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SF1.2

SUSTAINABILITY FRAMEWORK BENCHMARKING REPORT - NOWHOME VERSUS REFERENCE HOMES

A REPORT PREPARED FOR BEACON PATHWAY LIMITED

WRITTEN BY

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Creating homes and neighbourhoods
that work well into the future
and don't cost the Earth

SUSTAINABILITY FRAMEWORK BENCHMARKING REPORT -

NOWHOME VERSUS REFHOMES

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REFERENCE

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EXECUTIVE SUMMARY

The report describes and compares the sustainable (i.e. environmental, economic and social) features of two specific house types within the BEACON Pathway's research project. The two house types are the collaborative NOW House and representative houses of what is now being typically built in the Auckland region – termed the REF Houses. The key objective was to provide a practical and effective decision-making 'Sustainability Framework' (rather than a rating scheme) to assess key sustainability-related issues that could have applications in rating systems, design guidance and certification schemes.

An iterative process was required in the derivation of the Sustainability Framework, based around two questions: (i) what key sustainability-related features can be determined from just building consent documentation alone?; and (ii) is this amount of information enough to derive a representative picture of the selected building's overall sustainability performance?

A Draft Sustainability Framework was drawn up incorporating 14 thematic sustainability areas. The framework integrated a number of previously developed tools, including BEACON Pathway's *Targets and Benchmarks* and *Filtering Framework Tool* and BRANZ's *ALF3* and the *Green Home Scheme*. Where issues had no comparative or indicative quantitative-based metrics associated with them, representative quantitative-based methods were devised. The Framework was trialled on 19 randomly selected houses (REF Houses) from the Auckland region which were comparable in capital cost, location, year constructed and construction type to the NOW House. It was quickly determined that an adequate sustainability impression of only seven of the 14 thematic areas could be established from the REF Houses consent information alone. As a result, it was decided to conduct follow-up (i.e. post-occupancy) interviews for the previously selected houses.

Only five of the 19 selected REF House occupiers agreed to be part of the follow up interviews. From the follow-up information collected, only one (of the 14) thematic area remained for which an adequate sustainability impression could not be established. The NOW House was then compared to the five REF Houses, to determine what (if any) sustainability-related performance differences there were. It was found that the sustainable areas in which the NOW House really shines are Energy Use, Thermal Performance, CO_2 Emissions and Water Use. Also, Fire Safety and Land Use and Ecology are areas for which the NOW House shows some improvement over the REF Houses, but to a lesser degree. **These findings need to be viewed with some caution, given the very small sample size and the constraints placed on the sample population.**

Finally, a rigorous methodology for combining and ranking social, economic and environmental issues associated with sustainable construction was overviewed. The development of a similar system for the general assessment and rating of the NOW House was proposed as a replacement for BEACON Pathway's original Optimisation Tool project. The development of such a tool would require further research, but would have application in many of BEACON Pathway's research programmes requiring the weighting of sustainability issues.

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1. THE PROJECT

1.1 Background

BEACON Pathway Ltd (BEACON) is a 'research consortium' funded by shareholders and the Foundation for Research Science and Technology (FRST) to carry out research into the uptake of greater levels of sustainability in the residential built environment (RBE). Much of the housing stock in New Zealand is considered to be below par for even basic sustainability issues, such as energy and water efficiency, and in many cases is below World Health Organisation guidelines for human health requirements. Even houses perceived as higher quality may fall short of future requirements proposed by upcoming national goals for sustainability (e.g. the Building Bill and the Sustainable Development Programme of Action).

BEACON's goal is to establish a 'sustainability standard' for New Zealand houses, and inform a programme of interventions that will bring about uptake of greater levels of sustainability features such that 90%+ of houses meet the 'standard' by 2012. In addition, BEACON intends to inform the development framework for neighbourhoods, so that as they are developed and/or redeveloped the principles of sustainability are taken into account.

BEACON has defined a programme of research to be carried out over 2004-2009 to determine the means by which these goals will be achieved. The programme contains nine 'objective areas', each with a varying number of milestones to be met over the five-year research period. The objective areas are categorised as follows:

Consumers	**Neighbourhoods**	**National Scorecard**
New Build Technologies	**Integration**	**Sustainability Framework**
NOW Home	**Industry**	**Retrofit**

The first stage (July-September 2004) involved 11 'programme confirmation phase' projects to ensure the overall programme is well-informed and that the structure of the programme is optimal. The projects are:

- SF1.1: Sustainability Framework Design
- INT1: Prioritisation/Optimisation Tool
- CON1: Consumer Research Impacts and Alternatives
- IND1: Industry Research Impacts and Alternatives
- NEW1: New Technology Impacts
- NOW7: Demonstration Home Hypothesis
- RF1: Housing Stock Analysis
- NBH1: Neighbourhood Research Baseline
- NS1: Macroeconomic Models – Availability and Relevance
- SF1.2: NOW Home versus REF Home
- NOW1: NOW Home Knowledge and Future Monitoring Recommendations.

For more information about the overall programme and the programme confirmation phase projects, refer to the 'Research Programme' (commercial in confidence) and 'Research Project Specification' (dated 18 May 2004) documentation. This is available from BEACON Pathway Ltd (via Nick Collins, General Manager: nickc@beaconpathway.co.nz).

This report documents the development, execution and findings of SF1.2: NOW Home versus the REF Homes.

1.2 SF1.2 NOW Home versus the REF Homes

Introduction

The purpose of this report is to describe and compare the sustainability features of two specific house types defined within the BEACON project. The first house type is the collaborative NOW House, where the goal is to stimulate the building industry into thinking about more sustainable building solutions using existing materials and technologies. The second type is that represented by those houses being typically built – here named the REF(erence) Houses – constructed in a similar environment to the NOW House.

The aim of this project was to provide a practical and effective decision-making framework to assess key sustainability issues and so allow comparisons to be made between these two house typologies – the NOW House and the REF[1] Houses. The resulting framework is intended to facilitate the development of a broad range of relevant, easy to use and practical tools that add value to the stakeholder decision-making process. These tools will have applications in future rating systems, design guidance tools and certification schemes.

The sustainability-based decision-making framework was to be based largely on the work already carried out as part of the BEACON consortium, leading up to the NOW House development. Those specific tools were the (mainly quantitatively-based) *Targets and Benchmarks* and the (mainly qualitatively-based) *Filtering Framework Tool.* These two partially developed tools contained associated guidelines, codes and general reference documents within.

The project-specific deliveries for SF1.2 from the scoping document are:

- a methodology for selecting a random sample of recently consented REF Homes in New Zealand for benchmarking
- a benchmarking report describing and comparing the sustainability features of both the NOW House and the REF Houses
- an assessment of the rating of the REF Houses on the basis that the NOW House has the equivalent of 100 points.

The project was originally divided in two stages, with Stage One restricted to analysing consent-related documents and Stage Two completing the assessment with a post-occupancy survey. Specifically:

- Stage One involved the application of a simplified version of the developed NOW Home Sustainability Framework, focusing on sustainability issues that can be ascertained from building consent drawings. Provided enough sustainability-related features could be determined from just consent documentation, a developed framework was to be derived from that information only. If not, then Stage Two would be necessary.
- Stage Two involved the post-occupancy evaluation of recently completed REF Houses (together with their respective consent documentation) to fill any sustainability-related information gaps remaining from Stage One.

The report is divided into Part One (i.e. Sections 2-4) and Part Two (i.e. Sections 5-6), reflecting the staged nature of the project.

It should be noted that because this project was being developed in parallel to the SF1.1 Sustainability Framework (and many other BEACON projects), there may not be a perfect fit between what is developed and decided upon here and the recommendations within SF1.1's project.

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[1] Note that the REF(erence) Houses were originally referred to as ROM (for Run Of the Mill) Houses in the contract documents.

What this project is not

The resulting Sustainability Framework and rating tool were never meant to be a fully operational and realised domestic building assessment tool. This is beyond the realms of this project and is a much larger undertaking.

As stated in an early draft of the SF1.1 report:

> *It is important to note that a sustainability framework is <u>not</u> the same as a rating scheme. A rating scheme might utilise the framework as a basis for deciding what to rate. Instead, it is a guidance document that establishes and organises key <u>process</u> and <u>content</u> elements to provide users with a simple way to assess sustainability improvements. In order to do so, the framework identifies a baseline/reference point and an 'ultimate'/endpoint, and provides the means of determining where any given property 'sits' along the continuum between these two points. In other words, the framework aims to identify and describe the factors that should be taken into account when forming a view as to the sustainability of a house.*

The focus for SF1.2 is more on the technical issues detailing the content elements; specifically, aspects of *what* issues should be examined, *how* and *when*. As stated in the above quote from SF1.1, this does not mean that a baseline or reference point cannot be established using the Sustainability Framework. However, the resulting framework should be flexible enough that its application has a much wider scope.

2. STAGE ONE: CONSENT DOCUMENTATION ANALYSIS

2.1 Initial methodological approach

Determining an appropriate methodology for the rating of environmental, economic and social features (i.e. sustainability features) of the REF and NOW Houses was an iterative procedure. Essentially, the methodology evolved around two basic questions:

Q1. What key sustainability-related information can be gathered from just building consent documentation alone?

Q2. Is this amount of information enough to derive an accurate (or at least representative) picture of the buildings' overall 'sustainability' performance?

The approach can be described as a series of steps:

STEPS

1. Starting with the two tools developed as a result of the NOW Home research project (i.e. the *Targets and Benchmarks* and *Filtering Framework Tool*), along with their associated tools/references, determine:
    a. **what** the 'key' issues are. Key issues were considered to be those that are:
        i. able to be applied to both the NOW House and the REF Houses
        ii. significant as well as being relatively easily measured (i.e. can be practically measured over a short time period).
        iii. concerned more with assessing the building, rather than the behaviour of the homeowners
    b. **when** these key issues can be assessed, for example, at pre-construction, post-construction or post-occupation, and thus their likelihood for inclusion in the resulting framework.

2. Select those issues which meet the above criteria for 1.a., and perform a systems check to ensure the resulting framework is both broad and comprehensive, and therefore its application results in a representative sustainability rating. If possible, select as many issues which are quantitative (rather than qualitative), and are able to be determined from consent documentation only without significantly compromising the accuracy of the rating tool.

3. Ensure that the selected issues are nationally applicable, repeatable and practical to measure.

Once the sustainability-related questions have been agreed upon by SF1.2 TEAM members, then:

4. Determine a simple and practical method for randomly selecting building consents, using expert opinion.

5. Apply the framework to the randomly selected building consents from the Auckland region to match the contextual setting of the NOW House.

6. Perform a gap analysis to determine what sub-issues could not be ascertained through building consent data alone. Thus, determine the necessity (or not) of advancing to Stage Two: Post-occupancy evaluation.

Even though it was intended to use this stepped approach, the project did not develop as such. The main stumbling block for the SF1.2 TEAM was the lack of consensus on just what can be assessed from a 'typical' building consent. This occurred even though a pre-bid study had determined the likelihood of a particular (sustainability-related) issue occurring (refer Table 14), even if only for the Hamilton City case.

Disagreements as to the level of consent detail resulted, even between SF1.2 TEAM members who had considerable experience in submitting/examining building consent documentation. Consequently, a more tentative approach by the SF1.2 TEAM members in the selection and assessment of sustainability issues was taken – resulting in a Draft Sustainability Framework as a discussion piece.

2.2 The Draft Sustainability Framework

A Draft Sustainability Framework was developed, having two main objectives. These were to determine:

- What environmental, social and economic issues are key for a comparison between the NOW and REF Houses?
- When these issues can/should be addressed (e.g. either at the pre-construction, post-construction or post-occupation stages)?

The Draft Sustainability Framework was developed to be a fairly comprehensive listing of domestic-related sustainable construction (see Appendix B). The elements (i.e. categories) were derived from the NOW House Sustainable Footprint. Only six of the nine footprint elements are listed in the Draft Sustainability Framework: 1. Affordability, 2. Desirability, 3. Performance, 4. Personal Health, 5. Community Health and 6. Resource Use. However, almost all of the sub-categories within those nine footprint elements are dealt with in the draft version's six elements. This re-categorising was necessary due to a need for a more descriptive/representative grouping of assessable issues.

Upon appraisal of the Draft Sustainability Framework, it was soon realised that if only the short-listed sub-issues (defined as 'should be measured') were considered, a poor representation of what a building's actual sustainability-related performance was would result. This could lead to a superficial or inconclusive differentiation between examined houses. In part, this was a consequence of the criteria selection process making it too easy to discard a sub-issue if it was considered at all problematic to assess. These concerns resulted in a reappraisal of sub-issues which were previously put in the 'too hard' basket, most notably:

- thermal mass determination
- CO_2 emissions from energy end-uses
- (spatial) resource usage indicator
- environmental impact of the construction process.

Possible solutions to the assessment of these four sub-issues will be dealt with in Section 2.2.1.

There was also some concern that economic aspects did not feature highly, being one of core aspects of sustainability. In response to this, each sub-category's *secondary* as well as *primary* facet was explored. This resulted in Table 16 (Appendix C), which indicated that many of the sub-category issues proposed had economic considerations, even if only as a secondary theme. Also, another economic-related sub-category was put forth and agreed upon – life-cycle costing of the major cladding elements – for roof and wall construction. Its mechanics are described in Appendix E: Life-cycle costing of exterior cladding.

2.2.1 Possible solutions to tricky sub-issues

Some sub-issues had no comparative or indicative quantitative metrics associated that were user-friendly yet representative. Therefore, new metrics had to be devised to assess them. Possible solutions to four of the sub-issues – thermal mass, CO_2 emissions, spatial usage and site impact – are given here. The fifth sub-issue – material life-cycle costings – is detailed in Appendix E. It should be noted that the emphasis was on providing benchmarking tools which determine absolute/quantitative rather than comparative/qualitative data where possible, as was recommended in the bid proposal.

A. The usefulness of thermal mass

Thermal mass is an essential part of good passive solar design to ensure the moderation of internal diurnal temperature swings. Typical thermal mass elements are exposed concrete floor slabs or trombe wall systems. The proposed method to examine and assess the usefulness of thermal mass within a house is based on the likelihood of use and usability factors. It was developed with the assistance of a domestic energy specialist (Donn 2004). Although only an indicative measure, it is considered to be both practical, and representative, by all SF1.2 TEAM members. The details of its measurement and assessment are given in Table 1 below.

Table 1: Indicative usefulness of thermal mass.

Points	**Description** (as suggested by Donn 2004)
0	No northern, sun-exposed thermal mass
1	Significant northern, sun-exposed with no insulation
2	Significant northern, sun-exposed thermal mass with NZBC insulation
3	Significant northern, sun-exposed thermal mass with "GOOD" insulation
4	Significant northern, sun-exposed thermal mass with "BEST" insulation
+1	*Significant northern, sun-exposed thermal mass which cannot be covered (extra point)*

The 'GOOD' and 'BEST' insulation levels are defined by the *Designing Comfortable Homes* booklet (Donn and Grant 2001), which corresponds a heat loss reduction of about 35% and 50% respectively compared to current NZBC requirements (Jaques 2004).

B. CO_2 emissions form energy end-use

CO_2 is important as it is a major greenhouse gas. The CO_2 emissions from the two major household energy end-uses – space and water heating – can be a good indicator of the overall domestic-related CO_2 emissions. An estimate of the likely CO_2 emissions from space heating were derived from the ALF thermal program, while BRANZ indicative research was used to determine the relationship between hot water usage[2] and the number of occupants (Camilleri 2004). This indicative relationship for hot water energy usage is expressed in Table 2 below:

Table 2: Indicative hot water cylinder energy use (from Camilleri 2004).

Number of occupants	The total energy use (assuming an A Grade hot water heater) in kWh/yr
2	1600
3	2100
4	2600
5	3100
6	3700

[2] Includes standing and pipe energy-related losses.

Once the space heating requirements had been determined from the ALF thermal model, the assessment of CO_2 emissions was just a matter of determining the fuels used for the running of the space and water heating appliances, and then their associated efficiencies (including distribution efficiencies) for providing that service. Thus, the total CO_2 contribution/estimation could be determined, assuming 'standard' occupant behaviour patterns.

C. Spatial resource use indicator

A key part of sustainability is the efficient use of land and the built area. The trend in New Zealand is for newly built houses to grow increasingly larger, even though the average family unit number is decreasing. The most recent figures indicate that, on average, a newly built house is about 207 m^2 and having 2.4 occupants (Page 2005).

Several indicators to assess the 'effectiveness' of resource use were proposed for this project:

- house area divided by the number of occupants
- bedroom area divided by the number of occupants
- covered area (i.e. building plus driveway) divided by the number of people.

These three indicators were all trialled as it was thought that simply having a singular indicator may be misleading, and a better representation of reality would be more likely satisfied using this multi-assessment approach.

D. Environmental impact of site works

It is recognised that site works in the establishment, setting out and construction of any building has an impact on the local environment. This indicator chosen was derived from work carried out in the UK (Baldwin et al 1998), which divides the *likely* ecological impact of a site into the following categories:

> ***Detrimental:*** where no plan has been put in place which mitigates the environmental impacts resulting from construction
> ***Neutral:*** where a building has previously occupied the site and has been demolished or extensively reused.
> ***Minor but positive:*** where a concerted plan mitigates the environmental impacts resulting from construction.
> ***Significant and positive:*** where significant resources have addressed things such as landforms, habitat, restoration, visual impact etc.

