Changes Associated with Efficient Dwellings project –Final Report

Prepared by Moreland Energy Foundation in association with Strategic, Policy and Research, WTP partnership and Building Environmental Assessment Company

May 2017

For the Department of the Environment and Energy, on behalf of all Australian jurisdictions under Measure 31.2 of the National Energy Productivity Plan
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The ‘Changes Associated with Efficient Dwellings Project’ aims to contribute to research in the residential buildings sector, by conducting an independent study into, and providing examples from the building industry of, the changes that have been implemented and that are associated with constructing more energy efficient dwellings.

This work supports and complements other studies currently being undertaken as part of the research program to inform the development of improved building energy efficiency over time through Measure 31.2 of the National Energy Productivity Plan (NEPP).

This current project has posed the fundamental research question as to how the industry responded to the introduction of the 6 star energy efficiency standard – for example, by changing designs, construction materials and specifications, or construction techniques, and the associated costs – and how has this response changed over time to estimate likely changes in the future costs of compliance with potential new National Construction Code (NCC) requirements. The research undertaken includes two principal components:

Firstly, a qualitative research component, which included:

- 17 interviews reporting on the experience of development industry representatives in the transition to 6 star and experience going beyond the regulatory minimum
- A survey distributed through member organisations to gain some statistical depth to the stakeholder consultations which received 187 responses inclusive of architects, building designers, builders, energy raters / sustainability consultants along with a number of local product manufacturers with representation from all jurisdictions.

Secondly, a quantitative research component based on a sample of 58 representative dwellings obtained from industry, which sought to answer the following:

- How did the actual incremental costs of moving to and achieving 6 star performance change over time?
- What are the actual incremental costs of achieving beyond 6 star (and up to 8 star) performance?
- What are the outcomes of an indicative benefit cost analysis?

A summary of the project findings are provided below.

### 1.1 Qualitative Findings

Most stakeholders interviewed agreed that the principal change initially, in response to the introduction of the 6 star equivalent energy efficiency requirements in the Building Code of Australia (BCA) 2010, was to increase the level of specification in glazing and insulation. This assertion was supported by the survey results.
There was general agreement amongst stakeholders and survey respondents that the introduction of BCA 2010 added cost, but there were varying views on how much. In the survey, 34% of respondents indicated the initial cost was neutral or less than $2000, 36% of respondents indicated that the initial cost impact was between $2,000 and $5,000 and 30% indicated the increase was more than $5,000.

Stakeholders generally agreed that the cost could be managed better depending on the strategies adopted and that there were pathways available to be cost neutral whilst increasing star rating. Industry capacity was noted as a significant determinant in managing the cost associated with stringency increase, this includes a lack of knowledge restricting practitioners from taking a least cost approach.

Stakeholders generally noted the capacity for industry to learn to optimise designs over time and there was some evidence of this in the survey responses, however there were varying perspectives on the extent to which this is actually occurring. A number of other factors were found to influence learning, including business structure or type (larger organisations with in-house design capacity improved learning).

Other factors such as macro-economic influences and planning regulation were highlighted as being significant costs determinants (greater than thermal performance changes) and likely contributed to significant variation in costs found in the representative sample below.

### 1.2 Quantitative Findings

A capacity to learn is evident in the findings of the quantitative analysis which examined 58 dwellings representative of the period 2010 to 2017.

In examining the incremental cost of voluntary improvements beyond 6 star, while it is possible to fit a trend line to the data, there is a very high degree of ‘scatter’, due to the significant variability in cost of dwellings. Noting this limitation:

- The area-adjusted analysis for Class 1 dwellings implies a cost/sqm per star of around $18, or $2,700 for a 150sqm dwelling.

- The results for Class 2 dwellings indicates a cost/sqm per star of around $7, but again the confidence is very low.

It is unlikely that the costs of achieving above 6 star, and up to 10 star, performance would increase in a linear fashion. Taken over the whole period for which we have data from the representative sample, from 2010 to 2017, costs rose initially (to 2013) then start to fall. This data incorporates a limited number of dwellings which were designed before the implementation of BCA 2010 so an initial increase is not unexpected. As the primary focus of the work was to look at the potential for declining cost over time following the introduction of BCA 2010 a large sample before the introduction was not the focus of data collection.

When the learning rates are derived only from the 2014 – 2017 sample of dwellings (after the initial incremental cost appears to have been overcome by learning effects) a learning rate is evident. Overall, for both Class 1 and 2 dwellings together, an annual learning rate of 7.5% per year was observed through this period, with results of 7.1% for Class 1 dwellings and 1.7% for Class 2 dwellings. Built form investigations into glazing to wall ratios also showed a decline especially from 2013 onwards, which may support this finding that industry learning is taking place.
For Class 1 dwellings, applying an incremental cost of around $18/sqm per star, and a learning rate of 7.1% per year (from 2020, the assumed first year of application of a possible new standard), shows that at least 7 star dwellings should be cost effective when an indicative benefit cost analysis is undertaken. Similarly, for Class 2 dwellings, and using an incremental cost of $7/sqm per star, at least 7 star dwellings should be cost effective.

Whilst these results indicate the sort of trends we would expect based on the qualitative analysis, they are based on too few data points to be considered with confidence, due to the large variation in costings (as discussed due to non-thermal performance related factors).

The extreme variability in the real world data does nevertheless carry valid information. It indicates that the costs of construction in the real world do indeed vary widely, and the likelihood is that much of this variation – perhaps most of it – is unrelated to energy performance.

Overall we conclude that the representative sample size is not large enough or has too much variation due to other factors to draw meaningful conclusions about the incremental cost of achieving higher star ratings. This is especially the case considering that voluntary improvement beyond 6 star is likely to be at greater cost than if prompted by a regulatory increase which would promote factors such as product economies of scale.

1.3 Further research and recommendations

The lack of confidence in the data trends indicates the need for new approaches to be explored to increase the confidence in the results of what is an important research area.

Fundamentally, the use of actual drawing and specifications data has proved challenging to source from industry and has provided low confidence in the results. An alternative method would be to undertake a traditional bottom-up approach to assessing the impact on building cost. More detail on how this could be undertaken is outlined in Section 6.3.

Despite the lack of certainty in the results the trends encountered indicate there is enough evidence to provide support for any future residential RIS, however it would need to be designed to overcome the limitations identified by this research. The key to providing industry certainty in the results of any future RIS process is a serious cost study that takes a bottom up approach to overcome these limitations or sources sufficient data from NatHERS databases to determine key changes over time (and then cost those key changes). Any study would also need to account for sensitivity to higher costs in early years following any proposed increase in stringency, the scope for economies of scale and other learning effects to reduce incremental construction costs over time, and consider one-off costs such as the costs of redesign.

There is also evidence to suggest that the cost impact of any future change in stringency could be reduced through building the capacity of practitioners to take a least cost approach in their response, noting there are other drivers (such as the cost of redesign itself and a preference for project builds to work on multiple orientations) that may limit this.

A number of complementary pieces of work, such as setting trajectories for the foreseeable future and improving compliance were also highlighted in the stakeholder analysis and are worthy of further consideration – indeed several stakeholders considered increases in stringency should only be considered if compliance was also addressed.
2 Introduction

2.1 Background

In 2010, the energy efficiency provisions of the Building Code of Australia were updated at a national level and the energy efficiency requirements for new dwellings was increased from an equivalent 5 to 6 stars under NatHERS. The standard, and other requirements of BCA 2010, took effect progressively as individual states and territories adopted it. This occurred only in 2014 for Tasmania and the Northern Territory is yet to adopt it. The energy efficiency standard is enacted through state and territory building laws and regulations. The NatHERS rating scheme is managed by the NatHERS administrator within the Department of the Environment and Energy. In many states the new standard has now been in place for several years and an opportunity presents to reflect on the actual impact of this regulatory change on both the design of dwellings and the associated cost and other impacts. A joint project team comprising Moreland Energy Foundation (MEFL), Strategy. Policy. Research (SPR), WT Partnership and Built Environment Assessment Company (BEAC) has been commissioned by the Department of the Environment and Energy (the Department) to investigate the initial and ongoing impact of BCA 2010 across a number of areas.

The context for this project reaches back to the previous building code upgrade that was agreed in 2009. At that time, the question of how designs would evolve over time, and whether the incremental costs of compliance with the proposed 6 star standard would fall or remain constant over time, was discussed at length. At that time, a judgement was made to assume, for the purposes of benefit cost analysis, that the ‘learning rate’ (or rate of change in compliance costs over time) would be set at zero.

Subsequent research, including CSIRO’s ex poste evaluation of 5 star and a March 2012 report commissioned by the Department from Sustainability House, have shown that zero or even negative incremental costs have been, or can be, achieved simultaneous with higher star ratings. Other reports establish the concept that the transition to 6 star can be achieved at zero or negligible cost, but the question remained as to what actually happened – how did industry respond?

Two reports for the Department by pitt&sherry indicated that the learning rate is the most sensitive and critical variable in benefit cost analysis of the optimal stringency for residential energy efficiency standards. The second report also noted that there is a lack of evidence as to what is the appropriate learning rate to use for benefit cost analysis and regulatory impact assessment.

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purposes, and it therefore recommended focused research be undertaken, in time to enable the
results to be taken into account ahead of any RIS for a possible NCC stringency change in 2019.

Finally, a June 2015 report by Moreland Energy Foundation Limited, in partnership with
pitt&sherry, on a methodology for a 6 star ex poste evaluation, also recommended that research be
conducted into the actual effectiveness and cost effectiveness of the 6 star standard, including
specifically addressing the question of learning rates and, more broadly, how industry responded to
the introduction of the 6 star standard.

The policy context for this work stems from the release of the National Energy Productivity Plan
(NEPP) in December 2015. The NEPP provides a framework and work plan to deliver a 40 per
cent improvement in Australia’s energy productivity by 2030.

1. NEPP Measure 31 – Advance the National Construction Code (NCC)

2. Measure 31 of the NEPP Work Plan notes:

3. The [COAG Energy] Council recognises that there is a need to gather more evidence
around the effectiveness of existing Codes and standards, particularly for residential
dwellings. The Council will engage in an intensive research programme to inform
development of updated building efficiency requirements.

At this stage neither the COAG Energy Council nor the Building Ministers Forum have committed
to any energy efficiency stringency increase for residential in NCC 2019, however work is ongoing
by CSIRO and others.

2.2 Learning rates

Critical to the concept of the ongoing cost of meeting a regulatory obligation is the “learning rate,”
defined as the fractional reduction in cost for a defined increase in cumulative production or
capacity. In this context, it is concerned with the rate at which industry learns how to optimise their
design and specifications in response to the introduction of the standard. The quantitative analysis
will determine whether this is a function of time, or volume of new builds under the new standard.

Understanding how the costs of compliance with the thermal performance standard change over
time is of key importance for analysts and decision-makers concerned establishing a trajectory for
increased stringency.

Over the past several decades, the concept of a learning curve (or experience curve) has been
employed increasingly to relate historically observed decreases in the cost of a technology or
practice to key factors affecting its adoption and diffusion. Learning rates derived from such models
are now widely employed by researchers and policy analysts to project future trends in the energy
and environmental domains.

This research seeks to build evidence on what happened when the 6 star standard was introduced
and combine it with evidence as to how industry is currently going well beyond minimum
compliance to understand the likely impact of any future increases in stringency.
2.3 Jurisdictional variations and implementation

The ability to track design and cost changes in relation to increased stringency over time is clouded by the non-uniform implementation timeframe across the jurisdictions. One of the clearest examples is in Victoria as the 6 star standard was introduced relatively quickly, there are large volumes of development and the state was relatively accepting of the change in standard (compared to other jurisdictions).

