BRANZ

STUDY REPORT SR 323 [2014]

LEARNINGS FROM THE BRANZ REFURBISHMENTS

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PREFACE

This report is best viewed electronically as it contains a number of hyperlinks to on-line videos and other items. Many of the plots make use of colour scales which may not be accurately represented when printed or displayed on certain devices.

ACKNOWLEDGEMENTS

A large project like the BRANZ refurbishment project involves many people however these acknowledgements relate more specifically to the evaluation of the resulting buildings and is consequently more BRANZ-focussed. Acknowledgements are made to;

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ABBREVIATIONS AND ACRONYMS

BEES	Building Energy End-Use Study; A study of New Zealand non-residential buildings which coincidentally included BRANZ (see www.branz.co.nz/BEES)
DCV	Demand Control Ventilation; A ventilation strategy that frequently includes the measurement of CO_2 in spaces to allow for the ventilation rate to be adjusted appropriately.
BMS	Building Management System; A computer system that provides the control functions and data reporting for the efficient operation of the building.
EIS	Energy Information System; A means of quickly providing energy performance and IEQ information to building users
EnMS	Energy Management System; A set of processes and practices that enables an organisation to reduce its energy use. ISO 50001:2011 is concerned with EnMS's.
EMS	Environmental Management System, A set of processes and practices that enables an organisation to reduce its environmental impacts. ISO14001:2004 is concerned with EMS's.
POE	Post Occupancy Evaluation; A means of providing information on the operational stage of a building. Common techniques include occupant surveys including the BUS methodology occupant survey.
BUS Methodology	Building Use Studies Methodology; An occupant evaluation survey method based on extensive research and developed over many years.
MT & R	Monitoring, Targeting and Reporting; steps that may be included in EnMS or EMS.
M & V	Measurement and Verification, objective assessment methods in considering the merits of an ECM.
ECM	Energy Conservation Measure; Something that is put in place to reduce energy use.
IPMVP	International Performance Measurement and Verification Protocol; an agreed process to measure and evaluate energy conservation and efficiency strategies.
EVO	Efficiency Valuation Organization; The organisation responsible for the IPMVP and related procedures
SWH	Solar Water Heating.

CONTENTS

1. INTRODUCTION

BRANZ refurbished a number of its buildings between August 2010 and March 2012. These refurbishments included construction of a new open plan office building and a rebuild of the main administration building and of the building containing the science laboratories and offices and are briefly outline in Section 3 of this report.

To coincide with this redevelopment, this project was commissioned to monitor and review the performance outcomes achieved by the BRANZ refurbishments. This report is intended to capture some of the experience gained from assessing the impacts of the refurbishments from a resource use and service level provision point of view. This report reviews how energy and water use have altered since the refurbishments as well as how the indoor environments have changed. Key to the success of any measures is the acceptance and attitudes of the building occupants. Therefore the project included an assessment of how the occupants found the refurbished buildings. This report discusses these survey results and documents the approach taken to provide information back to the building users on how the building is operating.

Minimising resource use is a key outcome of a well performing building but it is important that lowering resource use does not comprise the usability of the building to its occupants. For example, you can reduce space heating by having heaters of limited capacity which do not heat the space effectively and is therefore likely to result in dissatisfied building users. This is shown diagrammatically in Figure 1 which shows resource (energy) use on one axis with performance (service) level on the other. A well performing building (the star) could have its energy use below threshold value while its service level is above a minimum acceptance level. A poorly performing building (the cross) may have energy higher than necessary while not adequately providing for the occupants needs.

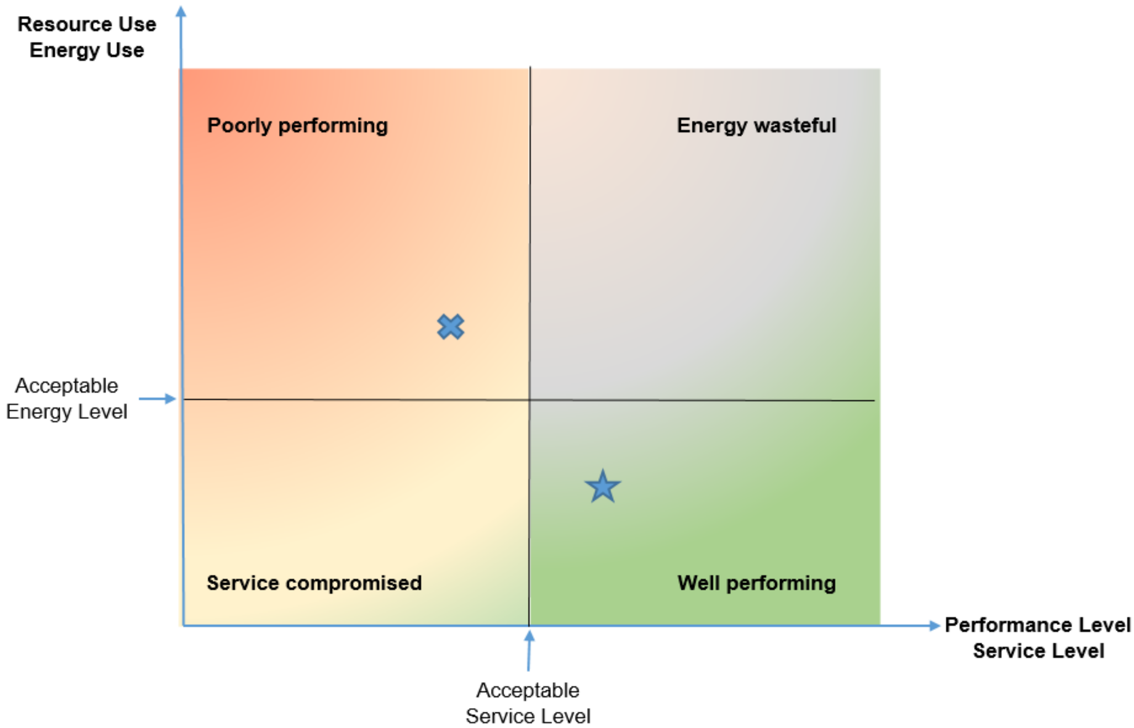

Figure 1 Consideration of both energy performance and service delivery

When the activities within the building are similar to other buildings, energy thresholds or benchmarks can be set which can give an indication of how the building is performing against other similar buildings. Typically when a new resource efficient building is constructed, design energy levels are established and are frequently used as the performance credentials for the building regardless of how many resources the building really uses in practice (Newsham et al., 2009) however there are now emerging operational performance tools such as NABERSNZ which look to assess how the building is performing after construction.

As the BRANZ refurbishments included both office and laboratory areas, it is difficult to determine appropriate energy levels however the framework illustrated in Figure 1 is still useful as general process downwards (reduced energy use) and to the right (improved service levels) is desirable. Monitoring, Targeting and Reporting (MT & R) are key components of energy and environmental management systems. BRANZ has an Environmental Management System (EMS) which includes tracking of resource use and is a member of the Enviromark scheme which provides the essential external auditing for such a system.

In this report, Section 4 discusses resource use and management in general with Section 5 discussing energy use and Section 6 water use in more detail.

The horizontal axis in Figure 1 is concerned with the service level achieved. This axis is less clearly defined than the vertical axis as it does not directly relate to a physical measurement. The axis could be, for example, the proportion of the time the indoor environment of the building is within a range that the majority of building occupants find it acceptable. Section 7 of this report looks at the amount of time the indoor temperatures within the office areas are within the 18-24°C range before and after the refurbishments.

In addition to quantifying the service level of the building by measuring a range of indoor environmental parameters, the achieved performance level of the building can also be established by directly asking the building occupants themselves. Section 8 of this report introduces the BUS methodology which is a standardised occupant evaluation survey.

The final section of this report (Section 9) outlines the approach taken at BRANZ to provide feedback to the building occupants on how the building is operating using measurements from the Building Management System (BMS) system.

The following section (Section 2) provides a summary of this report and provides a series of recommendations for others involved in evaluating energy conservation measures in buildings.

2. LEARNINGS AND RECOMMENDATIONS

ENERGY USE

The refurbishments provided an opportunity to improve the energy performance of a number of key building services. The resistive electrical heaters throughout the Totara and Rimu buildings have been replaced with radiators feed from a wood pellet burner. The electric water heating in the Totara building was also upgraded to include a Solar Water Heating (SWH) system.

Measuring the change of energy use since the refurbishments is difficult. The original Totara and Rimu buildings did not include separate electricity meters before the refurbishment which could have been used in a long-term before and after analysis. In order to get a long-term data set before the refurbishment it was necessary to consider the project boundary as the energy use for the entire site and use the billing records to track changes in energy use. Measuring the energy use for the whole site makes it difficult to attribute changes in energy use to an Energy Conservation Measure (ECM) that only impacts on a smaller part of the overall energy use. The energy use after the refurbishments also included additional energy types; wood pellet use and solar energy contributing to the SWH system but excluded energy types not used in the refurbished buildings such as diesel (used for vehicles) and gas (used in the laboratories).

Recommendation: It is important to define the monitoring and measurement boundaries appropriately so that additional activities (such as additional buildings, or laboratories) are kept to a minimum.

The energy use within the refurbished buildings is now measured at each electrical distribution board. The data from these electricity meters are feed into the Building Management System (BMS). This will enable future assessments to consider smaller project boundaries (ie examine one building) to allow for more precise estimates to be made of the impacts of particular ECMs.

Recommendation: As part of any current work, ensure that opportunities are taken (such as installing sufficient meters) to allow for future assessments to be made.

The BMS also includes information on the heated water from the pellet burner. Data on the other component of energy use, the solar energy for the SWH system, can be extracted from the Splash monitoring website. The management of the data from these systems was more involved than expected and has limited how much information can be provided to the BRANZ Environmental Management System (EMS).

Recommendation: It is important to ensure an effective data management process is used with building data to ensure that the Monitoring Targeting and Reporting (MT & R) process does not get unnecessarily slowed down.

WATER USE

The BRANZ water use before the refurbishments was very high due to a number of a problems however the refurbished Totara building is currently achieving a good level of water performance.

As water use becomes under greater focus, the building industry needs to support building users wishing to better understand their water use which will allow better identification of water efficiency and conservation strategies. Retrofitting water meters to an existing BRANZ site required much time to be spent on locating pipes and undertaking extensive excavations and consequently was very expensive.

Recommendation: Appropriate levels of water sub-metering should be included in the construction phase to allow water use to be better understood without the need for costly retrofitting of water metering points once the construction has been completed.

Previously it has taken a long time to realise there was a problem with the water distribution on the BRANZ site. Leaks develop over time and the time between meter readings was such that much water was wasted before it was realised there was a problem.

Recommendation: The time between meter readings should be keep short to allow abnormal use, such as leaks, to be more promptly identified.

INDOOR ENVIRONMENTAL QUALITY (IEQ)

Measurements of the achieved indoor environments within a new or recently refurbished building quantifies the levels of performance, the building and its systems is providing. Measurements can provide objective information that can be used alongside energy use data to verify that the new building or upgrade has been successful. Measurements can be made at low cost and can be collected over a short term or a long-term timeframe depending on the required need.

Recommendation: More use of objective data of the service levels achieved in buildings will allow for better understanding of building operation.

The temperatures during winter in the Rimu building before and after refurbishment were similar during the working week daytime but outside of this period the old Rimu building cooled down considerably reaching 6.3°C at times. After the refurbishments the temperatures in the Rimu building remained above 15.9°C.

The higher insulation performance levels and use of double glazing throughout the refurbished Rimu building was seen to significantly reduce the heat loss out of the building providing better temperature control and requiring less heating.

The summer and winter temperatures throughout Nikau and the refurbished Rimu and Totara buildings was broadly within good operating ranges however some summertime overheating was seen in the North side of the Rimu building.

CO_2 MEASUREMENT

A number of CO_2 sensors were installed to examine the ventilation within the refurbished buildings. Unfortunately the type and quality of the CO_2 sensor proved inadequate and reliable measurements were not possible.

Recommendation: It is important to ensure that building sensors are providing suitable information so that control systems based on their output will operate as expected.

OCCUPANT EVALUATION

The feedback of people's experiences to the buildings they occupy is important for the construction industry to capture so that lessons can be learnt and future buildings be improved from a building user's point of view. Greater use of occupant evaluation, using standardised surveys such as the BUS methodology, would allow the construction industry to achieve better outcomes.

Recommendation: More use should be made of standardised occupant evaluations, such as the BUS methodology, so that occupant evaluation is better recognised and profiled within the building industry.

A standardised BUS methodology occupant survey was undertaken in the new Nikau, Totara and refurbished Rimu buildings as well as the old Kauri building.

The design of the new Totara building scored highly as it did for functionality. Interestingly the old 1970's Kauri building also scored well on functionality, perhaps indicating that an effective working space can be still be achieved within an old building. The Nikau building scores well on Design, Lighting and Temperatures in Winter; but struggled in some of the other areas which provided guidance on how to improve the working environment within this newly constructed building.

DISPLAY OF BUILDING PERFORMANCE

A display of the building performance (Energy Information System) can provide useful means to engage the building occupants and visitors to the building with how resources the building is using, what sort of performance levels are being achieved as well as how the various systems are operating within the building.

Recommendation: Energy Information Systems should be easy to understand and provide sufficient information to building occupants to allow them to understand how the building is operating.

Recommendation: The data from an/ Energy Information System should be able to be easily accessed in a convenient format.

3. REFURBISHMENT OUTLINE

BRANZ's laboratories and offices are located on a campus at Judgeford, Porirua. An aerial photograph looking south, identifying the main buildings prior to the refurbishment, is shown in Figure 2. The main administration building (Totara), science building (Rimu) and workshops at BRANZ were constructed around 1978 and form the main buildings east of the creek dividing the BRANZ campus. West of the creek are the Fire and Structures labs, a number of standalone research buildings as well as two office buildings (Kauri and Matai).

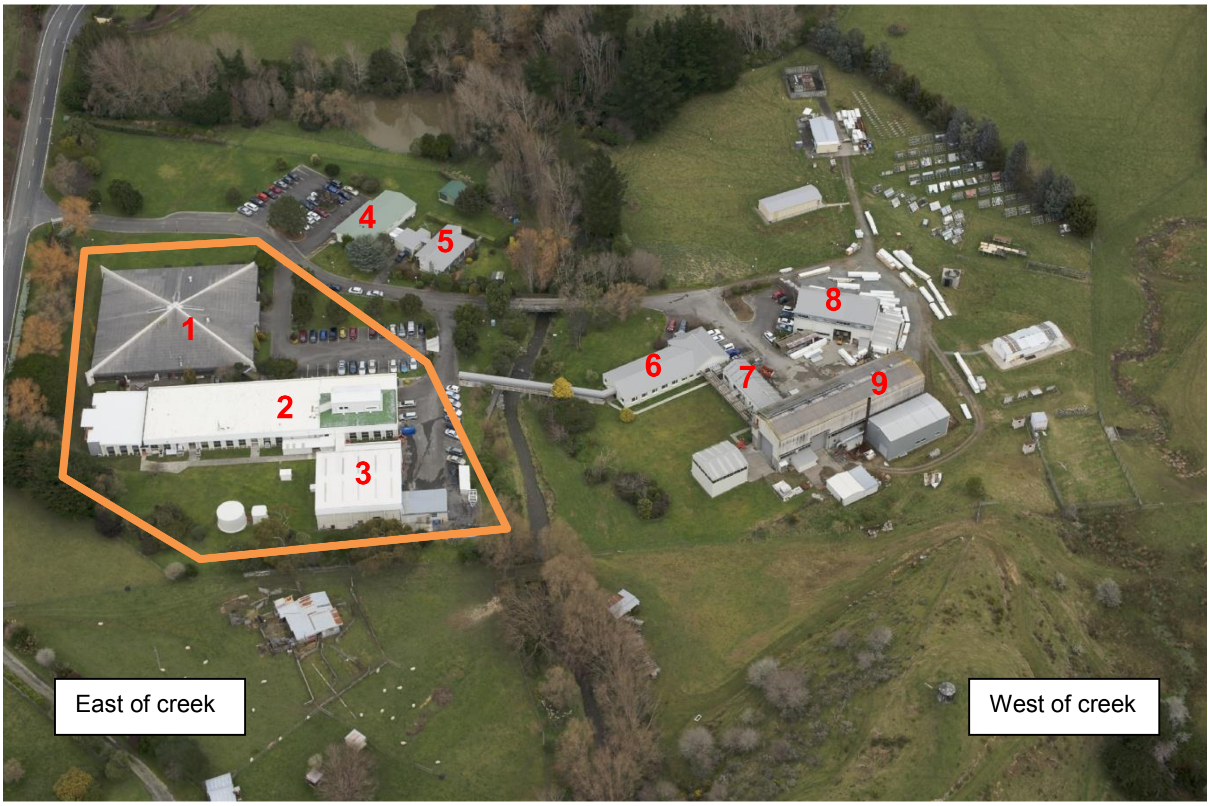

Figure 2 Aerial view of the BRANZ campus prior to the refurbishment. The buildings involved in the refurbishment are shown with an orange outline. The main buildings are

1. **Main administration (Totara),**
2. **Science offices and labs (Rimu)**
3. **Workshop**
4. **Prefab offices**
5. **Caretakers house**
6. **Offices (Kauri)**
7. **Offices (Matai)**
8. **Structures labs**
9. **Fire labs**

The refurbishment project sort to upgrade the Totara, Rimu and Workshop buildings (within the orange outline in Figure 2). A plan view of the functional areas of these buildings immediately before the refurbishments is shown in Figure 3.

The Totara building was a square building with largely single occupied offices around the perimeter. Central areas included the library, meeting rooms, the cafeteria, the reception area, copier rooms, toilets and general storage areas. The need for additional office areas in later years, was accommodated by converting areas in the library and cafeteria into offices.

The Rimu building comprised of offices on the north side with one or two person offices on the south. A later extension to the east provided for additional offices and an additional meeting room.

The Workshop building contained the electronics workshop, timber and metal workshops. Areas on the west side of the building were later converted into a concrete laboratory. There were five one or two person offices on the mezzanine floor.

Figure 3 Functional areas of the Totara, Rimu and Workshop buildings prior to the refurbishment.

The refurbishment provided an opportunity to;

1. Provide a modern look
2. Improve the functionality of the offices, creating more open plan, team work areas
3. Provide a demonstration of the structural timber construction method in the Nikau building.
4. Reconfigure the laboratory space to better match needs
5. Removal of the asbestos roofing
6. Relocate staff located in a disconnected small office building
7. Provide a good level of environmental performance through the use of
    a. Higher insulation levels
    b. Double glazing
    c. Radiator heating system feed from pellet boiler

d. Natural ventilation
e. Solar water heating
f. Improved daylighting and lighting controls
g. Solar shading on west windows
h. Improved data on energy and water use of the buildings

The refurbishment agreed to the BRANZ board in 2009 and a competitive tender process was won by Warren and Mahoney Architects with Fletcher Construction (Roberts, 2011). Construction began in August 2010 and concluded with the official opening in March 2012.

