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STUDY REPORT

SR 236 (2010)

Building Energy End-Use Study (BEES) Year 3

Nigel Isaacs (ed.), Kay Saville-Smith, Michael Babylon, Rob Bishop, Michael Camilleri, Michael Donn, John Jowett, Duncan Moore, Hans Roberti

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The work reported here was jointly funded by BRANZ from the Building Research Levy, the Foundation for Research, Science and Technology (FRST) from the Public Good Science Fund, the Department of Building and Housing (DBH) and the Energy Efficiency and Conservation Authority (EECA).

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Executive Summary

Building Energy End-Use Study (BEES) Year 3

Authors

Nigel Isaacs (ed.), Kay Saville-Smith, Michael Babylon, Rob Bishop, Michael Camilleri, Michael Donn, John Jowett, Duncan Moore, Hans Roberti

Introduction

This Executive Summary provides an overview of the full report, which can be downloaded from www.branz.co.nz or purchased from the BRANZ Bookshop.

BEES is jointly funded by BRANZ from the Building Research Levy, the Foundation for Research, Science and Technology (FRST) from the Public Good Science Fund, the Department of Building and Housing (DBH) and the Energy Efficiency and Conservation Authority (EECA). Their support is gratefully acknowledged.

The BEES programme will provide a greater understanding of the how, why, where and when of energy and water use in New Zealand's non-residential buildings. Through actual measurement and analysis of energy use in buildings, BEES will identify opportunities for increased operational energy and water efficiency. The programme has eight key objectives:

- Quantify and characterise the energy use in N.Z. non-residential buildings
- Understand how energy is used in today's non-residential buildings
- Improve the basis for government policy development and implementation
- Improve models of non-residential building energy use
- Provide guidance to create more productive work environments
- Support the reduction of GHG emissions and adaptation to climate change
- Provide design and operation guidance to reduce energy consumption and GHG emissions
- Improve the basis for development of the New Zealand Building Code (NZBC), Standards and energy rating tools such as GreenStar.

Understanding the non-residential buildings sector

The non-residential buildings sector has been divided into five floor area strata (see BEES Year 1-2 report), to give approximately equal total floor areas for each group, as shown in Table i. This approach increases the statistical precision of the survey. It should be noted that these numbers continue to be provisional, as there is no national list of non-residential buildings. They are based on amalgamation of valuation data into 'Building Records', and will be refined as the results of the various BEES activities provide greater certainty. For example, initial work has shown that 4.4% of the Building Records have 2 buildings, while 1.7% have 3 or more buildings

Table i: Non-residential size strata

Floor Area Strata	1	2	3	4	5	Total
Minimum Floor Area	5 m²	650 m²	1,500 m²	3,500 m²	9,000 m²	
Approx. No. of 'Buildings'	33,781	10,081	4,288	1,825	564	**50,539**
% of Buildings	67%	20%	8%	4%	1%	**100%**
Total Floor Area (million m²)	9.9	9.6	9.5	9.6	9.8	**48.3**
% floor	20%	20%	20%	20%	20%	**100%**

BEES has now obtained data on approximately 2,000 buildings, including location, floor area, foot plate etc, which has allowed the production of simple 3D computer models. This has been achieved making use of PropertyIQ valuation data, web searching including online mapping systems and site visits. This forms a unique database of the non-residential stock, and will support a range of future analysis based around the buildings rather than the traditional statistical exploration of business economic activities. This database also supports the random selection of buildings for the other research components.

A **national telephone survey** was planned, specified and undertaken on a sample of approximately 1,000 Building Records. Although the unit of analysis is the building, it is necessary to survey individual building premises. The phone survey requested information on: occupancy and use; energy and water supply; tenure conditions; and building characteristics, Rather than asking for detailed energy and water use data, permission was requested to access revenue meter data. Where the premise responds positively, the revenue records are obtained and subjected to preliminary analysis. 268 premises responded positively, although the resultant number of buildings is about 146. The data will be subject to analysis in Year 4.

