REPORT

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Energy-efficiency: building code star-ratings

What's optimal, what's not

Prepared for

Master Builders Australia

Centre for International Economics
Canberra & Sydney

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TheCIE's professional staff arrange, undertake and publish commissioned economic research and analysis for industry, corporations, governments, international agencies and individuals.

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Foreword

This report has been prepared by the Centre for International Economics (The CIE) and is based on model simulations conducted by *pitt&sherry* and Energy Partners using AccuRate Software.

Glossary

ABCB	Australia Building Code Board
ACTHERS	Accredited FirstRate Assessor Course
AGO	Australian Greenhouse Office
BCA	Building Code of Australia
COAG	Council of Australian Governments
CPRS	Carbon Pollution Reduction Scheme
CSIRO	Commonwealth Scientific and Industrial Research Organisation
DG	Double glazing
EER	Energy-efficiency Rating
kWh	Kilowatt hours
MCE	Ministerial Council on Energy
NABERS	National Australian Built Environment Rating System
NatHERS	Nationwide Energy Rating Scheme
NPV	Net present value
PC	Personal computer
RIS	Regulation Impact Statement
SHGC	Solar Heat Gain Coefficient
The CIE	The Centre for International Economics
TSG	Single glazing

Executive summary

Residential building energy star ratings are widely perceived within the community to be a measure of economic efficiency. A higher star rating is perceived as innately desirable. However, energy efficiency is not economic efficiency. Energy efficiency is only achieved at a cost to the economy. Relentlessly pursuing ever higher energy efficiency star ratings in building with no consideration of costs creates political pressures to achieve incorrect economic targets. It amounts to assuming that energy savings can be achieved at no resource cost. This is economically reckless. It ignores the other important half of the optimal resource use equation.

Findings in this report are that, generally it pays to achieve a 5 star rating for new houses: the benefits of energy savings up to this point are greater than the costs of the energy saving technologies required to achieve the saving. However, above this point, for most houses in Melbourne, Sydney and Brisbane (representing about 80 per cent of Australian city residential houses), the benefits diminish and cost start to escalate. Forcing home owners to build houses with higher star ratings (using mandatory minimum standards) will be financially detrimental to most new home owners and economically detrimental to the community. It will manifest itself in higher house prices and lower disposable incomes of Australians and it will not result in efficient reductions in greenhouse gases.

Benefits diminish sharply as star ratings rise

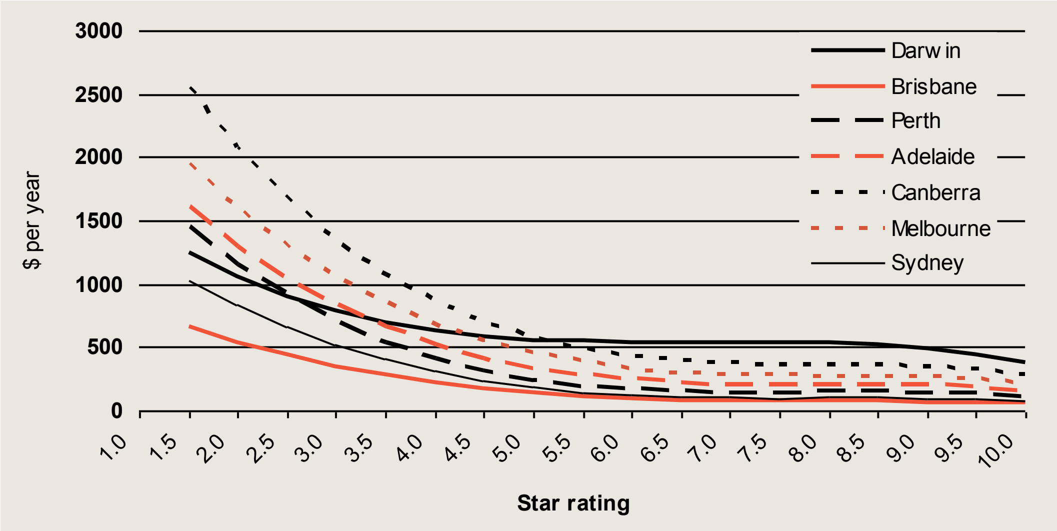
The biggest incremental energy savings are achieved at low star ratings (chart 1).

- The way that star bands are constructed means that the marginal benefit of increasing the star rating diminishes rapidly. The benefits of increasing the star rating beyond around 5 stars are therefore minimal.
- For instance, increasing the star rating in Sydney from 1 to 2 stars could save a householder around $980 per year. However, moving from 5 to 6 stars would save the house owner only about $148 a year and moving from 6 to 7 would save about $124 a year. Moving from 9 to 10 stars saves only $95 a year.

Costs escalate sharply as star ratings rise

The cheapest savings will be made first and so they will be made at low star ratings. To achieve ever higher star ratings requires deploying increasingly expensive energy-saving technologies. For instance, for a typical new home in Sydney:

1 **Marginal benefit of increasing the energy efficiency of a residential building**



Data source: NatHERS, The CIE. Note: assumes a 24/7 occupancy and whole house heating and cooling which may overestimate savings by as much as 50 per cent.

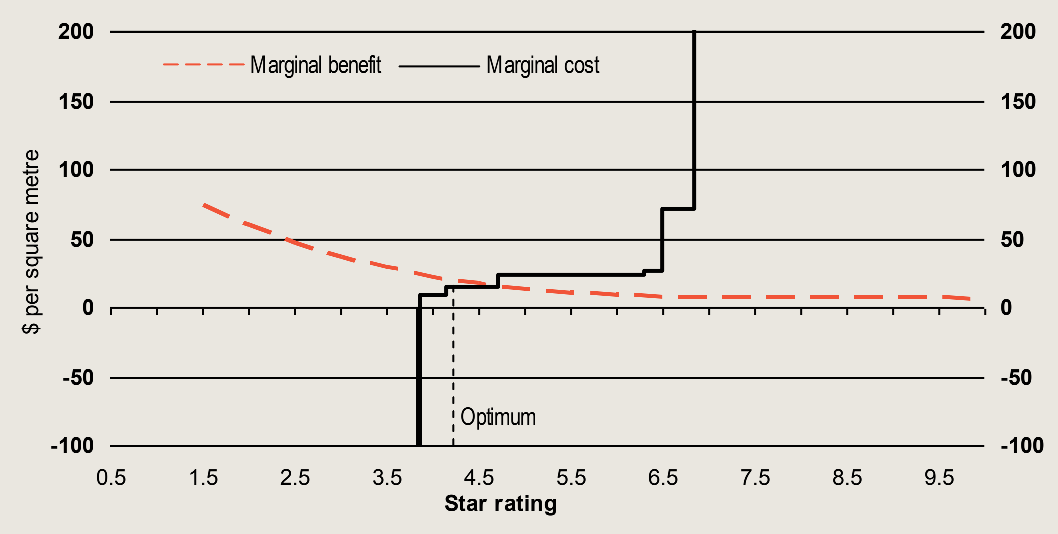
- a 1 star rating improvement from 4 to 5 stars by incorporating a concrete floor and additional ceiling insulation would deliver a net benefit (savings minus costs) of nearly $100 per square metre, however;
- to achieve a 6 star rating (from 5 stars), requiring a move to double glazing and additional wall insulation, would impose a net cost of $40 per square metre;
- to achieve a 7 star rating (from 5), requiring additional floor insulation, would impose a net cost of $70 per square metre;
- to achieve a star rating of 8 (from 5), by adding improved ducting and external shading, would impose a net cost of $190 per square metre.

Once costs exceed benefits, higher star ratings are wasteful

Because incremental benefits from higher star ratings diminish sharply (even with markedly higher future energy prices under a carbon pollution reduction scheme (CPRS)) and incremental costs rise steeply, beyond a certain star rating it does not pay to pursue higher star ratings. The optimal star rating will be found by increasing the star rating up to the point where diminishing marginal benefits equal escalating marginal costs. Pursuing higher energy star ratings beyond this point will be an expensive way to achieve energy savings and greenhouse gas reductions.

Chart 2 shows the rapidly diminishing marginal benefits and escalating marginal costs for a typical new two storey family home in Sydney assuming CPRS-5 future electricity prices modelled by Treasury. The optimal star rating for this home is 4.2 stars. Further, the marginal benefits (or the electricity price) would have to increase by about 144 per cent (above CPRS-5) to justify a 6 star rating for this typical new house (from $9.3 to $22.7 per square metre).

2 **Marginal costs and benefits of new house type 8 — Sydney**

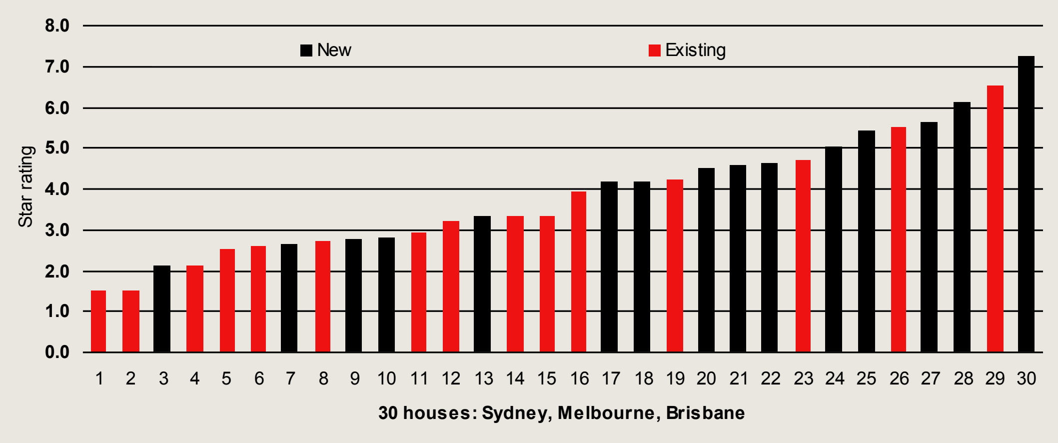


Data source: The CIE. The first technology used provides a negative cost (that is, a benefit). The technology is a concrete floor used in place of a timber floor. Concrete floors on ground are cheaper per square metre than wooden ones and thermally more efficient. The costs however, do not include the greenhouse gas costs of concrete. The application of all other technologies has a positive cost.

Optimal star rating varies by location and house design

Chart 3 sets out the optimal star rating for ten houses (five new and five existing) designs in Melbourne, Sydney and Brisbane (30 houses in all) assuming CPRS-5 electricity prices. Eighty percent of city houses in Australia are located in these three cities.

3 **Optimal star rating for 30 typical houses in Sydney, Melbourne and Brisbane**



Data source: The CIE.

Optimal star rating is generally around or below 5

Apart from one particular house design with several site advantages, most other typical new designs in most locations have optimal star rating below 6 and many are below 5. These results are consistent with the recent Regulation Impact Statement (RIS) which assessed the benefits and costs of the Building Code of Australia (BCA) being revised to raise the minimum required star rating from 5 to 6 stars. It found that a shift to 6 stars would impose net costs on the Australian economy.

- The results from the RIS and chart 3 show that the current minimum energy efficiency requirements for new homes are likely to be at, or already past, the optimal level in most areas.
- Any future increases in the minimum energy efficiency requirements for new homes will result in larger and larger costs and smaller and smaller benefits. The net cost to the community will therefore increase significantly with each incremental increase in the minimum energy efficiency requirements for new homes.

Some gains may be possible in existing homes

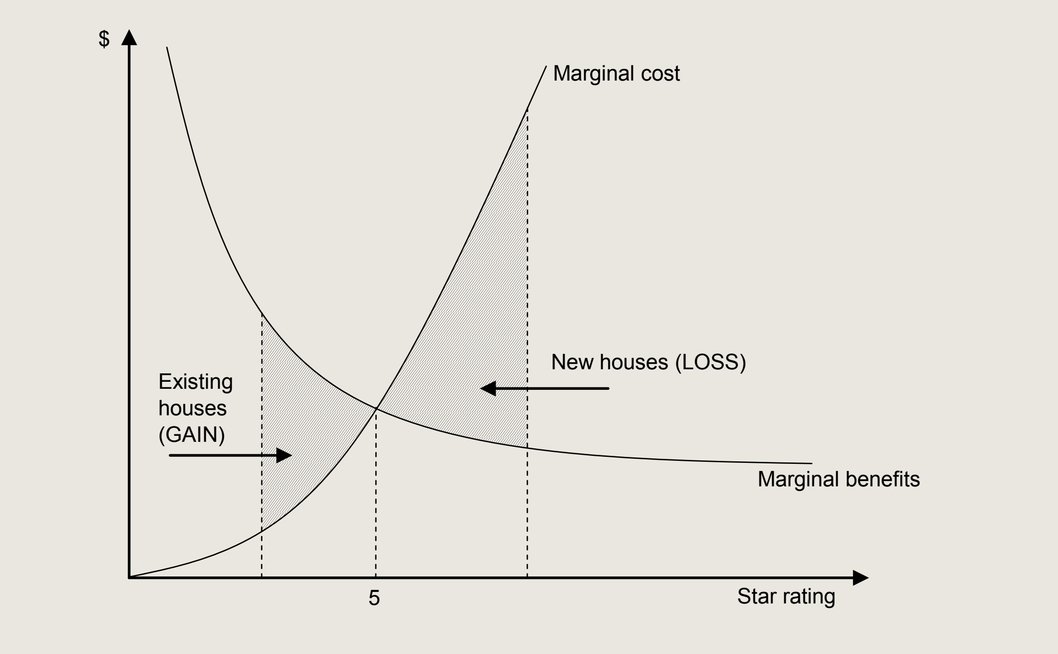
Optimal star ratings for existing houses are generally a lot lower than those for new houses (chart 3). However, current star ratings of many existing homes are also very low (many around 1) and are well below their optimum. On these grounds, it appears that it may be economical to deploy cheaper energy–saving technologies such as ceiling insulation, floor insulation, weather sealing and in some case wall insulation to raise the star rating by up to 2 stars from currently very low levels. This suggests there may be potential benefits to home owners and the economy more generally of encouraging existing homes to raise their star ratings.

Gains and losses: new versus existing homes

Chart 4 provides an illustrative summary of the potential gains and losses from pursuing higher star ratings. It shows that gains may be possible from raising the low star ratings of existing homes but losses will be incurred from forcing new homes to achieve higher star ratings. Chart 5 shows the extent of these gains and losses per square metre for 35 existing and 35 new homes across Australian capital cities (excluding Hobart).

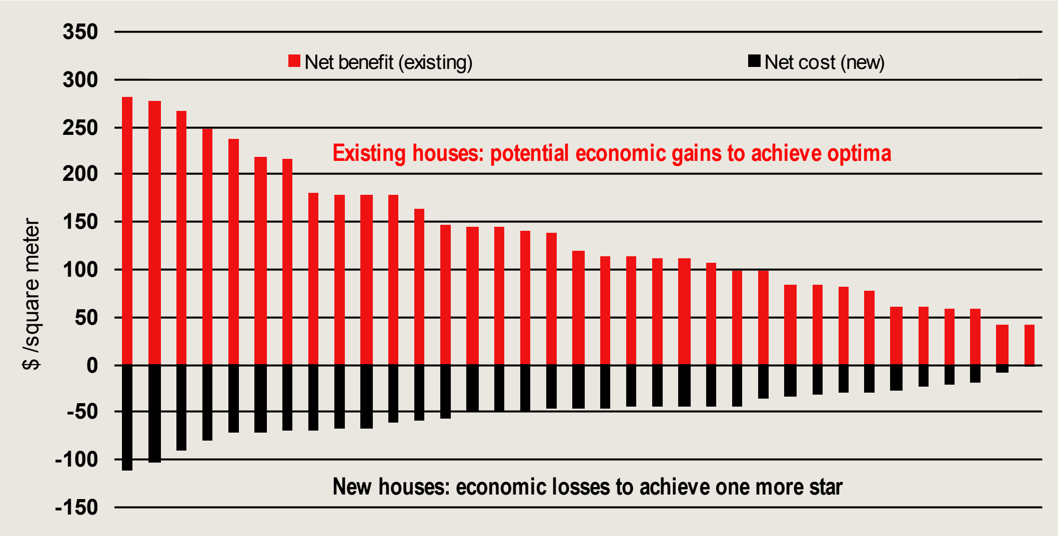
Moving to the optimal star rating for existing house designs indicates potential for significant net gains (benefits minus costs) of over $100 per square metre for many of

4 Illustrative representation of potential gains and losses



Source: The CIE.

5 Net benefits/costs from changing star ratings



Data source: The CIE

the 35 homes considered (chart 5). That said, some ambiguity surrounds these results. The Federal Government's recent home insulation program may have already captured a sizeable share of these gains. If so, gains are still possible but may be less than indicated.