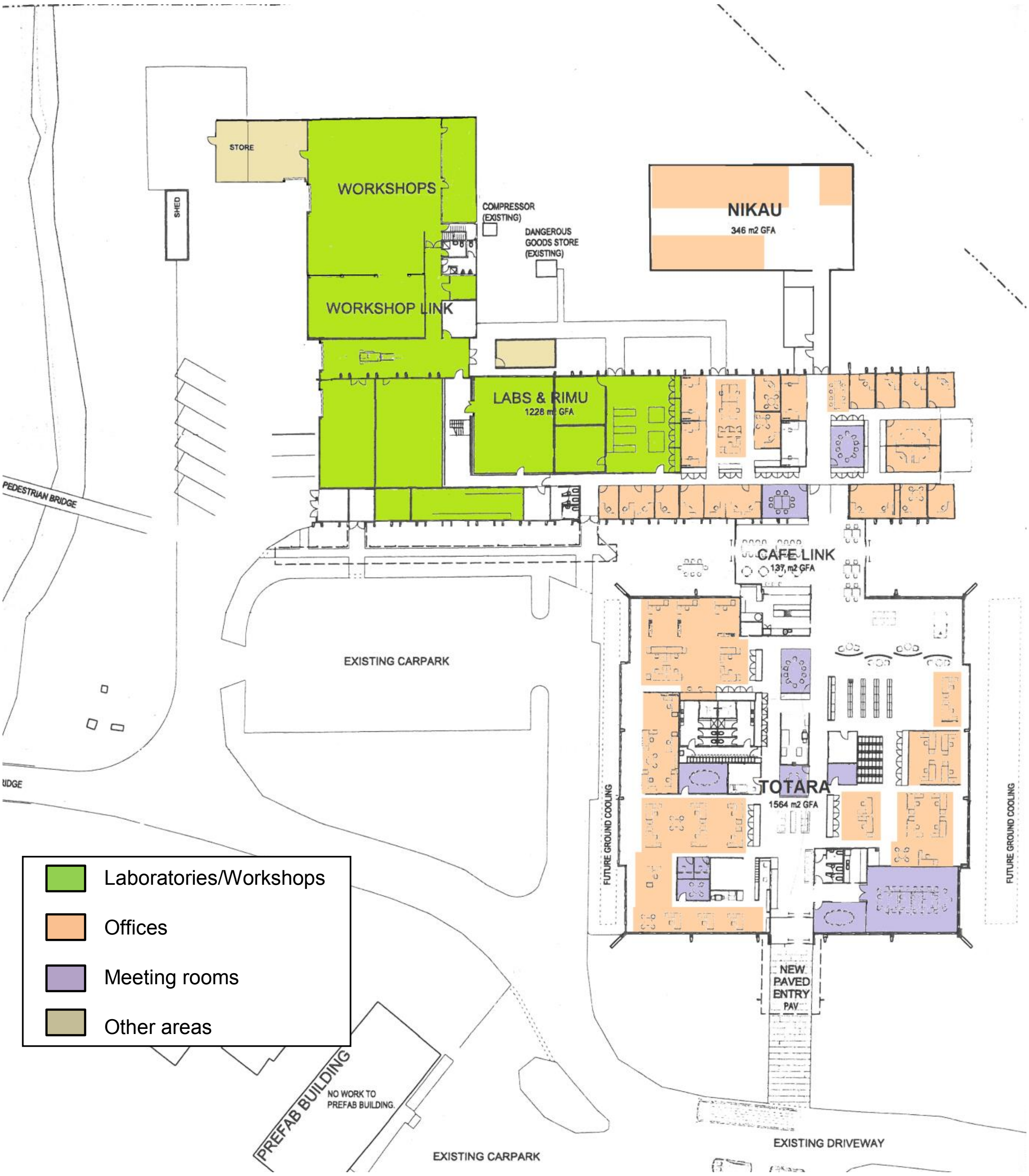

Figure 4 New and refurbished buildings indicated functional areas.

The reconfigured layout of the refurbished buildings is shown in Figure 4. The new structural timber building (Nikau) was the only new building constructed being located to the North of the Rimu building. Details of its construction can be found in the BUILD magazine article by McGechie (2011). Nikau is used as an open plan office area for a number of technical groups of BRANZ staff who previously occupied the Rimu and Totara buildings.

The Workshops and Rimu building were internally deconstructed with large sections of the exterior envelope redeveloped. The external electronics workshop attached to the main workshops was removed to allow for Rimu and the Workshops to be linked. The office configuration for Rimu was re-established with a greater number of double occupancy offices in the east half of the building. The offices in Rimu are occupied by the Building Performance team who use the laboratories and the Sustainable Built Environment team who was previously housed in the Prefab building to the South of Figure 4 which subsequently is used for storage.

The Totara building was stripped back to the foundation slab and main superstructure. The redeveloped Totara building features a large passive ventilation chimney at its centre with large open workspaces arranged predominantly around the perimeter of the building. The Totara building includes a number of smaller meeting spaces but does not include any separate offices. A visual look through the Totara building is available from this link.

The target performance level for the redeveloped buildings was to achieve an equivalent performance to a 4-star Green Star office rating. An actual Green Star rating for the redeveloped buildings was not possible as a number of laboratory spaces were including within the buildings. Since this project began the operational performance tool NABERSNZ has also become available but again this tool is for office buildings.

Lynda Amitrano, Appraisals and Environment Manager at BRANZ, profiles the sustainability features of the refurbishments in this video. If this link is not assessable to you, such as you are reading a hard copy version of this report, then you can access this video by scanning the QR code to the right on appropriately equipped smart phones and mobile devices.

4. RESOURCE USE

Over the last few years, BRANZ has also looked to improve its environmental practises. Don Richards, BRANZ's existing Quality Manager, took on the added responsibility as Environmental Manager and began to formalise an Environmental Management System (EMS) for BRANZ. This has included the development of an environmental policy and Monitoring, Targeting and Reporting (MT & R) of a number of environmental factors including resource use and publishing the tracking of these measures on the BRANZ website (http://www.branz.co.nz/environmental_performance). The EMS is externally audited by Landcare's Enviro-Mark scheme in which BRANZ has achieved the highest level possible (Diamond) in 2009. This is equivalent to BRANZ being certified to ISO 14001:2004.

The ISO system management standards (which include ISO14001, and ISO9001) have recently been expanded with the development of ISO50001:2011 which provides guidance for organisations to establish, implement, maintain and improve Energy Management Systems (EnMS).

The difficulty with EnMS's is in attributing the change of energy use due to the Energy Conservation Measures (ECMs) applied. An EnMS essentially measures the energy not used due to the ECMs. A simple example of this is given in Figure 5, which is taken from the International Performance Measurement and Verification Protocol (IPMVP) (EVO, 2012). The IPMVP provides an extensive guidance to Measurement and Verification (M & V) of ECMs which is at the core of Energy Management Systems.

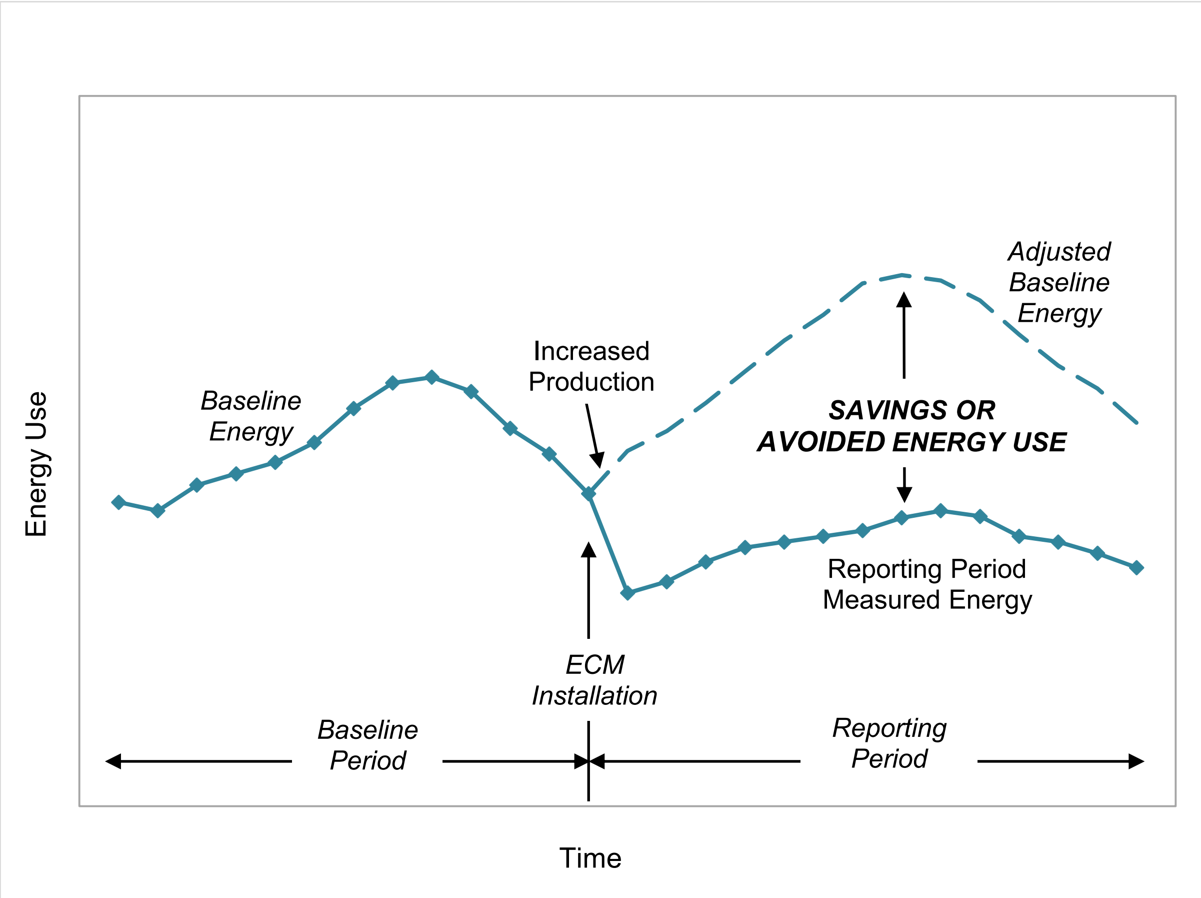

Figure 5 Evaluation of the energy savings due to an ECM. (taken from EVO, 2012)

It is also important to establish the scope of the resources used so that an accurate picture can be made of how this has changed due to the ECMs. The focus for assessing the resource-use of the BRANZ refurbishments has been to consider the operational phase of the various buildings before and after the refurbishments.

Water use is becoming an increasing important issue as growth in urban water demand has placed strains on supply networks. During the original development of the BRANZ site in the 1970's less of a focus was played on water demand management and few additional water metering points were included. Since the mid-2000's, BRANZ has looked to improve its water use by having more timely information on water use, more metered locations, better identifying leaks and undertaking water audits to better understand the nature of the water use. As there is little historical information of the water use specifically for the new and refurbished buildings, this assessment will focus on broader BRANZ-wide water use issues over period when the refurbishments were undertaken and is provided in Section 6 of this report.

The other major resource use is energy. Like water, the energy use was not always separately identified, however overall BRANZ use was available.

Before the refurbishments, the energy use within the office buildings was electricity, with the heating system being predominantly electric panel heaters which are still used in the Kauri building. The electricity was not recorded separately for each of the buildings and is only recorded collectively for the overall site.

The Fire labs used Diesel and later Gas to fuel the furnace used for testing and research but this, like the Petrol and Diesel use of the BRANZ vehicles, are excluded from this analysis as the refurbishment did not impact on these uses.

The new Nikau and refurbished Rimu and Totara buildings replaced most of the electrical heating with a radiator heating system which was feed from a wood pellet boiler (see Figure 6). A solar water heating (SWH) system (see Figure 7) also contributes to the energy mix in the new buildings. In addition to the new building additional electricity meters were installed as part of the Building Management System (BMS) to record the electricity use within each area of the refurbished buildings in more detail.

There are problems comparing the before (total site electricity) and after (total site electricity, pellet use and SWH) energy use for the BRANZ site;

1. The total site electricity also includes the Kauri building as well as the Fire and Structures Labs which mean that differences between before and after can be affected by changes of use in these other areas.
2. Changing levels of performance for the services. The old electrical heating system did not work very effectively and should not be directly compared to a system that is delivering a more improved service.
3. Services have been shifted from one energy type to another. Comparing electricity alone is not meaningful as before the refurbishment the electricity included all the heating while after the refurbishment it did not.

The greater disaggregation of the energy data after the refurbishments will however be useful for assessing specific ECMs applied to particular areas of the buildings in the future. Energy use is discussed further in the next section.

Figure 6 The new wood pellet boiler (left) and the hopper (centre)

Figure 7 The Solar Water Heating panels on the Rimu building

5. ENERGY USE

This section looks at the measurement of energy use at BRANZ.

The refurbishments has provided an opportunity to improve the energy services through replacements of energy inefficient systems, the resistive electrical heaters throughout the Totara and Rimu buildings has been replaced with radiators feed from a wood pellet burner. Likewise, the electric water heating in the Totara building now includes solar water heating.

Energy use can be measured in a number of different ways with Table 1 providing a listing of those undertaken before and after the refurbishments. The broadest measure of energy use are identified in Table 1 by the use of *italics* and are usually taken from billing records how this has changed over time is shown in Figure 8.

For the electricity, consumption figures for the site are provided from the electricity retailer on a monthly basis. This electricity use if for the whole site and includes energy use from intensive testing undertaken in the laboratories. Only a proportion of the electricity use is due to the Totara, Rimu and Nikau offices.

For the solid fuel heating system, the wood pellets were delivered by truck in bulk at irregular intervals. The energy content of the wood pellets can be calculated from their calorific value however the weight of pellets burnt over a certain interval is not known. For Figure 8, the energy content of the load delivered is evenly distributed over the time until the delivery is made. This method does not reliably attribute the energy use to when it was used and will include anomalies such as averaging high usage at the end of the winter with little or no usage over the spring and summer.

The broadest measure of the energy for solar water heating is to measure the quantity of solar energy falling on the solar panels. Monthly solar radiation data was adjusted for the size (16m^2) and angles on the panels.

These broad measures are also gross energy measurements in that only a proportion of that energy is available for other purposes. For example, the solar radiation incident on the solar panels cannot be 100% utilised to reduce water heating loads as solar thermal systems are of the order of 40% efficient at converting solar energy into water heating.

In order to refine these estimates or to consider how energy is delivered by a particular energy service or to different buildings, additional measurements are required. The Building Management System (BMS), discussed further in Section 5.1, provides data on all of the electricity meters covering the refurbished buildings. The BMS also provides information of the heated water provided by the pellet burner. Further information on the energy use of the Solar Water Heating (SWH) is available from the Splash monitoring system.

Table 1 Types of energy information before and after the refurbishments

Before Refurbishment			After Refurbishment		
Type	Coverage	Frequency	Type	Coverage	Frequency
Electricity: revenue meter	*Site wide*	*Monthly*	*Electricity: revenue meter*	*Site wide*	*Monthly*
Electricity: TOU meter	Site wide	½ Hourly	Electricity: TOU meter	Site wide	½ Hourly
Electricity: BEES	Totara, Rimu, Kauri, Prefab offices	Temporary 1 minute	Electricity: BMS meters	Totara, Rimu, Nikau	15 Minute
			Solid fuel: Pellet deliveries	*Totara, Rimu, Nikau*	*Irregular*
			Solid fuel: BMS heat flow	Totara, Rimu, Nikau	15 Minute
			SWH: Solar energy	*Totara*	*15 Minute*
			SWH: Thermal energy	Totara	15 Minute

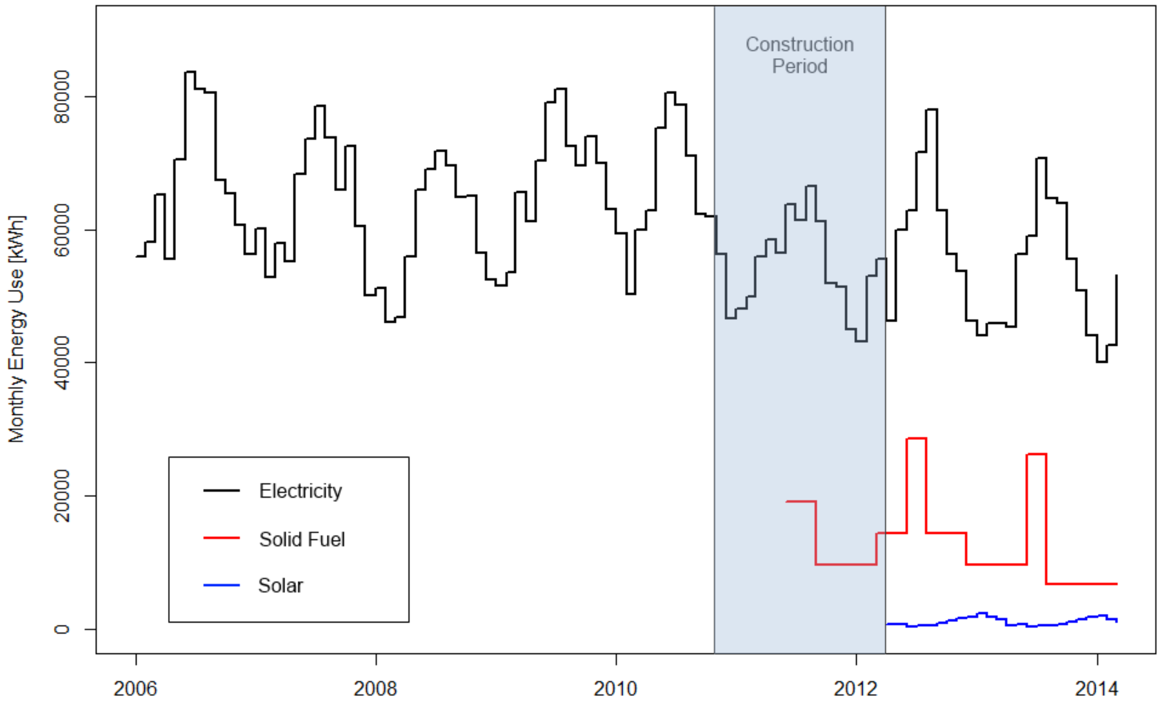

Figure 8 Total BRANZ energy use before and after the refurbishments

5.1 Building Management System

One of the key elements to improve the operation and energy use of the refurbishments was a Building Management System (BMS). This system provides:

- measured data on a wide range of building parameters including electricity use
- control over the various services (such as the heating, ventilation, lighting, etc)
- ability to vary temperature setpoints in the different areas
- information on how the buildings are operating via a screen in the reception area (see Section 9)

This system was supplied by Building Automation Services (BAS) as part of the construction contract. This system operates via a secure interactive webpage. Figure 9 and Figure 10 give example screenshots of temperatures within the various heating zones within the new and refurbished buildings, showing by a colour scale those parts of the buildings that have yet to reach the heating setpoints (screenshots were taken on a cold winter morning).

The data from the BMS system will be useful in the future to provide a much more targeted assessment for energy conservation measures such as they applied specifically to individual buildings, for example, to set benchmarks for the Totara office building.

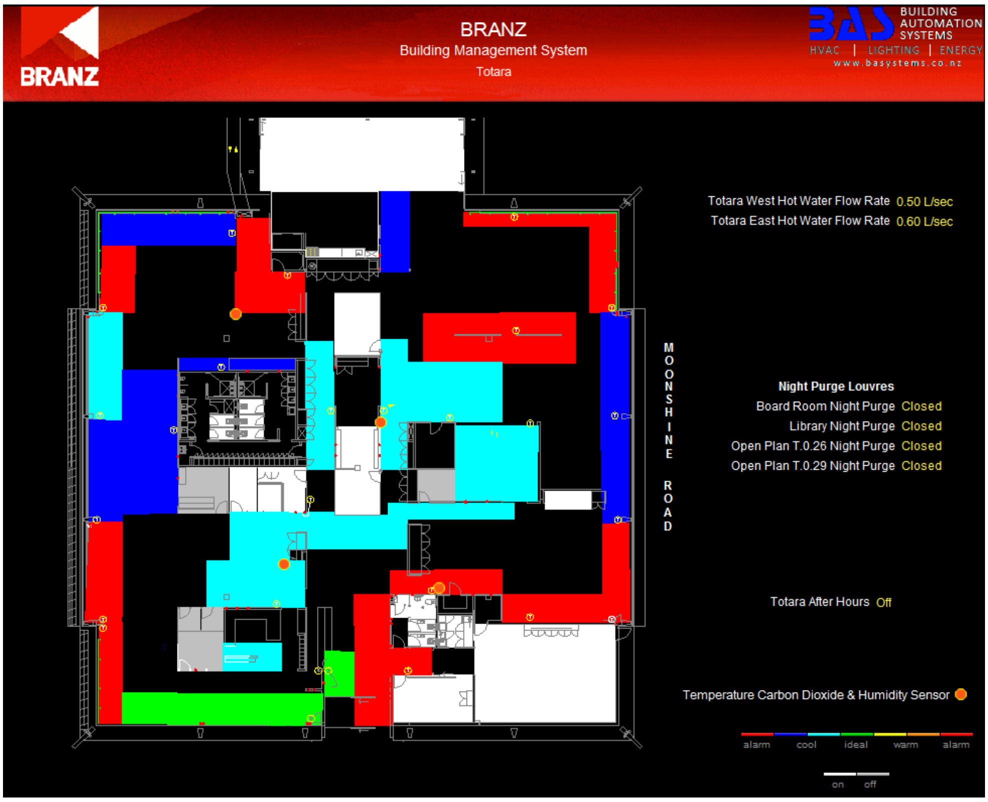

Figure 9 Environmental conditions screen for Totara from the BMS system

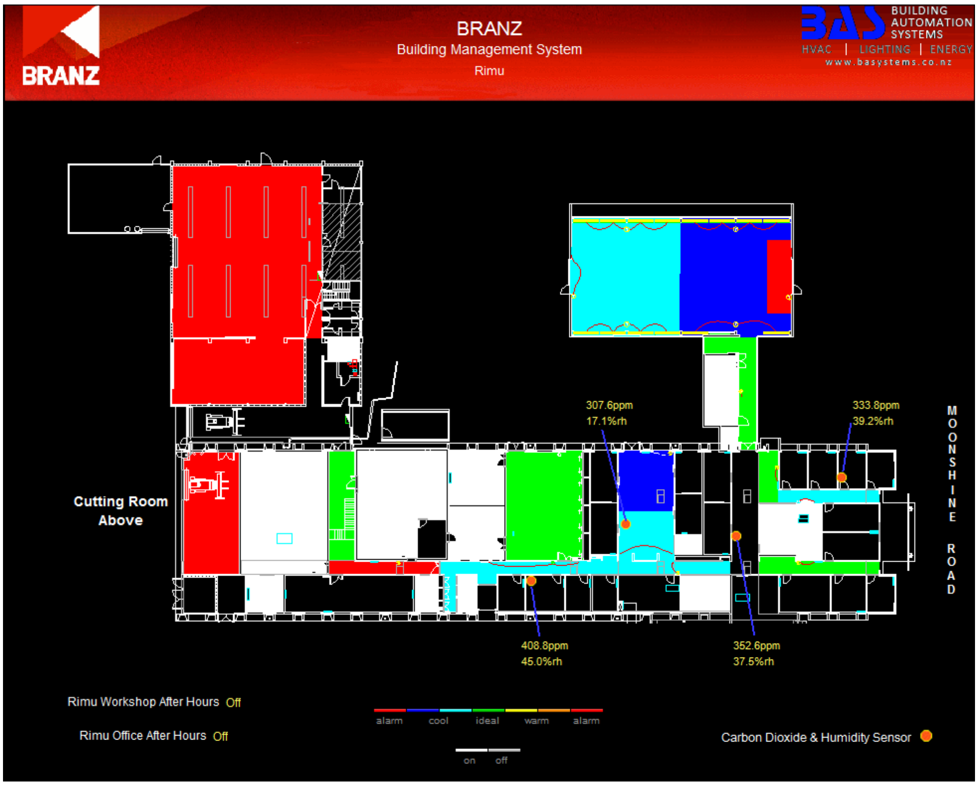

Figure 10 Environmental conditions screen for Rimu, Nikau and the Laboratories from the BMS system

5.2 Data Management

At the start of this project, the format of the various energy, water, and environmental data sources were not considered. It was assumed that extracting and processing the various data sources would be secondary to the analysing and tracking the information. As it turned out, the separate data sources tended to have their own format and were more difficult to deal with and integrate than anticipated.

