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Measuring our sustainability progress: Benchmarking New Zealand's new detached residential housing stock

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- Christian Hoerning representing the Energy Efficiency and Conservation Authority
- Ian Mayes representing the Eco Design Advisors and Building Officials Institute of New Zealand.

James Sullivan, PhD candidate at Victoria University, Wellington, undertook the considerable thermal modelling simulation work.

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Abstract

The building and construction sector plays a vital role in terms of New Zealand's sustainable development. Where New Zealand stands as a nation in terms of new-build residential sustainability is unknown. This report addresses that by:

- advancing previous foundational work carried out in New Zealand, mainly by Beacon Pathway
- concentrating on existing reporting of environmental, economic and social-related information where possible
- accounting for the last 10+ years of development in terms of international building indicator work
- providing actual results for a set of core indicators, effectively providing a Year Zero benchmark to which future results can be compared.

Keywords

New Zealand housing stock, sustainability, benchmarking.

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Executive summary

The building and construction sector plays a vital role in terms of New Zealand's sustainable development. Where New Zealand stands as a nation in terms of new-build residential sustainability is unknown. This report addresses that by:

- advancing previous foundational work carried out in New Zealand, mainly by Beacon Pathway
- concentrating on existing reporting of environmental, economic and social-related information where possible
- accounting for the last 10+ years of development in terms of international building indicator work
- providing actual results for a set of core indicators, effectively providing a Year Zero benchmark to which future results can be compared.

Fourteen core indicators over eight domains provided key metrics that were considered to be most useful for capturing the New Zealand scene:

- Energy/CO_2
- Water
- Indoor environment
- Functional resilience
- Affordability
- Consumer demand
- Industry capacity
- Policy/regulation

A summary of the key indicators and their associated metrics are shown in Table 1. An indicator of whether the specific metric is largely based on desktop modelling and simulation studies (M) or actual practices (A) is provided.

A variety of data from national-based agencies is used to provide data on the various sustainable attributes. Where possible, nationally representative figures were used.

The exception for this was in building performance metrics, where there was a lack of comprehensive, representative data available. Consequently, some 210 building consents randomly selected from the year 2012 were collected from three councils – Auckland, Hamilton and Christchurch – and assessed in detail to provide the requisite information.

Given that 2012 was the first year that these (often disparate and sometimes new) metrics have been formalised, comparative benchmarks were sometimes lacking. To clarify interpretation for readers, a basis for comparison was required. The NOW Home® – a proof-of-concept sustainable house designed and built in 2008 in the Auckland suburb of New Lynn – was used in these instances. Being well known in the sustainable building and environmental communities and a proven performer means that it is a useful yardstick.

This BRANZ project will be periodically repeated to provide updated core indicators to track new stand-alone residential housing stock.

Table 1. Summary of the core new-build indicators and their respective metrics.

Domain	Core indicator	Metric(s) used	Modelled or actual
Energy and CO_2	Energy use for active space conditioning	kwh/m^2, kWh/household and kWh/person	M
	CO_2 emissions for hot water heating	CO_2 emissions/person/year	M
	Potential of site for harnessing solar energy	Percentage availability of sun for specific sites	M
	Whole-house resource efficiency rating	Ratio of floor area to number of bedrooms	A
Water	Uptake of household water-saving devices	Proxy: inclusion of rainwater tanks in specification	A
Indoor environment	Comfortable indoor temperatures achieved passively	# of hours/year in main living area	M
	Healthy indoor temperatures in a key occupancy zone	Extreme heat (# degree-hours/year above 25°C) and critically cold (# of days/year less than 12°C)	M
Functional resilience	Proximity to key amenities/public transit	Walk Score™ and Transit Score™ ratings	M
	Inclusion of universal design features	# Lifemark™ Design Standard awards	A
	Climate change implications on indoor thermal comfort achieved passively	Overheating (hours/day) and underheating (hours/day) projections for years 2030 and 2080	M
Affordability	Initial financial cost of five key environmental features	Cost of improving thermal performance, energy efficiency and water management	A
Consumer demand	Demand/sales of some key sustainable products and services	Products: Specification of various home-related products Services: # of whole-house environmental awards Features: NZGBC and realestate.co.nz annual survey	A
Industry capacity	Supply of some key sustainability- related services	# of supporting building industry- related professionals # of banks providing some type of green mortgage # of trade-specific capacity-building initiatives.	A
Policy and regulation	Supportive governmental policy and regulation	# of specific existing and long-term initiatives implemented	A

1. Introduction

The principal objective of this BRANZ study is to further develop a robust, practical and useful set of sustainability indicators quantifying New Zealand's new-build (stand-alone) housing stock. By data mining existing publicly available information resources where possible, the aim is to establish a Year Zero baseline of where New Zealand is in terms of the key sustainability indicators. By repeating this metadata collection and analysis exercise periodically, a longitudinal examination to better determine progress (in the form of trends) can be tracked over time.

Essentially, this work provides a snapshot of the sustainability-related performance of and impactors on new housing stock for a particular year. It allows the building industry to build a comprehensive picture about the state, impacts and pressures across a variety of sustainability domains when repeated periodically. Where indicators show little positive change, the second stage of the project will identify the barriers that prevent progress.

BRANZ recognises the need to improve New Zealand's housing stock but also to support the New Zealand Building Act (2004). The Act requires, through both its purpose and principles, that "buildings are designed, constructed, and able to be used in ways that promote sustainable development". To manage the existing housing stock better, a clearer picture is needed to inform just where the shortfalls are in terms of a variety of sustainability metrics. Some quantitative indicators are being collected by a disparate assortment of New Zealand agencies currently. However, historically, little in the way of aggregation has been carried out to provide a more comprehensive sustainability picture that would be useful for a greater number of interested parties.

This BRANZ study builds on previous New Zealand indicator work in the area of sustainable housing, most significantly the Beacon Pathway framework developed in the late 2000s.

2. Background

2.1 Scope of study

This BRANZ study is directed at the overall sustainability of New Zealand new-build national housing stock – not the sustainability of individual houses. There are other tools operating to assess sustainability at an individual house level – most notably the New Zealand Green Building Council's (NZGBC's) Homestar® tool. Although these independently rated and certified houses contribute to the national housing stock, they are a very small and unrepresentative sample (in 2012). In addition, in all likelihood, these rated homes will remain very much a fringe activity for the foreseeable future given their small uptake so far.

Ideally, this study would have liked to examine all dwelling typologies – detached houses, terraced homes, studios, multi-level apartments and so on. However, there are very large consequential resource needs in establishing typology-specific indicators, and many publicly available metrics are based around stand-alone homes. Therefore, it was decided to keep things simple and start with a single typology – with the opportunity of increasing the scope in future work.

This study is limited to indicators concerned with the dwellings and their immediate facilities. Its scope does not include the wider sustainable urban form where a comprehensive methodology for measuring comparative sustainability performances already exists (Ghosh, Vale and Vale, 2007). The exception to this is where the proximity to key amenities and public transportation is examined, as this is considered by many to be a key influencer of a home's overall sustainability performance (Crane and Schweitzer, 2003).

2.2 What is an indicator?

A sustainability indicator for buildings is formally described as a quantitative, qualitative or descriptive measure representative of an aspect of building that impacts on the economy, environment or society (adapted from ISO 21929-1:2011). They are designed to simplify, quantify and communicate a situation at a point in time. Their key characteristics vary by stakeholder and specific end purpose. Statistics New Zealand (Brown, 2009) provides a selection of characteristics that indicators should embody:

- **Valid and meaningful** – should adequately reflect the phenomenon it is intended to measure and should be appropriate to the needs of the user.
- **Sensitive and specific to the underlying phenomenon** – relates to how significantly an indicator varies according to changes in the underlying phenomenon.
- **Grounded in research** – requires awareness of the key influences and factors affecting outcomes.
- **Statistically sound** – needs to be methodologically sound and fit for the purpose.
- **Intelligible and easily interpreted** – should be sufficiently simple to be interpreted in practice and intuitive.
- **Relate where appropriate to other indicators** – best interpreted alongside other similar indicators.
- **Allow international comparison** – should reflect New Zealand-specific goals but where possible should also be consistent with those used internationally.

- **Ability to be disaggregated over time** – able to be broken down into population subgroups or areas of particular interest, such as ethnic groups or regional areas.
- **Consistency over time** – have the ability to track trends over time.
- **Timeliness** – have a minimal time lag between the collection and reporting of data to ensure that indicators are reporting current rather than historical information.
- **Linked to policy or emerging issues** – reflect important/emerging issues as closely as possible.
- **Compel, interest and excite** – the indicator should resonate with the intended audience.

Furthermore, it is sometimes stated that the number of indicators should be as small as possible but not smaller than necessary – which is a good reminder to keep things simple. These characteristics were used as a touchstone when refining the original Beacon Pathway indicators for this BRANZ study.

2.3 The need for a New Zealand housing stock indicator

Seven years after the publication of Beacon Pathway studies on the need for a national housing indicator framework for New Zealand (Kettle, 2008; Trotman, 2008), little has progressed in terms of populating the indicators put forth. Not only is there still "no coherent means or allocated responsibility in NZ for measuring the sustainability of the residential housing stock" (Trotman, 2008), but the list of reasons why it is important has grown even more pressing:

- New Zealand new-build housing stock is worth approximately $6 billion annually. New, stand-alone New Zealand dwellings built in 2012 numbered 13,871 (i.e. 82% of all new dwellings), making up the majority of the 16,903 new dwellings in total (M. Curtis, BRANZ Economist, personal communication, March 2014). It is recognised that the quality of our new-builds (Page, 2014) and therefore their likely performance (in terms of resource use, utility provision and comfort) is less than exemplary. Determining just how far below the 'exemplary' performance line new-builds are will provide opportunities for improvement. Until now, there has only been piecemeal and disaggregated information available from a variety of sources, albeit with data gaps in important areas.
- New Zealand, like many other nations, is facing some fundamental changes both in the medium and long term. This includes such issues as an ageing demographic, climatic instability and the growing scarcity and increasing cost of non-renewables. We need to understand how our housing stock can better plan for, adapt to and respond to these threats and challenges.
- The New Zealand Building Act requires that "buildings are designed, constructed, and able to be used in ways that promote sustainable development". Consequently, the New Zealand Building Code (NZBC) prescribes functional requirements and performance criteria (rather than Acceptable Solutions) for residential buildings on the:
    - energy and use of renewable sources of energy
    - use of materials and material conservation
    - use of water and water conservation
    - reduction of waste during construction.
- The requirements cited in the NZBC are largely seen by industry as good practice resulting in good performance, rather than a minimum performance level.[1] Given

[1] www.level.org.nz/passive-design/insulation

the major changes New Zealand is facing, just where we sit nationally needs to be well established to better target resources where changes are needed.
- There is a lack of understanding on how recent environmental initiatives (such as the independent Eco Design Advisors™ along with the more recent Home Performance Advisor service) have impacted on new housing stock.

These national building stock indicators can sit alongside other New Zealand national environmental indicators, such as the Ministry for the Environment's natural environmental indicators[2] to provide a more complete snapshot of where New Zealand is at currently.

2.4 Audience and uses

The main audience envisioned for this BRANZ study are those who have a responsibility for and interest in better understanding the sustainability of New Zealand's national new-build housing stock. When repeated, this study will also provide critical information of how the sustainability of New Zealand's stand-alone housing stock is trending as a result of stressors on it. Examples of interested parties may include government departments, government agencies, Standards New Zealand and environmental building professionals (researchers, educators and advisors) including BRANZ and Beacon Pathway and their associated stakeholders. This BRANZ report is intended to be living, so all of these groups will be able to provide input to improve and fine tune it as necessary as the data is recollected periodically.

The intended uses for this indicator study remain largely unchanged since 2008 (Trotman, 2008):

- To provide a foundation from which to track changes in key aspects of the sustainability of the residential housing stock into the future, when repeated.
- To support strategic decision making and action leading to more sustainable homes (i.e. influence policy, planning, action and behaviour at agency level) and identify key levers of change and raise awareness of these.
- To be useful and relevant to the audiences above
- To support uptake and use of this framework into the future.
- To catalyse better data and information gathering on the sustainability of New Zealand homes.

[2] http://mfe.govt.nz/more/environmental-reporting

3. Methodology

3.1 Introduction

This study sought to develop and/or fine tune existing indicators and metrics to reflect the characteristics of indicators outlined in section 2.2, but also to:

- leverage existing databases and data collection resources already available provided that they are robust and likely to continue into the future for ease of tracking
- be as relevant as possible
- be low cost to data mine and accessible in succeeding BRANZ updates.

A steering group was set up as part of the project's establishment. The group's main objective was to provide a variety of organisations with the opportunity to influence what core indicators might be most appropriate – whether already existing, partially adapted or developed from new. Members representing environmental educators, local and central government, building research consortiums, building officials and independent environmental consultants participated.

3.2 Previous international indicator work

There has been some international work to provide standardisation in the area of specialised metrics targeting sustainable residential buildings. The most notable is ISO 21929-1:2011 Sustainability in building construction – Sustainability Indicators: Part 1: Framework for the development of indicators and a core set of indicators for building. This document forms part of a suite of ISO sustainability standards on building works and provides measures to express the contribution of buildings to sustainable development.

The 14 core indicators cited in ISO 21929-1:2011 are seen as being essential for assessing the contribution of a building to sustainability but are not necessarily comprehensive. Details of the ISO core indicators and how they fit in with the finalised core indicators used in this report can be seen in Appendix A.

ISO 21929-1:2011 was used for general guidance for this BRANZ study, being more of a high-level document and having:

- no obvious means to quantitatively measure some of the proposed core indicators in a practical way that would be repeatable longitudinally (for example, aesthetic quality)
- insufficient detail provided on how to measure many indicators quantitatively, with many being only qualitative based
- no corresponding data collection available specifically targeting new residential building stock (for example, air quality, serviceability and access to services).

Although there are other international efforts in understanding the sustainability features of house building stock, they almost always have a very constrained scope (Kavgic et al, 2010) and therefore were of limited value for this study. By far the most concentrated effort has been on single residential assessments, for which there are a multitude of tools available, for example, USA's LEED, the UK's Code for Sustainable Homes and New Zealand's Homestar™.

Nationally, by far the most work around this area of sustainability metrics for housing stock was carried out by New Zealand-based research consortium Beacon Pathway in the mid to late 2000s. Beacon Pathway has previously presented an indicator framework in the their inception (Kettle, 2008). Several associate papers were published (Trotman, 2008; French and Camilleri, 2008; Page and Jaques, 2006) that examined potential metrics for both the new and existing housing stock. Ten key domains were identified, based on their High Standard of Sustainability (HSS™) work. Within each of the domains, core indicators (along with their proposed measurements) were suggested.

Specifically, the Beacon Pathway work provided:

- New Zealand-specific issues of importance and therefore appropriateness
- housing stock indicators that were nationally based rather than targeted at individual homes
- a useful spectrum of practical issues underpinned using a collaborative process providing a rigorous framework to allow comparisons to be made.

As a result, the Beacon Pathway framework development and resulting indicator set formed the foundation of this BRANZ report to a large extent, being relevant today.

3.3 Developing core indicators

Although having an expansive suite of indicators may be appealing, this conflicts with the overall desire to simplify interpretation and therefore communication of the issues. The core indicator set was formulated by the process outlined in Figure 1 and the associated notes with the steering group:

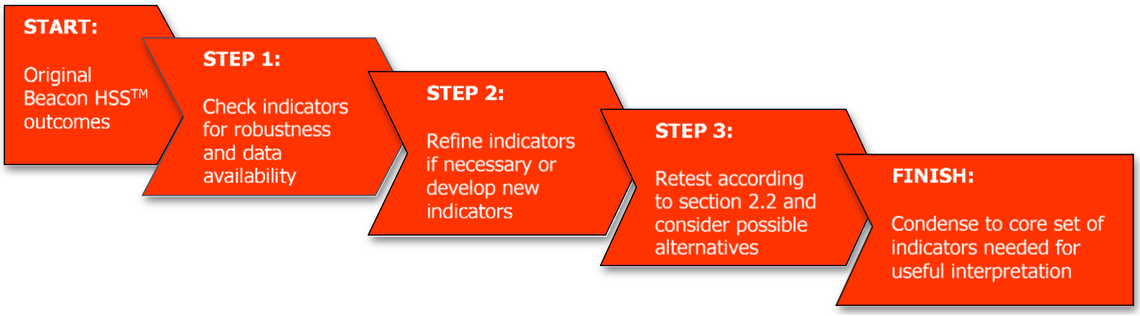


Figure 1. Process for the refinement of core indicators.

START: The original 10 domains developed by Beacon Pathway (Trotman, 2008) as part of their High Standard of Sustainability (HSS™) with their associated core indicators were the starting point for this study.

STEP 1: Check the original Beacon Pathway indicators meet current requirements for technical measures (such as data robustness) but also practical measures (such as data availability and cost to acquire).

STEP 2: Refine as necessary, ensuring currency, relevancy, transparency, robustness (including repeatability, and representativeness) remain intact.

STEP 3: Test whether the resulting measures of the metric meet the section 2.2 characteristics as far as practically possible. Consider and compare the most viable alternative and placeholder measures that provide the same or similar indicator.

FINISH: Condense the number of indicators to a core set for ease of interpretation but ensure that original usefulness for quantitatively measuring changes remains high.

The 10 original Beacon Pathway domains:

1. Energy
2. Water
3. Indoor environment
4. Materials wastage
5. Functional resilience
6. Affordability
7. Consumer demand
8. Industry capacity
9. Policy/regulation
10. Sustainability

These remained in this BRANZ study, apart from two exceptions – materials wastage and sustainability defined. These two domains had either no practical way of measurement or the uptake hadn't been what was anticipated, respectively.

The core indicators within the remaining domains, however, were in many cases considerably fine tuned, usually for practical reasons.

It should be noted that there were several important sustainability issues for which an adequate indicator could not be provided for, such as:

- household water use
- the susceptibility of the housing stock to several (non-temperature-related) climate change-related risks, such as flooding, storms and changing sea levels.
- durability of housing stock
- construction waste generation.