For new homes, chart 5 shows the marginal net costs (costs minus benefits) per square metre of forcing each new house design to increase its star rating by around one extra star from its optimum. In many cases, the net costs of forcing higher minimum star ratings are substantial and average $51 per square metre. For a house with 230 square metres of floor space, a $50 per square metre net cost would add $11 500 to the lifetime cost of the house and an even higher build-cost. For most houses in most locations it requires deploying expensive technologies such as double glazing, floor insulation or external shading.

It is always easier and cheaper to incorporate energy saving technologies into new houses compared with existing homes. However, each year there are only around 100 000 new detached homes built in Australia. This compares with a stock of around 7 million existing detached homes.[1] So, were there any possibilities for energy improvements in existing houses, the quantum of energy saving gains may be considerable.

Moreover, standard new homes with standard new technologies may achieve star ratings of between 3 and 5 within their standard design features. They typically have certain amounts of insulation installed as a standard feature. However, existing homes, with older technologies, will not have these energy-saving technologies as standard. Many existing homes may have star ratings of 1 or less. Given the underlying diminishing marginal benefits built into the star rating system, the energy savings of advancing from 1 to 2 stars for existing homes are about five times those of advancing from 4 to 5 stars for a new home.

Although the marginal costs may be higher to achieve star rating improvements in existing homes, the marginal benefits will also be higher, and if marginal benefits exceed marginal costs, the marginal net benefits would apply to a considerably larger housing stock in the case of existing homes relative to new ones.

These results are robust

Some uncertainty surrounds the estimates of optimal star ratings presented here. But overwhelming any concerns about such uncertainties is the low sensitivity of the optimal points to changes in key assumptions. In all new house designs evaluated, marginal costs escalate rapidly above 6 stars, while benefits continue to diminish. For many new house designs this occurs at lower star rating (around 5 stars). Even quite large increases in electricity prices or falls in construction or design costs will make very little difference to the conclusion that raising the minimum mandated star rating above current levels will be economically detrimental to Australia.

For existing homes, potential for economic gain may exist. For those homes with very low existing star ratings, those with star rating of 1 or below, there is probably potential for an economical 1 to 1.5 star gain.

[1] Flats and townhouses are additional to these estimates.

1 Introduction

Background

The Australian Government has identified improving energy efficiency as a cost-effective way of reducing greenhouse gas emissions. Residential buildings account for around 13 per cent of greenhouse gas emissions. To improve energy efficiency in this area, minimum energy performance requirements for new residential buildings have been included in the *Building Code of Australia* (BCA) since 2003.

These minimum energy performance requirements have been specified in terms of the Nationwide House Energy Rating Scheme (NatHERS). NatHERS accredits software tools that rate, using a 10 star band, the potential energy efficiency of the building shell of a home in terms of the heating and cooling energy required per square metre to keep the home at a reasonable level of human comfort.

Initially, these minimum energy performance requirements specified in the BCA aimed to achieve a level of energy efficiency equivalent to 3.5 to 4 star rating under NatHERS. However, the minimum standard has been incrementally tightened.

- From 2005, Class 2–4 dwellings (apartments, boarding houses, etc.) were required to meet a minimum of 3 stars for all units, an average of 4 stars for units within one building in cool/temperate climates, and an average of 3.5 stars for units within one building for warmer climates.
- From 2006, Class 1 buildings were required to meet a minimum of 5 stars.[2]
- The Australian Government earlier this year announced that the minimum energy efficiency requirement in the BCA will increase from a 5 star rating to 6.
- The National Building Energy Standard-Setting, Assessment and Rating Framework proposes to set increasingly stringent minimum performance

2 Senior Officials Group on Energy Efficiency, 2010, *National Building Energy Standard-Setting, Assessment and Rating Framework: National Strategy on Energy Efficiency*, Public Discussion Paper, March, p.41.

standards over time for new buildings and major renovations (subject to regulatory impact assessment).[3]

So far, mandatory provisions have not been extended to existing homes.

The issue

The energy efficiency star rating scheme is based on a single measure of conditioning energy required to achieve a certain level of human thermal comfort — the measure is derived from energy modelling software — AccuRate[4]. It is widely perceived within the community to be a measure of economic efficiency and a higher star rating is perceived as desirable. However, it is **not** a measure of economic efficiency. It partially defines potential economic benefits, but it does not define economic costs. The assumption that energy use by a building equates with greenhouse gas emissions is also not correct. The economic efficiency of pursuing star ratings and the economic optimum of any star rating are more complex issues.

The economic dimensions of relentlessly pursuing higher star ratings are poorly understood politically and within government. The Productivity Commission has previously expressed concern about how the star rating system is applied. It has also recommended that a detailed, *ex post*, economic analysis be conducted on the previous decision to move to the 5 star rating. This has not occurred. In addition, the Final Regulation Impact Statement and benefit cost analysis[5] behind the recent decision to move to 6 stars showed that economic losses would be imposed on most states should it be adopted, but the Ministers Building Forum decided to proceed anyway.

The problem may be that the star rating scheme creates political pressures to achieve incorrect economic targets. A proper economic framework is needed to help policy advisors in government and politicians better understand the important economic efficiency issue that stand above simple energy efficiency concepts. The building industry too needs to better understand the proper economic targets so they can

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3 Senior Officials Group on Energy Efficiency, 2010, *National Building Energy Standard-Setting, Assessment and Rating Framework: National Strategy on Energy Efficiency*, Public Discussion Paper, March, p.5.

4 AccuRate models conditioning energy required to be added or removed to achieve comfort. The actual amount of conditioning energy used depends on electricity (grid or renewables) and gas used by the conditioning appliances, which in turn depends on household practices and the energy efficiency of the conditioning appliances. In addition, significant other energy use occurs during the operation of a house.

5 ABCB 2009, *Final Regulation Impact Statement for Decision (Consultation RIS 2009-05), Proposal to Revise the Energy Efficiency Requirements of the Building Code of Australia for Residential Buildings — Classes 1, 2, 4 and 10*, Canberra.

influence building designers and consumers. Getting this wrong could be very costly to Australia.

This report

This report identifies the costs and benefits associated with each incremental increase in a building's NatHERS star rating and sets out a framework for determining the optimal star rating to aim for. The remainder of this report is structured as follows:

- Chapter 2 identifies and describes the nature of the costs and benefits of tighter energy efficiency standards.
- Chapter 3 sets out a framework for determining the optimal energy efficiency rate for each building.
- Chapter 4 applies the framework to a representative houses in each mainland capital city.
- Chapter 5 concludes.

2 *The benefits and costs of more energy-efficient residential buildings*

Since the minimum energy efficiency requirements in the BCA are defined in terms of NatHERS star ratings, it is critical to first understand the star rating system and the assumptions that underlie it.

The Nationwide House Energy Rating Scheme

NatHERS accredits software tools that rate the potential energy efficiency of the building shell of a home. The ratings are based on the heating and cooling energy required to keep the home at a reasonable level of human comfort. NatHERS uses a ten star band, where:

- zero stars means the building shell does practically nothing to reduce the discomfort of hot or cold weather;
- a 5 star rating indicates good, but not outstanding, thermal performance; and
- a 10 star rating means that occupants are unlikely to need any artificial cooling or heating.[6]

NatHERS has unique starbands for each climate zone taking into account the extremes of the local weather conditions. The impact of the weather on the building design is calculated every hour for a full twelve month period.

NatHERS takes into account factors such as the thermal characteristics of the building material and the building's design. To enable houses of different sizes to be compared within a single climate zone, the energy rating is calculated on the basis of energy loads per square metre of house floor area.

Since energy requirements to achieve thermal comfort depend on factors such as the function of each room and occupancy, NatHERS makes a number of assumptions to allow fair comparisons between buildings. For the purpose of assessing a building, each room (space) is allocated a function or functions and is allocated a period of time whereby that space is to be maintained at a thermal comfort range appropriate to its likely use.

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[6] NatHERS website, http://www.nathers.gov.au/eer/index.html, Accessed 1 April 2010.

- For living spaces (including kitchens and other spaces typically used during waking hours), a minimum heating thermostat setting of 20˚C is applied between 7.00am and midnight.
- For sleeping spaces (including bedrooms and other spaces closely associated with bedrooms), a minimum heating thermostat setting of 18˚C is used from 7.00am to 9.00am and from 4.00pm to midnight; and a heating setting of 15˚C from midnight to 7.00am.

NatHERS energy star ratings are therefore a useful tool to compare the potential energy efficiency of a building. However, it is not an indicator of energy usage or greenhouse gas emissions. Actual energy usage will depend on a range of other factors, such as the behaviour of the residents, including the appliances they use for heating and cooling, their tolerance to heat or cold, how often they are home and so on. NatHERS also does not consider the cost of meeting increasingly stringent energy efficiency standards. It is therefore not a measure of economic efficiency — economic efficiency will depend on both the benefits of greater energy efficiency and the costs.

The benefits of greater energy efficiency

There are significant benefits associated with a more energy-efficient residential building stock. All else being equal, residents of buildings with a high NatHERS star rating will use less energy for heating and cooling to achieve a comfortable temperature.

- The most obvious benefit of lower energy consumption is the private benefit to the resident from a lower energy bill. These energy bill savings accrue over time.
- Reduced energy consumption will also reduce the greenhouse gas emissions of the residential building stock. However, the nature of those benefits depends on the policy environment. In particular, whether there is a price on greenhouse gas emissions and how that price is applied.
- With no price on greenhouse gas emissions as is currently the case, lower energy consumption for residential heating and cooling will contribute to achieving Australia's greenhouse gas abatement targets. These external benefits (benefits that are enjoyed by others), are normally not taken into account by the home owner.
- However, under a 'cap and trade' emissions trading scheme (ETS) such as the Australian Government's proposed Carbon Pollution Reduction Scheme (CPRS), the cost of greenhouse gas emissions is borne by the residents. The benefits of reduced greenhouse gas emissions as a result of more energy efficient residential buildings therefore accrue to the residents. Total greenhouse gas emissions are capped, so lower energy use for heating and cooling residential buildings will not affect total emissions. Instead, lower demand for energy from residential buildings will mean that the price of carbon permits will be lower than they

otherwise would have been. This means that the cost of greenhouse gas abatement for other energy users will be lower.

The diminishing nature of benefits

The way NatHERS star bands are defined, means there are diminishing marginal benefits from each incremental increase in a building's star rating.

- The marginal benefit is the value of the energy saved from each incremental increase in the NatHERS star rating. Diminishing marginal benefits means that the energy saved by moving from no stars to a 1 star rating is higher than moving from 1 star to 2 star rating and so on.
- The marginal benefits will also vary depending on the location of the building site.
  - The energy saved for a given increase in NatHERS star rating is highest in cooler climate zones, such as Melbourne, Canberra and Hobart and lowest in more temperate climates, such as Sydney or Brisbane.[7] This is because residences in regions with cooler climates require greater energy for heating to maintain a comfortable temperature, compared with residences in more temperate regions. Therefore, less energy is saved by increasing the energy efficiency of the building. The benefits also vary by location depending on the main type of energy (electricity, gas or wood) used in that region.
  - The specific location of the building within a given climate zone may also affect the energy saved by increasing the level of energy efficiency of the building. For example, in most parts of Australia north-facing blocks tend to use less energy than south-facing blocks. This is because they receive more sun in winter, which reduces the need for heating and, with sufficient eaves they can be shaded from the sun in summer, which reduces the need for cooling.
- Chart 2.1 shows the marginal benefit curve from increasing the level of energy efficiency of a new one-storey home in a range of different climate regions (assuming the average 2010 electricity price of 15.6 cents per kWh). The marginal benefit curve shows the relationship between the NatHERS star rating (on the horizontal axis) and the energy saving (in dollar terms) achieved from moving a full star increment (on the vertical axis). The curve is downward sloping because as the star rating increases, the incremental energy saving decreases.
  - It is also important to note that the curves are convex. The benefits of moving from half a star to one star can be quite large, but this quickly diminishes as the star ratings increase. The benefit of increasing beyond around 5 stars in many

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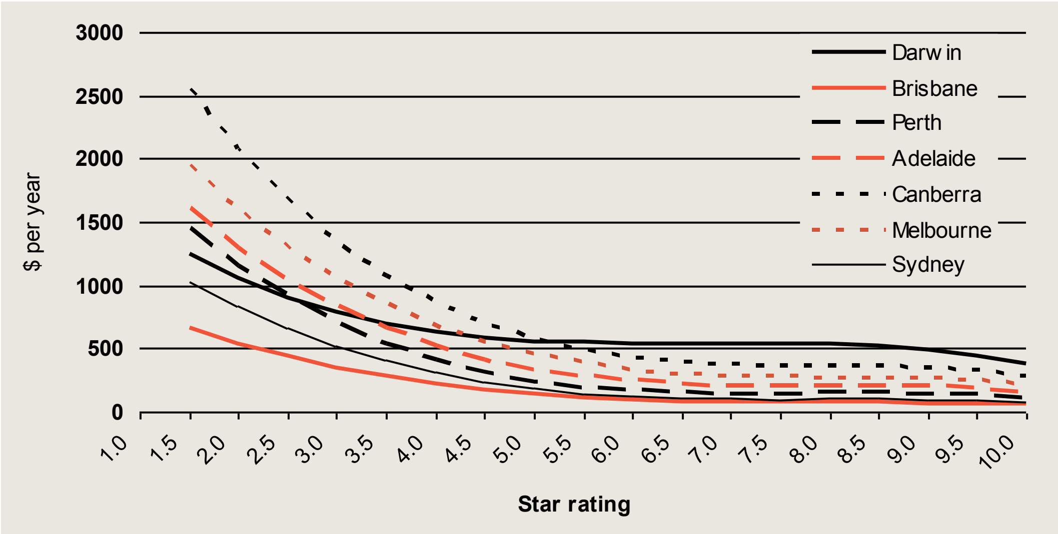
7 ABCB 2009, *Final Regulation Impact Statement for Decision (Consultation RIS 2009-05), Proposal to Revise the Energy Efficiency Requirements of the Building Code of Australia for Residential Buildings — Classes 1, 2, 4 and 10*, Canberra. http://www.abcb.gov.au/index.cfm?objectid=BE1E5D93-0B04-11DF-B1DD001143D4D594

2.1 **Marginal benefit of increasing the energy-efficiency of a residential building**



Data source: NatHERS, The CIE. Note: assumes a 24/7 occupancy and whole house heating and cooling which may overestimate savings by as much as 50 per cent.

areas is minimal. For instance, increasing the star rating in Sydney from 1 to 2 stars could save around $980 per year. However, moving from 5 to 6 stars would save the house owner only about $148 a year and moving from 6 to 7 would save about $124 a year. Moving from 9 to 10 stars saves only $95 a year.

– Moreover, the calculated energy benefits are relevant to a real house with 24/7 occupancy, and whole house heating and cooling. However, in terms of an average Australian house, with average occupancy and typical zoning patterns for heating and cooling appliances, the calculated savings value may be reduced by 50 percent or more. Zoning relates to the difference between the energy requirement of ducted heating/cooling system and a single room heating/cooling appliance. In the stock of existing houses most houses do not have ducted heating, and in many parts of Australia most houses are not air-conditioned. A discussion of the relationship of AccuRate outputs and occupancy of real houses by real families and zoning issues can be found in *Energy Use in the Australian Residential Sector 1986-2020*. If behavioural aspects of house usage actually reduce energy usage to around half that assumed by AccuRate Software, then annual potential savings would also be halved.

- The diminishing nature of the marginal benefits of increasing a building's star rating is critical to understanding the optimal star rating for that particular building.
- However, these benefits are only one side of the optimality condition. The other side is cost.

The costs of greater energy efficiency

COAG's approach to energy efficiency, as articulated in the National Energy Efficiency Strategy, is to incrementally increase the minimum energy efficiency requirements for new buildings over time.

- The implicit assumption appears to be that a higher star rating is necessarily better than a lower star rating. However, this approach does not take into account the costs associated with tightening the minimum energy efficiency standards.
- Capital costs are higher for more energy efficient buildings. Unlike the benefits of more energy efficient buildings which accrue over time, the costs of increasing the energy efficiency of a new building are mostly incurred upfront.
- There are a range of technologies that can increase the energy efficiency of a building's shell. These include:
  - the building's design and orientation to the sun;
  - concrete, rather than timber flooring;
  - improved ceiling insulation;
  - cavity wall insulation;
  - floor insulation;
  - double glazed windows;
  - tinted windows;
  - external blinds;
  - weather sealing/draught proofing;
  - screen/security doors to allow cross ventilation;
  - improved ductwork insulation; and
  - outside colour alteration.
- Some combination of these technologies is required to meet the minimum energy efficiency requirements specified in the BCA. Each of these technologies adds to the cost.
- There are also hidden costs associated with some of these technologies — particularly in terms of greenhouse gas emissions — that are not fully appreciated.
  - For example, the Productivity Commission (2005) cites a study that found that concrete floors reduce emissions from occupants' energy use, compared to timber floors. However, as concrete production is relatively greenhouse gas-intensive, it would take 62 years for the greenhouse gas saving from lower energy use to outweigh the higher emissions embodied in the concrete floor.[8]

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[8] Productivity Commission, 2005, *Energy Efficiency*, p. 217.

