Initial Scoping Work for Implementation of NEPP #31 – Advancing the National Construction Code

Final Report

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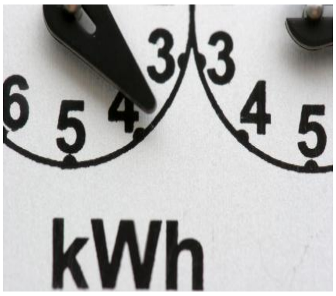

Prepared for: Dept of Industry, Innnovation & Science

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Date: 22 June 2016
Rev 00

Inspired thinking embracing
the challenges of a changing world.

pitt&sherry

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Executive Summary

This report has been commissioned by the Department of Industry, Innovation and Science as an input to measure 31 in the National Energy Productivity Plan, 'Advancing the National Construction Code'. The report identifies two prioritised short-term research programs that could be undertaken to inform a future regulation impact statement (RIS) – that is likely to be undertaken in early 2017 – relating to possible changes to the energy performance requirements for residential buildings in the 2019 edition of the National Construction Code.

The first research program addresses the question, 'to what extent would it be feasible to base a set of future energy performance requirements for residential buildings in Australia on real world data, as distinct from modelling?'

Chapter 2 notes that the dividing line between modelling and real world data is in fact not a sharp one. Models utilise as much relevant and available data as possible in order to make plausible projections about scenarios. Many of these scenarios are in the future, these scenarios therefore have no current or real world data. However, given that current residential energy performance requirements have been in force for over six years, there are now many real dwellings that 'over-comply' with minimum energy performance requirements, and these dwellings could potentially provide valuable real world data for the purposes of a RIS.[1]

The key questions that we would want to illuminate with real world data include:

- Can we have confidence that higher star ratings will generate additional energy savings (and other economic benefits)?
- Can we have confidence that the costs associated with achieving these benefits will be reasonable and that the regulation will be cost effective?

To answer these questions, we identify a suite of seven research projects (two of which could represent alternative methodologies to answer the same research question) that could be undertaken within a 6 – 9 month timeline. These projects are prioritised with reference to criteria such as how critical they are to the expected outcome of a RIS, the extent to which they can access real world data, and the breadth of their scope (coverage of all residential building forms, climate zones). These are:

1. Using existing NatHERS ratings to identify and estimate incremental costs associated with above-6 star dwellings in Australia;
2. Using energy bill data to determine the extent to which higher star-rated dwellings use less energy than lower star-rated dwellings;
3. Using existing energy monitoring data to assess the extent to which NatHERS accurately predicts summer and winter space conditioning energy consumption, and whether there is a case for separate summer/winter performance requirements;
4. Using available data to document the values of external or indirect costs and benefits associated with higher energy performance requirements;
5. Assessing the extent to which under-compliance in relation to existing requirements may be altering both costs and benefits;
6. Working with industry to identify how designs, specifications and costs changed over time in response to past energy performance requirements;
7. Direct (low-cost) pre-occupancy measurements of the thermal performance of new dwellings.

[1] We note that these dwellings are not a perfect analogy for higher performance dwellings constructed to comply with a future mandatory minimum requirement, as this would induce economies of scale and scope (aka, learning) that has not applied to dwellings built to the same performance level to date.

For details and costings, please refer to Chapter 2 and Appendix A. We also identify additional/longer term research projects that would ideally be undertaken but which are assessed as lower priority than those above.

The second research program addresses the question, 'to what extent would it be feasible to set future energy performance requirements for residential buildings in Australia on a 'whole of house' basis, as a replacement for the current NatHERS 6 star performance requirement?'

Chapter 3 explores this question in an incremental fashion, beginning with the fundamental question of what objectives are being targeted? Specifically, to what extent would adding new requirements be likely to meet specific public policy objectives, including those referenced in the National Construction Code? We note that there are different objectives identified in the Code (sustainability, reducing greenhouse gas emissions, improving energy efficiency) and they are not always applied in a consistent manner. We note that there may be a need to re-interpret what the phrase 'minimum necessary standards' means in the light of Australia's overall greenhouse gas abatement obligations.

We then examine the current scope of Code energy performance requirements and provide an overview of the pros and cons of adding changing requirements in these areas and/or adding new ones. The potential additional scope areas include the (energy or greenhouse) performance of space conditioning devices, fixed appliances used for cooking, and portable appliances. We also consider the case of photovoltaic (PV) systems, noting that they could be considered either as element of the building fabric or as a fixed appliance. We consider the issues associated with allowing trade-offs between different performance requirements, and also the differing situations of Class 1 and Class 2 buildings.

Our tentative conclusion is that there may not be a strong *a priori* case for adding new scope to the current energy performance requirements, with the possible exception of PV. However, our brief was not to reach definitive conclusions, but rather to identify the research program that would be required to do so. This program includes:

1. A feasibility study examining the extent of likely materiality, additionality and cost effectiveness associated with potential additional energy performance requirements; the alignment of existing and potential new performance requirements with specific public policy objectives; potential risks to consumer choice; and how these results are likely to vary by state/climate zone and dwelling type;
2. A detailed analysis of the case for including space conditioning equipment and PV (and associated storage and smart energy management) within the scope of Code performance requirements, including the extent of allowable trade-offs and additionality vis-a-vis MEPS and labelling in particular;
3. A detailed analysis of the case for including fixed cooking appliances and dishwashers within the scope of the Code, including an examination of interactions between cooking equipment and thermal loads in summer and winter, and also peak load impacts;
4. An examination of the optimal performance requirements in 2019 for fixed appliances already included within the current scope of the Code; that is, hot water, lighting and pool/spa pumps.

We note that there would be a case for undertaking projects 1 and 4 initially, as they could both inform a RIS in 2017, while projects 2 and 3 might logically follow project 1, subject to its findings. We do not at this stage recommend further analysis of the inclusion of portable appliances, or 'plug load'. This option will be further considered in Project 1 in any case, but we consider it unlikely that it would be found to be practical to include portable appliances within the scope of Code requirements.

1. Background

1.1 Purpose

The purpose of this report is to scope a research program to underpin a future regulation impact statement (RIS) relating to possible changes to the energy performance requirements for residential buildings in the 2019 edition of the National Construction Code. Noting the requirement for new Code requirements to be posted with a year's notice to industry, and with consultation processes prior to that date, research to underpin 2019 requirements will need to be substantially completed during the second half of 2016.

In this context, we were engaged by the Department of Industry, Innovation and Science to examine two possible pathways for a future performance requirement, and develop two corresponding research programs.

The first pathway asks, 'to what extent would it be feasible to base a set of future energy performance requirements for residential buildings in Australia on real world data, as distinct from modelling?' This report scopes out this question and identifies the key research questions that would need to be addressed, in the short term, to facilitate this approach.

The second pathway asks 'to what extent would it be feasible set future energy performance requirements for residential buildings in Australia on a 'whole of house' basis, as a replacement for the current NatHERS 6 star performance requirement?' Again this report scopes out this question and identifies the key research questions to be addressed.

For both tasks, the key outputs are justified and prioritised research programs that are designed to illuminate the key issues, sufficient to facilitate a RIS being undertaken to test specific regulatory proposals.

1.2 Scope

1.2.1 Task 1 – Use of Real World Data

To expand on the above, Task 1 of this project is to propose a research program, to be undertaken over 2016, to develop a methodology for undertaking a RIS for increasing the stringency of the current NCC residential energy efficiency standard that would particularly focus on how to base the benefit and cost analysis in the RIS on real world data rather than relying on modelling. This work will:

- briefly review the previous 2009 RIS for the move to the current stringency settings in the 2010 NCC and stakeholder comments and research studies on the adequacy of this RIS, particularly any comments on the variance between NatHERS and economic modelling and what actually happened after 2010 NCC changes were introduced;
- scope research on the role that the CSIRO Energy Use Data Model (EUDM) could play in providing actual residential energy use data to inform the development of the business-as-usual baseline and the modelling of household energy use under any proposed new building energy efficiency standards;
- scope how to research how real world data could be collected on the costs of complying with proposed new building energy efficiency standards and how these costs may reduce over time as builders adapt to the new standard (industry learning), and on determining the actual impacts on house prices;
- scope how to leverage and integrate any other supporting industry, government and research analysis and input currently underway, such as ASBEC's building energy performance project and the research work of the CRC for Low Carbon Living;
- scope how to take into account the different circumstances of class 1 and 2 buildings;
- scope how to identify and quantify other benefits and costs of any Code change;
- set out proposed projects, timelines and estimated costs for completing the research program.

1.2.2 Task 2 – Whole of House Performance Requirements

Task 2 of this project is to ppropose a research program, to be undertaken over 2016, that could analyse different models for moving to a whole-of-house performance requirement as a replacement for the current NatHERS 6 star energy efficiency performance requirement in the NCC. This work will:

- scope a review of the NCC's energy efficiency objectives and consideration of the advantages and disadvantages of using different metrics such as sustainability, energy performance, energy efficiency and greenhouse emissions;
- scope an analysis of how a whole of house rating tool could be structured to meet the desired NCC objective (once decided), in terms of:
    - what components could be included in the whole-of-house performance requirement (taking account of whether other energy efficiency elements are already included in the NCC), how standards could be set for each component and how trading off could be allowed between them;
    - whether and how the existing building fabric thermal performance requirement could be split into separate heating and cooling performance requirements;
    - how to take into account the different circumstances of class 1 and 2 buildings;
    - how to take account of the increasing installation of renewable energy systems both across the grid and by individual households;
- set out proposed projects, timelines and estimated costs for completing the research program.

2. Setting Energy Performance Requirements with Real World Data

2.1 Key Issues

2.1.1 Use of Real World Data for Regulation Impact Assessment

Best practice guidelines for regulation impact assessment (RIS) and benefit cost analysis (BCA) of policy proposals do not require the use of real world data – a phrase that implies known, certain, historical facts. Rather, the general standard of evidence is that information and data relied upon for a RIS or BCA should be 'best estimates' or fit for purpose. However, it is clearly advantageous to utilise high quality and relevant data, drawn from real world situations, to assist in policy analysis wherever it is available.

By way of background, RISs are generally required to support decision making on major policy decisions. The Building Ministers Forum – a forum of Australian, state & territory building ministers – is the body that sets the strategic direction that underpin the performance requirements in the National Construction Code. The ABCB is then responsible for deciding and implementing changes to the Code. The ABCB is obliged to follow COAG principles on best practice regulation so significant changes are progressed under a RIS process. The COAG RIS principles include:

1. establishing a case for action before addressing a problem;
2. a range of feasible policy options must be considered, including self-regulatory, co-regulatory and non-regulatory approaches, and their benefits and costs assessed;
3. adopting the option that generates the greatest net benefit for the community;
4. in accordance with the Competition Principles Agreement, legislation should not restrict competition unless it can be demonstrated that:-
    a. the benefits of the restrictions to the community as a whole outweigh the costs, and
    b. the objectives of the regulation can only be achieved by restricting competition;
5. providing effective guidance to relevant regulators and regulated parties in order to ensure that the policy intent and expected compliance requirements of the regulation are clear;
6. ensuring that regulation remains relevant and effective over time;
7. consulting effectively with affected key stakeholders at all stages of the regulatory cycle; and
8. government action should be effective and proportional to the issue being addressed.

In the context of a RIS, benefit cost analysis is generally used to "...measure the economic and social impact of government action by reference to the 'net social benefits' that action might produce".[2] The guidelines do not require that real world data be used as the measurement standard. Indeed they note that "The values included in a CBA are the 'most likely' or 'best' estimates", and they recommend that uncertainty about key values is handled through sensitivity analysis. Also, the guidelines note that "obtaining and analysing information also incurs costs...The more significant a proposal and the greater the likely economic and social implications, the more expenditure on a CBA can be justified." [3]

Overall, while there is no requirement to use real world data for a RIS, such data – where relevant and available at a reasonable cost – would be used in preference to, or in conjunction with, modelling to project the likely future impacts of a policy change. The selection of values for the benefit cost analysis component of a RIS is critical. There is a clear obligation to base analysis on the best possible data and projections.

The Department is keen to see greater use of real world data to guide residential building energy policy and proposed code changes. In general there is a strong desire to use robust evidence as the basis of policy development. More specifically the 2009 RIS was widely criticised for making projections that weren't clearly linked to real world data. The Department would like to ensure that the next such RIS is built on transparent and well-founded data and values.

2.1.2 Real World Data and Modelling

Various forms of modelling are routinely used in RISs, including because the exact data required for a particular RIS scenario may not be available. Typically RISs address themselves to novel scenarios and envisage policy and market outcomes that do not currently prevail in the real world. Therefore it will very often be the case that there is no real world data that directly informs the policy scenario envisaged.

That said, it is generally possible to identify data that can provide a strong *analogy* for the anticipated policy change. This may be, for example, because the data relates to a similar change made in the same market in the past, or a similar change made in a related market or policy context. It is very unlikely, however, that these will provide perfect analogies for a future regulatory change. The market, related policy, technology, behavioural and other contexts in which that 'real world data' was captured will inevitably have changed or be different to those that are likely to apply after the anticipated regulatory change, to some degree, simply due to the passage of time.

To take an example, even if we had perfect information about the actual costs and benefits today of, say, 7 star housing relative to 6 star housing, could we say that this data perfectly describes the expected impacts associated with a hypothetical move to 7 star housing in 2019? The hypothetical regulatory change would require *all* new house construction work to meet this standard from 2019, and this would shift practices, designs and associated costs in ways that do not apply in the current market. Also, the value of future savings will depend on shifts in real energy prices, for example, that cannot be predicted with certainty. Further, we have three years before any regulatory change may take effect – including at least one and perhaps two years in which the market will have advance notice of the details of the expected change. This is a significant amount of time in which to innovate and prepare to meet the new requirements in an efficient and cost effective manner.

Even though we cannot know the future, we can make reasonable and evidence-based projections about likely or expected[4] outcomes, and this is what regulatory impact assessment and benefit cost analysis requires us to do. Generally, we use models – based on real world data – for this purpose. Models generally turn relevant, real world data into a set of algorithms or functions that can be shown to

[2] Ibid, p. 21.
[3] Ibid, p. 25.
[4] In this report, we use the phrases 'expected outcomes' or 'expected values' in accordance with their economic definitions; that is, a probability-weighted outcome or value reflecting a plausible range of likely outcomes weighted by their probability of occurring.

accurately represent the underlying data (that is, they are validated), and which are then able to predict values associated with points on that function that are not yet resolved in reality, such as a future energy performance requirement.

The more relevant real world data we have, the greater the confidence we can have in models and in projections of the future. Data without structured analysis, which will often include modelling, can remain incoherent information. So models and real world data are not alternatives to each other, but complements.

Finally, in some cases there will be real world data that can directly inform at least aspects of a policy proposal under consideration, and examples of this are described in this Report in the specific context of possible future energy performance requirements for residential buildings. However, before considering this, we briefly review the history of RISs in this area, as it helps to illuminate current concerns regarding modelling and real world data.

2.1.3 Factoring in Uncertainty, including "Real World Behaviour"

One commonly-heard criticism of models – and NatHERS in particular – is that they may fail to accurately predict the specific energy consumption of a given product or house. Some stakeholders appear to hold the view that this fact invalidates the use of NatHERS as a tool to support energy performance regulation in housing. However, this misunderstands both what NatHERS is and its role in regulation. NatHERS does not purport to represent the total energy consumption of specific dwellings, but rather only the thermal loads on a particular building design in a particular location (climate zone), given a set of assumptions about its occupants and their behaviours. Second, its function in a regulatory context is not to regulate the total energy consumption of a dwelling – or rather, its occupants – but only to ensure that the thermal shell of the house functions effectively and cost effectively to provide comfort and shelter to its occupants without requiring the costly consumption of large amounts of energy. Thirdly, NatHERS can be used to make a useful contribution to assessing the likely or potential energy consumption of a house under typical use. This feature is vital to the RIS where an assessment of likely future energy cost savings is required.

It is well understood that the actual energy consumption of a house is primarily a reflection of the numbers and behaviours of its occupants, and these are not factors that house energy performance regulation seeks to control. Rather, the approach recognises that dwellings form part of the collective built environment. While they are often privately owned, they change hands on average every seven years. Their original designers cannot foresee the future occupants and their behaviours that will affect their energy consumption through time. They can, however, ensure that this key element of society's social infrastructure is inherently energy efficient, requiring modest and affordable amounts of energy to maintain healthy and desirable living conditions.

It may be helpful to compare house energy performance regulation with another energy use that is required to be tested. The fuel consumption (expressed as CO2 emissions) of new light passenger motor vehicles in Australia has for many years been required to be measured and declared in fuel efficiency labelling. Governments do not require *ex poste* monitoring of statistically significant samples of the hundreds of models of cars to ensure that the fuel consumption figures are delivered. The underlying Australian Standard is based on the application of physics, engineering and behavioural research, and then extensive dynamometer testing which generates a lot of real world data in controlled conditions. However, most people appear to understand that *actual* fuel consumption of vehicles is affected by a wide range of behaviour factors – loaded vehicle weights, driving behaviours, terrain, traffic conditions and other factors. Also, this message has been reinforced over the years by the label itself and in information campaigns by governments. We accept that the fuel consumption values shown on labels are based on a model of reality, which give us valuable information about the *relative* fuel efficiency of different models, while we are responsible for deciding where and how we use individual vehicles, and therefore for their fuel consumption in the real world. That said, ex poste monitoring of actual vehicle fuel use would further strengthen the integrity of the scheme. While the test standard is robust, there is still the possibility that some industry participants game the test procedure to deliver favourable results that can't be re-produced under actual use. The recent Volkswagen controversy regarding air pollution emissions testing in the US is a case in point.

Similarly, the key regulatory requirement for the energy performance of housing is based on designs (not actual houses) achieving a certain star rating, where the star rating represents the amount of purchased energy (for heating and cooling) required to maintain reasonable temperature stability inside a dwelling in a given climate zone. As with vehicle fuel efficiency testing, NatHERS assessments are based on a set of parameters which have been developed and modelled using physics, engineering and behavioural research. The software delivers results in terms of modelled temperatures (the principal determinant of comfort) that closely correlate with experimental measurements. All experiments to demonstrate the performance of AccuRate in calculating internal dwelling temperatures based on the occupant behaviour assumptions in the software have produced satisfactory or better outcomes.[5] However there is a concern, based on actual energy consumption data, that AccuRate may not be producing highly robust estimates of cooling loads experienced in summer. Further research in this area would be valuable.

However, to a much greater degree for houses than for cars, the predicted energy performance of NatHERS is less transparent to a house owner, and much less directly comparable using real world data like energy bills. First, NatHERS does not predict energy costs, nor total energy consumption that could be related to costs, and in fact it is complex and very expensive to collect real world data of the kind that could be used to validate the performance of NatHERS. Unfortunately some opportunities to do this at marginal cost appear to have been missed. For example, the CSIRO (2013) study on the *ex poste* evaluation of 5 star houses captured 30 minute interval temperature data for the main living area in over 400 houses, that could have been compared with AccuRate calculated temperatures, but we understand this analysis has not yet been done.