Table 1 - Summary of 5 star and 6 star standard application by date

<table>
<thead>
<tr>
<th>State</th>
<th>5 star application</th>
<th>6 star application</th>
</tr>
</thead>
<tbody>
<tr>
<td>ACT</td>
<td>2006 – May 2010</td>
<td>2010 to present</td>
</tr>
<tr>
<td>NSW</td>
<td>N/A (BASIX introduced in 2004, equivalent to approximately 4.8 star)</td>
<td>N/A (most recent update to BASIX Thermal Comfort protocol is December 2014 includes splitting of heating and cooling loads – planned increase in stringency – July 1, 2017)</td>
</tr>
<tr>
<td>Northern Territory</td>
<td>Class 1 (5 star) May 2010 – present</td>
<td>N/A</td>
</tr>
<tr>
<td></td>
<td>Class 2 (3.5 Star) May 2010 – present</td>
<td></td>
</tr>
<tr>
<td>Queensland</td>
<td>March 2009 – May 2010 (class 1) May 2010 – present (class 2)</td>
<td>May 2010 to present (Class 1)* Not applicable to Class 2</td>
</tr>
<tr>
<td>South Australia</td>
<td>May 2006 – September 2010</td>
<td>September 2010 to present</td>
</tr>
<tr>
<td>Tasmania</td>
<td>From 2006</td>
<td>May 2013 for apartments and May 2014 for single dwellings</td>
</tr>
<tr>
<td>Victoria</td>
<td>July 2005 – May 2011</td>
<td>May 2011 to present</td>
</tr>
<tr>
<td>Western Australia</td>
<td>From 2006</td>
<td>May 2012 (including 12 month transition period)</td>
</tr>
</tbody>
</table>

* Note – Under the National Construction Code (Volume Two) an optional credit of up to 1 star energy equivalence is available in climate zones 1 and 2 for a class 1 building if it includes an outdoor living area that meets minimum specifications. Additionally in Queensland since 1 May 2010, an optional credit of 1 star energy equivalence is also available if a class 1 building includes a photovoltaic (solar) energy system. If optional credits are included the building shell will need to meet a minimum baseline star rating depending on the climate zone. For class 2 dwellings the use of the optional credits are available for the inclusion of outdoor living areas and these can only be used when calculating the building’s overall average (not to individual units).

In Queensland, although the 5 star standard was in operation for just over one year, the availability of 6 star samples are fewer because of the State variation that includes the use of optional credits (i.e. solar systems and outdoor living areas) to achieve compliance with the relevant star rating standard. There is also no 6 star rating applied to class 2 apartment dwellings in Queensland.

2.4 Study objectives

The ‘Changes Associated with Efficient Dwellings Project’ aims to contribute to research by conducting an independent study into, and providing examples from the building industry of, the changes that have been implemented and are associated with constructing more efficient dwellings.
This work will support and complement other studies also currently being undertaken as part of the research programme to inform the development of improved building efficiency over time.

This current project has posed the fundamental research question as to how the industry responded to the introduction of the 6 star standard – for example, by changing designs, construction materials and specifications, or construction techniques, and the associated costs – and how has this response changed over time.

2.5 Research components

The research undertaken includes two principal components:

A qualitative research component which included:

- 17 Interviews reporting on the experience of development industry representatives in the transition to 6 star and experience going beyond the regulatory minimum

- A survey distributed through member organisations to gain some statistical depth to the stakeholder consultations which received 187 responses inclusive of architects, building designers, builders, energy raters / sustainability consultants along with a number of local product manufacturers.

Secondly, a quantitative research component which examined using a sample of 58 representative dwellings obtained from industry exploring:

- How the actual incremental costs of moving to and achieving 6 star performance changed over time?

- What are the actual incremental costs of achieving beyond 6 star (and up to 8 star) performance?

These two quantitative analyses are then be combined to estimate likely changes in the future costs of compliance with potential new NCC requirements with the input of an indicative benefit-cost model.

This report presents the findings of both the qualitative and quantitative phases of the research project.

It is important to note that this work focuses primarily on building the evidence base, rather than detailed policy review. As such, the analysis is informed by previous studies to the extent that they are relevant, but the focus of this project is on primary research of a new set of representative data.
Qualitative analysis

The project team engaged with a range of industry professionals to investigate the impact of the introduction of 6 star, both initially and ongoing. A comprehensive list of stakeholders was developed in consultation with the Department and later refined to include the following key organisations:

- Housing Industry Association (HIA)
- Master Builders Association (MBA)
- Association of Building Sustainability Assessors (ABSA)
- Building Designers Association of Victoria (BDAV)
- Urban Development Institute of Australia (UDIA)
- Australian Institute of Architects (AIA)
- Victorian Building Authority (VBA)
- Sustainability Victoria (SV) (owner of NatHERS software FR5)
- Australian Sustainable Built Environment Council (ASBEC)
- NSW Department of Planning (BASIX)
- Commonwealth Scientific and Industrial Research Organisation (CSIRO)
- Council Alliance for a Sustainable Built Environment (CASBE)
- City of Sydney
- Frasers Property
- Cedar Woods
- Burbank Homes
- Villawood Properties

A number of other informal discussions took place in addition to the above.

3.1 Industry roles

In order to fully appreciate the various perspectives of the stakeholder consultation and survey responses it is worth considering industry roles and how they interact with the legislation in
question. The qualitative interview and survey processes extended to the following list of industry professionals:

- Member organisations
- Land and built form developers
- Builders
- Councils and other authorities
- Energy raters and consultants
- Architects’
- Research organisations

Whilst the roles of most of these industry players are relatively clear, the following observations stemming from the qualitative interviews are of note:

- Membership of HIA and MBA extend to only a portion of the building industry. The HIA felt that many industry professionals are difficult to reach through professional development and other channels and may find additional constraints in being able to respond to regulatory change
- The HIA felt this was especially prevalent in the townhouse market where generally small developers engage contractors directly and contact with professional development and industry support is reduced
- Councils outside Victoria (where an Environmentally Sustainable Design assessment process is in place) or in NSW where information relevant to BASIX is noted on plans do not have good resolution on the specification changes over time and generally have only ad hoc evidence of how designs have changed
- Land developers who do not always actually build (but partner with builders) identify as being ‘at arms length’ from the building regulatory approvals process. In many instances, the responsibility for meeting the thermal performance standard will be part of a builder’s contract and they will need to manage the risk accordingly
- There is often significant time lag between the point of sale of land and the building approval process, meaning the disconnect between the land developer and the regulatory standard is more marked
- There is some perception in the industry that meeting the thermal performance standard is not the responsibility of the designer (architect or building designer) - as a building regulation it can be seen as ultimately the builders responsibility – this has ramifications for builders who may be forced to ‘up-spec’ if they are required to make changes to comply
- This ‘disconnect’ between designers and builders is improving according to industry sources and may have positive benefits for managing the cost of compliance if low cost measures of thermal performance improvement such as glazing ratios are increasingly seen as design responsibilities.
3.2 Stakeholder interviews

Stakeholder feedback was gathered using a combination of semi-structured interviews both face-to-face and by telephone. Each engagement focused on the following three questions:

- What was the initial impact of the introduction of the 6 star standard in terms of design and specification change and cost?
- What was the ongoing response in terms of design and cost to the 6 star standard and how was this different to the initial response (if at all)?
- What is the experience with going well beyond the 6 star standard, how is it being achieved and what can that tell us about the potential to further increase stringency?

Feedback to these questions has been documented and consolidated to respond to the key research questions.

3.3 Industry survey method

In order to understand the views of a broader group of industry professionals, a survey was conducted and distributed through a number of channels, principally the online newsletter of the following member organisations:

- Housing Industry Association (HIA)
- Master Builders Association (MBA)
- Association of Building Sustainability Assessors (ABSA)
- Building Designers Association of Victoria (BDAV)
- Australian Institute of Architects (AIA)
- Australian Sustainable Built Environment Council (ASBEC)

The survey was distributed through these 6 industry organisations with 187 people completing the survey over a three week period. The largest response came from members of the Housing Industry Association with 69 respondents.

There was a relatively even spread across the different industry professions (Figure 2), however 35% of respondents selected ‘other’, with a majority of these indicating that they worked in manufacturing, particularly window-related industries. Of the 65 respondents that selected ‘other’, 54 were either a member of HIA or MBA.
Survey responses were received from all states and territories in Australia as evident in Figure 3. The response rates tend to reflect the population in these states and territories as a proportion of the national population.
The majority of respondents typically work across all the dwelling typologies stated (Figure 4). Other typologies mentioned included; container based relocatable houses, Class 1b Rooming houses, commercial, renovations and extensions, and aged care.

Figure 4: Typologies respondents typically work in

The results and associated discussion stemming from the qualitative analysis is presented by theme in the next section of the report.
4 Qualitative results and discussion

This research is concerned with the question of what happened as a result of BCA 2010, both initially and over time. Secondly it examines how industry is going beyond 6 star, and considers the potential for industry to respond to possible further increases in stringency for thermal performance standards.

4.1 Initial design response

One of the fundamental research questions posed in this work is to understand the initial design and specification change through the period of the most recent increase in stringency in the thermal performance standards. Notwithstanding the challenge of relating this to year of design and year of construction (given differences in the timing and state based variation on standards) the survey and stakeholder interviews provide some good guidance on how designs changed initially. These qualitative responses have been augmented by a detailed quantitative analysis of approximately 60 plans across climate zone, jurisdiction and typology. This section of the report details the initial response to the introduction of 6 star through BCA 2010.

4.1.1 What design change occurred?

Most stakeholders agreed that the main initial design change was to increase the level of specification in glazing and insulation. Discussions with Queensland stakeholders indicated that the option to include photovoltaic (solar) energy systems and outdoor living areas was the preferred method in meeting the standard in that jurisdiction. What was stressed by many stakeholders was that those designers and builders who opted for a specification change (e.g. glazing improvement) rather than a design change (e.g. alteration of glazing ratio) took on unnecessary additional construction costs, despite the fact that they may have avoided some cost of redesign. Many stakeholders including the BDAV, AIA and the MBA acknowledged that builders and designers did not initially respond according to passive design principles and therefore have increased the impact on cost of compliance for their customers. The BDAV set up the 10 star challenge to demonstrate the ease with which higher performing dwellings could be achieved.

According to the survey sample, by far the most common design and specification changes that were made initially to meet BCA 2010 included;

- Higher glazing specification (63%)
- Increase insulation in walls (49%)
- Increase insulation in ceiling or roof (46%)
- Double glazing (32%)
The full breakdown of survey responses are below, providing some clarity on the design changes versus the prevalence of specification changes. Although specifications were much more prevalent, design changes such as window to wall ratios were evident.

Evidence from stakeholder interviews indicated that the impact of the increase in standard on apartments was felt less strongly than other typologies, principally because of the much reduced exposure of the building envelope to outdoor conditions. The principal design changes for apartments including insulating above car parks and providing more protection for top floor apartments from excessive cooling loads. These results may also be consistent with research suggesting that apartment (Class 2) energy efficiency standards are relatively less stringent than those for Class 1 dwellings.\(^5\)

In the single dwelling market, there was evidence from some builders in cooler climates that the reduction in eave width improved heating loads and was adopted as a design response, but this is not backed up by the survey – a larger quantitative analysis may be more instructive.

In the tropical climate zones the impact of BCA 2010 had a reduced impact. Respondents considered that home designs in Queensland did not need to significantly alter the thermal fabric of

the building due to the availability of optional credits for outdoor living areas and photovoltaic (solar) energy systems to meet the standard.

In the Northern Territory the 6 star standard has still not been introduced, but the introduction of the 5 star standard saw an increase in eave width (cyclone safety guidelines permitting) and some increased use of reflective foil blankets in roofs.

Interestingly, despite a lack of increase in overall thermal performance stringency, a NSW interviewee (who declined to be attributed with the comment) suggested that the splitting of heating and cooling loads in NSW had done more for energy efficiency outcomes than the increase in stringency relating to BCA 2010 in other states. The new Better Apartments Design guide in Victoria proposes the same strategy.

4.1.2 Cost elements

Stakeholder interviews highlighted the multiple cost components of the impact of the introduction of BCA 2010. Broadly, these included the increased cost of the dwelling construction (although some indicated they felt it was cost neutral) and the cost of time associated with modifying designs and specifications to meet the increased stringency.