Results of trialling

The five proposed sub-issues were trialled by the SF1.2 TEAM in the Developed Sustainability Framework. The resulting conclusions from the trial on actual house consents were as follows:

- ***Thermal mass*****:** This method was very easy to use. Its representativeness would be very difficult to ascertain, due to the complexities of thermal properties of both buildings and the building-occupant interaction. However, its support from a leading New Zealand energy expert gives it the credibility required, and it therefore should be adopted in the (more refined) Developed Sustainability Framework

- ***CO_2 emissions*****:** This method was easy to use. ALF is considered to be a good indicator of energy use in houses, being based on internationally recognised dynamic simulation programs and verified in HEEP studies. The look-up table for the hot water energy use is considered to be representative for the New Zealand situation. However, it was often difficult/impossible to determine the space and hot water heating/fuel types and therefore their resulting CO_2 emissions. This could easily be determined from a post-occupancy check.

***Spatial resource use*:** The first two indicators examining the effectiveness of resource use were easy to determine and therefore use. Determining the third indicator proved to be difficult in many instances, due to the variances in drawing detail. Also, the usefulness of accounting the driveway as a resource indicator was also questioned by some of the SF1.2 TEAM. The representativeness of the first two indicators are probably both *reasonable*, rather than particularly good. They are very similar in that, generally, house size is a reflection of the combined bedroom size and a reasonable proxy for the number of occupants is the number of bedrooms plus one. However, both ideally need to incorporate modifiers to account for confounding factors, such as unconditioned spaces, home offices, sleep-outs etc, which can have significant impacts on the representativeness of the metric used. Questions such as how does one determine whether a particular space is *too small* to be lived in sustainably must also be answered. A more representative indicator, probably incorporating a matrix or sliding scale, would address these extra factors. However, this is beyond the scope of this study. For now, the focus will be on using the first two indicators, given that a better New Zealand system was not available.

- ***Impact of site works*:** This indicative *qualitative* metric was easy to apply. Being a qualitative measure rather than quantitative as the rest, its representativeness is not able to be determined as such. Although this is based on a UK approach, there seems to be little reason why it cannot be applied to New Zealand, and would be equally representative.

- ***Life-cycle material costing:*** This look-up table was very easy to use. It is also very representative, due to it being based on extensive durability testing carried out in New Zealand which can be relatively easily quantified.

2.3 Developed Sustainability Framework

A descriptive summary of the more refined Developed Sustainability Framework is detailed in Table 3. It is a short-list of the possible issues that can be practically measured, resulting from the combination of the tools developed as part of the NOW House and metrics specifically designed for the project. The short-listed issues were seen as being likely to be able to be assessed at building consent stage, as well as providing enough sustainability-type information for a good indication of a particular design's overall sustainability-related performance.

It should be noted that the elemental categories have altered from those suggested by the NOW House footprint elements. This change was necessary to better describe and group the sub-issues, recognising that many of the issues examined fall into more than one category (for example energy use which can be allocated to many of the original nine footprint elements). It also recognises the important issue is the sub-issue measure and assessment, rather than the element it falls under.

A full listing of the themes/issues examined at consent stage is detailed in Table 17 in Appendix D. The exception to this is the very first thematic area (i.e. consent cost), which was of a similar range for all the buildings sampled by default. Table 17 was used as the checklist on all the randomly chosen REF Houses sampled as well as the NOW House. It should be read in conjunction with Table 3 to get a more complete understanding of the way individual issues were examined. It should be noted that the developed short-list made use of other tools (both partial and wholesale), including:

- *ALF3* – a thermal analysis tool specifically designed for New Zealand
- *Green Home Scheme* – a New Zealand developed whole building environmental assessment method.

The Developed Sustainability Framework now satisfied by far the majority of the SF1.2 TEAM members, using the previously defined filtering criteria. Although there was general agreement by the SF1.2 TEAM on the revised framework, there was still opportunity for inclusion of other important (and previously unaccounted for) issues, if appropriate. Where possible, the overlapping of the assessment of discrete issues was minimised. Some overlapping of issues was necessary, however, due to the nature of the assessment process. The benefit of this is that it can result in a more robust framework, due to the availability of cross-checks.

Table 3: Descriptive summary of Developed Sustainability Framework.

Element	Thematic area	Description of issue
Affordability	**#1: Consent Cost**	Known directly from consent documents. Single unitary figure. Is within a small range \$160,000-\$200,000 for all REF Houses – i.e. similar to NOW House price.
Affordability	**#2: Material Life-cycle Costs**	Based on BRANZ research, for wall cladding and roofing only, but using relative figures and most common differential maintenance regimes. Uses average values for durability and exposure conditions. Costs adjusted for the different material life-spans. Refer Appendix E.
Affordability	**#3: Energy Use**	Indicative, based on thermal envelope performance (derived from ALF) and hot water usage only, since this typically makes up the majority of all energy use in a house. ALF assumes same heating schedule (both morning and evening) and heating level set-point of 18^{o}C. Hot water usage is based on indicative BRANZ research data, and is related to the number of occupants in the house. Examines percentage of hot water and heating needs provided from renewable sources. Provision of clothes-line and use of energy-efficient lighting in high use areas also factored. Refer Appendix F.
Health/Safety	**#4: Fire Safety**	Based on technical indicators (provision of smoke alarms/detectors, sprinkler systems). Includes the wiring and battery life aspects of smoke detectors also.
Health	**#5: Indoor Air Quality**	Based on active indoor ventilation (i.e. in all potential 'wet' areas) and where the venting is to (i.e. interior/exterior). Also, whether carpets are installed in wet-areas – such as entry-ways, bathrooms and kitchens.
Health / Desirability	**#6: Noise and Outdoor Air Quality**	Proximity to, quality of, and traffic heaviness of nearby roads (i.e. unsealed road/main highway/arterial/minor/cul-de-sac); proximity to external pollution sources (petrol stations/commercial orchards etc).
Health/ Desirability	**#7: Safety**	Indicators only based on: internal stairs and external steps, slope of section and provision of secure cupboards for hazardous materials.
Desirability	**#8: Security and Privacy**	Based on technical indicators (e.g. burglar alarm, security lights, safety catches etc), visual indicators (i.e. visually permeable fencing, clearly defined point of access), and access indicators (physical and visual barriers restricting access to back of house) derived from Waitakere City Council literature.
Emissions	**#9: CO_2 Emissions from Main Energy Uses**	Based on the Energy Use assessment sub-category above for space and hot water heating, but applying appropriate emission figures for the various fuel types used.
Resource Use	**#10: Thermal Performance**	Based on usefulness of thermal mass (qualitative indicators only) and the Energy Use assessment above, and heat loss calculations, NZS 4244 slab insulation levels, room layout, presence of air locks at entry-points etc. Indicators for how much shading the house gets (and therefore possible overheating) from eave sizing only.
Resource Use	**#11: Land Use and Ecology**	Indicative, based on neutral, minor or significant reference points, using applicable international data which examines the environmental impacts from construction, including percentage permeability and bulk excavation. Provision of composting and recyclables containers. Exterior spatial resource use indicator is based on coverage area (house, garage and driveway) divided by number of occupants.
Resource Use	**#12: Water Use**	Examines water harvesting capability and the inclusion of low water usage devices.
Resource Use	**#13: Transport Energy**	Proximity to transport hub with two indicators: town size and web-based transport information.
Resource Use	**#14: More Sustainable Materials**	Based on the use of well-managed timbers, untreated timbers in low risk areas, low environmental impacting products.

2.4 What Sustainability Framework issues were chosen and why

This section provides some background information on the issues addressed within the Developed Sustainability Framework and provides a rationale for the consideration of sustainability-related issues. The idea was to have fair comparisons between the NOW House and the REF Houses on the basis of meaningful sustainable objectives.

1. Consent Cost: It was a required condition that all the REF houses chosen were to be within a build cost of between $160,000 and $200,000, i.e. within approximately 10% of the expected build cost of the NOW House. The NOW House build cost of $180,000 was based on what was considered to be affordable and in keeping with the New Lynn area house prices, circa 2005.

2. Material Life-cycle Costs: Material maintenance and replacement costs over the lifetime of the building are a significant indicator of overall building expenses, and therefore its overall affordability for the owner (Page 2004). Also, there is a minimum durability performance requirement as part of the 2004 New Zealand Building Code (NZBC).

3. Energy Use: Household energy use has implications for the use of non-renewable resources, human-induced climate change, discretionary spending and self-sufficiency for both the homeowner and the nation. The efficient use of energy is also part of central Government's core strategies. The NOW House design team regarded energy efficiency as a significant priority for a more sustainable home.

4. Fire Safety: Good fire detection reduces the likelihood of injury, death and property damage caused by fire. These are important sustainability issues. In New Zealand, close to 90% of building fire deaths result from domestic fires. In residential fires, the risk of death in houses is reduced by 50% with well-placed smoke detectors compared to houses without smoke detectors.

5. Indoor Air Quality: It is estimated that people in New Zealand spend between 70% and 90% of their time indoors (Hope 2001) and a large portion of this is likely to be in our homes. There are many features specific to the New Zealand lifestyle which impact on our indoor air quality and which have a detrimental impact on the health of the occupants. Examples of this are the high use of unvented gas heaters, the limited insulation in older homes and the cold indoor conditions typical in much of New Zealand's older housing stock (PHAC 2002).

6. Noise and Outdoor Air Quality: Constant noise is a health issue as it can be debilitating in the long term – whether from internal or external sources. Careful layout and selection of building systems can greatly reduce this problem.

Poor outdoor air quality results in compromised indoor air quality. Auckland's air pollution can be worse than in London (Ministry for the Environment 2002). The proximity of a dwelling to known polluters such as high volume traffic, industrial areas and petrol stations provides an indicator of the local outdoor air quality.

7. Safety: Buildings can be unsafe and disabling; therefore it makes sense to design houses so that they are universally accessible and safe. Enabling homes to be usable for people whatever their age makes sound sense as it reduces dependency, the chance of accidents, the cost of maintenance and it provides comfort and freedom for the occupier (Bullyment 2001).

8. Security and Privacy: Burglaries constituted 26% of all dishonesty offences and 16% of all offences in 2000 (Statistics New Zealand 2004). Active crime prevention methods, such as the use of alarms, may reduce the offence rate for these offence classes. Passive crime deterrent measures, such as those associated with the visibility and layout of the house, can also contribute to the security of a house.

Privacy aspects are important in any home and are a key element in making the house desirable. However, these need to be balanced by sometimes conflicting security requirements. Privacy aspects can be addressed both within the home and between the house and the surrounding neighbourhood.

9. CO_2 Emissions: CO_2 is globally the most significant greenhouse gas connected with climate change and New Zealand's second most important greenhouse gas. The burning of fossil fuels in the provision of services, food and transport to a home all result in the production of CO_2. Given CO_2's strong link with fossil fuel usage, it is also a good indicator of the depletion of valuable natural resources as well as a resource efficiency indicator.

10. Thermal Performance: Good thermal performance of a home is a fundamental requirement of sustainable design. The thermal performance requirements of the NZBC are considerably lower than what is required for good passive solar design. This is reflected in the generally poor thermal performance of New Zealand houses. Improving a home's thermal performance has implications for the health of the occupants, disposable income as well as the use of non-renewables.

11. Land Use and Ecology: The uptake of space for buildings relates to two different issues: land use as a resource, which then cannot be used for other purposes, and the change of quality of the land which affects biodiversity, the water cycle etc. Both issues are highly relevant for New Zealand, with its rate of urban expansion in the order of 4-5% per year. In terms of the land use (footprint), there is a growing trend for new houses to increase in size well beyond that which could be termed 'sustainable'. This has implications for both initial as well as ongoing resource use.

Impermeable land is reaching very high proportions in some inner city sites, which has led to increased storm-water contamination as the water is no longer filtered by vegetation. This results in increased flooding downstream. Reducing the amount of impermeable land is therefore a key aspect of improving water quality in urban streams and harbours and in reducing localised flooding.

12. Water Usage: There are two core issues at stake relating to water usage – the requirement for potable water exceeding supply in some areas, and discharges from wastewater treatment plants resulting in oxygen depleted aqueous bodies (NZ Water Environment Research Foundation 2002). Focus in some areas has therefore shifted to reducing demand through water saving devices, and water self-harvesting using rainwater tanks to meet non-potable needs in reticulated areas. Reducing water use is increasingly seen as a key aspect of household sustainability.

13. Transport Energy: New Zealand is a highly car-dependent nation. Most of our travel is made by car – a relatively inefficient (and higher polluting) form of travel compared to public transport options. Often trips could easily be made by cycling or walking – as one third of all trips are for distances of 2 km or less. This has implications for emissions to the atmosphere and discharges to land and water, amenity impacts, the use of non-renewables, land uptake etc (Ministry for the Environment 2005).

14. More Sustainable Materials: It is recognised that the choice of building materials, components and assemblies has lasting environmental and economic implications (Anderson and Howard 2000). The difference in the environmental and economic impacts between two materials having the same function can be vast. Where possible, effort should be made to lessen this impact over the lifetime of the building. Determining which materials are more sustainable for a given function is a difficult task. Currently in New Zealand the only independent method for individual materials is that provided by the Environmental Choice scheme.

2.5 Random sampling method of REF Houses

Due to the need to have a fair comparison between the REF Houses and the NOW Houses sustainability-features, it was suggested that the comparative REF Houses have some 'similar' features as the NOW House. Thus, all the sampled REF Houses were first pre-selected to ensure that they:

- fell between a consent estimated value of \$160,000 and \$200,000
- are all from the Auckland region (to ensure a similar climate and perhaps building style)
- are all stand-alone (i.e. detached) houses.

The statistical method suggested to sample the building-related consent documentation from Local and Territorial Authorities (TLAs), so that it is random, is based on that suggested by a Wellington statistician (Jowett 2004). The suggested method also meets the other critical objectives – specifically, it is a simple and practical method that would give repeatable results.

The sampling method is:

1. From TLA building consent files, which are usually listed by receipt date, first despatch with those consents which fall outside the parameters of the survey. In this case, all houses outside the \$160,000 to \$200,000 range which were not stand-alone and not built recently. Also, in case a follow-up interview was necessary later, the building consent applications had to be at least one-year-old to ensure that the house had enough time to be constructed. However, to be representative of current construction, the building consents could not be any more than three-years-old.
2. Once the short-list was compiled, the consents were randomly shuffled (using a standard function within MS Excel).
3. Every 20^{th} submission is then drawn out to make up 19 houses in all (although only 15 REF Houses were required contractually it was thought to have some spare). This sample size was chosen to cover the likely variations in design within the sampling constraints imposed (Page 2004). These 19 drawn consents are then analysed.

This method is seen as an easy and practical solution to the problem of randomly sampling from a large population where some preconditions exist.

There were some exclusions to those initially selected, in particular, where the estimated value of the building consent did not seem to correspond to the proposed built area. These were rejected based on their unrepresentativeness. It is known that the cost estimations of building consents can be arbitrary at times, with pressure on the submitter to significantly underestimate the building cost, thereby reducing the building consent cost. For example, a 400 m^2 house was initially selected which had an estimated value of \$200,000. This house was rejected for analysis, as in all likelihood it would fall outside the price range in reality. The sampling pool was further reduced by the number of TLAs who were able/willing to provide the necessary documentation *pro bono* and within the very short timeframe. In the end only three TLAs were able to satisfy these conditions – Waitakere City Council, Manukau City Council and Auckland City Council. It was from these three regions that the 19 houses were randomly selected and analysed.

It should be noted that the consent-related procedures and processes of each TLA vary – sometimes considerably. Thus, at best, this random selection of houses (within the constraints above) should be considered indicative only for houses in the sampled Auckland areas.

3. RESULTS AND ANALYSIS

3.1 Results

In all, 19 REF Houses were assessed using the Developed Sustainability Framework (i.e. APPENDIX D). Although it was originally estimated that only between 10 and 15 houses needed sampling, it was decided that should follow-up interviews be required (i.e. Stage Two), a few extra houses were reviewed to have a safety buffer in case there was an unwillingness to participate by owners/dwellers.

The key question posed was – **“How many of the short-listed sub-issues within the Developed Sustainability Framework could be assessed at the building consent stage?”** This is a difficult question to answer, depending to some extent on the assumptions made in the assessment process (see Section 3.2 for a listing of these). For this study, it was thought that at least 90% (i.e. 17 out of the 19 sampled REF Houses) is an appropriate cut-off for determining whether an issue can be typically answered by using consent data alone. Although this figure has been arbitrarily picked, it recognises that for a framework to work, it should at least be possible for the majority of the population to practically apply it. A higher percentage would result in a reasonable compromise in the breadth and depth of assessment. When this 90% rule is applied, 33 (or 55%) of the 60 short-listed sub-issues could not be assessed at the consent stage using ‘typical’ building consent documentation.

The reasons for a particular sub-issue not being able to be assessed at this stage included the:

- simplistic, stylised and often under-developed nature of the drawings
- often generic nature of the accompanying specification documents, probably derived from template documents
- issue not being a requirement for building consent for that particular Council.