Second, the energy performance of a house is likely to vary even more than does the energy performance of a car. This is because there are more variables that can vary over a wider range, for houses than for cars. For a typical open plan house with ducted heating/cooling and occupants who lived as assumed by NatHERS tools in ratings mode – with respect to behavioural variables such as opening/closing windows and adding/removing external shading when appropriate – and who occupied the house 24/7, we would expect a result very close to the modelled result. However, as soon we account for variability in actual occupancy patterns, holidays, zoning out some nominally conditioned spaces, etc., we would expect to see wide variation in actual versus modelled conditioned energy. Other occupant behaviours such as energy conservation could further reduce conditioning, whereas 24/7 occupancy by the very young or very old or occupants with various health issues could raise conditioning energy. Ideally assumptions on behaviour will reflect current typical use as closely as possible. As mentioned earlier there is some concern that assumptions for summer use don't align well with typical behaviour.

We note that in previous residential baseline modelling (EES 1999, EES 2008), analysts have indicated that the alignment of top-down state aggregate residential energy data with bottom-up modelling requires that modelling outcomes be discounted by ~50% for the modelling of the entire stock. Such a discount reflects the fact that, on average, NatHERS would appear to be overstating space conditioning energy consumption, when compared to reality. Among the likely explanations are variance in occupant behaviour, design differences across the stock (older less energy efficient dwellings may be easier to zone), typical occupancy (EES 2009) patterns being less than 24/7, different service levels (eg, comfort) being achieved, and under-compliance with Code performance requirements.[6] Testing such hypotheses, and using the results to improve modelling assumptions, can be expensive and require sustained research effort over time.

[5] Stephen Berry & Tony Marker (2015): Australia's Nationwide House Energy Rating Scheme: the scientific basis for the next generation of tools, International Journal of Sustainable Building Technology and Urban Development, DOI: 10.1080/2093761X.2015.1025451

[6] *National Energy Efficient Buildings Project Phase 1 Report*, pitt&sherry/Swinburne University of Technology, December 2014.

At the same time, this report identifies research methodologies that can potentially capture real world data from many thousands of houses at modest cost, and provide highly robust analysis of the actual energy performance on average of those houses.

2.2 Past RISs and Reviews

2.2.1 2009 RIS

There have been three RISs undertaken over the last 15 years relating to residential energy performance requirements in Australia. The first two, that supported the initial requirements introduced in 2002-03 and then the upgrade to 5 Star in 2005-06, was undertaken in-house by government officials. The 2009 RIS that supported the move to 6 Star was undertaken by the Centre for International Economics[7] and is briefly described below. Included in the Final 2009 RIS was a Section 11 that described, indirectly, some key issues that had been raised by stakeholders during consultations, and presented the results of some sensitivity analyses designed to illustrate the effect of different assumptions. The key issues identified included:

- The choice of discount rate;
- Housing affordability;
- Building costs;
- Regional weightings; and
- Electricity and carbon prices.

Many of these issues reappear in the discussion below, as they remain relevant today. While this RIS process was considered controversial by some stakeholders, it is important to recall that this was not primarily because of specific details, but because of the overall finding, noted at p. 148 of the Final RIS, that the expected outcome of 6 star (as modelled) would be "...a net loss to the Australian economy...of $259 million, a BCR of 0.88". Our professional assessment is that if this expectation were tested retrospectively, using real world data about what actually happened, it would be very likely to show that this regulatory change in fact created a significant net economic gain, in addition to wider social benefits such as reduced greenhouse gas emissions and electricity infrastructure requirements. However, this research has not yet been commissioned. This example also illustrates that the choice of values for benefit cost analysis can have a significant impact on stakeholder views about regulatory proposals, as well as on public policy outcomes, and this creates an obligation to base that analysis on the best data that is available.

2.2.2 George Wilkenfeld & Associates' Review

In 2011, the then Department of Climate Change and Energy Efficiency commissioned George Wilkenfeld & Associates (GWA) to review the approaches used to benefit cost analyses used in regulation impact statements applied to building regulations in Australia and overseas. This review generally supported the approach taken by Centre for International Economics (*Economic evaluation of energy efficiency standards in the Building Code of Australia: Standardising the cost-benefit analysis*, January 2009) and concluded that it provided "a sound starting point for future RISs" (p. 5). That said, it noted that there were several areas where future analyses could be improved, and that research should be undertaken ahead of a next RIS to reduce uncertainty in key areas. Key areas included the value to be afforded to greenhouse gas abatement, the scope of performance requirements and trade-offs between them (see Section 3 below), inter alia. It recommended explicit target periods and regular (five yearly) review periods. The issue of 'real world data' does not feature in the GWA review. However, the report raised several specific issues which are listed below for consideration for future RIS:

- Grouping building classifications with regard to energy characteristics – this issue relates to whether the various NCC building classifications should be grouped according to similar energy use

[7] *Final Regulation Impact Statement for Decision (Final RIS 2009-06): proposal to revise the energy efficiency requirements of the building code of Australia for residential buildings classes 1, 2, 4 and 10*. Centre for International Economics, December 2009.

and energy system characteristics (recommended) or remain as currently grouped on the basis of fire safety issues.

- Building and system life – a two-tier system incorporating building system life and equipment life was proposed to accommodate permanent design features and equipment ('independent', or not constrained by the building fabric) with shorter life times. This would be difficult to incorporate in a building code, as a builder would not necessarily be aware of proposed 'independent' appliances.
- Scope and compliance criteria and tradable requirements – building codes all over the world are heading towards increasing stringency in energy efficiency. The NCC has already expanded to incorporate lighting, hot water and swimming pool pumps. As more areas of energy use are covered more options for tradability between them occur, and need to be modelled in CBA. While a strong case can be made to maintain the overall thermal resistance of building fabric (R- or U-values), the significant cost reduction in on-site renewable energy (PV) has made tradability more relevant. This was not a factor in the context of the 2010 NCC or the RIS. The BASIX scheme in NSW already allows some tradability. The report recommended tradability should be restricted to fixed systems, and not plug-in appliances. Again, the issue here is that the NCC is a building code which provides dwellings with suitable energy performance before occupants with various lifestyles move in.
- Emissions intensity and on-site energy production – it is recommended that on-site energy production should be recognised in the NCC as an offset to building energy demand, specifically in terms of greenhouse gas emissions so the renewable and fossil fuel based energy can be fairly compared. Obviously, the cost of PV (and battery storage) has reduced to such an extent since 2009 that tradability is now economically realistic, and will be covered in other sections of this report.
- Cost-Benefit Analysis, discount rates, pricing emissions, distribution of costs and benefits, baselines – the approach of the NCC to adopt both energy efficiency and economic efficiency objectives is supported, and notes that net benefits should be economic or monetary only. If reducing greenhouse gas emissions is a national policy objective, then the measure's contribution to realising the objective should be quantified. From a national policy objective, NCC options may need to be weighted against options unrelated to the NCC, and such issues should be clarified before the next RIS. The familiar territory of discount rates is discussed, as well as pricing of emissions, which is a political choice. It is noted that any future RIS on NCC energy efficiency requirements should more clearly identify the distribution of 'winners' and 'losers' from regulatory change. The baseline for measuring the impact of any change due to a regulatory measure is what would happen in the absence of the measure, and it is reasonable to assume that very little would change from the existing minimum performance standard in the absence of a new measure. This is observed in the case of appliance energy standards. Some import of international ideas/technology and builder learning rates could lead some builders to market higher energy performance in a luxury market, but this would not spill over to the standard dwellings.
- Climate types and extremes – the current eight NCC climate zones for DTS are claimed to be adequate. We believe these zones are too "coarse" and that some more representative zones of the 69 zones of AccuRate need to be incorporated in the NCC due to some different climates with large numbers of dwellings being included the same NCC zone (e.g. Darwin and Cairns/Townsville, Western Sydney (Richmond) and all three Melbourne climates). We note that climate modelling suggests that increasing temperatures will change the pattern of heating/cooling requirements in most parts of Australia which means that greenhouse gas reduction goals will be better achieved by dwelling designs appropriate to the future climate. It is recommended that regulatory change require building performance to separately meet both summer and winter thermal comfort and energy use criteria. This approach already applies in BASIX.
- Building plans – modelling for the number of building plans and AccuRate climate zones used in the 2009 RIS was supported as the basis for a future RIS (despite the larger number in 2006 RIS), with a second stage of modelling with a wider range of designs where the B/C is close to or below 1. Designs used in RIS modelling need to reflect local building styles and materials. Given the prospect of climate change, it may also be appropriate to model against 'constructed' 2030 climate files as a

sensitivity measure to help builders understand what design features are appropriate for future climates.

- Selection of fixed heating and cooling, and appliance MEPS – it is noted that the modelling of projected heating and cooling could be improved. The large improvement in the COP of reverse-cycle air conditioning since 2009 (compared with little change in gas heating), together with the low cost of PV, has radically changed choice options. More information needs to be available to allow optimal use of RCAC in future dwelling designs. MEPS for fixed and plug-in appliances has continued to provide energy cost improvement benefits for consumers.
- Building costs – NatHERS modelling is a form of 'industry learning' as the cost of modelling is much less than the cost of DTS compliance. It is not clear how much 'execution learning' by builders occurs over time as new skills are required, and almost impossible to objectively verify. Building costs are a major bone of contention in RIS calculations, as industry resists change, but ex post studies have established that actual costs have been less than the conservative estimates used in the RIS. Wilkenfeld concludes "...there is no evidence of price changes induced by energy efficiency regulations" (p. 55), but at the same time notes that this in and of itself is not evidence of 'industry learning', as other factor prices may have changed at the same time but independently. He recommends specific research, including direct surveying of building firms, to establish the learning rate, noting that "...structured interviews have long been part of the impact evaluations of MEPS and energy labelling [for appliances and equipment]" (p. 55).
- Value of peak load reduction, generation cost savings – relevant issues were discussed, with a recommendation that peak load impacts and their costs and benefits should be incorporated in future RIS. Since 2009 the whole issue of peak load impacts of RCAC has changed due to higher penetration and higher efficiency, along with the massive impact of PV behind the meter. This has become much more of an economic issue for utilities, which try to penalise PV generation while hypocritically overlooking the massive peak load impacts of RCAC. Utilities have yet to recognise and accommodate in tariffs the behind the meter PV generation, which can reduce utility generation and distribution costs.
- Savings in equipment capital costs – such benefits are based on the concept that more efficient buildings can be conditioned with smaller RCAC and HVAC systems than previously specified. Lower kVA loads also feed-back to reduced peak loads.
- Rebound and comfort effects – such impacts have been noted when changing from poor levels (say, 1 Star) to the initial energy performance requirement (4 Star), but with the current standard delivering good comfort standards such impacts do not need to be explicitly modelled in future. Comfort effects have been closely linked to health outcomes in past research, and, in future, expectations of a warmer climate with extended periods of extreme heat may need to be explicitly recognised in RIS, with costs for the consequences of not addressing health impacts.

2.2.3 Critique by Alan Pears and Tony Isaacs

As part of this project, we were given access to a draft paper currently under preparation by two Australian energy efficiency experts, Alan Pears and Tony Isaacs, which critically reviews the 2009 RIS. In particular, it criticises the key finding of the RIS – that 6 star was not cost effective – and notes that with small and reasonable changes in various economic assumptions used in the RIS, the 6-Star standard is very cost effective.

The paper picks up many of the same issues as GWA (above). The key benefits from government pursuit of regulatory energy efficiency are listed as energy productivity, moderating energy price growth, and addressing climate change. The report does not mention real world data but does note that retrospective reviews of other energy efficiency programs have indicated lower costs and greater benefits than originally estimated. Some key points raised were:

- Government policy requires that in a RIS all costs and benefits should be quantified, and even when difficult to monetise all such issues (even unquantifiable ones) should be taken into account. Typically, building energy RIS take a very conservative approach with high costs and tend to ignore unquantifiable issues (e.g. long term health costs of low comfort levels).

- Some field studies of compliance costs have noted actual costs were lower than estimated in the 2009 RIS: ACIL (2008) for the Victorian 5-star standard; SBE (2010) identified design adaptation to lower cost techniques; CSIRO (2013) found that houses with higher ratings (5-Star) were lower cost to build than houses with lower energy ratings based on analysis of hundreds of houses; and Sustainability House (2012) found that redesign to meet standards could lead to lower costs at 6-Star than for 5-Star using then current design approaches.
- The house designs used for the 2009 RIS reflected typical house designs prior to the introduction of energy regulation, and the RIS noted the absence of market adaptation to regulation. Industry learning and new technologies should have driven design adaptation by 2009 so that the step from 5-Star to 6-Star should have been available at lower cost than estimated in the RIS. This issue is particularly relevant for any future stringency change as industry has already had 13 years to adapt and learn.
- The issue of the sharing of compliance costs between buyer and seller of new houses is complex and difficult to verify as every dwelling is sold on an individual contract. There is evidence from hedonic pricing analysis in the ACT and the UK that energy efficiency should be seen as an investment (not a cost) as it is capitalised in the value of the dwelling when sold.
- The estimates of energy prices used in the RIS were criticised as the very large actual increase in distribution costs was not anticipated. The apparently reasonable energy cost estimates at the time therefore significantly underestimated the financial benefit of improved energy efficiency. Also, failure to recognise higher cost time-of-use tariffs further reduced calculated benefits. Any future RIS must reflect national and international climate change policy, with a carbon price or shadow carbon price.
- Peak load reduction is a relevant issue that should be accommodated in any future RIS (e.g. UTS study, and P&S project for WA where peak reduction benefit was modelled using Koomey approach). The 2009 RIS recognised the benefit but did not quantify it. The peak load issue is further complicated by the current higher level of RCAC use and the massive increase in PV behind the meter in the residential sector, and likely in future in the commercial sector. The potential growth of batteries behind the meter further complicates the issue. The SP Ausnet data for Melbourne published by BREE (2014) provides a clear indication of the impact of building energy efficiency on peak load. This is ex poste data and should be used for policy making.
- Climate change will have an impact on peak loads based on studies by BRANZ (2007) and UniSA (2008), with larger peak summer reverse cycle air conditioning (RCAC) loads. In addition, longer periods of heatwave weather will have significantly adverse health impacts. Much of southern Australia is heating dominated, with housing designs appropriate for such climates. Models of future climates (using synthetic AccuRate weather files) indicate that southern Australia could become increasingly cooling dominated (e.g. about 50:50 rather than 10:90 for Canberra). As a consequence, building designs would need to respond to such climate changes given houses last 40+ years, and policy choices would need to be made about weather files used for modelling in future RIS, including sensitivity to a more extreme 2025 weather synthesis.
- Regulation can deliver economy-wide benefits and contribute to economic growth. The RIS undertaken narrowly focuses on B/C analysis for those directly affected. In Victoria analysis in 2002 showed that economic benefits to the whole state for a 5-star standard would be double that for a 4-star standard (Other studies have illustrated such economy-wide benefits from energy efficiency, including a recent IEA (2014) study. Economy wide modelling is a significant and expensive task. For the proposed Victorian 5-star standard modelling was undertaken on 300 dwellings in over 8,000 combinations of orientation/materials/climate. Such a task was clearly beyond the 2009 RIS study. Future RISs, however, should be informed by more extensive building modelling and economic analysis. The building industry is $100+ billion per year and employs ~10% of the national work force, governments should invest significantly to make informed policy choices relating to the whole economy rather than relying on a narrow B/C analysis in a convention that only engages stakeholders to protect their current interests.
- There was an extensive discussion on the well trodden ground of the appropriate discount rate to be used in a RIS for building energy performance regulation. Calculations of B/C with revised

adapted costs, current energy prices and 3% discount rate resulted in all 11 modelled climates of the RIS with B/C > 1 (range 1.4 – 16.2), whereas in the 2009 RIS only three (more extreme) climates had B/C>1 (range 0.5 – 4.3). Several major city climates (Brisbane, Adelaide, Perth, Sydney) had B/C<0.6 in the RIS.

- Other issues identified as not being adequately treated in the RIS were resale values, health benefits, and the societal cost of carbon emissions.
- The rebound effect, used to favour cautious RIS approaches by economists, was addressed with the conclusion that as reasonable comfort levels were reached (5-Star) any future increases in performance should have virtually no rebound impact. The CSIRO (2014) study was identified as a possible means to identify rebound, but no conclusion could be drawn. This study in comparing nominally 4-star and 5-star dwellings found significant improvements in heating energy savings, but no cooling energy savings. The possible explanations do not invalidate the NatHERS tools or involve rebound.

2.3 Information/Data Requirements for a RIS – Overview

Noting the above discussion of RIS, benefit cost analysis and regulatory burden measurement, it is clear that a large amount of data and other forms of information must be compiled and assessed in the context of a (long form) RIS. To an extent, the detail of that data and information is contingent on the precise nature of the regulatory proposal. However, this section aims to provide an overview of the classes of information needs, to help inform where 'real world data' could at least potentially be gathered and applied.

In short, we need data and information to analyse:

Table 1 Information/Data Needs for a RIS

Policy Question	Key Data/Information Needs	Details
What would be expected to happen in the absence of (new) regulation/ intervention?	• Current and historical data on housing stock composition and changes through time	• Annual stock turnover/ vintage model, ideally capturing new builds, major renovations, demolitions – by climate zone – for each building class – ideally by height for Class 2s • Dwelling numbers and floor area (to account for varying average size of dwellings)
	• Current and historical data on actual energy consumption	• All fuels, same spatial, building type and temporal resolution as above • Must resolve at least space conditioning energy use, lighting, hot water, pool and spa pumps and 'other plug load' end-uses by fuel • How many houses have access to gas as well as electricity? • Numbers of appliances as well as their efficiency – a stock turnover/vintage model for appliances • Peak demand trends through time as well as annual energy consumption • Impacts of existing policy measures on the above

Policy Question	Key Data/Information Needs	Details
	• Statistically valid picture of occupancy, relevant occupant behaviours, demographics or other factors	• Could be surveyed • Persons per dwelling • Hours of occupancy and particularly space conditioning • Changing trends, eg, with respect to cooking, ventilation/shading behaviours (windows, curtains) • Other performance indicators like internal temperatures and variability • Population, household and dwelling statistics, including projections over the expected life of new houses affected by the regulations
	• Distributed or 'behind the meter' generation	• Installed capacity and output by technology type (generally PV)
	• Technology cost/performance expectations (under BAU assumptions)	• Historical, current and plausible expectations • Necessary to establish BAU trends, against which to compare 'policy scenarios' below • Expected impacts of existing policy measures (eg, MEPS and labelling of appliances)
What would be expected to happen with the regulatory proposal, and also with at least two other options?	• Information/ data to represent the expected impacts of the interventions • A generic framework is as follows: ○ document all the available savings options that are available, their cost and performance, by climate zone, by house type, persistence of benefits and costs through time ○ the starting point uptake of the above measures/behaviours today (prior to intervention but including as affected by earlier or related policy measures) ○ the expected rate of *additional* uptake of these measures/ behaviours <u>attributable to</u> the regulatory proposal (or other non-regulatory measures) – stringency of requirements, expected/ least cost solutions, how	• Savings options need to be fully characterised for their *incremental* costs and also savings performance – noting that these may be contingent on climate, dwelling type and other factors ○ This is why the actual costs and outcomes under BAU must be calculated, as above, to enable *incremental* impacts to be separated from total or absolute ones ○ Where possible, real world data on the savings performance of induced investments or changes, and also their costs, should be used, noting that both can vary through time. • The persistence of costs and benefits through time is critical ○ Persistence of benefits is generally associated with the economic life of the induced investments or other changes. Generally only 'first round' changes are modelled, and not future re-investment post the economic life of the first round

Policy Question	Key Data/Information Needs	Details
	prescriptive is the regulation? ○ the maximum feasible/ likely uptake – physical or other forms of limit on maximum uptake ○ the direct costs and direct benefits of each option on a with/without or before/after proposal basis; ○ the indirect or external costs and benefits attributable to each option ○ sensitivity analysis on key variables •	changes, due to uncertainty. ○ Persistence of costs is represented by the learning rate, as discussed in this report. • External or indirect costs and benefits can be very difficult to quantify – but OBPR guidance (see below) makes it clear that this should be attempted to the extent possible, with qualitative description used as a fallback.

