% in 2010, and setting efficiency improvement targets for thermal power stations to be achieved by 2010. The first objective would achieve a 2% reduction in greenhouse gas intensity, all else being equal. While no targets have been announced for the second objective, it has been assumed that this will result in a further 1% reduction in intensity by 2010.

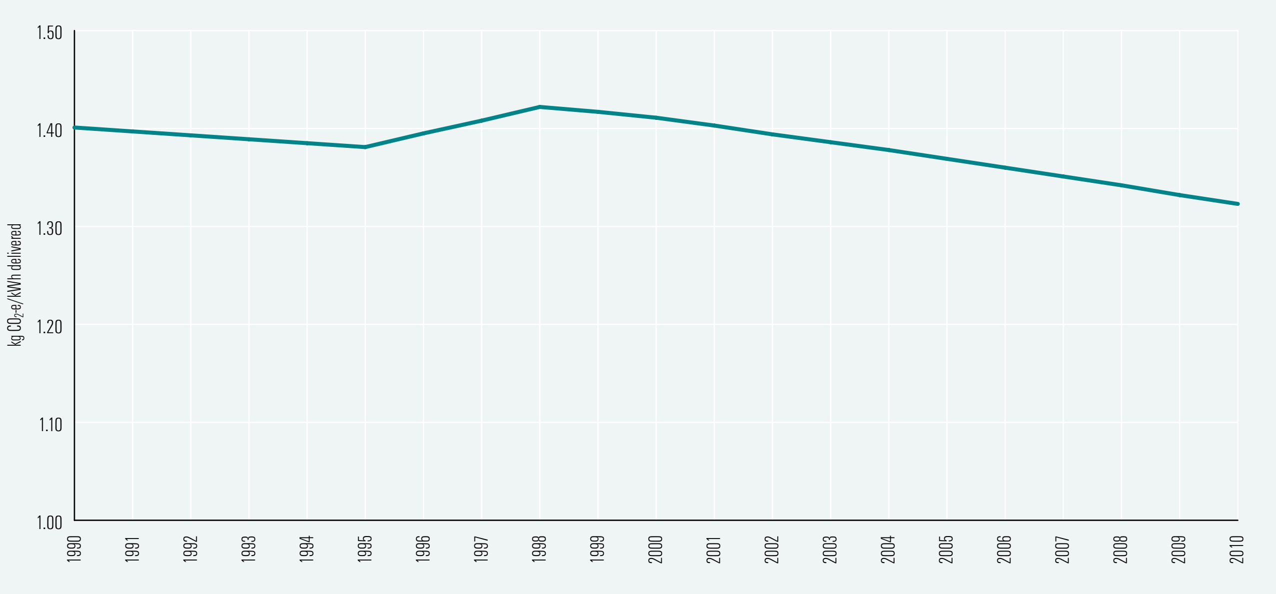
The greenhouse gas intensity of electricity has been projected on the assumption that the objectives of the Prime Minister's program will be met, and that fuel mix will change as projected by ABARE with certain modifications as described in the GWA study.

Figure 44 illustrates the result of these trends. It should be noted that the coefficient for Victoria in 1998 was higher than in 1995. This is consistent with the decline in the natural gas share of generation fuel in Victoria, from about 8% in 1995 to little more than 0.1% in 1998, and the effect of lower Snowy Mountains Hydro-Electric Authority (SMHEA) production.

These emission projections are used to calculate the greenhouse gas emissions from electricity to be supplied for residential uses in each year to 2010. The emissions from residential natural gas supply are assumed to remain constant at the values in Table 29.

26 For complete details regarding the application of fugitive emissions to the Figures presented reference should be made to Electricity Greenhouse Gas Coefficient Projections, 1997/98 to 2019/20 (GWA 2000).

Figure 44 Greenhouse gas emissions per kWh electricity delivered – Victoria



Wood accounts for a significant share of the energy used in space heating, but a far smaller share of the greenhouse gas emissions. The greenhouse intensity of wood use is low, because unlike coal, gas and petroleum, wood is a renewable fuel. For national greenhouse accounting purposes, it is considered that the CO2 produced from the combustion of wood and other biofuels is exactly balanced by the takeup of carbon from the atmosphere when the biomass regrows.

Therefore the greenhouse-intensity of wood use comprises only the effect of the CH4 and N2O produced during its combustion (expressed as equivalent CO2). Wood burned in closed combustion heaters has a low greenhouse gas intensity (about 4 kt CO2-e/PJ), but when wood is burned in an open fire under poorly controlled conditions, the greenhouse impact is about 58 kt CO2-e/PJ, comparable to burning natural gas.

REFERENCES

REFERENCES

ABARE 1997, Australian energy consumption and production: Historical trends and projections to 2009-10, ABARE Research Report 97.2, February 1997.

ABARE 1998, State level energy consumption from 1972 to 1997 with national projections to 2010 (unpublished), personal communication with Shane Bush, Australian Bureau of Agriculture and Resource Economics (ABARE), Canberra, November 1998.