The BMS system contains many channels of data but only a few channels of data could be exported at any one time which also required a number of manual steps. The underlying data in the BMS system appears to be stored in a local database however time did not permit to fully explore how to make use of this.

The solar water heating (SWH) performance information was collected by a Splash Monitoring system which has provides a web interface to allow a variety of graphs of different parameters over varying times to be selected.

Monthly electricity readings for the BRANZ site are part of the electricity billing information and are manually entered into a spreadsheet. Electricity metering is becoming increasingly sophisticated and half-hourly Time of Use (TOU) information may be available from the retailer but would require specific processing methods developed.

Water use information was collected in a number of different ways including manual monthly meter readings recorded into a spreadsheet as well as fully automated half hourly readings which were emailed in a text file once a month. Water use information is further discussed in Section 6.

In order to provide a data store that can readily be used for analysis and tracking, the data warehouse approach (Kimball and Ross, 2002) provides a framework to manage the individual data source and to provide data extracting, cleaning and processing as required. The end goal of the building level data must be high level reporting to allow for use within an EnMS or EMS.

6. WATER USE

The water metering arrangement for the BRANZ site, when it was commissioned back in the 1970's, was quite basic. As shown in Figure 11 the metered council water was directed into a tank on the hillside at the back of the BRANZ (height about 20 m), which was then used throughout the site. Adjoining properties also had metered connections before the tank which could then be reconciled with the readings from the council meter.

Since the mid 2000's there has been an increased interest in water efficiency and conservation at BRANZ, both within the research projects undertaken and within its own management of water use on the BRANZ site.

Research projects have looked at both residential (Heinrich, 2007 and Heinrich and Roberti, 2010) and non-residential (Isaacs et al., 2009) water use. BRANZ was used as a pilot study in the non-residential BEES project. As part of this, the BRANZ site was used to examine the practicability of water metering with a number of new water meters installed on several buildings. Water audits and end-use analyses were also carried out to better understand the current water use. Details of this pilot study can be found in the Years1 & 2 report of the BEES project (Isaacs et al., 2009). The outcome was a number of additional metering points (shown in Figure 12) allowing for the water use to be better understood.

6.1 Intended metering and data outcomes

As part of the site refurbishment there was an opportunity to build on the previous work to further improve how water use is managed on the BRANZ site and in the refurbished buildings.

Installing additional water meters would allow the water use to be better understood so that future water audits would be easier to undertake and specific water efficiency and conservation measures could be more easily applied and results verified appropriately. It was also the intention that automated collection of water data would be included so that it would be quicker and easier to respond to leaks and abnormal water use than was the case when data was only available from the site (including some adjoining properties) from 3-monthly meter readings.

In looking at the existing water meter locations as indicated in Figure 12, it would be desirable to install a water meter at point '1' which would provide the total water use from the BRANZ site. The water use for the Workshops could be fed through the meter on the Rimu building and the water use on the West side of the creek be broken down with meters on each of the Fire and Structure Labs as well as a meter for the Kauri offices.

In looking at providing a means of data collection, four approaches can be considered:

1. Manually reading the meters. This can always be done as it does not require any additional equipment, however as the number of metering points increases and data is required to be recorded more and more often the time to do this increases. Manual meter readings then need to be recorded separately into a database or spreadsheet.
2. Attaching data loggers to the meters. This requires suitable data loggers and their associated equipment and software. They also require regular downloading but provide data at regularly collected intervals which would otherwise be too time consuming. The data could also provide insights into how the water is used during the day or between weekdays and weekends. If the data is collected at a very fast rate with well resolved meters then end-use analysis may be possible (see Isaacs et al., 2009).

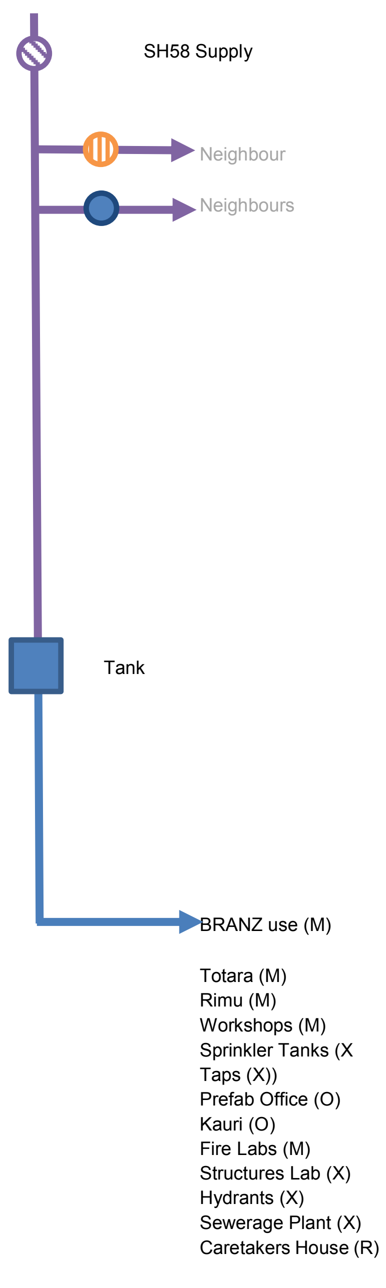

Figure 11 Water metering arrangement as built

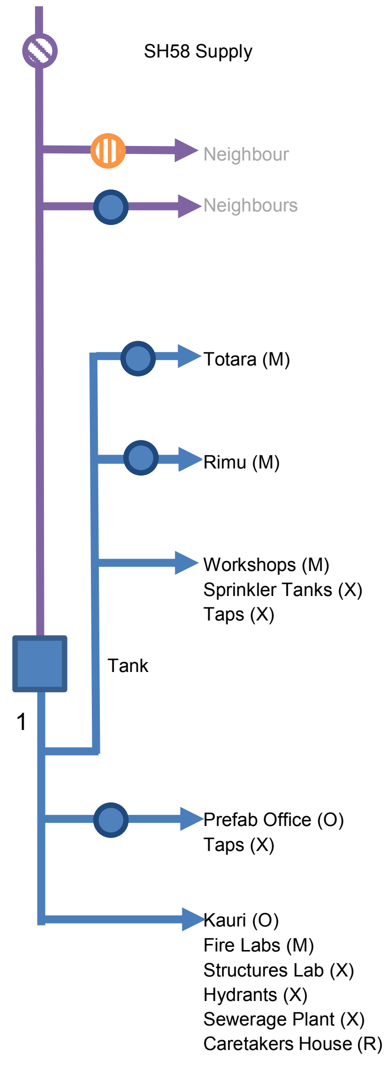

Figure 12 After BEES case study

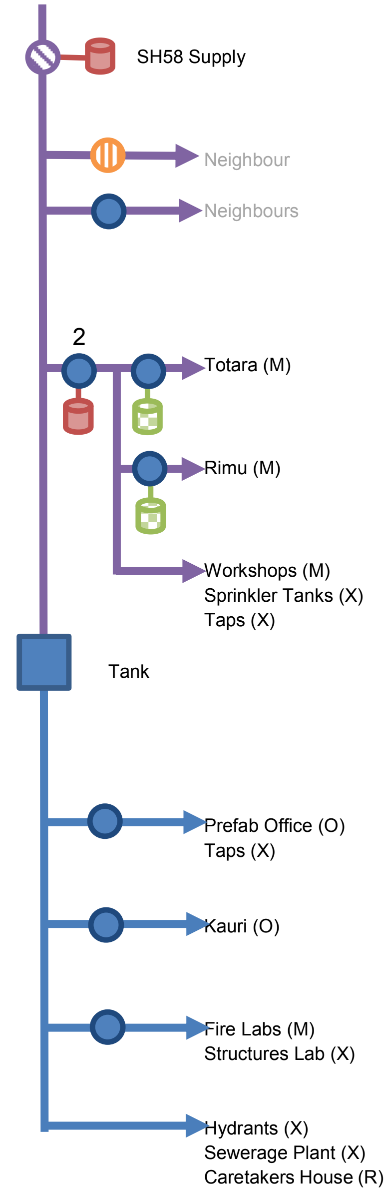

Figure 13 After refurbishment

Legend

Council meter read 3 monthly

Neighbour's meter read yearly

Water meter read monthly

Wireless data integration (30 min) into MonitOr

Wired data integration (15 min) into BMS

High pressure water line

Low pressure water line

(O) Office

(X) Other use (eg Labs)

(M) Mix of Office & Other

(R) Residential

3. Attaching the water meters to the BMS system. When a BMS system is used and cabling for the BMS system is nearby, the water meter could be also be connected to this system to provide the water data collected alongside the other data collected.
4. Attach wireless data collectors to the water meters. Wireless data collection systems are useful where the water meter is remote from other systems or regular downloading of data loggers is impractical. The wireless data collection system can use a variety of connection methods but frequently interface into local computer networks or use Cellular or Landline telephone networks to connect to servers in which to store the information.

In order to provide as much information as possible, all four of these methods have been used at BRANZ and are discussed in the next section.

6.2 Achieved metering and data outcomes

The water meter positioning that resulted after the site refurbishments is shown in Figure 13. There were a number of variations from what was intended.

Point ‘1’ was a difficult location to add a meter with the piping after then tank having a large diameter. More importantly, in order to improve the water pressure to the Laboratories, the refurbished buildings (Totara, Rimu and the Workshops) were connected to a high pressure line before it reached the tank so that point ‘1’ would no longer measure the entire BRANZ use. The meter intended for point ‘1’ was instead used to measure the water use for the refurbished buildings (point ‘2’ in Figure 13).

Progress on installing sub-meters on the buildings on the west side of the creek (Kauri, Fire Lab, Structures Lab) also proved difficult. It was intended to meter each of these buildings separately and connect them to a wireless data collection system. The costs of excavating the pipework at the point of separation between the Kauri office building and the Fire and Structures Labs, and installing the water meters (see Figure 14) ran considerably over budget and meant that the further work to install a meter to separate the Fire Lab and Structures lab and to purchase wireless data collection equipment for these meters could not be completed.

The costs of installing meters to existing buildings where the pipework is not readily assessable is high. Appropriate levels of sub-metering should be included in the construction phase to minimise later costs should water use be proportioned between different parts of the site or building.

Figure 14 Water metering for the Fire and Structure Lab’s and the Kauri building

All of the new meters are read by the BRANZ caretaker on a monthly basis. These are provided to the Environmental Manager to include in a spreadsheet of indicators included in the BRANZ EMS. The additionally installed meters will allow future investigative data logging to be undertaken.

The two existing meter locations that were covered by the refurbishments (the Rimu meter and the Totara meter) were maintained, however the particular meters used were changed to allow for them to be more easily interfaced with the BMS system. In addition to storing 15-minute readings from the two meters, the BMS system also displays the real time water data from these two locations via the Energy Information System (EIS) described further in Section 6.

6.2.1 Wireless data collection system

Some of the water meters of interest are some distance from the refurbished buildings. The council meter for the site is approximately 300m 'as-the-crow-fly's' with the hill tank being around 250m. The meter recording the water use for the refurbished buildings was also around 50m away. The council meter alongside State Highway 58 is located within a lockable 'pit' (see Figure 15) making manual readings or attaching data loggers impractical.

Rather than attempting to run permanent cables from these meters, a wireless metering system (MonitOr) provided by Arthur D Riley was trialled. This system involved attaching a transmitter to the pulsed output of the water meter and installing a receiver unit at the convenient location. The receiver unit was located in the vacant Prefab offices as this location provided a good signal level from the transmitter (see Figure 16).

Figure 15 Attaching a transmitter to the water meter at SH 58

Figure 16 Antenna for the receiver unit atop of the Prefab office building

The receiver unit uploads the meter readings to an Arthur D Riley server. Users can log-on to a secure website and view the water use within a few hours from the data being collected.

The main display window for the MonitOr system is shown in Figure 17 and is made up of four parts. At the left is a list of meters that can be examined. At the top is a selector to allow for a range of data from the previous month to be displayed in the main window. The main window displays the water use of this selected period using an appropriate time base with the dials at the bottom of the screen showing the minimum, maximum and flow rates for the selected period.

When the selected period extends over several weeks, a weekly total is shown in the main display, when a number of days are selected (as is the case in Figure 17) the daily totals are shown and when a single day is selected hourly data from that day is shown in the main window (see Figure 18)

A text file containing half-hourly data from the MonitOr system is sent from the supplier, Arthur D Riley on a monthly basis.

Regularly using the MonitOr system gives a good understanding of when water is used and when usage is not typical. One of the unfortunate outcomes was that not all of the BRANZ water use was isolated via the wireless metering system. Water uses not covered by the refurbishment meter such as water use in the Kauri offices and the Fire and Structure Lab's were not separately recorded and only appear in the aggregate usage (BRANZ plus neighbours) recorded by the meter at SH 58. Over the summer period, the water usage from the SH58 can appear quite high while the water usage for the refurbishments meter is low. Often this high unknown load is due to the neighbours (being rural, irrigation is a common use) rather than for the unmetered parts of the BRANZ site.

Figure 17 Overall view from the MonitOr system

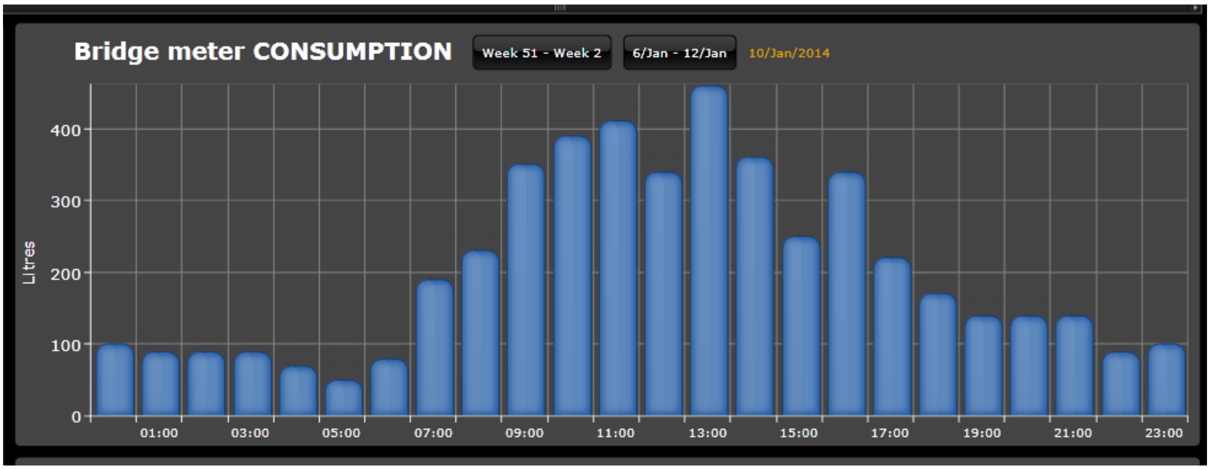

Figure 18 Hourly information from MonitOr when one day is selected

6.3 Overall water use and impacts of the site refurbishment

As part of the site refurbishments, much of the pipework and fixtures within the refurbished buildings were replaced. Shortly after the refurbishment was completed a new sewerage treatment plant was commissioned to replace the original BRANZ sewerage treatment plant which had come to the end of its life.

Figure 19 shows the approximate breakdown of water use on the BRANZ site since August 2007. This graph displays monthly data however some data sources are collected at longer time intervals (neighbours water use is recorded annually while the total water use recorded at SH58 was initially only collected every six and then three months) so there is some balancing of water use from these sources to achieve more realistic water use.

A number of specific events relating to how the metering has been undertaken and what was happening to the buildings are indicated by letters in Figure 19. From August 2007 until point A (December 2008) none of the BRANZ site was sub-metered so only the total water use (recorded at six monthly intervals) was available. From point A, meters were added to the Totara, Rimu and Prefab Office buildings (read monthly), however a large proportion of the water use remained unknown. Point B (June 2009) indicates when three monthly meter reading commenced.

During 2009 large leaks were discovered and repaired in the pipes leading to the tank which would account for a large proportion of this 'other' use. During 2010 the water use in the Rimu building began increasing steadily. Point C (August 2010) indicates when the site refurbishments commenced. While a meter remained in the Rimu building, the use of this building was considerably different from previously and the meter data is not displayed from this meter from Point C until Point D (May 2011) and water use during this period will appear in the 'other' category. In undertaking the refurbishment the main feed pipe to the Rimu building located within the slab floor was determined to be leaking beyond repair and was replaced with a new main feed. The 'other' water use while the refurbishment was undertaken (from point C (August 2010) to point F (Mar 2012)) is shown in a lighter shade of grey. From Point D until Point F, the Totara building was undergoing refurbishment and the meter data for this building is not displayed on this graph.