A range of data is available on the businesses and their premises e.g. 70% of the businesses had a fixed term and 14% a periodic lease. Just over half (53%) of the business had been in their premise for up to six years, with 11% for over 22 years. Although the majority of businesses directly purchase their energy, 15% of gas users and 11% of electricity users had it included in the rent. On the other hand, only 18% of business report paying directly for their water. Equipment data was also collected e.g. 92% of businesses had 1 or more computers, while 50% had a water cooler.

Approximately 60 premises, selected from the database, were targeted for the installation of **specialist monitoring** equipment and each monitored for about 2 weeks. For each premise, this includes: monitoring of energy and environmental data; an appliance audit; a lighting audit; a building audit; a hot water audit; a water audit; an equipment audit (e.g. HVAC, lifts etc); and an occupant details questionnaire. The monitoring equipment has been supplied by Multivoies (www.omegawatt.fr) which connect through the GPRS cellphone network to provide remote data collection and Energy Logger Pro (www.onsetcomp.com/data-logger). A camera based system has been developed for monitoring of large gas and water meters. Based on a low-cost commercial time-lapse camera, it provides an effective solution to this difficult problem.

Agreement has been reached with Ove Arup to use the BUS instrument for the social research component of the project (www.usablebuildings.co.uk). This instrument has been internationally used and validated over a number of years, offering a valuable baseline for the evaluation of the BEES buildings. The selection of the BUS instrument included an evaluation of the cost of creating a BEES survey instrument and calibrating it compared to using existing options.

Early monitoring results – energy & environmental

The monitored data is processed and subjected to a preliminary analysis. The major electrical end-uses in the surveyed buildings are: premises total; lighting; air-conditioning; plug loads; and hot water. Based on the small number of monitored buildings, daily electricity use varies widely, from 7.1 kWh/day for a small shop to about 1,500 kWh/day for a large office building.

The sample is too small to make useful breakdowns by business type or size; however there appear to be some obvious patterns in the data.

The smaller shops are usually small suburban or provincial town shops, which often have no dedicated heating or HVAC system. Their energy consumption is usually very low (10-30 kWh/day). For these types of business the lighting is often the dominant end-use, and is often a high percentage of the total electricity consumption. One small shop had 97% of the electricity used for lighting. This proportion was verified, as the shop had no hot water system, no heating, and only a handful of small appliances.

Air-conditioning is present in only some premise. Some are central HVAC systems, but most are single or multi-split systems. As the time of year monitoring was done varied, the energy consumption for air-conditioning does not represent a full year. Consequently the air-conditioning electricity consumption for the short periods monitored is highly variable, ranging from 1% to 58% of total electricity consumption.

Power point (plug load) electricity consumption appears to be slightly more consistent, ranging from 21% to 70% of total electricity consumption.

Hot water appears to be a minor end-use. For those premises where a hot water system existed and was monitored separately the use was usually about 1% to 2% of the total. Some premises had hot water systems that were turned off or disconnected.

Computer servers are difficult to monitor as occupants often refuse to allow monitoring equipment to be installed due to concerns over possible power interruptions (which we note is unlikely with the BEES monitoring equipment). For the three servers monitored so far, consumption ranges from 3.2 kWh/day to 48.1 kWh/day. These are typical business sized servers – one large server farm in a monitored BEES building, which consumed 160 kWh/day (~60,000 kWh per year) for one of two server rooms, excluding the room HVAC. These preliminary results could suggest that server electricity consumption might be larger on average than hot water energy consumption in commercial buildings.

The monitored electricity data already shows the wide variation of electricity consumption between premises and between end-uses. Even in the small selection so far, the range from lowest to highest electricity consumption is a factor of 200.

Temperature, humidity and light are monitored in several locations within each of the premises. As the monitoring is for a short time period it is not an annual average.