- The Commission argued that the current approach of ignoring many building-related emissions has undermined the effectiveness of building standards in reducing Australia's energy use and emissions.

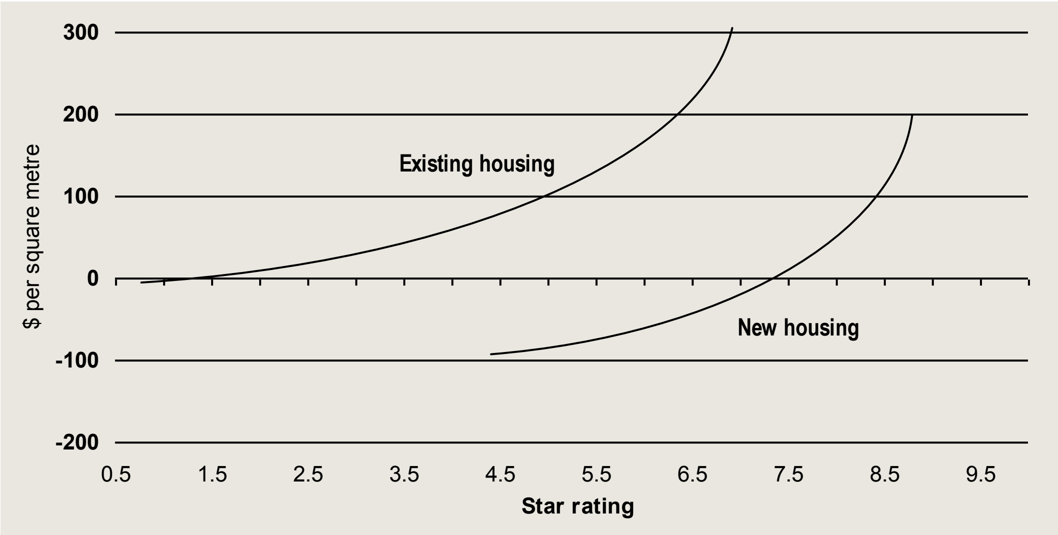
The escalating nature of costs

Unlike the benefits, the marginal cost of each incremental increase in a building's star rating is likely to increase.

- The marginal cost is the increase in the capital cost from each incremental increase in the star rating. Increasing marginal costs mean that the marginal cost of moving from nine stars to ten stars is greater than the marginal cost of moving from eight stars to nine stars and so on.
- Although there are many technologies that can be deployed to achieve energy savings, each has a finite ability to deliver savings and their costs can range from low to very high.
  - Low cost solutions will usually be preferred to expensive ones. The expensive ones will be the last deployed.
  - Also, energy efficiency technologies often become less effective when used in conjunction with other measures. That means that the energy saved by utilising multiple energy efficiency technologies is usually less than the sum of the energy saved by each of the technologies in isolation.
- A marginal cost curve shows the relationship between the NatHERS star rating (on the horizontal axis) and the incremental cost increase (in dollar terms) achieved from moving from the previous star rating (on the vertical axis).
- Chart 2.2 shows indicative marginal cost curves for new and existing houses in Sydney. The derivation of these curves is explained further in chapter 4. Marginal cost curves are constructed by:
  - incrementally adding energy efficiency technologies in order from the most cost effective (based on the benefits received relative to the cost) to the least cost effective;.
  - scaling the curve so it shows the marginal cost per NatHERS star increment.

Using a framework for determining the economically optimal level of energy efficiency must consider both the benefits and the costs.

2.2 **Indicative marginal cost curve — Sydney**



Note: the first technology used provides a negative cost (that is, a benefit). The technology is a concrete floor used in place of a timber floor. Concrete floors on ground are cheaper per square metre than wooden ones and thermally more efficient. The costs however, do not include the greenhouse gas costs of concrete. The application of all other technologies has a positive cost.

Data source: pitt&sherry, The CIE.

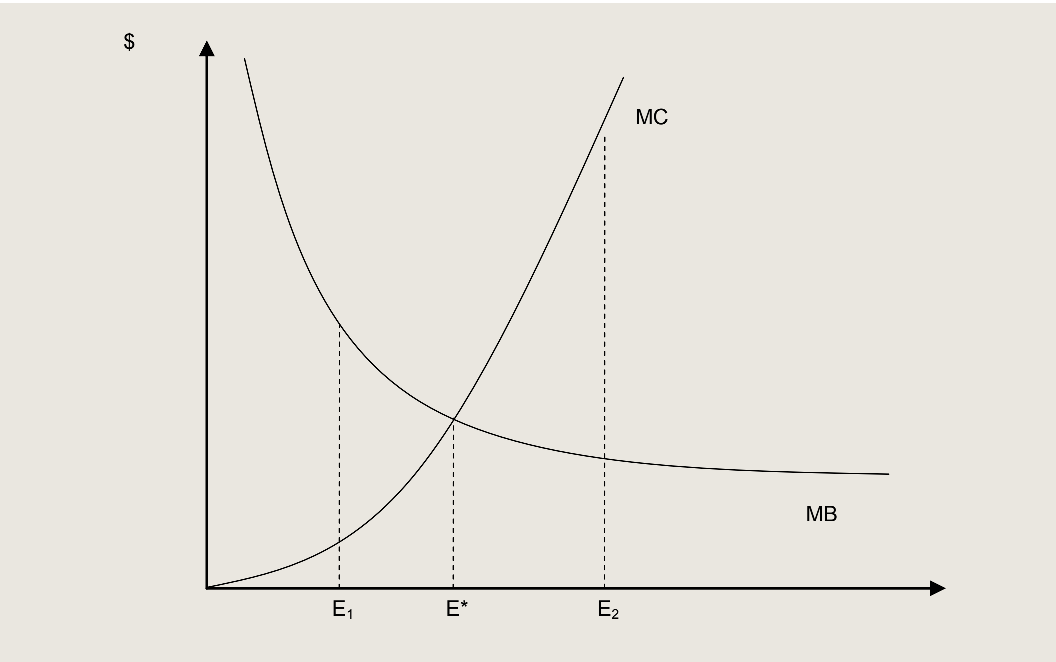
3 A framework for determining the optimal level of energy efficiency

This framework for determining the economically optimal level of energy efficiency for a particular building needs to take into account both the benefits and costs of increasing the energy star rating of the building. Determining the optimal level of energy efficiency is complex and depends on a wide range of factors.

The optimal level of energy efficiency

The optimal level of energy efficiency is where the marginal benefit (including external benefits that may not be considered by the home owner) of increasing energy efficiency is equal to the marginal cost. On the simplified depiction shown in chart 3.1, that is at the star rating (E*) where the marginal benefit curve intersects the marginal cost curve.

3.1 **The optimal level of energy efficiency**



Source: The CIE.

- At star ratings below the optimum (such as E_1), the marginal benefit of increasing the star rating exceeds the marginal cost. The community could therefore be better off if the star-rating on that building is increased.
- On the other hand, at star ratings higher than the optimum (such as E_2), the marginal cost of achieving that star rating exceeds the marginal benefit. The community is therefore better off with a lower star rating.

The optimal level of energy efficiency will vary for each climate zone, specific site and house type.

Factors affecting the optimal level of energy efficiency

Any factor that affects the benefits and costs will affect the optimal star rating.

Benefits

There are a range of factors that determine the energy saving benefits from increasing the star rating of a new or existing residence. Since the benefits of greater energy efficiency accrue in the future, they can not be known with any certainty at the time of building. However, achieving greater energy efficiency is cheaper at the building stage than later on.

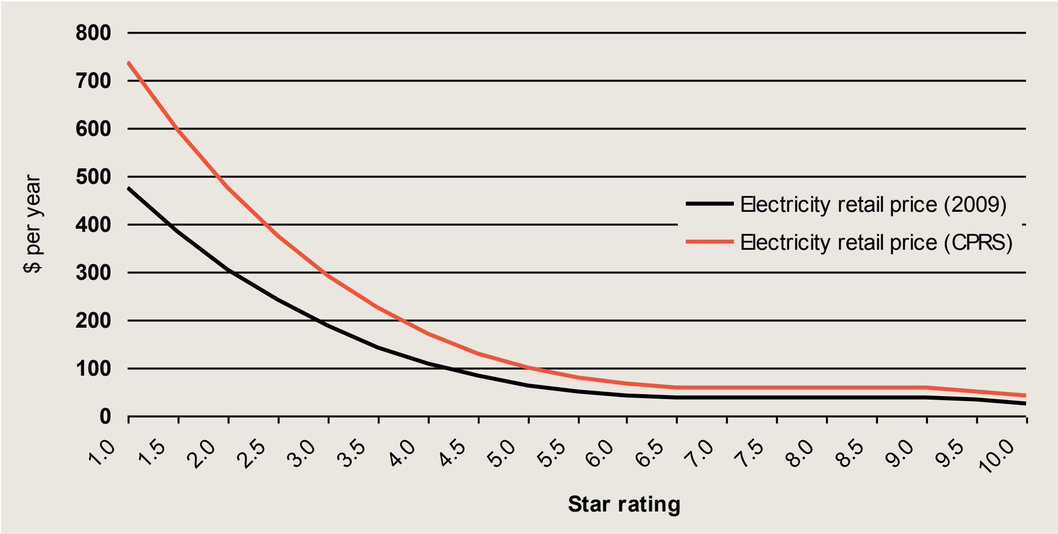
Future benefits of lower energy bills must be discounted, so they are comparable with the upfront capital costs.

- The discount rate of the home owner will also affect the expected marginal benefit of increasing the level of energy efficiency.
- An individual's discount rate will reflect their cost of capital, since they are likely to need to borrow extra money to fund the additional upfront capital costs.
  - The future price of energy is likely at some point to incorporate the cost of a home's greenhouse gas emissions and Treasury modelling of the CPRS-5 gives estimates of how this could raise electricity prices. Although they are likely to rise substantially in the future, discounted to the present, they are effectively less than the nominal increases that will occur.
  - How the CPRS-5 cost of greenhouse gases will affect energy saving benefits is indicated in chart 3.2.

As discussed previously, the location of the building site will also affect the marginal benefit curve and therefore the optimal level of energy efficiency will be different for each different location.

The lifetime present value benefits per square metre of moving from 6 stars to 10 stars for new houses and from moving from 1 star to 3 stars for existing homes are set out in table 3.3 assuming CPRS-5 electricity prices. The savings are also reported on a per star basis. For a new house in Sydney the maximum gross benefit that could

3.2 Marginal benefit curve for Sydney under different electricity prices



Data source: NatHERS, The CIE.

3.3 Marginal lifetime benefit[a]

	1 star to 3 stars		*6 stars to 10 stars*	
	$ per m^2	$ per m$^{2/}$ /star	$ per m^2	$ per m$^{2/}$ /star
Sydney	96	48	28	7
Melbourne	189	95	75	19
Brisbane	63	32	20	5
Perth	133	67	40	8
Adelaide	152	76	56	14
Canberra	244	122	98	25
Darwin	**131**	66	139	35

[a] Over 40 years, using estimated retail electricity prices under the CPRS-5 and a discount rate of 7 per cent.

Source: TheCIE.

be achieved is $28 per square metre or around $6000 for a house of 220 square metres were it increased from 6 to 10 stars. In other words, it would not pay to spend more than $6000 to improve a house to achieve a 10 star rating from an existing 6 star standard. Generally, potential gross benefits are much higher for increases at lower star ratings and for house in more extreme climates (either cold such as Melbourne, or hot such as Darwin).

Costs

The magnitude of the upfront capital cost will also depend on a range of factors.

- The location of the building site is a key driver of cost.
  - Energy saving technologies achieve different energy savings in different locations. For example, weather sealing may achieve substantial energy savings in a cooler climate, but less energy savings in more temperate climates.

  - The specific location of the building site within a particular climate zone may also be important. For example, it may take a different mix of technologies with different costs to achieve a particular star rating depending on whether the block is facing north or south.
- The type of residence (house, townhouse or flat) is another key driver of cost.
- Installation and other input costs of the various technologies may also vary across different locations; however, this is likely to be a less important driver of cost differences.

4 Applying the framework: the optimal star rating in mainland capital cities

To estimate the marginal benefits and costs of increasing star ratings, AccuRate modelling has been used to identify marginal energy saving increments (star increments) from various energy saving technologies deployed in new and existing houses. The AccuRate simulations involve five new and five existing house designs, each modelled in seven different NatHERS climate zones, covering a total of ten incremental technologies, for a total of 700 observations. The seven climate zones cover all the main Building Code of Australia (BCA) climate zones (1, 2, 5, 6 and 7) and all capitals (except Hobart, which is in the same BCA climate as Canberra). The ten incremental strategies differ between the new and old houses, as some are possible only in new houses (for example, insulation under slab) while others are relevant and practical for new and existing houses (for example, improved ceiling insulation).

Why existing houses are considered

The BCA only targets new homes based on the logic that most energy efficiency improvements are cheaper to provide in a new house than in an existing one. While insulating an attic ceiling is about the same in either case, most improvements to the stock of existing houses involve replacement of otherwise serviceable components or challenges of access as in walls and under floors. However, each year there are only around 100 000 new detached homes built in Australia. This compares with around 7 million existing detached homes. So, were there any possibilities for energy improvements in existing houses, the quantum of energy saving gains may be considerable.

Moreover, because of newer and better technologies new homes will typically be built to a much higher star rating even before considering BCA star rating requirements. So the potential for improvement in new homes may be limited. Standard new homes with standard new technologies may achieve star ratings of between 3 and 5 within their standard design features. For instance, new houses will typically have certain amounts of insulation installed as standard.

Existing homes, with older technologies, will not have these energy saving technologies as standard. Many existing homes may have star ratings of one or less.

Given the underlying diminishing marginal benefits built into the star rating system, the energy savings of advancing from 1 to 2 stars for existing homes are about five times those of advancing from 4 to 5 stars for a new home.

So, although the marginal costs may be higher to achieve star rating improvements in existing homes, the marginal benefits will also be higher, and if marginal benefits exceed marginal costs, the marginal net benefits would apply to a considerably larger housing stock in the case of existing homes relative to new ones.

Selection of locations for modelling

The selection of locations was based on consideration of covering the main population centres in Australia, while covering all BCA climate zones with significant numbers of residential dwellings. Table 4.1 shows the locations chosen, together with their AccuRate climate zones and climate characteristics.

4.1 **Locations and climate characteristics**

Location	***BCA climate zone***	***AccuRate climate zone***	***AccuRate 5-star*** **(MJ/m^2)**	***Climate type***
Darwin	1	Z1	413	Hot, tropical,
Brisbane	2	Z10	55	Hot, sub-tropical
Sydney (Mascot)	5	Z56	66	Temperate
Melbourne (Moorabbin)	6	Z62	165	Temperate and cool
Adelaide	5	Z16	125	Temperate
Perth	5	Z13	89	Temperate
Canberra	7	Z24	216	Cool, inland

Source: pitt&sherry.

Selection of new house designs

The new house designs were taken directly from the existing NatHERS second generation validation protocol set. The house plans are set out in appendix A. Table 4.2 provides a brief overview of the designs. These designs are considered to be fairly representative of the type of house built around Australia before mandatory minimum star rating began to come into effect.

One advantage of using a set of plans for which AccuRate files are publically available is that the work can be repeated by others. The orientations of each house have been taken from the original report, and it is recognised that a changed orientation could improve performance, though not necessarily to the same degree in different climates. It should also be remembered that changing orientation could impose an opportunity cost in terms of lost amenity or an actual financial cost if it requires more site preparation or difficulty in building.