The survey suggested a modest increase in cost as a result of the introduction of BCA 2010 as outlined below. Results are illustrated in regards to the initial cost impact. 36% of respondents indicated that the initial cost impact was between $2,000 and $5,000 and 30% indicated the increase was more than $5,000. Architects and energy raters were more likely to suggest a lower cost of initial compliance compared with builders.

![Figure 6 - Initial cost impact of BCA 2010 from survey](image)

The ongoing cost impact on dwelling construction is discussed elsewhere, but the cost of redesign requires some reflection. In general, stakeholder interviews highlighted a significant difference in the cost of redesign to meet an increased thermal performance standard, depending upon the business type or structure.

Generally speaking, the larger volume builders have in-house design teams, which routinely update designs – dropping those with poor sales records in favour of new designs. This process of design iteration occurs largely unrelated to the staging of stringency increases to the thermal performance standard, however if adequate notice is provided and the stringency increase is planned for, then the cost of updating designs is relatively low because it is absorbed in a process...
that would have been occurring anyway. Additionally, in the apartment market, architects undertake a process of improvement to apartment layouts which can incorporate modest increases in stringency relatively easily, however the drivers for the design iterations are more likely to be improved efficiencies of space, better bedroom or living area layout. The design cost of the stringency increase can be ‘absorbed’ to an extent in the iterative process of design change – given the generally greater lead times between design and build in apartments, this relationship between the design and a particular regulatory environment is less pronounced.

Stakeholder interviews suggested that the cost of redesign associated with an initial response to the stringency increase is seen most significantly by smaller builders and developers, across the single dwelling and town house typologies. This is where businesses have to outsource expertise to update designs. This can include the need for a designer (architect or building designer) charged with the responsibility to improve designs to meet an increased stringency or it becomes the responsibility of an energy rater to ‘make it work’.

It would seem (though it wasn’t specifically mentioned) in this first scenario, the cost of redesign is higher as the design time and an energy rater’s time is combined to deliver the outcome. In the latter scenario, the energy rater’s time alone must be accounted for in terms of cost. The outcomes of these two scenarios are likely to be different in terms of cost of construction – the first scenario, where design elements such as window placement, sill heights and glazing ratios can be challenged is likely to produce an increase in thermal performance at lower cost, whereas the energy rater only scenario will likely concentrate on his or her brief to ‘make it work’ by increasing the specification of insulation or glazing or using other ‘add-ons’ such as additional shading.

4.1.3 Challenges of climate zone
Previous studies have noted the challenges with particular climate zones in achieving compliance with increasing stringency in thermal performance standards. In particular speaking to Queensland and Northern Territory designers and house energy raters, frustration was evident with the software due to the apparent lack of reward for dwellings with high ventilation (e.g. traditional Queenslander home). This was highlighted as a current challenge, as well as one associated with any further increase in stringency. Regulations in these northern climate zones were considered by some designers as a constraint on traditional design. It is not within the scope of this report to make comment on the efficacy of these claims.

With the exception of these comments in relation to Climate Zones 1 and 2, stakeholders expressed no particular challenges in going beyond the current minimum in the remaining areas. Climate Zone 5 (which takes in Perth, some of Sydney and the coastal area of Adelaide) was highlighted as a particularly straightforward climate zone to achieve compliance in, and without the use of double glazing that is prevalent in colder areas e.g. Victoria.

4.1.4 Challenges by typology
Apartments were regarded as generally very easy to rate to the averaged existing thermal performance standard in the cool and temperate zones, and indeed many individual dwellings were seen to rate above just by virtue of their position in the building. In particular, it was noted that

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6 pitt&sherry/Swinburne University of Technology, National Energy Efficient Building Project - Phase 1 Report, November 2014.
dwellings with adjacent dwellings on each side (and particularly those facing north in middle levels) often rated above 8 stars with standard specifications.

Conversely, apartment dwellings with two or more external walls which are immediately above car parks offer some challenge in meeting thermal performance standards without specification improvements, however energy raters interviewed indicated that it was manageable as it was isolated to a small portion of the building only. Top floor apartments in general offer some challenge if shading is not well managed.

Some challenges were noted in townhouses due to issues with zoning living areas over two levels.

4.1.5 Industry capacity

Stakeholders noted variations in the ability and willingness for industry professionals to respond to regulatory change including increases in stringency for thermal performance. The capacity of industry professionals has had a significant impact on the ability of the industry to transition through increases in stringency in the thermal performance standards. The skill sets of three main groups are at play here:

- **Builders** – when they are responsible for managing the cost of the build – do they have the knowledge to take a least cost approach?
- **Energy raters** – what is the capacity to influence design beyond specification changes?
- **Designers** – what has been the role of designers in adapting to new standards and how does this vary within the sector?

4.1.5.1 Builder capacity

Industry organisations offered professional development for builders in association with the most recent increase in stringency, however it is difficult to understand the reach of this communication and the capacity of the building industry to take on this new knowledge. Off the record discussions with a teacher of building professionals indicated a generally poor understanding of the principles behind thermal performance.

The HIA and MBA have confirmed that there is varying capacity in the building industry to adapt to increases in stringency, but that one of the key constraints is time between stringency upgrades. Swinburne University of Technology also documented significant shortcomings in the knowledge and skills of the building industry in this area.

4.1.5.2 Design objectives and alignment

It was noted by Chris Barnett from the AIANY that it is only a very select (usually highly affluent) demographic engage an architect for an individual dwelling (as opposed to building designer or builder). Architects are more commonly used for apartment design and large townhouse developments, however registered architects are used relatively rarely on individual bespoke homes. What this leads to (according to Chris) is the seeking out of designers with specific sustainable design skill sets if thermal performance is an important client need. If it is not, design will be driven by other factors such as maximising view lines and natural light and may lead to increases in the specification for glazing in particular to offset the increased glazing area. This can make achieving the standard more costly, but does not tend to impact those on very restrictive budgets.

4.1.5.3 Practitioner flexibility or adaptability

The willingness and ability of design professionals to adapt was noted by the BDAV as a determinant in the ability to meet increased thermal performance standards easily. It was noted
that there remained resistance (in particular amongst older designers) to designing in new ways in order to meet changes to regulation.

This is extenuated by the relatively new Certificate IV accreditation requirement for energy raters which was reported to have risked breaking the past integration between the two disciplines of building design and energy rating. Prior to raters needing the Certificate IV qualification, often building designers and energy raters undertook both as part of their business, which allowed for more seamless testing of design iterations and their impact on thermal performance.

When a rater is largely disconnected from the design process, the process of improving the design against the thermal performance standard is generally limited to increasing specification of glazing and insulation or, if cooling loads are the issue, recommending shading options.

A building designer who also rates dwellings is in a better position to cost effectively test design alternatives such as reduced glazing ratios or wall to floor ratios.

4.1.5.4 Acceptance of increases in stringency

There are also some cultural approaches to acceptance of the most recent increase in stringency. Some interviewees felt the widespread resistance to the regulation change in WA in particular has hampered the ability for the industry to actually move on and design to the increased stringency. The combination of the prevalence of the VURB method and the very different construction method (double brick etc.) is of significance.

4.2 Ongoing response

4.2.1 What design changes are occurring?

Stakeholders noted the capacity for industry to learn to optimise designs over time, however there were varying perspectives on the extent to which this is actually occurring. The figure below demonstrates the survey respondents’ perceptions of ongoing cost per dwelling as a result of the standard, in contrast to the initial impact. Whilst it is acknowledged that the question could be interpreted in different ways, in general it is clear that there is an appreciation that the ongoing cost is lower (or more likely to be cost-neutral) when compared with the initial cost impact of the increase in stringency. The quantitative analysis bears this out in greater detail, but some initial observations are shown below.
The types of ongoing design iterations made to optimise designs against the standard indicated a much greater spread of strategies to optimise design compared with the initial response.

Figure 7 - Ongoing cost impact of BCA 2010

Figure 8 – Ongoing strategies to optimise design
4.2.2 Design review practice

Interviews with a broad section of the development industry including developers, member organisations, builders and architects indicated significant variation in the design review practice dependent on organisational capacity and type.

4.2.2.1 Single Dwellings

The design review process in the volume builder industry was reported to be in a constant state of change. Volume builders did not report undertaking a systematic review of all their standard drawings, but rather go through ongoing processes of dropping poor selling designs in favour of new designs. Feedback from Burbank and the HIA indicated that a volume builder may drop for example three or four designs a year in favour of new designs. Additionally, existing designs are ‘tweaked’ or ‘refreshed’ to keep pace with market preferences and ensure that consumers who have been in the purchasing phase have a reason to revisit their collection of homes. What this means is that it is indeed possible to use this iterative process of design review to optimise designs for thermal performance over time, but it is rarely the driver behind the design iteration.

Feedback provided by Burbank did indicate that their energy rater had two input points into the new home design process and that significant changes to existing designs would also be reviewed against the thermal performance standard.

4.2.2.2 Insensitivity to orientation

Many volume builders do not develop land themselves, but they have a commercial interest in ensuring that when partnering with land developers their designs retain flexibility over the way in which they are orientated. Whilst a site responsive design would reject the notion of ‘insensitivity to orientation’, for volume builders who are competing for market share, there is a commercial reality to making designs work on the greatest number of lots.

Anecdotally what this has led to is a trend since the introduction of the 6 star standard to spreading a number of moderate sized windows across a dwelling to reduce sensitivity to a poor orientation. At the same time as this reduces the benefit of a north orientation to the rear of the property, it reduces the risk of a rating less than 6 star on a poorly orientated lot and having to increase the insulation and glazing specifications at cost. That is, designs are being optimised with the builder’s costs in mind, and not the lifetime running costs of the dwelling.

4.2.2.3 Insensitivity to climate

In the same way that builders have opted for designs with insensitivity to orientation, builders who work across jurisdictions and climate zones will often maintain the same design. Additionally, if there are variations then these should be simple changes such as dropping the double glazing for Adelaide as a variation from a Victorian design. This means regional variations that could improve thermal performance at low cost are not always adopted.

This can provide substandard outcomes in optimising thermal performance but does limit the design cost element of meeting the thermal performance standard. Its impact on cost of construction is less pronounced as there are benefits in material supply chains and standardisation, however there would be potential cost savings which are not captured as well.

4.2.2.4 Impact of software updates

The impact of software updates to the NatHERS software was highlighted as the source of some frustration amongst practitioners with standard designs. Iterations of software have resulted in dwellings rating to 6 star in one version needing to be modified to meet the standard in subsequent versions. What this means is that a significant investment made in a standard design which received a star rating of 6.1 may rate under a new software version as below minimum compliance.
Just when industry should be learning and optimising, this can lead to increases in the time related cost of compliance and potentially in the cost of construction itself if easily identifiable cost neutral remedies are not available.

We note the prevalence of this issue is evidence that the building industry does actively seek to minimise the costs of compliance with building energy performance standards, including by ensuring designs ‘just pass’ regulations.

In an isolated example for one of the volume builders, a practice note clarification on the way zoning should be addressed led to a reduction in ratings of an existing 7 star collection and not being able to market at 7 star led (at least in part) to their withdrawal from the market.

4.2.2.5 The apartment market
The practice of ongoing design review in multi-residential dwellings generally does not occur in the same way as it does for standard single dwelling and town house designs. Apartment building designs vary more with site constraints and are generally driven by an architect with guidance from their client developer.

According to the stakeholder responses, architects will often maintain and amend ‘a pattern book’ of apartment typologies which are marketed to developers and can be adapted for different sites, but detailed dimensions and other layout considerations are generally driven by the individual site constraints.

What this means is that an opportunity exists in the design process to tailor the built form outcome to produce a design that responds well to its environment and therefore rates well against the thermal performance standard. The tension points with thermal performance in apartments are in the protection of the design aesthetic by the architect (façade look and feel) and the protection of marketability from the developer perspective (e.g. lots of glass for maximising view lines).

4.2.2.6 Self-shading of windows and balcony depth
Of particular note in the apartment market is that cost savings on glass have been made through strategies such as self-shading of windows through articulation and “getting a bit clever” with the depth of balconies on the north side to shade dwellings below.