2.4 Existing Data/Research

Building on the general framework above, this section reviews and assesses the current and expected availability of real world data that may be able to be applied to the problem of determining the appropriate level and character of future (2019) energy performance regulation for residential buildings. This leads to an overall assessment of opportunities and gaps in the knowledge framework and, as a function of this, an analysis of research needs. These needs are then prioritised on the basis of their importance to a future RIS and also practical constraints, such as the time and cost required to complete the research to a 'fit for purpose' level. Prioritised research tasks are then summarised, with an assessment of expected timelines and costs, and a research brief provided for each in Appendix A.

2.4.1 Public Domain Data

There are significant data resources in the public domain that are routinely used for RIS and related purposes. These are well known and not reviewed in detail here, but briefly noted.

Australian Bureau of Statistics

They include numerous statistical series from the Australian Bureau of Statistics (ABS). This is of course survey data which is carefully designed for statistical significance, but which does not purport to describe every 'real world' situation. Relevant series include population data, dwelling numbers, household composition, new housing starts and completions, and the Energy Use and Conservation series (4602).

Energy Consumption Data

Energy consumption data by fuel, state and ANZIC code is compiled by the Office of the Chief Economist (OCE), formerly ABARE, then BREE, and published under the primary title of Australian Energy Statistics. This activity occurs under an agreement with the ABS. Since 2011 this publication has also been informed by data from the National Greenhouse and Energy Reporting scheme, NGER. The latter relates primarily to the energy consumption at sites that consume 0.5 PJ or more of energy annually – essentially, very large energy users. While the OCE data is helpful, it is much too coarse to provide anything other than 'top down' observations of total residential energy consumption by state, for example. This data is useful for validating stock turnover models, but otherwise cannot be directly used in the context of a residential RIS.

The Australian Energy Regulator publishes RIN (Regulatory Information Notices) data, sourced from electricity and gas distribution businesses, which indicate total energy consumption in calendar years, by sector (residential, non-residential) for the whole of the distribution area (these can be quite large). The data does not reveal the extent to which embedded generation is present which, to the extent that it is, means that 'real' demand would be higher than the apparent or metered demand shown. The data may be used to calculate distribution area wide average energy intensities, for example, or to validate models of residential energy consumption.

The underlying source of this data is electricity and gas meter data, generally referred to as 'NMI data' (National Meter Identifier). NMI data is a key potential source of 'real world data' source, and the possible application of such data is discussed further below. The key limitations are as follows:

- The data is collected by Meter Data Service Providers, as a contestable service under the NEM, for the primary purpose of billing.
- The data is not publically available in any form other than the RIN data, as above, and therefore the potential to use much of the information in this data (time of use, location, etc) is in fact lost in the aggregation process.
- To match the NMI data with a particular household requires access to additional and private data sources (names and addresses, for example held by electricity retailers for billing purposes) or the permission of the relevant householder.
- Without such information, NMI data on its own does not indicate the nature of the dwelling or household 'behind the meter', for example, how many persons live there, how large is the dwelling, what other fuels are being used in the house, is there embedded generation at the site and, if so, how much, what is the star rating of the house, what is the age of the house, etc? This information could potentially be ascertained through surveys or other research techniques.
- Similar gas meter number data exists for retail gas billing purposes, but there appears to be even less transparency about the extent and quality of this data than there is for electricity. There also appears to be no industry standard for a 'residential consumer' and therefore the limited public reporting by Energy Gas Australia is presented by consumption size only, without identifying the nature of the end use consumer.

Overall, the potential to derive much greater value from energy meter data, without compromising privacy or confidentiality concerns, is very large. **pitt&sherry** has previously provided detailed analysis and recommendations on this issue in our *Energy Efficiency Data Framework* report for the Department, 2012 (unpublished). CSIRO currently has a relevant research project in this area which is described below.

Residential Building Baseline Study

The Residential Building Baseline Study (2014) commissioned by the Department is essentially a model of housing and appliance energy use in the residential sector. The primary real world data that informs this model includes the ABS and OCE data noted above, along with highly detailed sales data (supplied by GfK) for many classes of appliances and equipment. These sources can be combined to enable detailed statistical models of housing and appliance stock turnover to be modelled. However, such models should ideally be validated with extensive, statistically significant 'bottom up' or real world data on the actual patterns of appliance and housing energy use across Australia. The Baseline Study itself provides very little useful information, and model results are presented primarily as figures and charts, with little transparency as to the underlying data. The Department holds the model and data and may be able to assist with further analysis.

House Energy Monitoring

Some individual house monitoring studies have been undertaken by the Australian Government and other institutions. The *Residential Energy Monitoring Program* led to five houses in Victoria being monitored at a highly detailed level for a year, but plans to expand that program to at least 60 houses in three climate zones were abandoned. The primary reason for this was cost. It can cost at least $20,000 per house to install and maintain monitoring devices, and of course this is an 'invasive' methodology that requires very significant investment of time and effort to recruit willing volunteer households. This, together with cost constraints on the total number of houses able to monitored, limits the statistical validity and usefulness of the results.

Further houses in South Australia and Queensland have been similarly monitored over significant periods of time by the University of South Australia and QUT respectively, and these results would provide 'deep dives' into a limited number of houses in those specific climate zones. CSIRO utilised a similar methodology for over 400 houses for its 5 Star *ex poste* evaluation project, as described below. A current CRC for Low Carbon Living study evaluating the BASIX scheme in NSW is monitoring nearly 50 dwellings around Sydney and the results will be available in 2017.

Overall, this type of data – if collected in the context of a valid methodology – can be extremely valuable for understanding how specific homes are used by their occupants, specifically with reference to their energy-using behaviours. However, the results are limited in their statistical significance. Much larger sample sizes – hundreds or thousands of dwellings, of all times and across a spectrum of climate zones – would be required for analytical purposes. Finally, all of these monitoring exercises that we are aware of relate to Class 1a) dwellings only: we have no similar data for terrace houses or apartment buildings.

2.4.2 CSIRO Research

CSIRO is undertaking at least four relevant research programs that both offer significant potential to deploy real world data to help establish future energy performance requirements for houses:

1. Development of the Chenath/AccuRate rating tool under the Nationwide House Energy Rating Scheme (NatHERS)
2. Energy Use Data Model (EUDM) – pilot study
3. Ex-Poste Evaluation of 5 Star Housing and related ongoing research.

CSIRO also participates in the Cooperative Research Centre for Low Carbon Living, and other relevant projects are underway in this context. These are described briefly in turn below. Note that our understanding of these projects is limited to that which has been able to be gleaned from public domain sources, such as websites, together with brief discussions with several researchers. More detailed descriptions would be available from CSIRO and other CRC participants.

Chenath/AccuRate/NatHERS

The Nationwide House Energy Rating Scheme, commonly known as NatHERS, was developed by the Australian and State/Territory Governments, in partnership with CSIRO, in the early 1990s as a 'measuring tape for energy efficiency' (NatHERS website) for Australian homes, or rather for their heating and cooling energy use. NatHERS is a scheme that provides homes with a star rating out of ten based on a modelled estimate of a house's 'potential' heating and cooling energy use, given their particular design, construction, location and other factors. NatHERS '...encourages energy efficient building design and construction by providing a reliable way to estimate and rank the potential thermal performance of residential buildings in Australia'.[8]

All three current NatHERS accredited rating tools are ultimately based on a thermal simulation engine that was developed by CSIRO, known as Chenath, including CSIRO's own tool AccuRate. Chenath essentially models the amount of purchased energy that would be required by a given house design to maintain reasonable comfort (an internal temperature band, normally 18 – 24 degrees) in that location and given the design/specification details entered by the assessor.

CSIRO maintains an active research and development program around Chenath/AccuRate and this program has accelerated following the institution of an effective 'royalty' of some $8 - $10/assessment that is returned to CSIRO for research purposes from all assessments undertaken using NatHERS-accredited tools.

[8] *Administrative and Governance Arrangements*, NatHERS National Administrator, August 2015, p. 3.

CSIRO estimates that at least 70% of all new house energy performance compliance assessments are undertaken using NatHERS-accredited tools. The primary reason for the assessment industry 'voting with its feet' in this way is that NatHERS simulation tools provide a mechanism for the designer/builder to achieve the required energy performance standard at least cost, by varying designs, orientations, specifications, materials to find optimal and least-cost solutions.

Of particular relevance in this context of this study is that since mid 2014, NatHERS-accredited tools have started to generate a 'Universal Certificate' that carries key, summary information about each rating, with details of each rating being sent to an online database (one tool, BERS Pro, only started using the universal certificate in May 2016). There are currently two databases, one managed by CSIRO which collects ratings from AccuRate and BERS Pro, and one linked to FirstRate5.


Nationwide House Energy Rating Scheme* Certificate

Certificate number: 87654321 | Date of certificate: 12 April 2014 | Star rating: 6.5

Assessor details

Accreditation number: 12345678
Name: Fred Williams
Organisation: Capital Building Assessors
Email: frederick.williams@cbassessors.com.au
Phone: 0412 123 456
Declaration of interest: Employed by designer of the building
Software: FirstRate5 v5.5.11
AAO: ABSA

6.5
The more stars the more energy efficient
NATIONWIDE HOUSE ENERGY RATING SCHEME
Predicted annual energy load for heating and cooling based on standard occupancy assumptions
1234 MJ/m²
For more information on your dwelling's rating see: www.nathers.gov.au

Overview

Dwelling details

Address: Unit 15, 237 Edwina Mountbatten Drive
Suburb: West Wyndham
State: NSW | Postcode: 2345
Type: New dwelling | NCC Class: 01
NatHERS climate zone: 14
Lot/DP number: 9/53 | Exposure: Suburban

Key construction and insulation materials (see following pages for details)

Construction: Brick veneer; Ceramic tile roof; Slab on ground
Insulation: R1.5 wall insulation; R3.5 ceiling insulation
Glazing: Timber frame; Single glaze clear

Ceiling penetrations (see following pages for details)

Sealed: 5
Unsealed: 18
TOTAL**: 23

**NOTE: This total is the maximum number of ceiling penetrations allowed to a ceiling (under a roof) for this certificate. If this number is exceded in construction then this certificate IS NOT VALID and a new certificate is required. Loss of ceiling insulation for the penetrations listed has been taken into account with the rating.

Principle downlight type: Compact fluorescent

Net floor area (m²)

Conditioned: 55
Unconditioned: 23
Garage: 12
TOTAL: 90

Annual thermal performance loads (MJ/m²)

Heating: 576
Cooling: 658
TOTAL: 1234

Window selection – default windows only

Note on allowable window values: With a 10% tolerance to the nominated SHGC window values shown on page 2, the following ratings are achieved:
-10% SHGC 6.3
+10% SHGC 6.6
NB: This tolerance ONLY applies to SHGC, the U-value can always be lower but not higher than the values stated on page 2.
If the rating listed above falls below 6.0 stars or the required rating, then the window with this tolerance can NOT be selected.

Scan to access this certificate online and confirm this is valid.

Plan documents

Plan ref/date: Ref24/88
Prepared by: Wyndham Sustainable Homes

* Nationwide House Energy Rating Scheme (NatHERS) is an initiative of the Australian, state and territory governments. For more details see www.nathers.gov.au

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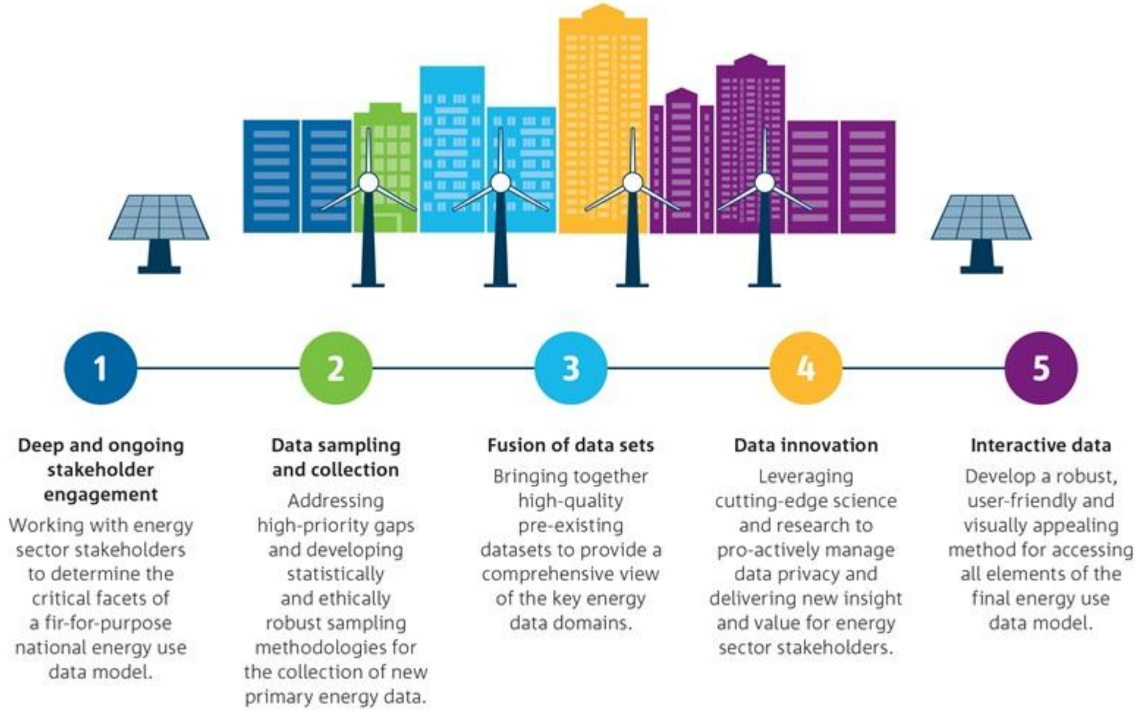
Figure 1: NatHERS Universal Certificate (Sample)

As a result of this, CSIRO has access to a database that is understood to currently hold some 24,000 records of individual dwellings rated by NatHERS accredited tools since July 2014. The Department does not have direct access to this data. The size of this database will grow rapidly in future, particularly with the recent re-accreditation of BERS Pro. CSIRO has indicated that 15%, or some 3600, of the current records relate to dwellings with a star rating of 7 star or more. This opens up the possibility that this data could be used to assist in understanding the actual as well as modelled energy consumption of a very large number of houses, including those with a performance level beyond the current minimum requirement (6 star in most jurisdictions). Importantly this could include data on Class 2 as well as Class 1 buildings. This possible research program is discussed further in Section 2.3.5 below.

End Use Data Model –Pilot study

CSIRO, with Departmental funding, is currently working with stakeholders from across the energy sector to create an integrated Energy Use Data Model (EUDM) that will provide publicly accessible fine-grained energy-use data through a central online platform, capturing not just measured consumption, but also key demographic and technological facets of Australian consumers.

This rich dataset will provide the foundation for the energy sector to develop the efficient energy system of tomorrow, enabling new insight into how peak load, daily load shape, demographics, technology and environment all interact to shape contemporary Australian energy behaviour.



Through extensive stakeholder engagement across the sector, EUDM will develop a one-stop-shop for critical energy-use data to help energy researchers, policy makers, regulators, market operators and consumers explore how people are using energy in Australia and the many factors that are influencing that use.

Of particular relevance to this report is the current CSIRO plan to conduct a trial, beginning in July 2016, to capture and analyse data on up to 4000 homes in Victoria where the key data source would be smart meter data information (with permissions from participating households), backed up by extensive surveys of households to establish parameters such as building construction details, occupancy, appliance uptake and use, and other factors. It is understood that the star rating of the houses will not be captured (as it may not be known by the current occupants) but that the date of construction (or first connection) will be captured as a proxy.

While we do not have a detailed description of this pilot, which is still under design at the time of writing, it offers the potential for both a 'deep dive' into specific households and their energy consumption behaviours, matched with a very large sample size. Further, as a pilot, the value of this study (for RIS analysis purposes) could be significantly expanded if similar data/analysis became available for other states and territories. While it is understood that the study will be undertaken in the second half of 2016, it is not yet clear when the results will be published and in what form and resolution. Clearly, the limitation to one state (although NSW may join the pilot) would limit the direct value of the results for RIS purposes in the short term, it may also support Australia-wide observations as well.

From the perspective of a future RIS, the particular opportunities for this study would include:

- That every effort is made to capture data on, or otherwise discover, the star rating of each dwelling. This would potentially then enable the data to be analysed in cohorts by star band. Data should be sought in at least the 6 – 8 (or more) star bands (eg, selecting dwellings with ratings +/- .25 star of these points), to facilitate both retrospective analysis of 6 star and prospective analysis of possible new performance requirements.

- A specific opportunity may exist to match the data compiled for this study with data from the NatHERS database, as described above, by simply matching addresses between the two data bases (assuming the house designs that were rated are now built and occupied). This would amount to a material improvement on the above methodology, as age of dwelling or date of first connection to services is only a rough proxy for star rating and specifically would not resolve those houses that over (or under) complied with the relevant standard applying at the time of first connection. This means that the cohort of above-current-minimum-standard dwellings could not be isolated and analysed independently of the 6 star houses. Knowing the star rating for at least a large sample of the houses surveyed would enable specific correlations of actual energy consumption with star rating which, for a large sample, should indicate a predictable negative correlation on average (declining energy consumption with increasing star rating), while the survey data would enable normalisation of energy consumption data for a range of key factors, notably including occupancy but also potentially many other behavioural factors.
- Further, we note that rather than selecting a random sample of houses for survey/data analysis, it would be possible to use the NatHERS database (which includes addresses and star rating information) to seek to recruit specific cohorts of houses that correspond to specific (rated) star bands (eg, 5, 6, 7, 8). This would facilitate cohort based analysis that would potentially be directly applicable to a future RIS.
- Data should be layered by building class, resolving Class 1a)i), Class 1a)ii) and Class 2 dwellings.
- Data would need to be captured on electricity and gas metered consumption; whether or not PV is installed 'behind the meter'; and if so, either kW installed or (better) measured annual output.
- Ideally additional climate zones beyond Victoria would be included in the study.
- The study would need to be completed by early in 2017 to input into a RIS.
- CSIRO would need to agree to share/publish the (de-identified) data with the entity undertaking the RIS.