The following issues, along with their thematic areas, were **not** able to be assessed at building consent stage using the 90% rule. The listing below is therefore essentially a gap analysis.

ENERGY USE
- **Hot water heating metrics**
- **Provision of a clothes-line**
- **Energy-efficient lamps in high use areas**

FIRE SAFETY
- **Total number of smoke alarms**
- **Power source of those alarms**
- **Interconnectedness of those alarms**

INDOOR AIR QUALITY
- **Bathroom mechanical ventilation**
- **Kitchen mechanical ventilation**
- **Laundry mechanical ventilation**
- **Carpet in wetter areas**

NOISE AND OUTDOOR AIR QUALITY
- **Other factors lessening outdoor air quality**

SAFETY
- **Secure cupboards for hazardous materials**

SECURITY AND PRIVACY
- **Technical indicators for security and privacy**
- **Visual indicators for security and privacy**
- **Access indicators for security and privacy**

CO_2 EMISSIONS
- **Main space heater fuel use**

THERMAL PERFORMANCE
- **Well-positioned house for sun access**

LAND USE AND ECOLOGY
- **Environmental impacts of construction**
- **Bulk excavation**
- **Provision of a composting bin**
- **Provision of kitchen-handy recyclables bin**

WATER USE
- **No toilet(s) having a flush capacity >6 litres**
- **Water use reduction devices installed**

MORE SUSTAINABLE MATERIALS
- **Sealing of all engineering boards, if used**
- **Low environmental impacting paints**
- **Low environmental impacting finishes**
- **Low impacting carpets**
- **Other low impacting products**
- **Locally sourced recycled building material**
- **Using well-managed untreated timbers**

The considerable and non-trivial gaps can be seen in the frameworks areas: Energy Use, Fire Safety, Indoor Air Quality, Security and Privacy, CO_2 Emissions, Land Use and Ecology, Water Use and More Sustainable Materials. Significant gaps are also found in the thematic areas of Noise and Outdoor Air Quality and Safety. This leads to the conclusion that further information is required before a realistic impression of the sustainability features of the REF Houses can be determined and raises the following question: **“Which of the building consent-related inaccessible sub-issues are likely to be answered by a follow-up post-occupancy survey?”**

It is likely that almost all of these sub-issues could be determined from a post-occupancy survey with the following (likely) exceptions:

1. the type of some surface finishes for the majority of coated surfaces
2. the application, or not, of structural timber treatment
3. the sourcing of any recyclable building materials.

This list assumes that the whole building and surrounding section is accessible, with all building and landscaping works complete and with the building being resided in.

So how did the REF Houses perform for those issues on which they could be assessed? The results of the assessable issues are summarised in Table 4 following for the 19 houses selected. Note that these results for Stage One are preliminary for the REF Houses, since the consent documentation examined may vary considerably from that of the finished product. It is likely, however, that for most issues minor changes will *not* affect the overall sustainability performance of the building.

Table 4: Results of assessable sub-categories for REF Houses.

Thematic Area	Assessable sub-issue (refer to Appendix D for details)	Results for the 19 REF Houses (refer to Appendix D for details)	Interpretation
Material life cycle costs (LCC)	External cladding life-cycle costing	Medium for 17 houses; Low for 2 houses	Low is better
	Roofing life-cycle costing	Low for all 19 houses	Low is better
Energy Use	Space heating requirements	Ranged between 475 and 803 kWh per person Ranged between 16 and 21 kWh per m^2 habitable space	Low is better for both measures.
	Heat loss reduction, compared to NZBC requirements	No houses had significantly above NZBC insulation requirements.	
	Hot water needs from renewables	None	
	Space heating needs from renewables	17 = 0%; 2 = 70% (estimated)	The higher above zero percentage the better
Noise and Outdoor Air Quality	Outside noise and air quality indicators	Zero = 8; Low = 6; High = 5	Zero is better.
	Indoor generated noise	High level = 5 out of 19 houses	High level = noisy.
Safety	Slope of section	At risk = 4 out of 19 houses	
	Internal steps/stairs	At risk = 6 out if 19 houses	
CO_2 emissions	CO_2 emissions from space heating	Ranged between 317 to 548 kg per person Low = 7; Medium = 9; High = 3	Low is better.
Thermal Performance	The usefulness of thermal mass	No houses made use of thermal mass	
	The overall estimated heat loss (per person)	Ranged from 70 to 117 W/^{o}C per person Low = 6; Medium = 7; High = 6	Low is better.
	SNZ PAS 4244 insulation levels	All 19 houses had NZBC minimums for insulation	
	Edge insulated concrete slab	18 = No; 1 = NA (pole house)	
	House plan longer in the east/west direction	5 = Yes; 14 = No	Yes is preferable.
	Airlock at entry	3 = Yes; 16 = No	Yes is preferable.
	Airlock at garage	1 = Yes; 18 = No	Yes is preferable.
Land Use and Ecology	Resource use indicator (in m^2 per person)	From 6.7 and 11: bedroom area / # of occupants From 27 and 46: house area / # of occupants From 31 and 58: covered area / # of occupants	Low is better for all.
Water Use	Inclusion of means of harvesting water	18 = Not able; 1 = Able	'Able' is preferable.
	Inclusion of a composting toilet	No houses had composting toilets	
Transport Energy	Likelihood of public transport being available	All houses had high likelihood of public transportation (as urban area)	
	Likelihood of using public transportation	High = 5; Medium = 4; Low = 10	High is preferable.
More Sustainable Materials	Percentage of sustainably managed timber	All 19 houses had 50% sustainably managed timber	
	Low environmentally impacting insulants	None	

3.2 Assumptions made

In the analysis of the REF Homes many assumptions had to be made due to the paucity of information available. The assumptions include the following (listed along with its corresponding sub-issue number from APPENDIX D, Table 16).

1. The insulation value of concrete and polystyrene pod/grid-style flooring was estimated to having a similar thermal performance as an ordinary floor slab (**2** and **9**). This is due to the large amount of thermal bridging negating almost all the benefits of the insulation (Cox-Smith 2004).[3]
2. The droop of under-floor foil insulation was estimated to be 50 mm. This is not thermally-optimum, but is more representative of 'typical' field practice (Cox-Smith 2004) (**2** and **9.2**).
3. The number of occupants in a dwelling was assumed to equal the number of bedrooms plus one. Studies, studios and guest rooms were excluded from the bedroom count (**2**, **8** and **9.2**).
4. In cases where a hot water cylinder was known to be electric and indoors, it was assumed to be an 'A Grade' since this is always almost true (**2.1**) (Amitrano 2004). Where a cylinder was located externally, and had no fuel type indicated, it was classified as 'unknown' as there is a much higher likelihood of it being gas fuelled.
5. The occupant behaviour for space heating for all the assessed buildings was standardised; defaulting to a 'morning and evening' heating schedule with a set-point of temperature of 18^{o}C (**2** and **9**).
6. For determining CO_2 emissions (**8**) it was assumed that:
    a. space heating was achieved using 100% resistive-type electric heaters if no solid fuel burner was indicated (gas or highly efficient heat pumps were never used)
    b. the solid fuel burners all had an efficiency of 65% (Camilleri 2000) which is an average figure for newer units
    c. the indicative (and provisional) estimation from BRANZ research for electric hot water usage is based on the number of occupants (Camilleri 2004).
7. If the chances of a sub-category being met serendipitously or by accident were close to nil, then it was assumed that these issues would not be addressed within the finished building. This includes such things as:
    a. the concrete slab being utilized for heat storage, as it would typically be covered with carpet or rugs (**9.1**)
    b. the inclusion of a composting toilet (**11.2**) which would have required special consent
    c. the correct disposal of treated timber (**10.4**)
    d. the provision of a composting bin (**10.6**).
8. In the determining of the amount of bulk excavation (**10.2**) for flat (or near-flat) sites which had no excavation figures attached, it was assumed that only the top 150 mm is excavated. For pole houses it has been assumed that there is no excavation.
9. The ensuite area is not counted as bedroom area in the resource use indicator (**10.3**).

There were some issues where it was difficult to gauge the likelihood of whether they would be carried out by chance, but were *more* likely to be met than those listed in #7 above. Examples of these issues are: the provision of a kitchen-handy recyclables bin (**10.7**) and toilets having a flush capacity of less than six litres (**11.3**). These were therefore classified as being 'unknown'.

Naturally, the merit of some of these assumptions can be argued. However, for this report, where only a framework was required (rather than a fully developed assessment tool), it was seen to be suitably rigorous and SF1.2 TEAM members were supportive of the approach.

3.3 Discussion

The question was asked: **"If Stage 2 were not to go ahead, what percentage of each of the themed sustainability areas, providing the sub-issues are weighted appropriately, could be assessed purely from consent-based information?"**

Examining Table 5 shows that we can derive, in effect, 100% of the information about material cost and 70% of the information about energy use etc that we need for assessing the 'sustainability' of the

[3] A more accurate value can only be determined through complex three-dimensional modelling, due to the variability of the insulation throughout the concrete slab-on-ground.

house, based on building consent data only. This led to the realisation that current consent documentation (for the Auckland region anyway) is seriously lacking in sustainability-related information on: Fire Safety, Indoor Air Quality, Safety, Security and Privacy, CO_2 Emissions, Water Usage and More Sustainable Materials. Thus, seven of the 14 areas are deficient in information. Once again, this statement must be made with some caution, due to the very limited sampling.

Table 5: Sustainability impression based on consent information only for REF Houses.

Thematic area	Estimated percentage completeness using consent data only
1. Consent Cost	95
2. Material Cost	100
3. Energy Use	70
4. Fire Safety	0
5. Indoor Air Quality	0
6. Noise and Outdoor Air Quality	80
7. Safety	10
8. Security and Privacy	20
9. CO_2 Emissions	50
10. Thermal Performance	90
11. Land Use and Ecology	60
12. Water Use	30
13. Transport Energy	100
14. More Sustainable Materials	15

This led to the following questions: **"What percentage of the full sustainability range would be answered by the aspects able to be determined from the building consents?" "Is 55% by count (that could not be assessed) the same as 55% by importance?" Using the Pareto principle, we often expect 20% of the factors to have 80% of the impact. By the time you are up to 45% of the factors, you have something like 95% of the impact. So on that basis, given the percentages in Table 5, have we got most of the impact, or doesn't this work that way?"**

The consensus view by the SF1.2 TEAM was that the various sustainability aspects (in this case Table 5's thematic areas) cannot be traded off one against another. For example, being able to measure 100% of one category cannot compensate for a 30% measurement in another. Each sustainability theme is important and must be measured and determined individually for a good understanding of the sustainability attributes of a house. Thus, the short answer to the first question is "It doesn't work that way". This concept of trade-offs was discussed early on in the development of the NOW House project by the Design Team for the Filter (footprint) elements.[4] The Design Team decided that each element should be treated separately, as they are all important. The same applies to the categories listed in Table 5.

In terms of the 14 thematic areas in the Developed Sustainability Framework, it seems that it is possible to obtain from consent-only documentation:

- **an excellent** impression of consent and material costs, transport-related energy and thermal performance
- a **very good** idea of site factors, such as land use, energy use and ecology

[4] They are: *Affordability, Resource Use, Future Proof, Desirability, Performance, Landscape, Investment Potential, Personal Health and Community Health.*

- a **modest idea** of greenhouse gas emissions (specifically CO_2) from the main energy end uses
- a **poor impression** of water use, safety, noise, outdoor air quality, security, privacy and more sustainable materials
- and **no impression** of fire safety or indoor air quality-related issues.

The above estimations are reliant, naturally, on the building being built as submitted and all the assumptions made in the assessment of the consent documentation being reflective of actual/standard practice.

Based on expert opinion, the only sustainability-related themes for which we were able to gain an *adequate* picture from building consent data alone were those that achieved at least a 'very good' impression, i.e. Consent and Material Life-cycle Costs, Energy Use, Thermal Performance, Land Use and Ecology and Transport Energy. If we assume that all the 14 themes are weighted evenly, it seems that we only know about 60% of the factors that are necessary to make an adequate assessment of a house's sustainability features.

This led to the following question: **"How did the NOW House compare in its consent documentation?"** That is, how many of the 14 themes could be adequately assessed using the NOW House consent documentation alone? This is a difficult question to answer, due to the complex and staged nature of the detailed design process. However, the consent information (the plans dated 12/12/04, structural calculations dated 14/12/04 and the GJ Gardener specification) presented to Council for consent of the NOW House was not significantly more comprehensive in its sustainability-related information as that presented as part of the REF House consents.

It should be noted that assessing the NOW House from consent-only documentation would lead to a false impression (in this case a considerable under-rating) of its overall sustainability performance. This is due to either a lack of information or misinformation being provided as part of the consent drawings. As examples, the consent documentation had:

- no provision for whether the solar hot water heating, space heating type, or fire/smoke detection was made or detailed
- incorrectly labelled insulation (R-values) for both the ceiling and wall construction elements
- undetailed/missing material and appliance information, such as hot water cylinder type and insulation, paints, floor coverings specifics etc.

All these issues have significant implications for the overall sustainable performance of the house. In summary, the building consent information provided by the NOW House was not significantly better in detail (or accuracy) to those submitted by the REF Houses.

4. INTERIM SUMMARY

4.1 Interim conclusions

The conclusions for Stage One are only tentative, due to the small sample size of REF Houses and the very limited amount of information gained from their respective consent documentation.

Building consent documentation of 19 randomly selected Auckland houses, which were similar in general building profile to the NOW House, were assessed on a range of sustainability features. It was found that:

- There were several sustainability-related thematic areas for which the building consent documentation provided very little, if any, data resulting in an *inadequate* assessment of that attribute. In effect, only approximately 55% of all the sustainability indicators (i.e. areas) proposed could be determined from consent documentation alone. This lack of the complete sustainability picture is considered 'critical'[5] in terms of an assessment, and may result in a skewed sustainability picture of the house.
- The only sustainability-related thematic areas for which the SF1.2 TEAM were able to gain an *adequate* picture from building consent data alone were those related to: Consent and Material Life-cycle Costs, Energy Use, Thermal Performance, Land Use and Ecology and Transport Energy.
- As a result, it is estimated that only about 60% of the factors that are necessary to make an adequate assessment of a house's sustainability features were known.
- It seems that there are significant inaccuracies in consent documentation for issues such as site coverage area, resulting in incorrect assessments. This is due, in part, to the different way TLAs define their terms.
- Since the adequate analysis of even one of these thematic areas is considered to be a severe compromise, the SF1.2 TEAM agreed that Stage Two of the project must be pursued, as it is highly likely that nearly all of the information gaps could be rectified with a site visit to the randomly chosen buildings in question.
- The NOW House building consent documentation was not substantially different in adequacy of information provided (based on the 14 thematic areas) to that submitted by the 19 houses selected randomly as part of this study.

4.2 Interim recommendations

The recommendations as a result of the Stage One process can be summarised as follows:

- A post-occupancy interview be carried out by the SF1.2 TEAM of occupants of all the 19 REF Houses, applying the Developed Sustainability Framework to more clearly determine the selected buildings' overall sustainability impact.

[5] Why are these issues considered to be 'critical'? This is because sustainability must be covered in a significant amount of breadth and depth to be credible. Just where the 'significant' and 'insignificant' boundary lies is problematic to determine, but suffice to say that earlier iterations of the Sustainability Framework which had a limited scope were considered by many experts in the group to be less than adequate.

5. STAGE TWO: POST-OCCUPANCY EVALUATION

5.1 Survey methodology

In late October 2004, post-occupancy survey forms were developed to determine which of the remaining sustainability-related gaps pertaining to the REF Houses could be filled by post-occupancy evaluation interviews. Interest was focused on the issues ranked as having ‘poor’ or ‘no’ information available (refer to Section 3.3). The post-occupancy survey was kept as short as possible, with questions grouped under six thematic areas: Energy Use, Air Quality, Fire Safety, Safety and Security, More Sustainable Materials, and other issues (including Water Use). Once the survey was finalised, a letter of introduction was sent to all the 19 occupiers of the REF Houses, providing them with an invitation to participate in the project. A $50 petrol voucher was provided as an incentive to participate in the half-hour survey. In addition, a response form (along with a reply paid envelope and a news-clipping of BEACON project for background information) was also included in the send-out. A copy of the introductory letter and survey questionnaire are provided in the Appendices.

After the initial cut-off period for replies, only three respondents agreed to become part of the survey. The remaining REF House occupiers were approached in February 2005 and given a second chance to participate. Two more occupiers decided to participate as a result, giving a total of five respondents – or a 26% success rate. This was less than hoped for, but after much discussion it was decided that offering a larger financial incentive (of say $100) was unlikely to generate a better response, due to the very personal nature of the survey questions.

Interview times were then arranged with the occupiers, with the (person-to-person) post-occupancy surveys being carried out during February and March 2005.

5.2 Post-occupancy results for the REF Houses

The flowing results were gained from the post-occupancy interviews of the REF Houses. These results should be viewed as an *indication* of what is commonly being built today in the Auckland region, due to the small sample size. The other constraints in the selection criteria – such as the location of the houses, the build cost, and their detached nature – need to also be considered.