One of the early findings from HEEP was that winter indoor temperatures in New Zealand houses were low, and often poorly controlled (see www.branz.co.nz). In the BEES premises monitored thusfar, the indoor temperature profiles usually do not show evidence of tight control of the internal temperatures. Most premises seem to be left free-running after hours, and only a few show evidence of being conditioned 24 hours a day to a controlled set-point temperature. It seems that many non-residential premises are not well controlled, possibly due to a lack of a centrally-controlled HVAC system, insufficient capacity or poor control. The belief that non-residential buildings in New Zealand are operated to a well-controlled set-point and schedule might not reflect the actual operation of many buildings. This result can be expected to change as increasing numbers of different building sizes and uses are monitored.

Patterns of lighting (lux) suggest that lighting is used mainly during the day, and that light levels (and perhaps lighting energy consumption) are reasonably stable throughout the day.

Humidity and CO_2 levels are also being monitored, and will be reported on in subsequent analysis.

Case Studies

Five trial case studies were designed and carried out to explore what drives the variation in energy use in non-residential buildings. The results of this work also provided the opportunity to examine the value of case studies to the overall research.

Case Study 1 compared the measured energy usage for similar premises and found wide variation across the four premises in the one building.

Case Study 2 looked at the data requirements for measuring temperature-dependent building energy loads, concluding that the annual temperature response of a building in the mild Wellington climate cannot be determined from short-term measurements.

Case Study 3 looked at understanding long-term changes in building energy use, and concluded that increases in non-temperature dependent electrical load correlated to the increases in the background building electrical load, while temperature dependent variations related to the consistency of the HVAC control and the external temperature.

Case Study 4 explored the possibility of energy savings opportunities resulting from the BEES monitoring, and concluded that opportunities do exist.

Case Study 5 examined the accuracy of circuit labels – how many circuits in a premise actually do what the labels say they do? It found that the problem was sufficiently serious to require details to be recorded during monitoring of any unclear or mislabelled circuits.

Systematic Review

The method for a systematic review on the efficacy of energy optimisation policies, practices and programmes was developed with BEES. However, in applying the systematic review template to the body of literature reviewed in the BEES project, it became clear that the research base was still very limited and continuing would add little materially to the work already undertaken by the United Nations Environment Programme’s 2007review of buildings and climate change. For that reason, the focus of activity shifted to: distilling the best practices around optimising energy efficiency in the building stock; and comparing those practices with those that prevail in New Zealand.

Educational and Health Buildings

A separate investigation was completed into the availability of data on energy and water use in educational and health buildings. It was found that that there is insufficient data collection, reporting systems and management systems of the energy and especially water use in New Zealand education buildings and hospitals. What data is reported is inconsistent between sources in terms of the quality and the details of what is collected and reported.

The lack of standardised collection, reporting formats and management systems arises across these sectors and was a common issue regardless of the type of building (with the only exception being universities) and whether it was energy or water consumption being measured. As a result the current data on energy and water consumption in the majority of education buildings and hospitals is disparate. There is a need therefore for a standardised data collection structure to be established, and support provided for the additional work that this would require, if an improved understanding of the use of energy and water in education and health buildings is to be gained.

These systems cannot be created by an ad hoc research project, even though such a project could collect, analyse and report on data. The history of energy management in the health and education sectors has been long on research projects and recommendations, but short on their implementation.

Modelling and Forecasting

The data collected was used to create thermal simulation models of the buildings. These models use the computer programmes such as Google Earth, SketchUp, OpenDesign, Radiance, su2rad and EnergyPlus. The work explored the generation of building models in a standardised and quasi-automated manner. The goal of the work has been to both improve the empirical basis of the models themselves, thus improving their accuracy at the individual building level, and (unlike EERA) generate scenarios that show the distribution of responses to a change (e.g. a single change in NZBC H1 might improve thermal performance of one part of the non-residential stock but decrease performance in another).

Aggregate survey data was used to develop and update EERA (Energy Efficiency Resource Assessment), which is a computer-based tool for modelling scenarios of aggregate energy demand e.g. in response to changes in energy efficiency (see www.crl.co.nz/climate_change/energyEfficiency.asp). EERA was then used to explore a trial energy efficiency scenario – the effect of a 1% decrease lighting power density in the finance and insurance sub-sector.