4.2.3 Other design factors influencing cost
Over the last five to ten years there have been a small number of design trends not driven by thermal performance, but that have an influence on it.

4.2.3.1 Zoning changes
Those stakeholders representing the volume builders noted trends such as the increased segmentation of large open plan areas, upstairs living spaces and butler’s pantries. These have an impact on zoning and therefore on the design rating, but are clearly driven by market preferences rather than thermal performance.

4.2.3.2 Materials choices
The use of different external material choices in the town house and single dwelling market has influenced thermal performance outcomes to a small extent. It was noted by volume builders that this is particularly evident in two storey dwellings where more and more light-weight cladding or Fibro Cement (FC) sheet is being adopted at upper levels to save dollars and to improve façade variation / interest. Depending on the type of lightweight construction, compliance with thermal performance standards can be more challenging. The fact that this is accompanied by a lower
construction cost means that extra budget may however be available for improved product specification as an offset.

4.2.3.3 Size of dwellings
Trends in home size also have a significant impact on cost, although only marginally on the thermal performance as energy use is normalised for size through the MJ/m\(^2\) metric. Many consider that house size has peaked in Australia and is on the decline and that the introduction of BCA 2010 coincided with the peak housing size. Incidentally, residential energy consumption peaked in the same year and has declined in a similar trajectory since. The sample used for the quantitative analysis has been normalised for dwelling size.

In Victoria at least, the significant slowing of the housing market in 2012 led to smaller lots being sold (with smaller homes). According to the UDIA, part of this trend was an increase in two storey dwellings being sold on smaller lots at an overall decline in cost. Conversely the cost of construction (due to two storey building being more expensive) may in fact have risen even if the land cost declined significantly.

Ceiling height has also gone through some change with an increased preference for ceilings over the legal minimum of 2.4m. This can have a significant impact on cost – dependent on the volume builder this represents an increase in consumer cost of up to $10,000 for a 300mm increase in ceiling height for a medium to large family home. Higher ceilings also are associated with higher energy use due to vertical temperature stratification in rooms, and this may increase the cost of compliance with energy performance requirements.

4.2.3.4 Unrelated design taste changes e.g. 2 bathrooms
There is also a number of unrelated design trends such as second bathrooms, which significantly increase cost of construction, but which do not impact thermal performance. The quantitative analysis only references the elemental cost of thermal performance and is therefore unaffected by these sorts of design trends.

4.2.3.5 Design efficiencies for apartments
In speaking to architects and others engaged in apartment development, several factors other than thermal performance were noted to drive designs. It was confirmed by several of these stakeholders that the ability to improve the efficiency of the layout for example (off a central corridor) may be more influential on construction cost than the cost of glazing for example. Additionally given the minimal external walls, additional cost of thermal insulation is not significant. The cost of the individual apartments is also only a portion of the total build cost – the car parking, lift core, service runs and other shared infrastructure is not attributed to the actual apartment but is factored into the price the consumer pays. The combination of shared walls, floors and ceilings and the shared infrastructure means that the relationship between thermal performance and cost is likely to be less marked in apartments than dwellings with high wall to floor ratios.

4.2.3.6 Acoustics
It was also noted by two architects that the increased tendency to double glaze was partly being driven by the prevalence of apartment buildings on busy transport corridors and that there was an expectation in the market that it was required for acoustic rather than thermal performance reasons. Many cities have such requirements in local planning schemes for acoustic comfort reasons.

This multiple benefit – acoustics, energy efficiency and comfort slightly muddies the attribution of cost.
4.2.3.7 Planning regulation

Conversations with apartment developers and architects experienced in multi-res noted the significant influences of state based built form regulation for apartments. This was especially noted in the Melbourne and Sydney markets where the vast majority of Australian apartments are built. In responding to the cost question in relation to the thermal performance standard, some respondents indicated that the thermal performance standard was less influential on cost than the SEPP 65 Apartment Design Guidelines in NSW and the Better Apartments Design Standards will likely be in Victoria. It is difficult to undertake any assessment of the influence of SEPP 65 as distinct from BASIX due to their introduction in relatively close succession.

It was indicated that the new apartment standards in Victoria (based reasonably closely on the NSW standards) were likely to affect costs to a greater degree than the thermal performance standards because of their influence on the built form issues such as building separation. According to developers, the minimum sizing of apartments will also affect their ability to deliver affordable product.

Another significant influence is daylighting, which has over the last several years in Victoria particularly been debated strongly as part of planning approvals. There is a balancing act for designers between cost and thermal performance, as daylight amenity is driven in part by window sizing and the visible light transmittance of glass. Maintaining large windows without driving up heating and cooling loads is a challenge most simply met by high performance glass, but this is done so at cost to apartment construction.

The existence of the Council based Sustainable Design Assessment in the Planning Process (SDAPP) program in Victoria has had an impact on the consideration of sustainability more generally at the planning stage, similar to the effect of BASIX in NSW. Stakeholders had mixed views on the effectiveness of the program to drive thermal performance outcomes beyond minimum compliance, with BDAV articulating their policy position which raises the issue of a double up between planning and building legislation. This notwithstanding, the promotion of the practice of undertaking sample ratings of apartment and townhouse designs to understand their ability to meet the standard was highlighted as a beneficial input into early design which improves the ability to meet building code requirements at lower cost.

4.2.4 Macro-economic factors

The importance of other economic factors influencing cost was highlighted from a number of sources, both member organisations and developers. Broadly these economic factors included trade and supply chain considerations, market maturity (in part driven by regulation), other construction costs and general market fluctuations.

4.2.4.1 Trade and supply chain considerations

Developers in particular highlighted overseas trade and supply chain as critical in determining cost. It was noted that the window market in particular and to a lesser extent the insulation market have gone through significant change since 2010. The expansion of the trade of windows from China has put significant pressure on local suppliers to ‘sharpen their pencils’. According to a volume builder the majority tend to still use Australian suppliers, however the apartment market is transforming to overseas imports. In either case, the increased competition has led to a more favourable buyer’s market for some products.

Anecdotal evidence from industry sources suggest that the introduction of the 5 star standard in the mid-2000’s signalled to international suppliers of products such as windows and insulation that the market was now ‘worth investing in’.
In relation to the Northern Territory, almost all windows are locally made, but the cost of windows is increased by the small market and transportation costs. As an aside it was noted that these windows are not always able to be represented in NatHERS software as they do not routinely go through the registration process.

4.2.4.2 Market maturity
The cost of double glazing in particular represents the starkest example of market maturity. Overwhelmingly, the survey suggested that there has been a decline in cost for double glazing, with over half the survey respondents reporting a decline in cost compared with approximately 15% who felt that the cost of double glazing had increased since the introduction of BCA 2010. Stakeholder interviewees broadly share the view that the cost of double glazing had reduced significantly, and that this was attributable (at least in part) to the implementation of BCA 2010 in Victoria.

This concept of regulatory instruments driving market maturity was picked up in a number of conversations with architects and member organisations.

There are also a number of economic influences that were seen to have a greater or equal impact on cost of construction, than thermal performance regulation itself. An interview with a developer indicated that the price of the Australian Dollar, the existence of free-trade agreements (or not) and at the admission of one developer “whether Donald Trump was elected”, were all likely to have comparable or greater influences on the product cost of delivering to the thermal performance standard than the specification itself. It was noted that there were ebbs and flows to this that were smoothed out in the cost to the consumer of a new dwelling, but very much impacted the size of the builder or developer margin, especially when contract prices had been agreed well in advance of construction.

4.2.4.3 Cost of labour
Noted by many developers, by our own cost consultant and by other stakeholders was the role of the cost of labour and builders’ margins on the cost of construction. This was noted to be approximately 60% in some cases, dependent on the building typology. Whilst the volume building market based on feedback from Burbank homes was less volatile because builders were engaged on waged longer term contracts, just the sheer ‘busyness’ of the trades can escalate project cost especially in regions where there are shortages. This was noted by several developers as more challenging than the cost of product in getting dwellings to market at a cost competitive price. It was noted that bricklayers in Victoria for example were currently in short supply and this was (amongst other factors) driving growth in alternate materials such as cladding that reduce the risk of this labour cost.

It was noted that labour cost increases due to increasing thermal performance standards were very marginal and constrained to specific areas of the building. For example the cost of installing R5 ceiling insulation as opposed to R3.5 represented no additional labour cost, although there was a small impost in terms of product cost as well as storage and transportation to site (bulkier by definition). There was an increase in labour cost of installation of higher performance windows (they are heavier and therefore require more tradespeople) but this is a marginal cost, and double glazing is not a NCC requirement and appears to be constrained to certain climate zones.

Where there were new requirements driven by the thermal performance standard increase, this was noted to have an impact on labour costs. These examples were relatively isolated – installing external shading structures and insulating over the top of car parks under 1st floor apartments (necessitated by the increase of the minimum apartment rating from 3.5 to 5 stars).
4.2.4.4 Market ebbs and flows
General market fluctuations – principally the size of the consumer market and the relationship of this to land and apartment supply – have a relationship to the purchase price of new dwellings, just as the supply of existing dwellings does in the broader housing market. These influences (driven by population growth, wages growth and general performance of the economy) have little influence on the price of construction, but the margins of builders and developers contract or grow depending on this level of consumer activity.

If this work is to be defined by cost of construction to the builder / developer then the market fluctuations are confined to labour, transport and product cost variations, but the consumer price may be different, dependent on the relationship between demand and supply of housing. Whilst increased land and apartment supply is a rather simplistic way of addressing affordability concerns it may be a potentially a more significant determinant of cost to consumers than thermal performance standards.

Villawood properties in their interview noted the ‘market cliff’ in 2012 in south-eastern Australia which rapidly slowed the amount of growth area sales, contracting developer margins. Their response was to offer a suite of smaller lots for sale (with smaller building footprints) which reduced the overall cost to consumers at a time when the impact of the standard change associated with BCA 2010 was purported by the member organisations to be raising costs of construction.

All developers interviewed highlighted the influence of these other economic factors.

4.2.5 Consumer influences

4.2.5.1 Housing affordability
It was stressed by several stakeholders the importance of managing the interests of buyers who have significant challenges in accessing home ownership. This is traditionally the domain of growth area in house and land packages. Developers and membership organisations such as the HIA highlighted that the difference between purchasers being able to afford to purchase a home or not comes down to small margins.

For these consumers, it was reported, the difference between affording the home or not is more important than the difference in running costs despite their significance, because the benefit is staged over several years. This type of deferred benefit is not seen as important to someone who risks missing out on home ownership altogether.

4.2.5.2 Consumer knowledge and awareness
According to stakeholders, the knowledge and awareness of consumers in most jurisdictions has improved since the introduction of BCA 2010.

There is also a market expectation growing in Victoria at least, that double glazing is a more standard provision – this has fundamentally changed with the introduction of BCA 2010 and a market tipping point has been reached such that fewer and fewer dwellings are being built without double glazing as standard. The accompanying price reduction has been referred to elsewhere.

In particular it has been noted that there are pockets of highly aware consumers (such as the inner north of Melbourne) because of the existence of local exemplars (such as ‘The Commons’). Individual projects such as Aquarevo in Lyndhurst which test the boundaries in growth areas are also growing, with volume builders being increasingly challenged by purchasers.
Where consumers are still lacking in knowledge according to the HIA is the understanding of what makes the most different to the energy outcome of a home. Others noted that many consumers had become expert at understanding good orientation and daylighting and the terminology had also changed from ‘energy cost’ to ‘comfort and lifestyle’.

4.3 Going beyond 6 star

There are a number of examples of designs going well beyond minimum compliance with the current standard. The 2014/15 data release from Sustainability Victoria indicated significant over-compliance in the new apartment market, but not so in the single dwelling market. The granularity of the data is such that a 6.9 star house would be communicated in the report at 6 stars however, so there may be some hidden over-compliance. There is evidence of over-compliance in BASIX, however this was felt to be generally driven by systems improvements (e.g. hot water) with more limited examples of over-compliance on strictly thermal performance.