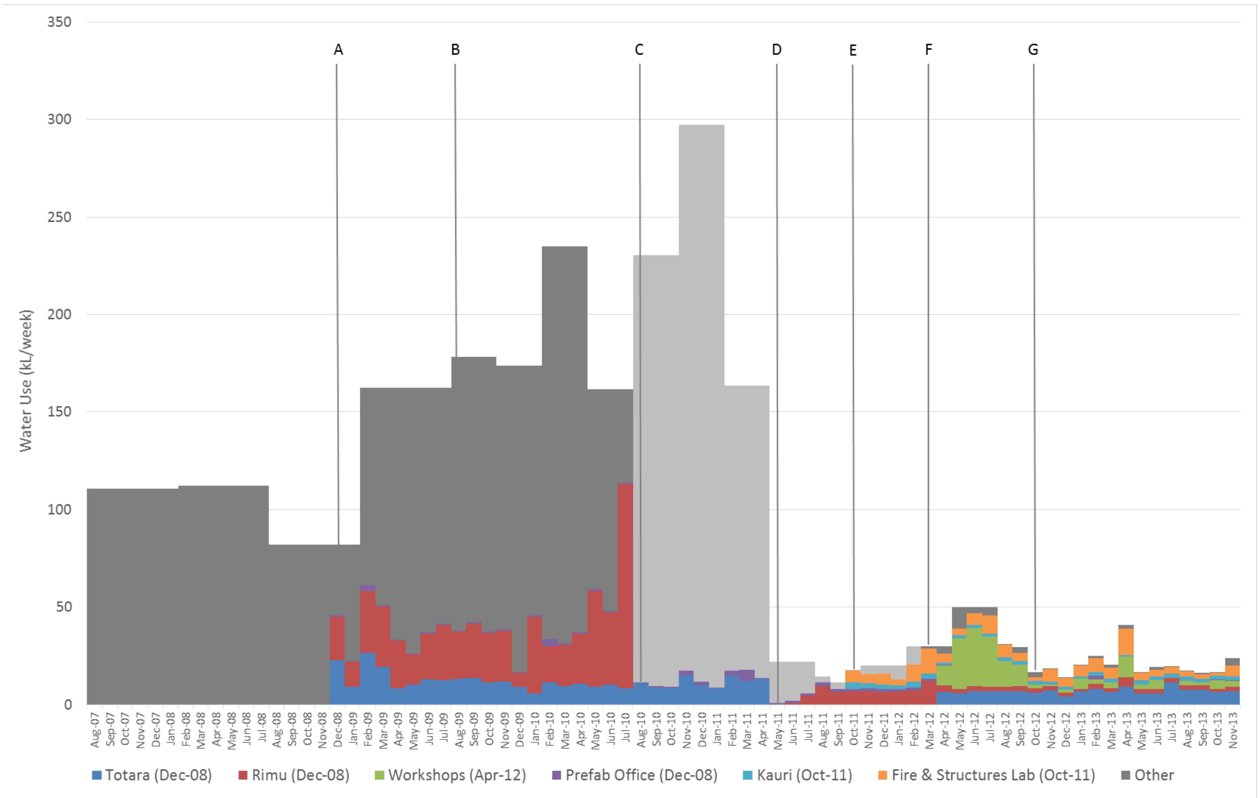

Figure 19 BRANZ water use since August 2007

At point E (October 2011), three additional meters were added to record water use from the Kauri building, the Fire and Structures Labs and for the refurbished buildings. The meters for the Rimu building and the Totara building could be subtracted from meter covering the refurbished buildings (the meter at point '2' in Figure 13) to provide a figure for the Workshops and Sprinkler Tanks and Taps ('Workshops') which is shown in Green in Figure 19. Data is only available from Point F (March 2012) as the water meter from Totara was out of action until this point. A large amount of water use is seen being used in these areas in the months after Point F. This corresponds to the time when the newly installed Sprinkler Tanks were being filled.

From Point G (October 2012), monthly data was recorded from the meters at SH 58 and for the meter covering the refurbished buildings allowing the data to be better resolved. One noticeable event after this date is high use in April 2013 particularly from the Fire and Structures Labs meter. This corresponds to when the new sewerage treatment plant was commissioned and some of the atypical filling of tanks may have taken from a water supply feed from the Structures Lab.

The BRANZ water use has changed dramatically before and after the site refurbishments. Major water leaks both in the supply to the water tank for the BRANZ site and within the Rimu building contributed to BRANZ's excessive water use. While the water use in the Rimu building is significantly lower after the refurbishments the Labs in the Rimu building were extensively repurposed so a direct comparison before and after is not valid. Where a before and after comparison could be made is in the Totara building. This building's function has largely remained the same before and after the refurbishments (housing the same Corporate and Knowledge Transfer groups as well as the BRANZ Café).In the year before the refurbishment the water use in the Totara building was 9.6 kL/week and in the year after, was 38% lower at 6.0 kL/week. This is equivalent to a water use benchmark of 0.32 kL/m².yr which is a well performing level.

Water use will continue to be monitored as part of the BRANZ EMS.

7. INDOOR ENVIRONMENTAL QUALITY (IEQ)

The indoor environment within a building can be quite varied and includes aspects such as the thermal conditions, ventilation, lighting, noise and the presence of pollutants. Collectively the acceptability of the indoor environment is known as Indoor Environmental Quality (IEQ).

A focus to minimise energy use within a building can have unintended consequences on IEQ. While some options will have some no or positive effects on IEQ some measures will negatively impact on IEQ. For example, excessively limiting the heating will reduce energy use, but may provide an inhospitable environment for the occupants.

The second volume of the International Performance Measurement and Verification Protocol (IPMVP) (EVO, 2002) discusses the interrelationship between energy efficiency goals and IEQ and identifies potential influences on IEQ from particular options which are referred to in the IPMVP as Energy Conservation Measures (ECMs). For those undertaking energy efficiency upgrades, it is advisable to review such material to reduce the likelihood the upgrade will impact on IEQ.

The IMPVP volume 2 (EVO, 2002) also discusses methods to verify the IEQ after particular options have been implemented and gives the following options;

1. **No IEQ verification.** Where the option does not have a strong influence on the indoor environment, no specific IEQ verification is necessary.
2. **IEQ verification based on modelling.** A variety of methods can be used to predict impacts on IEQ for certain options.
3. **Short term measurements of selected IEQ parameters.** A snapshot of selected IEQ parameters can provide useful information as to how the options may be influencing IEQ.
4. **Long-term continuous measurements of selected IEQ parameters.** Continuous measurement of core IEQ parameters (temperature, humidity, CO_2 levels) can be cost effective and can help better understand the impacts on IEQ from the options chosen.
5. **Surveys to assess occupant perceptions and ratings of IEQ.** An alternate approach to the measurement of IEQ parameters is the surveying of building occupants to determine their assessment of the IEQ once the options have been undertaken.

In considering the BRANZ refurbishments, a significantly different indoor environment would be provided by the refurbished buildings so approach 1 was not considered.

For approach 2, computer thermal design tools and other tools could be used to examine a ‘design’ indoor environment. Setting up thermal simulation models can take up a lot of time and while certain models were used by the design team, for example to understand the performance of the Totara passive ventilation system, this approach was not fully explored as it was decided to emphases the actual achieved indoor environment rather than the design environment. As was mentioned in section 1, designed energy performance can differ from actual measured performance (Newsham et al., 2009) so it may be expected that the designed indoor environment will also differ from the actual measured indoor environment.

The subjective assessment by the building occupants of the IEQ (approach 5) is part of the occupant evaluation which is discussed in section 8.

Approaches 3 and 4 make use of measurements of the indoor environment and a mixture of these were used for this project.

As the refurbished building was going to have a BMS system installed, continuous measurements of a range of IEQ parameters would be possible after the refurbishments were complete. Assessing the indoor environment could be undertaken by exploratory data analysis to identify patterns (averages, variations, unusual events) within the data. This could include seasonal effects and time of day information to examine how much the indoor environment varies. In general, there have been few published confirmatory studies measuring the long-term indoor environmental characteristics in non-residential buildings, however this type of work is more common in residential studies (French et al., 2007). As the focus for this project was to assess the changes in the indoor environment before and after the refurbishments, confirming the indoor environment after the refurbishment was not a priority for this project as is discussed only briefly here.

An effective graphical summary of a variable over an extended period of time is the carpet plot. Carpet plots of the indoor temperatures over winter and summer for specific locations in the Nikau, Rimu and Totara buildings are shown in Figure 20 to Figure 25.

A carpet plot shows the measurement of interest according to a colour scale at the intersection of two axes. One axis (in this case the vertical axis) provides the time of day while the other axis gives the day of year. This representation allows regular time of day patterns to be identified as well as regular patterns such as weekends.

The colour scale for the measured indoor temperatures shown in Figure 20 to Figure 25 is shown in the centre of the page. The colour scale ranges from shades of red when the temperature is over 27°C and shades of orange over 24°C. Shades of green relate to generally acceptable temperatures of between 18°C or 24°C while temperatures below 18°C are shown as light blue colours than deepen in colour as the temperature drops. Periods of the graphs that are shown in white indicate periods of missing data.

The graphs at the top (Figure 20 and Figure 21) give the indoor temperatures in the Nikau building. The middle graphs (Figure 22 and Figure 23), the temperatures in the Rimu building while the bottom graphs (Figure 24 and Figure 25) gives the temperatures in the Totara building. The graphs on the left (Figure 20, Figure 22 and Figure 24) give the temperatures during winter 2013, while the graphs on the right (Figure 21, Figure 23 and Figure 25) give the temperatures during and 2013/14 summer.

During winter, the temperatures in the specific locations in the three buildings is largely acceptable (18-24°C) during the occupied daytime period (8am-5pm) as indicated by the central horizontal area being mostly green. The weekends are identifiable by regular darker green or light blue vertical shading indicating the cooler temperatures within the buildings on the weekends when the heaters are not operating. Of the three locations, the north location in the Nikau appears the coolest, followed by the central location in the Totara with the north location in the Rimu being the warmest. The temperatures do not drop excessively low indicated by limited areas of dark blue colours.

The temperatures in all three locations are warmer than 18°C over summer as there are no blue colours in Figure 21, Figure 23 or Figure 25. During the mornings all three of the locations are in the acceptable green range (18-24°C) however the afternoon temperatures have shades of orange in all three buildings and some red shades in the Rimu building indicating warm temperatures and some overheating in the afternoons.

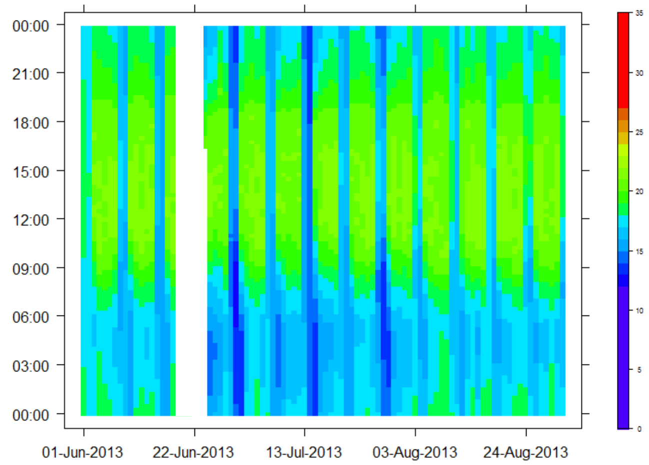

Figure 20 Temperatures in the Nikau building (North side) during winter (white is missing data)

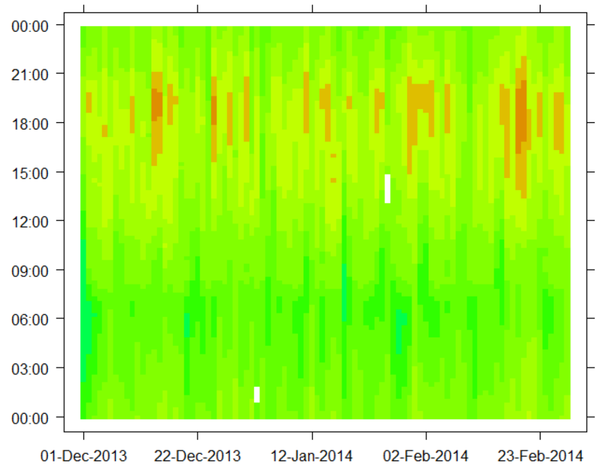

Figure 21 Temperatures in the Nikau building (North side) during summer

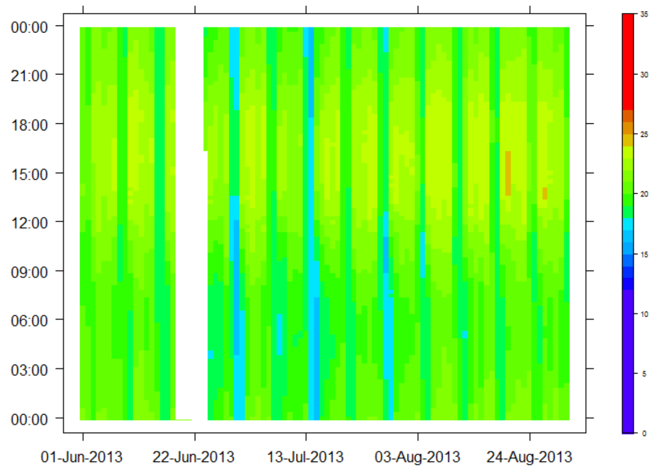

Figure 22 Temperatures in the Rimu building (North side) during winter after refurbishments (white - missing data)

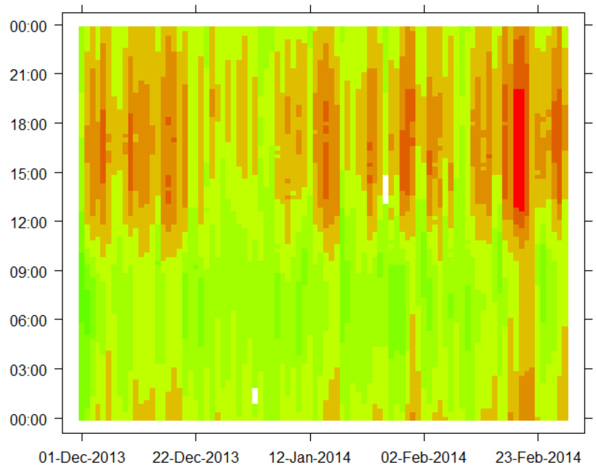

Figure 23 Temperatures in the Rimu building (North side) during summer after refurbishments

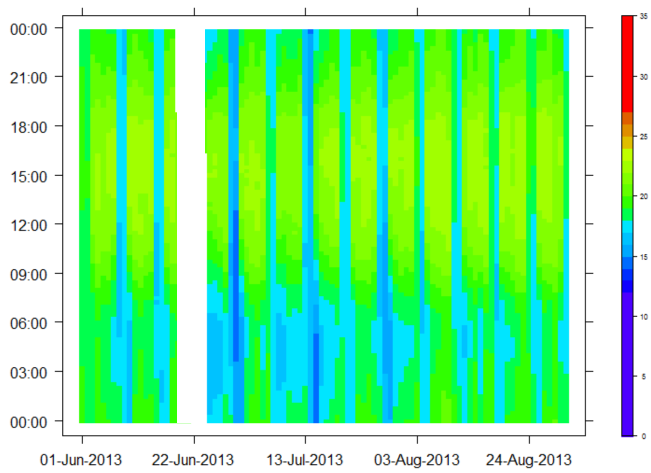

Figure 24 Temperatures in the Totara building (central) during winter after refurbishments (white – missing data)

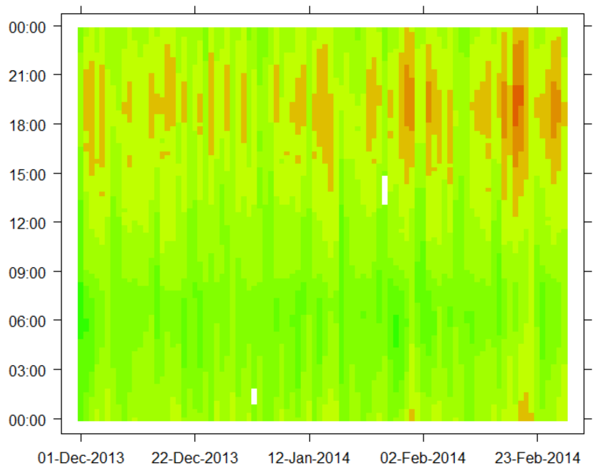

Figure 25 Temperatures in the Totara building (central) during summer after the refurbishments

7.1 Indoor environment before and after the refurbishments

Examining how the indoor environment has changed is difficult and requires data on the indoor environment both before and after the refurbishment. Two periods of interest are during winter when the heating system is operating to provide a comfortable environment and during summer when overheating may occur if the building is not sufficiently cooled via passive ventilation. With limited time and budget before the renovations took place, long term monitoring of BRANZ was impractical. BRANZ, however, had been randomly selected to be included in the BEES (Amitrano, et al., 2014) sample so some short term monitoring (2-4 weeks) of the indoor environments were available.

The BEES monitoring was undertaken in Totara and Rimu, (see Figure 2) as well as in Kauri and the Prefab Offices which were excluded as they were outside of the refurbishment areas. Totara was measured in March 2009 while Rimu was measured in June-July 2010. Temperatures in March are less extreme than they are in January and February so data comparisons before and after were focussed on the winter heated period in the Rimu building.

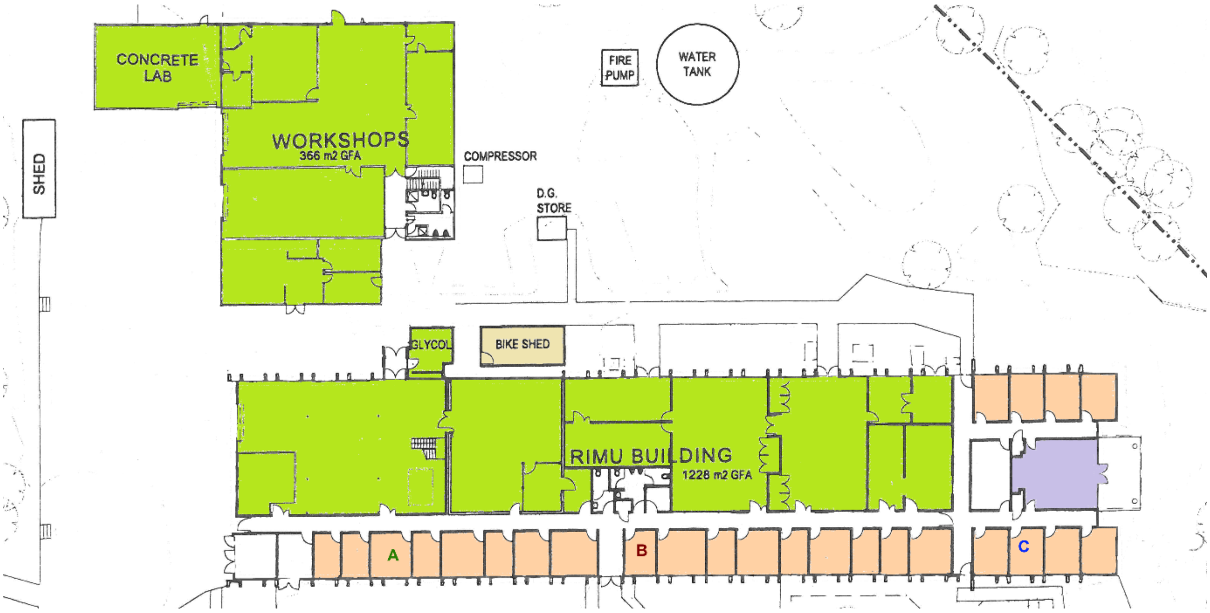

Figure 26 Temperature measurement locations in the Rimu building before the refurbishments

Figure 27 Temperature measurement locations in the Rimu building after the refurbishments

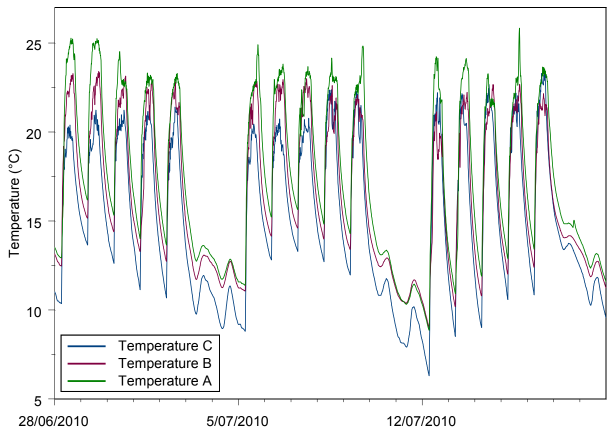

Figure 28 Temperatures in the Rimu building before the refurbishments from the locations in Figure 26

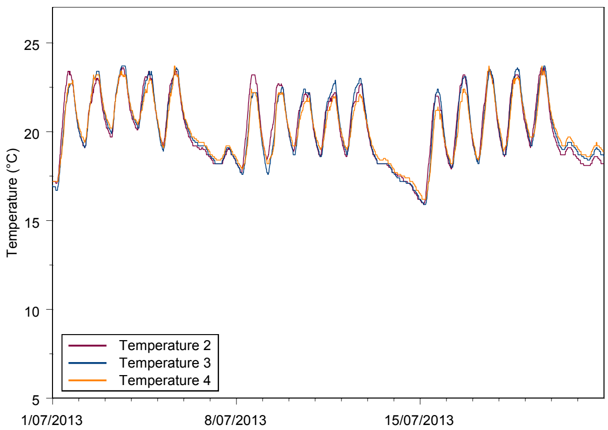

Figure 29 Temperatures in the Rimu building after the refurbishments from the locations in Figure 27

Table 2 Comparison of weekday daytime (9am-4pm) temperatures before and after the refurbishment for locations in the Rimu building for three weeks at the start of July

Location	Temperature std. dev.	Mean Temperature	Mean Temperature	Temperature std. dev.	Location
A	1.2	22.7			
B	1.3	21.1	22.1	0.9	2
C	1.1	20.5	21.9	1.1	3
			21.5	1.2	4

Table 3 Comparison of temperatures outside of the weekday daytime (9am-4pm) period before and after the refurbishment for locations in the Rimu building for three weeks at the start of July

Location	Temperature std. dev.	Mean Temperature	Mean Temperature	Temperature std. dev.	Location
A	3.9	16.0			
B	3.3	15.0	19.7	1.7	2
C	3.4	13.5	19.7	1.8	3
			19.8	1.6	4

Figure 26 and Figure 27 gives the locations of three temperature measurement points before and after the refurbishments. Two of the locations are in close proximity to one another however the third location is different (south office west end before the refurbishments, north corridor east end after the refurbishments). The resulting temperatures over the first three weeks in July are shown in Figure 28 for before the refurbishments (2010) and in Figure 29 for after the refurbishments (2013). The range of temperatures before the refurbishments appears much greater than was the case after the refurbishments. Table 2 compares the average temperatures during the working week daytime (9am to 4pm) period and shows there is slightly less difference between measurement points after the refurbishments while the temperatures before and after are similar. Table 3 gives the average temperatures outside of the working week daytime period and shows the temperatures pre-refurbishment are colder than after the refurbishments.