We note that this study follows a previous one by the Department using SP Ausnet data with results published in *Energy in Australia 2014* (BREE 2014). This electricity consumption data over a short period for stocks of pre-2007 (mostly 4-Star), 2007-2010 (mostly 5-Star) and post-2010 (mostly 6-Star) dwellings within its distribution area clearly showed significant improvements in electricity demand for both mild and especially hot days. The large sample size allows for variability in occupant hours and behaviours to be 'washed out' in the averages. That said, the lack of resolution of the exact nature of the houses, their star ratings and of occupant behaviours, *inter alia*, limits the utility of this analysis, and the CSIRO methodology above is expected to overcome these limitations.

A second part of the EUDM pilot study that we understand is under active consideration for a potential July 2016 commencement is a project that will co-locate CSIRO staff with AEMO to essentially map and understand the potential for relevant data flows to be captured, in de-identified form, by the EUDM project for further analysis. We understand the objectives of the project will include exploring the scope to associate energy consumption data – potentially both electricity and gas – with parameters such as climate zone, household demographics, building characteristics including age, and also to use load analysis to identify appliance use within overall household energy use and to develop representative customer profiles. The scope of this project will be national, or at least NEM-wide. We understand that the primary focus will be to capture annual consumption data, on the grounds that quarterly data from accumulation meters may be estimated rather than read. We note that only a percentage of quarterly billing data is estimated, and there is likely to be value in quarterly data, in particular to track seasonal trends, particularly if individual consumption data is adjusted retrospectively following meter reads. The primary data source to be explored will include AEMO's MSATS (Market Settlement and Transfer Solutions) database. It is not clear whether gas data will be able to be compiled, but this is strongly recommended.

5 Star Ex Poste Evaluation

This study was based on a large and valuable collection of measured ex poste conditioning energy data for some 209 (from an original recruitment of 414) dwellings in Brisbane, Adelaide and Melbourne around the

4- to 5-star level (i.e. before and after the 2006 increase in stringency in the NCC). The star ratings of all dwellings were modelled with AccuRate (rather than relying on the original regulatory compliance rating); energy bills were obtained and internal and external temperatures measured. Statistical methods were used to explore whether measured heating and cooling energy related to star ratings.

The key results of the CSIRO study are found in Section 10 of the study report – *The Evaluation of the 5-Star Energy Efficiency Standard for Residential Buildings*. The 209 houses fitted with data loggers were grouped into two cohorts after being re-rated with AccuRate: <5-star, in fact <4.5-star; and 5-star or better, in fact >4.5-star. The basis for this recruitment into cohorts was to ensure meaningful sample sizes, and also to account for the fact that the houses when designed would have been rated with an older version of the NatHERS software which may give slightly different results to later versions. Various factors, however, made it difficult to draw robust conclusions:

- Uneven distribution across star rating values means that sample size restricts statistically meaningful conclusions;
- Small sample size means uncertainty over the degree to which the data set is representative of Australia (with regard dwelling type, occupancy numbers and user behaviour);
- Above average summer temperatures made it likely that RCAC and AC units were running at full capacity making it difficult to detect differences between low and higher star rating cohorts;
- Higher rated houses were generally newer than lower rated houses (no surprise given the progression of regulatory stringency over time), and may have resulted in some inherent bias – newer houses were more likely to contain younger children and be occupied all day;
- The expected energy ratings of new houses in the sample did not increase in line with changes in building regulation – this could be an issue of timing between approval and construction, or a failure of regulatory compliance.

The focus of the results is the correlation between star rating (i.e. the sum of heating and cooling conditioning energy in MJ/m^2) and actual heating and cooling energy differences between the '4-star' and '5-star' cohorts. One issue that emerged was that the winter temperatures of "5-star" were 0.6-0.9^oC higher than the '4-star' dwellings. The reason for this was not determined, but this difference was compensated for in comparing energy savings to ensure a like-for-like basis. There is no reference to AccuRate modelling being used to compare actual temperatures with modelled temperatures for houses in both cohorts, with the aim of exploring this difference.

The main findings were as follows:

- The 5-star standard reduced energy needed to maintain comfort in winter, with calculated results for Brisbane (-20%, 0%), Adelaide (-39%, -19%), and Melbourne (-56%, -50%) indicating significant benefits. The second percentage figure shows the benefit without adjustment for reducing the temperatures in the 5-star houses.
- The average cooling energy use in summer was higher in the 5-star houses in all three cities, with no differences in average temperatures between the lower- and higher-rated houses. No conclusion was drawn as to the reason for this outcome, with various options suggested (5-star standard, house occupancy with more kids in higher-rated cohort, higher full-time occupancy, and behavioural factors such as operation of windows and blinds).
- Overall, for the 5-star cohort, greenhouse gas emissions were reduced in all cities despite more cooling energy in summer.
- For the 5-star cohort, total conditioning energy costs increased in Brisbane, fell slightly in Adelaide, and fell significantly (-37%) in Melbourne.
- The higher-rated houses cost at least $5000 *less* to build in Adelaide and Melbourne and up to $7000 less in Brisbane <u>for those elements of the building related to energy efficiency</u> than lower-rated houses. Increased insulation and an apparent shift to more rectangular house design were the main factors observed in the shift to higher-rated houses. Note that, for any given floor area, a perfect square minimises exterior wall area, and therefore reduces cost.

We note that because these dwellings were modelled in AccuRate, in non-rating mode there was a capacity to determine and compare measured and modelled internal temperatures for all houses in both cohorts and to compare measured and modelled heating and cooling energy for all houses in both cohorts. We are unaware of any reports exploring correlations between actual heating and cooling energy with AccuRate modelled heating and cooling energy totals. Such analysis may help resolve the apparent anomalous results for measured cooling energy, and produce better correlations that those between heating and cooling energy with the sum of heating and cooling energy (i.e. Star rating). The same issue may have clouded the analysis of energy bills.

Like others (eg, Pears/Isaacs above) we have noted that most Australian homes are built in heating climates, and it appears that the housing industry's response to addressing 5-star involved a focus on reducing heating loads, which are generally cheaper to reduce than cooling loads. It can be noted that the street appearance of new houses changes little from southern climates to Brisbane, with project home designs in particular being remarkably consistent regardless of widely different climate conditions. Also we note that waste heat from cooking and from appliances tend to reduce the need for heating in winter but increase the need for cooling in summer. Noting that climate change is expected to increase the frequency and severity of extreme events, including heatwaves, the relatively poor performance of houses in summer should be a source of concern, with the underlying causes understood and addressed in the 2019 version of the NCC.

A major surprise from the CSIRO analysis was the significant reduction in costs ($5000) for "5-star" compared to "4-star" in sharp contrast to building industry lobbying on all energy performance requirements. Essentially every house construction is a separate contract, which makes obtaining sufficient statistically significant data on costs very difficult, with both privacy and commercial-in-confidence issues involved. Construction techniques observed for higher-rated houses were more rectangular designs, higher levels of insulation, increase in waffle-pod slabs, double-glazing and changes in window orientation. Most involve additional costs, but some reduce costs. In particular a rectangular or squarer design reduces wall area, and a reduction in glazing area further reduces costs. The squarer design can reduce wall and window area while maintaining the wall-to-window ratio. Details of the CSIRO cost analysis (Section 7, Appendix F) are provided in the following extract from the report.

The cost analysis involved extracting a list of materials and components, and their corresponding quantities, from the AccuRate file for each house. Essentially, this resulted in a bill of quantities for those elements of the house that affect star rating. For each star-rating cohort in each city, the quantities of the various elements were summed and then divided by the number of houses in the cohort to derive an average quantity of each element for a 'typical' house. The resulting quantities for each element were then costed using cost data obtained from Rawlinsons Cost Guide 2011 (Rawlinsons, 2011). Appendix F lists the unit costs that were applied.

Finally, the following assumptions were made to allow cost comparisons.

- Expanded polystyrene in floors was considered to be waffle pods.
- The cost of waffle pod concrete slab and standard in-ground concrete slab was considered the same, so no cost difference was calculated.
- All windows (both single and double-glazed) were considered to be awning windows with aluminium frames.
- All external walls were considered to be brick veneer with timber stud and painted plasterboard.
- All wall and ceiling insulation was considered to be glasswool batts of the specified R value.

Such an approach has been used in the past (e.g. ABSA project for the AGO in which three typical dwellings in some 20 locations were selected, modelled and improved to 5-star in the model, with the improvements costed).

CSIRO continued to collect energy use data from many of the houses in the project past the time of the initial report, but no further data has been released by CSIRO. The real world data obtained by CSIRO can be used to obtain further insights on the relationship between modelled and measured energy. However, to obtained statistically valid understanding of differences between lower- and higher-rated dwellings much larger samples are needed to "wash out" variations caused by occupants. The alternative to spending more millions on measurements is to give modelling a real world stamp with more research and development using the measured energy data already available.

For the purposes of a future RIS, we note that this data set was compiled exclusively for Class 1a)i) (detached) dwellings and therefore provides no insights into the actual performance of semi-detached and apartment buildings.

2.4.3 CRC for Low Carbon Living

The CRC for Low Carbon Living (CRCLCL) is a national research and innovation hub that seeks to enable a globally competitive low carbon built environment sector and is supported by the Commonwealth Government's Cooperative Research Centres (CRC) program. The CRC for Low Carbon Living's research leverages world class expertise from five universities and CSIRO as well as industry and government (45 partners). The research builds on multidisciplinary expertise, existing technology development, social research and national benchmark software tools in application to low carbon living in the Australian context, addressing the unique requirements of the Australian climate, construction practices, demographics and policy environment. The CRCLCL has three research programs, reflecting the three pivotal "bridges" that must be crossed in order to deliver a low carbon built environment.

The CRC runs two research programs that may be of relevance to a future RIS: the Integrated Building Systems program – developing new low-carbon products and finding ways to communicate best practice design through rating tools, standards and display homes – and the Engaged Communities program. Under the Integrated Building Systems program, some relevant projects include:[9]

- RP1021: Reframing Building Regulation - *This project will examine the role of best practice building codes, standards and regulations as a catalyst for transitioning to low carbon living.* Project leader: Prof. Peter Newman
- RP1026: Evaluation of Next-Generation Automated Fault Detection & Diagnostics Tools for Commercial Building Energy Efficiency. This project will assess emerging automated FDD tools across a range of commercial building types and HVAC systems. Project leader: Dr Josh Wall (note that while this project is commercial building focused findings could be relevant, especially to apartment buildings)
- RP1023: Forecasting and home energy analysis in residential energy management solutions - This project will develop algorithms for software that interprets energy supply and demand at the system level. Project leader: Associate Professor Alistair Sproul
- RP1017: Validating and Improving the BASIX Energy Assessment Tool for Low-Carbon Dwellings - This study will help identify areas for improvement of BASIX assessment models and inform future sustainability strategies and policy. Project leader: Dr Lan Ding
- RP1006: Viable Integrated Systems for Zero Carbon Housing Systems. Project status: Complete; Project period: October 2012 to October 2013; Project leader: Prof. Wasim Saman, UniSA; See more at: http://www.lowcarbonlivingcrc.com.au/research/program-1-integrated-building-systems/rp1006-viable-integrated-systems-zero-carbon-housing#sthash.a4mNzBcf.dpuf
- RP1006: Lochiel Park Monitoring Case Study: http://www.lowcarbonlivingcrc.com.au/sites/all/files/publications_file_attachments/rp1006_lochiel_park_monitoring_case_study.pdf
- RP 1024: Facilitating the transition to low carbon housing (which includes developing the 'third generation' of NatHERS tools). This project is just commencing.

[9] http://www.lowcarbonlivingcrc.com.au/research/program-1-integrated-building-systems)

The Lochiel Park research builds on similar research on six dwellings at Mawson Lakes (prior to 2004) but covers 103 dwellings in Adelaide. In the Lochiel Park development (2010 – present, with ongoing monitoring) dwellings as planned were required to deliver 7.5-Star performance. In a recent publication based on 11 of these dwellings (with multi-year data) the correlation between AccuRate modelling and actual conditioning energy was explored. The average energy performance in Lochiel Park showed the expected reduction from the average of Mawson Lakes, but there was a significant spread of results (in both small samples) due to occupant behaviour.[10] Monitoring at Lochiel Park is continuing, and the full significance of the work will not be available until the multi-year rear results are available for all dwellings.

2.5 Key Knowledge/Research Gaps and Opportunities

2.5.1 Introduction

Our assessment of key knowledge/research gaps and opportunities draws firstly on the (brief) literature review in Section 2.2 above. Second, we conducted informal interviews with a number of researchers from CSIRO and a number of universities involved with the CRC for Low Carbon Living. Third, we held an invited expert workshop in Melbourne on 31 May 2016 that was attended by:

- Alan Pears
- Robert Foster (Energy Efficient Strategies)
- Tony Isaacs (invited but withdrew due to ill health)
- Gavin Ashley (Moreland Energy Foundation Limited)
- Gordon McAllister (DIIS)
- Dr Tony Marker (pitt&sherry)
- Dr Elena Tinch (pitt&sherry)
- Philip Harrington (pitt&sherry).

We note that this methodology does not amount to an exhaustive summary of all possible relevant research currently being undertaken in Australia, but rather amounts to a fit-for-purpose study in a limited timeframe that taps into the primary research service providers in this field in Australia. The views noted below should not be attributed to any party other than **pitt&sherry**.

Noting the short amount of time available for new research ahead of a RIS in 2017, we give precedence in this section to first-order research questions, without which it would be difficult or impossible to conduct a RIS in 2017 based (largely or exclusively) on real world data. We then more briefly note those other knowledge/research gaps that ideally would be researched, but may not have as large an impact on a RIS in 2017, or may be considered lower priority for other reasons.

2.5.2 Key Issues

Overall, the process followed above has highlighted that there are a large number of important knowledge gaps and research questions that would ideally be structured into a coherent and policy-relevant research program that is progressed in a structured and ongoing manner over time. We acknowledge that there is a significant amount of buildings-related research underway in CSIRO and various universities, but this research is not, so far as we are aware, co-ordinated and organised specifically to feed into anticipated future policy needs, and in line with the timelines required by policy processes. Despite this, as we note above, many of these projects are nevertheless highly relevant in a policy context.

In addition to the information and data needs to support an evidence-based RIS, drawing to the extent possible on real world data, past RISs – and stakeholder/expert reactions to them – have created a set of

[10] O'Leary, T, Belusko, M, Whaley, DM & Bruno, F 2016, 'Comparing the energy performance of Australian houses using NatHERS modelling against measured household energy consumption for heating and cooling', Energy and Buildings, v. 119, pp. 173 - 182. DOI 10.1016/j.enbuild.2016.03.025

expectations which, if not fulfilled, risk creating barriers to a future RIS and subsequent decision making process around possible future energy performance requirements in the NCC. In short these are:

- Do we have evidence to show that past energy performance regulation, and 6 star in particular, has been effective and cost effective in meeting the NCC's and COAG's objectives?
- In particular, are dwellings complying with the current standard? Were the costs of compliance higher or lower than anticipated?
- Have there been any unanticipated and potentially negative outcomes (such as the suggestion of better winter than summer performance)?

There are then specific questions that must be answered in a future RIS, and which should be illuminated by real world data to the extent possible:

- Can we have confidence that higher star ratings will generate additional energy savings (and other economic benefits)?
- Can we have confidence that the costs associated with achieving these benefits will be reasonable and that the regulation will be cost effective?

These general questions break down into specific knowledge needs with an associated research task or tasks.

2.5.2.1 Incremental costs

The incremental or additional costs of compliance are key input into the benefit cost analysis supporting a RIS. The key question, in broad, is 'how does the building industry respond to new energy performance requirements?' Does it simply add costs – such as better quality glazing, additional insulation, etc – or does it modify designs, for example to adopt more passive solar principles, or a combination of both? Do product, materials and technology suppliers innovate their product lines? By how much does the new demand for higher performance elements lead to economies of scale in their production and supply? Does it turn currently niche products (like high performance glazing) into market standards, leading to a reduction in price premiums now paid? How quickly does the construction industry innovate and learn new techniques, like new construction processes, new materials handling equipment, off-site pre-fabrication, etc?

We believe there is insufficient time to quantitatively answer all of these questions ahead of a 2017 RIS. However, we believe it is feasible and critical to at least determine:

- What real world data is available to help us understand the expected incremental costs associated with higher performance standards?
- What evidence is there about past responses in reality, and what does that indicate about the expected behaviour of industry in the lead up and subsequent to a potential regulatory change in 2019?

2.5.2.2 Energy Savings

Energy, and associated greenhouse gas emission, savings are a key rationale for energy performance requirements in the NCC, addressing its sustainability goals. It is therefore critical to have confidence that higher energy performance standards do in fact lead, on average, to material energy savings. We also need to have confidence that, when combined with the expected incremental compliance costs discussed above, these savings (and other co-benefits – see below) will be cost-effective.

We note that the potential *scope* of energy end-use covered by the NCC energy performance requirements is the subject of Task 2, discussed in Section 3 of this paper. Already this scope includes elements other than the star rating of the thermal shell, and there are a range of issues regarding scope that may feedback into this discussion of the overall energy savings and their cost-effectiveness. For example, the future performance targets for fixed appliances will have a material impact on the overall cost-effectiveness of future Code requirements, but these issues are considered in Section 3.

Setting scope questions aside, the key question is whether we can have confidence that lifting the thermal performance requirements will be effective (leading to material energy savings) and cost-effective. An inherent challenge in this context is the nature of the star bands within NatHERS. As discussed in the 2012 Pathway to 2020 report, each successive star band is associated with a declining amount of space conditioning energy use in absolute terms. For example, in Melbourne, the expected difference in thermal load on a 6 star versus a 5 star house is 40 $MJ/m^2.a$, while the expected difference in thermal load on a 9 star versus an 8 star house is 31 $MJ/m^2.a$. In Brisbane, the latter difference is just 7 $MJ/m^2.a$. Since direct energy cost savings are proportional to energy consumption, the incremental cost of achieving each additional star will increasingly become the determining variable.

This analysis also indicates that as the star rating of a typical house increases, the share of total energy consumption accounted for by end uses *other than* space conditioning will rise. This is why Task 2 – addressing the scope of Code provisions – will become increasingly important through time. That said, the question of what is the optimal star rating for thermal shells is a separate consideration that should be established with reference to evidence and not assumptions.

To address these questions analytically, there are two complementary approaches. These are set out below.

Thermal shell performance

The first approach is to determine the extent to which anticipated reductions in space conditioning energy consumption, as a function of higher star ratings, are achieved in reality.[11] In practice this is a very considerable challenge, because the star rating is associated with a set of assumptions which, as noted above, represent only one slice of the very broad spectrums of actual usage conditions of houses in Australia. Second, space conditioning energy consumption is not separately or easily identified within energy bills or otherwise transparent. Also, the demand for space conditioning varies widely throughout the year, and from year to year, as a function of ambient temperatures *inter alia*. As a result, measuring the actual demand for space conditioning energy generated by the thermal performance of a specific house, and separating this 'signal' from all of the other variables and energy demands in a home, requires very detailed and long term measurement of many parameters in a home, and comparing these with NatHERS predictions. Such research is expensive and inherently 'invasive', requiring researchers to seek the agreement of householders to participate in such studies. This, in turn, limits the sample size, geographic/climate zone coverage, and building type coverage, of such studies.