5.2.1 Issues established from post-occupancy survey

Table 6 details the issues that were able to be established as a result of the post-occupancy survey of the REF Houses. This table only examines the information gaps detailed in Section 3.1. APPENDIX D, Table 16 should be referred to for the coding (i.e. numbering) of the specific issues.

Table 6: Issues able to be ascertained post-occupancy.

Thematic Area	Assessable sub-issue post-occupancy	Results for the five Stage 2 REF Houses
Energy use	Hot water heating	2 gas; 3 electric
	Provision of a clothes-line	Yes = all
	Compact fluorescent lamps in high use areas	No = all
Fire Safety	Smoke alarms installed (type)	Yes = all (battery-powered)
	Interconnectedness of smoke alarms	No = all
Indoor Air Quality	Bathroom mechanical ventilation	Yes = 3; No = 2
	Kitchen mechanical ventilation	Yes = 4; No =1
	Laundry mechanical ventilation	No = 2; Unnecessary (as in garage) for 3
	Carpet in wetter areas	No = bathroom and kitchen Yes = 1; No = 4 for entry-way
Outdoor Air quality	Other factors lessening outdoor air quality	No = all for closeness to petrol station
		No = all for industrial site proximity
Safety	Secure cupboards for hazardous materials	No = all
Security and Privacy	*Technical* indicators for security + privacy	Security lights at entry points Yes = 4; No = 1
		Safety catches on vulnerable windows No = 4; Yes = 1
		Burglar alarm Yes = 2; No = 3
	Visual indicators for security + privacy	Boundary fences mostly permeable Yes = 4; No = 1
		Road frontage fencing low Yes = 1; No = 1; No Fence = 3
		Clearly defined access point to house Yes = all
	Access indicators for security and privacy	Physical access restricted to the back of the house: Yes = 4; No = 1
		Visual barrier restricting access to back Yes = all
CO_2 Emissions	Main space heating fuel type	Electricity = 2; Gas = 2; Unfinished = 1
Thermal	Well-positioned house for the sun	High = 3; Medium = 2
Land Use and Ecology	Environmental impacts of construction	Detrimental = all
	Provision of a composting bin (cubic metre)	No = 3; Yes = 1; Uncompleted = 1
	Provision of kitchen-handy recyclables bin	Yes = 2; No = 2; Uncompleted = 1
Water Use	No toilet having flush capacity >6 litres	Yes = all
Sustainable Materials	Sealing of all engineering boards	No = all

The following lists an overview of a trend resulting from the post-occupancy survey of REF Houses. A 'trend' is defined as where a particular issue within the survey has the same response for **every** house examined. They are:

1. Solar hot water assistance not chosen
2. Outside clothes-line chosen

3. Energy-efficient lights in high use areas not chosen
4. Window vents not incorporated into the fenestration
5. Carpet not installed in bedrooms or bathrooms
6. No petrol stations or industrial sites are within are 500 m of house site
7. There are no safety cupboards installed
8. There is a visual barrier restricting access to the back of the house
9. Composite (i.e. plywood and MDF engineering) boards are left unsealed
10. Dual flush toilets are installed (which are now by default 6 litres or less).
11. The post-construction site changes (in terms of landscaping) are all classified as 'detrimental' – i.e. where very little or no effort is made to mitigate the site impacts of the construction process.

5.2.2 Issues inconclusive from post-occupancy survey

There were only a few sub-issues which were not able to be ascertained even after the post-occupancy survey:

- how much bulk excavation was required during site establishment
- what paints (brand and type) were used for interior work
- what paints (brand and type) were used for exterior work
- what other finishes were used for the interior
- the brand of carpet(s) laid
- the details of insulation installed (brand name/R-value)
- whether low flow tap-ware or shower roses were installed (although given a longer survey assessment period this could be gained using appropriate instrumentation).

The reasons details of the sub-issues could not be established included:

- a recent change in tenancy leading to a difficulty in determining specific aspects of a product (e.g. brand names from plumbing fixtures and paint specifics)
- construction/landscaping information during the building process not being detailed on the consent data
- accessibility and timing issues (for example specifics on insulation materials installed in the ceiling and walls).

Table 7 below shows these remaining gaps in information associated with the category.

Table 7: Issues not able to be ascertained post-occupancy.

Thematic Area	Non-assessable sub-issue post-occupancy	Comments
Ecology	Bulk excavation	Difficult to determine post-occupation (refer Discussion 3.3). Could be effectively determined at time of construction
Water Use	Water use reduction devices installed	Specific devices are low flow taps and shower roses. This was a logistics (timing) problem only – and could be easily rectified with a water meter and a half-hour in time
More Sustainable Materials	Low environmental impacting paints	This is a logistics (timing) issue only, and has the potential to be easily rectified. Needs determination during the building process.
	Low environmental impacting finishes	As for low environmental impacting paints
	Low impacting carpets	As for low environmental impacting paints. This is unconfirmed however, as this questioned was omitted from the questionnaire accidentally
	Low impacting insulation	Pink batts was cited – but it was not established what type and make due to inaccessibility reasons
	Locally sourced recycled building material	As for low environmental impacting paints
	Using well-managed untreated timbers	As for low environmental impacting paints

5.3 Analysis

It can be seen that the post-occupancy survey resulted in a considerably more accurate gauge of the overall sustainable features of the REF Houses. Previously, it was found that there were critical deficiencies in eight of the 14 thematic areas about their sustainability-related information, based on consent-only information. Taking the post-occupancy survey into consideration, the thematic areas of Fire Safety, Indoor Air Quality, Safety, Security and Privacy, CO_2 Emissions and Water use,[6] can be added to the list of those areas *adequately* assessed. This leaves one remaining thematic area being classed as having an inadequate amount of relevant critical information available – More Sustainable Materials – even accounting for a post-occupancy survey. However, it is recognised that this situation could easily be rectified during the construction stage or with better documentation.

Table 8 summarises all the 14 sustainability thematic areas detailing *when* each area can be *adequately* determined. This assumes the building and consent work is conducted under current building practices, and that the consent documentation provided accurately represents what is actually built.

Table 8: Stages at which specific sustainability issues are likely to be determined.

Sustainability Thematic Area	Can be determined adequately …		
	At building consent	During construction most likely	At completion (post-occupancy)
Consent Cost	Yes		
Material Cost	Yes		
Energy Use	Yes		
Fire Safety			Yes
Indoor Air quality			Yes
Noise and Outdoor Air Quality			Yes
Safety			Yes
Security and Privacy			Yes
CO_2 from the Main Energy Users			Yes
Thermal Performance	Yes		
Land Use and Ecology	Yes		
Water Use			Yes
Transport Energy	Yes		
More Sustainable Materials		Yes	

5.4 The Proposed Sustainability Framework

5.4.1 Introduction

Table 9 on the following page provides a more detailed listing of what sustainability-related issues can be measured adequately, provided a post-occupancy survey (or similar) is conducted. Only those thematic areas which can adequately be addressed are included, therefore the More Sustainable Materials theme is omitted entirely. This theme could be easily addressed with monitoring during the construction phase, or perhaps by contacting the builder/designer.

Each sustainability-related issue is divided into two levels – single (indicated as a '1') or multiple (indicated as a '2+'). The number of levels suggested indicates the complexity of the issue. Where there is only one level, there is only the possibility of a yes/no solution. Examples of this include: having external steps or using only low flush toilets. Where there are a range of solutions possible, for example, when examining the life-cycle cost of wall claddings (for which there are 'low', 'medium' and 'high' cost rankings), multiple levels are assigned. The idea of assigning each issue a level is to provide an easier means for the Proposed Sustainability Framework to be adapted in the future, for

[6] The water use (i.e. flow rates) from the taps and shower rose would, in all likelihood, be able to be determined but for time constraints in the post-occupancy survey.

integration into assessment tools, benchmarking procedures etc. In addition, Table 9 details *when* the issue is assessable based on the 19 selected houses – at the consent stage or post-occupancy.

Table 9: Proposed Sustainability Framework.

Elemental Area	Thematic Area	Description of issues	Levels	At what stage is this issue assessable?
Affordability	**Consent Cost**	Capital cost of building	2+	Consent
Affordability	**Material Life-cycle Costs**	For wall cladding, based on initial and life-time costs For roofing, based on initial and life-time costs	2+ 2+	Consent Consent
Affordability	**Energy Use**	Space heating requirement (derived from ALF3 program) Space heating provided by renewables (estimated) Hot water usage (derived from HEEP information) Hot water needs provided by renewables (estimated) Provision of clothes-line Use of energy-efficient lighting	2+ 2+ 2+ 2+ 1 2+	Consent After occupancy After occupancy Consent After occupancy After occupancy
Health/Safety	**Fire Safety**	Provision of fire detection Power source of detection system Interconnectedness of detection system Provision of sprinkler systems	1 2 1 1	After occupancy After occupancy After occupancy Consent
Health	**Indoor Air Quality**	Use of passive ventilation for kitchen Use of passive ventilation for bathroom Mechanical ventilation to bathroom (vented to outside) Mechanical ventilation to kitchen (vented to outside) Mechanical ventilation to laundry (vented to outside) Carpets in bathroom, kitchen and entry-way	1 1 1 1 1 2+	After occupancy After occupancy After occupancy After occupancy After occupancy After occupancy
Health / Desirability	**Noise and Outdoor Air Quality**	Proximity to, and traffic heaviness of, nearby roads Proximity to external pollution sources Proximity of bedrooms to common areas Proximity of bedrooms to bathrooms	2+ 2+ 1 1	Consent After occupancy Consent Consent
Health/ Desirability	Safety	External steps Sloping site Internal steps/stairs Secure cupboards for hazardous materials	1 1 1 1	After occupancy Consent Consent After occupancy
Desirability	**Security and Privacy**	Security lights to most entry points Safety catches on all vulnerable windows Burglar alarm fitted Boundary fences mostly visually permeable Road frontage low or visually permeable Clearly defined point of access to house Physical barriers to restrict access to back of house Visual barriers to restrict access to back of house	1 1 1 1 1 1 1 1	After occupancy After occupancy After occupancy After occupancy After occupancy After occupancy After occupancy After occupancy
Emissions	**CO_2 Emissions**	Emissions from hot water usage based on standard use Emissions for space heating based on standard use	2+ 2+	After occupancy After occupancy
Resource Use	**Thermal Performance**	Usefulness of thermal mass smooth indoor temperatures Heat loss reduction compared to NZBC requirements Room layout for sun House orientation for the sun Perimeter/edge insulation of concrete slab Shading for overheating from eave size Air locks at entry and at garage	2+ 2+ 1 1 1 1 2	Consent Consent Consent After occupancy Consent Consent Consent
Resource Use	**Land Use**	Environmental impacts of construction Resource use indicator Provision of compost bin Provision of kitchen-handy recyclables bin	2+ 2+ 1 1	After occupancy Consent After occupancy After occupancy
Resource Use	**Water Use**	Percentage of self/site-harvested water Low flush toilets Inclusion of a composting toilet Inclusion of low flow tap-ware and shower rose Inclusion of grey-water recycling systems Inclusion of storm-water reduction system Other water reducing features	2+ 1 1 2+ 1 2+ 2+	Consent After occupancy Consent After occupancy Consent After occupancy After occupancy
Resource Use	**Transport Energy**	Proximity to transport hub Proximity to key services	2+ 2+	Consent Consent

It should be noted that there is some overlap in *what* the issues examine. This results in some redundancies if every issue were to be considered under each thematic area. This is a result of combining the two original tools (the *Filtering Framework Tool* and the *Targets and Benchmarks*) – with the many other existing tools and guidance documents used in this project. This redundancy means that for some issues there are two means of assessing them. For example, assessing the thermal effectiveness of the building, the Heat Loss calculation can be used (from Thermal Performance) or the BPI[7] figure (from Energy Use). A small overlap in this type of framework is unavoidable, and in some ways makes the use of the tool more flexible and robust as a result. Determining the most appropriate measure of a particular sustainability issue will depend on the application and end-use requirements.

The Proposed Sustainability Framework in Table 9 lists a series of possible elements that may be included in a range of applications, knowing that for any sub-category chosen, a very good impression of it will be able to be determined if the respective issues are examined. However, the Sustainability Framework is *not* a rating tool, nor should it be directly used for one. As stated in the introduction to this report – a Sustainability Framework is not the same as a rating scheme – a framework is a guidance document that establishes and organises key process and content elements. It aims to identify and describe the factors that should be taken into account when forming a view about the sustainability of a house.

5.4.2 Discussion

One of the core objectives of this report was to provide a practical and effective decision-making framework to assess key sustainability issues to allow comparisons between designs. The results and analysis of Stage One and Stage Two of this project have found that for an effective framework to work (given the limitations imposed), a post-occupancy survey is necessary. To get an even better impression of a house's sustainable performance, extra monitoring/recording needs to be carried out during the construction process itself and/or the builders/developers need to be questioned. An indicator of the framework's applicability and effectiveness is, in part, related to *when* the tool can be applied.

The choice of whether to use construction monitoring, as well as consent and post-occupancy survey information for the application of the framework, depends on the end-user requirements. Questions about the accuracy and representativeness of the information, timing and cost issues, available information, thematic areas interested in, etc, all have to be weighed up as part of the stakeholder decision-making process.

The (indicative-only) findings from this study are based on the following qualifiers that the information found here is fairly representative of building industry practices in New Zealand. This includes that:

- the amount of consent information provided to Councils is generic in nature
- building practices do not significantly differ considerably from region to region or due to consent cost
- these results are only reflective of newer stand-alone houses with an initial cost of between $160,000 and $200,000 and may differ significantly for other situations.

For a better understanding of how significantly impacting the qualifiers cited above are, a series of follow-up surveys would need to be carried out.

Due to the very limited nature of this survey, it is too difficult to determine the national applicability of the tool developed. For example, when trying to determine the confidence limits of the results for the five REF Houses comprehensively assessed, it is impossible to determine for all the questions

[7] Building Performance Index, climate-related energy use figure which is dependent on the house size.

where the same answer was given – whether a yes/no feature or a multi-criteria feature. This occurred in enough of the answers to make any statistical analysis picture critically incomplete.

5.5 Benchmarking the NOW House against the REF Houses

5.5.1 Introduction

Originally, a core objective in this SF1.2 Sustainability Framework research project was to use the developed framework to determine the NOW House's relative performance against the REF Houses. The intention was to scale/assign the NOW House as 'having 100 points', thus providing a numeric benchmark from which the randomly selected houses could be measured against. This assumed that the parallel project INT1.2 Prioritisation/Optimisation would result in a workable tool that could be applied to the SF1.2 Sustainability Framework. This was not to be, however, as the INT1.2 Optimisation Tool was not developed as originally intended – with the final outcome being far removed from the original programme confirmation phase bid (Page 2005).

As a result of this change in the INT1.2 output, the intended benchmarking objective cannot be fulfilled using this process. However, the more basic objective – to provide a method or process of combining different environmental, economic and social factors – is still possible using other existing techniques developed internationally. An examination of one of the most promising international methodologies and its possible application for this Sustainable Framework will be overviewed instead.

5.5.2 BRE's approach to benchmarking

The methodology behind one of the more rigorous approaches to combining construction-related social, economic and environmental issues is that developed by the Building Research Establishment (BRE). The methodology described here is set out more fully in a BRE digest (Dickie and Howard 2000).

The concept is based on that of Life-cycle Assessment (LCA), which is an internationally established method for analysing the impact of products and processes in a scientific manner. In the late 1990s, BRE initiated research to determine the relative importance of construction-related sustainable issues and to establish the degree of consensus on sustainability that exists between different interest groups. The first step was to establish a list of thematic areas of sustainable construction (see Table 10 following).

Table 10: Sustainability themes and issues (after Dickie and Howard 2000).

Theme	Environmental	Economic	Social
Sub-theme	Global	Construction	Equity
	Local and Site	Materials	Community
	Internal	Infrastructure	
Under each theme an extensive range of issues was identified including:			
Issues	Climate Change	Profitability	Poverty
	Resources	Employment	Minorities
	Internal Environment	Transport	Inner Cities
	External Environment	Stock Value	Transport
	etc	etc	etc

BRE hosted several workshops, typically convening a group of about 60 participants involved in building design and construction. This included experts from diverse fields – including government policymakers, construction professionals, local authorities, materials producers, academics and researchers, activists and lobbyists. They were presented with this pre-prepared list (see Table 10:). The experts were asked to add or delete issues, and come up with a common understanding of them. Then each participant was given a limited number of credits to 'spend' on the issues, reflecting on how important they thought they were. These credits could be distributed as desired. As a result, participants were forced to prioritise since there were more issues than available credits.

For the next exercise, participants were asked to score the relative importance of both the themes and sub-themes, to ensure that there was consistency between their previous ratings/rankings. Results showed that there was a good consistency between the two exercises – therefore showing a degree of objectivity to the subjectivity in the process. The exercise resulted in issues having weightings as shown in Table 11. Issue weightings have been amalgamated for space reasons.

Table 11: Weighting of themes and issues (after Dickie and Howard 2000).