4.3.1 What is occurring?

Where designs were going beyond the current minimum thermal performance standards, the stakeholder interviews indicated a number of reasons for doing so.

The first of these was related to the ease of which the current standard was achieved. This was noted by a limited number of interviewees, especially respondents in Victoria and NSW. As noted above there is significant variation in the apartment ratings within one building that often a building would have an average dwelling rating of above 6.5 stars by simply applying the same assumptions of the poorest performing dwelling to all dwellings in the building.

Secondly there are obvious brand considerations. Several of the member organisations and developers which were consulted during this qualitative stage indicated that it was seen as part of their brand to deliver highly performing housing to the market and this extended to a market expectation of their product.

The use of market tools such as GreenStar and EnviroDevelopment were seen as ways to communicate the approach that was being taken to the environmental performance of the development. Member organisations in particular highlighted that the corporate social responsibility of the very large operators dictated the need to benchmark on energy performance through reporting requirements to investors etc.

There are also isolated examples of local government pushing for higher thermal performance standards than those present in the NCC. These include the SDAPP framework in Victoria, and the state land development agencies such as Renewal SA and LandCorp in Western Australia.

The influence of awards was also noted by the HIA and the BDAV.

4.3.2 Quality and consistency of ratings

Issues associated with compliance through the entire development process were raised by many of the interviewees as relevant to any consideration of an increase in stringency.

The quality and consistency of designs claiming to meet the standard across the state and territory jurisdictions was seen as a relevant consideration. The verification using a reference building (VURB) method which is prevalent in Western Australia in particular, and “encroaching across the Nullabor”, is seen as undermining the performance requirement in the NCC. A view held by some
is that some jurisdictions have actively rallied and attempted to find work arounds, while some states have adopted changes to standards more amicably.

The use of the VURB method and to a lesser extent deemed to satisfy, blurs the impact of the regulation change in terms of cost impact. It means that Victoria, which passed through the change to 6 star within one year and has more universal application of the software method of compliance, represents the best national case study of what happened in response to the changes in BCA 2010.

Below is an excerpt which explains the various requirements for assessor accreditation.

Table 2 - Jurisdictional requirements for assessor accreditation

<table>
<thead>
<tr>
<th>Jurisdiction</th>
<th>Accreditation</th>
</tr>
</thead>
<tbody>
<tr>
<td>NSW</td>
<td>Thermal comfort simulations are entered into BASIX must be conducted by an accredited assessor.</td>
</tr>
<tr>
<td>VIC</td>
<td>Use of accredited assessors encouraged but not mandatory</td>
</tr>
<tr>
<td>TAS</td>
<td>Ratings can be prepared by accredited assessors, architects of building designers</td>
</tr>
<tr>
<td>ACT</td>
<td>Has its own scheme for licensing assessors</td>
</tr>
<tr>
<td>NT</td>
<td>Use of accredited assessors encouraged but not mandatory</td>
</tr>
<tr>
<td>QLD</td>
<td>Use of accredited assessors encouraged but not mandatory</td>
</tr>
<tr>
<td>WA</td>
<td>Use of accredited assessors encouraged but not mandatory</td>
</tr>
<tr>
<td>SA</td>
<td>Accredited Assessors are classified as ‘Independent Technical Experts’ and surveyors can rely on their certificates without further assessment</td>
</tr>
</tbody>
</table>

Even within the NatHERS framework there is significant variation in the accuracy of design ratings with variation between states as to the level of accreditation required by energy raters and the use of a universal certificate. A number of plans have been re-rated using our NatHERS consultant to test the accuracy of original ratings, but within this report it would be remiss not to raise the level of concern over the quality of the rating process. This was highlighted in great detail by BDAV and ABSA in particular.

4.3.1 Compliance with the thermal performance standard

It is well known through National Energy Efficiency Building Project (NEEBP) report and compliance checking across multiple jurisdictions that the built performance of dwellings is in many cases far lower than the modelled performance. This ‘loss’ is attributable to many factors including the comprehensiveness of building surveyor verification, poor caulking and draught proofing leading to leaky dwellings, faulty insulation installation (or none at all) and replacement of specified materials with cheaper alternatives. Several interviewees including CASBE expressed the view that whilst they may support higher stringency in the thermal performance standards, they felt this must be accompanied by far improved construction compliance.

More generally, the lack of certainty that designs are actually complying with the energy performance standards makes it hard to evaluate industry claims of increased compliance costs. We note that no state or territory undertakes regular compliance auditing with respect to building performance requirements, and previous reports have documented a widespread culture of non-compliance as a result.7

7 pitt&sherry (2014).
It is understood that parallel work is being undertaken to address some of these compliance concerns widely held by industry.

### 4.3.2 Challenges of climate zone

In determining the potential for industry to move beyond 6 star, there are reportedly some constraints to this occurring easily in the tropical climate zones.

The ability to use eaves as shading for tropical and sub-tropical dwellings was seen as challenging to go beyond, as eave width had to be balanced with cyclone protection (generally up to 900mm is acceptable).

Although not all stakeholders were specifically asked the question, stakeholders who did make comment on the ability to go beyond the minimum standard made reference to the many existing examples available through avenues such as the 10-star challenge, Josh’s House in Western Australia, the national Greensmart Awards run by the HIA alongside a number of other examples that the industry is doing as a matter of course or as part of ‘particular collections’ in the case of volume builders.

### 4.3.3 Challenges by typology

Generally speaking, apartments were noted as being able to cope relatively cost-effectively with increased stringency due to the existing over compliance and the smaller ratios of external wall to floor ratio.

When asked of the improvement potential of single dwellings, stakeholders indicated that there was also still significant potential to optimise single dwelling building envelopes for further improvement.

Notwithstanding the comments around this needing to be accompanied by improvements in compliance, the ability to improve site responsiveness of single dwellings to orientation and the generally more generous spacing around dwellings were seen by the BDAV and some architects as having significant potential for improvement (as is evidenced in the awards schemes).

The challenge would be for the volume building industry, as to whether they can maintain their objective of insensitivity to orientation and climate zone.

### 4.3.4 Industry capacity improvements

A number of comments were made on the way industry capacity could be managed through future stringency increases. In the first instance, improved channels to practitioners who are not members of the industry organisations was highlighted as having the ability to improve cost effectiveness of a higher standard.

Additionally, longer transitional arrangements and generous notice periods were seen by the HIA and others as enabling a smoother response from industry.

The lack of knowledge in understanding least cost pathways to refining designs following stringency increases is seen as a gap that can act to minimise the cost of compliance through any future stringency increases.

### 4.3.5 Stringency trajectories

The ASBEC interview highlighted the benefit in establishing a trajectory for stringency increase which is known well beyond the next cycle. Working group sessions in April 2016 found that
establishing a trajectory for increases in stringency would enable industry to prepare for higher standards in the future and reduce the regulatory uncertainty and burden associated with ad hoc upgrades. By extension, this may actually allow for an improved learning rate from industry;

- Firstly, establishing a trajectory reduces the incentive to go for a ‘band-aid’ approach to meeting a single increase in stringency – ie if a further increase is known to occur three or six years hence then specification increases (the more costly approach) may be less likely to be adopted in favour of approaches that address the core design responses required for the various typologies

- Secondly, it creates the potential to mitigate the need for multiple design iterations in favour of reduced number of step changes for designers. Highlighted in the ASBEC interview it was felt that there was potential to meet the needs of a planned increase in stringency in the short term (say 2022) by going beyond and incorporating measures that would also meet a further planned increase in stringency in 2025.

### 4.3.6 Synergies with software changes

Previous increases to stringency have been complicated by software changes occurring in parallel. Stakeholders were mixed on how software upgrades were best handled but there was general agreement that they affected learning rates. It is understood that the introduction of BCA 2010 at least in Victoria was accompanied by a relatively significant change to the software which made it more difficult for energy raters to cope with the increase in stringency.
5  Quantitative analysis

5.1  Quantitative method

This analytical phase of the project sought to answer two key questions in a robust and quantitative manner:

- How the actual incremental costs of moving to and achieving 6 star performance changed over time?
- What are the actual incremental costs of achieving beyond 6 star (and up to 8 star) performance?

These two analyses are then combined to estimate likely changes in the future costs of compliance if an increase in stringency was to be undertaken.

5.1.1  Representative Sample

The study sought a representative sample of between 50 and 60 dwellings from a range of sources. These were chosen as representative from a sample of more than 200 shared information sets (star rating information, specifications and construction drawings) from a range of sources. The sourcing of data from industry was challenging, with sources citing issues such as copyright and internal resourcing as reasons for not being able or willing to share data. In many instances, commitments were made to the project team, but these commitments were not followed through. Multiple channels were used to seek data sets from industry, however within the timeframes of the project, sourcing data remained a challenge.

Of the data sets sourced, 12 different sources of data were included in the sample. These included volume builders, multi-unit developers, architects and energy raters.

Data was sourced in all states and territories with the exception of Tasmania as per the figure below.
Data was also sourced in every year of the analysis, from 2010 to 2017, however due to practicalities the sample is biased slightly toward latter years. This was reflective of the samples shared with the project team and based on issues experienced by data sources including older data having been archived and a number of data providers only having been in the industry for less than five years.

Figure 9 - Representative sample by state

Data was also sought across a large range of star ratings such that the relationship between star rating and costs could be reasonably explored to understand the incremental cost in relation to star rating. It should be noted that in doing so to meet the requirements of the brief for a selection of higher rating dwellings, the cohort around 6 star was reduced.

A range of data sets were obtained for Class 1 and Class 2 dwellings. Within the sample, there were 36, Class 1 dwellings and 22, Class 2 dwellings. The sample also included a large range of size dwellings from 48sqm to 384sqm in size.

The sample was also selected to ensure a range of climate zones. Whilst there were no samples from climate zones 7 and 8, there were 15 samples from climate zone 6 included. The bar chart below outlines this spread.
A number of different material types were included in the sample, including brick veneer and lightweight construction.

The sample was targeted to be as representative as possible, however to be statistically significant a much larger sample would be required. The large amount of variation in the sample (required if it was to be representative) reduces the ability to draw meaningful conclusions because of the large number of variables (material types, climate zone, jurisdiction etc). The limitations of the data set are discussed in the following sections.

5.1.2 Costs

The project team, led by WT Partnership in this regard undertook a cost comparison which identified all the thermal performance related elements and costed them, reflective of the year of construction (based on historic documentation of costs and the tool they developed using their own historical benchmark data).

This was important to flesh out as in some cases a change in thermal performance standard has led to economies of scale, reducing costs as the industry matures.

WT Partnership undertook a measure of the 58 dwelling samples and documented the following attributes.

- All walls that attribute to the external envelope of the asset
- All windows and doors to the external envelope of the asset
- All floors, ceilings and associated finishes to the internal of the asset
- All roofing to the asset
- Assumptions of approximate dimensions based on industry standards when documentation is insufficient
- Assumptions of material type based on industry standards when documentation is insufficient
Using these measurements the thermal shell was costed in the year of construction. If the year of construction was not known, it was assumed to be the same year as the construction drawings were issued for Class 1 dwellings and the following year for Class 2 dwellings (reflective of longer build timeframes).

The costs were broken down in terms of the following elements of the building fabric and individual reports issued for each dwellings.

- External walls
- Windows
- Doors
- Concrete
- Floor finishes
- Suspended ceilings
- Roofing

From this costs per square meter (sqm) were derived for the key components of the quantitative analysis.

### 5.1.3 Ratings and re-ratings

As has been evident in other studies there can be inconsistency in the star ratings by different energy raters based on level of experience, software platforms and other factors. To ensure a good level of consistency, half the study sample was re-rated using the version of FirstRate5 that was active at the time of design. The component of the samples that were re-rated were also re-rated in the current version of FirstRate to ensure that there was not a large discrepancy between the original rating and how the same dwelling would be rated using contemporary software versions. Whilst there are some anomalies where a large discrepancy were present, there is no evidence of a trend that needed to be normalised for in the costing analysis.