Ideally, there would be a robust and straightforward way of collecting representative data that is easy and repeatable. However, currently one (or more) of the following reasons precluded a (potential) metric being realised for this BRANZ study:

- Data collection not periodic/consistent between regions/nationally.
- Data collection not carried out so that practical statistical sampling is possible at a reasonable cost.
- Data not disaggregated enough for meaningful interpretation.
- Tools not well developed or advanced enough yet to provide useful information.
- No metrics currently being used either nationally or internationally that could be adapted.

The status of these indicators will be reviewed for future incorporation.

3.4 Finalised core indicator set

Three themes – building performance, market forces and governance – have evolved as a natural grouping of the eight proposed domains by BRANZ:

- **Building performance** where core indicators measure the resource needs and utility provided, as well as the stock's resilience to future requirements, on a national scale.
- **Market forces** where core indicators measure consumer demand and industry capacity to supply key lower-impacting products and services for new housing stock.
- **Governance** where core indicators measure government support for a variety of initiatives that enhance the uptake and acceptance of higher-quality new-build housing.

How the three themes relate to each of the eight domains and the 15 core indicators contained within them is shown in Figure 2.

DOMAIN	Core indicators for new NZ houses	Section
	Building performance	
ENERGY and CO_2	Energy use for active space heating	5.1
	CO_2 emissions for hot water heating	5.2
	Potential of site for harnessing solar energy	5.3
	Whole house resource efficiency rating.	5.4
WATER	New-build uptake of household water saving devices.	5.5
INDOOR ENVIRONMENT	Comfortable indoor temperatures in key occupancy zones.	5.6
	Healthy indoor temperatures in a key occupancy zone.	5.7
FUNCTIONAL RESILIENCE	Proximity to key amenities and public transportation.	5.8
	Inclusiveness of Universal design features	5.9
	Thermal design performance that limits discomfort	5.1
	Market forces	
AFFORDABILITY	Financial cost of 5 key environmental features	5.11
CONSUMER DEMAND	Demand/sales of 8 key sustainable products and services	5.12
INDUSTRY CAPACITY	Supply of some key sustainable-related services by industry	5.13
	Governance	
POLICY AND REGULATION	Supportive central/local government policy.	5.14
	Supportive central/local government regulation.	5.15

Figure 2. Core indicators selected for new New Zealand housing stock.

Although there are many ways of grouping the domains and therefore the core indicators, it was felt this best reflected the BRANZ benchmarking approach. It also provides an informative snapshot of the scope of each domain and where in this document it is addressed in detail. It also allows the flexibility of further fine tuning as practices change and initiatives develop for future periodic data collection events. The domains and indicators are purposefully broad to ensure that they capture the areas of importance, both nationally and internationally.

The methodology used to examine each indicator on a nationwide basis and the resulting findings are detailed in section 5. More information on the background to each core indicator, such as its ISO Area of Protection, measurement method, reliability of data sources, data collection details and possible alternative indicators and metrics are provided in Appendix B.

3.5 Sample size for key core indicator

For many core indicators in the study, data was readily available in a usable form – either directly or indirectly – for providing metrics. However, for some of the building performance-specific indicators – such as space heating energy requirements, thermal comfort and hot water appliance emissions – there was little useful publicly available information. To examine these indicators, it was necessary to obtain building consent data from their local authorities and undertake detailed desktop examinations.

As undertaking these examinations requires considerable resource and because of the practicalities of engaging with multiple consenting authorities, only a subset of newly constructed detached dwellings were sampled. For this BRANZ study, three key locations (Auckland, Hamilton and Christchurch) were chosen to represent New Zealand's recently completed, detached housing stock. These three locations make up approximately 46% of the nation's population. Their respective local authorities had systems in place to easily provide building consent information on detached homes, making a random selection of 2012 consented homes practically possible. In addition to being locations of current interest (i.e. Auckland's residential undersupply and the considerable Christchurch rebuild), they correspond to the three NZBC clause H1 (2007) climate zones.

Space heating is the largest energy use type within most New Zealand houses (Isaacs et al, 2010). Thus, the space heating metric was selected to establish an appropriate sample size. A Beacon Pathway study (Jaques, 2009) provided some guidance around what an appropriate sample size might be, with space heating energy intensities for 20 randomly selected, detached Auckland houses. In addition, the Beacon Pathway sample homes were preselected to all have an estimated consent value of between $160,000 and $200,000 (in 2008 dollars), for comparative reasons. This sample had a mean space heating intensity of 18.9 ± 0.7 kWh/m².yr for a 95% confidence interval. Since the Beacon Pathway sample was more consistent than this BRANZ study, the observed sample standard deviation was doubled in the sample size calculation. Thus, for this study, it was desired to obtain a 95% confidence interval with a half range of 0.5 kWh/m².yr, which required a sample size of 66 randomly selected houses. Consequently, building consents from approximately 70 houses in each of the three selected regions all consented in the 2012 calendar year were studied in detail. Due to the very high resource needs to assess each consent (specifically associated with the thermal simulation runs), it would be very difficult to increase the sample size within the scale of the project.

Table 2 gives the results of the space heating energy intensity estimates for the three locations. The variability within each region was slightly larger than expected. This has increased the range of the confidence interval estimates for these regions. This will impact on how easily it will be to distinguish future changes in space heating energy intensity.

Table 2. Space heating energy intensity estimates for the three regions.

Location	Sample size (n)	kWh/m².yr			
		Sample mean	Sample standard deviation	Range	Mean space heating energy intensity at 95% confidence interval
Auckland	68	26.3	5.4	30.8	26.3 ± 1.3
Hamilton	70	42.0	5.2	29.2	42.0 ± 1.3
Christchurch	68	76.7	9.2	42.7	76.7 ± 2.2

4. Interpretation

4.1 Glossary of terms and abbreviations

Active space heating: Describes the use of artificial heating to provide the space heating necessary to achieve comfortable indoor temperatures (18–25°C) when solar and incidental gains are inadequate.

BOINZ: Building Officials Institute of New Zealand.

BPI: Building Performance Index. A performance level set in the New Zealand Building Code for thermal efficiency of residential buildings. The space heating energy of a building divided by the product of the heating degrees total and the sum of the floor area and the total wall area.

Climate change: A statistically significant variation in either the mean state of the climate or in its variability, persisting for an extended period – typically at least several decades.

Conditioned area: The volume of the home that is contained within (i.e. bounded by) the thermal envelope. For most houses, this excludes the garage area.

CSIRO: Commonwealth Industrial Scientific Research Organisation, whose global climate model for climate change forecasting (CSIR09) is used in the this report (Australian based).

Degree-hours too hot: A measure of overheating severity. Equates to the temperature difference between the overheated zone and the overheating threshold temperature (in this case 25°C) multiplied by the number of hours the zone is overheated. Provides a better indication of the human response (i.e. physiological stress) to overheating, i.e. 1 hour at 26°C is not equal to the human experience of 1 hour at 29°C.

EDAs: Eco Design Advisors. A free, independent, council-based advisory service for industry, community groups and the public, applicable to both new and existing residences.

Free-running mode: Describes when a house has only passive-solar means to provide comfortable temperatures.

Hadley: The global climate model developed by the Hadley Centre for Climate Prediction Research by the UK Meteorological Office.

HSS™: Beacon Pathway-developed benchmark defining a high standard of sustainability for New Zealand houses, based on five key performance areas.

Indicator: A quantitative, qualitative or descriptive measure representative of an aspect of building that impacts on the economy, environment or society, designed to communicate a situation at a point in time.

IPCC: Intergovernmental Panel on Climate Change. The leading international body for the assessment of the most recent scientific, technical and socio-economic information produced worldwide on climate change.

MEPS: Minimum Energy Performance Standard. These ensure that only efficient products that meet a minimum standard for energy efficiency are legally available for sale in New Zealand.

NIWA: National Institute of Water and Atmospheric Research (New Zealand based).

NZBC: New Zealand Building Code.

NZGBC: New Zealand Green Building Council.

Passive (solar) design: This design takes advantage of a home's site, orientation, climate and building materials to minimise purchased energy for heating, cooling and ventilation.

PHINZ: Passive House Institute of New Zealand

R-value: Physics measure of the resistance a material has to heat flow. The higher the value, the better the material is able to reduce heat flow from a warm zone to a colder zone (units = $m^2°C/W$).

Thermal competence: The ability of a building to be thermally comfortable using passive measures only.

Thermal envelope: The thermal barrier between the internally heated spaces within a home and the outside. Usually defined by the volumes bounded by external walls and windows, the insulated ceiling or roof and the floor, but typically excludes the garage.

4.2 Year Zero yardstick

A Year Zero yardstick house was used to provide an initial comparative measure of where the 2012 stand-alone housing stock sits in terms of the building performance sustainability indicators. It also aids interpretation of possibly unfamiliar metrics, for example, whole-house resource use and degree-hours. Beacon Pathway's NOW Home® research and demonstration project built in 2008 in the Auckland suburb of New Lynn was chosen as the yardstick as it:

- is well known and understood, having been heavily analysed and monitored both prior to and post occupancy (Kane, van Wyk and Pollard, 2004; French et al, 2006)
- has met a comprehensive variety of environmental, economic and social high-performance goals, thereby providing a robust example of what is practically achievable in New Zealand (Easton, 2007).

Beacon Pathway's NOW Home® "aimed to point the way for future housing design and construction by using materials and technologies readily available" by testing how an innovative design and construction concept can deliver a sustainable home. Essentially, a modest three-bedroom one-storey house, it sought to provide advanced environmental features at a similar cost as nearby similarly sized, more traditionally built homes. With its living areas north facing, it has a concrete slab-on-grade floor, double-glazed windows and insulation levels considerably greater than NZBC minimums. Compact in size, the house has a conditioned floor area of 122 m^2 and was built for approximately $240,000 (excluding landscaping and soft furnishings), which was very similar to the more traditional house cost (New Zealand Business Council for Sustainable Development, 2008).

The sustainability features of the NOW Home® include a solar hot water system, rainwater harvesting system, water and energy-efficient appliances and clever use of indoor space. It also has a thermally efficient passive solar design with the goal of achieving a pleasant temperature between 18–25°C for all but 10 days of the year. This was achieved by the first occupants in the first year of monitoring.

Figure 3. Beacon Pathway NOW Home® northern aspect, soon after completion.

4.3 Interpretation of the figures

Due to the nature of the data being examined, many variations on Figure 4 are used to communicate the results for a specific modelled or actual metric. Figure 4 uses annotations to demonstrate how to interpret the data. In this case, the environmental impacts of hot water heating within the 70 randomly selected houses are examined. The modelled hot water CO_2 emission intensities per person for the Auckland houses are shown in order of decreasing value. For consistency, in all the figures, the median (50th percentile) is shown as a continuous grey line, and the 20th and 80th percentiles (quintiles) are shown as dotted grey lines. The mean value (i.e. average) is shown as a cross, half way along the x-axis.

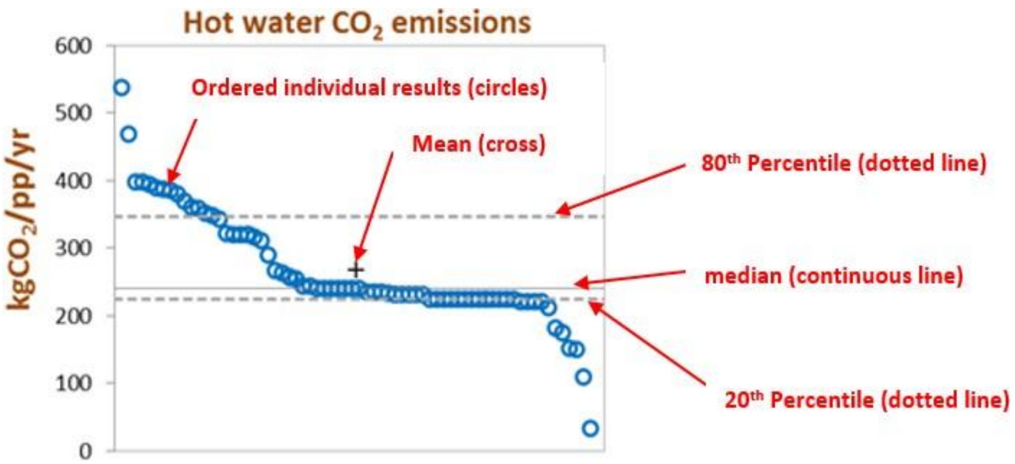


Figure 4. Annotations showing interpretation details for some 70 individual homes.

5. Results

5.1 Energy use for active space conditioning

Background

New Zealand's climate is reasonably temperate. In terms of space conditioning requirements, space heating is dominant throughout the land, using on average 29% of all energy end uses (Isaacs et al, 2010). The NZBC requires that new homes meet minimum thermal performance measures (see sections 5.6 and 5.7) by using one of three methods. In most instances, specifiers resort to using the NZS 4218:2009 Thermal insulation – Housing and small buildings schedule method, which dictates the elemental R-values (i.e. the construction R-values) required with qualifiers. The minimum insulation levels are dependent on the climate zone in which the dwelling is located. (New Zealand is divided into three climate zones.)

Providing a fair and useful metric for space conditioning-related energy use is not a simple exercise (Roberts, 2011). In this BRANZ study, three metrics are used to examine the selected houses, exploring different aspects:

- Space heating energy required per unit floor area (kWh/m^2).
- Space heating energy required per household (kWh/household).
- Space heating and cooling energy required per occupant kWh/person).

These metrics provide complementary understanding of how a region's homes perform thermally. They need careful interpretation.

- Measuring by floor area disadvantages very small homes, as their external surface area to footprint ratio (and therefore heat losses) is larger than for larger homes.
- Measuring by household disadvantages very large homes as they will naturally have larger energy requirements for their larger volumes being heated.
- The last metric's focus is on how many benefit from the utility provided, placing the occupant central to the equation.

For the detailed thermal models and simulations, 210 randomly selected, stand-alone 2012 building consents (approximately 70 each) from Auckland, Hamilton and Christchurch were used. The thermal simulations were carried out using AccuRate NZ, which relies on hourly climate files to provide an accurate assessment of heat flows. Temperature set-points for heating were 20°C for 7am–11pm for the living and bedroom zones. Active cooling starts at 25°C for all conditioned zones and continues 24 hours. This comfort regime is thought to reflect expectations of occupants in new homes better than the original Home Energy Rating Scheme comfort regime.

For this BRANZ study, the number of occupants equals the number of bedrooms plus one, reflecting the Homestar™ approach. 'Bedrooms' are classified as any sleeping area (including a bedroom, study or studio) that is larger than 6.4 m^2 in floor area. More thermal modelling specifics and defaults used can be found in Appendix C.

All conditioning energy use is assumed to be 100% efficient – thus, neither distribution effectiveness nor appliance efficiencies are accounted for. For comparison, the Beacon Pathway Waitakere NOW Home® is used. Although it was built for the warmest region in New Zealand, its overall design (and therefore insulation values) remains unchanged for the cooler climates of Hamilton and Christchurch.

Note that this metric was originally intended to provide an indicator for carbon as well – based on fuel-related CO_2 emission intensities – to complement the energy figures. However, it was not possible to determine fuel sources for a large percentage of the building consents selected as the space heater details were often left undisclosed. This issue is discussed in detail in Appendix D.

Findings

A. NZBC climate zone 1: Auckland

Figure 5 shows the annual space conditioning energy load for the 70 randomly selected Auckland-built houses. Three key submetrics – area, household and occupant – provide different perspectives on the homes' conditioning loading and thermal performance.

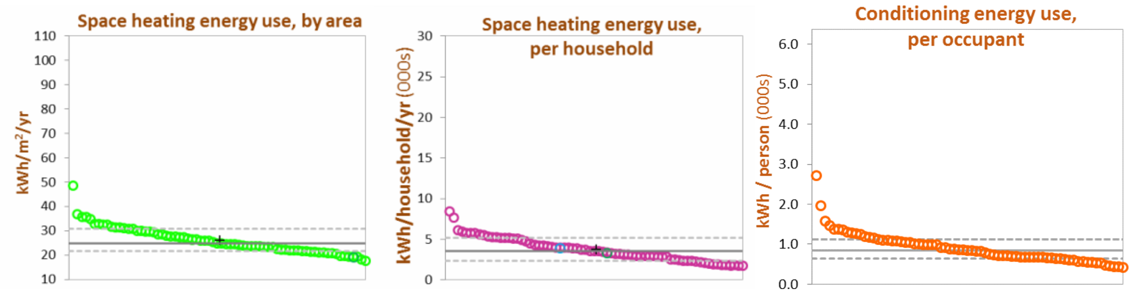


Figure 5. Space conditioning energy use – by area, by household and by occupant for Auckland homes.

Table 3 extracts some key space conditioning statistics for the randomly selected Auckland houses and uses the Waitakere NOW Home® as a basis for comparison.

Table 3. Key statistics examining household space heating energy for Auckland homes.

AUCKLAND Space energy use	NOW Home®	Mean	50th percentile	80th percentile
By area (kWh/m^2)	8	26	25	31
By household (kWh/household)	942	4,483	4,120	5,974
By occupant (kWh/person)	294	908	847	1,120

B. NZBC climate zone 2: Hamilton

Figure 6 shows the annual space conditioning energy load for the 70 randomly selected Hamilton-built houses.

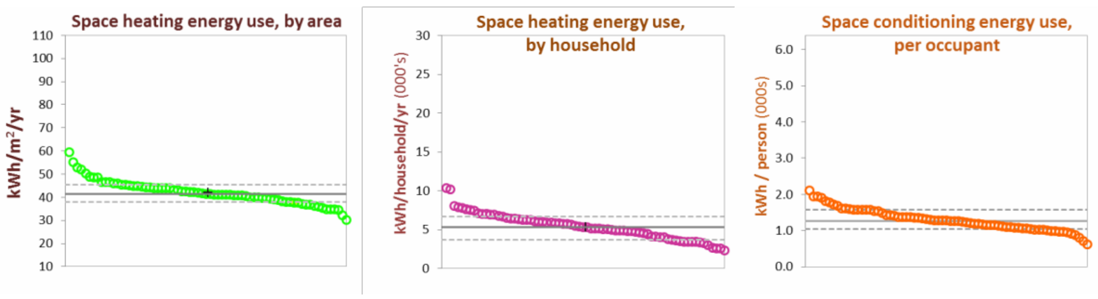


Figure 6. Space heating energy use – by area, by household and by occupant for Hamilton homes.