4.2 Base design characteristics of new houses

	House 1	*House 4*	*House 8*	*House 11*	*House 13*
House style	Single storey	Single storey	Double storey	Single storey	Single storey
Size (m)	154.88	228.14	216.48	219.67	202.7
Glazing ratio % (window to floor)	17.05%	17.53%	24.25%	19.98%	31.23%
External wall	Colourbond wall + air gap + R1.0 glass batt + plasterboard	Cavity brick + R.20 polstyrene	Cavity brick + R1 expanded polstyrene	Fibro cement (FC) + R2.0 plasterboard	Weatherboard wall + air gap + R1.5 glass batt + plasterboard
Window	Single clear glass in timber frame	Single clear glass in aluminium frame	Single clear glass in aluminium frame	Single clear glass in timber frame	Aluminium + SG
Ext. blinds	None	None	None	None	None
Ext. door	Timber (solid)	Sliding doors	Timber (solid)	Sliding doors	Sliding doors
Floor	Concrete slab	Concrete slab	Concrete slab lower suspended concrete slab upper	Suspended timber floor	Suspended timber floor
Ceiling	Plasterboard 13 mm with R2.0	Plasterboard 13 mm with R3.5	Plasterboard 13 mm with R3.5	R3.0 timber lining boards	Plasterboard 13 mm with R4.0
Internal walls	Plasterboard 13 mm with R2.0	Brick with wet plaster	Brick with wet plaster	Brick with wet plaster	Brick with wet plaster
Roof	Metal deck	Tiles (concrete) not insulated or sarked	Tiles (concrete) not insulated or sarked	Metal deck	Metal deck

Source: pitt&sherry.

Selection of existing house designs

The selection for the existing house designs aimed to identify those 'stock' houses representative of a variety of older homes with potential to be renovated. The house plans are set out in appendix A. Table 4.3 provides a brief overview of the designs.

4.3 Base design characteristics of existing stock of houses

	Stock 1 (PLS A)	***Stock 2 (PLS A)***	***Stock 3 (PLS C)***	***Stock 4 (PLS G)***	***Stock 6 (CBS 2)***
House style	Symmetrical cottage	Symmetrical cottage with extension	Single fronted cottage/villa	Duplex with attached garage	Cottage with attached garage
Size (m)	84.81	133.87	83.82	93.94	202.7
Glazing ratio % (window to floor)	24.43%	19.93%	14.30%	28.15%	29.56%
External wall	Cavity brick 110 + 50 + 110 mm	Cavity brick 110 + 110 mm/brick veneer R1.5 for extension	Cavity brick 110 + 50 + 110 mm	Brick veneer R1.5	Brick veneer R1.0
Window	Single clear glass in timber frame	Single clear glass in timber frame	Single clear glass in timber frame	Single clear glass in aluminium frame	Single clear glass in aluminium frame
Ext. blinds	None	None	None	None	None
Ext. door	Timber (solid)	Timber (solid)	Timber (solid)	Hollow core	Hollow core
Floor	Enclosed timber (hardwood)	Timber (hardwood)/ concrete slab 100 mm for extension	Enclosed timber (hardwood)	Timber (hardwood)/ concrete slab 100 mm for garage	Concrete slab 100 mm
Ceiling	13 mm plasterboard with no insulation	13 mm plasterboard/ 13 mm plasterboard + R2.5 insulation	13 mm plasterbaord	13 mm plasterbaord	13 mm plasterboard + R3.0
Internal walls	Brick with wet plaster	Brick with wet plaster/ cavity brick 110 + 110 mm (prior external wall)	Brick with wet plaster	Plasterboard on studs	Plasterboard on studs
Roof	Metal deck not insulated or sarked	Metal deck not insulated or sarked	Metal deck not insulated or sarked	Tiles (concrete) not insulated or sarked	Tiles (concrete) not insulated or sarked

Source: pitt&sherry.

Selection of incremental energy saving technologies/strategies

In general, the focus has been on technologies and strategies that are relevant to both new and existing houses. Orientation was taken as given in the plans for the new houses, and orientation is not a relevant strategy for an existing house. In some cases strategies are the same for new and existing houses whereas, in other cases, the target (windows) may be the same but the practical scope for cost effective improvements is quite different. There is always more flexibility for improvements in new houses, and usually at lower marginal cost. Table 4.4 summarizes the devised strategies for improvement in each case and the marginal (extra) cost per square metre of doing so. Costs have been determined from industry sources. The application of most technologies has a positive cost, however, the use of a concrete floor in place of a

4.4 **Energy efficiency improvements and costs**

Priority	*New houses*	*Marginal Cost* $/m^2	*Existing houses*	*Marginal Cost* $/m^2
1	Improved ceiling insulation (R4.0 in lieu of R2.0)	3.50	Improved ceiling insulation (R2.0 top up)	8.80
2	Wall insulation (R2.5 in lieu of R1.0)*	5.00	Cavity wall insulation (nominal R3.0 in BV)	29.00
3	Floor insulation (R1.0 under CSOG)	25.00	Floor insulation (R2.0 under suspended timber)	11.00
4	Double glazed windows (in PVC frame)**	150.00	Double glazed windows (in existing timber frame)	270.00
	Tinted windows (in PVC frame)	22.00	Tinted windows (aluminium frame)	118.00
5	External blinds	190.00	External blinds	190.00
6	Weather sealing/draught proofing	1 x 300.00	Weather sealing/draught proofing	1 x 500.00
7	All windows 90% openable (casements)	50.00	Screen/security door to allow cross-ventilation	2 x 380.00
8	Improved ductwork insulation (R2.0 in lieu R1.0)	4.00	Improved ductwork insulation (replace with R2.0)	15.00
9***	Improved heater efficiency (5-star in lieu 2-star)	2.50	Improved heater efficiency (replace with 5 star)	15.00
	Improved reverse cycle air conditioner (5-star in lieu of 2-star)	20.00	Improved reverse cycle air conditioner (replace with 5-star)	80.00
10	Change to concrete slab	-40.00	Outside colour alteration	18.00

*Could be R2.0 plus foil. **On average whole house basis including toughened or laminated panes required by safety standards. ***Area refers to material except for #9, which is GFA. All values include GST, but exclude builder's margin. The individual cost items are reflected in the cost spreadsheets for each particular house. A simplifying assumption has been made that costs are the same in each geographical location.

Source: pitt&sherry.

timber one provides a negative cost (that is, a benefit). Concrete floors on ground are cheaper per square metre than wooden ones and thermally more efficient especially on flat sites. The costs however, do not include the greenhouse gas costs of concrete.

Incremental savings and costs

Most of the incremental savings can be estimated by using AccuRate to simulate the house with and without a given improvement and comparing the results. Houses were first simulated without any of the improvements listed in table 4.4. This defined a least efficient energy efficiency design. Minimum (pre-improvement) star ratings for each type of house are set out in table 4.5. From these minimums, improvements were progressively added according to their relative economic efficiency.

Results

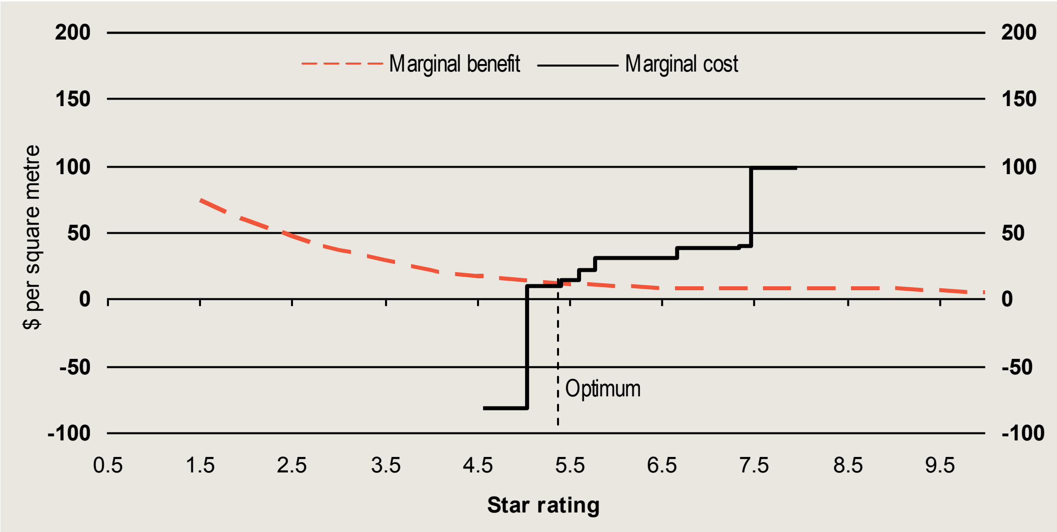
The marginal costs and benefits of deploying a range of energy saving technologies in a representative new single storey house with a gross floor area of around 228 m^2 (House 4 in table 4.2) in Sydney (Mascot) are shown in chart 4.6. Some of the calculations behind deriving these marginal costs and benefits are set out in table 4.7. This house has the benefits of a north-east orientation. In its simplest standard design it has a wooden floor, moderate ceiling and wall insulation and single glazing. With

4.5 Estimated minimum NatHERS star rating without energy saving technologies

	New houses					*Existing houses*				
	Type 1	***Type 4***	***Type 8***	***Type 11***	***Type 13***	***Stock 1***	***Stock 2***	***Stock 3***	***Stock 4***	***Stock 6***
	Stars	Stars	Stars	Stars	Stars	Stars	Stars	Stars	Stars	Stars
Sydney	3.4	4.6	3.9	2.5	1.6	0.9	1.5	0.9	0.5	0.7
Melbourne	3.2	4.4	3.5	2.2	1.5	0.8	1.6	0.9	1.2	0.5
Brisbane	2.6	4.9	3.8	1.6	0.4	0.8	1.5	0.8	0.5	0.5
Perth	3.7	5.3	4.5	2.5	1.5	1.3	1.9	1.4	0.5	0.6
Adelaide	3.8	5.0	4.0	2.5	1.5	1.0	1.8	1.1	0.6	1.0
Canberra	3.3	4.5	3.6	2.3	1.6	0.8	1.6	1.0	1.0	1.1
Darwin	5.7	3.8	3.9	4.6	4.2	0.7	1.5	2.1	0.5	0.5

Source: The CIE.

4.6 Marginal costs and benefits of new house type 4 — Sydney



Data source: The CIE.

this configuration of technologies it achieves a standard star rating of 4.6 as indicated in table 4.5. Chart 4.6 shows how the star rating can be progressively improved by the addition of more energy efficient technologies up to a star rating of 8.

- The marginal cost estimate is a lifetime cost per square metre of floor area over a 40 year period, based on cost data presented in table 4.4. Most technologies require only an upfront cost, although some such as weather sealing and external blinds require replacing every 10 and 15 years respectively.
- The estimated marginal benefit of deploying each technology is the value of the energy savings achieved by deploying each technology over 40 years.
  - The estimated annual energy savings are based on AccuRate Software and take into account the loss of effectiveness when multiple technologies are deployed concurrently.

4.7 **The costs and benefits of energy efficiency technologies — Sydney**

	Star rating	*Energy usage*	*Efficiency benefit*	*Marginal benefit*[b]	*Marginal cost*[a]	*MC per star increment*	*MB per star increment*	*Net MB/MC per star increment*	*Benefit cost ratio*
		MJ	MJ per m^2	\$ per m^2	\$ per m^2	\$ per m^2	\$ per m^2	\$ per m^2	
Least energy efficient design	4.6	74.0							
+ Alternative floor	5.1	64.6	9.4	5.7	-40.0	-81.6	11.5	93.2	>11.5:1
+ Ceiling insulation	5.4	58.6	6.0	3.6	3.5	9.5	9.8	0.3	1:1
+ Weather sealed	5.6	55.9	2.7	1.6	2.5	13.8	9.0	-4.8	0.6:1
+ Wall insulation	5.8	53.3	2.6	1.6	3.9	21.4	8.6	-12.8	0.4:1
+ Double glazing	6.7	41.6	11.7	7.0	26.3	29.9	8.0	-21.9	0.3:1
+ Floor insulation	7.3	32.9	8.7	5.2	25.0	37.5	7.8	-29.6	0.2:1
+ Improved ducting	7.5	31.2	1.7	1.0	5.0	38.9	8.0	-30.9	0.2:1
+ External shading	8.0	24.3	6.9	4.1	49.8	97.5	8.1	-89.4	0.1:1

[a] Lifetime costs over 40 years, including replacement costs where relevant.
[b] Marginal benefit over 40 years, using a discount rate of 7 per cent. Future retail electricity prices are derived from Australian Treasury modelling of the future wholesale electricity price under the CPRS.
Source: pitt&sherry, The CIE.

 – Annual energy savings do not take account of the potential for behavioural patterns affecting the use of the house which may result in lower energy usage and potential savings.
 – It is also assumed that the energy source for all heating and cooling is electricity.
 – The future retail electricity price is derived from Treasury modelling of the wholesale electricity price under the CPRS.

- All future costs and benefits are discounted using a discount rate of 7 per cent.
- The star rating is obtained from NatHERS star bands.

It is assumed that the energy saving technologies are deployed in order of cost-effectiveness.

- The technology that provide the highest ratio of marginal benefits to marginal costs are added first and the technology that provides the lowest ratio of marginal benefits to marginal costs would be added last.
- The most cost-effective energy saving technology is alternative flooring. A concrete slab is actually significantly cheaper than timber flooring used in many houses in Australia. As a result it is seen to deliver benefits or negative cost.

To achieve the optimal level of energy efficiency, the building owner should deploy the next most cost-effective technology if the marginal benefit exceeds the marginal cost.

- This suggests that the optimal level of energy efficiency in Sydney could be around 5.4 stars (for a type 4 house).

- Based on the data in table 4.7, the marginal benefit of adding a concrete floor and additional ceiling insulation would exceed the marginal cost and achieve a star rating of 5.4.
- To move beyond that star rating would require the next most cost-effective technology — weather sealing — to be deployed. However, the marginal cost of that technology exceeds the marginal benefit. To go above 5.4 stars to 8 stars for this house would cost $112.5 (NPV) per square metre, but it would deliver benefits in terms of energy saving of only $20.5 (NPV) per square metre over the 40 year life of the building. Therefore, pursuing an 8 star rating for this house would impose a net cost of $92 (NPV) per square metre. With a floor space of 228 square metres, this would impose an additional net economic cost of $21 000.

Effect of location and house design on optimal star rating

The optimal star rating varies by house and location (chart 4.8). The weighted average for new houses by location is between 4.4 and 5.5 stars[9]. The composition of house types varies by location with a tendency toward more two storied homes on smaller blocks in major cities with higher land prices. The type 4 house is a single storeyed new family home and benefits from having a predominantly northerly orientation and a full concrete slab floor in its optimal form. It tends to have its highest star rating in colder climates. House type 1 is also single storeyed and has a concrete slab in its optimal form, but it has a less favourable (mostly easterly) orientation than house type 4 and as a result has lower star ratings in all climatic zones except Darwin.

4.8 **Estimated optimal NatHERS star rating**

	New houses						*Existing houses*				
	Weighted average	***Type 1***	***Type 4***	***Type 8***	***Type 11***	***Type 13***	***Stock 1***	***Stock 2***	***Stock 3***	***Stock 4***	***Stock 6***
		Stars	Stars	Stars	Stars	Stars	Stars	Stars	Stars	Stars	Stars
Sydney	4.5	5.0	5.4	4.2	2.8	3.3	2.6	3.2	2.9	2.5	1.5
Melbourne	5.0	4.5	7.2	6.1	2.8	4.2	4.2	3.9	4.7	5.5	6.5
Brisbane	4.4	4.6	5.6	4.5	2.1	2.6	2.7	3.3	3.3	1.5	2.1
Perth	5.5	6.2	6.3	5.9	3.3	5.0	3.5	4.0	4.0	2.4	5.4
Adelaide	5.3	6.0	6.0	7.0	3.3	5.0	3.1	3.1	3.7	3.0	6.6
Canberra	5.4	5.3	7.0	5.9	2.8	4.2	4.2	4.7	4.7	3.5	5.2
Darwin	5.4	6.9	4.7	4.9	5.1	5.7	3.6	3.6	6.5	2.1	4.9

Source: The CIE.

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[9] The same weightings are used as were used in the ABCB RIS on the 6 star standard, see http://www.abcb.gov.au/index.cfm?objectid=BE1E5D93-0B04-11DF-B1DD001143D4D594

The technologies that it pays to use and not use for house type 1 are summarised in table 4.9. Key findings are:

- concrete flooring is a cost-effective energy saving measure in all seven locations;
- additional ceiling insulation is cost effective in all locations except Brisbane;
- weather sealing, additional wall insulation and double glazing are cost effective in the colder climates such Canberra, but double glazing does not pay in other warmer cities;
- external shading and floor insulation do not pay in any location.