When the heating system is operating during the working week daytime the achieved conditions before and after are similar, however before the refurbishments, the temperatures outside of the working week daytime period drop markedly and are at times below 10°C, reaching a minimum of 6.3°C. After the refurbishments the temperatures outside of the working week daytimes do not drop as low, reaching a minimum of 15.9°C.

This suggests that the higher insulation performance levels and use of double glazing throughout the refurbished Rimu building significantly reduce the heat loss out of the building requiring considerably less heating to heat up the building from cold as well as to maintain those temperatures throughout the day.

7.2 CO_2 measurement

An important consideration of the indoor environment is the ventilation. Overly restricted ventilation can create an unpleasant, stuffy environment that do not effectively remove pollutants. Excessive ventilation on the other hand, can create draughty environments that are not energy efficient and are difficult to heat.

One of the design features of the new Totara building was the ventilation stack or thermal chimney in the centre of the building. This system uses the buoyancy of warm air to create an airflow through the building from opening windows around the building perimeter. While most of the ventilation was passive, some mechanical systems were used for the meeting rooms and the internal offices in both the Totara and Rimu buildings.

Measuring the ventilation rates continuously in an occupied building is difficult. Measuring the CO_2 levels can provide an indication if the ventilation rates are too low or too high (Persily, 1997).

Eight CO_2 sensors (four in Totara and four in Rimu) were added to the BMS system to report on the CO_2 levels within the buildings. There were no specific specifications requested for these sensors are three models of two brands of single beam CO_2 sensors were installed. The CO_2 levels from each of the sensors in the Totara building and the CO_2 levels from the group work area in Rimu were chosen to be used in Energy Information System (EIS) screen (see Figure 41) displaying the current conditions within the buildings.

Once the buildings were occupied, it was soon discovered from the EIS display screens that the Rimu building CO_2 sensor (in the group work area) was producing unrealistic values. The CO_2 levels were often around 280 ppm, well below the outside ambient level, what would be the minimum for the system. Drift of the offset values for CO_2 sensors is well recognised (Apte, 2006) and others (Fisk et al., 2010) has previously expressed concerns at the response of CO_2 sensors. Side-by-side checks of each of the CO_2 sensors with a portable dual beam CO_2 was consequently organised to better understand the operation of the CO_2 sensors. Figure 30 shows a portable dual beam CO_2 sensor being used as a check on the installed (fixed) single beam CO_2 sensor.

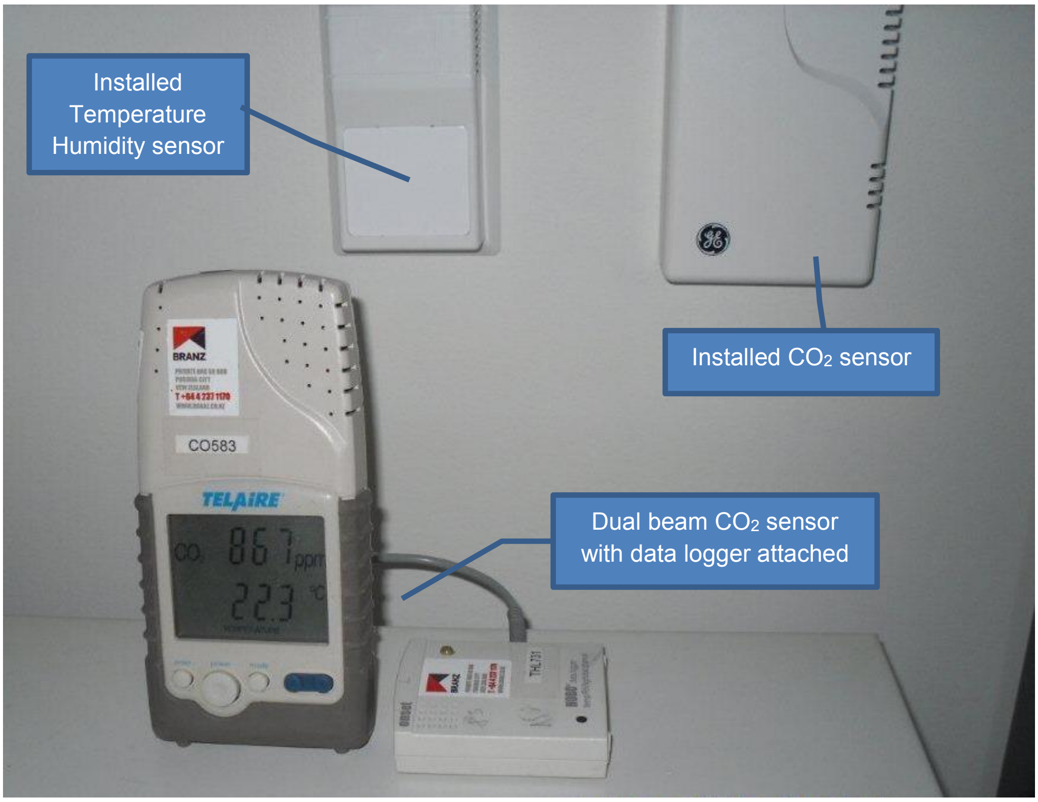

Figure 30 Checking of the installed CO_2 sensor with a dual beam CO_2 sensor as used in BEES

The monitoring was carried out over two separate weeks for each of the buildings. Figure 31 to Figure 34 give the response from each of the installed CO_2 sensors from the Rimu building alongside a 'reference' value from a dual beam sensor placed nearby. Figure 35 to Figure 38 give similar information for the sensors from Totara in the following month. The two weeks are from Monday through to Sunday.

The CO_2 levels as measured by the portable dual beam sensors appear low (Bishop et al., 2011). Only in the two offices (Figure 33 and Figure 34) were values higher than 800 ppm observed. These two locations also demonstrated a more 'peaky' response in the CO_2 levels seen. This is presumably when the offices were occupied with perhaps the door closed.

If you neglect biasing errors (allow the blue line to be shifted up and down the graphs) there is still concern about reconciling the values from the two different sensors in each of the cases shown which are further discussed below.

Despite a regular ~200 ppm increase (as measured by the dual beam sensors) in the weekday Rimu CO_2 levels in the open area's (Figure 31 and Figure 32), the response of the installed CO_2 sensors is virtually flat and is not responsive to the changing CO_2 levels in these spaces.

In the Rimu offices (Figure 33 and Figure 34) the installed CO_2 sensors do sometimes respond to the changing CO_2 levels in those spaces but not in a consistent way. In the single occupied office (Figure 33) there is no response on the Tuesday despite the dual beam sensor indicating an elevated CO_2 level. On the Wednesday there no response for a long period of time and then there is a short spike with no decay, returning to a lower level quickly. Later on towards the end of the elevated CO_2 levels the installed CO_2 sensor again responds but this time returns to a lower level only after a slow decay.

The CO_2 levels in the second office (Figure 34) are more peaked. The installed CO_2 sensor only provides a sizeable response on the Tuesday despite elevated levels on Monday, Thursday and Saturday.

Two models of a different brand of CO_2 sensor where used in the Totara building (Figure 35 to Figure 38). As the Totara building is open planned and has a low occupant density the observed CO_2 levels from the dual beam sensors are low, peaking up to only around 600 ppm. Again the response from the installed CO_2 sensors is not consistent. For all of the locations there are times when the dual beam sensors indicate an elevated level of CO_2 which the installed sensor does not respond to.

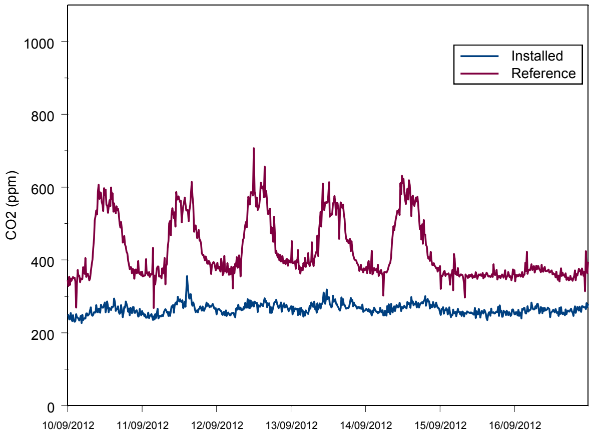

Figure 31 CO_2 from Rimu group work space over 1 week (sensor brand A).

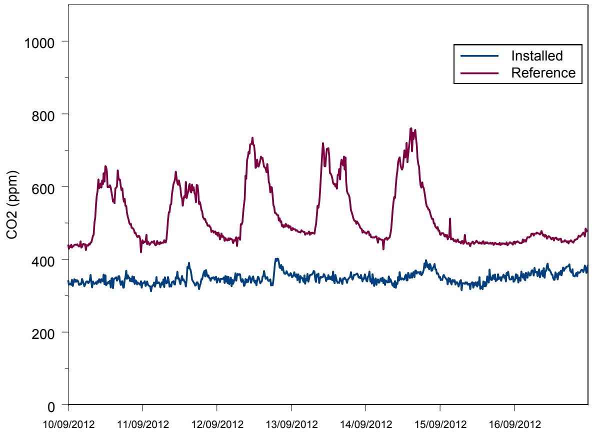

Figure 32 CO_2 from outside Rimu meeting room (transitory space) over 1 week (brand A)

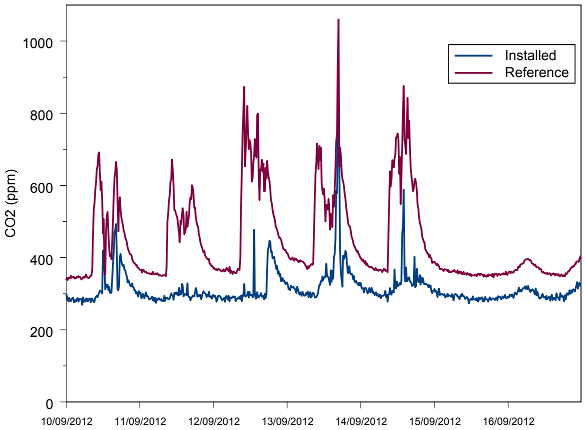

Figure 33 CO_2 from regularly occupied single Rimu office North side over 1 week (brand A)

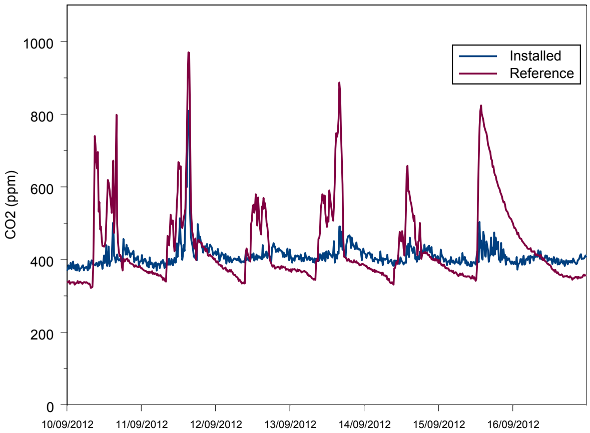

Figure 34 CO_2 from irregular occupied double Rimu office South side over 1 week (brand A)

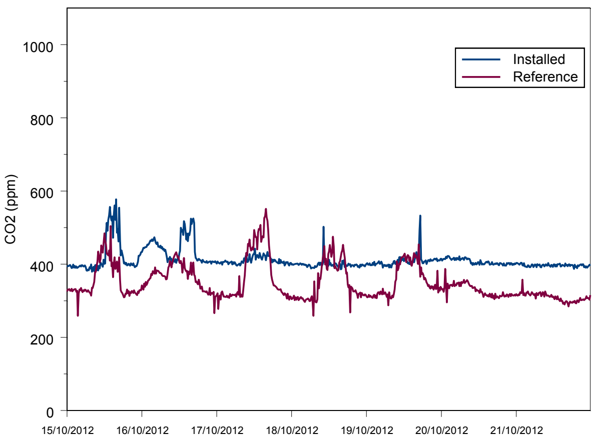

Figure 35 CO_2 from North West corner of Totara over 1 week (sensor brand B)

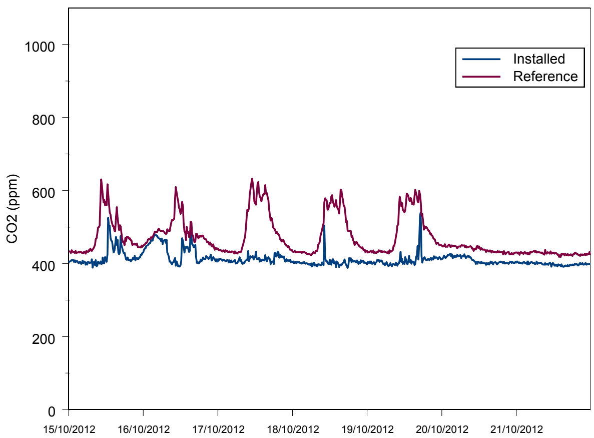

Figure 36 CO_2 from North East corner of Totara over 1 week (sensor brand B + display)

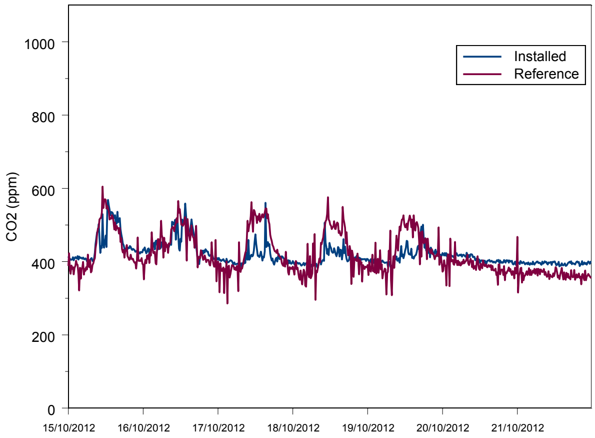

Figure 37 CO_2 from South West corner of Totara over 1 week (sensor brand B)

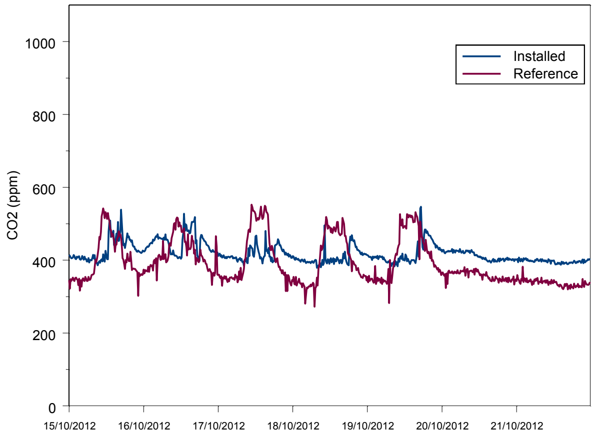

Figure 38 CO_2 from South East corner of Totara over 1 week (sensor brand B + display)

The installed CO_2 sensors are not of sufficient quality to measure CO_2 levels. The installed CO_2 sensors could not be calibrated as their response was not reliable. Measuring CO_2 levels is a core part of many ventilation systems such as Demand Control Ventilation (DCV) (Energy Design Resources, 2007). When CO_2 sensors are used, it is important to ensure that they provide reliable measurements so that systems dependent on them will perform appropriately.

8. OCCUPANT EVALUATION

Baird et al. (1990) gives the rule of thumb that the major costs in a commercial building are approximately in the ratio 1:10:100 for the operating costs (ie, energy, maintenance, rates) to the capital costs (ie ownership or rental) to the total salaries of occupants of the building over its lifetime. Building occupants and their working environment is therefore critical to consider.

Environmental impacts on occupants can be assessed either objectively or subjectively. An objective assessment uses judgements on what would be acceptable values for the evaluated criteria. For example, the objective assessment of the indoor temperatures that was discussed in Section 7, considered the temperature range 18-24°C as generally acceptable and considered the locations and times when the indoor temperature was outside of this range. The complement to objective assessment is subjective assessment. In subjective assessment, the occupants of the building are asked to provide feedback on the building and its services as to how well it meets their needs. There are a variety of feedback methods (Bordass and Leaman, 2005), with occupant surveys being most common.

Objective assessment provides a consistent and repeatable assessment for a building. Where the criteria are measured, these can be easily assessed over extended periods of time as they do not require input from the occupants. Objective assessments can also be undertaken when engagement from the occupants is not possible due to perceived intrusion on their time or when they are insufficient occupants such that variations in individual survey response will become a complicating factor. Objective assessments may also be able to be undertaken at the design stage of the building potentially allowing for design variations to circumvent future difficulties. When performed at the design stage they can be undertaken by such tools as computer simulation, however the repeated message in this report is that these design methods are not sufficient on their own and need to be followed up with the verification during the operating phase of the building.

One of the difficulties in using objective assessments is determining what and where the criteria will be examined. For evaluating the thermal environment, care must be taken to ensure that the measurement locations are as representative of the overall thermal environment within that building. This may require multiple measurements, especially when the environment within the building is varied.

Another difficulty with objective assessments is in establishing the criteria for what is acceptable. Individual human response to set criteria can be varied. An indoor environment which was objectively assessed as comfortable may still be viewed as either too hot or too cold by the occupants. The thermal comfort standards (for example, ISO 7730:2005), aim to minimise, rather than eliminate, the number of people that are not satisfied with the present conditions.

As the ultimate arbiter, the occupants play a key role in subjectively assessing a building. While a number of objective assessment criteria can explore issues such as comfort, the simple question to the occupant 'do you feel comfortable' can bypass many of the problems of objective criteria such as what are the acceptable values for the criteria.

Occupant surveys, frequently called Post Occupancy Evaluation (POE) surveys, are often used to examine what the occupants think about the building. Survey questions often seek to quantify people's assessment asking for people to score features on a satisfaction scale, such as; 'On a 1-7 scale with 1 being unsatisfactory and 7 being satisfactory, how would you rate x?'. Occupant surveys can also provide assessments for features that are difficult to measure, for example changes in perceived health or perceived productivity.

A requirement of occupant surveys is that sufficient numbers of people within the building are surveyed to reduce the influence of extreme responses to the overall responses. Surveys need to be constructed in a consistent manner so that the variability of responses to particular types of questions can be considered. A standard survey will also allow comparison of one building with another. This also requires that the types of buildings to be limited so that specialised features don't become a major point of distinction.

8.1 BUS methodology

A standardised occupant survey that has had considerable research and development is the BUS Methodology survey, now operated by ARUP (see www.busmethodology.org.uk). The repeated use of this survey has created a database of buildings that allows comparison of how a building is performing against a range of other buildings such as the example of the overall comfort assessment shown in Figure 39.