Table 4 extracts some key space conditioning statistics for the randomly selected Hamilton houses and uses the (relocated) NOW Home® as a basis for performance comparison.

Table 4. Key statistics examining household space heating energy for Hamilton homes.

HAMILTON Space energy use	NOW Home®	Mean	50th percentile	80th percentile
By area (kWh/m^2)	16	42	41	45
By household (kWh/household)	1,907	6,383	6,109	7,965
By occupant (kWh/person)	546	1,298	1,270	1,580

C. NZBC climate zone 3: Christchurch

Figure 7 shows the annual space conditioning energy load for the 70 randomly selected Christchurch-built houses.

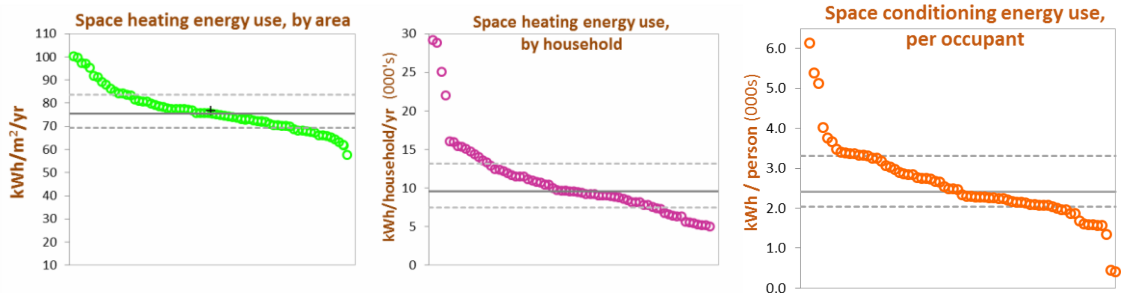


Figure 7. Space heating energy use – by area, by household and by occupant for Christchurch homes.

Table 5 extracts some key space conditioning statistics for the randomly selected Christchurch houses and uses the (relocated) NOW Home® as a basis for performance comparison.

Table 5. Key statistics examining household space heating energy for Christchurch homes.

CHRISTCHURCH Space energy use	NOW Home®	Mean	50th percentile	80th percentile
By area (kWh/m^2)	36	75	75	83
By household (kWh/household)	4,354	10,780	9,571	13,160
By occupant (kWh/person)	1,146	2,654	2,403	3,306

Notable points

- There is a considerable difference between the thermal performance of the worst and best house in terms of their active space heating requirements. The highest space heating use required per unit floor area is approximately double the lowest figure for each of the three climate zones.
- The difference between what could easily be achieved (i.e. the Beacon Pathway NOW Home®) and what is currently being achieved (i.e. the randomly selected
- homes) in terms of active thermal performance is large. This is true for all three climate zones and whichever energy use metric (by area, by household or by occupant) is chosen.

- This difference in thermal performance is most evident in the Christchurch example. Here, the NOW Home®, designed for a climate with half the heating days, has energy use metrics (by both floor area and by household) considerably less than the best-performing Christchurch-designed house.
- A practical and low-cost (approximately $2,200/household circa 2012) thermal upgrade would be to switch to thermally broken low-e glazing. Of all the randomly selected homes, only 4% of Auckland, 0% of Hamilton and 1% of Christchurch houses specified glazing with higher R-values than standard non-thermally broken aluminium-framed glazing. This upgrade reduces the average space heating requirements in Auckland by 26%, Hamilton by 14% and Christchurch by 16%.

5.2 CO_2 emissions for hot water heating

Background

Hot water heating is one of the top two energy end uses in New Zealand homes, accounting for some 29% of overall energy on average (Isaacs et al, 2010). It is recognised that a well designed plumbing system combined with renewable energy sources (such as solar or wetback assisted) can markedly reduce the CO_2 emissions of water heating systems.

The CO_2 emission estimator is based on hot water algorithms that were a component of the now-defunct voluntary EECA-developed Home Energy Rating Scheme. The hot water algorithm (called WHAT HO!) was originally co-developed with BRANZ to environmentally rate the impact of hot water provision (Burgess and Cogan, 2008). The calculation is based on stylised user behaviour to ensure consistent comparisons in terms of resulting hot water usage. The consequential CO_2 emissions of the designed systems being assessed are then compared to a reference system. Hot water demand is based on house size, occupancy, system set-up, assumptions on water use and climate (Burgess and Amitrano, 2008). The assumed behaviour and other defaults used are detailed in Appendix E.

As for section 5.1, building consent documents from 210 randomly selected stand-alone homes in Auckland, Hamilton and Christchurch were used. Unlike section 5.1, the type of hot water heater system is almost always specified in enough detail in building consent documentation to determine fuel type. Therefore, calculating the resulting carbon emissions with a reasonable level of certainty was possible.

Once again, for comparison, the Beacon Pathway Waitakere NOW Home® is used. It has a well oriented 3.7 m^2 flat-plate solar hot water panel to assist the 340 litre electric resistance hot water cylinder. This set-up results in varying annual CO_2 emission intensities only because of the differing standing losses from climatic differences between the regions.

The number of occupants equals the number of bedrooms plus one. 'Bedrooms' are classified as any sleeping area (including a bedroom, study or studio) that is larger than 6.4 m^2 in floor area.

Findings

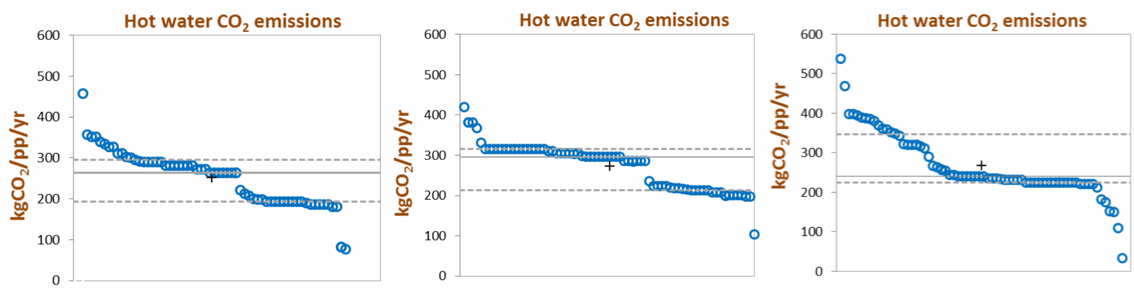


Figure 8. Hot water-related CO_2 emissions per person for Auckland, Hamilton and Christchurch homes.

Table 6. Household hot water CO_2 emission statistics for 2012-consented homes.

Hot water emissions (kg CO_2/person/yr)	NOW Home®	Mean	50th percentile	80th percentile
Auckland	73	251	264	294
Hamilton	86	274	296	316
Christchurch	101	268	240	347

Notable points

- There is a large difference between the highest and lowest CO_2/person emitting hot water systems.
- The change in average emissions intensity does not reflect the progressively colder climate of the more southern locations for the randomly selected homes.
- The Beacon Pathway's New Lynn NOW Home® provides an good example of what a well designed hot water system embodies, with emission intensities per person well below the 20th percentile for all three locations.

5.3 Potential of site for harnessing solar energy

Background

A well solarised site is a founding requirement for any high-performing, low-impacting new-build house. It has implications for the comfort and health of the dwelling's occupants (mainly via indoor temperatures, mood and daylight levels) and renewable energy generation (via solar thermal systems and solar photovoltaic panels). In addition, good solar access is required for food production – an often overlooked high-carbon issue related to dwellings (Ghosh, Vale and Vale, 2008). The focus for this section is on the harnessing of energy – either for high-performance passive solar design or for the generation of energy via renewable technologies.

An individual site's potential for harnessing solar energy can be measured by examining the extent of its received solar irradiance, which includes both the intensity and duration. As the sensitivity to solar shading is different for each of the three energy-harnessing systems shortlisted, they are examined independently to establish appropriate benchmarks. More details of each are discussed in Appendix F.

- Passive solar design is fairly tolerant of shading, with shading of 30% or more needed to result in a significant (approximately 10%) drop in the length of thermal comfort experienced by the occupants.

- Photovoltaic panels can be extremely sensitive to shading, but providing a threshold at which energy yield significantly declines is not possible as it depends greatly on the overall system set-up and the panel type affected.
- The implication of shading for solar thermal systems (as opposed to photovoltaic) is directly proportional to the reduced solar irradiation received – a 10% solar shading results in a 10% decrease in usable heat.

A low-cost tool to accurately determine a site's solar potential remotely that accounts for shading from topographic factors (such as nearby hills), adjacent structures and trees is not yet available. There are several commercially available tools (such as www.skelion.com) that can estimate the impact of solar shading, whatever the type. Because of the amount of manual entry required, the use of these tools was not justified for this study.

NIWA's online SolarView tool provided a practical solution, quickly and accurately estimating the solar energy potential for a given address but was limited to examining topographic-only shading influences. The solar potential represents the average amount of solar irradiance (both direct and indirect, accounting for clouds) over a whole year. A historic record (from http://solarview.niwa.co.nz/) of hourly irradiance (on a horizontal surface) is compared with clear sky values to infer how much of the measured irradiance is direct (from bright sunshine) and how much is diffuse (from sky or cloud). Since SolarView only accounts for topographic shading, it may overestimate the solar potential of some sites.

Findings

Table 7 shows solar potential for the building sites of the 210 randomly selected sites.

Table 7. Average solar potential for 2012-consented stand-alone homes in three locations.

Location	Solar potential
Auckland	99%
Hamilton	99%
Christchurch	100%

Notable points

- The homes in each of the randomly selected locations have excellent solar potential, indicating that there is a very good harvesting opportunity for all but a very few houses, at least when topographic features are concerned. However, nearby man-made structures and neighbouring foliage may reduce this figure either now or in the near future.

5.4 Whole-house resource efficiency rating

Background

As we live in a resource-constrained world, having a modest-sized home proportional to the number of occupants would seem a sensible response.

As stated in the Homestar™ Technical Manual (via www.homestar.org.nz for certified assessors only), "It is generally recognised that large homes consume more resources than smaller homes over their lifecycle." Extra resources typically needed for larger homes include the construction material and its ongoing maintenance, space conditioning-related energy use and the land area per houselot. Consumer demand for new, large houses in New Zealand has meant that, over the last two decades, the average size has increased by 65% while the occupancy rate has dropped from 3.1 to 2.2 persons over the same period (www.stats.govt.nz).

Providing an indicative metric for a house's overall resource use is challenging (Page and Jaques, 2006; Jaques, 2009). NZGBC's Homestar™ is one of the few international environmental assessment tools to account for whole-house resource use. Based on an approach from USA's LEED residential tool (US Green Building Council, 2008), it applies a global score multiplier to reward homes smaller than those typically sized today while penalising those larger than average. Nominated house size thresholds reflect the number of occupants likely to occupy the house, using the number of bedrooms as a proxy for average household lifetime occupancy rates.

For new homes, this BRANZ study uses the Homestar™ Resource Adjustment Factor metric – the conditioned area (the area contained within the thermal envelope) divided by the number of bedrooms. The lower the number, the more overall resource effective the home is going to be, everything being equal.

This approach was chosen as it is simple to understand and reflects an established and recognised proxy for overall household-related resource use. As for the Homestar™ Certified tool, 'bedrooms' are defined as any room such as a study or studio (that may get used by guests to sleep in) that are larger than 6.4 m^2 in floor area.

Once again, the 210 randomly selected stand-alone homes in the locations of Auckland, Hamilton and Christchurch were used as representative houses for the nation's stock. The results are shown in Figure 9, with key statistics derived from the graphs represented in Table 8. As a comparison, the Beacon Pathway NOW Home® has a resource efficiency ratio of 29 m^2 per bedroom.

Findings

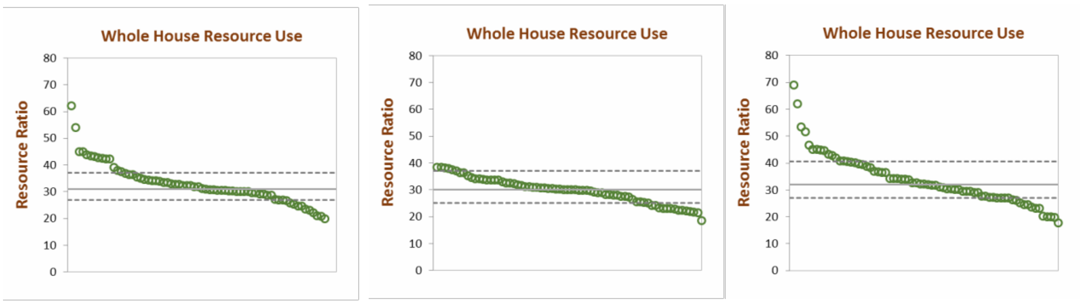


Figure 9. Whole-house resource efficiency for Auckland, Hamilton and Christchurch.

Table 8. Key statistics for whole-house resource efficiency in three locations.

Whole-house resource efficiency (m^2/bdrm)	NOW Home®	Mean	50th percentile	80th percentile
Auckland	29	33	31	37
Hamilton		30	30	34
Christchurch		34	32	41

Notable points

- The median resource efficiency ratios for the three locations are similar. However, the 80th percentile figures for Auckland and Christchurch are considerably higher than for Hamilton.
- Hamilton has the tightest whole-house resource use grouping of the three locations.

5.5 New-build uptake of household water-saving devices

Background

Access to potable water is critical for our existence, yet it is taken for granted in New Zealand. A growing demand for potable water in several areas means water resources are under increasing stress, and quality is becoming a concern (Water New Zealand, n.d.). The quantity and quality of potable water (and its associated wastewater) has implications for human health, energy use in its supply and treatment, resilience after a natural disaster event, contributions to the nutrient cycle and, increasingly, household economics. Thus, there is a pressing need to better understand and value water in New Zealand.

There is very little readily available and recent information on household water usage rates given the absence of universal metering. Even for those metered areas where daily per capita figures are available (calculated by dividing total residential consumption by the total connected population), the results have to be compared carefully because of differing data collection methods between agencies. The residential per capita consumption (the quantity of water used by households) in the Auckland region in 2012 was 157 litres per person per day (Klein, 2014). It is unknown if the usage figures are different for new-builds versus older households, as no disaggregation is carried out.

Beacon Pathway has carried out considerable work in the 2008–2013 period on various domestic water-related issues, such as general barriers, demand management, frameworks for valuing and policy for government (for example, Lawton, Birchfield and Wilson, 2008). As part of this, Beacon Pathway investigated the embodied energy of the supply and disposal of water. Using Palmerston North City as a case study, it highlighted the energy used to treat wastewater and pump supply water, which is usually overlooked (Kneppers, Birchfield and Lawton, 2009). This amounts to 0.15 kWh/m3 to supply and 0.32 kWh/m3 for removal. Thus, for a typical three-person home using (say) 600 litres per day or 219 m3 a year, 103 kWh of energy is needed.

It is recognised that collection of water in rainwater tanks – whether for internal or external use – is a key method for lowering the reticulated amount consumed (Lawton et al, 2008). With careful usage, a sizeable rainwater collection tank could supply the needs of most families for most of the year. Since building consent documentation seldom annotates other water-saving devices (such as low-flow showerheads, water-efficient taps and water-efficient toilets), it was decided to use rainwater tanks as a proxy for other efficient water management strategies in this BRANZ study as it is a logical extension of water efficiency and conservation.

Findings

Once again, the 210 randomly selected 2012 building consents from the three locations have been examined for evidential detail, with findings shown in Table 9.

Table 9. Percentage of rainwater tanks specified in new houses in three locations.

Location	Rainwater tanks specified (percentage)
Auckland	3%
Hamilton	0%
Christchurch	4%

Notable points

- Very few rainwater tanks are being installed in new stand-alone houses consented in 2012, in the regions of Auckland, Hamilton and Christchurch.
- If rainwater tanks are a reasonable proxy for well integrated water management in residential buildings, there is a great potential for improving water efficiency in new, New Zealand housing stock.

5.6 Comfortable indoor temperatures in a key occupancy zone

Background

Seeking to obtain comfortable indoor dwelling temperatures via passive solar[3]3 means is a core requirement of any high-performance house. Given New Zealand's comparatively clement weather, for the majority of the population, very little purchased/reticulated energy should be required to achieve comfortable indoor temperatures with careful design, specification, construction and operation.

However, achieving comfortable indoor temperatures passively year round is still very rare in new house designs (Jaques and McNeil, 2012). As a consequence, approximately a third of New Zealand's household energy end use (with its associated CO_2 emissions) can be attributed to purchase of assisted thermal conditioning fuels (Isaacs et al, 2010).

The current NZBC energy efficiency objective, functional requirement and resulting performance goal for housing is provided in Table 10. The overall aim is lowering the need for reticulated energy for providing thermal comfort (as well as two other major energy end users – hot water and lighting). NZBC clause H1 Energy efficiency provides only basic thermal performance requirements, informed by low national energy/fuel costs. Thus, there is considerable opportunity for specification improvement to radically improve current home designs (see, for example, the BRANZ Up-Spec4[4] suite of performance upgrades for stand-alone homes).

Table 10. NZBC clause H1 Energy efficiency.

Objective	Functional requirement	Performance
H1.1 The objective of this provision is to facilitate efficient use of energy when the energy is sourced from a network utility operator or a depletable energy resource.	H1.2 Buildings must be constructed to achieve an adequate degree of energy efficiency when that energy is used for modifying temperature…	H1.3.1 The building envelope enclosing spaces where the temperature … (is) modified must be constructed to provide adequate thermal resistance…

[3] Passive solar design takes advantage of a home's site, orientation, climate and building materials to minimise purchased energy for heating, cooling and ventilation.
[4] http://www.branz.co.nz/up-spec

Maintaining comfortable indoor temperatures passively has implications for a building's reliance on non-renewables and also climate change. With increasing climate instability, the need for buildings to be more resilient to extreme weather – especially when reticulated services providing thermal comfort may become unavailable for extended periods of time (Wilson, 2006) – has brought passive design into renewed prominence. This has been termed 'passive survivability'.[5]

The 210 randomly selected consents from Auckland, Hamilton and Christchurch were thermally modelled in free-running mode to better understand the level of occupant comfort achieved through passive solar means only. The number of daytime hours that the main living room temperature is comfortable, while the home in question operates passively, was used as a proxy for whole-house comfort. Comfortable temperature in this case equates to between 18°C and 25°C for the daytime hours of 7am to 11pm year round.