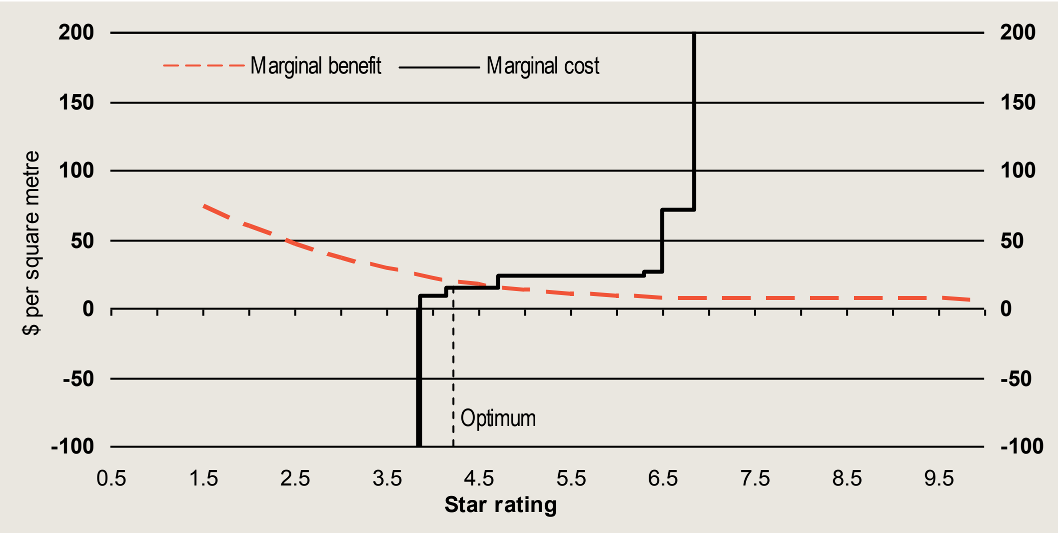
4.9 **Summary of optimal star rating in mainland capital cities: house type 1**

	Optimal star rating	*Concrete floor*	*Ceiling insulation*	*Weather sealing*	*Wall insulation*	*Double glazing*	*Floor insulation*	*External shading*
Sydney	5.0	Yes	Yes	Yes	Yes	No	No	No
Melbourne	4.5	Yes	Yes	Yes	Yes	No	No	No
Brisbane	4.6	Yes	No	Yes	Yes	No	No	No
Perth	6.2	Yes	Yes	Yes	Yes	No	No	No
Adelaide	6.0	Yes	Yes	Yes	Yes	No	No	No
Canberra	5.3	Yes	Yes	Yes	Yes	Yes	No	No
Darwin	6.9	Yes	Yes	Yes	Yes	No	No	No

Source: The CIE.

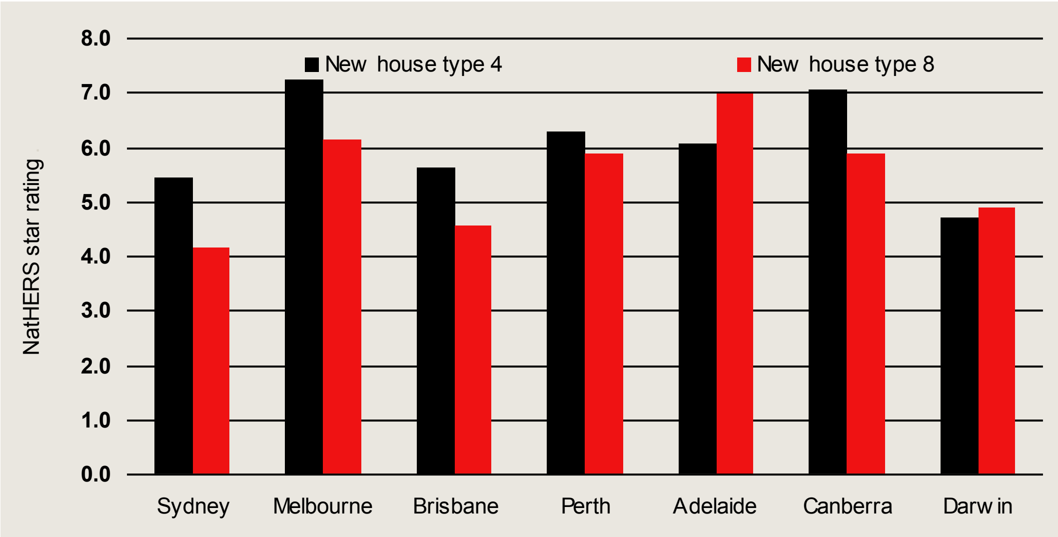
For house type 8 which has a similar floor size to house type 4 but is a two storeyed new family home with an easterly and partial northerly orientation, the optimal star ratings are considerably lower in most locations than a type 4 new house (charts 4.10, 4.11 and table 4.8). A two storeyed house is generally less efficient than a single storeyed house on a concrete slab except in Darwin where it may help with cooling.

4.10 **Marginal costs and benefits of new house type 8 — Sydney**



Data source: The CIE.

4.11 **Optimal star rating varies by house design**



Data source: The CIE.

The marginal net costs per square metre of forcing each new house design to increase by around one extra star rating from their optimum are set out in table 4.12. In many cases, the costs of forcing higher minimum star ratings are substantial ($51 per square metre average). For a house with 230 square metres of floor space, a $50 per square metre cost would add $11 500 to the lifetime cost of the house and an even higher build-cost. For most houses in most locations achieving one extra star rating requires deploying expensive technologies such as double glazing, floor insulation or external shading.

4.12 **Net marginal benefit (cost) of pursuing an extra star above the optimal rating for new houses**

	Type 1	*Type 4*	*Type 8*	*Type 11*	*Type 13*
	$ per m^2	$ per m^2	$ per m^2	$ per m^2	$ per m^2
Sydney	-19.6	-22.5	-23.0	-103.6	-9.1
Melbourne	-57.6	-45.1	-48.9	-61.3	-3.2
Brisbane	-69.0	-47.6	-36.3	-30.0	-45.9
Perth	-48.0	-47.6	-45.6	-80.4	-35.3
Adelaide	-73.1	-27.7	-44.9	-71.6	-30.6
Canberra	-48.2	-45.9	-48.4	-60.7	-91.3
Darwin	-69.2	-32.9	-68.9	-69.9	-112.2

Source: The CIE.

The results presented in table 4.8 and 4.12 are consistent with the recent Regulation Impact Statement (RIS)[10] of mandating an increase in the BCA from 5 to 6 stars. The RIS provided a detailed assessment of the economic impacts of more stringent energy requirements for new homes. It found that the increase in the minimum

10 http://www.abcb.gov.au/index.cfm?objectid=BE1E5D93-0B04-11DF-B1DD001143D4D594

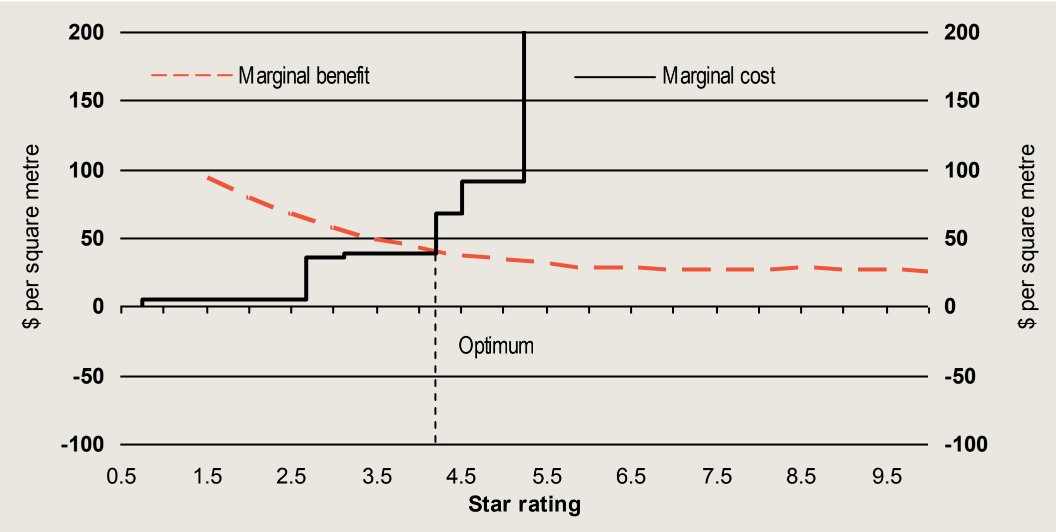
energy efficiency requirement for new homes to star rating 6 from 5 is likely to result in a net cost in most areas and a net present value cost to the Australian economy of $444 million for the thermal performance of residential buildings. In table 4.8, most house designs in most locations have optimal star ratings below 6 and many are below 5, with the weighted averages by locations between 4.4 and 5.5 stars.

- The results from the RIS and table 4.8 show that the current minimum energy efficiency requirements for new homes are likely to be at, or already past, the optimal level in most areas.
- Any future increases in the minimum energy efficiency requirements for new homes will result in larger and larger costs and smaller and smaller benefits. The net cost to the community will therefore increase significantly with each incremental increase in the minimum energy efficiency requirements for new homes.

Optimal star rating of existing homes

As can be seen in table 4.8, optimal star ratings for existing houses are considerably lower than those for new houses. An example of an optimum for an existing house is set out in chart 4.13.

4.13 **Marginal costs and benefits of existing house type 1 — Melbourne**



Data source: The CIE.

Based on the results in table 4.8, it appears that it is economical to apply cheaper technologies such as additional ceiling insulation, floor insulation, weather sealing/draught proofing and in some case wall insulation to reach optimal star ratings of between 2.6 for Sydney and 4.2 for Canberra for an existing family home of stock type 1. This assumes none of these technologies are already deployed. If true, the net marginal benefits per square metre from moving to the optimal star rating for each existing type of house are set out in table 4.14. The results indicate the potential for significant net gains. However, these results are somewhat ambiguous. The Federal Government's recent home insulation program may have already captured a sizeable share of these gains. Table 4.15 shows the size of net gains possible assuming all existing houses already have ceiling insulation.

4.14 **Net benefit of moving to optimal star rating**

	Stock Type 1	*Stock Type 2*	*Stock Type 3*	*Stock Type 4*	*Stock Type 6*
	$ per m^2	$ per m^2	$ per m^2	$ per m^2	$ per m^2
Sydney	83.5	58.3	82.0	111.3	40.7
Melbourne	215.1	139.4	217.0	178.1	144.5
Brisbane	59.9	41.4	60.8	136.8	57.0
Perth	113.2	76.8	110.2	176.9	82.5
Adelaide	145.4	98.9	145.0	178.8	97.8
Canberra	280.8	177.2	276.7	265.3	246.8
Darwin	111.9	105.7	118.5	235.6	163.8

Source: The CIE.

4.15 **Net benefit of moving to optimal star rating assuming ceiling insulation is already in place**

	Stock Type 1	*Stock Type 2*	*Stock Type 3*	*Stock Type 4*	*Stock Type 6*
	$ per m^2	$ per m^2	$ per m^2	$ per m^2	$ per m^2
Sydney	0.0	0.0	1.0	0.0	40.7
Melbourne	20.0	3.2	38.9	0.0	144.5
Brisbane	0.0	0.0	0.7	1.5	57.0
Perth	0.0	0.0	0.9	2.0	82.5
Adelaide	0.0	0.0	8.2	1.2	97.8
Canberra	32.0	4.1	51.6	0.0	246.8
Darwin	17.0	45.2	18.2	0.0	163.8

Source: The CIE.

Robustness of results

There are various factors that might suggest that the estimates of optimal star ratings for the house designs assessed here are over-estimated. These include:

- the optimal level of energy efficiency will depend on occupancy patterns which may be as much as 50 per cent over-estimated by AccuRate software;
- all results assume all household energy demands are met by electricity whereas houses in places such as Melbourne and Canberra are heavily dependent on cheaper gas supplies, so marginal benefits are likely to be over-estimated;
- embodied greenhouse gas costs are not included in the costs of materials, but the benefits of saving them are included in electricity prices.

  - TheCIE (2009)[11] estimates that cement and metals may increase by around 17 per cent by 2025 if electricity prices increase by 50 per cent by that time under CPRS-5 whereas wood price may increase by only 5 per cent;
  - as highlighted by the Productivity Commission, embodied energy prices in concrete and steel can be significant.

However, there are also reasons why estimates of optimal star rating for the various house designs assessed here may be under-estimated. These are:

- the benefits of delaying the costs of additional electricity generation and network impacts due to energy savings may not be included in electricity prices — in ABCB (2009), the benefits of delaying the costs of additional electricity generation are estimated to increase overall energy saving benefits by around 10 per cent;
- the costs of technologies such as double glazing may come down in the future as the size of the market grows;
- with additional design, some existing home designs energy rating might be improved by orienting them more toward the sun.

On balance, overestimation probably outweighs underestimation.

- On the issue of improved design to achieve higher star ratings, this should not be assumed to be costless as there will be an opportunity cost in terms of lost amenity value of moving from a preferred design, there will be additional design costs and there may be additional building costs to achieve the design.
- Given the calculated benefit to cost ratio on double glazing in many locations at less than 0.3 (see table 4.7), the cost would have to fall by 70 per cent for it to become economically efficient in many cases.

Overwhelming the consideration of under- or over-estimation of optima is the sensitivity of the optimal points to changes in assumptions. In all new house designs evaluated, marginal costs escalate rapidly above 6 stars, while benefits continue to diminish. For many new house designs this occurs at lower star rating (around 5 stars). Even quite large increases in electricity prices or falls in construction or design costs will make very little difference to the conclusion that raising the minimum mandated star rating above current levels will be economically inefficient.

[11] Centre for International Economics 2009, Simulations on impacts of the CPRS., unpublished.

5 Conclusions

Energy efficiency is usually achieved only at some cost to the economy. Relentlessly pursuing ever higher energy efficiency star ratings in building with no consideration of the costs will inevitably lead to expensive ways to achieve energy savings and reductions in greenhouse gases. Energy efficiency is not economic efficiency. Economic efficiency requires that costs as well as benefits (of energy savings) be considered.

The way that NatHERS star bands are constructed means that the marginal benefit of increasing the star rating diminishes rapidly. The benefits of increasing the star rating beyond about 5 stars are minimal. By contrast, the marginal costs of technologies required to raise a rating above 5 stars escalate rapidly for most house designs in most locations. Forcing home owners to build houses with higher star ratings imposes higher costs (in terms of building resources) than it saves in terms of the value of energy resources. It therefore imposes net costs that are financially damaging to home owners and economically detrimental to the community. It will manifest itself in higher house prices and lower disposable incomes of Australians and it will not result in efficient reductions in greenhouse gases.

For existing homes, potential for economic gain may exist because the marginal benefits are potentially higher than for new homes. For those homes with very low existing star ratings, those with star rating of 1 or below, there is probably potential for an economical 1 to 1.5 star gain.

Appendixes

A Approach

As part of this study, *pitt&sherry*/Energy Partners conducted an exercise using AccuRate modelling to identify energy saving increments from various energy-saving technologies in new and existing houses, and to provide cost estimates for these features.

Incremental savings were estimated by using AccuRate to simulate the house with and without a given improvement and comparing the results. Houses were first simulated without any of the technological improvements to define a least efficient energy efficiency design. From these minimums, improvements were progressively added according to their relative economic efficiency to define the marginal costs of increasing star ratings for each home design.

Notes on technologies for saving energy

Some technologies provide energy saving improvements irrespective of the climate concerned and are universal to new and existing buildings. Insulation of walls and roof/ceilings are in this category as are double glazing and greater openability of the windows for the added summer ventilation that they provide. Note that double glazing may have other features that are climate sensitive (for example, SHGC, location of low-e coating). However, most improvements are cheaper to provide in a new house and this strongly influences the cost effectiveness of several technologies. While insulating an attic ceiling is about the same in either case, most improvements to the existing houses involve replacement of otherwise serviceable components or challenges of access as in walls and under floors. Strategic timing of replacements can radically change the economic attractiveness of some retrofits such as waiting until the heater/cooler needed to be replaced anyway and then the marginal cost of 5-star in lieu of 2-star is almost as low as in the new house case. Another example is removal of external cladding for installation of wall insulation prior to planned re-painting of external walls.

Some improvements are climate specific improvements. Roof colour affects heating and cooling differently. In a hot climate darker colours are detrimental while the reverse is true in cold climates. As we are not in control of the colour of the existing house surfaces, we simulated roofs that are mid-coloured and light coloured, choosing the lesser performance as the base case. Indicatively, the difference between dark- and light-coloured roofs is twice the difference between mid- and light-coloured roofs and will evidently apply in many cases (for example, a dark pre-painted roof in the tropics could be repainted white).

Double-glazing (DG) is an alternative to tinted single glazing (TSG). Generally, the DG is applied in cold climates and TSG is applied in hot climates. While tinted DG and low-E SG are on the market, neither has been evaluated in this study. All climates have been simulated with DG and the hot climates have also been simulated with TSG.