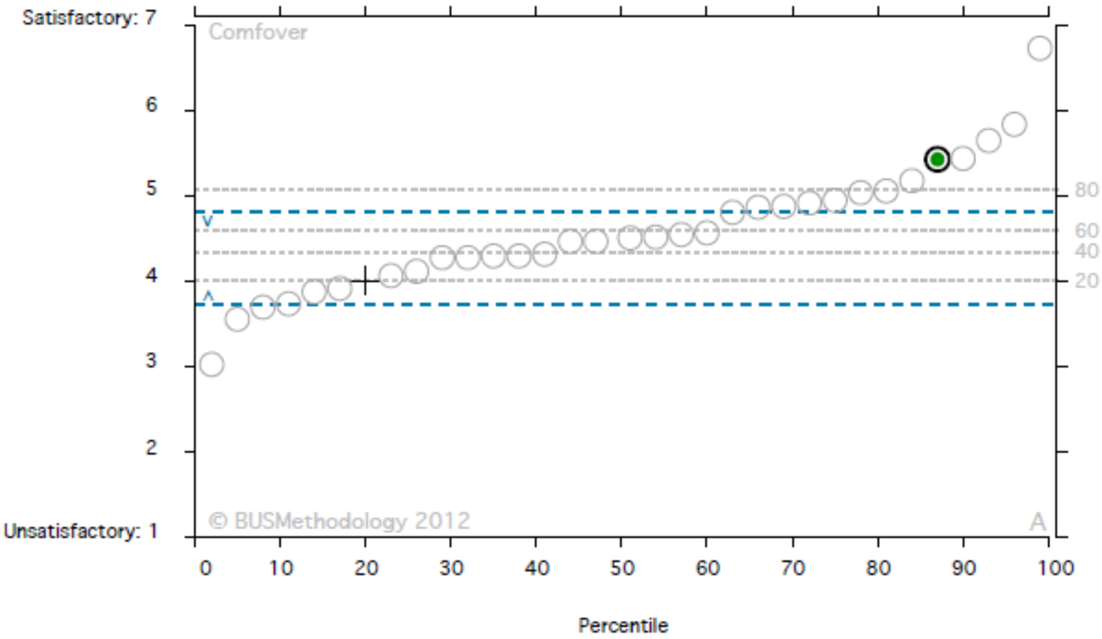

Figure 39 Average responses of overall comfort assessment from New Zealand BUS surveys. (BRANZ is shown in Green)

An occupant evaluation process (Burrough, 2012) was included for a small number of buildings participating in the BEES project. The BRANZ site was included as one of these sites (Amitrano, 2014).

In order to not exclude any staff and to ensure sufficient responses were collected, the BUS methodology survey included the existing Kauri building in addition to the new Totara building and refurbished Totara and Rimu buildings. Only the combined BRANZ responses (for example the green circle shown in Figure 39) can be compared to the New Zealand benchmarks as the number of people within individual buildings can be too small for robust comparison but do provide some indication of the importance of various issues between the buildings at BRANZ. Appendix A provides summaries of the responses from the separate buildings for a number of surveyed questions.

The new and refurbished buildings generally scored well on the occupant surveys. The survey was conducted before the first winter was experienced within the Totara building so the data was not meaningful for Totara for some questions such as their experience of temperatures during winter.

The design of the new Totara building scored highly as it did for functionality. Interestingly the old 1970's Kauri building also scored well on functionality, perhaps indicating that an effective working space can be still be achieved within an old building. The Nikau building scores well on Design, Lighting and Temperatures in Winter; but struggled in some of the other areas. The configuration of the Nikau building was quite different for those staff now occupying it so there was a period of reconfiguration and changes required (after the survey) to improve the working processes for the occupants. The operation of the passive vents were also modified to reduce the occurrence of higher temperatures in summer.

8.2 Laboratories

The questions asked in the occupant surveys are directed toward common experiences that can be examined between buildings. One of the unusual features of BRANZ is the inclusion of laboratories and these are key spaces for many of the technical staff at BRANZ. The workflow processes within the labs are also quite specific which can expand into a wide range of issues concerned with 'human factors'.

Many of the labs are climate controlled or have specialised equipment such as fume hoods, weathering equipment or equipment to heat or cool specific items operating that strongly impact on the environments within the room. The locations of specific equipment or temperature sensors were sometimes problematic to ensuring effective control of the environments. An example of this was a temperature sensor that was controlling the heating in one lab that was being affected by a cold draft from an adjoining lab which was kept at a much lower temperature.

Some of the labs that weren't specifically climate controlled, had radiators within them. These radiators were operated on the standard occupancy schedule so were not active during the evenings and on the weekends. It was found that some long duration tests (days or weeks long) undertaken within these labs were more difficult to control due to the varying temperatures within the lab.

Extracting data from how the laboratories are being operating and the resulting conditions within them was not an easy process to run (see section 5.2) and consequently was only undertaken to diagnose specific problems.

9. DISPLAY OF BUILDING PERFORMANCE

The Energy Information System (EIS) developed for the BRANZ refurbishment was built on the platform provided by the Building Management System (BMS). The overall goal of this EIS was to present the information in a simple and clear way so that a short viewing (up to five minutes) would provide some understanding of how the building was operating. Figure 40 shows the display screen in the reception area of the refurbished Totara building to the left of a screen showing a series of BRANZ videos.

Figure 40 Building operation screen on left with promotional screen on right in BRANZ reception area.

A series of four pages are displayed as a continuous slideshow. Three of the four screens display customised summary information about the buildings from the BMS system. These three screens were designed by BRANZ and implemented by Building Automation Systems (BAS), the suppliers of the BRANZ BMS system. A fourth screen displays information about the Solar Water Heating (SWH) system from a system provided by Splash Monitoring. The remaining of this chapter will discuss each of these screens in detail.

The first screen envisioned (Figure 41) was intended to summarise the current environmental conditions and current energy and water flows into the building.

There are multiple measurement points of temperature, humidity and CO_2 within the refurbished buildings, so representative measurements were chosen to summarise the office conditions within the buildings. The laboratories are not accessible for the majority of the staff and have varying temperature controls for each individual area so it was decided to not include them on the display screens. No humidity or CO_2 measurement points were included in the Nikau building so only the temperature was displayed. On the screen, a digital readout of the values of the environmental measures are displayed on an orange box within the area of interest (each quadrant of the Totara building, the offices in the Rimu building and the Nikau building). The frequently low value for CO_2 in the Rimu building was a motivation to examine the response of the CO_2 sensors in more detail (see Section 7.2).

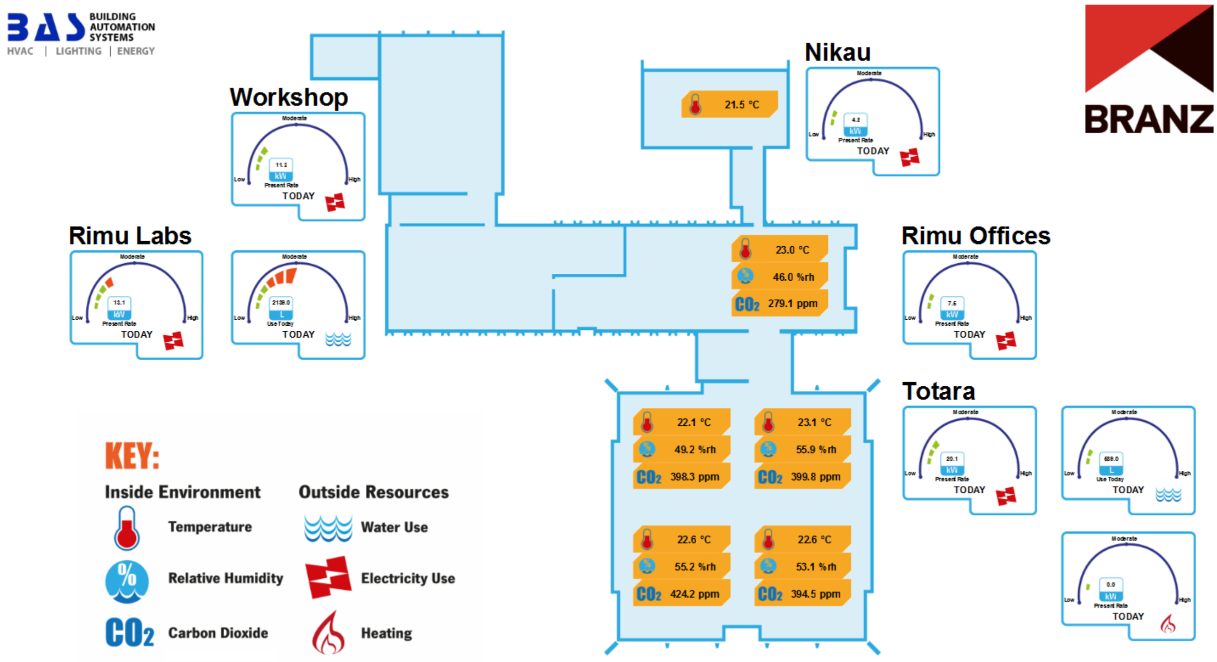

Figure 41 Current overall building operation screen.

The energy and water flows into the building are displayed in a series of dials arranged around the outside of the buildings. These dials have a graduated colour scale so that high readings are more likely to attract attention. A close-up of the Rimu labs electricity dial is shown in Figure 42. The current rate of consumption (kW for electricity) is given as a numeric value within the dial.

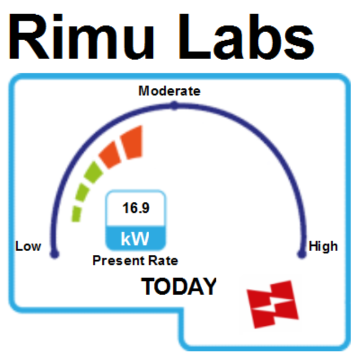

Figure 42 Close-up of the electricity use dial for the Rimu labs.

As there was no experience as to what could be expected as low, moderate or high electricity usage, a data entry screen was added to the BMS system (see Figure 43) so that threshold settings could be easily set by BRANZ staff for each of the dials. As the expected intensity level varies by time of day and day of year, separate thresholds can be specified for each hour of the day for each season of the year.

Operationally, the sensitivity of the dials has not been sufficient to allow building users to appreciate which areas are having abnormal usage. Most of the dials display low or moderate usage and vary little from that. This is as a result of having only one threshold for each dial which is generally set as to what would be a high usage. Perhaps the design of the dials need to be focussed more on typical usage with an emphasis on current usage being less or more than this value.

Figure 43 Screen for setting the seasonal thresholds for one of the consumption dials (Rimu labs electricity).

Electricity is well disaggregated and is shown separately for the Totara building, the Nikau building, the Rimu offices, the Rimu labs and the Workshops.

Heating is provided from a central pellet boiler via radiators feed throughout the refurbished buildings. In order to determine the heating this provides, measurement are made on the amount of water provided to the radiators, the temperature of the hot water supplied and the temperature of the return water. Measurements were made separately recorded for the Totara building as well as overall heating supplied by the pellet boiler.

Water is not used (except for the sprinkler systems) in the Nikau building or the Rimu offices (excluding the toilets which are adjacent to the Rimu labs). Water is used in the Rimu labs and Workshops for a variety of experimental tests as well as for toilets and showers. The water use in Totara includes toilet and shower use as well as potable water use in the Cafeteria and other areas.

As water use is more sporadic, displaying the instantaneous water flow would often result in zero values. In order to provide some averaging over time the water usage is displayed as the accumulated quantity used that day (in litres). The thresholds consequently involve increasing values during the day to give an approximate 'current' value for the water dials.

The second display screen (Figure 44) shows a cross section through the Totara building and provides information on how the natural ventilation system is operating. The core component of the natural ventilation system is a stack ventilation chimney at the centre of the building. As heat builds up within the building a temperature gradient will develop within the chimney allowing excess heat from the building to be vented on the leeward side of the chimney.

The temperatures near the top and bottom of this stack are shown as overlays in the display screen. When the screenshot was done in Figure 44 there was little temperature build up in the building. The temperature difference was only 0.3 °C between the upper and lower measurement points in the chimney and the ventilation outlets were consequently all closed.

Temperatures are shown from sensors around the perimeter zones of the building as well as temperatures from the core areas of the building. The outside temperature is shown to the right of the building. The state (open or closed) of the vents and whether the fan to assist with the stack ventilation is operating or not are also shown as pictorial overlays on the display screen.

In order for the stack to operate effectively, sufficient inflow is needed and this requires the windows from around the perimeter of the building to be manually operated. The display screen will indicate 'Ventilation Required' when opening perimeter windows would assist with the ventilation in the building.

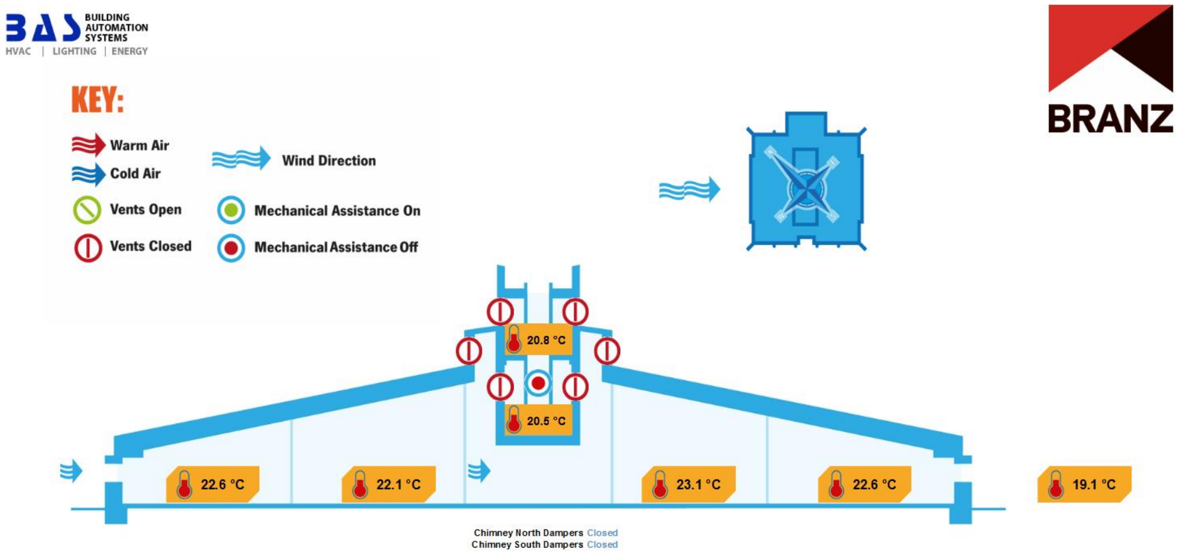

Figure 44 Second display screen showing a cross section through the Totara building and the characteristics of the natural ventilation system.

An initial mock-up of this screen provided a very static picture of the present operation of the ventilation system within the building. While temperatures changed and vents opened, it was difficult to appreciate the air movement within the building. A more engaging display screen was achieved by adding animated arrows to suggest air movements within the building these simply indicated movement to the core of the building from the windward side with the blue colour changing to red once the stack chimney begins to operate.

The third screen was intended to track progress on how energy was being used in the redeveloped buildings. Comparisons were intended to be made between today's usage and yesterday's usage, this month's usage with last month's usage and this year's usage with last year's usage.

The screen, as developed, is shown Figure 45. There were many problems with this screen and it is probably best to redevelop the concept for this screen rather than to work with what is here.

The problem with this screen is that comparison is difficult to determine just from a short examination of the screen. For a start, too many areas of the buildings are considered. Perhaps only one or two of the buildings (and none of the labs) should be included. While lighting can be an actionable item, it also doubles the amount of information presented on the screen.

The timescale for this figure is also difficult to understand and day to day changes are presented alongside longer term (monthly and yearly) reporting. How the building is performing on a longer term can be reported back in other ways and detracts from what could be a useful day to day comparison.

The Use Today, Use This Month, Use This Year categories are also incomplete so comparison to the Use Yesterday, Use Last Month, Use Last Year categories requires assessment as to how much of the day, month or year is complete. The scaling for each period (day month or year) is also different so guidance would need to be provided as to what ‘good’ figures would be for each of these values.

Energy Usage Power (kWhr)

	Use Today	Use Yesterday	Use This Month	Use Last Month	Use This Year	Use Last Year
Flexible Lab, Workshop	55.0	90.0	2267.0	1535.0	3802.0	0.0
Q Lab, Controlled Environment Lab, Hot box	108.0	193.0	6548.0	4418.0	10966.0	0.0
Electronics Workshop	0.0	2.0	31.0	21.0	52.0	0.0
Heat Transfer Lab	9.0	16.0	302.0	201.0	503.0	0.0
Clean Lab, Controlled Climate Lab, Chemical Lab	9.0	16.0	431.0	320.0	751.0	0.0
Rimu Office Area, Network Room, Toilets	36.0	61.0	1273.0	712.0	1985.0	0.0
Nikau	5.0	9.0	170.0	15.0	185.0	0.0
Totara Open Plan West, Core	28.0	58.0	1349.0	771.0	2120.0	0.0
Totara Open Plan East	16.0	31.0	664.0	395.0	1059.0	0.0
Kitchen, Cafe	80.0	105.0	2102.0	1299.0	3401.0	0.0
Nikau Server Room, PABX Room	54.0	97.0	2565.0	1316.0	3881.0	0.0

Energy Usage Lighting (kWhr)

	Use Today	Use Yesterday	Use This Month	Use Last Month	Use This Year	Use Last Year
Flexible Lab, Workshop	32.0	36.0	873.0	451.0	1324.0	1.0
Q Lab, Controlled Environment Lab, Hot box	8.0	10.0	241.0	177.0	418.0	0.0
Electronics Workshop	1.0	1.0	30.0	17.0	47.0	0.0
Heat Transfer Lab	5.0	8.0	97.0	104.0	201.0	0.0
Clean Lab, Controlled Climate Lab, Chemical Lab	10.0	7.0	314.0	216.0	530.0	0.0
Rimu Office Area, Network Room, Toilets	27.0	48.0	1008.0	631.0	1639.0	0.0
Nikau	0.0	0.0	0.0	0.0	0.0	0.0
Totara Open Plan West, Core	41.0	75.0	1532.0	1059.0	2591.0	0.0
Totara Open Plan East	42.0	74.0	1724.0	1109.0	2833.0	0.0

Figure 45 Overall energy performance screen.

An improved overall performance screen would be to show the daily energy consumptions for a particular building for a short period of time, perhaps two weeks, so that any weekly variations could be seen including the impacts of the weekends. Figure 46 shows a mockup screen showing how these elements could be represented. The orange line could be a suggested target for the operation of the building. In setting targets, it would be beneficial to ensure that the targets are achievable.

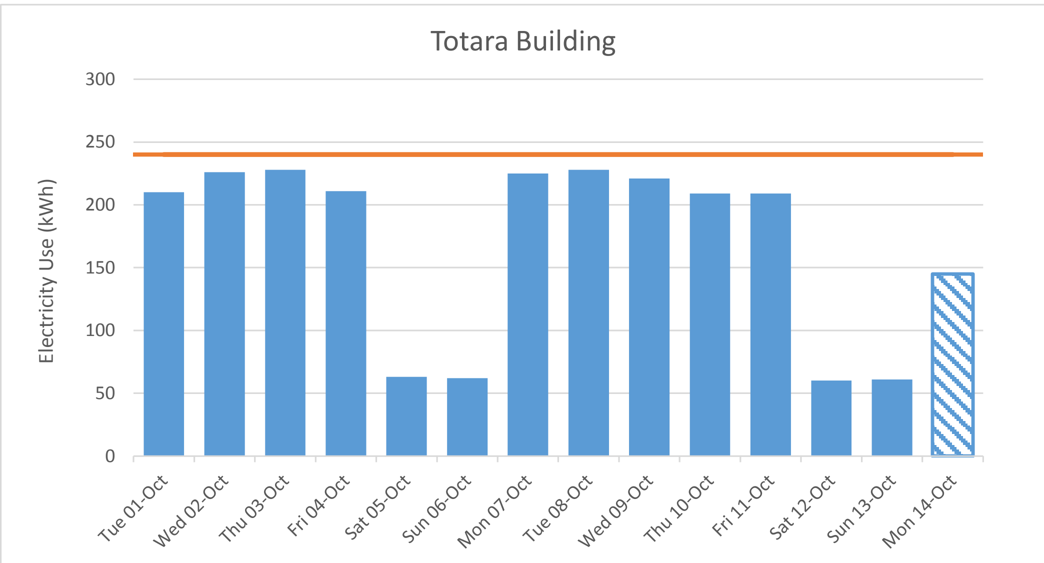

Figure 46 Concept for day to day overall energy performance screen.

The fourth screen displays information on the operation of the solar water heating system. This screen called up a webpage developed by Splash Monitoring who provides these type of displays for a range of solar water heating, solar photovoltaic and other performance monitoring applications.

In the display screen, the BRANZ solar water heating system is shown as a 3D schematic with a range of temperatures, flow rates and solar radiation levels overlaid. The graphic includes a high degree of animations including moving clouds, change skyline, pump movement, bubbles indicating water circulation and changing activities in the bathroom. The graphic is also directly viewable from the internet in the Splash Monitoring gallery located at http://www.splashmonitoring.com/system/branz.

Viewing this information on-line also allows access to a range of graphing options which can display a range of parameters over a wide time window.