More thermal modelling and simulation protocols are provided in Appendix C. As before, the Beacon Pathway NOW Home® is used as a comparative basis.

Findings

Figure 10 shows the amount of time living room temperatures are comfortable during 7am–11pm for the randomly selected 2012 stand-alone new-builds, with Table 11 extracting some key statistics by location.

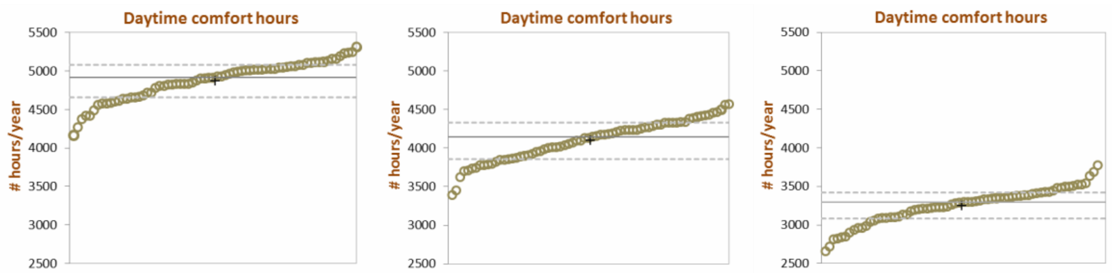


Figure 10. Comfortable living area daytime temperatures for Auckland, Hamilton and Christchurch houses.

Table 11. Key daytime living room statistics on comfortable temperatures via passive solar means only.

Location	NOW Home®		Random mean		50th percentile		80th percentile	
	hrs/yr	% of daytime	hrs/yr	% of daytime	hrs/yr	% of daytime	hrs/yr	% of daytime
Auckland	5652	97%	4877	84%	4921	84%	5079	87%
Hamilton	5299	91%	4099	70%	4142	71%	4332	74%
Christchurch	4419	76%	3248	56%	3296	56%	3422	59%

Notable points

- There is a substantial difference between the best and the worst-performing passive solar houses, even though they are nearly all specified using the default values in the H1/AS1 Schedule Method. This is true even for those 2012 selected houses that are in the top 80th percentile.

[5] www.resilientdesign.org

- There is a large difference between the thermal competence of the randomly selected stand-alone houses consented in 2012 and the NOW Home®. The NOW Home® was designed for a very temperate Auckland climate yet performs noticeably better than those houses in substantially less temperate climates for which the NZBC requires higher thermal envelope insulation values.
- The relative comfortable temperature provision reduces with decreasing latitude.
- These NOW Home® results reflect field testing of the built house in New Lynn where comfortable temperatures were almost always achieved via passive design in the years monitored.

5.7 Healthy indoor temperatures in a key occupancy zone

Background

This section follows on and complements section 5.6 but with a focus on temperature extremes achieved while the house is in 'free-running' mode. A home's passive solar performance provides a good insight into its thermal 'default mode', where thermal comfort is more dictated by its construction and placement on the section rather than its occupants. The degree to which a home's living zones experience extremes in cold or hot temperatures while operating passively is a robust indicator of its overall thermal design competence.

Various measures of temperature extremes could be used for national indicators, but simple metrics were defaulted to. For this study, the two chosen were:

- number of days where the temperature in the main living room drops below 12°C during 7am–11pm while the home is operating via passive solar means, year round
- the degree-hours too hot, where the temperature in the main living room exceeds 25°C during 7am–11pm while the home is operating via passive solar means, year round.

Overheating is becoming more of an issue in recently constructed New Zealand homes, due to a combination of design/construction features (such as larger areas) and homes being shut up during the working day (French, Camilleri and Isaacs, 2007). This trend is reflected in New Zealand's award-winning houses, where the percentage of glazing to wall area has risen 0.5% per year since 1985. When these homes have been thermally modelled, an average increase in the cooling load of 12 kWh/m^2 (or 6% per year) over the 1950–2010 period was displayed (Byrd, Ho and Nash, 2012).

The 12°C threshold is used, as temperatures below this are a health risk for vulnerable groups because cardiovascular strain risk is increased (Braubach, Jacobs and Ormandy, 2011). Direct impacts of cold homes on health include excess mortality from cardiovascular and respiratory disease among the elderly, increased respiratory problems in children, increased illnesses such as colds and influenza, mental health problems and exacerbation of conditions such as arthritis (Canterbury District Health Board, 2012; Marmot Review Team, 2011). Daytime is considered to be 7am– 11pm.

The severity of overheating is measured in this study using degree-hours, which is a common measure in building science. The 25°C threshold reflects previous BRANZ studies on building overheating as well as overseas work, such as CIBSE Guide A: Environmental Design (Chartered Institution of Building Services Engineers, 2007). This notes that, between 25°C and 28°C, increasing numbers of people may begin to feel hot or uncomfortable.

The 210 stand-alone new-builds which were randomly selected from Auckland, Hamilton and Christchurch stand-alone new dwelling 2012 consents were thermally simulated in AccuRate NZ. The living room area was used as a proxy for the thermal performance of the rest of the house. This assumes that the living room is representative, being the most used space in the house. As before, the Beacon Pathway NOW Home® is used as a comparative basis.

Note that the NZBC clause H1 requirements currently do not take cooling requirements into account for new houses, no matter the climate zone selected.

Findings

Figure 11 shows the amount of time living room temperatures are uncomfortably hot for the randomly selected 2012 stand-alone new-builds.

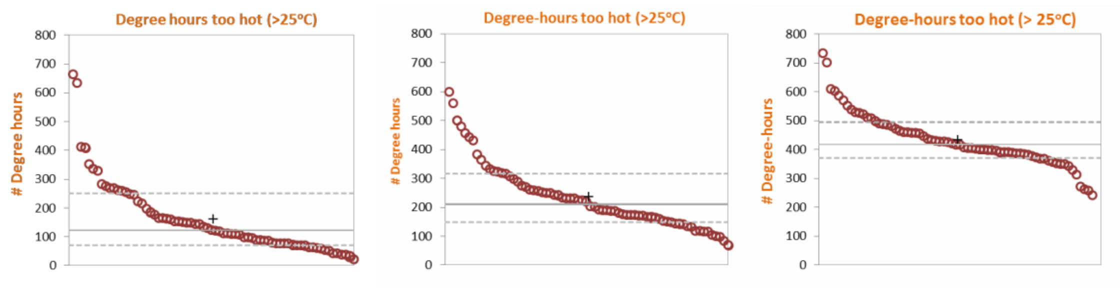


Figure 11. Overheating severity in main living room for Auckland, Hamilton and Christchurch.

Table 12 extracts some key statistics from the three locations and uses the NOW Home® as a basis for performance comparison.

Table 12. Key overheating statistics (25°C reference temperature) in three locations.

Overheating (degree-hours/yr)	NOW Home®	Mean	50th percentile	80th percentile
Auckland	32	161	122	250
Hamilton	105	236	212	316
Christchurch	151	433	417	496

Figure 12 shows the amount of time (number of days per year) living room temperatures are critically cold when not using artificial heating/cooling for the randomly selected 2012 stand-alone new-builds.

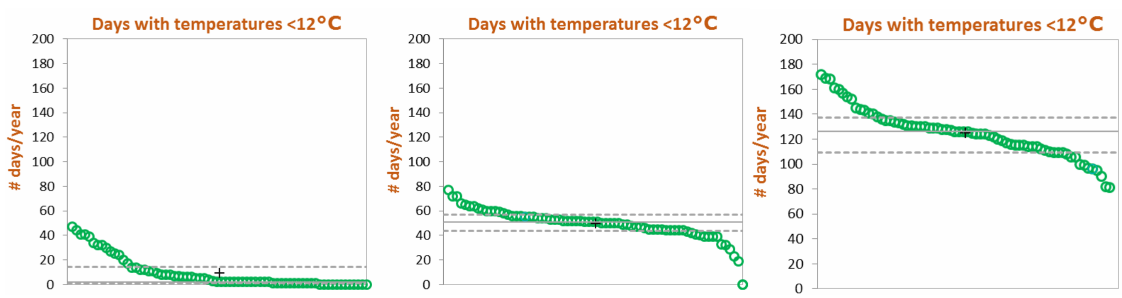


Figure 12. Critically cold living room daytime temperatures for Auckland, Hamilton and Christchurch.

Table 13 extracts some key statistics from the three locations and uses the NOW Home® as a basis for performance comparison with the randomly selected homes.

Table 13. Daytime length living room are critically cold, in three locations.

Location	# days outside temperature <12°C (days/year)	NOW Home® # days mean indoor temperature <12°C (days/year)	# days mean indoor temperature <12°C (days/year)	Random proportion of days indoor temperature <12°C (%)	Random # days indoor temperature @ 50th and 80th percentile (days/year)
Auckland	118	0	9	8	2
Hamilton	215	0	50	9	51
Christchurch	258	17	125	48	126

Notable points

- There is a large difference between the thermal competence of the randomly selected stand-alone houses and the NOW Home®. The NOW Home®'s thermal performance is considerably better for every passive design metric examined, with the exception of 50th percentile figures for Auckland, which were similar.
- Although the NOW Home® was designed for a very temperate Auckland climate, it outperforms homes designed for considerably colder climates even when all but the best (80th percentile) houses are excluded in the evaluation.
- Assuming that summertime season is approximately 90 days, the mean number of hours the living room temperature overheats is 1.8 hours/day in Auckland, 2.6 hours/day in Hamilton and 4.8 hours/day in Christchurch. This translates to a considerable discomfort period for the average house, especially for Christchurch.
- The mean number of days the randomly selected living rooms have critically cold temperatures (<12°C) increases with colder climate as would be expected – Auckland = 9, Hamilton = 50 and Christchurch = 125. The Now Home® simulations resulted in zero critically cold temperatures for the two warmer climates and 17 critically cold days for Christchurch. This reflects the effectiveness of considered passive solar design versus 'traditional' design.

5.8 Proximity to key amenities and public transportation

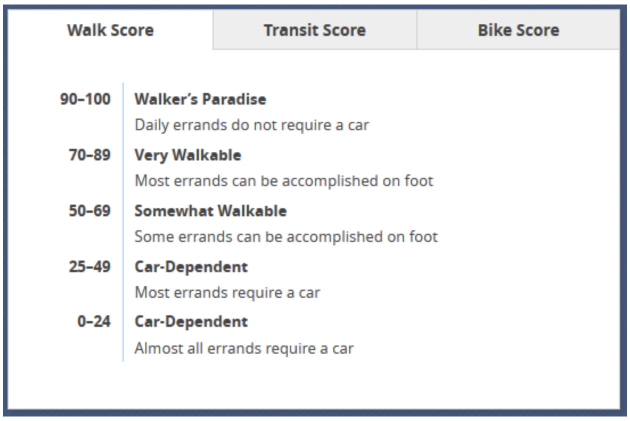
Background

Benefits to having homes close to amenities can be grouped into three themes: human health, affordability and environmental impact. The walkability of a location predicts higher levels of exercise and lower neighbourhood levels of obesity, hypertension and diabetes (Auchincloss et al, 2013). Walkable neighbourhoods will help produce more affordable housing as well as lower automobile dependency and therefore use of non-renewables (Rogers et al, 2011).

Suitable mapping tools for assessing the proximity of amenities and the usefulness of public transportation were explored, whether internet based or stand alone. Walk Score® – a USA-developed web-based tool that provides an easy to use and accurate measure of the walkability of residential locations – was selected for this BRANZ study. An extension called Transit Score® measures the usefulness of transit links for many larger cities around the world. Its validity has been extensively tested (Carr, Dunsiger and Marcus, 2011).

Walk Score®

The score is based on the distance to a variety of often used amenities – dining/drinking, groceries, shopping, errands, parks, schools and culture/entertainment. It also accounts for pedestrian friendliness by analysing population density and road metrics such as block length and intersection density. A score of 50 or more is considered 'walkable', with anything less being tagged as 'car-dependent'. Amenities within a 5-minute walk (400 m) are given maximum points. A decay function is used to give points to more distant amenities, up to a maximum distance of 2.4 km. Finer score interpretation is possible (see Figure 13).



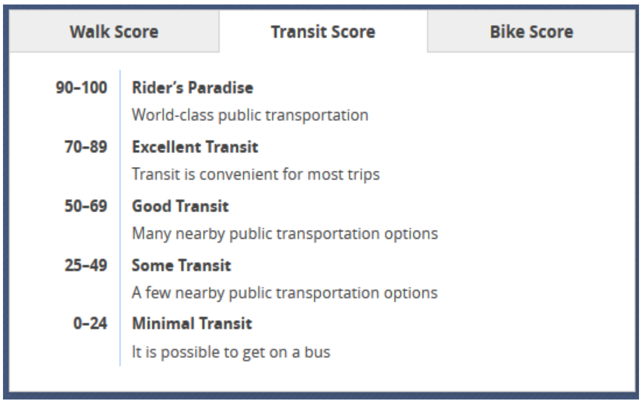
Walk Score | Transit Score | Bike Score

90–100	**Walker's Paradise** Daily errands do not require a car
70–89	**Very Walkable** Most errands can be accomplished on foot
50–69	**Somewhat Walkable** Some errands can be accomplished on foot
25–49	**Car-Dependent** Most errands require a car
0–24	**Car-Dependent** Almost all errands require a car

Figure 13. Interpreting Walk Score® ratings.[6]

Transit Score®

This measures how well a location is served by public transport and is based on data released in a standard format by public transit agencies. It is dependent on the frequency, mode (for example, rail, bus) and distance to the nearest stop on the route. A similar 0–100 rating system operates as for the Walk Score® tool, where the higher the score, the more transport options there are for a particular location. A score of 50 or more indicates many nearby public transportation options. Finer score interpretation is possible (see Figure 14). At present, only Auckland is serviced by Transit Score®, but this is likely to change in the near future (A. Jacobsen, Walk Score helpline, personal communication, 2015).



Walk Score | Transit Score | Bike Score

90–100	**Rider's Paradise** World-class public transportation
70–89	**Excellent Transit** Transit is convenient for most trips
50–69	**Good Transit** Many nearby public transportation options
25–49	**Some Transit** A few nearby public transportation options
0–24	**Minimal Transit** It is possible to get on a bus

Figure 14. Interpreting Transit Score® ratings.[7]

[6] Source: www.walkscore.com
[7] Source: www.walkscore.com

Findings

Figure 15 shows walkability to various amenities as determined by Walk Score® for the randomly selected 2012 stand-alone new-builds, with Table 14 extracting some key statistics by location.

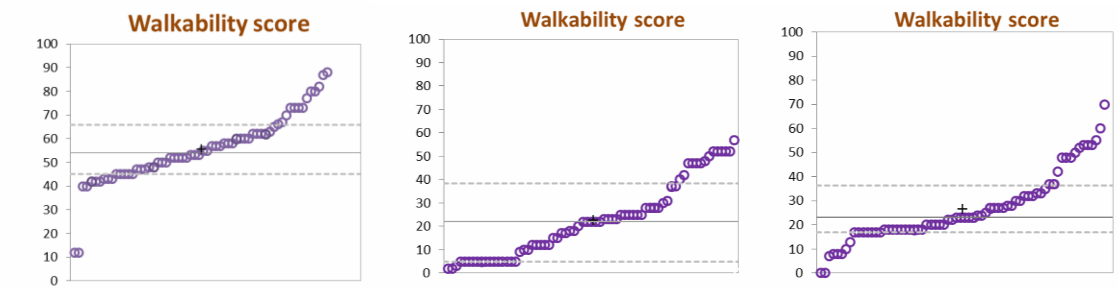


Figure 15. Walkability to key amenities for Auckland, Hamilton and Christchurch houses.

Table 14. Walkability statistics of randomly selected homes in three locations (circa 2012).

Walk Score® rating	Mean	50th percentile	80th percentile
Auckland	56	54	66
Hamilton	23	22	38
Christchurch	23	27	36

Figure 16 and Table 15 similarly show the results for Transit Score® trends. Only Auckland results are provided, as the tool doesn't yet connect with any other New Zealand transit protocols. This is likely to change in the near future as the tool develops.

The mean Auckland score results in a 'Good Transit – Many nearby public transportation options' Transit Score® rating.

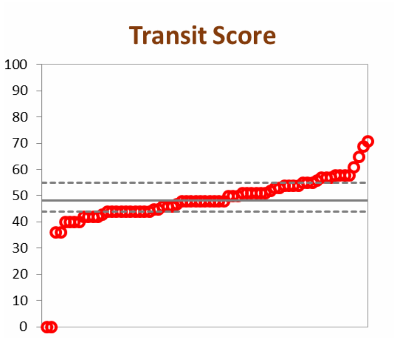


Figure 16. Public transport scores using Transit Score® (for Auckland houses only).

Table 15. Transit Score statistics for randomly selected homes in Auckland (circa 2012).

Transit Score® rating	Mean	50th percentile	80th percentile
Auckland	50	48	55
Hamilton	NA	NA	NA
Christchurch	NA	NA	NA

Notable points

- There is a large range in terms of the proximity of services available by foot in each of the three locations examined.
- Is seems that the majority (at 80th percentile) of new-builds in Hamilton and Christchurch are not very walkable, with almost all errands requiring a car according to this assessment method. In addition, some locations have no useful amenities at all within a 2.4 km boundary according to Walk Score®.
- Auckland fares much better, being rated at the 50th percentile as 'somewhat walkable', which translates to at least some errands being accomplished on foot.
- The walkability and transport situation is dynamic and likely to change with time as new developments and subdivisions in which the houses have been built mature.
- In terms of transportation needs, the randomly sampled homes in Auckland are provided with a good level of nearby public transit options, with many transportation options available. It is unknown how Hamilton and Christchurch rate in this area.