Appliances and duct work

One important and original feature of the work has been the additional processing to demonstrate the impact of improvements in appliance performance and improved thermal performance of ducts for space conditioning. Fully ducted heating and/or cooling is a feature that is increasing in market share in new dwellings.

The simulation software does not estimate the energy impacts of the efficiency of the ductwork or of the efficiency of the heating and cooling appliances. However, these are non-building aspects that impinge on the energy efficiency of the house as a comfort conditioned system. To evaluate their significance, hour-by-hour calculations based on selected output files from the simulations, which record the hourly loads in each room and their hourly temperatures, were undertaken.

In this work air conditioning has been assumed to supply both heating and cooling, with targeted calculations for ducted gas heating in Melbourne and Canberra. Equivalent metered energy values for ducted heat pump and/or gas heating systems were generated.

Residential energy star rating and AccuRate software

Energy modelling is based on standard heat flow physics — energy flows from higher to lower temperatures. For a building heat loss (or gain) is driven by a temperature difference, and can be routinely calculated as the sum of:

- Surface heat loss through the building envelope (roof, walls, windows, doors) directly to air or soil;
- Surface heat losses to unconditioned building spaces (for example, garage, basement, roof space); and
- Heat losses due to air exchange by mechanical ventilation or infiltration due to opening windows and doors, and air leaks around doors and windows and small gaps in the structure.

In addition, heat gains arise from internal heat sources (for example, people, pets, and appliances) and passive solar gains through windows (and corresponding infrared radiation losses).

Heat loss (measured in Watts) is given by: $\mathbf{H = A\ U\ (t_i - t_o)}$

Where,

A = area (m^2)

U = overall heat transmission coefficient (W/m^2K);

t_i, t_o = inside and outside temperatures, respectively

The conductance of an individual element is given by: $\mathbf{C = k/x}$

Where,

k = thermal conductivity of material (W/mK)

x = thickness (m)

The thermal resistivity of a building material element is given by: $\mathbf{R = x/k = 1/C}$

The total R-value for a construction element (for example, wall) is given by the sum of the R-values of all elements from the outside air film, to individual materials and air spaces in the structure and, finally, to the inner air film.

The overall U value for a building assembly (for example, wall with windows and doors) is given by: $U = 1/A\ (a_1/R_1 + a_2/R_2 + \ldots + a_n/R_n)$, ($a_1+a_2+\ldots+a_n=A$, area of building assembly)

For a concrete slab on ground, the soil temperature will usually be different from the air temperature, so that the heat flow will respond to a different temperature differential.

From such simple formulae it is possible to calculate the relative heat flows from any building at a point in time, but it is clear that knowledge of the instantaneous heat flow at night in winter for a house in Canberra does not tell the whole story for every hour of the year. During the day in winter, many windows will be the avenue to considerable heat gain, and welcome means of heat loss on summer nights. There is a solution: undertake a heat flow calculation for every hour of the year and compute the energy required to be added or removed to maintain a defined comfort band (that is, internal temperature range). This is the basis of energy modelling software.

The benefit of sophisticated software (such as AccuRate) is that all sources of heat loss and heat gain can be calculated for every single hour of the year. The net heat flow (power) required to add or remove heat each hour (time) to maintain a comfort band (typically in the range 15 – 24^{o}C, depending on time of day and climate zone) is then added up for the whole year to give a total energy (energy = power x time) for the whole year as a sum of heating and cooling energy. The supplied energy (electricity, gas, wood) required to deliver the heating and cooling services is determined by the efficiency of appliances (for example, 100 per cent for resistive heating, ~75 per cent for gas heating, ~250 per cent for cooling and reverse cycle heating). The software takes into account net solar gain from every window in a dwelling — a south facing window which never has direct sunlight has a different impact than a north facing window which may be the source of severe discomfort in summer (and require cooling energy) and considerable warmth in winter (and reduce the need for heating energy). The modelling also takes into account the capacity of different building materials to absorb solar energy during the day and emit this as infrared radiative heat at night ('thermal mass'). Finally, the modelling takes into account heat losses and gains from ventilation by accounting the wind direction and speed and by opening and closing windows according to relative temperatures and heat losses, and allowing for losses through vents. AccuRate has a sophisticated ventilation model and determines comfort on the basis of both temperature and humidity so that the benefits of air flow from room fans can be modelled to delay the need for air conditioning.

AccuRate Energy Rating Software

AccuRate is referred to as second generation NatHERS (Nationwide House Energy Rating Scheme) software, and is a more sophisticated modelling program than the original NatHERS software developed in the early 1990s by Dr Angelo Delsante (CSIRO). More details of the NatHERS and AccuRate can be found on the NatHERS web site.[1] The original NatHERS software was recognised as a valuable tool for heating-dominated climates of southern Australia, but by the early 2000s the building and design industries were critical of the software, with concerns over its use in cooling-dominated hot/humid climates of northern Australia, the adequacy of the tool to model contemporary designs (only three spaces could be identified), and the limit range of building materials which could be modelled. The introduction of the first set of energy standards in the BCA in January 2003 provided an impetus to update NatHERS and develop a nationally acceptable modelling tool that could complement the new national energy standards. It should be recognised that that capacity of NatHERS was essentially a reflection on the capacity of desktop computer of the early 1990s. After development on a main-frame computer, there was a limit as to how much complexity could be made available through a PC.

In mid-2003, funded through the MCE, the AGO commissioned Dr Delsante (CSIRO) to upgrade NatHERS, and AccuRate was the final product. AccuRate was developed using the best science available and a wide range of expertise was drawn on to support CSIRO. The goals in developing AccuRate were as follows:

- Rank buildings on the basis of human comfort (based on temperature, relative humidity and wind speed)
- Increased model sophistication and capacity (every room is a separate zone) due to significant increases in available PC computing power
- New ventilation model, able to incorporate the benefits of ceiling fans

- New treatment of skylights, underfloor and roof zones
- Directional heat flows (foil insulation)
- Increase climate data quality and range (69 climate zones)
- Increased and improved building product databases in software
- Develop nationally consistent approach to star bands, with a fair and equal reward in all climate zones
- Recognise good design beyond 6-star (the limit of NatHERS/FirstRate)
- Critically, maintain consistency with first generation NatHERS tools then in use, to ensure that houses rated 4- or 5-star in NatHERS/FirstRate achieved on average the same ratings in AccuRate.

To allow AccuRate to rank houses of different sizes within all climate zones, the energy required for comfort is measured as MJ/m^2 per annum. This calculation includes an area correction, because simple maths shows that large houses have a smaller surface area to volume (or floor area) than small houses. As heat flow through the building fabric depends on surface area, smaller houses would have greater difficulty in meeting each star level. This issue is exacerbated because often standard size windows in small houses are a larger percentage of floor area than for larger houses, and heat flows through windows are large — windows are the weakest thermal link. The area correction factor is unique for each climate zone, and is based on modelling of a simple house design of 50 to $500m^2$ in area, in $50m^2$ steps, with zero correction at $200m^2$. The correction is ~0.3-star for 150m2 and ~-0.3-star for $250m^2$. More details can be found at the NatHERS website.[1]

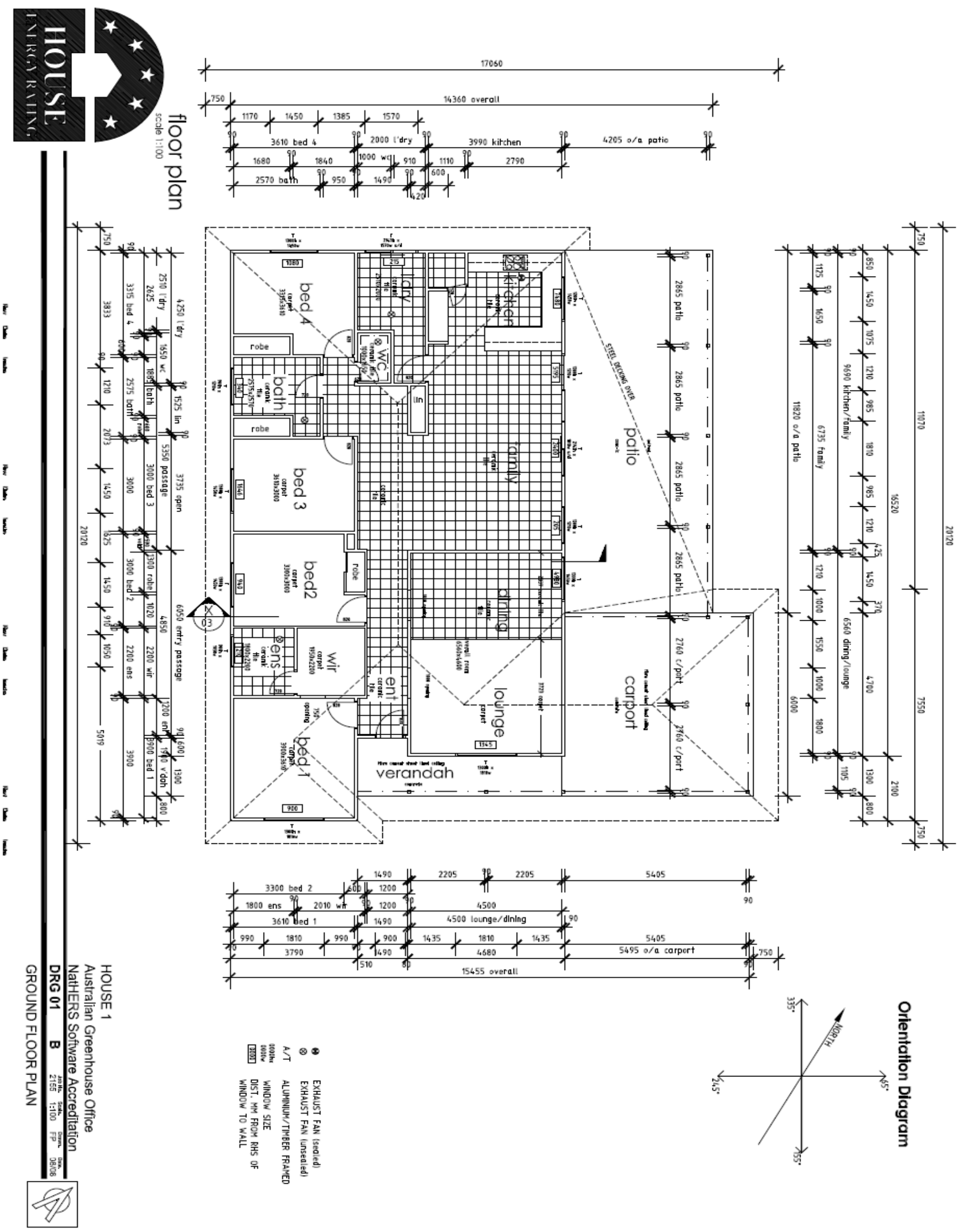
AccuRate star bands were based on a set of 625 houses (245 designs, 175 with improved energy efficiency features, 205 with reduced features) modelled in every climate zones with houses ranging from 0- to 9-star in each climate zone. Most of the designs were provided by jurisdictions and represent new housing stock of that period.

AccuRate has a scale of 0.5- to 10-star – 10-star corresponding to zero energy for comfort, apart from the necessary removal of the latent heat load due to water vapour. The saturated vapour pressure of water vapour increases with temperature, so that as sensible heat is reduced by air conditioning, some water vapour condenses to water and the latent heat of vaporisation must also be removed from the conditioned space. The process of setting star bands was based on the share of houses in the set of 625 houses using the first generation tools in climate zones where these tools had been used to set 4- and 5-star levels (it was critical that first and second generation tools gave the same ratings on average). These shares, after fitting to a smooth curve, were then applied to the number of houses in all climate zones across Australia. This produced a uniform approach in all climates zones, with the houses in the top 140+/-10 being 5-star or better. The energy steps between AccuRate stars amount to an average percentage reduction of 22-28 per cent for each 1-star step from 1-star to 7-star, and by larger percentages after 7-star. This means that each step gets smaller in absolute terms, reflecting the higher marginal effort and cost required to make each successive smaller step. In contrast, NABERS Energy for commercial buildings has linear steps — the energy improvement between 0.5-star and 1-star is the same as between 4.5-star and 5-star.

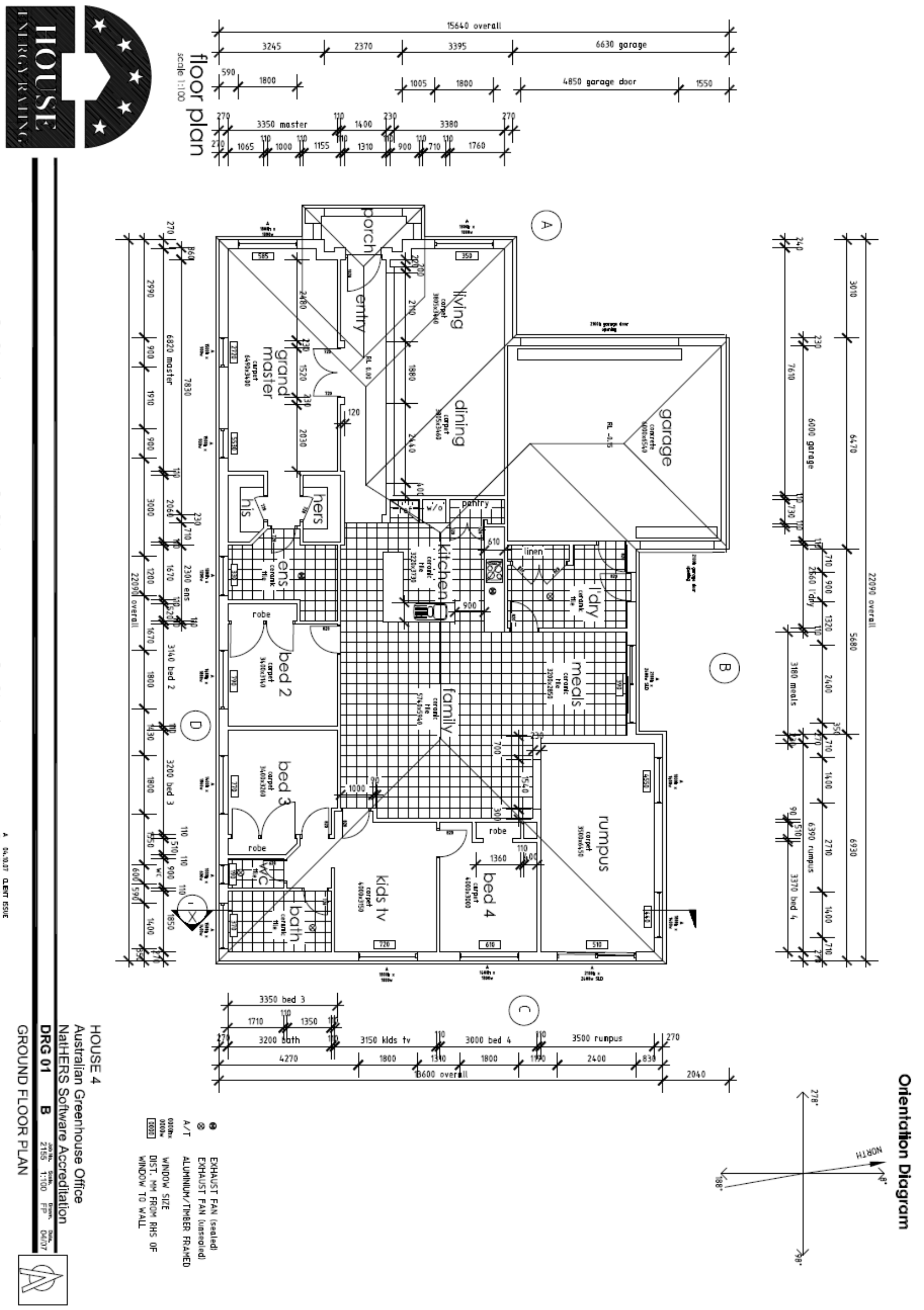
The range of energies covered in the star bands is necessary to cover Australia's existing house stock. While most modelling focus has been on new houses, some studies have been undertaken to give insights into energy performance of existing houses. In 1999 the AGO published a study of Victorian houses based on representative samples of house plans from 1990 (prior to the introduction of insulation standards in 1993 — nominally intended to deliver 3-star energy performance) and from 1999.[6] The average ratings were 0.8-star in 1990 and 2.2-star in 1999. The recent study of the impact of disclosure on house prices in the ACT also produced data on average energy performance.[7] Some 5000 detached dwellings built prior to 1996 (ACT 4-star ACTHERS introduced in 1995) showed a range of EER (Energy Efficiency Rating) values between 0- and 3-star, with a higher share at the lower end of the scale.