Technology Transfer

BEES research papers were presented to three conferences – 'Sustainable Building 2010' (SB10) in Wellington; 'The Business of Energy Management 2010' in Wellington; and 'Construction in Building' (CIB2010), in Manchester, UK. BEES supported papers were awarded 'Highly Commended' in both the open and student paper categories of the SB10 conference

BEES provided scholarships for research related to BEES goals to three PhD students and three Master of Building Science students in 2009/10. The 2008/9 scholarships were for one Master of Building Science student (since converted to a PhD examining water use in Auckland and Wellington CBD office buildings) and three Bachelor of Building Science (Honours) students which were successfully completed – two with first class and one with second class honours. The work of these students has permitted a range of topics to be explored in far greater detail than would have normally been the case, and provides support for a new generation of researchers.

International Links

Contacts with related researchers throughout the world have been further developed, with the establishment of formal agreements with The Bartlett Faculty of the Built Environment, University College, London (www.bartlett.ucl.ac.uk/architecture) for research co-operation and with the International Energy Agency (IEA) to participate in the Solar Heating and Cooling Agreement's Task 40 'Towards Net Zero Energy Solar Buildings'(www.iea-shc.org/task40/index.html). BEES is a major contributor to in this international research activity with Dr Michael Donn, Centre for Building Performance Research, Victoria University of Wellington, as co-leader of Subtask C: 'Advanced Building Design, Technologies and Engineering'.

Obtaining BEES reports

The BEES team has worked hard to ensure the results of BEES are available to the widest possible range of stakeholders – including the public, special interest groups, government agencies, universities and other researchers. References to previous BEES reports, and other publications on the BEES work, are given in the full report. Many of these are available for downloading at no charge from the BRANZ Bookshop on the BRANZ website.

Copies of the Executive Summary and the full Year 3 report are available through the BRANZ website:

Postal address:	BRANZ, Private Bag 50908, Porirua 5240, N.Z.
Phone: +64 (04) 237 1170	Fax: +64 (04) 237 1171
Email: BEES@branz.co.nz	Website: www.branz.co.nz

Preface

This is the second of a series of reports prepared during research into the use of energy and water in New Zealand non-residential buildings.

Acknowledgments

The work reported here was jointly funded by BRANZ from the Building Research Levy, the Foundation for Research, Science and Technology (FRST) from the Public Good Science Fund, the Department of Building and Housing (DBH) and the Energy Efficiency and Conservation Authority (EECA).

Note

This report is intended for researchers interested in understand the use of water and energy in the New Zealand non-residential building sector.

Later reports will provide further analysis and results from the research. These will be of interest to architects, designers, engineers, manufacturers and product suppliers.

Building Energy End-Use Study (BEES) Year 3

BRANZ Study Report SR 236

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Reference

Isaacs, N. (ed.), Saville-Smith, K., Babylon, W.M. Bishop, Camilleri, M., Donn, M., Jowett, J., Moore, D., and Roberti, J. 2010 **Building Energy End-Use Study (BEES) Year 3**. (BRANZ Study Report SR236) Porirua City: BRANZ Ltd.

Abstract

This report covers work for the Building Energy End-use Study (BEES) for the 2009/10 year. It reports on the national phone survey of premises in 1,000 randomly selected non-residential buildings; the design, implementation and preliminary results from monitoring the energy use and end-uses in 60 premises; the results of five case studies exploring the drivers of variation of energy use; a systematic review of national and international energy efficiency policies; an examination of energy and water data availability in education and health buildings; the development of energy simulation models based on the collected data; and the implementation of the preliminary data in the Energy End-use Resource Assessment model.

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1. INTRODUCTION

(Prepared by BRANZ)

This study report provides an overview of the outputs of the BEES research for the third year, 2009/10. As the quantity of research and outputs continues to increase, this report provides a brief overview summary of each of the key outputs. It builds on the work reported in 'Building Energy End-Use Study (BEES) Years 1 & 2' (BRANZ *Study Report 224* – Isaacs et al, 2009).

1.1 Background

This section provides a brief summary of the development of the BEES research as set out in the BEES Year 1 & 2 report.