5.9 Inclusiveness of universal design features

Background

Universal design (UD) is a design approach that recognises that buildings should be accessible, safe and simply usable for as long as possible during their lifetime. It has implications on the health, connectedness and productivity of occupants (Canadian Association of Occupational Therapists, 2009). Currently, the New Zealand construction industry is delivering expensive, poorly functioning houses, where the distinction between price (what the market will pay for a house) and cost (what level of service it provides) is blurred (Saville-Smith, as cited in Jaques, 2013; Saville-Smith and Saville, 2012). The concept is hard to sell because its benefits derive principally from creating a better everyday experience for users, which is easily overlooked.

One of the overriding drivers for the UD approach is the recognition that, in 2050, there could be over 800,000 households headed by older people in New Zealand, with about 25% of the population aged 65 years or more (Saville-Smith et al, 2009). However, UD benefits everyone at all stages of life – whether a toddler gaining independence or an adult with a handful of groceries accessing a house. In 2012, there were 61,031 births, 251,770 children were aged between 0 and 3 and 158,900 people claimed a workplace injury – UD is relevant here also (Matthews, 2014).

A lack of universal design in new homes has flow-on effects for society as a whole. The individual costs to its more vulnerable members are considerable. Australian studies show that a new home has a 60% probability that someone with a permanent disability will live in it during its expected 80-year lifetime (Bringolf, as cited in Jaques, 2013). In addition, it is financially prudent and less disruptive to build these UD features into an individual new home than to retrofit the same house later. For example, the average extra cost of equipping a new house with these features is NZ$1,700, while retrofitting these new houses at a later date would cost an extra NZ$17,000 on average (Page and Curtis, 2011).

In New Zealand, UD is formalised by Lifemark, a seal of approval system endorsed by Lifetime Design Limited, a charity established by CCS Disability Action (www.ccsdisabilityaction.org.nz) with assistance from the Ministry of Social Development. Lifemark's aim is to influence the design of housing so that a greater proportion of new homes built will be suitable for a wider range of people for a longer period of time. It addresses home design in seven specific areas: accessing the dwelling, getting around, fittings and fixtures, bedrooms, dwelling facilities, bathrooms and multi-storey access. Internal and external features are examined as part of the assessment, with some issues being compulsory to achieve an award.

Formal Lifemark certification was chosen for this BRANZ study as it reflects good practice, while the organisation is independent and has a proven track record. Lifemark is one of several New Zealand-specific organisations for advocating UD – others include Barrier Free NZ (www.barrierfreenz.org.nz), Enable NZ (www.enable.co.nz), Good Homes (www.goodhomes.co.nz), NZGBC through the Home Star® certification and BRANZ. Lifemark is now incorporated into Homestar – with a significant amount of points available for adopting inclusive features, directly corresponding to the Lifemark 3, 4 and 5 Star Standards.

Findings

For the 2012 calendar year, a cumulative total of 706 new, stand-alone houses were built to Lifemark Design Standards (levels 1–3) in New Zealand.

Notable points

- There are likely to be few 2012-consented houses that provide a comprehensive UD approach to specification and design equivalent to Lifemark certification yet are not captured here. This is due to the comprehensive design approach needed, which covers many critical aspects.
- Given that some 13,900 stand-alone houses were built in 2012 alone (Curtis, 2013), the number of those featuring comprehensive UD (~700) is small, assuming most (if not all) wanted Lifemark recognition for their endeavour.

5.10 Climate change implications on indoor thermal comfort

Background

It is now recognised that climate change presents a real and fundamental global challenge that has broad and far-reaching implications for buildings. Given the expected long lifetimes of dwellings, it is important to know the implications of changing climate conditions on the environment. The climate elements scientists have the most confidence in are temperature, sea level, drought, fire risk and UV radiation (Bengtsson, Hargreaves and Page, 2007). A New Zealand summary of these elements is shown in Table 16.

Table 16. Future implications of climate change.

Climate change element	2030	2080
Annual mean temperature rise	0.4–0.8°C	1.0–2.4°C
Mean sea level rise	0.07–0.16 m	0.23–0.52 m
Frequency of days above 25°C	Increase	Doubling or more
Drought (1 in 20-year events)	More frequent (excluding Hokitika)	Up to 5–10 years (excluding Hokitika)
UV radiation (cf. 1980)	2% higher	0% (i.e. recovered)

Of all the climate change-related impacts on housing (for example, changes in UV levels, flooding, extreme weather events, periods of extreme temperatures, sea level rise), those concerning temperature change are the least complicated to computer model and therefore quantify. Thus, only the implications of these predicted trends on dwelling comfort were explored.

As for previous BRANZ climate forecasting studies (for example, Mullan et al, 2006), scenarios with the most relative variance were chosen (the Hadley and CSIRO climate models) and compared to present-day climate data. The Hadley model generated the most moderate climate changes when based on the 25th percentile of the full IPCC temperature range for the 2 years selected: 2030 and 2080. The CSIRO model produced the largest changes from present-day climate when using the 75th percentile of the full IPCC range for the same period scenarios. Although based on 2008 forecasts and data, they are still relevant today. All changes are relative to the present climate, which is defined as the 1971–2000 period.

The impact this has on the number of days the maximum outside daily temperature exceeds 25°C can be seen in Table 17. Naturally, outside temperatures impacts on the comfort experienced inside buildings, but the relationship is non-linear and complex.

Table 17. Number of days/year where the outside maximum daily temperature exceeds 25°C.

Max. temp > 25°C	Present days	Additional days in 2030	Additional days in 2080
Auckland	21.3	6.9–14.6	25.9–52.6
Hamilton	25.6	4.8–14.9	21.3–49.2
Christchurch	31.2	2.7–10.2	12.7–30.2

To determine the predicted climate change impact on indoor (dis)comfort for a representative sample of stand-alone houses, the CSIRO and Hadley climate scenarios were adapted for use in the AccuRate NZ simulation weather file used for the 210 randomly selected 2012-consented houses. The passive solar 'discomfort' performance for the main living areas was examined, based on the average of the two future scenarios for each of 2030 and 2080. Both overheating and underheating times were examined for the summer and winter months, respectively. Due to the large amount of computation required (i.e. four weather files for each house), five 'typical' houses from each of the three locations were used to provide the summary results.

Findings

Table 18 and Table 19 show the averaged overheating (achieving greater than 25°C) and underheating (achieving less than 18°C) severity of the randomly selected houses. An average of two commonly used climate change forecasting scenario models were applied. Temperature achieved in the main living room is used as a proxy for the entire house. Computer thermal simulations were carried out for houses in their passive, free-running mode.

Table 18. Average estimated overheating period in main living area due to climate change for three locations.

Location	Current	2030	2080
Auckland	1 hour 22 minutes	2 hours 12 minutes	4 hours 50 minutes
Hamilton	1 hour 59 minutes	2 hours 37 minutes	5 hours 9 minutes
Christchurch	2 hours 4 minutes	2 hours 23 minutes	3 hours 20 minutes

Table 19. Average estimated underheating period in main living area due to climate change for three locations.

Location	Current	2030	2080
Auckland (over 4 months)	7 hours 12 minutes	5 hours 20 minutes	4 hours 10 minutes
Hamilton (over 7 months)	7 hours 18 minutes	6 hours 4 minutes	5 hours 43 minutes
Christchurch (over 9 months)	8 hours 30 minutes	7 hours 21 minutes	4 hours 1 minute

Notable points

Assuming the randomly selected houses are in their passive, free-running mode:

- The predicted (outside) discomfort from overheating in Auckland for the years 2030 and 2080 averages 10.8 and 39.3 additional days or 51% and 185% longer than current respectively. The predicted (inside) discomfort length from overheating in Auckland for the years 2030 and 2080 averages 62% and 354% more than current respectively.
- The predicted outside discomfort from overheating in Hamilton for the years 2030 and 2080 averages 9.85 and 35.3 additional days or 38% and 238% longer than current respectively. The predicted inside discomfort from overheating in Hamilton for the years 2030 and 2080 averages 31% and 258% more than current respectively. Thus, Hamilton homes reflect the increased outdoor overheating due to predicted climate change temperatures.
- The predicted outside discomfort from overheating in Christchurch for the years 2030 and 2080 averages 6.45 and 21.45 additional days or 21% and 69% longer than current respectively. The predicted inside discomfort from overheating in Christchurch for the years 2030 and 2080 averages 15% and 61% more than current respectively. Thus, Christchurch homes reflect the increased outdoor overheating due to predicted climate change temperatures.
- The indoor overheating impact can be greatly mitigated with the use of well placed external shading features over glazing windows (Donn and Thomas, 2010).
- Underheating in Auckland, Hamilton and Christchurch free-running homes is going to reduce by 26%, 17% and 14% in 2030 respectively, and 42%, 22% and 53% in 2080 respectively.

5.11 Initial financial cost of five key environmental features

Background

The purchase price differential between new homes with a standard feature set and higher-specified new homes is an important deciding factor for the majority of new owners whose principal focus is likely to be only on first cost. However, there is also the consideration that higher-performing features may not fetch their true value (in terms of resale price) when being on-sold (King, 2015). Consumers looking more at longer-term implications are more likely to be concerned with life-cycle costing.

Five environmental-related features applicable to new homes were chosen by BRANZ for financial examination – double glazing, insulation, thermal mass, lighting and water collection. They were selected based on their implications for health, resilience and proven environmental benefits as well as what could reasonably be expected to be specified (and up-specified) in a new home today. The financial focus is the initial purchase costs.

Findings

For the lighting features, no available lamps provide a similar lighting experience as LEDs do, so no existing option is cited. Two levels of brightness were chosen reflecting common sizes used in homes today.

For the water collection features, as collection tanks are rarely specified in urban situations, their existing price is not applicable. Three tank sizes are provided, covering some likely sizes for both supplemental as well as stand-alone water supplies.

Details on the information sources are provided in Appendix B but are mainly comprised of retail averages over the three locations concerned and the latest edition of Rawlinsons New Zealand Construction Handbook (Rawlinsons, 2012).

Note that, as only the initial purchase costs are given (sometimes including the installation as well), the results are less useful than if examining the longer-term financial and environmental costs. These longer-terms costs may include such considerations as the consequential reduction in energy costs, improved comfort/health of occupants and improved resilience in terms of self-reliance. These latter benefits are more considerably challenging to quantify economically.

The longer-term implications of better-specified homes were considered to be outside this project's scope but are explored more fully for nine New Zealand locations in the comprehensive BRANZ Up-Spec online resource (www.branz.co.nz/up-spec).

Table 20. First-cost implications of improving the typical 2012 house specifications.

Item	Improvement	Existing	Upgrade	Units	Price increase	Cost includes
Double glazing	Standard aluminium frame upgraded to thermally broken aluminium frame	473	528	$/m²$	10%	Purchase + installation
Insulation	Wall (R2.2 upgraded to R2.8) in zone 1, 2	9.8	17.5	$/m²$	44%	Purchase + installation
	Wall (R2.6 upgraded to R2.8) in zone 3	13.5	17.5	$/m²$	23%	Purchase + installation
	Ceiling (R3.2 upgraded to R4.6) in zone 1, 2	13.4	19.4	$/m²$	31%	Purchase + installation
	Ceiling (R3.6 upgraded to R5.0) in zone 3	14.2	21.1	$/m²$		Purchase + installation
Thermal mass	Standard carpeted concrete floor upgraded to exposed, highly polished finish	43.4	45	$/m²$	3%	Purchase + installation
Lighting	LED (5 W)	NA	18.49	$/lamp	NA	Purchase only
	LED (10 W)	NA	29.97	$/lamp	NA	Purchase only
Water collection	Rainwater tank (3,000 litre)	NA	1,029	$/tank	NA	Purchase only
	Rainwater tank (5,000 litre)	NA	1,363	$/tank	NA	Purchase only
	Rainwater tank (25,000 litre)	NA	3,023	$/tank	NA	Purchase only

Notable points

- Initial cost increases of higher-specified products vary markedly and need to be weighed up against their lowered lifetime benefits – not only financially, but also in terms of comfort and health.

5.12 Demand/sales of key sustainable products and services

Background

This section seeks to better clarify what the demand was (in 2012) for some key products and services that support new, more sustainable New Zealand houses. The shortlisted products and services are not comprehensive but aim to provide a snapshot of where we are as a nation based on the existing periodic monitoring by various organisations. Mainly focusing on environmental aspects, it complements the more financially focused section 5.11.

The key services/products have been divided into:

- individual features actually specified within consent documentation for 2012-consented homes in the three representative locations
- whole-house awards that are based on independent, rigorously appraised, multi-issue schemes operating nationwide
- individual features seen as desirable by those in the market for a new home.

Thus, both potential or perceived demand as well as actual sales for key sustainable products and services are examined.

Findings

Individual features actually specified

Table 21 shows the results from the annual BRANZ new-home owners' survey for 2012 (Curtis, 2013). It mainly examines new-home owners' perception of how satisfied they were with their builder but also studies issues such as the quality of the new home, disputes and a few sustainability features. The 2012 survey was based on 647 responses from 31 territorial authorities around New Zealand.

Table 21. Percentage of respondents demanding environmental features in a new home in 2012.

Location	Wanted to build for sustainability reasons	Feature incorporated into the home design		
		Integrated PV	Solar hot water	Rainwater storage
Auckland	9.9%	3%	6.9%	13.2%
Hamilton	0%	0%	0%	0%
Christchurch	13.5%	0%	13.5%	3.8%

It should be noted that there is some uncertainty regarding the sustainable benefits of installing each of the three features into homes – integrated photovoltaic panels, solar hot water and rainwater storage. This is because:

- sustainability's three tenets – environmental, social and economic – may each fare differently depending on what and how features are assessed (for example, public good versus private benefit)
- the rapidly changing economics of (especially) grid-tied photovoltaics in terms of purchase cost and likely life-cycle pay-backs
- the varying service infrastructures and reticulated costs between locations.

For this BRANZ study, it has been assumed that, in general and on balance, the overall (sustainability-related) benefits from installing any of these three features is positive.

Whole-house awards

For the 2012 calendar year:

- 18 Homestar™ homes were awarded certification by NZGBC (only accounting voluntary assessments)
- 1 Passive House home had been formally certified by the Passive House Institute New Zealand
- 0 Living Building Challenge homes were certified by the International Future Living Institute
- 0 Net Zero Energy Building homes were certified by the International Future Living Institute.

Note that there were other sustainable house-related awards available on a nationwide basis in New Zealand in 2012. However, under scrutiny, it was felt that there were issues with an aspect of their independence, transparency, comprehensiveness and/or process control. Thus, they were not considered appropriate for this BRANZ study.

Individual features seen as desirable

Table 22 shows the 2012 results from the NZGBC and realestate.co.nz annual national survey (M. James, NZGBC, Director of Marketing and Communications, personal communication, February 2015). Respondents are mainly represented by those that have either bought a new home recently or are currently in the market to buy or thinking about buying a residential property from a nationwide pool. The features are listed in order of desirability, with good solar orientation being the most popular, garnering nearly 90% of the vote. Renewable energy was examined for the first time in the 2013 version of the survey and is included here as a future placeholder. The nationwide survey was carried out in 2012 and had a sample size of 1,725.

Table 22. Resource-efficient features seen as important when purchasing a new home.

When purchasing a new home, which of the following features were rated as 'important' or 'very important'?	Percent of respondents (national)
Orientation to maximise the sun	87%
High level of insulation	78%
A large section … for fruit and vegetables	57%
Energy-efficient features	51%
Close to amenities	48%
Built with sustainable materials	33%
Close to public transport	31%
Water-saving features, e.g. rainwater tank	26%
Renewable energy	NA

Notable points

- The individual sustainability features (i.e. photovoltaics, rainwater tanks and solar thermal systems) actually installed with 2012 new homes for the city of Hamilton is well below that of Auckland and Christchurch, by proportion of builds.
- Very few comprehensive, whole-house sustainability-related certifications were awarded in 2012, numbering less than 20 for all of New Zealand. Some 13,900 stand-alone houses were consented in that year (Curtis, 2013). Assuming formal certifications capture only 10% of all sustainable homes consented in 2012, this still only accounts for approximately 1% of all the stand-alone houses consented.
- When those surveyed were asked the extent to which an independent rating and official certificate for the home's performance would contribute to a premium price, 49% thought the contribution would be high or very high.
- In terms of individual features in new homes, indoor warmth was seen as the most desirable by those in the market for new homes. This is based on requests for maximising the utilisation of the sun and desire for high levels of insulation.

5.13 Supply of some key sustainability-related services

Background

The New Zealand supply of some building and related services/providers plays a critical role in assisting specification, building and maintenance of financially viable new homes with a lower environmental impact over their useful lives.

This BRANZ study shortlisted three nationwide, industry-service types that were easily accessible to the general public in 2012:

- Environmental-based, whole-of-home industry professionals.
- 'Green mortgage' assistance offerings.
- Trade-specific environmental building support.

Note that these represent only a portion of all sustainability-related services.

There are many other high-quality, environmental and social-related housing services/providers operating in New Zealand but most are not available nationwide to the general population.

Findings

Industry professionals

Homestar™ – New Zealand's environmental certification scheme for all housing typologies – has several engagement methods to accredit industry professionals through the NZGBC. Three were available in 2012:

- Homestar Practitioners™ – who provide Homestar™-related advice and recommendations.
- Homestar Homecoaches™ – who provide practical assessments of existing homes.
- Homestar Assessors™ – who are able to provide homeowners with full Certified Homestar™ ratings.

The numbers of 2012 professionals (source: www.nzgbc.org.nz) in each category are shown in Table 23.

Table 23. Homestar™ industry professions for the year ended 2012.

Homestar™	Number of industry professionals
Practitioners	3
Assessors	6
Homecoaches™	2

Passivhaus – via the Passive House Institute New Zealand (PHINZ) – provides a whole-of-house energy and thermal efficiency building performance standard and certification system. The Passivhaus building approach derives from Germany's Passivhaus-Institut, which was established 1996. The New Zealand initiative is about advancing education, providing promotion and conducting research but was only established recently. Some key service-related statistics (G. Murdoch, PHINZ Chairperson, personal communication, February 2015) are provided in Table 24.