B New and existing/stock house drawings

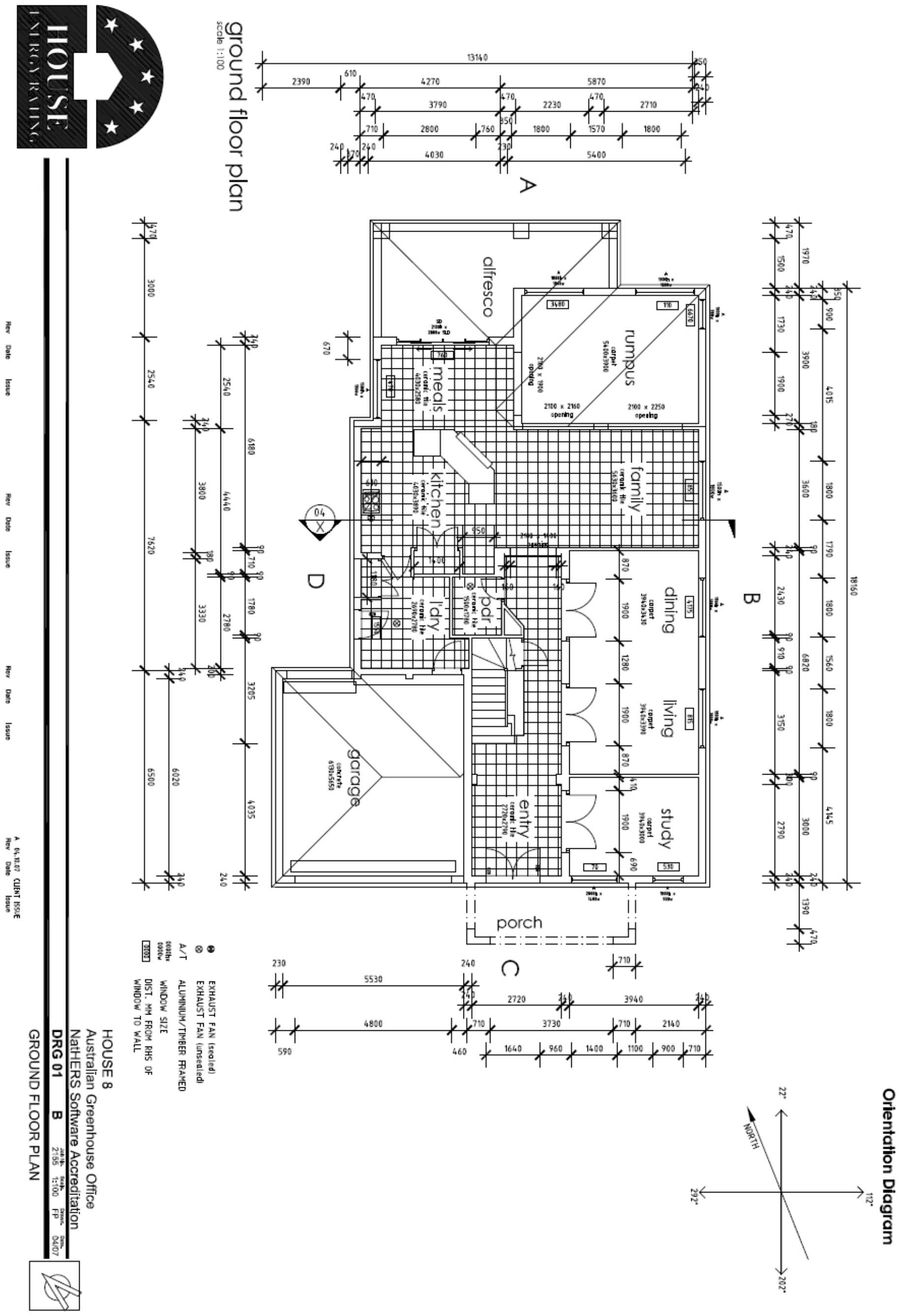
B.1 New house 1



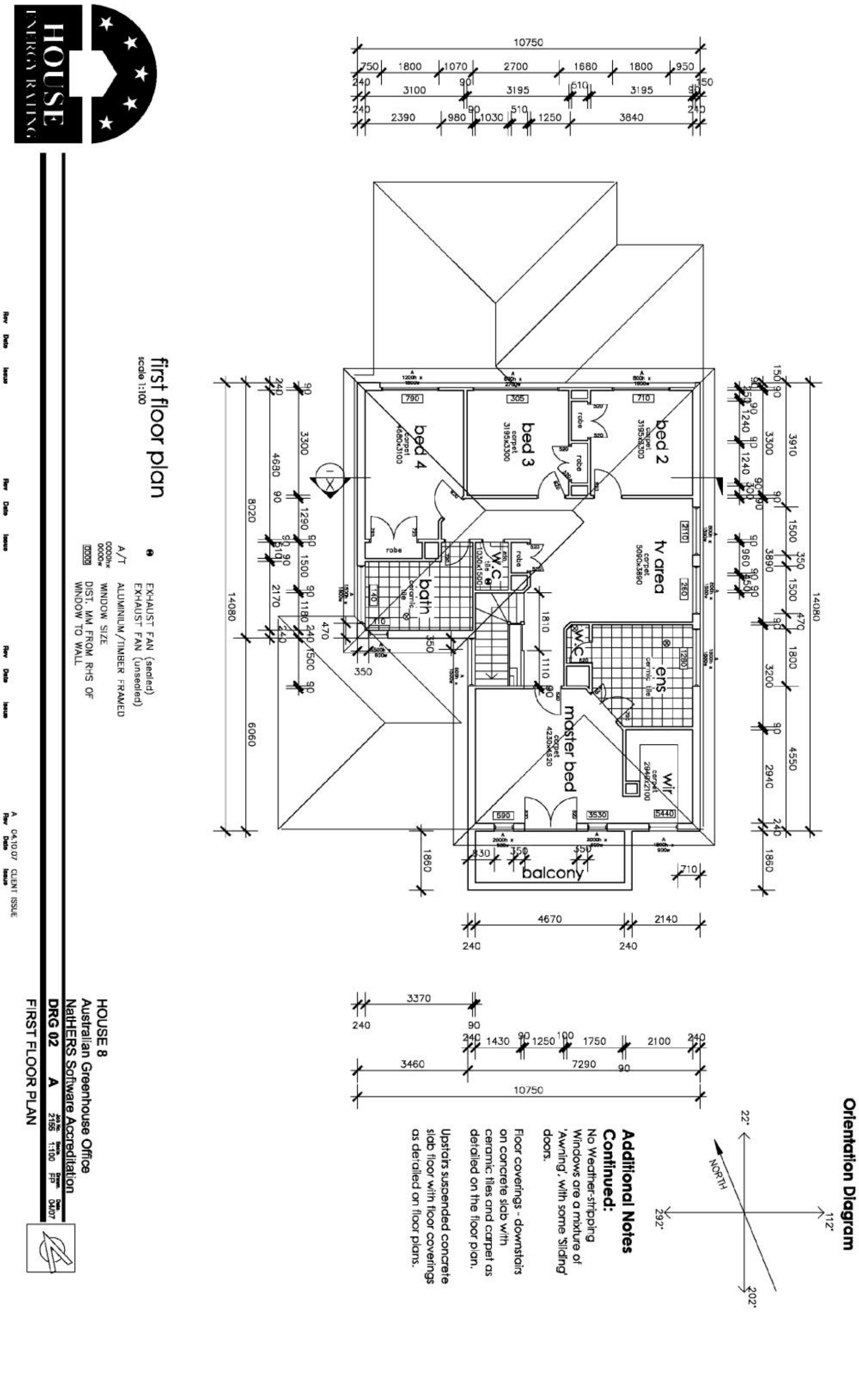
B.2 New house 4



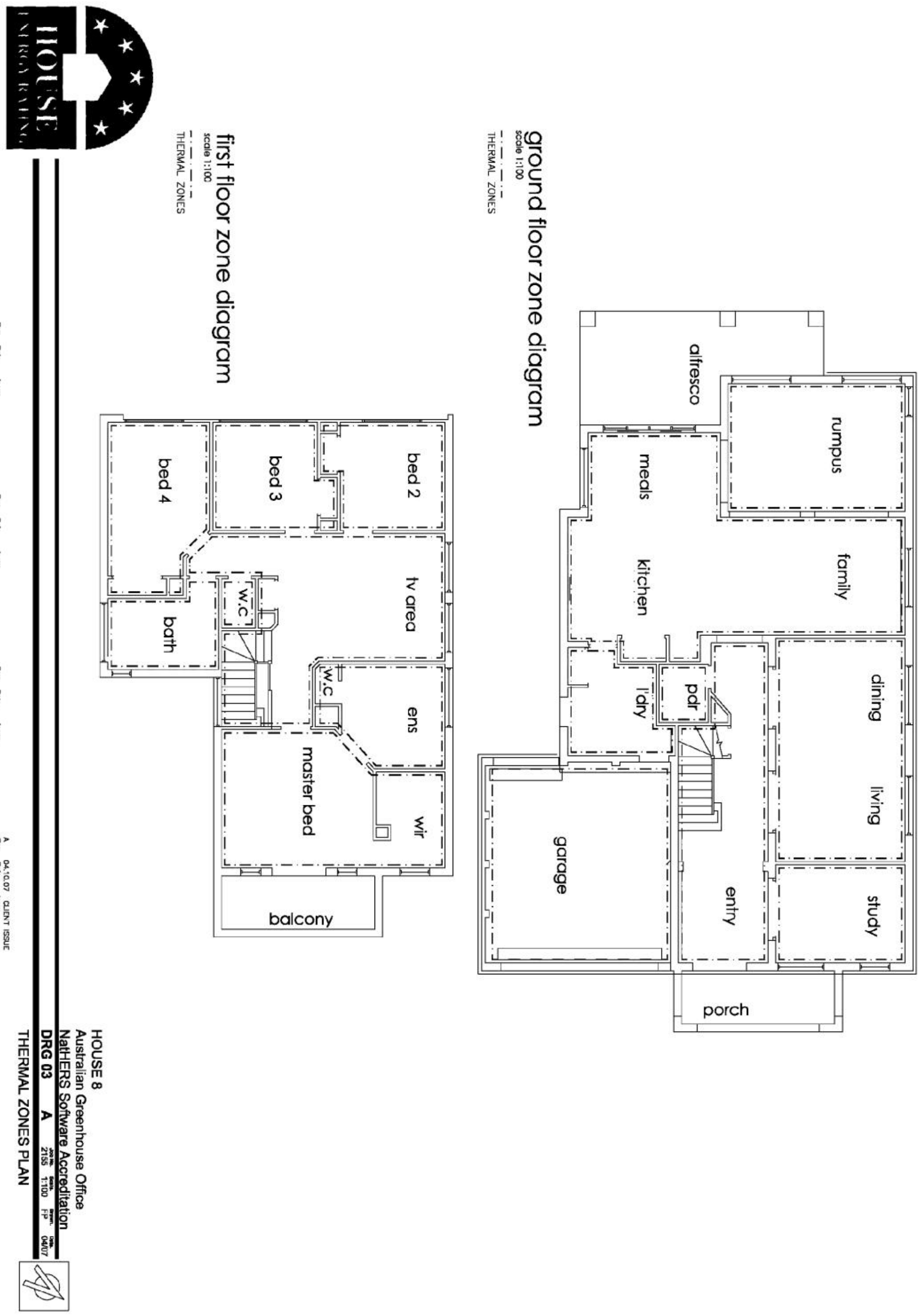
B.3 New house 8



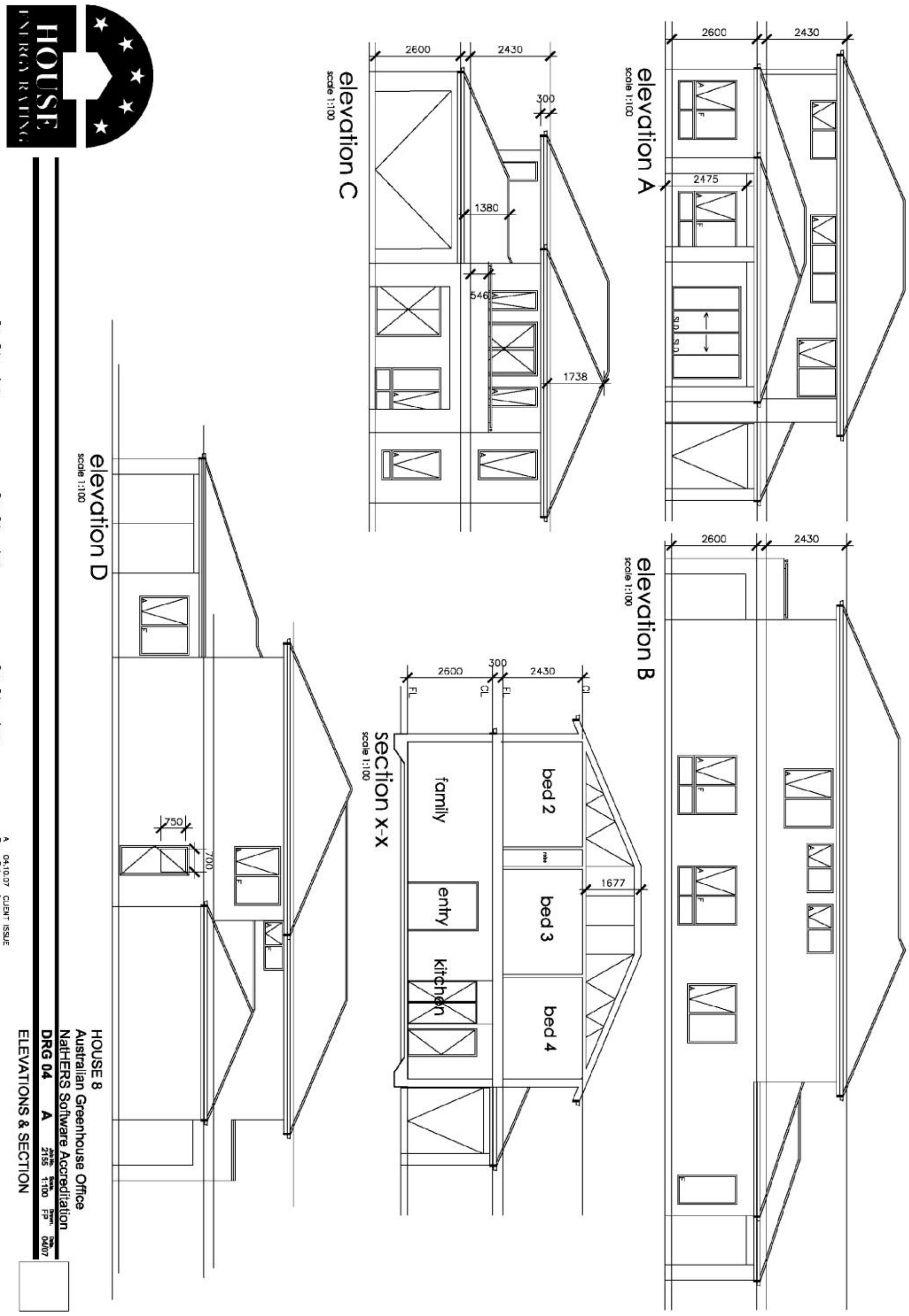
B3 **New house 8**



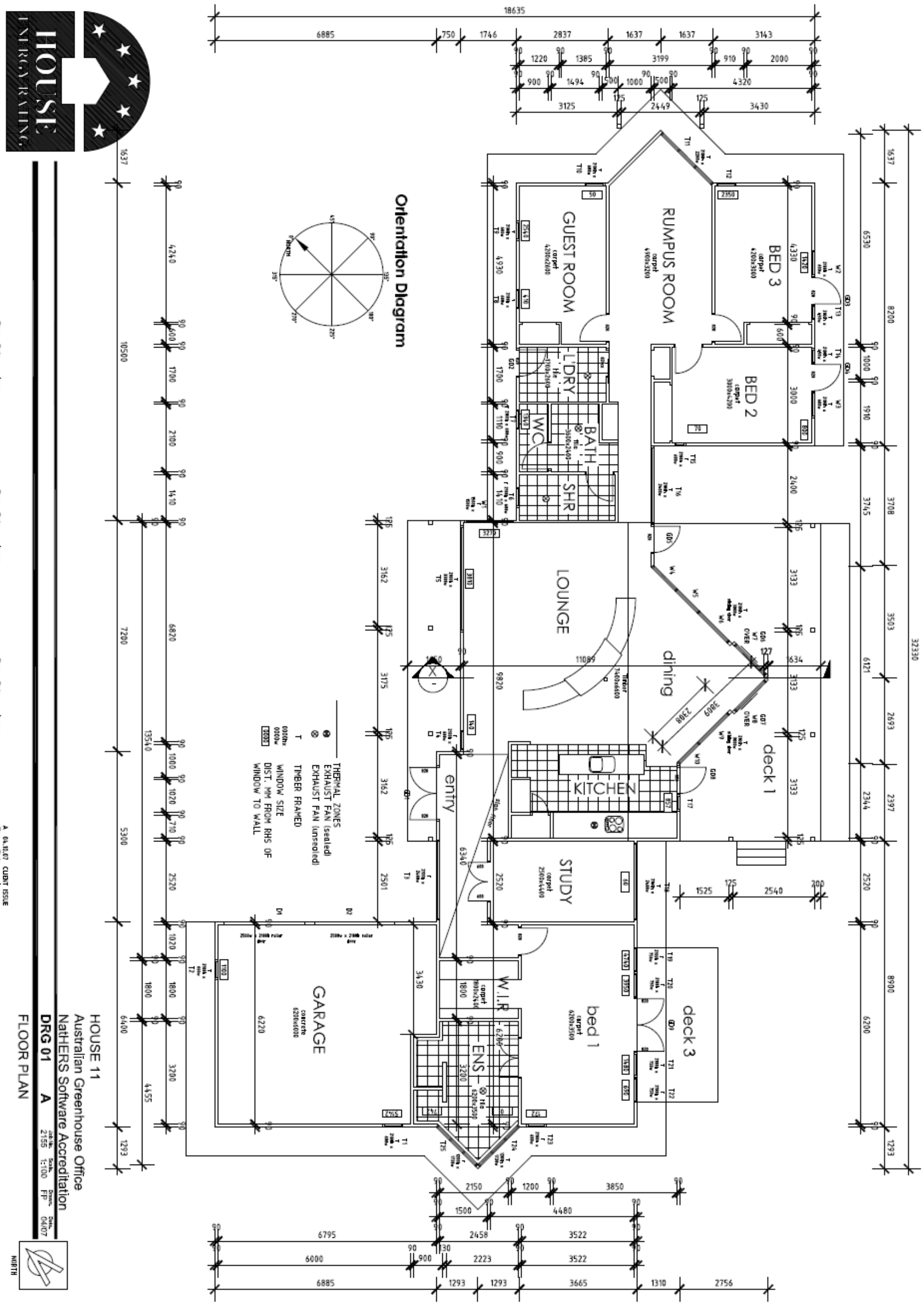
B3 New house 8



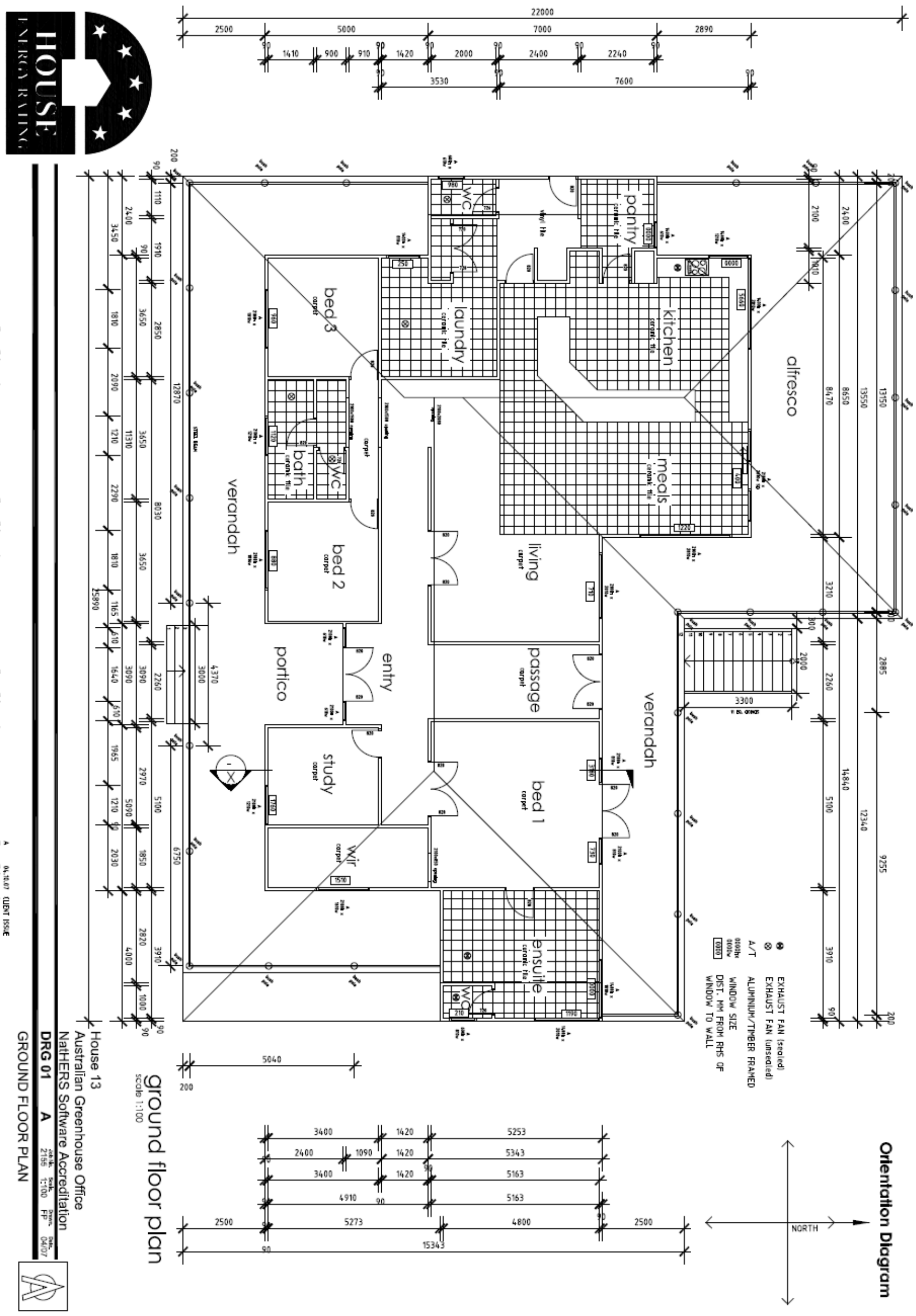
B3 New house 8



B.4 New house 11

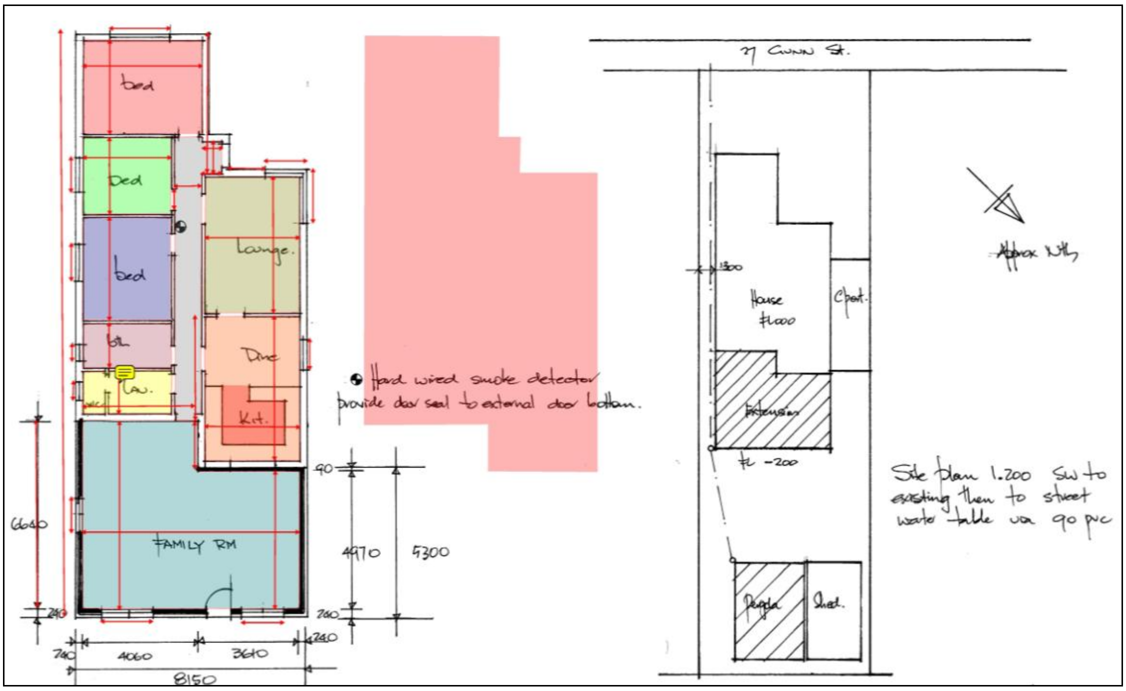


B.5 New house 13