Theme / Sub-theme	Issues	Weighting	Sub-totals
Environment			
Global Issues	Climate change, acid rain, ozone etc	19.8	
Local and Site Issues	Air pollution, water pollution etc	20	
Internal Environment	Health, comfort	3.8	
Economy			**43.6**
Construction	Profitability, employment etc	13.6	
Construction Materials	Profitability, employment etc	9.4	
Infrastructure	Energy and water etc	4.4	
Building Stock	Housing, industrial etc	4.8	
Social			**32.2**
Equity	Affordable housing, healthy housing etc	15.5	
Community	Urban identity, transport etc	8.7	
			24.2
	TOTAL	**24.2**	

This exercise was repeated for many groups, resulting in a ranking that has been very consistent from group to group. Surprisingly, only minor variations on relative weightings were exhibited, with the main sustainable themes rating similarly. It was found that the aggregate weight for the environmental issues was just over 40%, economic issues just over 30% and social issues just over 20%. It is recognised that these results are very time-dependent and therefore require regular updating. However, the method used proved to be effective in impartially determining the consensus view both within and between groups.

These weightings can be amalgamated in different ways, **"according to the issues that each is practically able to assess."** (Dickie and Howard 2000). BRE has applied this tool to both whole building assessment schemes as well as to their *UK Eco Points* system, which assigns a single unit measure of environmental impact of a particular product or process. These weightings have been also developed into BRE's *Green Guide for Specification*, www.bre.co.uk. This Guide provides quick and easy access to over 250 construction specifications, ranging from external walls and roofing elements through to partitioning and insulation.

It seems that BRE's methodology is applicable to the New Zealand situation. It would be relatively easy to determine a New Zealand-specific weighting for the three sustainability areas from a benchmark of, say, 100 points for the NOW House. However, there would need to be some discussion on more New Zealand-appropriate issue areas, and how to best group the individual building issues developed as part of this report's Sustainability Framewrok. It would also seem that BRE's voting and ranking process could be adaptable to an online survey, which would help keep the costs to a minimum, ensuring geographically distant experts could easily contribute.

The benefits from using BRE's process are that:

- it is a proven methodology, which has been fine-tuned over the years
- it is specifically designed for a process such as that required for BEACON Pathways
- good links to BRE have been established, so technical expertise can possibly be gained easily.

5.6 The sustainability features of the NOW versus REF Houses

A requirement in the SF1.2 research proposal was that an assessment of the sustainability features of the NOW House and the REF Houses would be performed. The results of the post-occupancy survey of the REF Houses, along with the NOW House assessment, can be seen in APPENDIX I. Table 12 combines the pre- and post-occupancy information to compare the differences in specific issues between the NOW House performance compared to that of the REF Houses. Only two thematic areas were excluded (Capital Cost and Indoor Air Quality), as issue-specific results were similar for both the NOW House and the REF Houses. Table 12 should be read in conjunction with APPENDIX D, Table 16 for a more complete understanding of individual issues.

Table 12: Comparison of sustainability features of NOW House and REF Houses.

NOW House performs considerably BETTER than the REF Houses in the issues of …	
Material Life-cycle Costs Lower external wall cladding costs over – lifetime maintenance and replacement **Energy Use** Space heating requirement – absolute and per person Space heating provided by renewables – passively Hot water provided by renewables – solar hot water assistance Overall heat loss reduction Efficient lighting – compact fluorescent lamps **Fire Safety** Power source of detection system – continuous mains and interconnectedness of fire detection system **CO_2 emissions** Low CO_2 emissions from space heating – both absolute and per person **Thermal Performance** Well-integrated passive solar techniques Very useful thermal mass for heat store in the concrete slab 'Better' overall thermal envelope Use of edge insulation for the concrete slab floor Airlock at entry	**Land Use and Ecology** Fully realised landscape plan Provision of kitchen recyclables area **Water Use** Storm-water control methods Low flow shower roses Rainwater harvesting **More sustainable materials** Paints being enviro-preferable (likely) Insulation being enviro-preferable (likely)
NOW House performing considerably POORER than the REF Houses in the issues of …	
Noise and Outdoor Air Quality Close proximity to service station – likely pollution resulting **Security and Privacy** Visual barrier to restrict access to back of house – none built in	

In short, the NOW House has many specific issues/features which are improvements over the REF Houses. The areas where the NOW House particularly shines are in Energy Use, Thermal Performance and Water Use. However, the Fire Safety and Land Use and Ecology areas also show a degree of improvement over the REF Houses.[8] It should be remembered that this comparison is only indicative – it is made from a random selection of only five similar REF Houses – so any results are tentative.

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[8] The thematic area of More Sustainable Materials cannot be included here, because it could not be adequately determined in the REF Houses. However, it is likely that that the sustainability performance in this area is higher in the NOW House than the REF Houses also.

5.7 Comparing sustainability categories

So how did the Sustainable Framework thematic areas align with the nine filtering elements proposed originally by BEACON? A listing of where the filtering elements align within SF1.2's Proposed Sustainability Framework (resulting from post-occupancy assessment) is shown in Table 13.

Table 13: Comparing BEACON's Filtering Framework Tool to SF1.2's Proposed Framework.

BEACON's Original Filtering Element	Included within SF1.2 Proposed Sustainable Framework?	How is this issue measured within SF1.2?
#1: Resource Use		
Energy	Yes	Space and hot water heating, hot water usage, efficiency of lighting, provision of clothes-line
Water	Yes	Self-harvested water, low flush toilets, composting toilets, low flow plumbing, grey-water recycling, storm-water reduction etc
Solid waste	Yes	Kitchen recyclables
#2: Future Proof		
Prepared for future	No	
Imaginative	No	
Telecommunications	No	
#3: Performance		
Improved building envelope	Yes	Both thermally and from reduced maintenance
Improved sound insulation	Yes	Double glazing.
Lower operating costs	Yes	Energy, water usage and waste water-related, material (cladding) life-cycle costs
Appliances and lighting	Yes	See Energy
Drying space	Yes	Provision of clothes-line
Durability	Yes	Material (cladding) life-cycle costs
Weathertightness	No	
#4: Community		
Impact on neighbours	No	
Emissions	Yes	From space heating and water heating only
Aesthetics	No	
Park and reserves	Yes	Land use in consultation with Council Parks department
Links to public transport	Yes	Proximity to transport hub and key services
#5: Landscape		
Solar	Yes	Siting of house and rooms within. Protection from overheating
Water harvesting	Yes	Self-harvested water
Surface run-off	Yes	Storm-water control methods
Aesthetics	No	
Privacy	Yes	Visually permeable fencing, access points, physical barriers etc
Road noise	Yes	Proximity to busier roads
#6: Desirability		
Quality of life	Not directly	Through comfort, good indoor air quality, privacy, fire safety, security and lower operating and maintenance costs
No compromises	No	
#7: Personal Health		
Warmth	Yes	Through thermal performance
Ventilation	Yes	Through good passive design
Privacy	Yes	Physical and visual barriers
Noise Reduction	Yes	Room placement/layout and proximity to roading. (Double glazing).
Security	Yes	Safety latches, security lights, intrusion alarms etc
Materials	Yes	Cladding, paints, insulation, recyclables, recycles, low processing etc
Air Quality	Yes	Low volatiles and no formaldehyde
#8: Affordability		
First Cost	Yes	Consent cost
Operating Cost	Yes	Energy, water and material ongoing costs
Total Cost of Ownership	Yes	Energy, water and material ongoing costs
#9: Investment potential		
Convenient Access	No	
Reliable utilities	No	
Proven technology	No	
Conservative design	No	

As can be seen, the proposed Sustainable Framework does not have any relevant corresponding issues for the filtering elements of Future Proof, Desirability and Investment Potential. Each of these elements (and therefore their respective sub-elements within) are very difficult to measure in a quantitative manner. However, there is a good correspondence between the filtering elements of Resource Use, Performance, Community, Landscape, Personal Health and Affordability and the Filtering Framework Tool sub-issues for most of the issues examined within.

6. FINAL CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusions

6.1.1 Methodology for selecting a random sample REF house for benchmarking

A simple but effective method to randomly select from many building consents is:

1. Approach the local authority and ask to provide consent registration data on the subset of houses interested in detailing necessary qualifiers. Ask for data to be provided in a spreadsheet form.
2. Randomly shuffle the consent registration data using a standard function within Microsoft Excel.
3. Draw out every 20th submission to make up the required number of houses (depending on the variables being assessed and the constraints imposed) for each Local Authority.

The random selection of a house building consent does not guarantee entry into it, and/or an interview with the occupant(s),[9] which is required to conduct a meaningful sustainability assessment. Therefore, the willingness of the selected house owners (or occupants) to provide information needs to be ascertained before research can be conducted. Due to the nature of the SF1.2 survey, especially the intrusiveness of the survey questions, the acceptance rate of the occupant is likely to be very low, even if incentives are provided. Since only 20% of sampled house occupants were willing to participate in a short post-occupancy survey, it is suggested that allowances be made for this in the number of people approached. Contacting the designer/builder alone will not provide the requisite level of information. This type of survey also involves a fair amount of goodwill for the consent authority – assuming it is carried out for free.

6.1.2 Development of a repeatable sustainable methodology

A sustainable framework was developed by the SF1.2 TEAM based on combining a number of resources. The resources included the unfinished *Targets and Benchmarks* and *Filtering Frameworks* tools (used for NOW House design-assistance work), energy and environmental assessment tools (such as ALF and the BRANZ *Green Home Scheme*) and several quantitative-based tools specifically developed to provide a more comprehensive sustainability assessment. The quantitative-based tools dealt with the issues of: the usefulness of thermal mass, CO_2 emissions from hot water energy use, a spatial resource indicator, the impact of the construction process on the site, and life-cycle costing of cladding materials.

The resulting framework has 14 thematic areas, rather than nine elemental categories, to better describe and group the sub-issues. Each of the sub-issues within the 14 categories underwent a filtering process to ensure that only appropriate sustainability-related questions were asked. The filter comprised of two questions:

- are these **key** issues for comparison between the two house types (the NOW and the REF houses)?
- **when** can these issues be addressed?

The 14 thematic areas developed as part of the sustainable framework are:

1. Consent Cost	8. Security and Privacy
2. Material Life-cycle Costs	9. CO_2 Emissions (from main energy uses)
3. Energy Use	10. Thermal Performance
4. Fire Safety	11. Land Use and Ecology
5. Indoor Air Quality	12. Water Use
6. Noise and Outdoor Air Quality	13. Transport Energy
7. Safety	14. More Sustainable Materials

[9] An alternative may be to contact the designer/builder, but this would not provide as comprehensive a response as interviewing the occupier.

The 14 thematic areas and their associated sub-issues were trialled on (initially) just the consent-documentation of the randomly selected 19 REF Houses and the NOW House. It soon became evident that many of the sub-issues could not be assessed, resulting in a far from representative picture of the assessed buildings' overall sustainable performance. In fact, only four of the 14 thematic areas could be determined adequately at the building consent stage. The reasons for this included the simplistic and frequently under-developed nature of the plans and the often generic nature of the accompanying specification documents. This was true for the documentation of both the REF Houses as well as the NOW House. The building consent information associated with the NOW House was not significantly better in detail (or accuracy) than that of the REF Houses.

Of the five specifically developed indicators (refer Section 2.2.1 for details), the following can be concluded about their applicability for inclusion into the Sustainability Framework:

- The stepped look-up table proposed for determining the **usefulness of thermal mass** was very easy to use and is thought to be representative, even though it would be difficult to measure without a longitudinal study. It was therefore adopted in the Sustainability Framework.
- The method proposed using ALF combined with a look-up table for **calculating CO_2 emission estimation** was easy to use. Both tools are considered to be good indicators of actual energy use in houses. It was therefore adopted in the Sustainability Framework.
- No elegant solution for determining an appropriate **spatial indicator** for examining the effectiveness of resource use was found. The first two proposed were preferable, but would ideally need to incorporate modifiers to be more representative. For now, either could be adopted in the Sustainability Framework, since no better solution exists for New Zealand.
- The method proposed for examining the **environmental impact of construction** was easy to apply. Being a qualitative measure (rather than quantitative as the previous three) its representativeness is more problematic to determine. Since no better indicators could be found, it was therefore adopted into the Sustainability Framework.
- The look-up table proposed for **life-cycle costing of materials** was easy to apply and is representative, as it is known to reflect the material's relative initial and typical maintenance costs. It therefore was adopted into the Sustainability Framework.

A post-occupancy survey was conducted on only five of the previously chosen 19 houses, as none of the remaining REF House occupants selected were willing to participate in the survey. The post-occupancy survey provided a considerably better idea of the sustainability of those houses – with only a few sub-issues (mostly under the More Sustainable Materials area) still being left undetermined. This resulted in a Proposed Sustainability Framework being drawn up (see Table 9). This resulting Sustainability Framework contains 13 thematic areas and enough sub-issues to obtain a very good impression of a building's overall sustainable aspects. The 14th thematic area, More Sustainable Materials, missed inclusion due to the inability to determine many of its associated sub-issues with an adequate level of certainty. It should be noted that the resulting table of the thematic areas and their respective sub-issues is not a rating tool, nor should it be used as one.

In terms of national applicability of the developed Sustainability Framework, given the very small sample for the second stage of the project, the unknown scope and therefore variability in requirements of the other local government agencies, a cautionary approach to interpretation should be used. Extrapolating the results from this report nationally, without qualifying the material, would be careless. Statistical analysis of the results was tried, however, for many of the questions where the answer was the same for all the REF houses sampled, no confidence limits could be established.

It was unfortunate that so few of the randomly selected people wanted to participate in the follow-up survey as part of Stage Two. This resulted in severely limiting the usefulness of the end result. To a large degree, this situation was the product of the many unknowns in the level of detail within 'standard' consent documentation.

6.1.3 An assessment of the sustainability features of the NOW House and REF Houses

Determining a house's sustainability features to an adequate level depends on *when* the information is collected. The more advanced the construction process is, generally, the better the sustainable representation possible. For clarity, the construction process was divided into *building consent* (i.e. all the information typically available through the consent documentation presented to the Local Authority), *during construction,* and *post-construction* (i.e. after the building has been occupied for a short period of time). The sustainability features examined in this report were divided into 14 thematic areas. The timing of when each of these areas can be adequately assessed is:

- **at building consent** for the thematic areas of Consent and Material Cost, Thermal Performance and Transport Energy
- **at construction** for the thematic area of sustainable materials
- **at post-construction** for the thematic areas of Energy Use, Fire Safety, Indoor Air Quality, Noise and Outdoor Air Quality, Safety, Security and Privacy, CO_2 Emissions from the Main Energy Users, Land Use and Ecology and Water Use.

If accurate records of the construction details were kept (e.g. the brand and type of paints, insulation, carpets and whether locally sourced and recycled materials were used), then an adequate determination of **all** the house's sustainability features listed above could be determined combining building consent documentation with a well-targeted post-occupation survey. Providing any less information (given standard building practices) undermines the completeness and therefore ultimately the representativeness of the sustainability assessment of the house.

It was suggested that perhaps by increasing building consent submission requirements (for example on a trial basis in a more pro-active Council) it may ensure more thematic areas could be adequately assessed earlier on. However, for a significant improvement in the adequacy of information, this idea depends on a whole suite of extra information being included as part of the consent documentation, and it is probably impractical to implement. Changes to the Building Act (e.g. 'Purpose' Clause 3d requires **"buildings that are designed, constructed, and able to be used in ways that promote sustainable development"**) may alter this situation. The impending changes to the NZBC reflecting this addition will enforce the need for a higher level of sustainability-related information provided as part of standard consent documentation. Just what the nature of this is likely to be is unknown at the time of writing. However, in all likelihood, even this information will not make a significant impact on the ability to determine the sustainability performance earlier on in the building process.

A sustainability comparison between the NOW House and the REF Houses was severely compromised by the limited number of REF Houses for which permission was given by their occupiers to conduct post-occupancy surveys on. Even after modest financial incentives were offered, only five of the 19 REF House occupiers were willing to participate. *Thus, the findings derived from these post-occupancy surveys should be regarded as tentative indicators.*

Given the constraints resulting from the very limited sample group, it seems that the sustainability performance of the NOW House is considerably better than that of the five randomly selected REF Houses in several *thematic* **areas**. The thematic areas where the NOW House particularly shines are: Energy Use, CO_2 Emissions from the Main Energy Users, Thermal Performance and Water Use. However, in the areas of Fire Safety, Land Use and Ecology, a degree of improvement over the REF Houses is also displayed. In total, these represent six of the 14 sustainability theme areas.

In terms of **individual issues** the NOW House performs considerably better than the REF Houses in:

- External wall cladding costs over lifetime (for maintenance and replacement)
- Space heating energy use requirements, both in absolute and per person terms
- The provision of the majority of space heating energy passively (i.e. through solar means)
- The provision of the majority of the hot water energy using renewable energy (solar)
- Energy efficient lighting – compact fluorescent lamps

- Improved fire safety with continuous mains and an interconnected system
- Very low CO_2 emissions from space heating – both in absolute and per person terms
- Very good thermal performance with well-integrated passive solar techniques
- Very useful thermal mass for year round indoor temperature moderation
- Superior (other) thermal performance features, such as having a fully insulated concrete slab and the provision of an airlock at entry
- Having a fully realised landscape plan
- The provision of a kitchen recyclables area
- Improved storm-water control methods
- The incorporation of low flow shower roses
- Rainwater harvesting through roof collection
- Paints being environmentally preferable (likely)
- Insulation being environmentally preferable (likely)

In terms of **individual issues** the NOW House performs considerably worse than the REF Houses in:

- Outdoor air quality, due to the proximity to two service stations and an arterial road
- Not having a visual barrier to restrict access to the back of the house, therefore compromising security.