In general the ratings were relatively similar between the original ratings and the re-rated sample. The cost analysis used the re-rated star ratings where they were available and the original ratings where they were not. Each source had at least one data set re-rated.

### 5.1.4 Cost analysis

SPR undertook three related analyses, the first two of these relate to the cost side of the equation. First, the data compiled by MEFL and WTP was analysed to derive ‘learning rates’, or the rate of change over time in the cost of 6 star housing, for Class 1 and Class 2 dwellings and also for the whole combined data set. This analysis includes an adjustment for inflation, in the form of a construction cost index, over time. Data sets were also normalised for star rating where they were outside the cohort of analysis.

Second, SPR examined what the data reveals with regard to the historical cost of achieving above 6 star performance. Again, this analysis was conducted separately for Class 1 and 2 dwellings, and also for the whole combined data set. As the data shows a clear trend of declining cost per square metre with increasing total dwelling size, the data was normalised for size before deriving incremental cost observations.
To support these analyses, investigation was undertaken by MEFL to understand where actual design/construction choices led to higher-than-necessary compliance costs and relevant trends in the documentation in relation to star rating. These were documented in the built form analysis below and further when analysing relationships between elements such as ceiling height and cost.

### 5.1.5 Benefit cost analysis

Using the results obtained above, both the learning rates and the incremental cost data derived in these analyses were applied to an indicative, or simplified, benefit cost analysis model, in order to translate these results into an indicative picture of the expected benefits and costs associated with regulatory standards above 6 star.

As is noted below, we conclude that a larger data sample is required to draw valid conclusions about the learning rate – particularly for Class 2 dwellings – and the cost effectiveness of above 6 star standards.

### 5.2 Results

The results of the quantitative analysis are documented below.

#### 5.2.1 Cost analysis results

The results of the costs analysis indicated a significant diversity in cost per square meter and overall cost of thermal performance related building elements. The sample of 58 dwellings included an absolute minimum of $50,000 and maximum of $294,000. When this is converted to a cost per sqm the range narrows significantly.

The chart below illustrates the range of absolute cost averages by state with reference to the cost breakdown of thermal performance elements.

![Figure 12 - Variation in dwelling cost elements by state](image)

#### 5.2.2 Overall results – Learning rates

Learning rates, in a regulatory context, refer to the rate change in compliance costs over time.
We examined the data to show the costs of dwellings that fell within the 5.5 – 6.5 star range, as a proxy for 6 star. As the underlying cost data was based in nominal terms, or dollars of this day, this data was first adjusted for inflation in construction costs over time, using a Construction Cost Index – set at 2% for the purpose of the overall analysis but variable to allow for sensitivity testing. The formula applied was as follows:

\[(1 + \text{Construction Cost Index [\%]}/100)^{\text{Age of drawings}}\]

Second, the data was normalised for an estimate of the incremental cost of stars, to ensure that the cost of those data observations that were above or below 6 star were corrected to a 6 star performance level as follows:

\[(\text{Stars existing version} - 6) \times \text{Star Cost Rate [\$/star]}\]

Note that ‘Stars existing version’ relates to the star rating using the version of the First Rate software that applied at the time the design was rated. This is to ensure that possible changes in stringency that may have been introduced in successive versions of the ratings software do not affect the measured results.

Learning rate observations were then made over two periods, as the data suggests an initial period of rising costs per sqm, followed by a period of falling costs per sqm, most notably for Class 1 dwellings.

![Figure 13 - Costs per sqm (2010 to 2013, numbers indicate star rating)](image-url)
Looking at the data over the whole 2010 – 2017, the general form appears to be slightly rising costs per sqm for 6 star in the early years following the stringency increase, followed by more marked falling costs over the 2013 – 2017 period. While this is intuitively appealing – suggesting an initial period of learning and adjustment, followed by increasing efficiency – there are insufficient data points for robust analysis. The measured learning rate is highly sensitive to the period selected, the Construction Cost Index and other variables. Over the whole period, the data suggests a counter-intuitive slight rise in real incremental costs per sqm over time. However, if a construction cost index of 4% is used, incremental costs fall through time. Even though the data is normalised for dwelling size, it is likely that other factors – such as differences in quality, amenity or style – may be driving the results. Overall, a much larger sample of data would be required for robust analysis.

A stronger – but still not statistically significant – trend in the data is the decline in incremental costs from around 2013 onwards, as shown in Figure 14. Overall, for both Class 1 and 2 together, an annual learning rate of 7.5% was observed. Class 1 dwellings alone showed a learning rate of 7.1% per annum over this period, while Class 2 dwellings alone measured 1.7% per annum. However, these observations are based on a very limited sample.

So far as we are aware, these results represent the first attempt to quantify the learning rate for residential dwellings in Australia. As has been observed in earlier reports, the cost effectiveness of possible increases in residential building thermal efficiency requirements will increasingly be determined primarily by the cost side of the equation – as the incremental benefits associated with higher star ratings becomes increasingly smaller as ratings above 6 are selected. This places an analytical premium on getting the costs story right. While overall learning rates derived here are larger than has been generally assumed, they are based on too few data points to be considered reliable. Chapter 6 offers some conclusions about possible strategies for increasing the confidence.

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8 pitt&sherry, Initial Scoping Work for Implementation of NEPP #31 – Advancing the National Construction Code, June 2016.
associated with both the learning rate and the incremental costs associated with higher star ratings.

**Figure 15 - Learning rates (declining costs) for 6 star dwellings from 2014 to 2017**

We note that the linear learning rate show results from a ‘best fit’ linear regression, but it is likely that a non-linear progression would occur (there is insufficient data to test this thesis experimentally). As noted above, it would appear that incremental costs of complying with 6 star increased for two – three years and then fell thereafter, however, a larger data sample would be required to confirm this result and to plot a more sophisticated curve for learning over time.

5.2.1 Overall results – Incremental cost by star

The second key focus of the quantitative analysis was to determine what the sample of actual dwelling data captured indicates about the incremental cost of achieving above 6 star performance.

By way of background, it should be noted that the strength of using real world data for such analysis is that it carries information about the actual costs that particular developers incurred, these costs are not the same as those that would apply in the case that higher minimum standards were applied in the National Construction Code.

In the latter case, building at the higher level would become the norm, with designs, practices and costs adjusting to this new reality, allowing economies of scale and other learning effects to reduce costs. In the data sample captured here, above-minimum star ratings represent voluntary decisions, and it is likely that those making such voluntary decisions represent a non-random sample of the population who are likely to be making other non-standard design decisions. It is likely that this sample will be skewed towards upper-income earners, and the incremental costs actually incurred may therefore carry other costs and qualitative aspects that are not likely to be carried by future dwellings just complying with higher minimum energy performance standards.

Second, and as noted above, our overall sample is limited in size, and reveals a surprising degree of variability. For example, Figure 16 below shows that whole data set of cost/sqm by star, without
any normalisation. While it is possible to fit an exponential trend line to this data, the $R^2$ value is 0.02, which indicates a very high degree of ‘scatter’ in the data, which is also evident in the subsequent figure.

Figure 16 - Cost per sqm by star for Class 1 and 2 building sample

As was noted earlier, one of the causes of scatter in this data is the observation that costs/sqm fall with increasing total dwelling size. The dwelling sizes in the above data range from 63 sqm to 384 sqm. Normalised for area, the data appears more coherent, but has a similar $R^2$ value of 0.07. See Figure 17 below.
This data suggests an incremental cost per star, for Class 1 and 2 dwellings together, of around $23. However, it is unlikely the costs of achieving above 6 star, and up to 10 star, performance would increase in a linear fashion. Colloquially, many offer the view that the costs of achieving a half or one star increase from 6 star is likely to be small for most designs, and particularly for Class 2 dwellings where individual apartments routinely ‘float’ between 5 and up to 8 star in any case; at the same time, the cost of 9 – 10 star dwellings is likely to be a significant premium over 6 star. In short there is not enough data in this sample – and particularly not at the high star rating end of the spectrum – to draw statistically significant conclusions.

When the results for Class 1 and Class 2 dwellings are considered separately, the already small sample is divided further. Broadly we see the same pattern as above replicated. When normalised for size, the data forms coherent patterns – with rising costs with increasing star ratings – but with a high degree of scatter and therefore limited confidence in the quantitative results. The area-adjusted analysis for Class 1 dwellings is shown in Figure 18 below, and it implies a cost/sqm per star of around $18. As can be seen, however, there is only one data point above 7.5 star, and so no conclusions can be drawn from this data about the cost of achieving higher star ratings. Similar fit is achieved with either logarithmic or linear trend lines.

The results for Class 2 dwellings are set out in Figure 19 below. This data implies a cost/sqm per star of around $7, but again the confidence is very low.

Overall we are forced to conclude that the representative sample size is not large enough to draw meaningful conclusions about the incremental cost of achieving higher star ratings. Data sets were chosen on the basis of ensuring the widest range of representation, but this has translated into significant variability in the data set. The options for remedying this situation are canvassed in Chapter 6. At this point, we re-iterate that the incremental costs associated with higher star ratings – along with the learning rate, or how that incremental cost changes over time – will be the key determinant of the cost effectiveness of higher dwelling thermal efficiency standards in Australia going forward. It is evident that while there is an understandable desire to base such analyses on
real world data, doing so would a require much larger data sample than compiled thus far for this project given the variation in the sample. We believe there would be considerable value in a bottom-up, elemental costing, of a range of typical home designs, in a range of climate zones, to provide deeper insight into the likely actual costs of achieving higher star ratings.

Figure 18 - Increasing Cost/sqm per star for Class 1 dwellings and normalised for size

Figure 19 - Increasing Cost/sqm per star for Class 2 dwellings and normalised for size

Also, the extreme variability in the real world data shown here does nevertheless carry valid information. It indicates that the costs of construction in the real world do indeed vary widely, and the likelihood is that much of this variation – perhaps most of it – is unrelated to energy.
performance. A more controlled, bottom-up analysis of just the components (or design elements) that must change to achieve higher star ratings would be likely to yield more accurate results, unless a very large data set were available for top-down analysis. The previous pitt&sherry citation, for example, recommended that the very large NatHERS database (understood to contain over 30,000 records, including at least 4500 records at 7 star or higher) could be mined for incremental cost data. If this data source could be used to deduce learning rates and incremental costs over time, it is likely that much more statistically significant results could be obtained.

5.2.2 Benefit cost analysis

Noting the qualifications above, we hesitate to apply the findings to a benefit cost analysis model, as the results will not be based on statistically significant information. Nevertheless, we do so for purely illustrative purposes, before comparing the results obtained with those from other sources.

For Class 1 dwellings, applying an incremental cost of around $18/star, and the post 2013 learning rate of 7.1% per year, the results are as shown in the figure below. This indicates that at least 7 star dwellings would be cost effective. However as noted, these results cannot be treated as significant. As noted above, it is more likely that the incremental costs of achieving higher star ratings would increase exponentially, rather than linearly, but this analysis provides insufficient data at the high end of the star rating range to substantiate such a function. Given such a function, it is likely that the benefit cost ratio would fall more rapidly at higher star ratings than shown in Figure 20.

For Class 2 dwellings, and using the derived values of an incremental cost of $7/sqm per star, and the derived learning rate of 1.7% per annum, at least 7 star dwellings are indicated to be cost effective. See Figure 21 below. However, we note that these results are not statistically significant. That said, the incremental cost value noted is similar to that calculated by quantity surveyors, Davis Langdon, of $5/sqm for 6 – 7 star, and also for 7 - 8 star, in the 2012 Pathway to 2020 study, while the learning rate applied is less than in that study.9

As with the Class 1 dwellings, it is likely that the incremental costs for higher star ratings (above 8 or 9) would increase exponentially – although we have noted that the ‘float’ in star ratings for Class 2 dwellings is already large, primarily as a function of orientation and façade length, and so it is critical for Class 2 dwellings that all cardinal points are considered and effectively averaged.