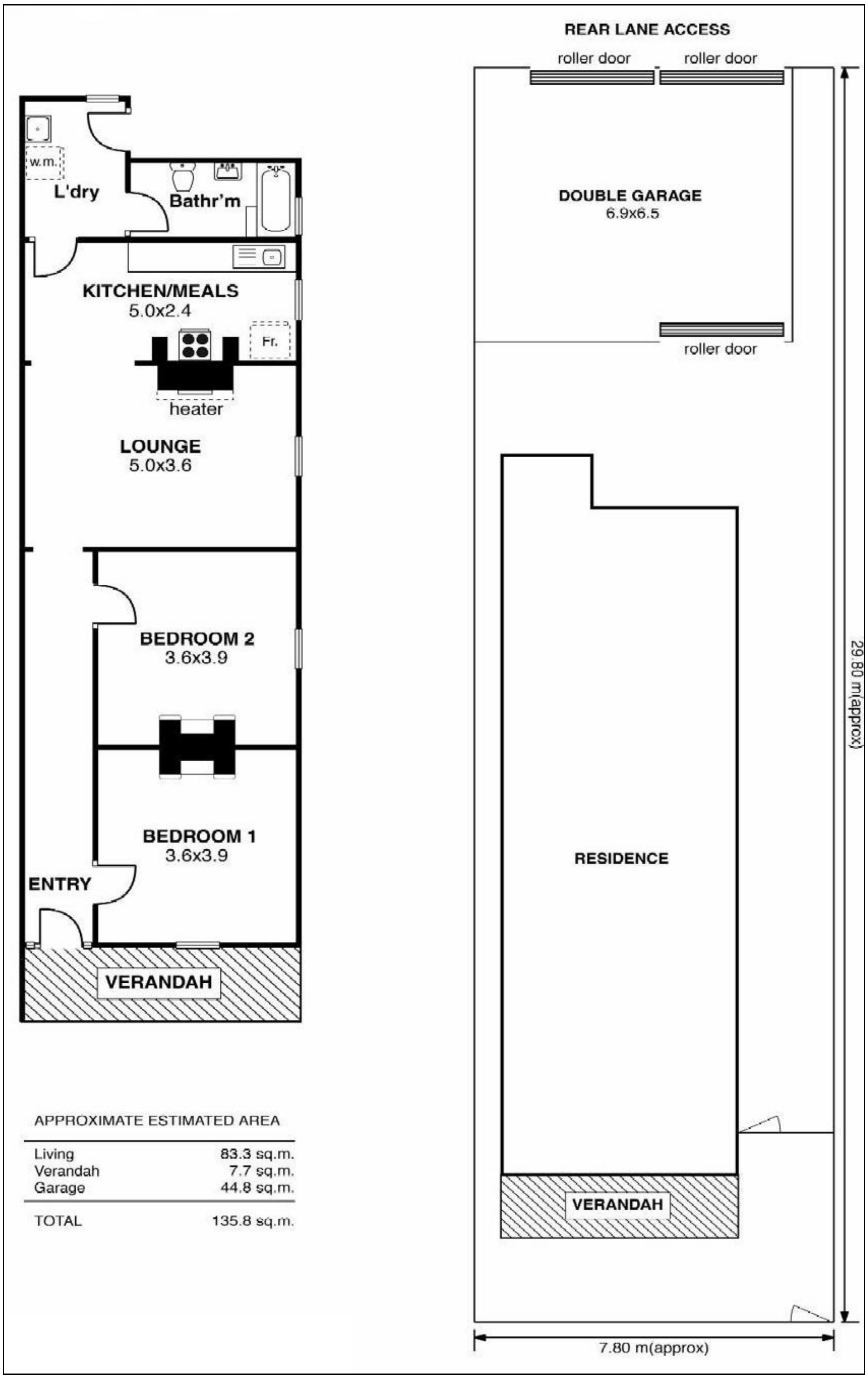


Stock house 1 includes the extension shown below as 'Family Room', whereas number 2 does not.

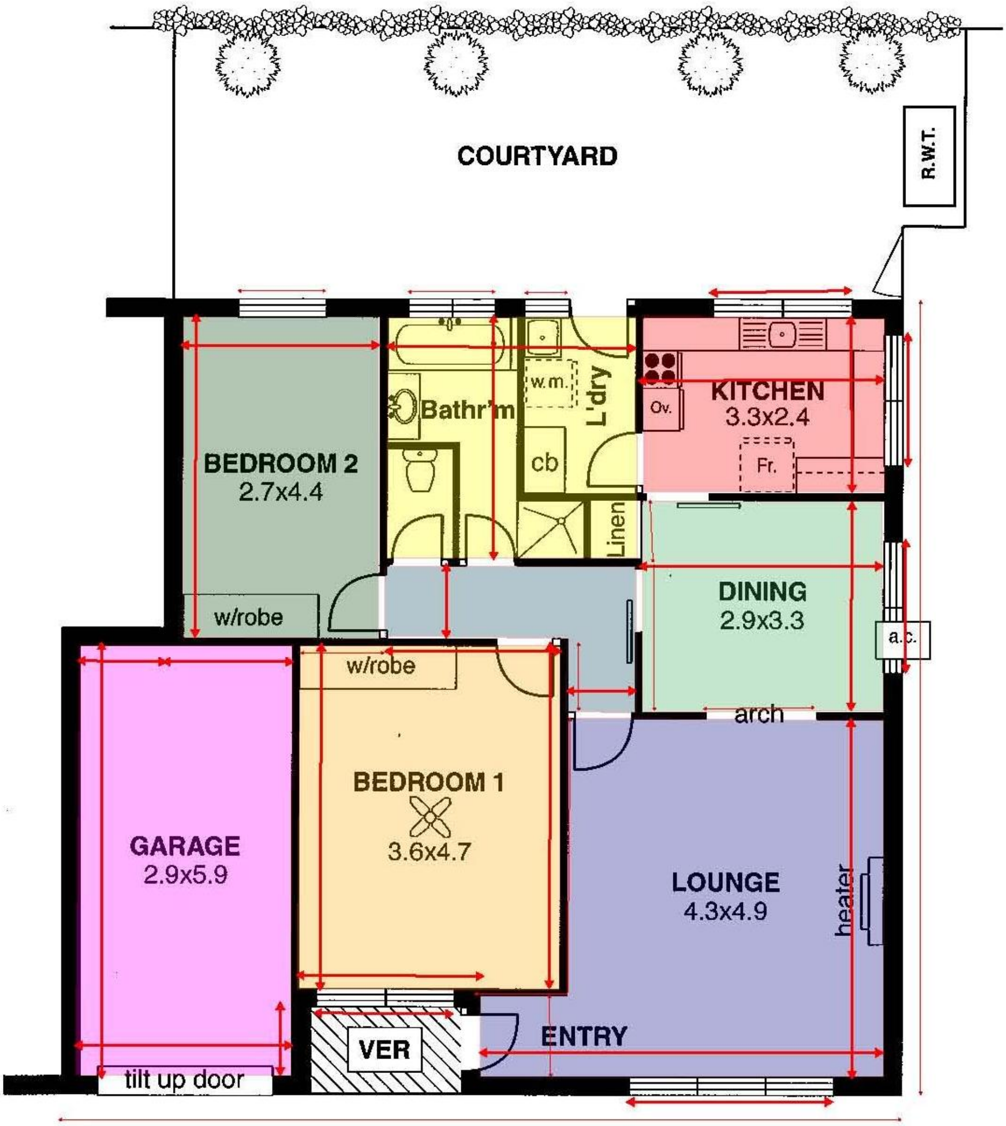
B.6 **Stock house 1 and 2**



B.7 **Stock house 3**



B.8 Stock house 4



APPROXIMATE ESTIMATED AREA

Living	99.4 sq.m.
Verandah	2.5 sq.m.
Garage	17.1 sq.m.
TOTAL	119.0 sq.m.

Stock house 6 is shown below. This design was used in a previous cost/benefit study based on 1st generation NatHERS modelling.

B.9 **Stock house 6**