Table 24. Passive House (PHINZ) uptake for the year ended 2012.

Passive House	Uptake
Professionals	12
Undergoing certification	2

The **Eco Design Advisor** (EDA) service provides free, independent advice on how to best use energy, water and materials on home improvement, building and renovation projects. EDAs are council based and numbered seven full-time equivalents (FTEs) in 2012. These were the only free, independent, nationwide (albeit only representing about 70% of the population) environmental-specific design assistance professionals operating. Note that the Certified Home Performance Advisors, an initiative of the Community Energy Network and partners that provide a complementary service to the EDAs, only began operations in 2014 (J. Wills, Community Energy Network Executive Officer, personal communication, August 2014).

Universal design – a design philosophy that recognises the differing needs of the occupants – is spearheaded in New Zealand by **Lifemark™**. It has also now integrated into the Homestar™ environmental certification tool, which is becoming mandatory for some regional authorities. Lifemark™ runs an accredited partnership programme for building professionals that provides various supporting attributes, such as training options and a plan review service. Statistics for Lifemark™ professionals are shown in Table 25 (N. Dyer, Lifemark Assesments Manager, personal communication, September 2013).

Table 25. Lifemark™ accredited partners for the year ended 2012

Lifemark™	Number of industry professionals
Builders	4
Designers	9
Design and build	34

Two of New Zealand's largest architectural/design professional organisations – the **New Zealand Institute of Architects** (NZIA) and **Architectural Designers New Zealand** (ADNZ) – did not provide any substantial, ongoing environmental-specific training as part of their continuing professional development in 2012.

Green mortgages

Kiwibank launched the Sustainable Energy Loan programme in October 2012, which makes it easier for consumers to get micro-renewables (i.e. solar power, wind energy, small-scale hydro or geothermal resources) installed in their homes. Providing key criteria are met (such as the renewables being commercially available to the general public and supplied/installed by an industry-approved person), the Kiwibank programme will contribute up to $2,000 towards the cost of the system over 4 years.

Due to commercial sensitivity as well as the very recent programme launch, no quantitative information detailing its uptake was available. However, when this benchmarking project is next updated, indicative data may be able to be provided by Kiwibank to determine the programme's progress (M. Wu, Kiwibank Executive Adviser, personal communication, September 2013). No other national bank offered a similarly focused loan in 2012.

Trade specific

The New Zealand offshoot of an Australian initiative – EcoSmart Electricians – started in 2009. EcoSmart Electricians are master electricians who have done further training in efficiency and work to ensure they make the most of opportunities to save energy. This was an initiative of the Electrical Contractors Association of New Zealand (www.ecanz.org.nz) in association with the Electricity Commission and is now defunct.

The Green Plumbing programme, which was also an Australian initiative rolled out in 2009, was supported by the New Zealand Plumbers, Gasfitters and Drainlayers Board. This programme also seemed to be either operating at a very low level in 2012 or in stasis.

Trade Me Property, currently New Zealand's leading online marketplace and classified advertising platform, launched in 2005. No statistics were collected of Homestar™ listed homes in 2012.

Notable points

- Three key professional bodies – NZGBC's Homestar™, PHINZ's Passivhaus and local authority EDAs – have a minimal number of professionals (only 32) operating, perhaps reflecting their relatively recent genesis.
- Lifemark had only 47 industry partners operating nationally in 2012.
- Only one New Zealand bank offered any specific financial support for those wanting to incorporate sustainability features in their homes in 2012.
- Trade-specific environmental building support was very limited in 2012, with very little in the form of industry education and training being carried out.

5.14 Supportive central/local government policy

Background

Policies and regulation for the 2012 calendar year that facilitated new (stand-alone) homes to be built in a more sustainable manner were examined. This could include initiatives around environmental rating tool requirements, active water management programmes, building warrants of fitness and rates reprieves with targeted reductions for energy-efficient/renewable energy measures. All these examples have been used overseas to bring about improvement in the housing stock.

Only those schemes and initiatives that are relevant to new residential construction (rather than just rebuilds or retrofits) are included here. Also, to be accounted for, the initiatives have to be operational rather than planned or proposed.

Central government, via the Ministry of Business, Innovation and Employment, requires that all building work in New Zealand must comply with the New Zealand Building Act 2004. This requires through both its purpose and principles that "buildings are designed, constructed, and able to be used in ways that promote sustainable development". The NZBC prescribes environmental-specific functional requirements and performance criteria for buildings, around the:

- use of energy and use of renewable sources of energy
- use of materials and material conservation
- use of water and water conservation
- reduction of waste during construction. Findings

By far the majority of government schemes active in 2012 to assist more sustainable homes targeted the retrofitting of existing homes. These mainly focused on retrofitting or upgrading insulation, installing more efficient water heating (using heat pump water heaters) via the Government's ENERGYWISE™ funding programme.

Rather than providing new house-specific information, EECA provided energy-related information for general homes – new, existing and those being renovated and retrofitted. The initiatives that new homes could make use of are:

- product standards and labelling (regulation of energy efficiency standards and labelling for products and appliances such as fridges, washing machines, dryers and computer equipment)
- RightLight (a campaign that encourages consumers to find energy-efficient lighting alternatives that serve their needs)
- ENERGYWISE™ information (website and other channels such as brochures, advertising and media releases to provide independent, reliable information about energy choices in and around the home).
- The Energy Spot (a television segment that brings energy efficiency messages to a mainstream audience)
- minimum energy performance standards (MEPS) (thresholds for various household appliances).

In March 2012, the Parliamentary Commissioner for the Environment surveyed all New Zealand local authorities to determine their interest in solar hot water systems. It was found that several government agencies were involved in policy and regulation (Parliamentary Commissioner for the Environment, 2012), including EECA, the Ministry of Business, Innovation and Employment, the Electricity Authority and the Commerce Commission. Subsidies for solar water heaters continued through until June 2012, and 30 local authorities had either become involved in promoting solar water heating or were considering doing so. All 78 councils replied to the survey. It was found that there were three levels of involvement: financing, subsidising building consent fees and pilot schemes and council demonstrations. Specifically, the survey found:

- 15 councils with existing subsidy for building consent fees
- 15 councils considering financing schemes
- 4 councils with pilot schemes
- 6 councils with demonstration installations.

Water management is a key area of concern for many councils. Very little summarised publicly available information could be found on how councils managed their water resources for the 2012 year that was comparable across (even some) councils.

Consequently, a short phone survey to understand the current situation was undertaken. In all, 13 local and territorial authorities were surveyed by phone as part of this BRANZ benchmarking project. Four questions were asked related to the 2012 calendar year:

Are water meters required in newly built homes?

- Was there a volumetric charge?
- Was there a water use excess charge?
- Was there any promotional campaign to better manage household water use?

The replies for the 13 councils can be found in Table 26. Councils active in water management at the house level are highlighted in green.

Table 26. Local authority initiatives supporting better water management (2012)

Council	Water meters required in new homes?	Volumetric-based charge?	Excess water use charge?	Any promotional campaign to better manage household water use?
Whangarei	Yes	Yes	No	Yes
Auckland	Yes	Yes	No	'Be Waterwise' campaign
Rotorua	No			Yes
Hamilton	No			Water alert levels 1–4
Tauranga	Yes	Yes	No	No
Gisborne	No – unless "extraordinary user"	Only "extraordinary user"		The last educational campaign of note was done back in 2010
Napier and Hastings	Only in the Bay View Water Supply Area	Yes – each property connected to the supply is charged a UAC for water (both Napier and Bay View)		Water conservation advertising campaign, newspaper ads mainly
New Plymouth	No – unless "extraordinary user"	Only "extraordinary user"		Newspaper ad in summer with water saving tips etc.
Palmerston	No			No
Wellington	No – unless "extraordinary user"	Only "extraordinary user"		Sent out flyer in summer
Christchurch	Yes	Residential customers are only charged a targeted rate based on the capital value of the property	No	No
Dunedin	No			No
Invercargill	No			TV ad to be mindful etc.

In terms of assisting the selection of environmentally preferred building materials, New Zealand has Environmental Choice New Zealand (ECNZ), which operates to internationally recognised standards and principles. ECNZ provides a free, credible and independent guide, operating to ISO 14024:1999 Environmental labels and declarations – Type I environmental labelling – Principles and procedures. A life cycle approach is used to identify and understand environmental issues (whether adverse or beneficial impacts) across the whole life of a product. Although independently operated, ECNZ was initiated and endorsed by the New Zealand Government so is included in this section.

By the end of 2012, ECNZ had several 'live' licensed building products. The specification names (with the number of companies licensed) in 2012 were: wool carpet (0), paints (4), gypsum plasterboard (1), thermal insulation (4), floor coverings (1), furniture and fittings (10), synthetic carpets (6), flat and long steel products (1), Portland cement (1), ready-mixed concrete (2), pre-mixed concrete (0) and interior lining products (in process). This list is growing every year. Internationally, several countries are further advanced in terms of providing specifiers with LCA-based, ISO-aligned building products, most notably Germany, France and the UK (D. Dowdell, BRANZ Principal Scientist and life cycle assessment expert, personal communication, August 2015).

Notable points

- In terms of encouraging new home (designs) to have better thermal performance than required by the NZBC, there were no targeted measures at a local government level.
- Energy efficiency and conservation initiatives, mainly in the areas of awareness campaigns, labelling schemes and regulation, were the government's main influence on new-builds.
- Water efficiency and conservation initiatives focused on awareness/education and were region specific.
- Of the 14 councils surveyed, only four required water meters to be installed in newly built homes in 2012, and four had no awareness/education campaigns running at all. This suggests that domestic-related water management has some scope for improvement, whether using mandatory or voluntary methods.
- Even through not targeted specifically at new homes, EECA's television infomercial 'The Energy Spot' is probably the most influential national campaign to target overall home energy efficiency in 2012 (Barton et al, 2013).
- ECNZ provides a certification service for a modest range of building products that are environmentally lower impacting than more traditional products.

6. So what does this all mean?

This section combines the findings from section 5. It discusses what the likely resulting implications are, including barriers to overcome, for New Zealand's recently consented, stand-alone housing stock. It should be read in conjunction with Beacon Pathway's Policy Options for Sustainable Homes (Howell and Birchfield, 2010).

The core indicators of space heating energy use, thermal comfort provision, healthy temperatures and climate change implications have all been amalgamated into the first subsection on thermal performance, due to their fundamental inter-relatedness.

6.1 Thermal performance

Context

The Building Act (2004) requires "the need to facilitate the efficient use of energy and energy conservation … in buildings". In addition, under the principles of the Act (section 4), (2)(b) is concerned with "the need to ensure that any harmful effect on human health resulting from the use … of a particular building design, or from building work, is prevented or minimised". Central and local government set out the policy and regulatory environment in which homes are built. Policy and regulation is a vehicle for responding to the problem of New Zealand's unsustainable homes as a means of improving the conditions in which New Zealanders live (Allen and Clarke Policy and Regulatory Specialists, 2007).

Thermal performance of new, New Zealand homes is a critically important component and indicator of overall housing stock sustainability. How well new homes perform thermally has implications for health, comfort, energy use, greenhouse gas emissions and economic viability. By modelling some 210 randomly selected, newly built homes from three key locations, this study provides benchmarks for the current levels of thermal performance in the new detached New Zealand housing stock. The expected influence of climate change for the years 2030 and 2080 has also been examined.

The Beacon Pathway NOW Home® built in New Lynn, Auckland, was the yardstick chosen to compare the randomly selected 2012 homes because its post-occupancy performance has met comprehensive environmental, social and economic design goals. This included being built for a similar price as similarly sized nearby homes using off-the-shelf materials and components.

A variety of metrics were chosen for thermal analysis so that a reasonably robust picture of the assessed homes would result. The metrics included, by location:

- space energy use by area, household and occupant, via active and passive heating
- amount of daytime the living room is a comfortable temperature, via passive solar means only
- severity of uncomfortably hot living room temperatures in the summer, when run passively
- severity of critically cold living room temperatures in the winter, when run passively
- predicted 2030 and 2080 climate (change) impacts on the living room overheating and underheating hours, when run passively.

In terms of space heating required via active and passive means, almost all the randomly selected homes fared considerably poorer thermally than the NOW Home®. This is true for whichever energy use metric (by area, by household or by occupant) is chosen. In terms of meeting daytime comfort (within the main living area) via passive solar means only, once again, there was a substantial difference between the thermal performance of the NOW Home® and the 2012 homes. In fact, the NOW Home® is more comfortable than all the selected 2012 houses in all locations – even though it was only designed for the warmest climate zone (Auckland). In terms of minimising the amount of uncomfortably warm and critically cold temperatures, once again, the NOW Home® displayed considerably better thermal performance than the 2012 houses. The NOW Home® even outperforms most of the 2012, 20th percentile homes in minimising both uncomfortably warm and critically cold temperatures in every location.

The resulting impact of climate change on indoor (dis)comfort is not a simple function of outdoor temperature rises and needs careful modelling. For this BRANZ study, the average of two New Zealand-developed climate scenarios was applied. This averaged climate file was then utilised in the house thermal simulations for a subset of the randomly selected 2012-consented houses. The passive solar discomfort performance for the main living areas was examined, based on the average of the two future scenarios for 2030 and 2080. In terms of expected overheating experienced, it was found that, for each of the three locations, the extra length is considerable, with Auckland the worst, Hamilton second and Christchurch last. By the year 2080, Auckland houses selected are expected to have almost four times the length of overheating as today, with Hamilton 2.6 times and Christchurch 1.6 times.

Conversely, underheating hours will reduce by approximately 38% in Auckland, 22% in Hamilton and 53% in Christchurch. International and national studies have shown that good passive solar design will reduce the length and severity of overheating (Donn and Thomas, 2010).

It is thought that by far the most popular means of demonstrating compliance with clause H1 Energy Efficiency is via the schedule method, which can be used where the glazing is equal to or less than 30% of the total area. The schedule method was designed to ease the compliance process for the construction industry. It is a very simplistic approach to mandating a minimum allowable level of thermal performance in new houses. This is achieved via a look-up table that specifies minimum allowable construction R-values according to construction type. Where the sum of the area of glazing on the east, south and west-facing walls (see Appendix H of NZS 4218:2009) is more than 30% of the total wall area, the calculation or modelling method shall be used. The calculation method can be used where the glazing is up to 50% of the total wall area, while the modelling method can be used for any design.

All homes examined in this BRANZ study did meet the schedule method requirements for their respective construction types. However, when the same buildings were examined using the more complex/accurate modelling method (in this case via AccuRate NZ), the correlation between schedule method levels and modelled Building Performance Index (BPI) pass rates was not 100% in any of the three climate zones. The results by location can be seen in Table 27.

Table 27. BPI statistics

Location	Mean BPI	Failure of random sample (where BPI < 1.55 when using modelling tools)
Auckland	1.01	4%
Hamilton	1.31	6%
Christchurch	1.49	31%

The BPI 'failure rate' in Christchurch is high – nearly one-third of homes. There is also a progressive increase in the 'failure rate' with increasing severity of climate. Thus, the schedule method doesn't appear to provide the level of thermal performance required in the colder climates as often as it does in warmer climates. However, compliance (under the schedule method) is still achieved.

Implications

From the findings above, the following is suggested to thermally improve New Zealand's new, detached housing stock in the near future:

- In the next iteration of the NZBC, the health and comfort implications of improving the thermal performance of new houses needs to be examined alongside simple financial cost-benefit calculations. Previous energy efficiency upgrades were perhaps too narrow in their focus with their concentration on the easy-to-quantify financial implications, providing sub-optimal results. It has been shown in this BRANZ study that ongoing (long-term) implications in terms of year-round thermal comfort, health and general liveability with the changes in climate are considerable. The NOW Home® provides a real-life example of how this can be done practically, using off-the-shelf systems and practices and minimal financial extra outlay.
- This study has demonstrated an immediate and increasing need to include requirements to address overheating in the NZBC. Overheating due to climate change in some locations (such as Auckland and Hamilton) is predicted to greatly increase in houses built to current standards. Selection of the most appropriate climate change weather files (such as applied to this BRANZ study) needs careful consideration. Instruction on well placed exterior shading devices – designed by orientation – can greatly reduce overheating severity. Care needs to be taken so that shading solutions don't have unintended consequences during the cooler months. Solutions not based on sophisticated modelling methods could still be very effective, providing practical guidelines targeting the most frequently used internal zones.
- There is a need to rectify the poor correspondence between the minimum performance outcomes of the various compliance methods for NZBC clause H1 Energy efficiency. The thermal minimums of the various means of NZBC compliance (whether very simple or complex) should be similar for the vast majority of cases. Differences between the schedule method and the modelling method outcomes for the colder (zone 3) climates are most significant and need to be addressed first. Given the large variation in climate within zone 3, adding more granularity to the number of New Zealand climate zones may be appropriate as part of the sensitivity studies.

6.2 CO_2 emissions from water heating

Context

Hot water heating is one of the top two energy end uses and energy-related greenhouse gas sources in New Zealand homes. A well designed plumbing system combined with renewable energy sources for hot water provision (such as solar thermal or wetback assisted) can markedly reduce the water heating-related reticulated energy/CO_2 emissions. This is true whatever the house size, occupancy or climate. The metric used for this study was CO_2/person/year from stylised hot water demand models based on house size, occupancy, plumbing system set-up and assumptions on water use and climate. The demand model algorithms were developed by BRANZ and were informed by the 210 randomly selected 2012 building consents.

The results showed that considerable reticulated energy/ CO_2 emission savings potential from well-designed systems that incorporate a renewable energy source. Very few 2012-consented houses incorporated renewables within their hot water systems.