An alternative and lower cost methodology to determine the extent to which higher star ratings lead to reductions in space conditioning energy consumption in reality, in new dwellings, is direct testing and measurement of their thermal performance post-completion but pre-occupancy. Around the world, blower door/thermal imaging tests are commonly used for this purpose. However, such tests primarily measure the air-tightness of dwellings and, at present, Australia's National Construction Code contains no airtightness performance requirements. An alternative approach that has been proposed is to utilise the space conditioning equipment already installed in a new dwelling to heat or cool the building to (carefully measured) levels, and then switch off the space conditioning and measure the change in temperature in the succeeding hours, including as a function of the external ambient temperatures prevailing during the test. Such a test will provide a composite measure of the 'thermal resistance' of the structure (total R values), together with its airtightness and the extent of internal thermal mass. Ideally, from a research perspective, the separate contribution of each of these effects would be examined independently. However, that would significantly increase the time and cost associated with the testing.

[11] Noting that the star rating is in fact a measure of thermal loads, not space conditioning energy consumption, with the key difference between these two being the efficiency of space conditioning devices. This is discussed further in Section 3.

We note that energy consumption by space conditioning equipment could also be measured, to provide direct observations of this variable, but again at additional cost. We also note that if testing of a particular dwelling is carried out at a given time of year, then it may be possible only to test one dimension of the dwelling's thermal performance – winter heating or summer cooling. Finally, if the dwelling as constructed fails to comply with Code requirements, or otherwise is affected by poor build quality, then this will affect its measured, real world performance in ways not anticipated by NatHERS. This highlights the importance of ensuring that there is, in fact, good compliance with Code energy performance requirements, and this is discussed further below. Despite these potential limitations, a program of thermal performance testing of ideally a large number of dwellings, in many different climate zones, and across a range of star ratings, would provide real world data on the extent to which higher star rated dwellings are associated with better thermal performance.

Total energy consumption

A second approach is to ask a slightly different question, and that is, 'Is there evidence that higher star rated houses use less energy in reality than lower rated ones?' This is a disarmingly simple question and, as set out below, potentially easier and cheaper to answer than the one above. However, it must be recalled that the Code does <u>not</u> regulate the total energy consumption of dwellings. Therefore what is being measured is not the same as the performance requirement. As noted above, there is ample evidence to attest to the fact that occupant behaviours are the primary determinants of total residential energy consumption and – to this point at least – the Code does not attempt to regulate those behaviours in any direct manner. The potential to widen the scope of Code requirements is discussed in Section 3 below.

That said, there are at least two ways in which we can abstract from the variability of actual household occupancy and user behaviours. The first is to capture and analyse energy consumption data from a very large sample of dwellings, large enough so that the occupancy patterns and other relevant behaviours are averaged out in both the control or reference cohort and in the higher star rated cohort. The second approach – which is more precise but also more expensive – is to directly measure/analyse the factors such as occupancy and other key behaviours, and use this data to normalise the measured energy consumption. As noted above, there are examples of both these approaches being used in Australia in the past, or proposed for the near future.

The first approach – which we label the 'big data' approach – essentially involves capturing total energy consumption data for a large sample of dwellings/climate zones, layered by the star rating of those dwellings so that we can compare their average energy consumption. While the energy use of individual houses within the sample, for any given star rating, may well be varying widely due to the behavioural (and also compliance) factors noted above, this analysis will show whether, on average, higher star rated houses are using less energy than lower rated ones. The key requirements include:

- That we can have sufficient confidence about the star ratings of dwellings in the cohorts studied;
- That we are capturing all, or at least most, of the actual energy consumption of the houses (eg, all fuels, and PV output in addition to 'purchased' energy);
- That the study observation period is long enough to include seasonal effects or, better yet, provides separate observations of seasonal averages (to examine summer vs winter performance).

Past studies (BREE 2013) have used 'date of first connection' of electricity services as a proxy for star rating, on the basis that houses built in particular years, at least since 2003, were required to comply with specific star rating requirements. Also, the date of first connection is typically available to electricity network businesses from their records. However, this methodology is blind to both over- and under-compliance in reality, unless additional direct sampling is undertaken (see below). Second, it is very unlikely to be able to resolve dwelling type (detached, semi-detached, etc), without additional sampling, as electricity businesses do not generally capture this information.

In this context, a very important information resource exists in the accumulated database of NatHERS ratings that have been undertaken and compiled since July 2014. CSIRO, which has access to this data, has indicated that there are currently some 24,000 dwelling ratings in this database, with the number growing steadily each week. A typical rating runs to 10 – 12 pages of quite detailed data on a house, which is identified by street address and climate zone. The dwelling type is identified. Importantly, CSIRO has noted that some 15%, or 3600 of these records, relate to dwellings with a star rating of 7 star or more. This offers the potential that this database could be used to select cohorts of dwellings by their street address, as a function of dwelling type, climate zone and star rating, specifically including above 6 star ratings. If we are able to associate these cohorts with their measured/metered energy consumption, then 'real world data' could be used as at least one methodology for assessing average energy savings associated with higher star ratings, as a key input into a future RIS. Note that there is a delay between the rating, produced at the design stage, and any energy consumption data collected during occupation. Accordingly the most recent dwelling ratings in the database are not yet candidates for matching with energy consumption data.

In future, it may be possible to match individual dwellings, via their street address, with metered energy consumption data directly, for example, via CSIRO's End Use Data Model or other sources such as MSATS. For the time being, however, a more practical methodology would require direct contact with the households identified, seeking either a) their permission for energy bills to be released by distribution service providers, or b) direct provision of energy bills (and potentially other information, as above) by the households, or indeed both of these.

With respect to fuel types, studies that only captured electricity use could be misleading, particularly in jurisdictions such as Victoria and the ACT that consume significant quantities of natural gas. Ideally, gas and electricity consumption data would be compiled, using common address fields, to gain a more comprehensive and accurate picture of total energy consumption. The same point can be made for 'behind the meter' photovoltaic (PV) systems. The presence of these will significantly affect metered purchases of grid electricity, with the latter providing an increasingly poor representation of a house's actual energy consumption. It may be possible to capture metered output of PV systems, or at least net exports, but this data may well be difficult to interpret as it may not be able to be easily related to actual energy consumption, at least without additional data such as PV system size. Another and simpler approach is to capture information of PV capacity installed, and to estimate annual output – which can be done with reasonable precision.

These challenges can be overcome, as per CSIRO's EUDM pilot project in Victoria described above, by direct contact with the house occupants. However, this adds a very considerable time and cost burden to what might otherwise be a largely 'desktop' study. But the 'big data' approach offers another solution to these challenges, and that is large sample size. Unless we have reason to believe that the distribution (and/or size) of PV systems, or the fuel mix, varies in a consistent way as a function of the age/star rating of the dwelling, then the *relative* energy consumption of the star-rated cohorts will not be affected by these factors. These factors can be independently assessed for the climate zones being studied and, where necessary, data could be normalised by the results.

In either case, a key requirement is to access meter energy data for specific dwellings (associated with specific star ratings). Ideally such energy consumption data – which is already compiled by or on behalf of energy utilities for the primary purpose of billing – should be made available in a statistically meaningful but de-identified form for such purposes. The EUDM pilot study being conducted by CSIRO in conjunction with AEMO is expected to explore this potential. Short of this, higher cost and more direct/invasive research techniques are required. This can involve recruiting a statistically-significant sample of dwellings, in each climate zone, star band and dwelling type cohort required for the study, and seeking – at a minimum – permission for utilities to provide access to meter data records for the specific dwellings. Alternatively, but at additional cost and effort for householders, energy bills may be collected and compiled directly from households. Past studies, including CSIRO's 5 star *ex poste* evaluation, have highlighted the difficulty and cost associated with such recruitment exercises. There are always risks of various forms of 'selection bias' in the sample. For example if households who volunteer to participate in such studies do so because they are proud of their frugal energy consumption, and are seeking positive reinforcement, then results will be biased towards lower-than-average energy consumption.

On the other hand, if we go the time and expense of recruiting specific households, then this method offers the possibility of obtaining additional and very valuable information – for example on occupancy hours and behaviours – at very low marginal cost. A short survey of households, and/or a 'walk through audit' can quickly resolve many of the uncertainties noted above, including the presence or absence of PV, installed kW of PV, the presence or absence of a gas connection, appliance numbers, types and efficiencies; *inter alia*. It *may* even be possible to verify (or estimate) the dwelling's star rating.

Overall, both the 'big data' and the 'direct contact' approaches offer powerful insights into a key question for a future RIS, and that is the extent to which there is real world data to substantiate the energy savings associated with higher energy performance requirements. Both approaches are recommended in the proposed research program below.

Compliance

We noted above that past RISs and related benefit cost analyses have implicitly assumed full compliance with Code energy performance requirements, while the *National Energy Efficient Buildings Project Phase 1 Report* reported widespread concerns about non-compliance. However, we are unaware of any subsequent research to quantify the extent and severity of potential non-compliance. The significance of this issue is that particular compliance issues – like substitution of low-performance for (specified) high-performance glazing, reducing insulation volumes, or post-approval design changes – could significantly reduce energy savings from levels anticipated. At the same time, such non-compliances may reduce construction costs, but that benefit may or may not be passed on to the house owner.

Given the large number of new dwellings constructed in Australia each year – some 232,000 in the year to April 2016[12] – and additional major refurbishments to current Code standards – even modest degrees of under-compliance with energy performance requirements could rapidly accumulate and amount to a significant additional, and unanticipated, source of energy cost and greenhouse gas emissions, as well as contributing to stakeholder concerns about the effectiveness, in the real world, of energy performance regulation. Therefore this issue is included in the research program below.

2.5.2.3 External Costs and Benefits

As noted in section 2.1.1 above, COAG's best practice guidelines for regulation impact assessment (RIS) and benefit cost analysis (BCA) of policy proposals clearly specify that their societal benefits and costs, and not simply private ones, are described and quantified to the extent possible. It notes, for example (pp. 21-22):

> *Public policy makers are expected to make judgments based on what is best for the community as a whole. By measuring 'social', as opposed to only private, market-based costs and benefits, CBA is a valuable tool when developing good policy responses to economic and social problems...*
>
> *Benefits and costs are 'social' rather than private or individual, in the sense that they are measured irrespective of the people to whom they accrue and are not confined to formal market transactions...*
>
> *CBA is also helpful where regulations impose 'spillover' costs or benefits on third parties. Often these do not receive due recognition because no formal market transactions take place. Through the use of shadow prices, values can be placed on non-market 'spillover' effects (for example, pollution, safety) and compared with market transactions.*

That said, the *distribution* of costs and benefits across certain parties, and potential impacts on competition, also need to be quantified.

[12] Australian Bureau of Statistics, 8731.0 Building Approvals, Australia

Despite these guidelines, in practice it is common for benefit cost analyses used for regulation impact assessment purposes *not* to quantify or, in some cases, even describe qualitatively key 'external' or indirect costs and benefits associated with the regulatory proposal. The primary reasons this occurs is due to a lack of research to establish the size and nature of these external effects, and a lack of time/budget to address them within the time constraints imposed by the policy process.

In the case of residential energy efficiency improvement, there is a large range of external impacts that could be anticipated to arise, and some of these may have monetised values equal to or greater than the direct costs and benefits. Some potential categories of external impacts are listed in Table 2 below.

Table 2 Possible External Impacts Associated with Residential Energy Performance Regulation

Impact Area	Potential Benefits	Potential Costs	Likely Magnitude/ Comments
Climate change	Reduced emissions and damage	Shadow carbon prices	Significant over time
Occupant health	Reduced time off work/school Reduce health system costs Reduce private health costs Reduced mortality	Concerns regarding mould, condensation in poorly ventilated dwellings	Significant – risks may be decreasing with increasing thermal performance; but increasing due to climate change.
Comfort	Perceived wellbeing from reduced cold, draughts, higher internal temperatures, reduced temperature variability, etc	Concerns regarding 'hotboxes' (poor summer performance)	Less significant, but likely growing due to a) climate change and b) an ageing population
Energy supply infrastructure	Reduced peak system loads and costs Downsized local distribution transformers Reduced electrical losses Reduced wiring costs		Significant
Indirect compliance costs, transactions costs		Search costs to discover regulatory requirements Lost time/additional labour costs to comply with regulatory requirements Record-keeping costs Reporting costs Learning/knowledge acquisition costs	Indeterminate and would occur regardless of the specific level of energy performance requirements included in the building code
Opportunity costs		Foregone benefits of alternative forms of consumption	Indeterminate
Capital appreciation	Increased value of housing on sale Increased rental value	Higher costs for home buyers, renters	Significant Simply the capitalised value of future energy

Impact Area	Potential Benefits	Potential Costs	Likely Magnitude/ Comments
	Ability to borrow/invest more due to higher capital values		savings, or greater due to intangibles? Private benefit, zero sum gain, due to higher costs for renters, home buyers
Housing affordability	Reduced operating costs	Higher purchase/construction costs	Significant – but these are direct rather than external effects
Macroeconomic spillovers	Net employment creation, including in product supply, professional services sectors Spillover benefits from additional investment	Lost spillover benefits due to opportunity costs	Indeterminate
Avoided capital expenditure	Downsize or eliminate space conditioning equipment (and cost)	Risk of additional cost associated with increasing airtightness (not an energy performance requirement at this time) – eg, need for mechanical ventilation	Modest – but non-linear. When critical thresholds are passed (eg, thermal shell performance) then space conditioning costs could be substantially reduced.

A particular concern that we highlight is the resilience of the housing stock to the anticipated increase in the frequency, severity and duration of heatwave events, combined with an ageing population that is likely to be increasingly vulnerable to such events. For example, the 2-week long heat wave that struck Paris in 2003 led to some 15,000 additional deaths (beyond the background rate), primarily of older persons.[13]

While not as relevant to new housing, we also note that recent research by the Queensland University of Technology shows that:

> *...many preventable deaths from the cold in Australia are due to the poor quality of our housing. According to a new study published in The Lancet, cold contributed to 6.5 per cent of deaths in Australia compared to only 3.9 per cent in Sweden. It also revealed that cold weather claimed more lives than hot weather in Australia. The fact that more people are dying due to the cold in Australia's relatively mild winters compared to Sweden's below-zero ones comes down to the quality of the housing.*[14]

Specific research to quantify these (and other) potential external costs and benefits can only practically be undertaken in advance of a RIS and, on this basis, a specific research project is included in the proposed program below.

2.5.3 Priority Research Projects - Overview

Following the analysis above, the key research priorities for the 'real world data' program are identified in priority order in Table 3 below. For further details, please refer to Appendix A.

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[13] See, for example, http://news.bbc.co.uk/2/hi/europe/3139694.stm

[14] http://architectureau.com/articles/australias-poor-housing-contributing-to-cold-related-deaths/

Table 3 Prioritised Research Program: Real World Data

No.	Title	Objective	Rationale for Priority	Risks	Cost Est. (excl. GST)
1	*Incremental Costs Associated with Higher Star Ratings – CSIRO/FR5 Data*	• To identify incremental costs associated with above-6 star dwellings in Australia, and how these costs have changed through time.	• Direct and critical input into RIS • Methodology uses real world data (actual plans and elements correlated with their star rating) • Independent (quantity surveyor based) observations of incremental cost • Very large sample size available covering all/most climate zones and building types	• Requires access to CSIRO and/or FirstRate5 database	$80,000
2	*Measured Energy Consumption of 6+ Star Rated Houses*	• To determine whether there is evidence that, on average over a large sample, higher star rated dwellings use less energy and, if so, by how much.	• Direct input into RIS • Large sample size available, sufficient to abstract from occupant behaviours • Methodology uses real world data • Could cover all building types and a large sample of climate zones	• Requires access to CSIRO database	$120,000
3	*Incremental Costs and Market Responses – Industry/ Quantity Surveyor Data*	• To identify incremental costs associated with 6 star and above dwellings in Australia and how these costs have changed through time.	• Changing compliance costs through time are a key variable in RIS • Considerable uncertainty as to appropriate values • This methodology more participative but higher cost/dwelling than project #1.	• Major risks are the need to recruit willing industry professionals, the time required for recruitment/analysis, and the quality/accuracy of their record keeping.	$140,000
4	*Thermal Shell Performance and Occupant Behaviours – Existing Monitoring Data*	• To assess the case for applying separate winter heating and summer cooling energy performance requirements. • Where NatHERS is used for RIS purposes, should predicted winter heating and summer cooling loads be adjusted to reflect real world data and, if so, by how much?	• Uses real world data (to compare with NatHERS predictions) • Poor summer performance is a key stakeholder concern and potential health risk • Occupant hours and behaviours are known to lead to predictions of space conditioning energy use that significantly exceed measured values. • Based on past practice, NatHERS simulation is likely to be used, in addition to real world data, to estimate energy savings for a RIS.	• Requires access to monitoring data held by a limited number of institutions: CSIRO and CRC for LCL partners. • Data only available for Class 1a)i) and a limited range of climate zones.	$160,000

No.	Title	Objective	Rationale for Priority	Risks	Cost Est. (excl. GST)
5	*Value of External Benefits and Costs*	• To quantify the values to be used in an RIS for external/indirect benefits and costs, based – to the greatest extent possible – on real world data rather than estimation.	• Direct input into RIS • Significant uncertainties as to appropriate values • Quantitatively very significant, relative to direct value of energy savings.		$90,000
6	*Compliance Audits*	• To determine the extent to which there is evidence that under- compliance with Code energy performance requirements is likely to alter the expected incremental costs and/or benefits associated with future energy performance requirements. Where justified, to recommend adjustment factors for RIS purposes.	• There is strong anecdotal evidence of poor compliance but very little quantified evidence of the scale of poor compliance • Benefits and costs may both be overstated if compliance is poor • Research could inform improved compliance mechanisms in addition to the RIS • Could be undertaken at low marginal cost in association with Project #3	• Requires access to the CSIRO database • Major risk is the time required to recruit households – this may be facilitated by linking Method 2 to the existing EUDM pilot study in Victoria. Similarly, Method 1 could be linked to	Method 1: $120,000 Method 2 (incremental cost only): $40,000
7	*Thermal Shell Performance – Pre-Occupancy Measurement*	• To assess the extent to which NatHERS accredited tools are generating accurate assessments of expected winter and summer thermal loadings, and whether higher star ratings are associated with improved thermal performance.	• Lower priority reflects the 'experimental' nature of the test • Compared to Project #3, this method would enable data capture on Class 1a)ii) and Class 2 dwellings, and a wider range of climate zones • Such a test would also have potential use as a compliance tool – this issue could be investigated as part of the project.	• Need to recruit willing participants/owners to participate in the study • Data interpretation may be complex – due to novel nature of the test	$75,000

2.5.4 Additional/Longer Term Research Projects

During the course of this project, many additional knowledge gaps and potential research issues were identified. As noted, we have de-prioritised these primarily on the grounds that it may be difficult to complete the required research within the timeframe available for a 2017 RIS. However, many of these issues may be significant in a quantitative sense and worthy of specific research, even if over the longer term. This may facilitate some of these issues coming within the scope of a future RIS targeting not 2019, but a later iteration of the Code.