In the analysis of the REF Houses many assumptions had to be made (especially for Stage One) for practicality reasons such as lack of easily available information, accessibility of parts of the structure and occupant behaviour. The likelihood of a particular issue being met was dependent on a mixture of common sense (i.e. what is considered to be common practice) and expert opinion. Many of the assumptions made in Stage One were verified in Stage Two.

6.1.4 Benchmarking the NOW House against the REF Houses

Originally, one of the key objectives of this report was to compare the two house types through the use of a numeric benchmarking system. The idea was to assign the NOW House as having 100 points, therefore providing a benchmark from which the randomly selected REF Houses could be measured against. This part of the project was reliant on the use of the parallel BEACON project INT1 Optimisation Tool for input into the Sustainability Framework scale. Unfortunately, this was not possible, as the output of the INT1 project varied from its original brief. However, an alternative method of combining and scaling different environmental, social and economic parameters into a single unitary score was proposed, based on that developed by the BRE in the UK.

The BRE system uses a repeatable methodology for determining the relative importance of construction-related sustainability issues. It relies on the Delphi process, where a diverse group of experts weight different issues based on a careful transparent methodology. This results in a prioritisation system for the three themes of sustainability – Environment, Economy and Social. These weightings can be amalgamated in a variety of ways, depending on the issues that each (thematic) area is wanting to assess. The flexibility, transparency and repeatability of this scheme could make it easily adaptable for the New Zealand situation and the inclusion into future projects such as BEACON's National Scorecard system.

6.2 Recommendations

The recommendations as a result of both the Stage One and Stage Two processes can be summarised as follows:

- Provide follow-up research to determine the variability of other Councils' consent documentation in other cities (say Hamilton, Christchurch and Wellington). From this, a more robust Sustainability Framework would result. Two studies need to be conducted for:
    - repeatability – the same constraints must be examined initially
    - comparison with the applicability of the original study – the implications of changing some variables (such as the house age, type or costs) need to be examined.

- For any future post-occupancy survey work, ensure that the occupants of any randomly selected houses are willing to be interviewed early on in the study. Also, ensure that plenty of substitutes are available if the initial occupants selected are unable to follow through with the survey.

- Explore a better method of addressing spatial resource use, as it is an important quantitative-based sustainability indicator. It needs to be fine-tuned so that it is more representative of how buildings and resources are used in real life. Issues such as how home office areas and non-conditioned spaces should be dealt with need to be practically assessed. At present, the indicator is overly simplistic, but there are no better solutions for the New Zealand case.

- The thematic areas and sub-issues within the proposed Sustainability Framework need to be refined some more if the framework is to be applied wholesale to a particular application. Although it was a goal to ensure that the amount of 'double counting' of sub-issues was minimised, improvement is still possible especially within the energy-related issues. Also, the 13 remaining thematic areas could be further rationalised to provide better grouping of the sub-issues into more descriptive sub-categories. A target should be to compress the thematic categories into not more than (say) eight or nine areas, as this should give enough scope to capture the diverse nature of the three aspects of sustainability without being too expansive. If only certain sub-issues or thematic categories are to be selected for further development, then more refinement may not be necessary.

- That the BRE methodology for weighting the different thematic areas and issues of sustainability be explored for the New Zealand Sustainability Framework. It has the potential to be a very useful tool, providing some degree of objectivity to an otherwise very subjective field, and has applications in many construction-related fields.

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APPENDIX A: HAMILTON CITY COUNCIL PRE-STUDY

The likelihood of a range of sustainability-related building issues being examined at the building consent stage were determined by using Hamilton City Council's consent procedure as a proxy for what occurs nationally. The specific question asked to the senior building consent officer (Kim Southcombe) in late August 2004 was: "**What is the likelihood of determining the following issues from typical building consent documentation (that is the submitted plans and specifications), if relevant for a building?"** The results are shown in Table 14 below.

The 'possible issues examined' derive from both existing tools and those developed as part of the NOW House project. Thematic areas are highlighted in yellow.

Table 14: Likelihood of a range of sustainability-related consent issues.

Possible issues examined in building consents	LIKELIHOOD			
	Always	**Mostly**	**Occasion-ally**	**Almost never**
BUILDING ENVELOPE and ENERGY				
Insulation material R-values for floors, walls and ceilings or enough details to determine them	X			
Double glazing units (preferably including frame type i.e. wood, PVC, aluminium)		X		
Carpeting (including brand name)		X		
Hot water system (e.g. electric, heat pump, solar assisted or gas, **with** a star rating for each)			X	
House orientation to the sun	X			
If enclosed firebox, brand name	X			
Type of space heater (if **not** enclosed fire-box) and therefore fuel type		X		
Surrounding vegetation resulting in both summer and winter shading				X
Major appliances (dishwasher) star ratings			X	
– fridge			X	
– washing machine			X	
Internal lighting used (amount and what type of lamps – CFL or usual)	No electrical plans are required			
WATER USAGE RELATED				
Rainwater collection tank installed	X		Not used	
A grey-water recycling system installed **and** details of distribution				X
Storm-water control systems – such as gravel drives, bunds etc	X			
Low flow/aerated fittings				X
Low flow shower heads				X
Composting toilet			Not used	X
The flush capacity of the toilet (6L or less)				X
Inclusion of a clothes-line/dedicated outdoor drying space			X	
Type of down-pipes and guttering used	X			
Type of water (plumbing) piping used (brand OR material type)	X			
Pathway material type	X			
Driveway material type	X			
LIFE-CYCLE COST and EMBODIED ENERGY				
External cladding material type and details for roof	X			
External cladding material type and details for walls	X			
Flooring material type	X			
Internal linings material type	X			
Capital cost	X			

Issues examined/required as part of consent documentation	Always	Mostly	Occasion-ally	Almost never
OTHER				
A dedicated area for composting food/garden material				X
The specifying of any recycled components (basins, tubs, doors etc)				X
Distance to public transport				X
Security lighting (external)				X
Extract fans in kitchen				X
Extract fans in bathroom			X	
Hardwired (built-in) smoke alarms				X
The types of paints used – preferably with brand name specified				X
The types of sealants (non-paints) used – preferably with brand-name specified				X
Land use change (i.e. details about landscaping), to categorise the impact into neutral, minor but positive, or significant but positive				X
Landscaping (not including drives and pathways)				X
Built-in sprinkler system (internal)				X
Lawn area as a proportion of overall site		X		
5L or larger space in kitchen for organic collection				X
What fencing is used (open or solid) for security				X
All of the rooms named (for determining acoustic separation)	X			

Also asked was how accessible is the building consent documentation for the general public. The response was that it is highly dependent on the Council.

Pre-study conclusion

Of the 44-odd issues examined, 26 (or 65%) are only 'occasionally' or 'almost never' included or able to be determined from building consent documentation alone, where relevant for a building. This is a preliminary indicator that, for SF1.2's Sustainability Framework, it is likely that Stage 2 will be required in the form of a post-occupancy survey.

APPENDIX B: DRAFT SUSTAINABILITY FRAMEWORK

Table 15 was derived from the NOW House *Targets and Benchmarks* and the *Filtering Elements Framework*. Grey-shaded issues are those considered to be largely dictated by occupant behaviour, so were addressed with caution.

Table 15: Draft Sustainability Framework.

Element	**Sub-Category** Enviromental (Env); Social (Soc); Economic (Ec)	**Target**	**What to measure and how to measure**	**Assessment Tool applicable to**	**WHEN able to measure** (pre or post-construction, or post-occupancy)	**Likelihood of issue being implicit or explicit in building consent doc <u>if relevant</u>**	**Key issue?** (i.e. is it important AND easily measured either pre- or post-occupancy?)	**Should be measured?** As part of SF1.2 NOW versus ROM houses
Affordability	Capital cost (Ec)	$150,000	Total cost (including landscaping?)	T&B, FEF	Pre and post-construction	Always	Yes	**YES**
	Special Items (Ec)	$15, 000	Cost at construction	T&B, FEF	Pre and post-construction	NA	NA	NA – special project item only applicable to NOW House
	Operating energy (Env)	**Operating** bills: ≤ $550/yr	**Operating**: sum monthly energy bills	T&B	Post-occupancy	None	Yes	NO – 50% of energy use is due to occupants.
	General maintenance costs (Ec)	**Maintenance**: ≤ $600/yr for first 10 years	**Maintenance**: sum maintenance log expenses	T&B	Post-occupancy – long term	None (although a guestimate would be possibly based on materials used)	No (accurate records would need to be kept long term)	NO
Desirability (Soc)	Ergonomics (Soc)	Checklist of key features by independent designer	Adherence to Standards	T & B	Post-construction	Not enough detail within consents	Unknown	**To be discussed**
	Aesthetics (Soc)	'Good' rating, POE review	Visual appeal	T & B	Some pre (i.e. overall structure) and some post (e.g. colour) occupancy	Unknown – mostly?	No (too difficult to measure objectively)	NO
	Saleability /Resale (Ec)	$150k building only	Professional evaluation (Evaluator's report)	T &B	Post-construction	NA	No (not important)	NO

Element	Sub-Category Enviromental (Env); Social (Soc); Economic (Ec)	Target	What to measure and how to measure	Assessment Tool applicable to	WHEN able to measure (pre or post-construction, or post-occupancy)	Likelihood of issue being implicit or explicit in building consent doc if relevant	Key issue? (i.e. is it important AND easily measured either pre- or post-occupancy?)	Should be measured? As part of SF1.2 NOW versus ROM houses
Performance	Fire Safety (Env)	Above NZBC Compliance – hardwired smoke alarms or full sprinkler system	Plans with full sprinkler system OR hardwiring	T&B, FEF T&B, FEF	Pre-construction if higher than Code Pre and post-construction	Unknown NA – special project item	Yes NA	**YES**
	Thermal (Env)	ALF **BPI** of 0.06 or less	Calculated performance using ALF to find building performance index (**BPI**)	T&B	Pre-construction	Always	Yes	**YES**
		Average passive indoor temp between 18ºC and 25ºC for all but 10 days/year	Monitoring of thermocouples (with meter-board loggers)	T&B	Post-occupancy only	No (although could make a guess)	No (time intensive for installing equipment and analysis)	NO
		Better than SNZ PAS 4244 "Best" specs	SNZ PAS 4244 Code of Good Practice	T&B	Pre-construction	Always	Yes	**YES**
		Completely self-sufficient in heating all year round	Dynamic model with Energy+ tool	NA – Ultimate goal	Pre-construction	Always	No – Energy+ time intensive programme	NO
	Indoor Air Quality (Env) (see also Moisture and Health and Safety sections)	None – pollutants levels cannot be benchmarked to 'normal' houses, as location and activity-dependent, so concentrations vary widely	NA – no guidelines to measure against. However, could use exposure standards for contaminants in NZS4303:1990. They give the following levels of no concern: formaldehyde <0.05 ppm; CO <2% COHb	T&B	Post-construction only	None	No	NO

Element	Sub-Category Enviromental (Env); Social (Soc); Economic (Ec)	Target	What to measure and how to measure	Assessment Tool applicable to	WHEN able to measure (pre or post-construction, or post-occupancy)	Likelihood of issue being implicit or explicit in building consent doc if relevant	Key issue? (i.e. is it important AND easily measured either pre- or post-occupancy?)	Should be measured? As part of SF1.2 NOW versus ROM houses
Performance (continued)	Noise – Internal (Soc)	Quiet areas ≤ 24 dB(A) over 24 hours. No plumbing noise.	Acoustic sensor in lounge and bedroom over extended periods	Public draft (AAAC, 2003), based on Australian guidelines for apartments and townhouses	Post-occupation only	Unknown	No (would require post-occupancy	NO
	Noise – External (Soc)	Living areas ≤27 dB(A) over 24 hours; bedrooms 27 dB(A) over 24 hours	Acoustic sound testing sensors over extended periods	Public draft (AAAC, 2003), recommended by Emms (2003)	Post-occupation only	None	No (time intensive)	NO
	Future proof - *Flexibility and services provision*.(Soc)	Unknown	Could find (say) 5-10 arbitrary issues	Unknown	Post-occupancy (early and late) as don't know all likely affecting technologies	Unknown	Unknown	**To be discussed**
	Light – Natural (Env)	POE 'good'.	Quality and glare	POE (Building Evaluation)	Post-occupancy only	Occasionally	Unknown	**To be discussed**
	Light – Artificial (Env)	POE	Quality and glare	POE (Building Evaluation)	Post-occupancy only	Almost never	Yes	**YES**

Element	Sub-Category Enviromental (Env); Social (Soc); Economic (Ec)	Target	What to measure and how to measure	Assessment Tool applicable to	WHEN able to measure (pre or post-construction, or post-occupancy)	Likelihood of issue being implicit or explicit in building consent doc if relevant	Key issue? (i.e. is it important AND easily measured either pre- or post-occupancy?)	Should be measured? As part of SF1.2 NOW versus ROM houses
Performance (continued)	Internal moisture (Env)	Room ambient air RH limited to 40-60% for living and 40-70% in bedrooms MC in wet-area framing to be similar to general framing MC	In-wall RH monitoring over extended time period	Suggested by Bassett (2003)	Post-construction only	Almost never	No (must be measured over long time period	No
Overall Eco-Performance	(Env)	"Excellent" overall performance rating (BRANZ 2004)	Mainly environmental, but also some health and safety features	BRANZ 2004 *Green Home Scheme* auditing procedure.	40% pre-construction according to HCC consents), 100% post-occupancy	40% only fall within the 'Always' or 'Mostly' likelihood category	Yes (all issues easily measured and National scheme)	**YES**
Personal and Community Health	Health & Safety (Soc)	No slips or falls which are 'building-induced' #	Building induced reports in house log book	T&B	Post-occupancy only	Almost never (Not unless obvious)	No (must be measured over long time period	NO
	Security with Privacy combined. (Soc)	No burglaries in two years and at least five of the WCC design goals met **	Has six generic criteria and two site-specific criteria (quantitative aspects)	WCC's *Designing Out Crime*	Post-construction – as many fixings and landscape details are necessary	Almost never	Yes	**YES**
	Comfort (see also Performance (light)	'Good' rating at POE review	Indoor temperature, draughtiness, noise and privacy and security (qualitative aspects)	NOW House 'Building Evaluation' form	Post-occupancy only	Almost never	Yes – thru one-on one post-occupancy survey	**YES – provided POE survey completed for REF Houses**
Resource use	Water consumption	140L/person or less daily town supply water	Monitoring of public supplied toilet and garden tap – also rainwater collected	T&B	Post-occupation only	Almost never	Yes	**YES**

Element	Sub-Category Enviromental (Env); Social (Soc); Economic (Ec)	Target	What to measure and how to measure	Assessment Tool applicable to	WHEN able to measure (pre or post-construction, or post-occupancy)	Likelihood of issue being implicit or explicit in building consent doc if relevant	Key issue? (i.e. is it important AND easily measured either pre- or post-occupancy?)	Should be measured? As part of SF1.2 NOW versus ROM houses
Resource use (continued)	Energy consumption actual (Env)	Less than 5100 kWh/yr	Monitoring of meter box	T&B	Post-occupation only	Almost never	Yes	**YES**
	Energy consumption indicative.(Env)	Warm Home Energy Check	5 stars or more	Amitrano (2003)	Post-construction	Mostly	Yes	**YES**
	Embodied energy (Env)	Less than 1300 MJ/m^2 Σ floor/walls/roof only (for super insulated construction)	Calculated/estimated from final design	Mithraratne (2001) for comparative houses; Alcorn (2003)	Pre-construction	Always	No (not easily measured)	NO
	Land Use and Ecology (i.e. site impact) (Env)	**Landscaping** assisted by Parks Dept – change in **ecology** of site is 'MINOR'%	Area disturbed by development, and resources used in construction and landscaping	T&B	Post-construction usually	Occasionally	No	**YES**
	Water production (grey) (Env)	No grey-water discharged on site?	Flow volumes for grey-water	T&B	Pre-construction	Always (as building consent required)	Yes	**YES**
	Water Production (storm) (Env)	No storm-water discharge from site at all.	Storm-water discharge difficult to measure accurately	T&B	Pre-construction	Almost never	No (not easily measured)	NO
	CO_2 emissions	≤2650 kg CO_2/yr gas/electric mix; or ≤ 3250 kg CO_2/yr all elect. system)	Utility bills for appliances converted using NZCSD emission figures	T&B	Post-occupation only	Almost never	No (occupant-dependent)	NO
	Materials (sustainable, renewable, non-toxic, healthy) (Env)	>90% all materials chosen are 'preferred' materials	Use material database decision assistance chart being compiled, as part of BEACON project	T&B	Pre-construction	Always	No (database incomplete)	NO

Element	Sub-Category Enviromental (Env); Social (Soc); Economic (Ec)	Target	What to measure and how to measure	Assessment Tool applicable to	WHEN able to measure (pre or post-construction, or post-occupancy)	Likelihood of issue being implicit or explicit in building consent doc if relevant	Key issue? (i.e. is it important AND easily measured either pre- or post-occupancy?)	Should be measured? As part of SF1.2 NOW versus ROM houses
Resource use (continued)	Waste (Env) Construction Phase	**Construction:** ≤4 m^3 in total;	Visual volumetric assessment monitoring during entire phase, by students	T&B	Post-construction	Almost Never	Yes (but does depend on builder habits)	NO
	Occupation Phase	**Occupation:** ≤ 4.3 kg/ household/week	Occupant recorded – NOT including that recycled	T&B	Post-occupation	Almost Never	Yes	NO

Key:
T&B = Targets and Benchmarks
FEF = Filtering Framework Tool
GHS = BRANZ Green Home Scheme
WHEC = Warm Home Energy Check
ALF3 = BRANZ Annual Loss Factor, version 3.