Implications

There is a missed opportunity in New Zealand currently in terms of renewables for hot water generation. In part, this may be because hot water heating from renewables has had a chequered history – particularly in terms of quality control and value (Pollard and Zhao, 2008). Some of these issues have yet to be resolved (almost a decade later) and must be before consumers can have confidence in the systems provided (Jansseune, 2015). The very recent alternative of a stand-alone PV energising the resistive electrical hot water element via a simple electronic control shows considerable promise. It suffers from few of the characteristics of solar thermal systems such as system complexity, high installation cost, lack of easy performance monitoring and ongoing specialised maintenance. This technology is seen by many experts as having great potential (Holladay, 2012).

MEPS were introduced in 2002 for residential water heaters, where their energy efficiency is examined, as opposed to the CO_2 emissions that result from their use. The single focus on energy efficiency as a metric is likely to change, given New Zealand's most recent climate change intensions. New Zealand's 2015 Paris negotiations submission to the Intended Nationally Determined Contribution was set at 11% greenhouse gas reduction by 2030, leading to 50% reduction by 2050 (using 1990 as the base year). Existing mandatory domestic hot water heating requirements are also being currently examined within a research project looking at energy efficiency, internal moisture and ventilation in New Zealand's new housing stock, which is being undertaken by BRANZ/MBIE in 2015/16. The BRANZ-developed hot water WHAT HO! model will be useful for energy/ CO_2/cost-benefit studies.

6.3 Harnessing solar energy

Context

New Zealand has a very good solar resource. Many areas receive over 1,500 kWh/m^2/yr, while many European countries on average only receive around 1,000 kWh/m^2/yr. This resource can assist new houses and their occupants in many ways – from hot water generation through to the creation of zero-carbon space heating. Just as importantly, a house with good solar access has positive implications for the occupants' psychological health. Three solar energy-harnessing indicators were shortlisted for this study – passive solar design, generation of electricity using photovoltaics and solar water heating. The 210-odd randomly selected house sites in three urban locations were individually assessed for their potential for harnessing solar energy by examining their received solar irradiance. The NIWA-developed tool applied accounts for topographic shading only so may overestimate the solar potential shading from other sources. The selected locations were found to have excellent solar potential – receiving at least 99% of the irradiance available. This indicates that there is an excellent harvesting opportunity for all but a very few new houses built in these three locations. This result is to be expected in new subdivisions, which are usually based on flat, greenfield development.

Implications

Given the amount and accessibility of the free solar resource we have in New Zealand, it seems that, for new housing stock, under-utilisation is a very real issue. In terms of passive solar design, considerable and economically viable thermal performance gains can be made with considered design. Missing this opportunity has long-term ramifications for the health, comfort and finances of the occupants. Cost-effective, practical and regionally based thermal improvement solutions are provided in the BRANZ Up-Spec online guide (www.up-spec.org.nz).

A more comprehensive investigation of cost-effective thermal upgrades covering all residential building typologies will be carried out for the BRANZ/MBIE NZBC H1 background investigatory project 2015/16. In terms of PV systems, the economic viability of a grid-connected system in New Zealand is very difficult to predict due to the dynamic nature of the feed-in tariffs, panel costs and system configurations. In terms of solar hot water systems, Consumer magazine reported (in September 2013) that: "evidence … suggests that in many cases the systems' cost savings … aren't enough for solar water heating to be economically viable". However, more recently (in July 2015), Consumer commented that "Electricity prices have increased since (2013), and solar hot water heating technology has also improved … (we) will have updated information available in time for summer". Thus, the current financial viability of this system for New Zealand is unknown.

6.4 Whole-house resource efficiency

Context

It is generally recognised that large homes consume more resources than smaller homes over their life cycle. Over the last two decades, the average house size has increased by 65% while the occupancy rate has dropped from 3.1 to 2.2 persons over the same period (Curtis, 2013). Finding a viable metric to assess the resource efficiency of a household is a challenging yet important task. The Homestar™ Resource Adjustment Factor metric, which is determined by dividing the home's conditioned area by the number of bedrooms, was used for this BRANZ study. Compared to a compactly designed home (for example, Beacon Pathway's New Lynn NOW Home®), the average new detached Auckland, Hamilton and Christchurch houses are all more resource wasteful. However, the 20th percentile houses in each of the three cities achieved lower scores (i.e. higher overall resource efficiencies) than the NOW Home®. There seem to be opportunities, with considered design, to further reduce the spatial/material/energy-related waste in new-builds, especially given the current restrictions of land in some of the most population-dense urban areas in New Zealand.

Implications

This metric will become more relevant as this study becomes longitudinal. Internationally, there is a growing design moment around compact houses (www.smallhousesociety.net). It will also be interesting to compare with NZGBC Homestar® certified houses in the same location. However, it may be some time before enough Homestar® houses are certified in the three locations chosen in this BRANZ study.

6.5 Uptake of water-saving devices

Context

The quantity and quality of water has implications for human health, energy use in its supply and treatment. There is very little current, readily available data on household water usage rates in New Zealand, given the absence of universal metering and consistent water accounting between jurisdictions. Due to the lack of detail within building consent documentation, the inclusion of rainwater tanks was used as the (proxy) metric for gauging the uptake of water-efficient devices. This is because rainwater tanks – whether for internal and/or external use – are a key method for lowering the reticulated water requirements. There was very little uptake for rainwater tanks/water efficiency in new, detached homes in New Zealand in 2012 – with Auckland uptake at 3%, Hamilton at 0% and Christchurch at 4%.

Implications

Water is a key sustainability aspect of the Building Act (2004), specifically under the principles of the Act (section 4), (2)(o) is concerned with "the need to facilitate the efficient use of water and water conservation in buildings". If rainwater tanks are a reasonable proxy for efficient water management in residential buildings, there is a great potential for improving New Zealand's new-builds. For example, the installation of domestic water meters has increased public awareness of their water consumption and led to reductions in demand. The benefits of water meters to more areas could be explored. This could be facilitated by the recent development of lower-cost water measuring, monitoring and controlling devices, using unobtrusive means. The stronger promotion of the New Zealand Water Efficiency Labelling Scheme (WELS) for consumer products could also ne investigated.

6.6 Proximity to key amenities

Context

The benefits of living within close proximity to key amenities can be grouped into three themes – human health, affordability and environmental impact. New Zealand is generally seen as a car-dependent nation, not assisted by its low population density. The USA-developed Walk Score® (for measuring the walkability of residential locations) and Transit Score® (for measuring how well a location is served by public transport) are fast but accurate metrics. They were applied to this BRANZ study. The average 2012-consented detached home in New Zealand is classified as 'car dependent' in Hamilton and Christchurch, while Auckland new-builds fare better, being classified as 'somewhat walkable'. Transit Score® results are only currently available for Auckland, where the average house is classified as having 'good transit' with many nearby public transport options.

Implications

This metric is important for roading, city planning and subdivision development due to its enduring nature and implications across a wide number of themes. In New Zealand, the Land Transport Management Act 2003 requires each region to prepare a Regional Land Transport Strategy (RLTS). The New Zealand Transport Strategy has the mandate to reduce energy use through reducing the need to travel. As an example of one regional authority's response, the Canterbury RLTS sets the strategic direction for land transport within the Canterbury region over a 30-year period. One of the outcomes it seeks to achieve is 'providing more choice'. This entails investing more in initiatives that facilitate walking, cycling and public transport use, particularly in urban areas, to provide greater mode choice. The Walk Score® and Transit Score® could facilitate this process very effectively by providing easy ways for accurate comparative assessment and benchmarking between plan options.

6.7 Universal design features

Context

It is likely that very few newly built, detached residences in New Zealand feature comprehensive universal design attributes, although this is impossible to gauge from building consents, given the lack of detail provided. In New Zealand, universal design is formalised by Lifemark™, a seal of approval system. Addressing home design in seven specific (mainly internal) areas, Lifemark™ includes some issues that are compulsory due to their importance. Lifemark™ seems to be the most suitable BRANZ benchmarking metric for assessing accessible uptake due to its robust approach and verification system. Nationally, only just over 700 Lifemark™-awarded homes existed in 2012 – a tiny proportion of the recently completed housing stock.

Anecdotally, awareness of Lifemark's benefits in the building industry is growing (Jaques, 2013) but whether this will transfer into actual increased uptake with no other encouragement remains to be seen.

Implications

In terms of the NZBC, universal design is alluded to in parts, such as within clause D1 Access routes. However, Lifemark™-awarded designs need to go well beyond NZBC requirements, even to meet their lowest (3 star) standard. Given the benefits of universal design for everyone and at all life stages combined with our rapidly growing proportion of elderly, it seems a missed investment opportunity. This is especially true when considering the high adaptive retrofit cost and the associated disruption compared to building in universal design (Page and Curtis, 2011). It is suggested that investigating the cost-benefit of all new-builds to meet Lifemark's lowest (3 star) category would be informative.

6.8 Initial financial cost of five key environmental features

Context

The purchase price differential between new homes with a standard feature set and those with an enhanced sustainability-related feature set is an important deciding factor for the majority of financially conscious new-home owners. Although using initial purchase cost as a metric is very limited in terms of lifetime cost, it is a simple way of tracking key environmental add-ons that would not normally be specified in new homes. Also, first cost doesn't account for the enhanced utility/quality in terms of user experience or the potential increased resale value. Initial purchase costs were determined, nationally for the common 'up-spec' building items of double glazing, thermal insulation, polished concrete floor, LED lighting and a rainwater collection tank. Cost increases for the higher specified items ranged from 3% (for the polished slab) through to 44% (for the upgraded wall insulation for zones 1 and 2).

Implications

There are international reports of the costs of building higher-specified homes reducing over time, reflecting the upskilling of the workforce and possible economies of scale as demand increased (for example, Element Energy and Davis Langdon, 2013). This metric will become more useful over time when this study is revisited.

6.9 Demand/sales of some key sustainable products and services

Context

To better clarify what the demand was (in 2012) for some key products and services that support new, more sustainable New Zealand houses, a shortlist was provided. Both the potential or perceived demand as well as actual sales for key sustainable products and services were examined. In terms of features actually specified, the three examined were integrated PV, solar hot water and rainwater storage. Auckland, Hamilton and Christchurch were canvassed. Hamilton was the only city where no sustainability features were specified at all in 2012 homes. Even the most popular environmental feature – solar hot water heating – was installed in only a very small percentage of the respondents' homes. In terms of whole-house awards that are based on independent, rigorous schemes operative nationwide, only the Homestar™ scheme broke double figures.

In terms of resource-efficient features seen as important when purchasing a new home, of the approximately 1,700 surveyed, issues related to thermal comfort were most popular. Specifically, a home's orientation to maximise the sun and having a high level of insulation were highest rated – far higher than then next most important issues.

Implications

In terms of actual sales, there seems to be a very mixed demand (between cities) for some key environmental add-on features for residential homes. It is unknown why this is the case. The demand for comprehensive, whole-house sustainability-related certifications in 2012 was close to nil. This result seems at odds with the large number of surveyed respondents who thought an independent home rating certificate would contribute to a premium price on a house's sale. Finally, the desire for a high level of thermal comfort in new homes is demonstrated once again, which provides useful support to any future upgrades in the NZBC's H1 requirements as well as local authority planning decisions.

6.10 Supply of some key sustainability-related services

Context

The supply of select building and related services/providers plays a critical role in assisting the development of viable, more sustainable new homes. Three types of service providers were shortlisted for this study – environmental professionals, green mortgage assistance and trade support. In terms of industry professionals, only a few dozen (i.e. some 77 nationwide) existed in 2012, whether Homestar™, Passive House, Eco Design Advisor or Lifemark™ accredited. In terms of green mortgage providers for homes, only one bank offers a loan for renewable energy. Finally, in terms of trade-specific offerings, there seems to be little activity in this area at all evident in 2012.

Implications

With the advent of the Auckland Unitary Plan in late 2013 making 6-star Homestar houses mandatory where five or more homes are within one development, the demand for the services available will get a major boost.

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Appendix A: ISO indicators integration

Table 28 shows the relationship between the 14 ISO proposed indicators and those core indicators formalised for this BRANZ report. The items in the table in green are also in ISO 21929-1:2011. They may have been directly used in this study report or implemented via proxies. As can be seen, about 65% of the ISO indicators proposed correspond to those formalised in this BRANZ report.

Table 28. Indicators annotated and adapted from ISO 21929-1:2011 Table 2.

#	ISO indicator	Details on how measured
1	Emissions to air	Greenhouse gas (GHG) emissions AND the release of gases that have a potential impact on the stratospheric ozone layer
2	Use of non-renewable resources	The consumption of non-renewable raw materials that has a potential impact on the depletion of non-renewable resources AND the consumption of non- renewable primary energy that has a potential impact on the depletion of energy resources.
3	Fresh water consumption	Consumption of fresh water resources that has a potential impact on the depletion of fresh water resources.
4	Waste generation	Measures the production of the total volume of non-hazardous and hazardous wastes that has a potential impact on the generation of waste for disposal.
5	Change of land use	Measures the avoidance of consuming of greenfield lands through the reuse of brownfield and derelict areas, refurbishment, using infill sites and re- development of existing built environment.
6	Access to services – public and personal modes	Measures the quality and proximity of access to public transport around the building AND access to and range of pavements (sidewalks), pedestrian footways and cycle tracks (bicycle paths) and networks AND the quality and proximity of green and open areas AND the presence (availability), quality (number and type) and proximity of basic services required by the users of the building.
7	Accessibility of the building site	Describes the possibilities for barrier-free use of all relevant parts of the building site (or curtilage), including yards and gardens AND the ability to enter a space with ease by all users of the building.
8	Indoor conditions and air quality	Measures the quality of indoor thermal conditions AND the quality of indoor visual conditions AND the quality of indoor acoustic conditions AND quality of indoor air that have a potential impact on the comfort of users of the building.
9	Adaptability	Measures the quality of space design, construction method, and capacity, as well as building services that have a potential impact on the adaptability in terms of changed user requirements and changed use/purpose AND the ability of the building to provide shelter that has a potential impact on the users and occupants of the building AND also on the ability to maintain the value of the property, in terms of unexpected loadings… from projected climate change.
10	Costs	Measures the costs of the building, including initial costs, operation and maintenance costs and end-of-life costs that have a potential impact on the affordability and value of the building. Both lifecycle costs and short-term costs may be considered.
11	Maintainability	The quality of design, building and its structures and surfaces and the quality of maintenance plan that has a potential impact on the maintainability in terms of the comfort of the users and in the ability of the building to function.
12	Safety	The resistance to loadings considering exceptional loadings arising from earthquake, explosion and exceptional loading from weather…, when relevant AND the resistance to fire loadings and provisions for early warning and means of escape, considering different fire scenarios, when relevant AND the usability of the building while limiting the…risk of tripping, falling and other…accidents.
13	Serviceability	This is limited to space design and information and communication technological services of the building in relation to the intended use and user requirements.
14	Aesthetic quality	Measures the aesthetic quality of the building, examining the integration and harmony of the building with the surroundings; the impact on the cultural value of a site and surrounds and consideration during the planning and design phases of the requirements of various interested parties for aesthetic quality.

Appendix B: Indicator framework templates

The framework templates on the following pages, which extend the original Beacon Pathway templates detailed in (Trotman, 2008), provide a background to the logic of the resulting core indicators applied to this BRANZ study.

Definitions

Outcome: The ultimate goal sought to improve the sustainability aspects of new, New Zealand houses.

Core indicator(s): The original indicators as proposed by the Beacon Pathway templates.

ISO areas of protection: The ISO 21931-1:2010 international standard has 10 listed areas of protection including Ecosystem, Health and Well Being, Social Equity and Economic Capital. The underlined areas for each outcome are considered to be pre-eminent.

Measurement: How the information or data used to describe an indicator is collected.

Data source(s): The main references use to develop the indicator.

Reliability of sources: A simple indicative rating system (Low, Medium, High) reflects the likely accuracy of the data collection process described in the method of measurement.

Data collection difficulty: A simple indicative rating system (Low, Medium, High) reflecting how challenging the data collection process described in the method of measurement is usually. Developed by the author.

Possible alternative measurement method: What measure could possibly be used as a substitute if the selected measure was unavailable.

DOMAIN – Outcome	ENERGY AND CO_2 – Ongoing reductions in energy demand and associated greenhouse gas emission resulting from new homes
Core indicators	New-build residential energy use and associated CO_2 emissions (refer sections 5.1–5.4)
ISO areas of protection	Ecosystem, Health and Well Being, Social Equity and Economic Capital
Measurement	Energy use for active space heating (kwh/m^2; kWh/household; kWh/dweller). CO_2 emissions for hot water heating (kg CO_2/dweller/year). Potential of site for harnessing solar energy (solar percentages). Whole-house resource efficiency rating (m^2/bedroom).
Data source(s)	1–4. Randomly selected building consent information in each of the three urban areas of concern: Auckland, Hamilton and Christchurch.
Reliability of source(s)	High – building consent information provides complete and accurate data. The assumption is that this reflects the finished building well. Medium – some judgement is required when incomplete information is provided within the plans and specifications. Medium – although geographic features are captured, hardscaping (e.g. boundary walls) and foliage (particularly large trees) are not. High.
Data collection difficulty	Medium – few councils are able to provide this data easily and/or cost-effectively.
Possible alternative measurement	To gain a significantly better understanding of water use practices in new homes, a sizeable time investment would have to be made through individual home monitoring. Randomly metering/monitoring of a sizeable number of homes in several locations (both metered and non-metered) over a year would be needed to gain volumetric data as well as occupancy rates. This is beyond the scope of this BRANZ project. Alternatives such as material durability and embodied carbon were considered but rejected due to the lack of systematic analysis tools currently available for New Zealand. The embodied CO_2 of materials was seriously considered as this automatically calculated in the Australian version of the AccuRate NZ tool. However, adapting it for New Zealand is a costly exercise that was outside the project budget. A composite figure incorporating water use and energy use requirements was also considered but decided against due to transparency.
Comments	A difficult indicator to develop an appropriate metric for.

DOMAIN – Outcome	WATER – New homes that have a lower reticulated water demand
Core indicator	New-build household uptake of water-saving devices (refer section 5.5)
ISO areas of protection	Ecosystem, Natural Resources and Economic Prosperity
Measurement	The number of integrated rainwater storage tanks for the collection of roof water for use either inside the house or for gardening in each of the three urban areas of concern: Auckland, Hamilton and Christchurch.
Data source(s)	Building consents from the 2012 calendar year in each of the three key cities.