Given time and scope constraints, we list and describe these issues only briefly below. These projects have not been prioritised.

Table 4 Additional/Longer Term Research Projects

Project	Issues and Opportunities
Life cycle energy/emissions performance	• As the operational performance of housing improves, the relative contribution to lifetime energy consumption and greenhouse gas emissions of construction material, associated transportation and construction processes will rise. • Embodied energy/emissions of many materials has been researched, including in Australia, but tends to vary significantly from place to place. • It may be administratively complex to include these considerations within the Code, at least in the absence of labelling or other disclosure mechanisms. • At the same time, and in the absence of carbon pricing, there is no incentive to develop/include lower carbon materials in the built environment.
DTS elemental/star rating equivalence – all dwelling types	• In principle, deemed to satisfy elemental and star ratings (and indeed other alternative solutions) are supposed to generate comparable energy performance results. The NEEBP Stage 1 project uncovered a widespread view that this is not the case. There is some evidence to suggest that the rating of houses approved through the DTS elemental solution can vary between 5 and 7 stars, depending on the climate zone and some building features. • Industry views about the utility of retaining DTS solutions within the Code vary widely. • The Pathway to 2020 study (**pitt&sherry** 2012, 2016) suggests that the relative stringency of Class 1 and Class 2 dwelling is considerably out of line, with much greater scope for cost effective improvements in the energy performance of Class 2 dwellings.
Future climate files	• Housing built in 2019 is likely to remain in use until 2050, a time when Australia's net carbon emissions will need to be close to zero and a time when we can expect significantly more severe climate conditions to prevail. • NatHERS tools in ratings mode, and regulatory settings, should anticipate these future climate conditions. The research tasks would include translating expected future climate condition (based on IPCC projections) into NatHERS climate files, and analysis of the social costs and benefits of adopting these 'future climate' files for regulatory purposes.

Appropriate discount rates	• This issue was controversial in the context of the 2009 RIS. Then and now, the Office of Best Practice Regulation requires a central value of 7% real discount rate to be used, albeit that other values (typically 3% and 10%) may be tested in sensitivity analysis. • A 7% real discount rate is increasing out of line with the real, risk-free cost of capital in Australia, which is one approach to valuing discount rates. • There is an active debate about the use of lower discount rates in the context of carbon abatement policies, with the underlying rationale being that shadow or current market carbon prices are likely to significantly undervalue future damage costs resulting from greenhouse gas emissions.[15]
Market transformation opportunities	• This report highlights the critical importance of incremental costs for determining optimal energy performance requirements from the perspective of cost effectiveness. • Debate centres on actual/historical market responses rather than the potential to actively change incremental costs, including through a structured policy approach known as market transformation. • Market transformation policies are widely used in other OECD countries but have rarely been used in Australia. • Specific policies could be used to improve the cost effectiveness of higher performance housing and housing elements (like glazing) in future.
Regional/climate zone variability	• RISs and related benefit cost analyses typically resolve a limited number of climate zones. However, it is widely believed that expected (and measured) energy performance varies widely even within existing climate zones and for identical designs. • It has also been proposed that energy performance requirements be set not by state/territory (reflecting the state/territory basis of enabling legislation) but instead by climate zone, as the latter is a much better predictor of energy performance.
Costs of delay	• Energy performance requirements determined in 2009, and taking effect from May 2010 or later, will continue to apply until at least May 2019. The social cost of delay - in terms of lost direct and indirect benefits - could be quantified and may assist decision makers and the public to understand the costs associated with delaying the implementation of new/optimal energy performance requirements.
Impact of state/territory variations	• Considerable time and expense goes into determining optimal energy performance requirements, including by state/territory. Despite an Inter Governmental Agreement that encourages national consistency in performance requirements, material state/territory variations persist, and are not subject to RIS/BCA requirements. • A study could determine the magnitude of foregone benefits (and costs) associated with these variations, with aim of encouraging a greater focus on the value of consistency.

[15] http://www.ipcc.ch/ipccreports/tar/wg3/index.php?idp=281

Rebasing/reframing the star bands	• This study and others have noted that there is a declining quantity of energy savings delivered by increasingly high star ratings. • Consumer research could address how well consumers discriminate between increasingly high star ratings (eg, the difference between 6 and 8 star). • Research from appliance energy efficiency standards suggests that 'rebasing' star ratings, eg, resetting to 0 – 5 star, would assist in consumer comprehension and policy effectiveness. Does this also apply in housing? • Would a more linear approach to star bands be preferable?
Airtightness and ventilation	• Airtightness is a common performance requirement in the building codes of OECD countries, but not in Australia. In the National Energy Efficient Buildings Project Phase 1 report, it was noted that many building professionals see this as a significant gap and as a barrier to higher energy performance. • Research could be undertaken into best practices overseas, the costs and benefits of introducing airtightness performance requirements in Australia, compliance tests and related issues including the adequacy of current Code ventilation requirements, and how these may need to change in accompaniment with airtightness requirements.
Effectiveness and cost effectiveness of alternative policy approaches	• RISs require analysts to consider alternative policy approaches. However, there may be little research to hand that would enable such alternatives to be explored on a like-for-like basis. • In particular, much less is known about the real world performance of voluntary, information-based and behaviour change policies and programs – specifically in the Australian housing context – than is known about the effectiveness and cost effectiveness of building codes. • Attribution problems afflict the stated performance of many such non-Code policies. Some voluntary ratings programs, for example, report as savings the measured change in total energy intensities of rated buildings over time, without regard to causation. This is likely to overstate the effectiveness and cost-effectiveness of such measures.
Class 2 common area energy consumption	• Current residential energy performance requirements focus on the star ratings of dwellings or sole-occupancy units, while the energy performance of other (common) areas of Class 2 buildings is regulated under the provisions of Section J, Volume 1 of the Code. • Research is required to determine the relative extent of common area vs sole occupancy energy consumption in Class 2 buildings and, in particular, whether there is a case for lifting the performance requirements for Class 2 buildings in Volume 1 of the Code.

3. Whole of House Performance Requirements

3.1 Existing Code Requirements and Objectives

The National Construction Code (NCC) is a set of agreed performance requirements for building, plumbing and drainage works across Australia. The detailed provisions often reference other documents – such as Australian Standards. The NCC is administered by the ABCB on behalf of the Australian, state and territory governments.

The energy efficiency provisions for Class 1 dwellings are contained in Volume 2 of the National Construction Code with provisions for Class 2, multi-residential buildings appearing in Volume 1.

The NCC provisions are national and are accordingly designed to allow for factors that vary across Australia (such as climate) that influence the energy efficiency of a particular building on a particular site. State and territory regulations call the provisions of the Code into effect. However some variations to the NCC are applied under those regulations in certain jurisdictions.

The Code first introduced residential energy efficiency provisions in 2003 with stringency increased to current levels in 2010 apart from some minor adjustments since.

The overarching goal of the Code, to which the energy efficiency provisions make a contribution, is "to enable the achievement of nationally consistent, minimum necessary standards of relevant safety (including structural safety and safety from fire), health, amenity and sustainability objectives efficiently"

Particular objectives for energy efficiency, the scope of provisions, along with important jurisdictional variations, are discussed further in the sub-sections below.

3.1.1 National Construction Code – Class 1 Buildings

The objective of the energy efficiency provisions in NCC Volume 2 for class 1 buildings is 'to reduce greenhouse gas emissions'

The functional statement is 'To reduce greenhouse gas emissions, to the degree necessary –

a) a building, including its domestic services, is to be capable of efficiently using energy; and
b) a building's domestic services for heating are to obtain their energy from-
    i. a low greenhouse gas intensity source; or
    ii. a on-site renewable energy source; or
    iii. another process as reclaimed energy

Explanatory information accompanying these statements state that "The greenhouse gas intensity of energy sources vary. For example, natural gas has a low greenhouse gas intensity compared with electricity generated from coal"

This implies, rather than explicitly stating, that heating energy should come from a source other than grid provided electricity in all states except Tasmania.

A set of performance requirements expands on the objectives and functional statements. There are two broad sets of performance requirements. Part 2.6.1 concerns the thermal performance of the building. Part 2.6.2 concerns the performance of domestic services.

Domestic services for Class 1 buildings are the systems that use or control the use of energy including heating, air-conditioning, mechanical ventilation, lighting, water heating, swimming pool pumps and heating.

Portable appliances and cooking facilities are excluded for the purposes of the code.

The performance provisions for domestic services are that they

a) have features that facilitate the efficient use of energy appropriate to
   i. The domestic service and its usage
   ii. The geographic location of the building
   iii. The location of the service
   iv. The energy source
b) Obtain heating energy from
   i. A source that has a greenhouse gas intensity that does not exceed 100g $C0_2e$ / MJ of thermal energy; or
   ii. An on-site renewable energy source; or
   iii. Another process as reclaimed energy

Explanatory information for Part 2.6.2 states that the intent of the heating energy provisions “is to constrain the use of a high greenhouse gas intensity source of energy. It does not prevent the use of electricity because the greenhouse gas intensity is related to thermal load rather than the energy consumption”

This heating energy provision is not well aligned with the functional statement; which simply states that heating energy should come from a low emissions source with no reference to thermal load.

The explanatory information also states that the qualification to the provisions “to the extent necessary” in fact allows electricity to be used “even by low efficiency plant when there are no reasonable alternatives”.

Performance Requirements in Part 3.12 of Volume 2 provide detail on how to achieve the provisions of Part 2.6.

These requirements relating to Provision 2.6.1 cover the thermal performance of the building envelope.

One compliance pathway is largely based on achieving a required energy rating which is 6 star except for NSW and NT. There is also an allowance for buildings in northern Australian climate zones of 1 or 2 that have an outdoor living area with an insulated and impervious roof or a permanent ceiling fan. Such buildings are only required to achieve 5.5 stars. Homes with outdoor rooms with both features have a requirement of 5 stars.

The second pathway sets out detailed requirements on building fabric; external glazing; building sealing; and air movement.

Then requirements for Services apply, specifically for insulation of services; central heating water piping; heating and cooling ductwork; electric resistance space heating; and artificial lighting.

Inconsistency between performance provisions and requirements

The Code has clear objectives and precise provisions relating to heating energy – the energy source must be no more than 100g $C0_2e$ / MJ of thermal energy.

However the only performance requirements relating to heating appears misaligned with the Code’s objective and provisions. The requirements only relate to electric resistance space heating – which will have emissions intensities well above the allowed level in all states and territories except Tasmania. The requirements are not accompanied by a note, for example, stating that electric resistance heating is only permitted in buildings with renewable energy installations.

3.12.5.4 Electric resistance space heating

An electric resistance space heating system that serves more than one room must have—

(a) separate isolating switches for each room; and

(b) a separate temperature controller and time switch for each group of rooms with common heating needs; and

(c) power loads of not more than 110 W/m^2 for living areas, and 150 W/m^2 for bathrooms.

Figure 2 - Heating performance requirements Class 1 (from Part 3.12.5.4 in Vol 2 of the NCC)

3.1.2 National Construction Code – Class 2 Buildings

The objectives, functional statements, provisions and requirements for Class 1 buildings are broadly repeated for Class 2 buildings. However they are split between *Volume 1* of the NCC which contains the performance requirements and the *Guide to the BCA Volume One.*

The performance requirements are contained in Section J0.1 and J0.2 of Volume 1. The non occupied spaces of class 2 buildings must meet deemed to satisfy requirements while the occupied units must collectively achieve an energy rating of not less than 6 stars and individually exceed 5 stars using house energy rating software accredited under NatHERS.

Services requirements apply to air-conditioning (J5); lighting (J6) heated water and pool plant (J7) and monitoring equipment. However in the case of air-conditioning and hot water the requirements do not appear to give further effect to the functional statements.

3.1.3 Variations to the Code by jurisdiction

The Northern Territory has not adopted the latest version of the Code (dating from 2010). The energy efficiency provisions and requirements that apply in the NT are contained in the Building Code of Australia 2009. Similarly, Queensland still applies the energy efficiency provisions of the 2009 BCA to class 2 buildings.

In NSW, the NCC provisions and requirements do not apply; they are replaced by BASIX. The differences between the approach of the NCC and BASIX to residential energy efficiency are interesting and are explored further below.

3.1.4 BASIX

Background

The Building Sustainability Index (BASIX) was introduced in July 2004 by the NSW Government as a sustainable planning measure. BASIX aims to deliver equitable, effective water and greenhouse gas reductions across NSW. It is implemented under the NSW *Environmental Planning and Assessment Act 1979* and applies to all residential dwelling types as part of the development application process in NSW.

BASIX sets sustainability targets for water and energy as well as minimum performance levels for the thermal comfort of the proposed development. The targets are calculated based on NSW average benchmarks. The BASIX assessment tool assesses a project based on these benchmarks – taking into account regional variations such as soil type, climate, rainfall and evaporation rates.

The targets for energy are

- up to a 40% reduction in greenhouse gas emissions

- BASIX also sets minimum performance levels for the thermal comfort of the dwelling for both heating and cooling.

The BASIX benchmark for energy is the average NSW annual greenhouse gas emissions from the residential sector on a per capita basis. The benchmarks are calculated from NSW average residential electricity and gas consumption data collected from state-wide energy utilities by government departments, with the benchmark expressed in terms of greenhouse gas emissions equal to 3,292 kg of CO2 per person per year. For example a 25% greenhouse gas reduction would mean that a dwelling will be designed to enable each occupant to reduce their greenhouse emissions to no greater that 2,469 kg of CO2 per person per year.

BASIX applies to all new class 1 and 2 buildings through separate assessment tools.

BASIX Thermal Performance and Energy Use Requirements

Both the Code and BASIX cover the thermal performance of buildings as well as the energy use of systems.

However the Code, while aiming to limit energy use and greenhouse gas emissions, explicitly excludes plug-in appliances and cooking equipment from consideration. The detailed performance requirements, aside from lighting, on included services are also very limited.

BASIX takes a considerably more interventional approach.

Specific requirements on a system by system are not stated. Rather the assessment tool allows for trade-offs on the way to delivering an overall pass or fail result. For instance electric resistance under floor heating is allowed but would necessitate a high performance shell, low emissions hot water and other efficiency features.

The tool requires that the following areas, that impact energy use, are addressed (see https://www.basix.nsw.gov.au/iframe/basix-help-notes/energy.html)

- Thermal comfort. The BASIX system is designed to ensure thermal comfort and reduce the need for space conditioning. The heating and cooling loads assessed in the thermal comfort elements of the tool are combined with the energy use elements (see points below) to provide the BASIX Energy score.
- Hot-water. All types including electric storage are allowed, but the assessment tool actively encourages the use of lower greenhouse emissions options like solar and heat-pump systems
- Space conditioning. The tool calculates heating and cooling loads in living rooms and bedrooms. If no fixed heating systems are entered, the tool assumes that portable electric heaters will be used and adjusts the overall score accordingly
- Ventilation. There is a requirement with the choice of natural and mechanical systems impacting the score
- Lighting. Assesses energy use on the basis of natural light and artificial lighting options
- Pools and spas – assesses energy use on the type of heating and pump timing arrangements
- Cooktops and ovens, with gas ovens scoring best (low emissions intensity) followed by induction with standard electric cook-top tailing the field
- Refrigerator space – the assessment considers the degree of ventilation of the space for the refrigerator, with spaces enclosed by cupboards on all sides penalised
- Appliances – the tool rewards the selection of high efficiency (as rated under the MEPS & Energy Labelling program) refrigerators, dishwashers, clothes washers and dryers.

The multi-dwelling BASIX tool has various adjustments that consider the energy use of common areas, car parks, lifts and other systems impacting energy use. The figure below shows the features that are encouraged by BASIX.

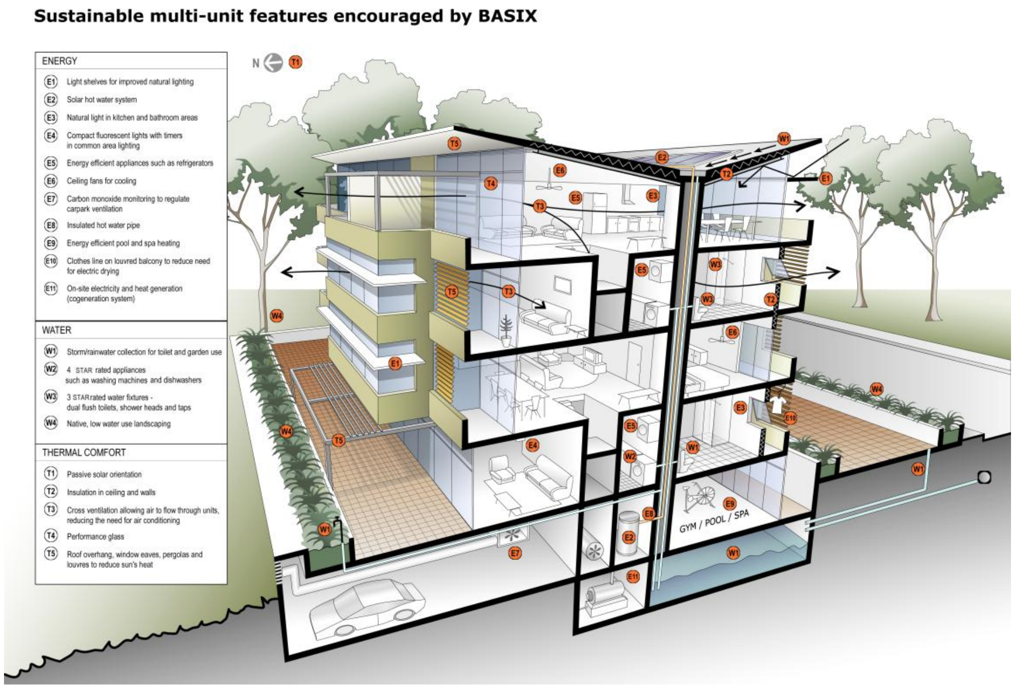


Figure 3 – Sustainable multi-features encouraged by BASIX

3.2 Key Issues

3.2.1 Introduction

The current scope of the energy performance requirements in the NCC reflects practical judgements, made in the past, about the ‘minimum necessary’ but also practical extent to which energy performance regulation of housing is required. The pros and cons of these judgements are discussed further below. Generally, we should recognise that the context in which the NCC is operating is changing, and this may well justify changes in – or at least thorough review of – the scope of the Code’s energy performance requirements and related objectives.

First, the Inter Governmental Panel of Climate Change (IPCC) amongst other expert institutions is providing incontrovertible evidence of climate changes. Dimensions of this change that are directly relevant for residential buildings include an expectation of the increasing severity, frequency and duration of heatwave events. This suggests that the thermal resilience and integrity of a dwelling’s thermal shell, and the appropriate design and performance of thermal mass, will be increasingly important to ensure occupant safety and well-being, without excessive and costly energy consumption.