Figure 20 - Indicative Benefit Cost Analysis for Class 1 Dwellings

Figure 21 - Benefit Cost Ratio by Star for Class 2 Dwellings with Derived Cost Data

Overall, our analysis has again illustrated that housing benefit cost analysis shows very significant sensitivity to observations of incremental cost, and also to the learning rate or rate of change in cost over time. For regulatory purposes, the government will require a costing methodology that is
highly detailed and robust, covering the full spectrum of representative designs, climate zones and construction methods.

This analysis suggests there are strict limitations on the extent to which it is feasible to base such observations on so-called 'real world data'. First, large amounts of such data would be required, and the costs of acquiring and analysing it may be prohibitive (but see below). Second, even with a much larger sample, allowance would need to be made for the voluntary (or random) nature of ‘over-compliance’ in the historical period, and the restricted economies of scale when compared to a situation in which higher performance was mandatory and therefore the industry norm. That is, the incremental costs revealed by historical, real world data are likely to systematically over-state the incremental costs that would be likely to be incurred in the case of higher performance standards being adopted in the NCC.

It is hard to escape the conclusion that the traditional bottom-up, or elemental, approach to building costing may be the superior approach. This offers the possibility to optimise design and construction solutions to minimise cost for each additional star. A careful elemental analysis, based on a range of typical dwelling designs – noting variations in state building practices – would create accurate observations of optimised incremental costs.

However, this study has also confirmed that designs and indeed construction methods are not generally optimised for energy performance. Feedback from the qualitative phase of this study suggests this is most likely because energy performance standards are modest and a minor consideration in the overall design and construction process, Further, there is also the strong suspicion that the routine lack of enforcement of the NCC encourages under-compliance with energy performance requirements – although the ongoing lack of compliance auditing means that the degree of compliance with the NCC remains unknown. Noting these factors, it may also be necessary to derive a range of incremental cost observations, including non-optimised ones (for example, where designs are unchanged and simple factors such as insulation levels and glazing quality is varied to meet the standard). This would result in significantly higher incremental costs for these solutions, but may be more reflective of actual practice. The difference in cost between optimised and non-optimised solutions would be a valuable piece of information indicating, for example, the potential benefits associated with enhancing knowledge and skill formation in industry; raising awareness of optimal and non-optimal design and construction solutions; and enabling consumers to become more aware of the operational cost consequences of different solutions.

It is also worth noting that ongoing work is being undertaken to refine RIS approaches as part of reviewing guidance on best practice regulation. Recent studies undertaken by Pears (2016) highlight the large range of benefits not traditionally included in benefit cost analysis.

\[\text{\textsuperscript{10}}\text{pitt\&sherry and Swinburne University of Technology, National Energy Efficient Buildings Project, Phase 1 Report, December 2014.}\]
5.2.3 Built form analysis

A deeper analysis was undertaken to understand trends and relationships in relation to built form. The following section outlines the highlights of this analysis.

5.2.3.1 Characteristics of higher rating dwellings

As the largest comparable component of the sample, the 10 highest rating Class 1 dwellings were examined to identify key characteristics which were shared by this sample compared with the remaining dwellings.

The key characteristics of the dwellings are shown in the table below.

Table 3 - Characteristics of higher rating dwellings

<table>
<thead>
<tr>
<th>Rank</th>
<th>Stars Existing Version</th>
<th>Floor to Ceiling Height (m)</th>
<th>Ratio Glazing to Floor</th>
<th>Ratio Glazing to Wall</th>
<th>Orientations</th>
<th>Total Floor Area (m²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>9</td>
<td>3.05</td>
<td>0.15</td>
<td>0.09</td>
<td>NW</td>
<td>128</td>
</tr>
<tr>
<td>2</td>
<td>7.5</td>
<td>3</td>
<td>0.29</td>
<td>0.25</td>
<td>N</td>
<td>129</td>
</tr>
<tr>
<td>3</td>
<td>7.3</td>
<td>2.7</td>
<td>0.19</td>
<td>0.19</td>
<td>N</td>
<td>229</td>
</tr>
<tr>
<td>4</td>
<td>7.2</td>
<td>2.7</td>
<td>0.18</td>
<td>0.12</td>
<td>N</td>
<td>172</td>
</tr>
<tr>
<td>5</td>
<td>7.2</td>
<td>2.7</td>
<td>0.14</td>
<td>0.14</td>
<td>E</td>
<td>234</td>
</tr>
<tr>
<td>6</td>
<td>7.1</td>
<td>2.7</td>
<td>0.06</td>
<td>0.07</td>
<td>SW</td>
<td>167</td>
</tr>
<tr>
<td>7</td>
<td>7.1</td>
<td>2.7</td>
<td>0.16</td>
<td>0.17</td>
<td>N</td>
<td>215</td>
</tr>
<tr>
<td>8</td>
<td>7</td>
<td>2.7</td>
<td>0.08</td>
<td>0.1</td>
<td>N</td>
<td>266</td>
</tr>
<tr>
<td>9</td>
<td>7</td>
<td>2.75</td>
<td>0.11</td>
<td>0.09</td>
<td>W</td>
<td>137</td>
</tr>
<tr>
<td>10</td>
<td>6.8</td>
<td>2.6</td>
<td>0.21</td>
<td>0.11</td>
<td>NW</td>
<td>84</td>
</tr>
<tr>
<td>Average top 10</td>
<td>7.32</td>
<td>2.76</td>
<td>0.16</td>
<td>0.133</td>
<td></td>
<td>176</td>
</tr>
<tr>
<td>Average all data</td>
<td>6</td>
<td>2.68</td>
<td>0.18</td>
<td>0.15</td>
<td>N/A</td>
<td>172</td>
</tr>
</tbody>
</table>

We note:

- Ceiling height is generally about average although a couple with above average.
- Glazing ratios (glazing to floor area and glazing to wall area) are generally less than average.
- Typical orientation of the main living area is north with no houses having south orientation for living areas – in particular the top 4 rating dwellings orientate their living areas to the north.
- Average total floor area is similar to the average for the whole data set with a large variation of sizes.

If we put this against cost (normalised only for size and year of design) we note there is not a substantially higher cost for this set of 10 dwellings and one of the reasons for this is the lower glazing ratios.

The following chart supports the influence of orientation on higher star ratings (north and north west are the highest performing dwellings).
5.2.3.2 Glazing ratios

If we investigate the glazing ratio the full period, whilst there is no significant trend, there is a downward trend evident since 2013 in the Class 1 sample. If the same trend was evident in a larger sample we could suggest with confidence that there is evidence of learning by reducing glazing ratios over time. There is no clear trend in the Class 2 sample. The results are presented below.

Figure 23 - Trajectory of glazing ratio over time (numbers indicate number of samples)
If this strategy of optimising by reducing glazing ratios was found to be present in a larger sample, the cost savings would be significant and would represent a key learning. The chart below demonstrates the relationship between glazing ratio and cost.

![Chart demonstrating the relationship between glazing ratio and cost](image)

**Figure 24 - Relationship between glazing ratio and cost**

5.2.3.3 Ceiling height over time

Some of the stakeholder feedback indicated that there had been increased preferences for increased ceiling heights in newer dwellings. In order to ensure that this was not masking a cost decline over time (higher ceilings increase cost) supplementary analysis was undertaken. The chart below would tend to support this observation and indicates, at least within the current dataset, that there has been a small increase in average ceiling heights over time. Again this would need to be substantiated in a larger sample.
5.2.3.4 Project home – star rating insensitivity to orientation

An analysis was undertaken of star ratings associated with a sample of project homes to determine their insensitivity to orientation. This was highlighted in the stakeholder feedback. Ten project homes were analysed with a maximum of 1 star difference by orientation. Many of the dwellings, particularly the newer homes varied less than 0.5 stars by orientation, supporting the qualitative feedback.
6 Conclusions

This section documents the key conclusions from the study, clearly outlines gaps and limitations of the results and recommends further research which may be useful in further building the evidence base.

6.1 Key findings

This section brings together the qualitative and quantitative analysis and highlights key findings from the study.

The qualitative analysis investigated the initial response to BCA 2010, the ongoing response and existing and future opportunities to go beyond 6 star with specific reference to design and cost. The quantitative analysis examined the incremental cost of achieving 6 star performance over time together with the incremental cost of achieving beyond 6 star (up to 8 star). This quantitative analysis relied on costs associated with thermal performance elements for a representative sample comprising 58 sets of data (construction drawings, specifications and energy ratings). The complete data set included twelve separate sources, from all states and territories except for Tasmania, every year from 2010 to 2017, across a range of star ratings, both Class 1 and 2 dwellings and across six out of the eight climate zones.

6.1.1 Initial response

Most stakeholders agreed that the main change initially in response to BCA 2010 was to increase the level of specification in glazing and insulation. This was supported by the survey undertaken. The representative sample demonstrated a large range of responses to BCA 2010, with no discernible difference in these values across the sample years.

The impact of the increase in thermal performance standard on apartments was felt less strongly than other typologies, principally because of the much reduced exposure of the building envelope to outdoor conditions and the ease of rating a higher star ratings – a multi-unit developer noted this as being approximately $500 per apartment.

In terms of jurisdictional variations, both New South Wales, Queensland and Northern Territory have either not applied the increase in stringency or have included optional credits which has meant that meeting the 6 star equivalent has been achieved in part by installing other energy services such as solar PV. This has reduced reliance on a thermal fabric upgrade to achieve the standard.

There was general agreement amongst stakeholders and survey respondents that the introduction of BCA 2010 added cost, but there were varying views on how much. In the survey, 34% of respondents indicated the initial cost was neutral or less than $2000, 36% of respondents indicated that the initial cost impact was between $2,000 and $5,000 and 30% indicated the increase was more than $5,000. The incremental cost analysis by star rating indicated generally consistent increases at least for Class 1 dwellings at around $18 per sqm, normalised for size, or $2,700 for a 150sqm dwelling.
Stakeholders generally agreed that the cost could be managed better depending on strategies adopted and there were pathways available to be cost neutral whilst increasing star rating. It was noted that these strategies sometimes competed with other priorities such as daylight amenity and the ability for project homes to be relatively insensitive to orientation.

The results indicate that the cost of redesign following a stringency increase and the cost of construction of dwellings should be treated as separate elements. The cost of redesign is dependent on whether standard designs exist and whether updating standard designs needs to be outsourced at cost. Large project builders were more likely to have in-house teams working on design iterations, the cost of redesign was seen most significantly at the smaller end of the scale where builders have to outsource this expertise.

Feedback from both multi-unit developers and apartment architects indicated the variation in apartment sites resulted in less standardisation of individual units, so this wasn’t a well held concern.

Industry capacity was noted as a significant determinant in managing the cost associated with a stringency increase, this includes knowledge of the builder to allow them to take a least cost approach, the alignment of the designer with thermal performance principles, practitioner flexibility and adaptability as well as general acceptance in the jurisdictions and by member organisations.

### 6.1.2 Ongoing response

Stakeholders generally noted the capacity for industry to learn to optimise designs over time, however there were varying perspectives on the extent to which this is actually occurring.

The survey sample suggests a greater range of strategies to meet the 6 star standard ongoing compared with the original response, but upgraded glass and insulation specifications remained the preferred strategy.

What we learn from the built form analysis is that there is some evidence of declining glazing to wall ratios especially from 2013 which may indicate learning, however the sample size is quite small.

#### 6.1.2.1 Learning rates

Taken over the whole period for which we have data from the representative sample, from 2010 to 2017, costs rose initially (to 2013) then start to fall. This data incorporates a limited number of dwellings which were designed before the implementation of BCA 2010 so an initial increase is not unexpected. However the sample is small, and too small for reliable results. Using the whole data set, for both Class 1 and Class 2 dwellings, produces an average learning rate of -0.8% per year.