Reliability of source(s)	High – this detail would almost always be part of the consent documentation at the time of the submission to council.
Data collection difficulty	Low – collected by council as part of normal operations.
Possible alternative measurement	To gain a significantly better understanding of water use practices in new homes, a sizeable time investment would have to be made through individual home monitoring. Randomly metering/monitoring of a sizeable number homes in several locations (both metered and non-metered) over a year would be needed to gain volumetric data as well as occupancy rates. This is beyond the scope of this project.
Comments	A difficult indicator to develop an appropriate metric for.

DOMAIN – Outcome	**INDOOR ENVIRONMENT – Homes that are more comfortable and healthier as a result of well integrated passive thermal design**
Core indicator	Comfortable and healthy indoor temperatures in key occupancy zones (refer sections 5.6–5.7)
ISO areas of protection	Ecosystem, Health and Well Being, Social Equity and Economic Capital
Measurement	Number of daytime hours that temperature in main living room is comfortable while home is operating passively, over whole year. Number of days where temperature in main living room drops below 12°C while home is operating passively, over whole year.
Data source(s)	1–2. Randomly selected building consent information in each of the three urban areas of concern: Auckland, Hamilton and Christchurch.
Reliability of source(s)	1–2. High – computer simulated using high-quality thermal modelling program.
Data collection difficulty	1–2. Hard – considerable time and effort is required to model, process and analyse each house.
Possible alternative measurement	There are limited useful alternative methods of measurement that fulfil the research requirements. In terms of desktop thermal examination, any lesser thermal simulation or modelling would severely compromise the accuracy/repeatability of the results. The Health Housing Index developed by BRANZ (in partnership with ACC and various other authorities and organisations) would have potentially been useful. However, this is not now active.

DOMAIN – Outcome	**FUNCTIONAL RESILIENCE – New homes that have good links to key amenities and services**
Core indicator	Proximity of house to key amenities and public transportation (refer section 5.8)
ISO areas of protection	Ecosystem, Health and Well Being, Social Equity and Economic Capital
Measurement	Distance to often used amenities, based on what can be reached by walking. Distance to public transport – whether rail, bus, ferry or other.

Data source(s)	Walk Score® is a research-recognised, web-based tool that is based on the distance to a variety of often used amenities, based on what can be reached on foot in 30 minutes. The following amenities are considered: dining/drinking, groceries, shopping, errands, parks, schools and culture/entertainment. Transit Score® is a research-recognised, web-based tool indicating how well a location is served by public transport. It is dependent on the frequency, type of route (rail, bus, etc.) and distance to the nearest stop on the route. A similar 0–100 rating system operates as for the Walk Score® tool, where the higher the score, the more transport options there are for a particular location. The addresses used for each were randomly sampled addresses from 2012 building consent data in the three New Zealand cities and the www.walkscore.com website.
Reliability of source(s)	High – Walk Score® and Transit Score® have become an established metric used by many agencies and research bodies in its country of origin (USA) and internationally. They have also been independently validated by academic researchers.
Data collection difficulty	Low – the calculator only requires the input of the new home's address.
Possible alternative measurement	Measuring each residential building's distance to key transport services and some key amenities (such as grocery supply, restaurant and parks) individually. This approach would be considerably more time consuming, less accurate and non- validated.
Comments	A key area of concern for new housing is its often low proximity to essential services and public transportation. This has long-term repercussions – most obviously financially, which often is not factored in by the new owners.

DOMAIN – Outcome	**FUNCTIONAL RESILIENCE – New homes that are more accessible, safe and functional for all occupant ages and capabilities**
Core indicator	Inclusiveness of universal design features (refer section 5.9)
ISO areas of protection	Ecosystem, Health and Well Being, Social Equity and Economic Capital
Measurement	Number of houses built to the Lifemark design standard.
Data source(s)	Data collected periodically by Lifemark New Zealand.
Reliability of source(s)	High.
Data collection difficulty	Low – this data is collected by Lifemark as part of standard practice.
Possible alternative measurement	This would be very challenging and resource intensive to measure using alternative means, as it would require visiting individual houses and developing a new standard to assess key criteria against. Alternatively, less robust indicators could be used such as number of hits to the BRANZ Universal Design hub of well targeted resources for housing for the architecture and design community, which complements other New Zealand-based resources.

DOMAIN – Outcome	**AFFORDABILITY – Lower the initial financial barrier associated with new, higher-performing New Zealand homes.**
Core indicator	Initial financial cost of five key environmental features, in new houses (refer section 5.10)
ISO areas of protection	Ecosystem, Natural Resources and Social Equity

Measurement	Extra cost of higher-performing (i.e. thermally broken) windows compared to that usually specified (i.e. thermally unbroken, double glazed). Glass-wool, segmented wall and ceiling thermal insulant from BAU to higher-spec product. Exposing concrete flooring to gain thermal mass benefits. Potable-ready rainwater tanks. Various sized, energy-efficient luminaires.
Data source(s)	Up-speced double glazing (i.e. insulated glazed units). Source: J. Burgess. (2012). Product Profile for Windows in New Zealand Housing. BRANZ Study Report SR274. BRANZ Ltd, Porirua, page 52. Considerably higher wall and ceiling insulation products. Source: BRANZ New Dwelling Survey (2012). Thermal mass. Source: Rawlinson's Construction Handbook 2012. 27th Ed. Note that the standard carpeted flooring is assumed to have a power float monolithic finish and loop 100% nylon pile carpet with a foam backing.. High efficiency lighting. Source: averaging of retail prices from large supermarket chains, rather than lighting-specific retail outlets. Potable-ready rainwater tanks. Source: Retail average cost from several large national tank suppliers.
Reliability of source(s)	1–5. High
Data collection difficulty	1–5. Low.
Possible alternative measurement	Other options could include determining the prices of other products such as efficient space heaters, low-flow devices, photovoltaic systems and solar hot water systems. Determine life cycle cost of products.
Comments	The features examined depend on the region interested in, i.e. low-e, thermally broken double glazing is not cost effective in Auckland in 2012, while electricity is cheap. See Up- Spec. Other features could be added over time.

DOMAIN – Outcome	**CONSUMER DEMAND – Increasing consumer demand for products and services that deliver lower impacting (than conventional) homes**
Core indicator	Demand/sales of some key sustainable products and services for new houses (refer section 5.11)
ISO areas of protection	Ecosystem, Natural Resources and Social Equity
Measurement	Individual features actually specified in new building consent documentation (such as integrated photovoltaic, solar hot water and rainwater storage installations). Whole-house awards, which are based on rigorously appraised, independent certification systems that are available nation wide Individual features seen as desirable in new homes, such as good orientation for the sun, higher than Code levels of insulation and placement of house close to amenities.
Data source(s)	From randomly selected building consent documents submitted to council in 2012 and BRANZ New House Owners Satisfaction Survey conducted periodically. Personal contact with the various organisations. New Zealand Green Building Council and real estate industry annual Homestar survey.

Reliability of source(s)	1–3. High.
Data collection difficulty	1–3. Low.
Possible alternative measurement	Other options could include surveying providers of environmental products and environmental service providers to track sales. However, this would be challenging due to confidentiality reasons. The number of hits to a website dedicated to assisting New Zealanders to produce lower-impacting homes. Unfortunately, independent, publicly accessible and robust websites like www.LEVEL.org.nz and www.EcoDesignAdvisor.org.nz, which target the homeowner/designer community, deal with existing owners as well as new owners. The proportion of each of these owner groups is unknown, so the new homeowner group cannot be disaggregated.

DOMAIN – Outcome	**INDUSTRY CAPACITY – Improvements in industry capacity to supply consumers with lower-impacting services**
Core indicator	Supply of some key sustainable-related services by the industry (refer section 5.12)
ISO areas of protection	Ecosystem, Natural Resources and Social Equity
Measurement	Number of formally certified Homestar industry professionals. Number of environmental design assistance providers. Green mortgage assistance offerings. Trade and professional body environmental building support.
Data source(s)	New Zealand Green Building Council. BRANZ and Community Energy Network. Kiwibank. Various trade and professional organisations.
Reliability of source(s)	1–4. High.
Data collection difficulty	1–4. Low.

DOMAIN – Outcome	**POLICY AND REGULATION – Ongoing improvement in policy and regulation that facilitate new homes to be built in a more sustainable manner**
Core indicator	Supportive central/local government policy and supportive central/local government regulation
ISO areas of protection	Ecosystem, Natural Resources and Social Equity
Measurement	Phone survey of local and territorial authorities approaches to household water supply and management. Policy that supports Homestar or other environmental rating tools.
Data source(s)	
Reliability of source(s)	1–5. High.
Data collection difficulty	1–5. Low.

Appendix C: Thermal simulation methodology

It was decided to use a New Zealand-specific thermal simulation tool called AccuRate NZ. This largely Australian-developed tool was specifically developed for the Australian and New Zealand residential building market. It is highly flexible in dealing with a variety of construction configurations and was approved by EECA and used for the (now defunct) Home Energy Rating Scheme. It has also been verified independently as being suitable for this type of application (Ren et al, 2011).

Of all the indicators used in this study, those dependent on thermal simulation are by far the most complex and resource consuming. This is because they are reliant on translating large amounts of building consent information into a format readable by thermal modelling programs. This process takes between 2 and 5 hours per house, depending on its complexity and has to be carried out by BRANZ.

Some of the principles and defaults are outlined in Table 29.

Table 29. Key modelling approaches for thermally modelling New Zealand houses.

Element		Approach
Conditioning	Heating and cooling	Heating set at 20°C from 7:00am to 11:00pm and 0°C overnight. Rationale: there is anecdotal evidence that overnight heating is uncommon, and 20°C is argued to be roughly what is expected for comfort in new homes today. Cooling set to 25°C from 7:00am to 11:00pm. Corridors, bathrooms and garages are assumed to be unoccupied/transitory spaces and are not conditioned.
	Ventilation	Windows are assumed to be opened at 23°C in order to attempt to prevent overheating. Ventilation provided through a 'realistic' number of windows (i.e. it is unlikely that people will open all the windows in their house). As a rule of thumb, no more than 2–3 windows in a room (depending on size). Internal doors should be modelled as controllable openings to allow air flow between rooms.
Walls	Solar absorptivity	If no particular information on wall colour is provided then assume: Medium (50%) for everything.
Windows	Dimensions	Use total window area including frame. Note that AccuRate assumes 16% framing.
	Curtains	Note that curtains cannot be modelled by AccuRate.
Infiltration	Site exposure	Check location in Google Earth if possible, else assume 'medium exposed'.
	Building complexity	Huge amount of uncertainty in any infiltration estimates. Does have significant effects on performance. Given the vagueness, it is decided to normalise all houses as 'simple'.

Construction	Various	Equivalent R-values of concrete floor slabs are estimated using research by Ian Cox-Smith to deal with AccuRate NZ's inability to handle edge loss complexities. Retaining walls are modelled as floors in order to touch the ground node. Timber-framed exterior walls are assumed to have 28% framing. If not specified, assume carpet has a rubber underlay. If floor linings are not specified, go with what is likely to be there. For example, particleboard is almost always going to be covered. Similarly, a concrete slab is probably going to be carpeted. Likewise, In bathrooms, the floor is going to be tiled or vinyl. Use 900 mm deep bottom chord of the trusses, unless otherwise stated. Double-glazed louvre systems are the equivalent to single glazing in terms of performance.

Appendix D: Determining useful space heating metrics

Thermal performance of housing is a core indicator of residential sustainability. Thermal performance can be gauged either via a home's active (i.e. reliance on reticulated services) or passive (i.e. reliance on the home's ability to make use of solar energy) means. Given that space heating accounts for the highest energy end use and fuel-related emissions, the possibility of providing a carbon indicator for this was explored – specifically whether there is enough information provided within consented plans/specifications to determine what type of space heater is used for which area, with a reasonable degree of certainty. If this is not possible, can reasonable assumptions be made?

There is reasonable data on the nominal performance efficiencies of the various space heater types in New Zealand, via assessment tools such as the (now defunct) EECA HERS tool and Homestar™. This includes both running and distribution-related efficiencies. However, there is no way of realistically determining what the space heating practices are for spaces where the building specification fails to include any detail, without post-construction inspection. For example, non-assigned spaces could use either (say) an unflued gas heater or a small 2.4 kW fan heater, resulting in very different sustainability characteristics. Also, for some space heater types – such as heat pumps – their performance efficiencies and resulting CO_2 emissions depend on their age, technology employed, size and system set-up so may vary considerably.

Findings

As a result, the first 68 randomly selected 2012 house plans were examined to see what the distribution of space heaters (by type) was. Table 30 presents the findings.

Table 30. Popularity of space heater types, from randomly selected 2012 consents

Space heater type	%
Gas fire	18%
Wood burner	6%
Heat pump	34%
Unknown	32%
Gas fire + heat pump	9%
Gas fire + under-tile heating	1%

As can be seen, in about a third of all the selected plans, determining the main space heating type (and thus the fuel source, associated carbon emissions and running costs) is impossible – let alone the fuel. When space heater information is specified on the consent documents, it is rarely detailed enough in terms of its size, efficiency and the zones conditioned by it to reveal an accurate picture. In the unlikely event all this information is contained, information lacks in terms of how the remaining (non-assigned) spaces are heated.

However, in almost all instances, houses with lower space heating requirements will always be environmentally lower impacting, healthier to live in and financially easier on the pocket for the lifetime of the home's occupation. Thus, both active and passive performance metrics are used in this BRANZ study, being seen as appropriate as a sustainability indicators. The associated carbon emissions and running costs can be extrapolated when necessary.

Decision

It is proposed to focus metrics on the thermal efficiency and comfort provision of the whole home, examining both passive and active performance. These metrics will provide useful measures of both the dwelling's thermal performance as well as the human comfort response, which can be objectively used as a good comparative basis.

Appendix E: Hot water heating modelling

The model algorithms used for this BRANZ study reflect those applied to the current (2014) Homestar™ certified tool. These are in turn based on EECA's HERS hot water algorithms developed by BRANZ in conjunction with CSIRO. Incidental changes to the HERS tool have been made to the emission rates and systems defaults to ensure better consistency with the Homestar™ certified tool.

The following assumptions are used in this BRANZ study:

- All homes will have a single hot water heating system.
- Household occupancy rate equals the number of bedrooms plus one.
- Each person takes one 10-minute 40°C shower per day.
- The cold water inlet temperature is at the ground temperature of the region.
- Storage cylinders are calculated as having heat losses that are proportional to the temperature difference between water stored at 60°C and the surrounding air temperature. This is dependent on the insulation around the cylinder and related to the size of the cylinder.
- The internal spaces within the building envelope where hot water cylinders are stored are fixed at 20°C. The outside temperatures vary as given by the external temperatures available in the AccuRate NZ climate data files.
- It is assumed that water storage temperature is 60°C, which provides a tempered temperature of 40°C for bathing.

The hot water calculation is based on the CO_2 emissions of the system being assessed compared to a reference system.

The CO_2 emissions (in kg CO_2/kWh) are the same as those used by Homestar™:

- Electricity = 0.18
- LPG = 0.22
- Fuel wood (i.e. wetback) = 0.01
- Natural gas = 0.19
- Oil = 0.25

These CO_2 emission factors were taken directly from the New Zealand Business Council for Sustainable Development Emission Calculator Tool in 2010.

Appendix F: Solar shading sensitivity

Three energy-harnessing systems were shortlisted for this BRANZ study. Each has unique characteristics, so were examined independently to establish appropriate benchmarks

Passive design

For passive solar design, a mini-study was conducted[8]8 to determine the influence of shading, in terms of the degree-hours too cold. A representative house was modelled in a very shaded site in Ngaio, Wellington. NIWA's Solar View tool (for kW-hr/m^2 determination) was used to adjust the solar gains within the Wellington weather file in AccuRate NZ. Five adjusted solar gains were trialled systematically: 80%, 60%, 40%, 20% and 0%. The implications of adjusting solar gain/shading were as follows:

- The house's passive performance is affected to a greater degree than its active performance. This is to be expected, as while the passive performance is heavily dependent on solar gains to warm up, heating energy use is more influenced by the thermal resistance of the building fabric and its ability to keep the heat energy inside.
- At 20% solar gain shading, the active effect on the space heating requirements is low (~5%). Thus, it may not be worth modelling the shading effects given the other shading uncertainties such as that provided by foliage and adjacent buildings.
- However, by 30% shading, the effects are reasonably substantial for the percentage increase in passive solar performance (being close to or more than 10%). Thus, they should be modelled in these cases.

All the randomly selected houses were examined to see how many broke through this 30% shading threshold. It was found that the threshold is not achieved or exceeded by any of the randomly houses in any of the cities.

Photovoltaic shading

The energy generation reduction as a result of solar shading is complex, with many dependent variables, including the type of solar cell, wiring between panels and inverter set-up. However, it is recognised that there is a disproportional effect of the influence of shading. For example, when cells are connected in a string, even partial shading of one cell may reduce the panel power by half. Built-in features such as bypass diodes used within modules, micro-inverters and power optimisers can assist to confine the impact to the individual shaded module. However, the reduction in energy generation potential is still typically many times higher than the percentage of shaded area. Figure 17 shows some examples of when partial cell shading reduces solar panel power by half.

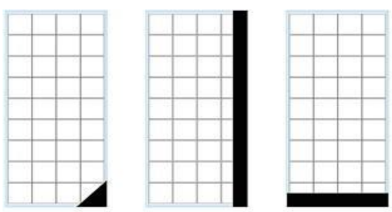

Figure 17. Plan views of solar PV panels and various partial shading examples.

[8] Carried out by James Sullivan, PhD candidate, Victoria University, Wellington in 2013.

However, probably the worst PV set-ups (in terms of wiring and performance) have been improved now so the new systems are likely to be more tolerant of shading. No quantitative figures could be sourced for this aspect.

Solar thermal panels

Solar thermal panels used in hot water heating tolerate shading considerably better than PV panels. The energy loss due to shading is proportional to the amount shaded. Thus, a 10 % shading will result in a 10% loss in its ability to generate hot water.