Second, the Paris Climate Agreement effectively commits the world, including Australia, to pursue efforts to limit global temperature increase to 1.5^{o} C, to accelerate reductions in greenhouse gas emissions, and to achieve a balance between anthropogenic emissions by sources and removals by sinks of greenhouse gases in the second half of this century (that is, net zero emissions) *inter alia*. It may well be the case that achieving these outcomes will require changes to business as usual policy trends.

Third, there are significant shifts in market trends, including the enhanced availability of clean energy technologies with higher performance and lower costs – notably for technologies such as photovoltaic systems, battery storage, energy management software and systems, very high efficiency heat-pumps, etc – that may change the opportunities for energy performance regulation of housing.

These and other changes call for a careful review of the scope of NCC performance requirements and related objectives. The purpose of this Report is not to undertake that review, but to recommend a program of further research and investigation that would inform future Code development processes. The balance of this Section is therefore structured as a brief overview of the pros and cons associated with expanding the current scope of energy performance requirements, followed by a proposed program of further work, to fully explore these issues.

3.2.2 Objectives

The optimal scope of any policy, including the energy performance requirements, must be informed by the policy objectives intended. This basic principle is clearly stated in COAG best practice guidelines (p. 4). In the case of the Code's energy performance requirements, there appear to be gaps and inconsistencies in the practical expression of the Code's objectives that warrant further investigation.

First, as noted above, the specific objective of the energy performance requirements in the Code is 'to reduce greenhouse gas emissions, to the degree necessary'. In principle, the phrase 'to the degree necessary' could be read as expressing a science-based judgement about by how much greenhouse gases need to be reduced, particularly to ensure the wider Code goal of '...the achievement of nationally consistent, minimum necessary standards of relevant ... sustainability objectives efficiently'. In this context, the Paris Climate Agreement, to which Australia is a signatory, '...recognises that deep reductions in global emissions will be required in order to achieve the ultimate goal of the Convention'. This would suggest that a contemporary interpretation of the phrase 'to the degree necessary' would highlight the need to lift the stringency of measures so as to achieve deeper emissions reductions consistent with the Paris Agreement. However, the Code's explanatory information notes that the phrase 'to the degree necessary' allows '...electricity to be used, even by low efficiency plant, when there are no reasonable alternatives'.[16] That is, it anticipates circumstances of 'carve-outs' from the general provisions, rather than the achievement of science-based targets. Clearly this interpretation of 'to the degree necessary' pre-dates the Paris Climate Agreement, however it would appear timely to review this interpretation for future editions of the Code, to ensure that it is consistent with Australia's international obligations.

Second, the overall objective for the energy performance requirements is then limited to a general energy efficiency requirement ('...the building and its domestic services[17] are to be capable of efficiently using energy'), while the building's domestic services *for heating* (emphasis added) are to obtain their energy from:

i. a low greenhouse gas intensity source; or
ii. a on-site renewable energy source; or
iii. another process as reclaimed energy.

The energy efficiency objective is given practical effect through the specific performance requirements in Part 3.12. The limitation that the building and its domestic services 'are to be capable of' efficiently using energy is included because '...energy consumption in a building is highly dependent on how the building is used' and also noting that occupants or tenants may install their own preferred services post-construction.[18] This is significant when considering possible changes to the scope of energy performance requirements in the Code, as it shows that, at least in the past, behavioural factors have been recognised as a limitation on what can practically be regulated through the Code. This is particularly relevant to the discussion of portable appliances below.

The requirement to obtain energy for heating from, effectively, a low-carbon source appears to be designed to prevent the use of electricity, in fixed heating appliances only, that is supplied with a greenhouse gas intensity greater than 100g CO2-e/MJ of thermal energy load. This is equivalent to 360g CO_2-e/kWh – a condition that can be met by direct firing of natural gas, but which requires the use of a heat

[16] NCC 2016 Building Code of Australia – Volume 2, p. 86.
[17] 'Domestic services' are defined in the Code as "...the basic engineering systems of a house that use energy or control the use of energy; and includes heating, air-conditioning, mechanical ventilation, artificial lighting and hot water systems; but excludes cooking and portable appliances".
[18] ABCB, NCC Volume One Energy Efficiency Provisions Handbook, 2016, p. 40.

pump where using grid-based electricity, except in Tasmania. In practice, this is likely to ensure that resistance heaters are not 'hard-wired' into a new dwelling, except in Tasmania.

We presume that the rationale for limiting this provision to fixed heating appliances only is again a pragmatic one associated with enforceability and behaviour, noting that households are free to purchase and use portable electric resistance heaters at any time post construction. It is not apparent however, on this basis, why cooking appliances are excluded from this provision, as they are generally installed during construction/renovation and could be considered as 'fixed' as space conditioning or hot water devices.

Underlying the choice of threshold intensity values is also the question of fuel choice, or the greenhouse gas intensity of energy used in the dwelling. If the objective of requirements is to reduce greenhouse gas emissions, then restrictions on the greenhouse intensity of energy used in a house should presumably apply regardless of the end use, at least to the extent that such provisions are enforceable. This would also imply that the greenhouse intensity value would need to be set at a level that did, in fact, reduce greenhouse gas emissions, otherwise it would not be effective in contributing to this Code objective. The extent to which this condition is currently met, across the range of states and territories, fuel mix and technology combinations, should be investigated in the proposed research program below, along with the optimal value(s) for the future that would ensure that the condition continues to be met from 2019 onwards.

In this context, the consequences of an expectation of changing emissions intensity of grid-supplied electricity, as the share of renewable energy rises under the influence of the national Renewable Energy Target *inter alia*, and also of the variability in this value from jurisdiction to jurisdiction, should be fully explored. A question is whether threshold values (such as the 100g CO2-e/MJ of thermal energy load) have been set in such a manner as to avoid or limit questions of fuel choice (noting that in the wider context of the National Energy Market, 'fuel neutrality' is a central principle) and if so, whether continuing to do so in future would be consistent with meeting the objective 'to reduce greenhouse gas emissions'. The research question arising, then, is to explore the consequences for fuel choice (and consumer choice more generally).

More generally, noting that the scope of energy use covered by BASIX is wider than that covered by the Code, there would be considerable value in reviewing outcomes realised in NSW under BASIX, and applying the lessons learned in that state to the consideration of the scope of NCC energy performance provisions.

3.2.3 Trade-offs

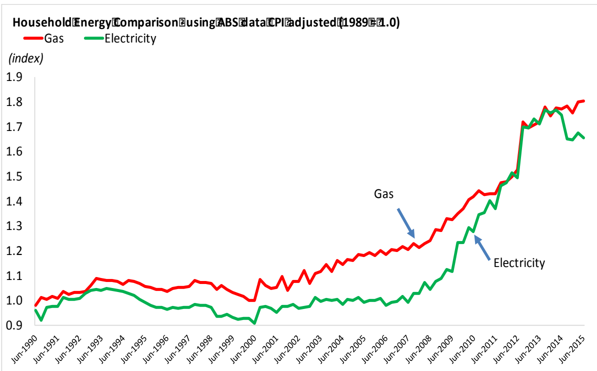
A general question that arises in the context of the scope of energy performance requirements under the Code is the extent to which it is beneficial to allow trade-offs between different performance requirements: that is, over-achievement in some areas should justify under-achievement in others, with an understanding that such trade-offs would occur in the context of a consistent overall performance outcome.

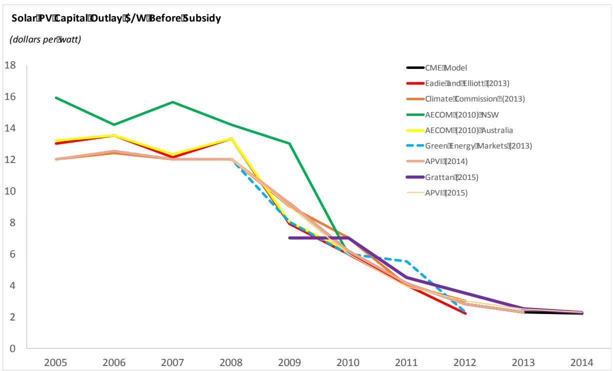
The rationale for such an approach derives directly from the Code's objectives: specifically, if requirements can be met more efficiently (that is, cost effectively) by over-achievement in one area, and under-achievement in another, then the 'efficiently' condition of the objectives has been met. However, the overarching goal of the Code also includes health, safety and amenity, as well as sustainability, considerations, and it appears intuitively clear that these should not be 'traded off' with sustainability outcomes, at least to any material degree. For example, an energy efficiency enhancement that endangered human health is unlikely to acceptable. At the margin however, decisions may have to be made that trade acceptable changes in one objective (eg, amenity) with desired changes in another (eg, safety or sustainability). Ultimately, such questions need to be answered by policy makers.

However, another class of potential trade-off concerns the elements that contribute to the sustainability or, in this context energy performance, objectives. For example, should more efficient portable appliances hypothetically be allowed to substitute for less efficient thermal envelopes? Generally we would answer 'no' to such a question – even if the amount of energy involved were equivalent and it could be shown that the trade-off would lead to lower compliance costs in the short term – on the grounds that the trade-off is very likely to be temporary. The refrigerator could be replaced at any time with a much less efficient one, while the (compromised) thermal shell will cause higher energy consumption and costs for potentially the next 50 or so years. Implicitly, then, the 'durability' or reliability of savings has been considered an important criterion when considering potential trade-offs. This will be relevant when considering the potential to move towards a whole-of-house approach under the Code, as the whole of house includes elements with varying degrees of permanence and reliability.

3.2.4 'Behind the Meter' Photovoltaic Systems

In this overview section, it is worth dwelling briefly on one of the key market trends, noted in Section 3.2.1 above, which is the significant reduction in the cost of photovoltaic systems. Noting that there are other public policy incentives for the uptake of such systems, for example under the national Renewable Energy Target scheme, a key driver of their current uptake appears to be the very significant (90% plus) reduction in at least PV panel costs (inverters and other system elements have also reduced in cost, albeit to a lesser degree), along with the equally significant rise in real energy prices in Australia, over approximately the last ten years.





Source: CME

It is very unlikely that the recent realignment of cost-effectiveness of PV, as a renewable energy generation technology, when compared with residential building energy efficiency options, will be reversed in future. Despite a levelling off of energy price rises in Australia, and particularly electricity, recently, costs of PV systems and components are generally expected to continue to fall in real terms.[19]

Distinctive features of PV systems is a) their longevity (at least 25 years economic life) and b) that they are very likely to remain 'fixed' to dwellings for at least this time and c) their energy production, while variable in the short term, is able to be predicted quite well over longer time periods. In that sense, the question arises whether they should be considered to be, effectively, part of the building envelope, or at least as a fixed appliance, and then the extent to which trade-offs between PV output. This is considered further in Section 3.3.4 below.

3.2.5 Conclusions

In summary, the research program into the future scope of energy performance requirements in the Code would usefully begin with a broader review, having reference to the general policy principles as per the COAG best practice guidelines *inter alia*, of:

- the rationale and public policy objectives for the Code's energy performance requirements, and in particular the extent to which they remain consistent with Australia's international obligations;
- the extent to which these objectives are carried through consistently in specific performance requirements;
- the extent to which behavioural factors and enforceability considerations should limit the scope of performance requirements;

[19] See for example http://reneweconomy.com.au/wp-content/uploads/2015/01/deutsche-solar-costs.jpg

- the extent to which, in principle, trade-offs should be allowed between different performance requirements.

These questions are covered in the first proposed research project below. We note, however, that a general treatment of these issues may not be sufficient to determine whether a particular element or energy end-use should be including within scope, and whether or not, and to what extent, trade-offs with respect to that element should be permitted. Therefore the following sections focus more narrowly on different 'domains' of energy use that comprise a 'whole of house' approach, and separately reviews the pros and cons of their inclusion. We include the current energy performance requirements in this brief review, as there may be equal grounds for changing these as there is including additional scope. Again, the intention is not to reach any definitive conclusions regarding these scope questions, but rather to highlight the issues and areas that may need further investigation in future.

3.3 Elements of a Whole of House Approach

The elements of 'whole of house' energy consumption/greenhouse gas emissions in principle include:

- Space conditioning energy consumption/emissions, which (in addition to behavioural choices) in turn reflect:
  - The thermal integrity/performance of the dwelling's shell or envelope,
  - The energy efficiency of space conditioning devices, and
  - The greenhouse intensity of the fuels consumed;
- Fixed appliance energy consumption including
  - Hot water services,
  - Fixed lighting,
  - Pool and spa pumps,
  - Fixed kitchen and cooking equipment (oven, cooktops, extractor fans/rangehoods, dishwashers);
- Portable appliances including
  - Whitegoods (clothes washers, refrigerators, microwave ovens, etc)
  - Blackgoods (TVs, stereos)
  - Entertainment/education equipment (gaming computers, other computing equipment)
  - Lamps
  - Other portable cooking devices such as BBQs
  - Other appliances (electric blankets, hair dryers, etc)
- PV

Noting the earlier discussion of objectives, and also that all energy use (other than from renewable energy sources) contributes to greenhouse gas emissions, we could state that the objective 'to reduce greenhouse gas emissions' creates a presumption that the wider the scope of energy performance requirements within the Code the better, *unless* there is a valid reason not to include a particular energy end use. Noting the COAG best practice guidelines above, a valid reason might include that an alternative policy approach or instrument may be able to achieve the public policy objective at lower social cost, amongst others.

3.3.1 Space Conditioning Energy Consumption

The table below summarises the current treatment under the Code of various elements of space-conditioning energy consumption and the pros and cons of inclusion in a whole of house system.

Table 5 Space conditioning treatment under a whole of house system

Element	Currently Included	Pros	Cons
Thermal performance of the shell	Star rating	Major impact on space-conditioning energy use. Must be included in some form	Precise relationship between thermal shell and household energy use is dynamic and therefore challenging to produce standardised whole of house requirements
Air tightness	Yes but not in a measureable form	Intrinsic to thermal integrity – the lack of air-tightness requirements undermine the intent of the star rating system	'As designed' requirements will have little meaning therefore 'as-built' requirements (as apply under other Codes) will have to be developed. This has ramifications for current compliance pathways
Separate heating and cooling requirements	Not in Code; is in BASIX	Better aligns with the challenge of designing houses that perform well in every season. Current housing designs appear to have stronger winter than summer performance	Introduction of further complexity
Space conditioning energy efficiency	No	Major impact on total energy use and cost	Requires a choice between a sophisticated requirements process that interlinks thermal performance and space-conditioning system or a simple, separated approach
Greenhouse intensity of fuels consumed	No	The objective and functional statement imply a 100gm CO2e maximum per MJ of thermal energy – this is not backed by performance requirements	The different greenhouse intensity of grid electricity state to state brings challenges – however the same issue highlights the need to introduce requirements in jurisdictions reliant on coal powered electricity

3.3.2 Fixed Appliances

The table overleaf summarises the current treatment under the Code of fixed appliance energy consumption and the pros and cons of inclusion in a whole of house system.

Table 6 - Fixed Appliances - under a whole of house system

Element	Currently Included	Pros	Cons
Lighting	Yes	Current methodology is robust. Stringency could be increased	Compliance hard to check as lighting choices and installation often done towards end of construction. Lights already subject to MEPS.
Hot water	No	A significant energy use. Code requirements can influence final performance regardless of behavioural variation	Potentially complex due to wide choice of fuels and interactions with on-site renewable energy / thermal energy capture.
Pool & Spa Pumps	No	Significant scope for system design and equipment spec to influence ongoing energy use	Under consideration for MEPS – but there is likely to be scope for the code to influence system desire beyond the equipment specific MEPS
Cooking	No	Cook-tops and ovens use energy in their own right – and influence space-conditioning requirements	Considerable research into understanding the energy and thermal impacts and possible code action pathways is required
Lifts and car-park ventilation (class 2 buildings)	No	Good scope for reducing energy waste. Addressed by BASIX multi-residential tool. Should be fairly straightforward to implement	
Refrigerator space	No	Placement of the fridge in a well ventilated space reduces energy waste. BASIX addresses this issue. Simple to address	Potentially limits cupboard space in small kitchens

3.3.3 Portable Appliances

The table below summarises the current treatment under the Code of portable appliance energy consumption and the pros and cons of inclusion in a whole of house system.

Table 7 - Portable Appliances - under a whole of house system

Element	Currently Included	Pros	Cons
White-goods	No	Fridges in particular are a significant energy users with a related impact on emissions and energy bills	Already addressed under MEPS. This suggests that a specific white-good requirement would be redundant in the code. However a whole of house performance requirement could easily take into account white-good performance.
Black-goods / entertainment and IT equipment	No	Potential to introduce an 'internet of things' requirement to holistically deal with networked equipment with potentially high standby energy waste	Complex and challenging to handle. Research required.
Lamps	No	Lamps can be significant energy users and contribute to heat loads with positive and negative effects	Some homes do not use high energy lamps, difficult to track this energy use.
Portable Cooking and food processing devices – grills, kettles, etc	No	A truly whole of house performance requirement would reflect this end use	Annual energy use is quite limited and varies considerably household to household. A requirement and verification mechanism is hard to envisage
Other appliances – hair dryers, electric blankets, etc	No	As above	As above

3.3.4 PV and other renewables

The table below summarises the current treatment under the Code of on-site renewable energy generation and storage and the pros and cons of inclusion in a whole of house system.

Table 8 – Renewable energy generation under a whole of house system

Element	Currently Included	Pros	Cons
PV	No	Huge scope, especially in Class 1, to limit household CO_2e emissions	Research required into the mode and size of performance requirements via feasibility and benefit-cost tests.
Storage	No	Potential to facilitate increased use of RE thereby limiting emissions and lifetime energy costs. Given rapid changes in the storage and battery market it would be sensible to 'future proof' the next edition of the Code so that conceivable gains and innovation are not inadvertently stifled	Complicates the 'trade-off' issue
Other RE – solar thermal, geothermal, wind etc. Both stand-alone (for class 1) and shared systems for class 2 and micro-grid estates should be considered.	No	While PV appears to offer the most cost-effective RE solution for class 1 dwellings, other solutions may have application in large Class 2 developments. The Code should allow for innovation in this space.	Research required into appropriate method for the Code to address this issue.

3.4 Research Questions and Program

There are numerous pieces of research that will be required to reach a landing on a whole of house solution.

We table some of the high priority issues below.