When the learning rates are derived from the 2014 – 2017 sample of dwellings – after the initial incremental cost appears to have been overcome by learning effects, then much larger learning rates are observed in the overall data sample. Overall, for both Class 1 and 2 dwellings together, an annual learning rate of 7.5% was observed, with results of 7.1% for Class 1 dwellings and 1.7% for Class 2 dwellings.
So far as we are aware, these results represent the first attempt to quantify the learning rate for residential dwellings in Australia. As has been observed in earlier reports\(^{11}\), the cost effectiveness of possible increases in residential building thermal efficiency requirements will be determined primarily by the cost side of the equation – as the incremental benefits associated with higher star ratings becomes increasingly small.

Whilst these results indicate the sort of trends we would expect based on the qualitative analysis, they are based on too few data points to be considered reliable, due to the large variation in costings (as discussed due to non-thermal performance related factors).

The extreme variability in the real world data does nevertheless carry valid information. It indicates that the costs of construction in the real world do indeed vary widely, and the likelihood is that much of this variation – perhaps most of it – is unrelated to energy performance.

### 6.1.2.2 Other factors influencing learning

The process of design review practice varies with organisational capacity and type. The design review process in the volume builder industry was reported to be in a constant state of change and therefore new designs which expand existing dwelling portfolios can accommodate stringency increases. When designing new dwellings there is a commercial interest for volume builders in ensuring that when partnering with land developers their designs retain flexibility over the way in which they are orientated. This may add to incremental cost in relation to star rating as dwellings are not optimised for a particular orientation. It is worth noting that the highest four star ratings all had north facing living areas and none of these were volume builds. What is not clear is whether there are flow on benefits to the consumer cost by maintaining insensitivity to orientation – certainly there is commercial value to the volume builder but it is unclear as to whether any of that value is passed onto consumers.

In the same way that builders have opted for designs with insensitivity to orientation, builders who work across jurisdictions and climate zones will often maintain the same design. This means regional variations that could improve thermal performance at low cost are not always adopted. Any increase in stringency from the current level may force volume builders to revisit their preference to designs which are insensitive to orientation and climate zone.

The impact of software updates to the NatHERS software was highlighted as the source of some frustration amongst practitioners with standard designs. Iterations of software have resulted in dwellings rating to 6 star in one version needing to be modified to meet the standard in subsequent versions. When dwellings were rated in the version of software in operation at the time of design as part of the quantitative study and then again in the contemporary version there was a significant variation in some results, although no confident trend in any direction.

A number of other design factors other than thermal performance were influencing cost, including:

- Zoning changes within dwellings – these include new features such as butlers pantries etc.
- Materials choices – largely driven by a need to refresh the look and feel of standard designs and cost reductions

\(^{11}\) pitt&sherry, Initial Scoping Work for Implementation of NEPP #31 – Advancing the National Construction Code, June 2016.
- Dwelling size – normalised in the analysis
- Unrelated design taste changes e.g. 2 bathrooms – excluded from the analysis
- Design efficiencies for apartments
- Acoustics – the prevalence of double glazing for Class 2 dwellings for managing noise which also provides thermal performance benefit
- Planning regulation – SEPP 65 Apartment Guidelines in NSW and the new Better Apartments Design Standards in Victoria as well as local and state daylighting provisions.

The importance of other economic factors influencing cost was highlighted from a number of sources, both member organisations and developers. Broadly these economic factors included trade and supply chain considerations, market maturity (in part driven by regulation), and other construction costs, e.g. cost of labour and general market fluctuations.

Although some of these factors have been able to be excluded or normalised for, the combined effect of all these factors undergoing constant change tend to cloud trends in the data.

### 6.1.3 Going beyond 6 star

In examining the current and potential future practice in going beyond 6 star, there were a number of motivations highlighted by stakeholders, including:

- It is relatively easy to do so
- Brand considerations and use of tools such as GreenStar and EnviroDevelopment
- Market edge or point of difference
- Readiness for future stringency increases

In examining the data set together with the stakeholder feedback, it is clear that orientation, generally lower glazing ratios and for Class 2 dwellings the virtue of the position in the building were key ingredients to higher performing dwellings. It is interesting to note that none of these measures add cost, but there are barriers for project builders in wanting to retain insensitivity to orientation for their product and lower glazing ratios may have impacts on daylight, especially if adopted for Class 2 dwellings.

One of the primary issues highlighted was the value in a stringency increase in the absence of improved compliance. Concerns stemmed from the quality and consistency of designs claiming to meet the standard across state and territory jurisdictions including the increasing prevalence of the VURB method and a level of built performance which has been shown by successive projects including the NEEBP report as being generally far lower than the modelled performance (noting obvious difficulties in comparing design and performance metrics).

This notwithstanding there is no evidence to suggest that any typology or climate zone will have insurmountable challenges responding to an increase in stringency, however the benefit of increases from a pure financial standpoint are expected to decline with successive increases.

Stakeholders noted some challenges in the tropical climate zones under further increases in stringency.
**6.1.3.1 Incremental cost by star**
The quantitative analysis undertook an analysis of cost increase (or benefit) by star rating. The strength of using real world data for such analysis is that it carries information about the actual costs that particular developers incurred. These costs are not the same as those that would apply in the case that higher minimum standards were applied in the NCC. In the latter case, building at the higher level would become the norm, with designs, practices and costs adjusting to this new reality, allowing economies of scale and other learning effects to reduce costs. In the data sample captured here, above-minimum star ratings represent voluntary decisions, which have potential to be skewed towards upper-income owners. The sample is also limited in size, and reveals a surprising degree of variability.

While it is possible to fit an exponential trend line to this data, the R2 value is 0.07, which indicates a very high degree of ‘scatter’ in the data. Noting this limitation:

- It is unlikely if the costs of achieving above 6 star, and up to 10 star, performance would increase in a linear fashion
- The area-adjusted analysis for Class 1 dwellings implies a cost/sqm per star of around $18
- The results for Class 2 dwellings a cost/sqm per star of around $7, but again the confidence is very low.

Overall we conclude that the representative sample size is not large enough or has too much variation due to other factors to draw meaningful conclusions about the incremental cost of achieving higher star ratings.

While there is an understandable desire to base such analyses on real world data, doing so would require a much larger data sample than compiled thus far for this project.

**6.1.3.2 Benefit cost analysis**
Noting the qualifications above, we hesitate to apply the findings to a benefit cost analysis model, as the results will not be based on statistically significant information. We have done so only for illustrative purposes.

For Class 1 dwellings, applying an incremental cost of around $18/star, and a learning rate of 7.1% per year (from 2020, the assumed first year of application of a possible new standard), shows that at least 7 star would be cost effective – however, this result is not based on statistically significant data. This value is a little lower than that used in pitt&sherry’s 2012 *Pathway to 2020* study, which were around $30/sqm per star. This, together with the higher learning rate – and other changes like higher energy prices since 2012 – help to explain the significantly higher benefit cost ratios found.

For Class 2 dwellings, and using an incremental cost of $7/sqm per star, at least 7 star would also be cost effective, however this observation is based on data that is not statistically significant. In this case, however, the observation agrees with stakeholder feedback suggested was the cost of compliance between 5 star and 6 star (“approximately $500 per dwelling” – or around $4/sqm for an 80 sqm apartment), and also with earlier studies such as the *Pathway to 2020* report cited earlier.

We conclude that it is not feasible to base incremental cost observations, for regulatory purposes, on a limited sample of existing dwellings. A much larger sample of dwellings, covering the full range of star ratings, would be required for this purpose given the variation we have found in the sample. Alternatively – and perhaps more practically – a detailed bottom-up cost analysis of mainstream designs, and necessary design and specification changes, would be a more robust
methodology for establishing the incremental costs associated with higher energy performance levels.

6.2 Gaps, uncertainties and limitations

As noted, in a number of sections of this report, whilst the qualitative analysis for the project has provided a number of insights into industry learnings in relation to the topic of design change and its associated impact on cost, the variation of the costing results in the sample has led to very low confidence in the quantitative analysis outcomes.

Further work is required to either expand the existing data set to a size which can address the variation (including by segmenting the data set by their characteristics) or a new approach to derive costs over time is required.

The uncertainty is underlined by sensitivity analysis which indicated that the removal of individual data points could change the results relatively significantly. The high degree of scatter (with R² values under 0.1) indicate this sensitivity and the difficulty in plotting a confident trend line through the results.

A second limitation of the results is the uncertainty around the difference between voluntary increases in thermal performance above 6 star and a regulated increase in stringency. On reviewing other design elements present in higher performing dwellings, we suggest that voluntary over-compliance may result in a higher incremental cost than a regulated increase. Although this was to some degree normalised for in the analysis, we note the limitations of using these values to predict a regulated response.

A third limitation was the challenge in obtaining a representative data set within the timeframes set for the project. Whilst a second round of data sourcing provided the basis of a representative sample, a greater number of 2011 and 2012 data sets would improve representativeness. The challenge in obtaining data sets has also compressed the costing and analysis phases of the project.

6.3 Further research and recommendations

The lack of confidence in the data trends indicates the need for new approaches to be explored to increase the confidence in the results of what is an important research area.

Fundamentally, the use of actual drawing and specifications data has proved challenging to source from industry and has provided low confidence in the results. An alternative method would be to undertake a traditional bottom-up approach to assessing the impact on building cost.

This offers the possibility to optimise design and construction solutions to minimise cost for each additional star. A careful bottom-up analysis, based on a range of typical dwelling designs – noting variations in state building practices – would create accurate observations of optimised incremental costs.

It would also be necessary to derive a range of incremental cost observations, including non-optimised ones (for example, where designs are unchanged and simple factors such as insulation levels and glazing quality is varied to meet the standard). This would result in significantly higher incremental costs for these solutions, but feedback from industry has indicated this was the standard response, at least initially. The difference in cost between optimised and non-optimised
solutions would be a valuable piece of information indicating the potential benefits associated with enhancing knowledge and skill formation in industry.

Such a study could, for example, identify the 10 largest-volume project home designs around Australia, and perhaps 5 popular or common Class 2 dwelling designs (whole floors), and provided detailed descriptions of a) the specifications and costs required for these dwellings to comply with NCC2016, and b) the minimum necessary design and/or specification changes required to meet higher star ratings, and associated costs; for a representative sample of climate zones.

An alternative approach would be to target specific states and climate zones of high growth, whilst placing a limitation on variation in the sample. For example, investigation into brick veneer, single storey volume builds in Queensland or the medium rise apartment market in Victoria could limit some of the uncertainty of a modest sized representative sample across all climate zones and jurisdictions.

Large statistical samples from the Sustainability Victoria reporting and the Energy Use Data Model (CSIRO) may also boost understanding of the design measures that are currently being applied and in time may be used to show trends. The very large NatHERS database (understood to contain over 30,000 records, including at least 4500 records at 7 star or higher) could be mined for incremental cost data. If this data source could be used to deduce learning rates and incremental costs over time, it is likely that much more statistically significant results could be obtained.

Whilst the study itself was limited in what it could demonstrate with confidence in relation to the quantitative analysis, when drawing in the qualitative analysis there is evidence to support a learning rate to be applied to future research to underpin a potential increase in stringency.

Despite the lack of certainty in the results the trends encountered indicate there is evidence to provide support for a future residential RIS, however it would need to be designed to overcome the limitations identified by this research. The key to providing industry certainty in the results of any future RIS process is a serious cost study that takes a bottom up approach to overcome these limitations or sources sufficient data from NatHERS data to determine key changes over time (and then cost those key changes). It would also need to account for sensitivity to higher costs in early years following any proposed increase in stringency.

The study also highlighted a number of measures to help minimise the cost impact of further stringency increases in the future. A key determinant was to build the capacity of practitioners to take a least cost approach in their response, noting there are other drivers (such as the cost of redesign itself and a preference for project builds to work on multiple orientations) that may limit this. A cost study using an optimised and non-optimised elemental approach could underpin such industry engagement.

Further measures to minimise the cost of further stringency increases include:

- Establishing a trajectory for stringency increase which is known well beyond the next cycle
- Ensuring adequate ‘breathing space’ between software changes and stringency increases to allow learning to take place
- Clearer and potentially longer transitional arrangements

A number of other measures such as a focusing on improved compliance (both design rating compliance and building compliance) are also recommended as key areas of ongoing research focus.