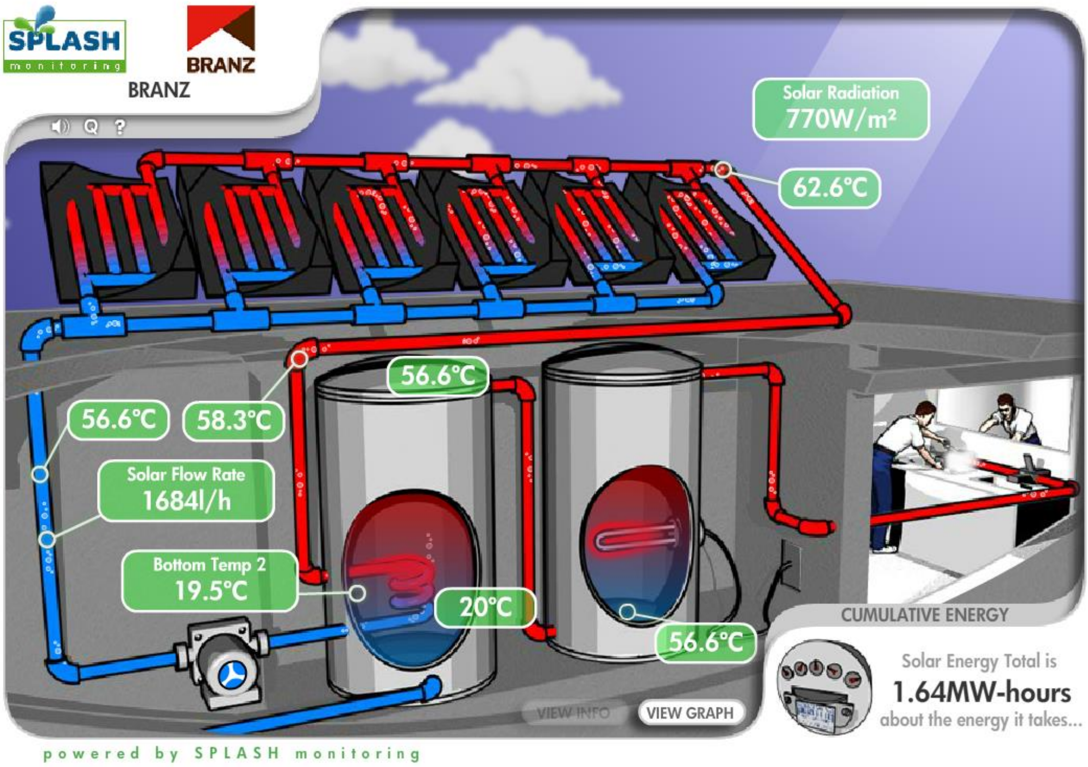

Figure 47 Solar Water Heating (SWH) performance screen (Splash Monitoring).

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10.1 BRANZ Media videos

General look through the Totara building;
http://www.youtube.com/watch?v=CFj2iZt4B-I

Lynda Amitrano's guide to the sustainability features of the Totara building
http://www.tinyurl.com/branztotarabuilding

The official opening of the BRANZ refurbishments
http://www.youtube.com/watch?v=qPSL7WwnGXE

APPENDIX A: BUS METHODOLOGY RESULTS BY BUILDING

This appendix contains summary scores and comments from the BUS method occupant surveys for the individual BRANZ buildings. The analysis given here is from the individual responses and no judgement is made of the scores. In particular, the Productivity and Health questions are of individual's assessment of these issues.

Averages of the scores for particular questions appear on a vertical scale from low scores at the bottom to high scores at the top.

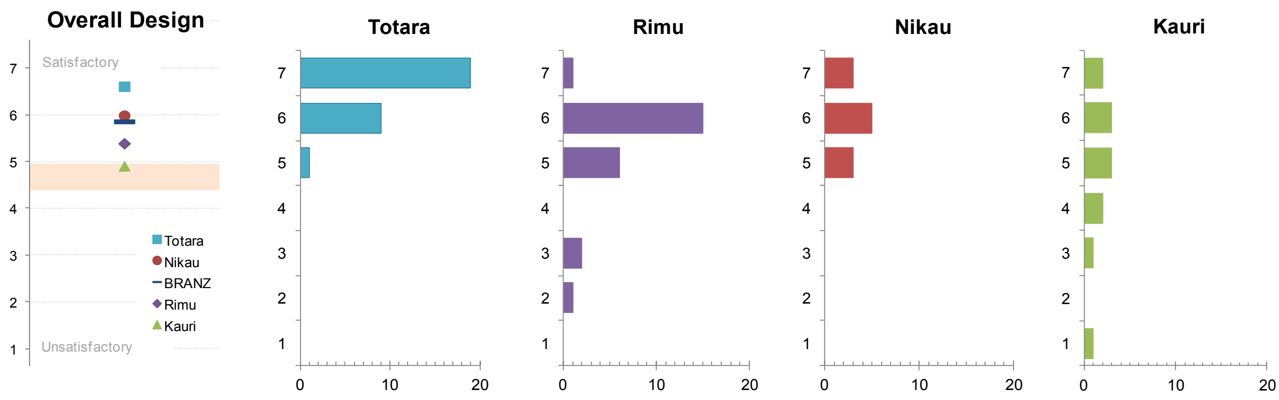
The New Zealand benchmarks appearing in this report should only be compared against BRANZ as a whole, as the sample size for individual buildings is too small. The different scores for the different buildings does provide some indication of the importance of these various issues which can be further examined by the breakdown of individual scores (number of response to each score) given along with a review of specific comments.

Some comments have been edited to prevent the respondents from being identified.

	Totara	Rimu	Nikau	Kauri
Works well	Everything else fine.	No problems.	Close to colleagues.	Own office.
	Coffee station has a better flow.	Good space to work around.	Good daylight and Natural Ventilation.	Individual offices. Nice View.
	Good contact with colleagues - especially café space.	Specific working areas for different jobs and testing.	Good light, access to resources.	Quiet times when concentrating.
	Friendly, open environment. Good workspace for users and around desk. Good natural light (although not sufficient without lights).	It works well to be abel to use the thermal lab for the occasional experiment. Clean and tidy.	Good to have team discussions, however this adds to the problem above.	Ability to close office to concentrate/discuss personal issues with staff.
	Lovely open feeling, staff close by - good for interaction. Excellent for outside visitors - V.G first impression. Good ambiance.	Separation of laborotories from offices. Having my own office so I can shut the door on noise.	Nice working space with a nice outlook. Team interaction when need.	Own offices can control environment to a certain extent.
	Collaborative collegial space, industry meetings, staff social space.	Ability to be able to close door if need to concentrate	Sitting close to colleagues.	Own office means I can shut the door when I am in need of undisturbed time to work.
	Amount of personal space - desk, cupboards, pinboard. Good communication systems. Good air and light.	Space and lighting is good. Open design with glazing stimulates team communication.		When jobs are properly planned and executed.
	The space and the natural light. I love being able to see outside.	Great office space. Good bench space in labs to work on.		Generally work well.
	Great that I sit next to my manager.	Individual offices. Opening windows.		Ability to close the office door for quiet working. Reasonable access to printer and resources.
	Plenty of space and storage.	Sharing an office, view outside, pleasant environment.		Computer.
	Space - both work and social, access to meetings rooms, light, temperature.	Size and space are good. Rooms are clean.		
	Having great places to put things - we are in a rural area and it usually takes extra day to get stuff out here.	Good access to facilities (printers, copier, storage, meeting rooms).		
	Lots of space, so getting to printer and storage without getting in the way of others and vice versa is easy. Also, temperature is generally better.	Out of the way, disruptions are only when people want to see me.		
	More desk space.	Plenty of Lab space.		
	The phone rooms work well - loud conversations can be distracting in open plan offices.	being able to close the door when colleagues are being noisy.		

	Totara	Rimu	Nikau	Kauri
Hinder	The sun shines into my eyes from the windows above reception late in the day	Noise from corridor (sometimes).	Interruptions by open plan, too hot in summer.	Not much.
	Light - the lights appear to be constantly dimming and strengthening - very quickly - needs to be gradual. At the end of the day the windows in the centre of the building ' ceiling level' hit my desk making it impossible to work.	Lab space in chem lab is uncontrolled and often at ~28 oC … no cooling. Water pressure problems. Skylight windows have cable trays blocking light.	Interruptions.	Noise.
	Lights sometimes go a bit dim - automatic system needs fine-turning.	Arrangement of different rooms for different testing purposes are not very friendly.	Lack of individual spaces. Noise in the open plan scenario.	Noise interruptions. Visual interruptions
	Being unable to change the light (bright or dim).	Too many doors, passages. Things spread out over site. Vehicle access poor.	Noise and Interruptions.	Storage.
	I am a bit blocked in with my workstation as the orientation of my desk was changed at my request..	Lack of quiet spaces available with easy access to hard copies. Sharing is a step backwards re privacy.	Noise levels, interruptions, easy access to relevant information on desk.	Smoke from fire lab entering building through vents, noise from lawn mower.
	Building too hot for me	Too few toilets for number of people.	Open plan, no privacy, too many impromptu meetings.	
	Privacy - unable to have private conversations or work on documents such as performance reviews at your desk.	Lack of a whiteboard. Not as 'peaceful' as when we (generally) had our own offices.	Unable to shut myself away from the rest of the team to carry out tasks that require quiet. This is something I need to do ~50% of the time.	Storage space for items to be filed. Air conditioning! In summer shade from sun. Large pin boards enable me to pin up relevant info.
	Interruptions from other people.	Glare: but this is easily remedied.		Lack of proper planning sometimes..
	Loud conversations, desk too close together.	I really dislike working when cramped.		Environment internally - too hot or cold. Old and tired. Noisy at times.
	Noise - can hear noise from half the building… people talking, phones ringing and people walking down central walkway.	People using corridor through laboratories as a general accessway. Noise from cafeteria.		Noise at the tea/coffee making station. Temperature not controlled effectively
	Noise (occasionally).	Computers can overheat room in summer. Lack of whiteboards in office space.		Resource room full.
	Noise levels - sound carries and nearby conversations can be distracting.	The laboratory environment, i.e. temp and humidity.		
	Noise outside lunch/tea breaks. Major part of collection have to be stored in another building.	Pinboards would be good. Glare from the sun can be a problem.		
	Good flow throughout my area, the equipment needs to be in it's right place, right storage space put in it's	Multiple access controlled doors can sometimes be a problem with moving trolleys etc.		
	Too much talking - lol. Open plan. The café I have put on 5 kg's.	Unable to have light on or window open due to room-mates needs.		
	None.	Too much low angle sunlight at workstation.		

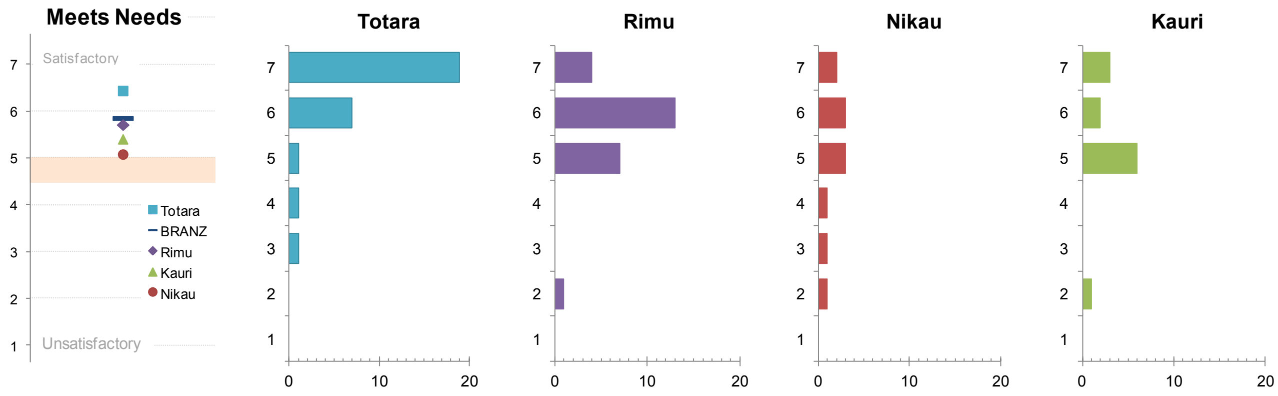
Overall Design



Positive comments	Beautiful design, spacious clean, bright, happy environment.	Good lab spaces. Good office. Toilets a bit budget.	Good Space. Warm.	Own Office - control interruptions, like solid (not glass) walls.
	Brand new building with state of the art technology on energy, lighting, working areas	Great that the café, reception and most of the staff are all close.	Pleasant outlook.	Single offices work well.
	Building design interesting and contemporary.	Totara seems good - the rest, not so much.		Office size is sufficient, services are satisfactory.
	Comfortable, pleasing to the eye - quite beautiful.	Much improved after renovations!		
	Feels very modern and light and airy.	The building is amazing. Great open plan!		
	It's a light, airy building and feels fresh and comfortable.			
	Modern, spacious.			
	New totara building has exceeded my expectation.			
	Nice light.			
	Very impressive.			

Negative comments	Meeting rooms are too reverberant.	Wasted spaces such as corridors could have been used for better toilets and showers.	Overheats in summer.	Old building in need of TLC.
	A bit echoey.	Looks good, not as functional as could be. Short sighted e.g. skylight windows/cable trays.	Too hot in summer.	The building is not having an energy - efficient heating system.
		Hard to find where a given person sits. Glass 'Decoration' is horrible.		Window sill too high.
		Acoustics need sorting.		

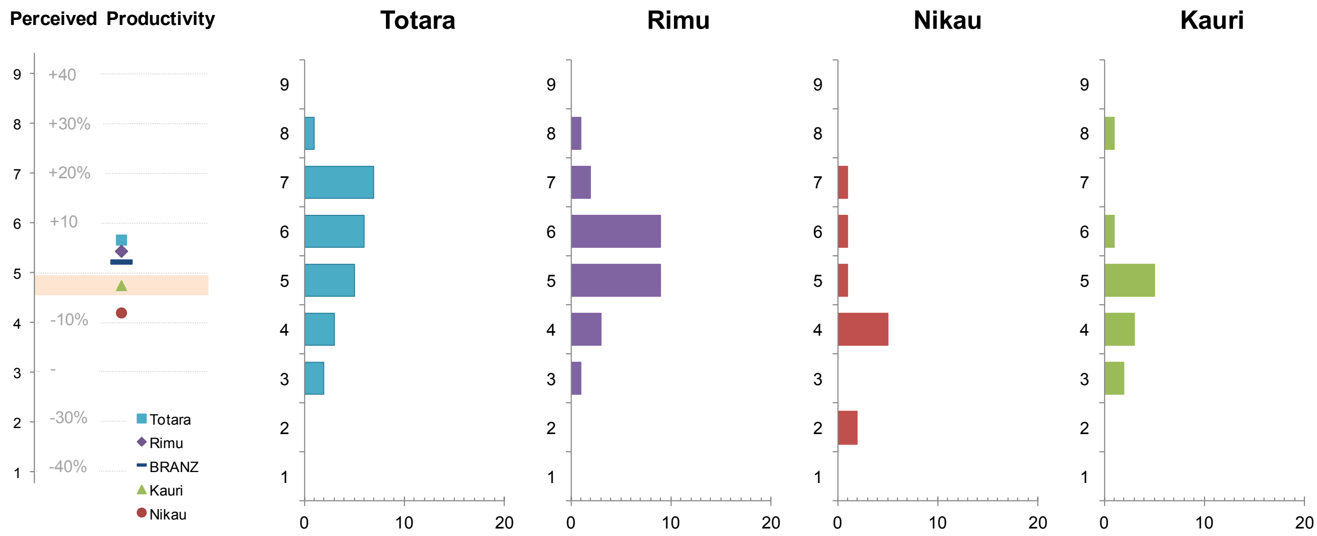
Meets Needs



Positive comments	All excellent apart from privacy.	Nothing is too far away. They are very well furnished.		
	Only issue is the heating I get very hot during the day.	Great to have an individual office.		
	We had an opportunity to say what we needed in this building.			

Negative comments	Can be noisy.	Designer didn't consult users and as a result have not been able to provide specific needs.	No water.	Works fine, although we would like our Admin Asst back.
		Toilets are at one end of the offices (would be great if they were more central) and often there is not enough of them.	Noise reduction.	Could benefit with small meeting/office space for clients/visitors. The meeting space is adequately covered by new admin building, and general practice (going forward) would be to limit the intrusion of visitors/clients into office spaces.
		Toilets are pretty tight in Rimu.	Preferred an office.	Space for fire safe storage.
			Unable to shut myself away. Lack of storage close to my desk.	Very cold in the morning.

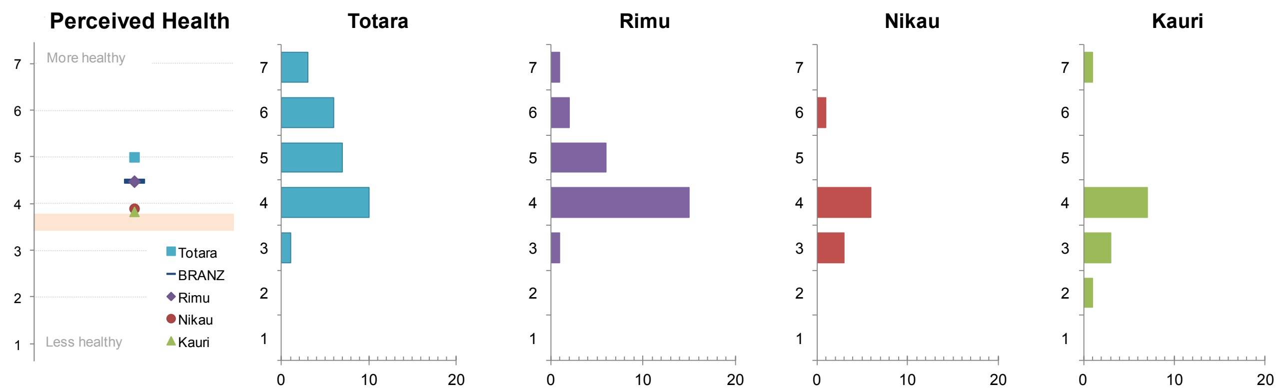
Perceived Productivity



Positive comments				
	I'm still moving in so it will take a while to find homes for everything at the moment. But it is much nicer.	Having more space to work in makes me feel more relaxed, clear headed and able to get on with my task more effectively.	I believe that the gain in productivity of being closer to colleagues is greater than the negative impacts of noise and interruptions.	Hard to tell because I have not worked in a different situation for many years.
	Not sure - can't evaluate just yet.	Hard to estimate - space is nice but I'm not sure if it impacts on my effectiveness.		
	Not sure if the new building has had an effect yet.	Building has helped to overcome issues with vision.		
	Not sure, but it is a wonderful place to work in.			
	The environment does not effect me - just focus on what I'm doing.			

Negative comments				
	Noise breaking concentration.	For me the additional noise and interruptions caused by co-workers and visitors makes concentration difficult sometimes.	Interruptions and noise make working much more difficult.	In a cold room, you can not focus and you won't be as productive as you should be.
	While adjusting am finding myself distracted by noise colleagues and harder to focus.		Get distracted by other interesting conversations.	Can't work if my feet are cold need to heat them up, have a foot warmer for that. My own solution.
			Open plan generally not favourable for research, writing reports, need to phone with research.	

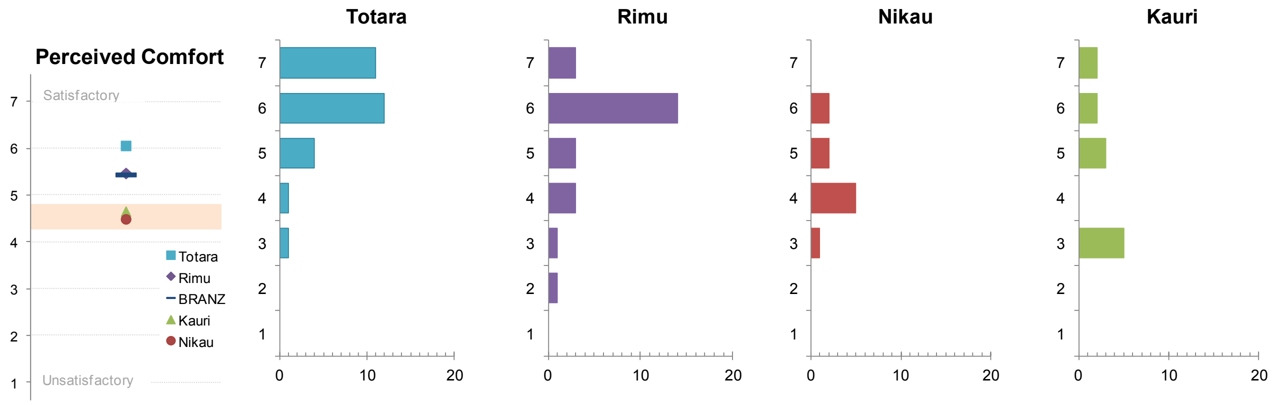
Perceived Health



Positive comments	Not sure.	The clean air is amazing.		Prefer outdoors for health.
	Hasn't affected my health.	Less dust, dirt, better hygiene facilities.		Does '4' mean 'normal healthy'?