ABM 1997, Daily Maximum and Minimum Temperature Data for 8 Australian Capital Cities from 1970 to 1997, data purchased in electronic form from the Australian Bureau of Meteorology, National Climate Centre, Melbourne, October 1997.

ABS = Australian Bureau of Statistics

ABS Census of Population and Housing – 1966, 1971, 1976, 1981, 1986, 1991 & 1996 (summary data reported in various Year Books and various Census reports)

ABS 2015.0, 1996 Census of Population and Housing – Selected Social and Housing Characteristics.

ABS 2409.0 to 2417.0, 1976 Census of Population – Housing Summary Files.

ABS 2452.0, 1981 Census Summary Tables

ABS 2498.0, 1986 Census Summary Tables

ABS 2710.0, 1991 Census Summary Tables

ABS 3101.0, 1997 Australian Demographic Statistics.

ABS 3102.0, 1997 Australian Demographic Statistics, 1997

ABS 3222.0, Projection of the Populations of Australia, States and Territories 1997 to 2051.

ABS 3229.0, 1996 Household Estimates Australia.

ABS 4133.0, 1988 Housing Survey – Characteristics of Dwellings.

ABS 4172.0 1994 Cultural Trends in Australia, May 1994

ABS 4172.0 1997 Cultural Trends in Australia, December 1997

ABS 4602.0, 1994 Environmental Issues – People's Views and Practices.

ABS 4602.0, 1999 Environmental Issues – People's Views and Practices.

ABS 8212.0, 1981, National Energy Survey – Household Appliances, Facilities and Insulation, Australia 1980, published July 1981.

ABS 8212.0, 1984, National Energy Survey – Household Appliances, Facilities and Insulation, Australia 1983, published June 1984.

ABS 8212.0, 1987, National Energy Survey – Household Appliances, Facilities and Insulation, Australia 1985-86, published June 1987.

ABS 8213.0, 1984, National Energy Survey: Annual Consumption of Reticulated Energy by Households, Australia 1983.

ABS 8213.0, 1987, National Energy Survey Annual Consumption of Reticulated Energy by Households, Australia 1985-86, Canberra.

ABS 8218.0, 1988, National Energy: Survey Weekly Reticulated Energy and Appliance Usage Patterns by Season Households, Australia 1985-86, October 1988.

ABS 2000 – Buildings Research and Outputs Group, Building approvals data 1987 – 1997, Victorian state and LGA data purchased for the project, April 2000.

ABS – Concordance of postcodes and Victorian LGAs.

AG102, Approval Requirements for Gas Water Heaters, Australian Gas Association.

AG103, Approval Requirements for Gas Space Heaters, Australian Gas Association.

AGA 1998, Gas Statistics Australia, Australian Gas Association, Canberra. Selected data has been extracted from previous versions of this report back to 1985.

AGA 1995-2000, Approved Appliances and Components, Australian Gas Association and the Australian LPG Association, Canberra (various editions).

Antweiler, W. 1996, The Pollution Terms of Trade, Economic Systems Research, Vol. 8, No. 4, pp. 361-366.

AS2627.1, Thermal Insulation of Dwellings – Thermal Insulation of Roofs/Ceilings and Walls, Standards Australia, Sydney, 1993.

AS3823-1998, Performance of Household Electrical Appliances – Room Air Conditioners – Part 1.1 Non ducted air conditioners and heat pumps – Testing and rating for performance, Standards Australia, Sydney (based on ISO5151).

Ballinger, J., Prasad, D., Lawson, B., Samuels, R., and Lyons, P. 1995, R & D of current environmental technologies in Australia, Proceedings: Pan Pacific Symposium on Building and Urban Environmental Conditioning in Asia, Nagoya, March, 9 pp.

Bartels R., Household Energy Consumption (Analysis of the ABS 1983 Household Energy Survey), for Energy Authority of NSW, report EA85/50,1985.

Bartels R., Fiebig D., Aigner D. & le Roux T., Domestic End Use Study (Load Shape Study) , for Electricity Commission of NSW, report PD88/5, 1988.

BIS Shrapnel 1994, Study to Investigate the Alterations and Additions Sector of the Housing Industry, BIS Schrapnel, Sydney.

BIS Schrapnel 1998a, Household Appliances Market in Australia 1998-2000, BIS Schrapnel, Sydney, September 1998, Volume 1 – Whitegoods, Volume 3 – Climate Control.

BIS Schrapnel 1998a, Household Appliance Survey, BIS Schrapnel, Sydney, September 1998, unpublished results of August 1998 household survey.

Building Control Commission, 1999, Basis Data base (private communication).

Building Control Commission, Building Code of Australia. – 1996.

Choice Magazine, consumer magazine published monthly by the Australian Consumers' Association, Sydney (various editions 1990 to date).

Coldicutt AB, et al, 1977, The Value of Insulation, Thermal Insulation Institute of Australia, Melbourne.

Crabb N., Tang P., Gangopadhyay G, Bartels R. & Fiebig D., Domestic End Use Study in NSW, paper presented to ESAA Forecasting Forum, 18-19 November 1993, Adelaide.