** Public and private space must be clearly identified, so intrusion cannot occur accidentally (WCC 2003). STANDARD: About 25% of existing suburban homes meet a significant number of the (six general) criteria in the *Designing Out Crime* document (Mills 2003). TARGET: Include some of these design principles (from WCC 2003): 1. Side and rear boundary fences are visually permeable … 2. Regardless of orientation, road frontage fencing is low or visually permeable … 3. There is a strong visual connection between the dwelling and the ECO Trust building. 4. That planting and landscaping on the property does not provide screening for people to gain access to the house … 5. Window and door fastenings are robust and not easily tampered with … etc

[%]**Ecology target**: Examines the post-construction site changes and categorises them as either:
– DETRIMENTAL: i.e. where undeveloped land has topsoil removed and lawn planted
– NEUTRAL: i.e. where a building has previously occupied the site and has been demolished or extensively reused
– MINOR but POSITIVE: where a concerted plan mitigates the environmental impacts resulting from construction
– SIGNIFICANT and POSITIVE: where significant resources have addressed things such as landforms, habitat, restoration, visual impact etc.

APPENDIX C: SECONDARY-RELATED FACETS OF SUB-ISSUES

Table 16: Exploration of secondary facets of sustainable issues.

Element	Sub-category	Primary Facet	Main Secondary Facet(s)	Comment
Affordability	Capital Cost	**Ec**	**Soc**	Social and economic are closely tied for this issue
Performance	Fire Safety	**Env**	**–**	
	Thermal Efficiency (ALF3 audit)	**Env**	**Ec; Soc**	The thermal efficiency of a building influences energy bills and comfort
	Thermal Efficiency (NZS PAS 4244)	**Env**	**Ec; Soc**	The thermal efficiency of a building influences energy bills and comfort
	Lighting (Natural and Artificial)	**Soc**	**–**	
Overall Eco	BRANZ Green Home Scheme	**Env**	**Soc**	Affects health and well-being
Personal and Community Health	Security and Privacy (focus on quantitative aspects)	**Soc**	**Ec**	The security of a house may influence insurance premiums
	Comfort: indoor temp, draughtiness, noise, privacy and security	**Soc**	**–**	
Resource Use	Energy Consumption (actual)	**Env**	**Ec**	The thermal efficiency of a building influences energy bills
	Energy Consumption (indicative)	**Env**	**Ec**	The thermal efficiency of a building influences energy bills
	Embodied Energy	**Env**	**Ec**	Embodied energy is a crude indicator of material cost
	Land Use and Ecology	**Env**	**Soc**	A positive dwelling environment influences mental health
	Water Production (grey-water)	**Env**	**Ec**	Saves on infrastructure costs

KEY:
Ec = Economic
Soc = Social
Env = Environmental

From Table 16, it can be seen that most secondary issues associated with the sub-categories of the various elements have an economic or social component to them – making for a considerably more balanced appraisal of sustainability-related issues.

APPENDIX D: DEVELOPED SUSTAINABILITY FRAMEWORK

Table 17: Developed Sustainability Framework.

CONSENT-RELATED QUESTIONS	House number																		
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
1. Material Life Cycle Costs																			
1.1 External Wall cladding COSTS																			
High, **M**edium, **L**ow	M	M	M	L	M	M	M	M	M	M	M	M	M	M	M	M	M	L	M
1.2 Roof cladding COSTS																			
High, **M**edium, **L**ow	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L
2. Energy Use																			
2.1 Space + water heating metrics																			
See Appendix F (Part A) for details																			
2.2 Heat loss reductions, cf NZBC																			
Heat loss reduced by >35%	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no
Heat loss reduced by >50%	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no
2.3 % of hot water needs from renewables	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2.4 % of space heating from renewables	0	70	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	70	0
2.5 Provision of a clothesline																			
yes						x								x			x		
unknown	x	x	x	x	x		x	x	x	x	x	x	x		x	x		x	x
2.6 Energy efficient lamps in high use areas																			
unknown	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
yes																			
3. Fire safety																			
3.1 Total number of smoke alarms																			
unknown	x	x	x	1	x	x	x	x	x	x	x	x	x	x	x	x	x		x
3.2 Power source of those alarms?																			
Battery			x											x					
unknown				x	x	x	x	x	x	x	x	x	x		x	x	x		x
3.2 Interconnectedness of the smoke alarms?																			
unknown	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	NA	x
3.3 Are spinklers used?																			
Yes																		x	
4. Indoor Air quality																			
4.1 BATHROOM mechanical ventilation																			
none			x													x			
to outside									x										
unknown	x	x		x	x	x	x	x		x	x	x	x	x	x		x	x	x
4.2 KITCHEN Mechanical ventilation																			
none			x	x										x		x			
to roof space		x																	
unknown	x				x	x	x	x	x	x	x	x	x		x		x	x	x
4.3 LAUNDRY Mechanical ventilation																			
none		x	x	x		x			x					x					
unknown (or if in garage)	x				x		x	x		x	x	x	x		x	x	x	x	x
4.5 Carpet in wetter areas																			
Kitchens																			
yes																			
no	x				x									x	x	x			
unknown		x	x	x		x	x	x	x	x	x	x	x						
Bathrooms																			
yes											x								
no	x				x									x	x	x			
unknown		x	x	x		x	x	x	x	x		x	x						
Entryways																			
yes															x				
no	x				x						x			x		x			
unknown		x	x	x		x	x	x	x	x		x	x				x	x	x
5. Noise and Outdoor Air Quality																			
5.1 Noise and outdoor air quality indicators																			
Adjacent to cul-de-sac	x		x	x		x		x	x	x			x						
Adjacent to minor road		x			x						x	x				x	x		
Adjacent to arterial road							x							x	x			x	x
Adjacent to a highway																			
Adjacent to unsealed road																			
5.2 Other factors lessening outdoor air quality																			
Close to petrol station																			
Close to air polluting industries																			
Unknown	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
5.3 Indoor generated noise																			
Bedrooms separate from common areas																			
yes		x				x				x		x					x		x
no	X		x	x	x		x	x	x		x		x	x	x	x		x	
Bedrooms adjacent to bathrooms																			
yes	X	x	x			x	x	x		x		x			x	x	x		
no				x	x				x		x		x	x				x	x

CONSENT-RELATED QUESTIONS	House number 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
6. Safety																			
6.1 External steps																			
Yes				x		x									x			x	
Not needed	x	x	x		x		x	x			x	x	x	x			x		x
Unknown									x	x						x			
6.2 Slope																			
Level					x	x	x	x				x	x				x		
Gentle slopes	x	x	x	x						x				x					x
Steep									x						x	x		x	
Terraced																			
6.3 Internal Stairs/steps																			
None	x	x	x		x	x	x	x			x	x	x	x		x	x		
two storey house															x			x	x
garage to house				x					x	x									
6.4 Secure cupboards for Haz materials storage																			
unknown	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
7. Security and privacy																			
7.1 Technichal indicators																			
Security lights to most entry points														x		x			
Safety catches on all vulnerable windows																x			
burglar alarm																			
unknown	x	x	x	x	x	x	x	x	x	x	x	x	x		x		x	x	x
7.2 Visual indicators																			
Boundary fences are mostly visually permeable	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?
Road frontage fencing is low/visually permeable	?	?	yes	NA	?	?	?	?	?	?	?	?	?	?	?	?	NA	?	?
Clearly defined point of access to property	?	?	yes	yes	?	?	?	?	?	?	?	?	?	?	?	?	x	?	x
7.3 Access indicators																			
Clearly defined point of access to house (i.e. door)																			
Yes	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Physical barriers restrict access to back of house																			
Yes						x								x			x		
no	x	x	x	x														x	
unknown					x		x	x	x	x	x	x	x		x	x			x
Visual barriers restrict access to back of house																			
yes						x								x			x		
no	x	x		x														x	
unknown					x		x	x	x	x	x	x	x		x	x			x
8. CO2 emissions from main energy uses																			
See Appendix F (Part B) for details																			
9. Thermal Performance																			
9.1 The usefulness of thermal mass																			
See Section 2.3.1 for details	nil	nil	nil	nil	nil	nil	nil	nil	nil	nil	nil	nil	nil	nil	nil	nil	nil	nil	nil
9.2 The overall estimated heat loss																			
See Appendix F (Part A) for details																			
9.3 SNZ PAS 4244 insulation levels																			
Code, **B**etter, Be**s**t	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C
9.4 Well sized eaves																			
eaves ±20% correct size, for Nth windows	no	yes	yes	no	yes	yes	no	?	no	no	no	yes	no	?	no	no	yes	no	yes
9.5 Well positioned house for sun access																			
House in shade throughout winter																x			
House looses sun in late afternoon / early morning			x	x					x		x			x	x		x	x	x
House never shaded																			
Unknown	x	x			x	x	x	x		x			x						
9.6 Edge insulation on concrete floor slab																			
No	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x		x
NA																		x	
9.7 House plan is longer in east/west direction																			
Yes					x		x	x		x			x						
No	x	x	x	x		x			x		x	x		x	x	x	x	x	x
9.8 Airlock at entry																			
Yes							x	x	x										
No	x	x	x	x	x	x				x	x	x	x	x	x	x	x	x	x
9.9 Airlock at garage																			
Yes								x											
No	x	x	x	x	x	x	x		x	x	x	x	x	x	x	x	x		x

CONSENT-RELATED QUESTIONS	House number 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
10. Land Use and Ecology																			
10.1 Environmental impacts of construction																			
Detremental **N**eutral **M**inor **S**ignificant **U**nknown	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U
10.2 Bulk excavation																			
Site excavation required (in cubic metres)	131	?	?	17	11	10	4	9	293	?	30	7	11	?	?	313	9	26	30
10.3 Resource use indicator																			
Bedroom Area divided by the people	6.7	7.8	7.8	8.1	6.6	10	10.6	10	11	10	10.7	8.9	11	8.3	10.6	9.7	9.4	10	11
House area divided by number of people	29	25.5	27.3	28.3	32	27.3	28.8	34	33	32.4	44.3	28.8	35.2	27	35.4	35	30.6	28.8	45.5
Covered area divided by the number of people	38.3	57.5	30.6	57.8	39.9	33.7	43.8	42.7	48.4	38.1	56.2	37.2	41.8	34.7	33.3	45.3	36.6	30.9	38.3
10.4 Disposing treated timber offcuts correctly																			
yes																			
no																			
unknown	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
10.6 Provision of a composting bin																			
yes																			
no																			
Unknown	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
10.7 Provision of kitchen-handy recyclables bin																			
yes																			
no																			
unknown	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
11. Water Use																			
11.1 Inclusion of means for water harvesting																			
Able to	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No	Yes	No	No	No
11.2 The inclusion of a composting toilet																			
yes																			
no	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
11.3 Toilet(s) having a flush capacity > 6 litres																			
Yes																			
No																			
unknown	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
11.4 Water reduction devices installed																			
stormwater control methods																			
greywater recycling																			
sink waste disposal unit														yes					
aerated taps																			
low-flow shower roses																			
other																			
not known for any of the above	x	x	x	x	x	x	x	x	x	x	x	x	x		x	x	x	x	x
12. Transport energy																			
12.1 Liklihood of useful public transportation																			
Main, **N**on-Main, **R**ural locality	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M
12.2 Likelihood of public transport use																			
less than 250m (very likely = high)		x				x						x						x	x
less than 500m (likely = medium)	x							x		x				x					
more than 500m (unlikely = low)			x	x	x		x		x		x		x		x	x	x		
13. More sustianable materials																			
13.1 Percentage of sustainable managed timber	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50
13.2 Sealing of all engineering board, if used																			
unknown	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
13.3 Low environmental impacting paints																			
unknown	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
13.4 Low environmental impacting finishes																			
unknown	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
13.5 Low impacting carpets																			
yes																			
no																			
unknown	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
13.6 Low environmental impacting insulants																			
no	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
13.7 Other low impacting products																			
unknown	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
13.8 Locally sourced recycled building material																			
yes																			
no	x	x	x	x														x	
unknown					x	x	x	x	x	x	x	x	x	x	x	x	x		x
13.9 Using well managed untreated timbers																			
Yes		x																	
No				x	x		x			x	x	x	x	x	x	x	x		
unknown	x		x			x		x	x									x	

APPENDIX E: LIFE-CYCLE COSTING OF EXTERIOR CLADDING

The following procedure was used to determine the most likely life-cycle cost of wall and roof claddings, as a way of providing a representative economic indicator which is verifiable and credible. The life-cycle costing for these two building elements has been expressed as an equivalent annual cost, consisting of the initial cost plus the maintenance costs for roofing and wall materials. The most likely maintenance regimes were chosen as a basis for assessment, rather than the optimum regime. This means that the maintenance regime is not always the cheapest option. The analysis method adjusts for the different life span of the materials by determining the cost per year of the product. The analysis assumed average values for material durability, exposure conditions and quality of workmanship.

The tables below are based on the work of Page (1997).

Table 18: Wall cladding life-cycle costing

WALL CLADDING Material type	Annual $/m^2$	COST ranking
Concrete block masonry	4.66	low
Clay brick	7.67	med
Radiata weatherboard	10.3	high
Cedar	9.17	high
Fibre-cement WB	4.67	low
Fibre-cement sheet	8.15	high
uPVC Board	6.22	med
Plywood	4.26	low
EIFS	7.15	med
Stucco	7.11	med
Aluminium clad timber	3.93	low

Notes for both tables:

1. Salvage and disposal costs have been ignored – as these are considered to be small in relation to the other costs.
2. Transportation costs are not included, as averages were unknown at the time of writing.
3. An 8% discount value was used (all costs are 1997 figures, which are **relatively** applicable to 2004/2005 figures).
4. Thermal performance effects were not accounted for – as it is considered elsewhere in the NOW House framework.
5. The 'high/medium/low' figures are based on a simple linear scale.

Table 19: Roof cladding life-cycle costing.

ROOF CLADDING Material type	Annual $/m^2$	COST ranking
Concrete tile	3.92	low
Concrete shingles	4.65	low
Galv corrugated steel	4.84	low
Pre-painted galv steel	3.78	low
Aluminium corrugated	6.59	low
Metal tiles, aggregate coat	4.05	low
Metal tiles, factory coat	3.68	low
Timber shingles, cedar	8.05	med
Fibre-cement shingles	7.65	med
Glass reinforced polyester shingle	5.3	low
Slate butyl rubber	14.56	high
Fibre-cement, corrugated	8.07	med
Butyl rubber membrane	9.68	med
EDPM	11.55	high

APPENDIX F: SPACE AND HOT WATER HEATING METRICS

Part A: Energy use for space and hot water heating

Table 20: Estimated space and hot water heating.

House Number	Space Heating Energy Use (kWh/year)	HL current (W/°C)	HL reference (W/°C)	Number of occupants	Habitable Area (m^2)	Space Heatg reqd per person (kWh.pp)	Heating reqd kWh per habitable area (m^2)	HWC Energy Use (kWh/yr)	TOTAL Energy Use (kWh/year)	TOTAL Energy Use per person (kWh)
1	**2431**	359	365	4	116	608	21	**2600**	5031	**1258**
2	**2082**	335	323	4	102	521	20	**?**	?	**?**
3	**2213**	318	317	3	109	738	20	**?**	?	**?**
4	**1899**	321	308	4	113	475	17	**2600**	4499	**1125**
5	**3120**	456	477	5	160	624	20	**?**	?	**?**
6	**3051**	422	456	6	164	509	19	**3700**	6751	**1125**
7	**2876**	493	496	5	144	575	20	**3100**	5976	**1195**
8	**2703**	434	422	4	135	676	20	**2600**	5303	**1326**
9	**2669**	411	413	4	133	667	20	**2600**	5269	**1317**
10	**2729**	489	491	5	162	546	17	**3100**	5829	**1166**
11	**3206**	452	486	4	177	802	18	**2600**	5806	**1452**
12	**2176**	291	225	4	115	544	19	**2600**	4776	**1194**
13	**2748**	374	508	5	176	550	16	**?**	?	**?**
14	**3202**	463	483	6	162	534	20	**3700**	6902	**1150**
15	**3116**	552	543	5	178	623	18	**?**	?	**?**
16	**2653**	389	397	4	140	663	19	**2600**	5253	**1313**
17	**3096**	465	488	5	153	619	20	**3100**	6196	**1239**
18	**2737**	461	424	5	144	547	19	**?**	?	**?**
19	**3207**	467	462	4	182	802	18	**2600**	5807	**1452**
NOW	**1067**	250	400	4	124	267	9	**2600**	3667	**917**

Explanation of terms:

HL – heat loss of thermal envelope

Number of occupants – assumed to be the number of bedrooms plus one

Habitable area – the area encased by the thermal envelope (i.e. usually the house area minus the garage area)

HWC – hot water cylinder.