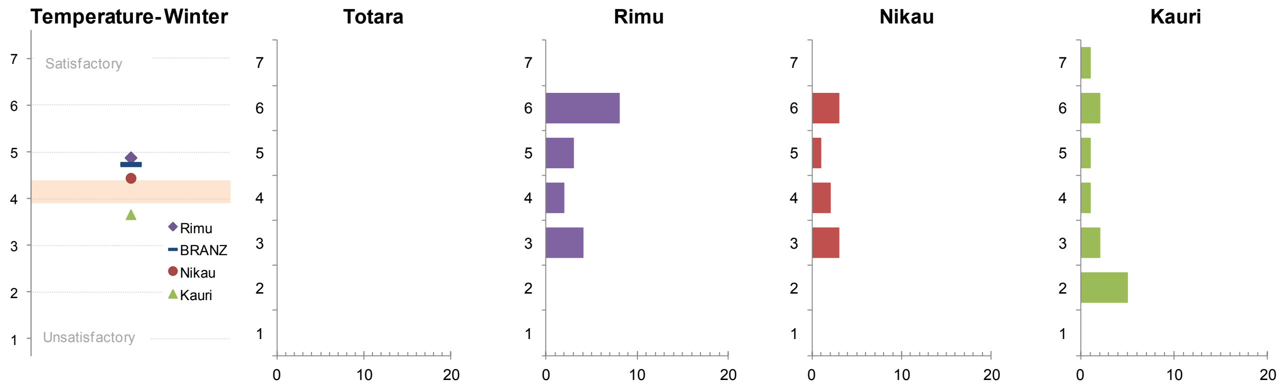
Negative comments	Have been a bit wheezey and had to go to doctors but its settling down.	Early days. I was surprised at the higher VOC paints used though... Would have chosen ones that were both low VOC and Enviro-choice certified.	Near late afternoon recent smoking area has changed and left-over smoke lingers in building..	Dusty conditions have not been mentioned, the old carpet lets go of clouds of dust and fire lab contributor too, aggravate sinus problems.
	Since moved have had headaches everyday.		Good lighting and temperature. Bugs more easily spread in open plan.	Work area is noisy and dusty and fairly physical.
			Colleagues colds/coughing are more apparent	

Perceived Comfort

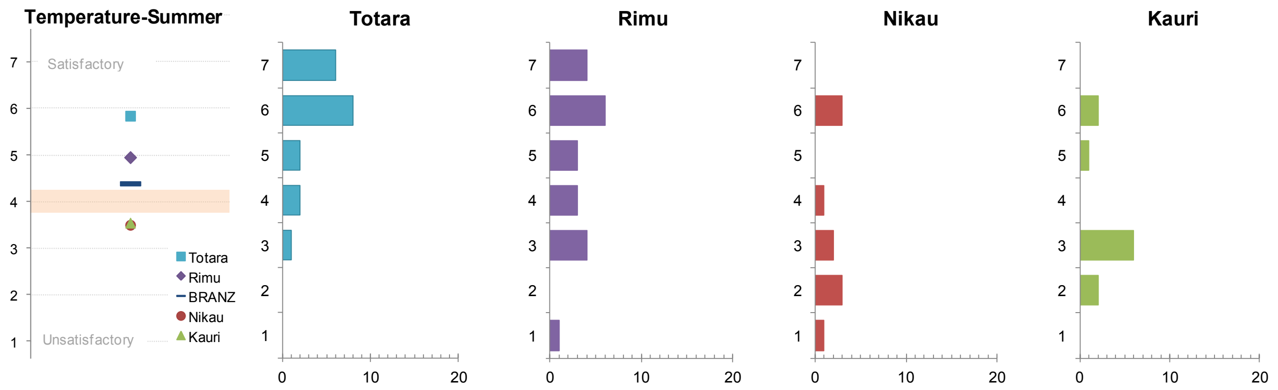


Positive comments	Very accommodating.			
	Very comfortable.			
Negative comments	Can be draughty where I am located. Kitchen smells in a new building - Oh dear! Not good.	The lack of natural ventilation can be trouble at times, we have a small window that causes the blind to make a lot of noise when it is being used.	Hire an electric radiator which we use in winter.	Air quality, heating - cooling needs some attention.
	Light and airie but cold draughts sometimes.	Tricky to answer - have had to discount tradespeople who are temporary.	Temperature control the biggest issue for me.	Concrete floors are unheated and some of us oldies have bad circulation and get cold feet.
		Really stuffy in the office and window system is poor.	Comfort and lighting - good. Work inability to close myself off - bad.	

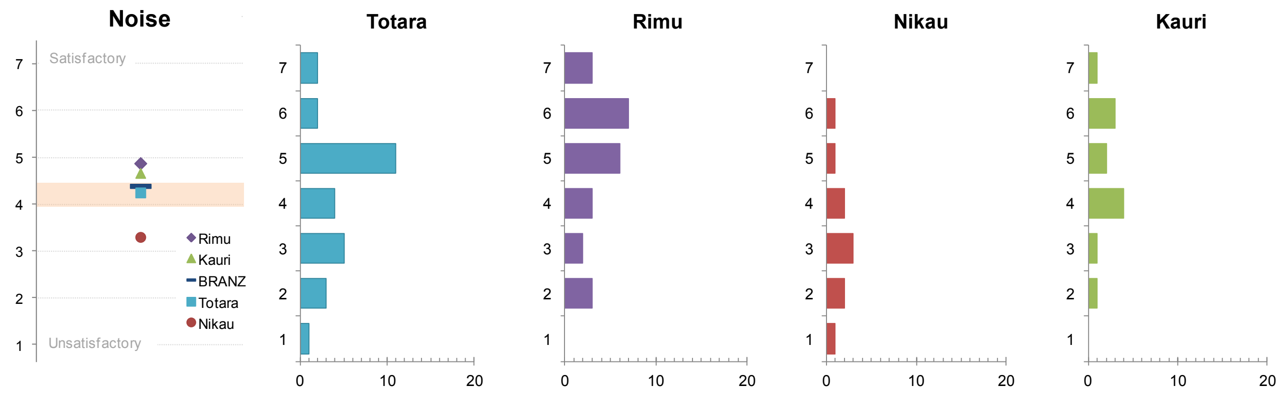
Temperature - Winter



Temperature - Summer



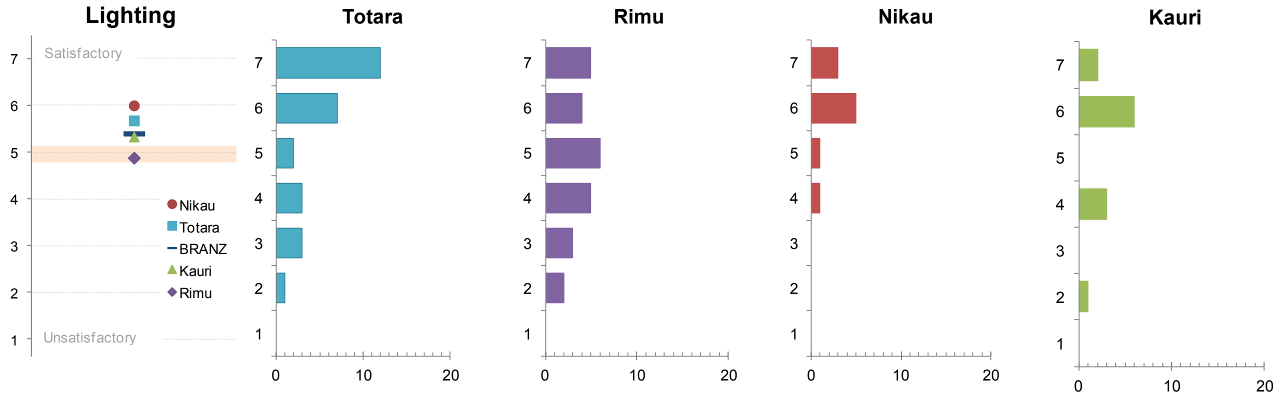
Noise



Positive comments	I like it - no hiding behind doors to talk - only if it is private - this is available too.	Can be controlled by closing door.		
		Not excessive background noise.		

Negative comments	I really feel that acoustics need far more attention. Noises from kitchen, rec area, reception and people walking around all happen during the day to an excess amount.	Construction noise was a pain but has stopped.	Conversations by others.	How can you get 'too little' noise'
	A lot of noise from phones and visitors at reception.	Computer. Lawnmower and buildings cutting stuff. Smokers.	Difficult to ignore colleagues noise. Visitors particularly loud.	Can always close my door if there is too much noise in corridor. Can't do that in 'open plan'.
	Can hear other people's conversation when they are on the phone.	Corridor is quite noisy (not carpeted).		The work area is a very noisy environment at times. That is the nature of the job.
	Sources of noise: People talking in half of building from reception to work areas. Shoes on central walkway. Toilet door squeaking. Phones ringing (especially unanswered calls).	Staff cafeteria noise bounces off glazing into our office and angled at my desk!	In an open plan area with >5 other people doing similar work to me, meeting with SME's talking to each other, talking on phones there is just too much continuous babble to work effectively.	Grass cutting can be very disruptive. Very sociable office with regular impromptu meetings to discuss projects. We can shut our doors if necessary to shut out noise.
	I would make more noise in my area, more than anyone else in this section.			Noise not generally too bad because of individual office.
	Our area gets noisy if there a lot of people in reception.			Bloody lawnmower.
	During morning and afternoon tea the level does rise. Also others may congregate at a colleagues work station for a chat.			
	There is a noise in Reception BUT you can overcome it in most situations.			

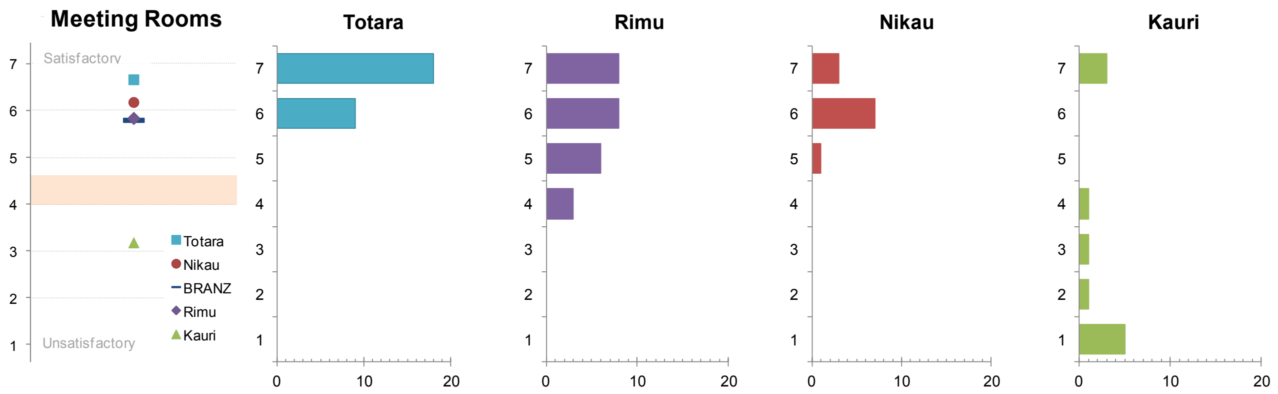
Lighting



Positive comments	Savings on fuel and energy as well as $$ money.		Lighting design is very good.	Lights on or off blinds open or closed, sunny or not. I can always get the level that suits.
	Good lighting.			

Negative comments	For a short time during a sunny day, there is sun beaming in from skylight windows but the desk is so lovely and big, you can get away from it. This may last for about 30 mins only.	Have to have blind permanently shut to prevent direct sunlight and glare off joinery. This then bangs around when we have to open the window.	Blinds mitigate low sun glare in winter but not completely.	In summer months cannot open blinds as it gets too hot. In winter when sun is low similarly need blinds closed.
	Would like to be able dim lights at times. Cannot see the purpose in the light vents outside the North windows	Glare from sun. Blinds work but then the space is very dark and if the window is open the blinds often move and make noise.		Old fluorescents.
	The artificial lights dim and strengthen very quickly - quite off-putting. The natural light coming from the windows above reception (in the centre of the building it hits xxx desk's - too bright - cannot work.	Glare can be a problem because of on-going sight problems. Sun filter on window would be useful at times.		
		Unable to turn on main light in order to meet roommate's needs. Window not by desk but light through glass wall is good.		
	Lighting is great in this area, I should be able to switch lights on and off	Glare in winter low angle sun not controllable with blinds, cuts out too much light!		
	Generally fine, although the aforementioned glare from the sun can be a problem.	Some lighting is great. But in some small rooms it is way too bright.		
		At times need to draw curtain to prevent glare.		
		Positioning of lights to work stations not ideal.		

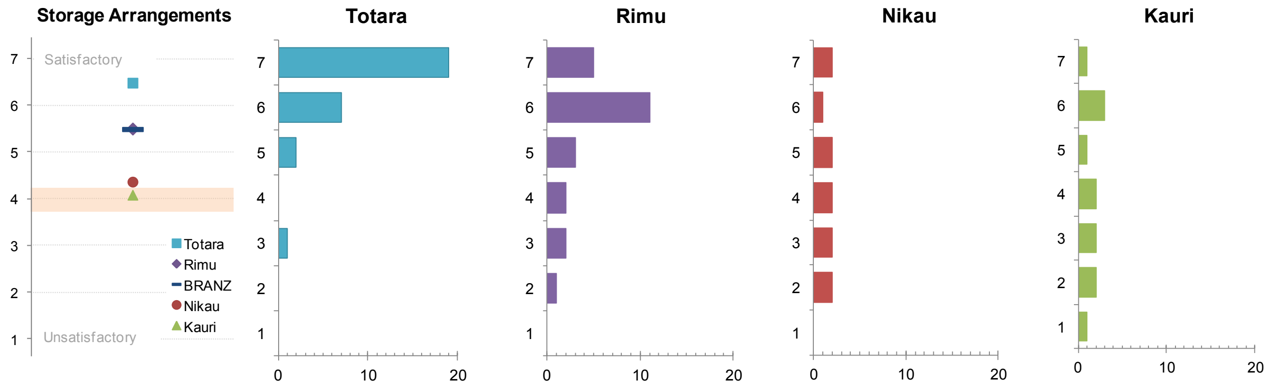
Meeting Rooms



Positive comments				
	We have plenty of meeting rooms.	Has been a problem the last year, but should get better now with Totara.		I have a meeting space in my office which I use regularly. New admin and café provide adequate spaces for this.
	Haven't struggled to find a meeting room yet.	Much better now main building is open.		
		Used to be poor until Totara came on-stream. Nobody has given us a list and location of the new meeting rooms.		
		OK but could offer more privacy.		
		Usage of meeting rooms has recently changed it was a '3'. New building opening = no more problems.		

Negative comments				
	More whiteboards would be good.	No heating in early am can be a problem. Acoustics need sorting.	Not that private.	N/A no meeting room
	Need an hour to set up the big Kiwi Conference room.	Poor acoustics. Generally freezing, glass walls = bad idea.		We do not have a meeting room.
	All meeting rooms should be double to able to be booked - not just the large ones. This includes the finance one.	Both Kakapo and Gecko have no natural light and rather claustrophobic.		No meeting rooms in the building.
				None, but needed.
				No meeting or client rooms.

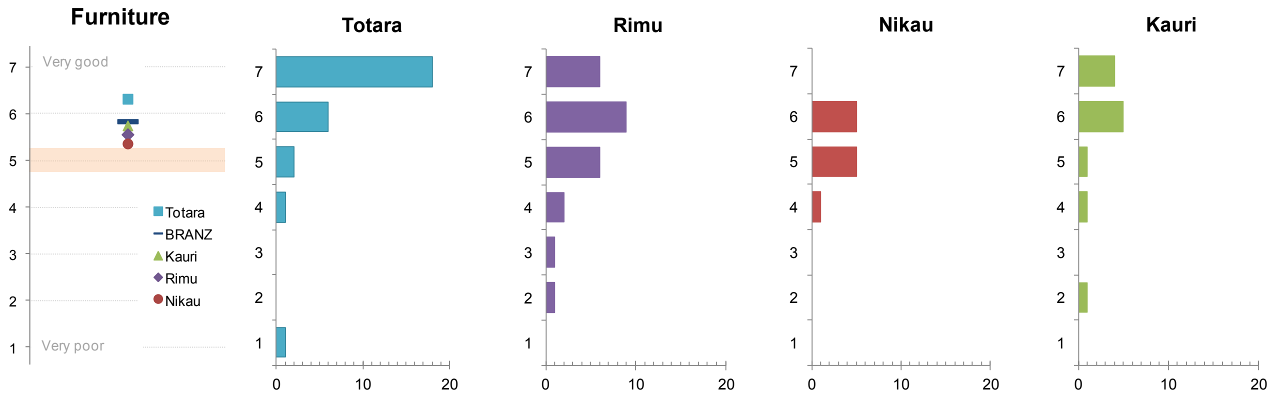
Storage Arrangement

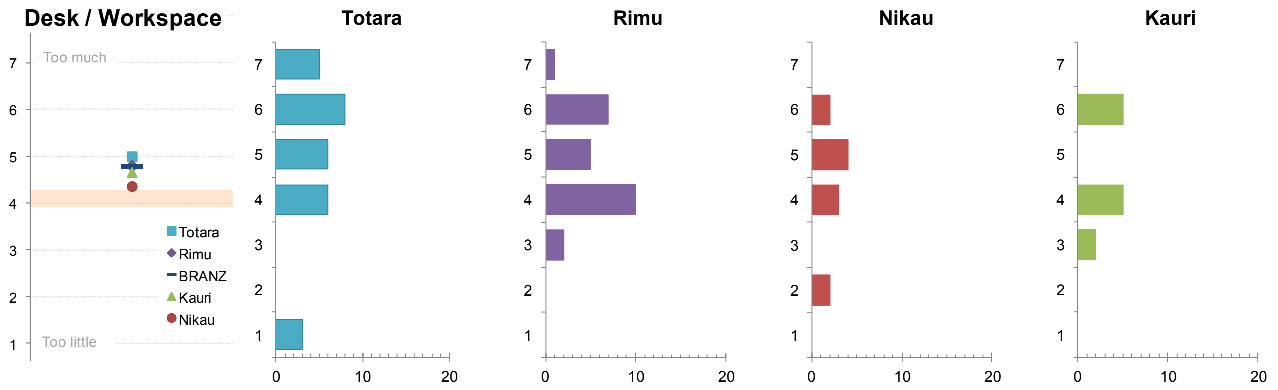


Positive comments	I do not have much to store.	No great demands.		Should improve now that staff have moved out of Matai.
	The lockers are very useful for keeping gym gear.			
	Yes!! Now I have somewhere to put boxes.			

Negative comments	Not well thought out.	We have taken a step back when it comes to storage, our offices are smaller and we have no cupboards at all.	Lack of storage near desk.	We need bigger resource area with storage space for items to be filed!
		Could be more closed in storage in staff offices for personal effects.	Larger items hard to store.	Cramped.
		Some storage areas are oddly placed.	Need more storage for samples close to work area.	
			Poorly conceived.	

Furniture / Desk or Workspace





Positive comments		New chair and adjustable height desk very useful for comfort. Needed to build my own stand for monitor.	Good. Plenty of storage space to keep desk tidy.	
		Very open, good space to spread out. I love it. Great view! Nice to have openable window.		

Negative comments	I dislike my back having such an open space behind can be really draughty sometimes.	Not sure there's been an improvement since re-furb.	It's OK, old set up with separate PC station was better.	I am not at the desk for very long so it is OK.
	Refer to my comment above about being a bit blocked in.	Lack of storage space makes it easy to clutter.	Storage and layout space needed.	Very ad hoc, not comfortable, location on ideal.
	Desk is too small. We process a large volume of paper based work. Need more room to pin up important information at the desk. Drawers - not big enough and no pencil insert supplied - others looked at too big or small.	Furniture not necessarily suited to way it's used! Layout of plugs mean inflexible layout of furniture. It would be better to have adjustable desks. Would like a pin board.	Desk and chair is good. Lot less space than previously around my desk. Files no longer to hand.	I would like to have a better chair, clean carpet.
	Lower drawer is narrower than my old one, so I can't hang folders in it as easily.	Very limited in how furniture can be set up in the space.		Would be better if I kept it tidier.
	Need space for my printer.	Desk is scheduled for replacement as too low.		