Table 9 - Whole of House requirements research priorities

No.	Title	Objective	Rationale for Priority	Risks	Cost Est. (excl. GST)
1	Pre-Feasibility Study - Overview	To assess the value of including additional elements of energy consumption & generation within the scope of NCC energy performance requirements for residential buildings	• Direct and critical input into strategic direction and shape of future codes	• Limited and low	$40,000
2	*Space Conditioning / PV Analysis*	To determine what specific case exists for including space conditioning energy consumption and/or PV generation within the scope of NCC energy performance requirements for residential buildings.	Critical and interlinked issue for whole of house performance	• Project may require a larger budget and larger scope	$60,000
3	*Cooking Analysis*	To determine what specific case exists for including cooking energy consumption within the scope of NCC energy performance requirements for residential buildings.	Cooking is an unregulated energy use area (no MEPS) with a little understood impact on whole of house performance	The proposed study is desk-top only so will generate many more questions and research areas	$60,000
NOTE: Projects 1,2 and 3 are related and could be bundled together by the Department for procurement and project management purposes					
4	*Existing Appliance Performance Requirements*	To determine the optimal performance requirements, for a 2019 version of the NCC, for 'fixed' appliances already included within the scope of Code energy performance requirements (lighting, hot water, pool & spa pumps).	These areas are covered – but poorly. Optimisation or re-configuring into a genuinely whole of house system will bring strong benefit	Contingent on answers supplied in Project 1	$60,000

Note: Details in Appendix B

Appendix A: Proposed Research Program – Real World Data

<table>
<tr><th>No./Title</th><th>Summary Description</th><th>Estimated Cost (exc. GST)</th></tr>
<tr><td>1. Incremental Costs Associated with Higher Star Ratings – NatHERS Data</td><td>Research objective:
To identify incremental costs associated with above-6 star dwellings in Australia and how these costs have changed through time.
Key research questions:
What does the evidence show about average incremental construction costs for residential buildings in Australia following the introduction of past energy performance requirements? The answer must separately consider the evidence for Class 1a)i) (detached houses), Class 1a)ii) (semi-detached houses) and Class 2 (apartment) dwellings. What were the trends in designs, products and other features that impacted on energy efficiency?
By how much did incremental costs change for each building class? The answer should reference the specific star ratings implied in the data, noting that NatHERS star bands involve non-linear energy savings and may be associated with non-linear incremental costs.
To the extent supported by the data, what has been the path of incremental costs through time for each building class? If there is evidence that incremental costs change through time, what is the rate of change expressed as a percentage change relative to initial or first year incremental cost?
What is the distribution of results around the mean or averages described above? Is there evidence to suggest that the level of incremental costs, and/or its pathway through time, is affected by factors such as:
The size of the construction firm (measured in terms of the number of houses/year constructed)?
The extent of notice provided to industry about a future increase in performance requirements?
Is there reason to believe that future trends will be similar to or different from those in the past? Why?
Methodology/data sources
This study will draw on the CSIRO and/or FirstRate5 ratings database and apply industry-based cost estimates (or quantity surveyor/Rawlinsons cost estimates, but only if adjusted with ‘real world’ evidence) to specific elements referenced in the rating for individual dwellings that are deemed relevant for energy performance. A consistent set of elements should be used, to the extent possible. The study should document results for at least 10 Class 1a)i), 10 Class 1a)ii) (semi-detached houses) and 10 Class 2 dwellings for each of the 8 NCC Climate Zones (where supported by the data). That is a total of 240 dwellings, subject to data availability. Where data from earlier years is not available, more recent data may be used for at least 5, 6 and 7 star dwellings, noting this may limit the ability to examine changes in incremental costs through time.
This methodology was used by CSIRO in its ex poste evaluation of 5 star. If the project were to be undertaken by a consultancy, it would be essential that the Department first secured data access agreements from all data owners.</td><td>$80,000</td></tr>
<tr><td>2. Measured Energy Consumption of 6+</td><td>Research objective:
To determine whether there is evidence that, on average over a</td><td>$120,000</td></tr>
</table>

No./Title	Summary Description	Estimated Cost (exc. GST)
Star Rated Houses	large sample, higher star rated dwellings use less energy. *Key research questions:* • Is there evidence that, on average, 7 star dwellings use less energy than 6 star dwellings, and that 6 star dwellings use less energy than 5 star dwellings? If possible, layer this data by dwelling class (1a)i), 1a(ii) and 2). Electricity and gas consumption should be covered if possible. • If there is such evidence, what is the average difference in energy consumption, and what is the distribution (variability) of measured energy consumption at each of the 5, 6 and 7 star bands? • How does the measured difference compare, in percentage terms, with the modelled difference in thermal loads for 5, 6 and 7 star dwellings for that climate zone? • If supported by the data, do the results vary (in percentage terms) in summer and in winter? That is, is there evidence of greater or lesser savings in reality than predicted in winter and in summer? • Comment on the confidence in the results, including with reference to issues such as the likely impact on the results of 'behind the meter' PV, the presence/absence of gas connections or data on gas consumption. *Methodology/Data Sources* • This is a 'big data' study, where the emphasis is on sample sizes that are large enough to average out differences in occupancy, appliance use, etc, at the individual household level – at least 100 dwellings for each dwelling type, star band and climate zone covered (smaller samples may be justified for climate zones with fewer rated dwellings). • Householder permissions and/or the co-operation/participation of one or more energy market institutions or energy distribution companies are required for this study. The study also requires access to the CSIRO and/or FR5 rating databases. • Proxy measures may be used to estimate the star rating of dwellings in the data sample, for example with reference to the date of first connection of energy services. • If the project were to be undertaken by a consultancy, it would be essential that the Department first secured data access agreements from all data owners.	
3. Incremental Costs and Market Responses – Industry/ Quantity Surveyor Data	*Research objective:* • *To identify incremental costs associated with 6 star and above dwellings in Australia and how these costs have changed through time.* *Key research questions:* • *What does the evidence show about average incremental construction costs for residential buildings in Australia following the introduction of past energy performance requirements? The answer must separately consider the evidence for Class 1a)i) (detached houses), Class 1a)ii) (semi-detached houses) and Class 2 (apartment) dwellings.* • *By how much did incremental costs change for each building class? The answer should reference the specific star ratings implied in the data, noting that NatHERS star bands involve non-linear energy savings and may be associated with non-linear incremental costs.*	$140,000

No./Title	Summary Description	Estimated Cost (exc. GST)

	• *What does the evidence show about the path of incremental costs through time for each building class? If there is evidence that incremental costs change through time, what is the rate of change expressed as a percentage change relative to initial or first year incremental cost?*
	• *What is the distribution of results around the mean or averages described above? Is there evidence to suggest that the level of incremental costs, and/or its pathway through time, is affected by factors such as:*
	  o *The size of the construction firm (measured in terms of the number of houses/year constructed)?*
	  o *The extent of notice provided to industry about a future increase in performance requirements?*
	
	Methodology/data sources
	• *This study will recruit project home builders, energy assessors and/or other building professionals with access to historical documents that show evidence, for actual dwelling projects, what design and/or specification changes were made to dwellings after the introduction of energy performance requirements (at least BCA2010, but earlier data may be used. For NSW, it may only be feasible to examine data following the introduction of BASIX. At least 2 examples each of a Class 1a)i), Class 1a)ii) and Class 2 dwellings should be examined for each NCC Climate Zone, subject to data availability, a total of 48 dwellings.*
	Data may be available from the same sources as to the actual changes in costs incurred, attributable to the new energy performance requirements, and if so, this data should be captured and reported. In any case, independent quantity surveyor cost estimates must then be prepared for each project documented, based on the QS's own judgement about the costs that are attributable to the new energy performance requirements.	

4. Thermal Shell Performance and Occupant Behaviours – Existing Monitoring Data	*Research objectives:*
	• To assess the extent to which NatHERS accredited tools are generating accurate assessments of expected winter and summer thermal loadings, and whether higher star ratings are associated with improved thermal performance.
	• To assess the extent to which behavioural assumptions in NatHERS-compliant ratings tools influence realistic assessments of expected space conditioning energy consumption.
	
	Key research questions:
	• Is there evidence to suggest that the measured performance of dwellings matches, to a reasonable degree, the modelled performance in NatHERS, specifically with respect to:
	  o Summer cooling energy consumption;
	  o Winter heating energy consumption; and
	  o Internal temperature stability?
	• Quantify the extent to which the measured and modelled performance agrees or differs, and where possible the reasons for any differences, ideally for a range of:
	  o Class 1a)i), Class 1a)ii) and Class 2 dwellings
	  o NCC climate zones
	  o Star ratings, including ideally 5, 6 and 7 star.
	• Is there evidence to suggest that key behavioural assumptions in NatHERS-compliant ratings tools (in ratings mode) - such as occupancy hours, thermal comfort strategies (use of windows,
		$160,000

No./Title	Summary Description	Estimated Cost (exc. GST)
	ceiling fans, HVAC equipment), clothing/bedding, thermostat settings, use of blinds, etc – are unrealistic? • For each behavioural assumption, what is the evidence about actual behaviours, how does it compare with the ratings mode assumptions, what is the distribution around the mean, and how significant, in terms of expected annual energy consumption, is the difference between assumed and actual behaviours? • How does the significance of any difference vary by climate zone, by dwelling type and by season? *Methodology/Data Sources:* • This project will require access to existing house monitoring data, such as that held by CSIRO, CRC for LCL universities, Victorian houses monitored by EES, etc. The project is most likely to be undertaken by one of these parties or a consortium of them, which may assist in accessing data on dwellings in a range of climate zones. We note that there may be limited or no data available, via this method, for Class 1a)ii) and Class 2 dwellings, and data may be restricted to a small number of climate zones. • The available data will be examined to compare NatHERS predicted space conditioning energy consumption and temperature stability (eg, in free running mode) with measured results, taking into account ambient temperature conditions and other factors that may impact on the results.	
5. Value of External Benefits and Costs	*Research objective:* • To quantify the values to be used in a RIS for external/indirect benefits and costs, based – to the greatest extent possible – on real world data rather than estimation. *Key research questions:* • Review existing research and/or, where possible, undertake original analysis to quantify the full range of external costs and benefits expected to be associated with a possible change in NCC energy performance requirements for dwellings. For research purposes only, a lift in star rating of one star could be assumed. Where results are expected to be non-linear with increasing stars, this should be noted. • The scope of external effects examined should include, but is not limited to, health impacts and costs (specifically including the potential to limit impacts associated with heatwaves), avoided greenhouse gas emissions/climate damage, avoided time off work/school, poverty alleviation/increased disposable income, housing affordability/stress, peak load and infrastructure impacts (transmission and distribution), asset value increases, job creation, and energy security effects. *Methodology/Data Sources* • The project will include an exhaustive literature review, focusing on Australian sources but including key and relevant sources from other countries. This literature will be analysed to conclude: what are the relevant classes of external impact? How well quantified/understood are they, in Australia or overseas? What are the most significant values to quantify? • Original analysis will then be undertaken to estimate, to the extent possible, the most an appropriate range of values, and an	$90,000

No./Title	Summary Description	Estimated Cost (exc. GST)
	‘expected’ or probability-weighted mean value, for use in benefit cost analysis. Methodologies will vary for each externality class, but we note that original analysis could include modelling/analysis of the thermal performance of houses in ‘free running’ mode. • The project will conclude with an assessment of the confidence in each of the values referenced and any conclusions or recommendations for further research. • The research should be framed with reference to the requirements of the COAG best practice guidelines for benefit cost analysis/regulation impact assessment, including an assessment of the extent to which each externality class is likely to be consistent with these guidelines.	
6. Compliance Audits	*Research objective:* • To determine the extent to which there is evidence that under-compliance with Code energy performance requirements is likely to alter the expected incremental costs and/or benefits associated with future energy performance requirements. Where justified, to recommend adjustment factors for RIS purposes. *Key research questions:* • To what extent is there evidence that dwellings, designed to achieve (at least) 6 star performance (or BASIX in NSW), are in fact complying with NCC/BASIX energy requirements? • How frequently do dwellings under-achieve the mandatory minimum energy performance requirements, and by how much? • What is the expected additional annual energy consumption attributable to under-compliance with mandatory requirements? • Estimate the value of any avoided construction costs attributable to non-compliance. *Methodology/Data Sources* • The study must consider all relevant energy performance requirements, including thermal envelope performance, fixed appliances (hot water/lighting energy density, pool/spa pumps). Also consider Class 1a)i), Class 1a)ii) and Class 2 dwellings. • The study should cover at least three dwellings of each type in at least three climate zones, that is, a total of 27 dwellings. Depending upon the methodology, a larger sample may be available. • Method 1: Work with data from the NatHERS database to access ratings and universal certificates for a range of dwellings – or otherwise to secure a range of NatHERS assessments to cover the required scope – and then to seek the owners’ permission to conduct a walk-through audit (including with the use of thermal imaging cameras) of each dwelling to verify at least the presence of insulation, lighting energy density, other fixed appliances, glazing (eg, where high performance glazing is specified). The auditor would survey occupancy, note appliance numbers/types, the space conditioning equipment and model numbers, and request and obtain energy bills (for at least 12 months). The researcher would then assess the extent of non-compliance and the extent to which this is correlated with additional energy consumption and/or avoided construction costs. • Method 2: Additional value could be added if this analysis were	Method 1: $120,000 Method 2 (incremental cost only): $40,000

No./Title	Summary Description	Estimated Cost (exc. GST)
	undertaken on dwellings already/previously monitored by CSIRO/CRC, as this would facilitate correction of the results of the walk through audit with any gap between modelled and measured space conditioning performance, and an analysis of the extent to which gap is attributable to non-compliance [as per the Thermal Shell Performance – Existing Monitoring Data project above]. Alternatively, this task could be added on to that project. CSIRO's EUDM pilot study in Victoria could potentially be modified to include this scope at low or no marginal cost. • As this project requires access to NatHERS ratings data, and potentially to house monitoring data, it is likely that it may best be undertaken by CSIRO/CRC universities. If the project were to be undertaken by a consultancy, it would be essential that the Department first secured data access agreements from all data owners.	
7. Thermal Shell Performance – Pre-Occupancy Measurement	*Research objective:* • To assess the extent to which NatHERS accredited tools are generating accurate assessments of expected winter and summer thermal loadings, and whether higher star ratings are associated with improved thermal performance. *Key research questions:* • Is there evidence to suggest that the measured performance of dwellings matches, to a reasonable degree, the modelled performance in NatHERS, specifically with respect to: o Summer cooling energy consumption; o Winter heating energy consumption; and o Internal temperature stability? • Quantify the extent to which the measured and modelled performance agrees or differs, ideally for a range of: o Class 1a)i), Class 1a)ii) and Class 2 dwellings o NCC climate zones o Star ratings. *Methodology/Data Sources:* ▪ This project requires new performance measures to be made for a sample of new dwellings that are completed but prior to occupancy. This will require recruitment of willing developers/owners to participate in the study. At least two tests should be applied. First, monitoring internal temperature stability in 'free running' mode (without space conditioning) as a function of variation in external ambient temperature. Analysis of the resulting data will need to take into account thermal inertia effects. Longer data observations would be helpful where available. A second test would involve introducing a measured amount of heat/coolth via existing space conditioning equipment, and measuring the subsequent path of internal temperate relative to external ambient temperature. Analyse the extent to which the measured performance matches that predicted by the star rating for the dwelling. ▪ This study should be undertaken for at least 2 dwellings each of Class 1a)i), Class 1a)ii) and Class 2, in each of at least 3 differing climate zones, that is, a total of 18 dwellings. Ideally the two dwellings (for each climate zone/type) would have star ratings that differ by at least one star.	$75,000

Appendix B – Proposed Research Program - Whole of House

Title	Summary Description	Estimated Cost (exc. GST)
Pre-Feasibility Study - Overview	*Research objective:* • To assess the extent to which it is likely to be valuable to include additional classes of energy consumption within the scope of NCC energy performance requirements for residential buildings, taking into account the likely materiality, additionality and cost effectiveness of energy savings; the enforceability of requirements and potential risks to consumer choice. *Key research questions:* • What objectives and related metrics would be optimal for whole-of-house energy performance requirements, taking into account the differing situations of all states and territories? • How do these considerations affect the scope and form of energy performance requirements? • Considering space conditioning, cooking (including use of exhaust fans/rangehoods), non-fixed appliances (plug load) and also PV, what is the likely significance, cost effectiveness, reliability/permanence and additionality of energy savings from NCC energy performance requirements in each area? For PV, the case for allowing PV as part of the building solution (essentially offsetting other energy consumption) should be considered? • Would different performance requirements be required by state/climate zone/dwelling type? Consider relevant existing state/territory variations in this context. *Methodology/data sources:* • Desktop analysis drawing on existing energy performance and cost data and knowledge of existing policy frameworks.	$40,000
Space Conditioning / PV Analysis	*Research objective:* • To determine what specific case exists for including space conditioning energy consumption and/or PV generation within the scope of NCC energy performance requirements for residential buildings. *Key research questions:* • Assuming that space conditioning energy consumption were included within the scope of NCC performance requirements for residential buildings, to what extent would this create additional energy savings not already attributable to MEPS/labelling? • What specific performance requirements would be cost effective? • What impacts would these requirements have on consumer choice and fuel choice by state? • What is the expected duration of anticipated energy savings? • To what extent should over-performance in this area allow under-performance in other areas, and which other areas? • If PV generation were allowed as part of the building solution, to what extent would this create opportunities for performance trade-offs with space conditioning equipment and/or thermal shell performance requirements? • Should local storage and/or 'smart' energy management systems also be incorporated within the scope of Code energy performance requirements? How?	$60,000

Title	Summary Description	Estimated Cost (exc. GST)
	Methodology/data sources: • Desktop analysis drawing on existing energy performance and cost data and knowledge of existing policy frameworks.	
Cooking Analysis	*Research objective:* • To determine what specific case exists for including cooking energy consumption within the scope of NCC energy performance requirements for residential buildings. *Key research questions:* • Assuming that cooking energy consumption were included within the scope of NCC performance requirements for residential buildings, to what extent would this create additional energy savings not already attributable to MEPS/labelling? • What specific performance requirements would be cost effective? • What impacts would these requirements have on consumer choice and fuel choice by state? • What is the expected duration of anticipated energy savings? • To what extent should over-performance in this area allow under-performance in other areas, and which other areas? • What effects do the choices of cooking equipment/fuel, and also use of extractor fans/rangehoods, have on other aspects of energy performance – including on space conditioning energy in summer and winter and on peak loads? *Methodology/data sources:* • In the first instance, desktop analysis drawing on existing energy performance and cost data and knowledge of existing policy frameworks. • NatHERS or other modelling of a range cooking appliance options and their whole-of-house energy performance implications by season is then likely to be necessary.	$60,000
Existing Fixed Appliance Performance Requirements	*Research objective:* • To determine the optimal performance requirements, for a 2019 version of the NCC, for 'fixed' appliances already included within the scope of Code energy performance requirements (lighting, hot water, pool & spa pumps). *Key research questions:* • Is there a strong justification for continuing with hot water energy/greenhouse performance requirements in the 2019 version of the NCC? If so, what performance requirements would be optimal? • Is there a strong justification for continuing with lighting energy performance requirements in the 2019 version of the NCC? If so, what performance requirements would be optimal? • Is there a strong justification for continuing with pool and spa pump energy performance requirements in the 2019 version of the NCC? If so, what performance requirements would be optimal? *Methodology/data sources:* • Examine additionality of inclusion of these end-uses within the Code, along with other factors such as materiality, enforceability, extent of known compliance/non-compliance. • Benefit cost analysis should used to determine the optimal stringency of performance requirements to apply from 2019.	$60,000

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