NOTE: Table 20 was derived using a combination of ALF3 (for the space heating requirements) and the Household Energy End-use Project data (for the water heating information – see Table 2).

Part B: CO_2 emissions from space and hot water heating

Table 21 details CO_2 emissions estimations for each of the 19 assessed REF Houses based on space and hot water heating energy use only. The CO_2 emissions by fuel type figures in Table 22 are derived (and averaged) from various sources including Alcorn (2003), Vale (2004), Nebel (2004) and the IPCC (1997).

Table 21: Estimated space and hot water related CO_2 emissions.

House Number	Space heating CO_2 (kg CO_2.per household)	Space heating emissions per person (kg CO_2 /person)	HWC heating CO_2 (kg per household)	HWC heating CO_2 (kg per person)	TOTAL CO_2 emissions per household (kg per hh)	TOTAL CO_2 emissions per person (kg per person)
1	1621	405	1734	434	3356	839
2	1667	417			?	?
3	1476	492			?	?
4	1267	317	1734	434	3001	750
5	2081	416			?	?
6	2035	339	2468	411	4503	750
7	1918	384	2068	414	3986	797
8	1803	451	1734	434	3537	884
9	1780	445	1734	434	3514	879
10	1820	364	2068	414	3888	778
11	2138	535	1734	434	3873	968
12	1451	363	1734	434	3186	796
13	1833	367			?	?
14	2136	356	2468	411	4604	767
15	2078	416			?	?
16	1770	442	1734	434	3504	876
17	2065	413	2068	414	4133	827
18	2740	548			?	?
19	2140	535	1734	434	3873	968
NOW	788	197	1734	434	1222	306

Table 22: Estimated CO_2 emissions by fuel type.

Fuel Type	kg CO2/kWh delivered	kg CO2/MJ delivered
Electricity	0.67	2401
Gas (mains)	0.19	684
Gas (LPG bottled)	0.22	792
Coal	0.36	1296
Diesel	0.25	900
Fuel wood*	0.13	468

*Fuel wood emitted CO_2 is difficult to estimate as it depends on many variables. Currently there is no New Zealand agreement on this figure by New Zealand experts, but it is generally recognised that even this source of energy should not be tagged as 'fuel neutral'. An average figure was finally decided, as an indicative-only figure.

APPENDIX G: POST-OCCUPANCY SURVEY COVER LETTER

COHFE
Centre for Human Factors and Ergonomics

BRANZ
BUILDING ON KNOWLEDGE

<date>

<address>

<name>

Re: Survey of Sustainable Features in New Auckland Housing

The Building Research Association of New Zealand (BRANZ Ltd) and Forest Research are conducting interviews on domestic sustainable (i.e. environmental, social and economic) features with people who are dwelling in recently completed homes in the greater Auckland area.

These interviews are part of a research project funded by the New Zealand Government through the Foundation for Research, Science and Technology, designed to find out more about resource (i.e. energy, material and water) use in new homes. A more detailed overview of the project is provided with the attached press release.

Your house was randomly selected as one of 20 recently built houses in the Auckland region, and has been already studied from consent plans prior to purchase. We would very much like to now come and conduct an interview with yourself or another adult household member to complete the study. The interview takes about 20 minutes, and can be at any convenient time to suit you. We shall be interviewing in December before the Christmas break. In recognition of taking up your valuable time, all households that help with the interviews will receive a $50 petrol voucher.

If you are happy to take part, please add your contact details to the attached form and return in the stamped addressed envelope provided by the 6th December. Alternatively, you can email us at dave.moore@cohfe.co.nz

Dave Moore will ring you closer to the time to arrange an interview time. If you have any questions about the project, please do not hesitate to call us on the phone numbers below.

Regards

Dave Moore
Senior Researcher
Centre for Human Factors and Ergonomics **Forest Research**
Ph 09 415 9026 Mob 025 290 6954

Roman Jaques
Sustainable Building Scientist
BRANZ Ltd
Ph 07 839 5360

APPENDIX H: POST-OCCUPANCY SURVEY QUESTIONNAIRE

(Over Page)

Sustainability aspects of recently constructed houses in Auckland

Project SF1.2 (Stage 2)

Date: Code:

This questionnaire is being conducted by BEACON – a research group whose aim is to greatly improve the housing stock of New Zealand by better understanding house design and living. If you would like to find more about our project, please go to www.nowhome.co.nz

Information from this survey will be kept confidential by the researchers, with the results being combined and summarised.

Queries:
If you have any questions relating to this survey, please contact either:

Dave Moore, **Forest Research**, ☎ 09 415 9026.
OR
Roman Jaques, **BRANZ** Ltd, ☎ 07 839 5360

A. Background

1. How many people live in your household usually? *(Please state number)* _____________

B. Energy Use

1. What is your main type of hot water cylinder? *(Please tick one)*

   [ ] gas (AGA 1 Star OR AGA 2 star)

   [ ] electric (A grade OR B grade)

2. Where is it located within the house? *(Please tick one)*

   [ ] Inside [ ] outside

3. Do you have a solar hot water heater? *(Please tick one)*

   [ ] Yes [ ] No

4. Do you have an outside clothes-line? *(Please tick one)*

   [ ] Yes [ ] No

5. Do you have energy saver bulbs for the majority of lighting in the kitchen/entry/dining/other area _____________? *(Please tick/state appropriate areas)*

6. How well is this house positioned for sun access during winter? *(Please tick one of the following)*

   [ ] house shaded throughout entire winter
   [ ] house loses sun in late afternoon/early morning
   [ ] house never shaded during winter

C. Air Quality

1. Do you have air vents (i.e. grills) built into your window frames or elsewhere? *(Please tick one)*

   [ ] Yes [ ] No

2. Do you have extractor fans in your:

   Bathroom [ ] Yes [ ] No *(Please tick one)*
   Kitchen [ ] Yes [ ] No *(Please tick one)*
   Laundry [ ] Yes [ ] No *(Please tick one)*

3. If so, are they all vented to the outside/garage?

   Bathroom [ ] Yes [ ] No *(Please tick one)*
   Kitchen [ ] Yes [ ] No *(Please tick one)*
   Laundry [ ] Yes [ ] No *(Please tick one)*

4. Do you have carpet in your:

   Bathroom [ ] Yes [ ] No *(Please tick one)*
   Kitchen [ ] Yes [ ] No *(Please tick one)*
   Entry-way [ ] Yes [ ] No *(Please tick one)*

5. Is your house situated within 100 m of a petrol station?

   [ ] Yes [ ] No *(Please tick one)*

6. Is your house situated within 500 m of an industrial site? *(Please tick one)*

   [ ] Yes [ ] No [ ] Don't Know

D. Fire Safety

1. Have (stand-alone or other) smoke alarms/detectors been installed at appropriate locations?

   [ ] Yes [ ] No *(Please tick one)*

2. How are these alarms powered?

   [ ] Standard Battery [ ] Long-life battery [ ] Mains

3. Are they interconnected?

   [ ] Yes [ ] No *(Please tick one)*

E. Safety and Security

1. Are their any external steps on the property (not including entry steps)?
   [ ] Yes [ ] No *(Please tick one)*
2. Is there a cupboard for storing hazardous substances (medicines/sprays/thinners etc) which has a child-resistant lock OR is at least 1.2 m above the floor?
   [ ] Yes [ ] No *(Please tick one)*
3. Are there more than one of these cupboards?
   [ ] Yes [ ] No *(Please tick one)*
4. Are there security lights to the main entry to the house?
   [ ] Yes [ ] No *(Please tick one)*
5. Are there security/safety catches on all vulnerable (i.e. easily reached) windows?
   [ ] Yes [ ] No *(Please tick one)*
6. Have you installed a burglar alarm?
   [ ] Yes [ ] No *(Please tick one)*
7. Do you have boundary fences around the perimeter?
   [ ] Yes [ ] No *(Please tick one)*
8. Are the majority of boundary fences mostly easy to see through?
   [ ] Yes [ ] No *(Please tick one)*
9. Do you have road frontage fencing?
   [ ] Yes [ ] No *(Please tick one)*
10. Is the road frontage fencing low (under 1.2m) OR easy to see through?
    [ ] Yes [ ] No *(Please tick one)*
11. Is there a physical barrier to restrict access to the back of the house?
    [ ] Yes [ ] No *(Please tick one)*
12. Is there a visual barrier to restrict access to the back of the house?
    [ ] Yes [ ] No *(Please tick one)*

F. Materials

1. Has all the particle/plywood/MDF board been sealed?
   [ ] Yes [ ] No (Please tick one)
2. What paints have been used in the interior mainly? (Brand/name?)………………………………………………
3. What paints have been used in the exterior mainly? (Brand/name?)………………………………………………
4. Have any other finishes been used? (e.g. waxes, linseed oil, etc) ………………………………………………………..
5. What carpets have been used? (Brand and name)
   ....
6. What insulation has been used in walls and ceiling?
   Walls (specify Brand)...
   Ceiling (specify Brand)..
   (If unsure, at least specify the colour.)
7. Have any of the materials been locally sourced OR recycled (Either name materials/No/Don't know)
   ....
   ....

G. Other Issues

1. What groundwork was carried out before, during or after construction? *(Please tick one of the following)*
   [ ] only small attempts to reduce silt run-off/use native plantings/retain landforms/minimise impact etc
   [ ] land was previously an industrial site, OR house replaces demolished building
   [ ] a large effort was made to address issues such as landforms/habitat etc using consent documents.
2. Is there a compost bin of at least 1 cubic metre?
   [ ] Yes [ ] No *(Please tick one)*
3. Is there a bin with at least two separate compartments (capacity of at least 20L) for sorting household wastes, within or near to the kitchen?
   [ ] Yes [ ] No *(Please tick one)*
4. Are all your toilets dual (i.e. two-button) flush?
   [ ] Yes [ ] No *(Please tick one)*
5. Are there any of the following water caring-related devices used on site? *(Please tick as appropriate)*
   [ ] storm-water control methods
   [ ] grey-water recycling?
   [ ] aerated taps? (brand name?) ....
   [ ] low-flow shower heads? (brand name?) ....
   ....
   [ ] rainwater storage
   [ ] other?

Thank you for your help.

If you have any further comments on the topics raised, please contact the researchers listed at the beginning of the document.

APPENDIX I: POST-OCCUPANCY SURVEY RESULTS

Table 23: Post occupancy survey results

Thematic Areas and Issues	House Code					
	1	2	3	4	5	NOW
1. Material Life Cycle Costs						
1.1 External Wall cladding lifetime COSTS						
High, **M**edium, **L**ow	M	M	M	M	M	L
1.2 Roof cladding lifetime COSTS						
High, **M**edium, **L**ow	L	L	L	L	L	L
2. Energy Use						
2.1 Space + water heating metrics						
space heating (kWh/yr)	2213	3051	2729	2653	3207	1078
space heating per person (kWh/yr/person)	738	509	546	802	663	270
Hot water heating (net kWh/yr)	2100	3700	3100	2600	2600	780
hot water heating / person (kWh/yr per person)	700	616.7	620	650	650	195
2.2 Heat loss reductions, cf NZBC						
Heat loss (W per degree C) reduced by >35%	no	no	no	no	no	yes
Heat loss (W per degree C) reduced by >50%	no	no	no	no	no	no
2.3 % of hot water needs from renewables	0	0	0	0	0	70
2.4 % of space heating from renewables	0	0	0	0	0	0
2.5 Provision of a clothesline	yes	yes	yes	yes	yes	yes
2.6 Energy efficient lamps in high use areas	no	no	no	no	no	yes
3. Fire safety						
3.1 Smoke alarms provided	yes	yes	yes	yes	yes	yes
3.2 Power source of those alarms?						
Battery	x	x	x	x	x	
Mains						x
3.2 Interconnectedness of the smoke alarms?						
unconnected	x	x	x	x		
connected					x	x
3.3 Are sprinklers used?	no	no	no	no	no	no
4. Indoor Air quality						
4.1 BATHROOM mechanical ventilation						
none		x		x		x
to outside	x		x		x	
4.2 KITCHEN Mechanical ventilation						
none		x				
to roof space						
to outside	x		x	x	x	x
4.3 LAUNDRY Mechanical ventilation						
none	x			x		
unknown (or if in garage)		x	x		x	x
4.5 Carpet in wetter areas						
Kitchens	no	no	no	no	no	no
Bathrooms	no	no	no	no	no	no
Entryways	no	no	yes	no	no	no
5. Noise and Outdoor Air Quality						
5.1 Noise and outdoor air quality indicators						
Adjacent to cul-de-sac	x	x	x			
Adjacent to minor road				x		
Adjacent to arterial road					x	x
Adjacent to a highway						
Adjacent to unsealed road						
5.2 Other factors lessening outdoor air quality						
Close to petrol station	no	no	no	no	no	yes
Close to air polluting industries	no	no	no	no	no	no
5.3 Indoor generated noise						
Bedrooms separate from common areas	no	yes	yes	no	yes	no
Bedrooms adjacent to bathrooms	yes	yes	yes	yes	no	yes

Thematic Areas and Issues	House Code 1	2	3	4	5	NOW
6. Safety						
6.1 External steps						
Yes						
Not needed	x	x	x	x	x	x
6.2 Slope						
Level		x				x
Gentle slopes	x		x		x	
Steep				x		
Terraced						
6.3 Internal Stairs/steps						
None	x	x		x		x
two storey house					x	
garage to house			x			
6.4 Secure cupboards for Haz materials storage	no	no	no	no	no	no
7. Security and privacy						
7.1 Technichal indicators						
Security lights to most entry points	x	x	x	x		x
Safety catches on all vulnerable windows				x		
burglar alarm installed						
7.2 Visual indicators						
Boundary fences are mostly visually permeable	no	yes	no	no	no	yes
Road frontage fencing is low/visually permeable	no	yes	no	no	no	yes
Clearly defined point of access to property	yes	yes	yes	yes	yes	yes
7.3 Access indicators						
Clearly defined point of access to house (door)	yes	yes	yes	yes	yes	yes
Physical barriers restrict access to back of house	yes	no	yes	yes	yes	no
Visual barriers restrict access to back of house	yes	yes	yes	yes	yes	no
8. CO2 emissions from main energy uses						
8.1 CO2 from hot water usage (kg CO2/yr)	1401	2468	2068	1734	1734	520
CO2 emissions per person	467	411	414	434	434	130
8.2 CO2 from space heating usage (kg CO2/yr)	492	339	104	126	152	180
CO2 emissions per person	164	57	21	32	38	45
9. Thermal Performance						
9.1 The usefulness of thermal mass						
Graded from 0=useless to 5 = most useful	0	0	0	0	0	5
9.2 The overall estimated heat loss						
Measured in Watts per degree Celcius	318	422	489	389	467	232
9.3 SNZ PAS 4244 insulation levels						
Code, **Bet**ter, **Best**	C	C	C	C	C	Bet
9.4 Well sized eaves						
eaves ±20% correct size, for Nth windows	yes	yes	no	no	yes	yes
9.5 Well positioned house for sun access						
Low, **m**edium, and **h**igh	h	h	m	h	m	h
9.6 Edge insulation on concrete floor slab	no	no	no	no	no	yes
9.7 House plan is longer in east/west direction	no	no	yes	no	no	yes
9.8 Airlock at entry	no	no	no	no	no	yes
9.9 Airlock at garage	no	no	no	no	no	no

Thematic Areas and Issues	House Code 1	2	3	4	5	NOW
11. Water Use						
11.1 Inclusion of means for water harvesting						
Able to	No	No	No	Yes	No	Yes
11.2 The inclusion of a composting toilet	No	No	No	No	No	No
11.3 Toilet(s) having a flush capacity > 6 litres	yes	yes	yes	yes	yes	Yes
11.4 Water reduction devices installed						
stormwater control methods						yes
greywater recycling						
rainwater storage				yes		yes
sink waste disposal unit						
aerated taps						
low-flow shower roses						yes
Unlikely to have any of the above	x	x	x		x	
12. Transport energy						
12.1 Liklihood of useful public transportation						
Main, **N**on-Main, **R**ural locality	M	M	M	M	M	M
12.2 Likelihood of public transport use						
less than 250m (very likely = high)		x			x	
less than 500m (likely = medium)			x			x
more than 500m (unlikely = low)	x			x		
13 More Sustainable Materials						
13.2 Sealing of all engineering board	no	no	no	no	no	no
13.3 Low impact paints	no	?	?	no	?	yes
13.4 Low impacting finishes	no	no	?	?	no	no
13.5 Low impacting carpets	?	?	?	?	?	no
13.6 Low impacting insulants	No	No	No	No	No	Yes
13.7 Low impacting other	No	No	No	No	No	No
13.8 Locally sourced recycled materials	No	No	No	No	No	No