CSIRO 1980, Heating Degree Days for Australian Localities, by P.J. Walsh and J.W. Spencer, Division of Building Research, Technical Paper number 35, Commonwealth Scientific and Industrial Research Organisation, 1980.

Department of Planning and Urban Growth, October 1990, Regulatory Impact Statement – Victoria Building (Thermal Insulation) Regulations 1990.

DOE 1996, Engineering & Financial Statistics of Electricity Supply Authorities in NSW 1994/5.
NSW Department of Energy, Sydney.

EES 1995, Potential for Greater Energy Efficiency in Domestic Appliances in Queensland, prepared for the Queensland Electricity Commission by Energy Efficient Strategies and George Wilkenfeld & Associates, April 1995.

EES 1999, *Study of greenhouse gas emissions from the Australian residential building sector to 2010*, prepared Energy Efficient Strategies for the Australian Greenhouse Office, Canberra, February 1999.

Energy Victoria 1994, Energy Efficient Housing Manual – Design Guidelines and Case Studies (now SEA).

ESAA 1998, Electricity Australia, Electricity Supply Association of Australia, Sydney.

ESAA 1993 Electricity Australia, Electricity Supply Association of Australia, Sydney.

FARIMA 1983, Energy Conservation Through Insulation Incentives, Fibreglass Insulation Manufacturers Association, Melbourne.

FARIMA 1997, Incentives to Encourage Home Insulation, Submission to the Commonwealth Department of Primary Industries and Energy Task Force White Paper on Sustainable Energy.

Fiebig D. & Woodland A., Residential Energy Consumption in NSW (Analysis of the ABS 1989 NSW Household Energy Survey), for NSW Office of Energy, 1993.

Fiebig D.& Woodland A., Residential Energy Consumption in NSW (Analysis of the ABS 1985-86 Household Energy Survey), for NSW Dept Minerals & Energy and ECNSW, report DME 91/110, 1991.

Gas and Fuel Corporation of Victoria – Economic Policy and Research Department, Gas demand management discussion paper 2 – Home Insulation Penetration And Gas Savings In Victoria, 1990.

GWA 1991a, Appliances – Assessment of Energy Efficiency Trends, prepared for SECV by George Wilkenfeld and Associates, June 1991.

GWA 1991b, Review of Residential Appliance Labelling, prepared for SECV by George Wilkenfeld and Associates, with Test Research and Artcraft Research, September 1991.

GWA 1993 – Benefits and Costs of Implementing Minimum Energy Performance Standards for Household Electrical Appliances in Australia, Final Report, prepared for SECV by George Wilkenfeld and Associates, with Lawrence Berkeley Laboratory, for ANZMEC, July 1993.

GWA 1998, Australia's National Greenhouse Gas Inventory 1990 and 1995 and 1997: Cross-Sectoral Analysis of Emissions. Report prepared for Environment Australia, by George Wilkenfeld and Associates Pty Ltd, February 1998.

GWA 1999, George Wilkenfeld & Associates, personal communication.

GWA 2000, Electricity Greenhouse Gas Coefficient Projections, 1997/98 to 2019/20, George Wilkenfeld & Associates, Sydney, July 2000.

Mogg 1999, personal contact with Mr Bruce Mogg, Environmental Director for the Australian Home Heating Association (formerly the Australian Wood Heating Association), Queensland, January 1999.

Moller 1997, Frequency analysis of capital city weather data used for Bunyip modelling program, personal communication, Steve Moller, BCE, CSIRO.

NIEIR 1997, Estimates of residential household numbers and floor area, for Department of Primary Industries and Energy, by National Institute of Economic and Industry Research, Melbourne.

Pacific Power 1996, The Residential End-Use Study, A detailed study of how and when electricity is consumed by the residential class in NSW, Pacific Power and NSW Electricity Supply Industry.

Pears 1998, Strategic Study of Household Energy and Greenhouse Issues. A Report for Environment Australia by Alan Pears, Sustainable Solutions, Melbourne.

Schipper et al 1998, Energy Use in Australia in an International Perspective: Comparison of Trends through the early 1990's, by Lee Schipper, Fridtjof Unander, Celine Marie, Ian Walker, Roger Gorham – IEA and Michael Ting, Marta Khrushch, Tom Krackler – Lawrence Berkeley Laboratory, for DPIE.

SEA 2000a, "User Guide for SEA – The Computer Simulation Tool for House Energy Rating", 2000.

SEA 2000b, "Recommendations for Revised Star Bands for NatHERS", Sustainable Energy Authority Victoria, unpublished data, 2000.

SEA 2000, *FirstRate* software and data files.

SOLARCH 1995, "A Window Energy Rating Scheme for Australia", report to the Australasian Window Council by Unisearch (UNSW), Sydney, December 1995.

Test Research 1995, Appliance Use Survey, prepared for NAEEEC by Test Research (ACA), February 1995 (postal survey of 2,900 Australian Households).

Wilrath H 1998, "Thermal Star Ratings for Queensland Houses", unpublished report for Queensland Department of Public Works and Housing, Brisbane, 1998.