Eight key research questions were identified for BEES as given in Table 1:

Table 1: BEES key research questions

Comp.	**Key Research Questions** (summary)	**Focus**
←A→	1. Aggregate energy and water use? 2. Average kWh/m²/yr 3. Identify largest use categories	All Non-residential Buildings
← B,C →	4. Average kWh/m²/yr by category? 5. Energy and water end-use patterns 6. Determinants of use patterns e.g. Building structure and form; Function; Other attributes, etc	Sub-set of Non-residential Buildings for Targeted Survey and Case Studies
D	7. Critical intervention points to improve resource use efficiency?	All Non-residential Buildings
E	8. Likely future changes as stock type and distribution changes?	Future (New & Retrofit) Non-residential Buildings

These key research questions were developed into five inter-related study components, as listed in Table 2. Each component uses a different research method, and is designed not only to help answer one or more of the key research questions, but also to verify the data and triangulate the analysis of the other study components.

Table 2: BEES study components

Study Component	**Key Research Questions**	**Primary Research Method**
A. Aggregate Resource Use Patterns	1 – 3	Aggregate Survey
B. Determinants of Resource Use	4 – 6	Targeted Survey & Coarse Monitoring
C. Building Dynamics	4 – 6	Case Studies (to commence 2010-11)
D. Facilitating Improved Resource Management	7	Occupant Behaviour & Attitudes
E. Modelling/Forecasting	8	Modelling & Simulation

These key research questions and components form the basis for the structure of the BEES research activities, and for this report.

The sample frame is based on valuation records obtained from PropertyIQ and the Auckland City council valuation department. As the valuation records relate to a legal tile, it has been necessary to group them into 'Building Records'. There may be more than one building in a Building Record, so the values below are first estimates. The sampling frame has been divided into 50 strata based on PropertyIQ data:

- **5 size strata (strata)** – based on estimated total floor area by Building Record. Table 3 provides the non-residential size strata and the approximate number of buildings and their floor area.
- **5 use groups (uses)** – 'office', 'retail', 'mixed', 'Industrial Service' (IS) and 'Industrial Warehouse' (IW), based on the use category of the PropertyIQ parent record. As not all Building Records with these uses are eligible for inclusion in BEES, further selection activities have to be undertaken.
- **2 geographic groups** ('Auckland' and 'rest of New Zealand') – the Auckland group is defined by the area covered by the Auckland Regional Council in 2009. Approximately 22% of the Building Records and 33% of the floor area is in the Auckland region.

Dividing into floor area strata is necessary to vary the sampling rates from size group to size group. The grouping has been done to give approximately equal total floor areas for all five groups. This approach increases the statistical precision of the survey.

Table 3: Non-residential size strata

Floor Area Strata	1	2	3	4	5	Total
Minimum Floor Area	5 m²	650 m²	1,500 m²	3,500 m²	9,000 m²	
Approx. No. of 'Buildings'	33,781	10,081	4,288	1,825	564	**50,539**
% of Buildings	67%	20%	8%	4%	1%	**100%**
Total Floor Area (million m²)	9.9	9.6	9.5	9.6	9.8	**48.3**
% floor	20%	20%	20%	20%	20%	**100%**

1.2 BEES achievements: Year 3

Internationally the need for the BEES type of study was clearly stated by the International Energy Agency (IEA) in its report 'Energy Efficiency Policy Recommendations 2008 in Support of the G8 Plan of Action'[1] prepared for the leaders of the G8 group of countries (France, the US, the UK, Russia, Germany, Japan, Italy and Canada.). In the recommendations dealing with buildings, it states:

> *2.3 Existing Buildings*
>
> *Governments should systematically collect information on energy efficiency in existing buildings and on barriers to energy efficiency.*

Within New Zealand, the value of the BEES research was recognised by the Hon. Maurice Williamson, Minister of Building and Construction, in his 27 May 2010 speech to the NZ Sustainable Building Conference (SB10). He noted that "initially, the findings will help businesses, landlords and tenants know where they can save energy – and money." He also pointed out the "The results of this research will also be used to help Government decide if any policy intervention is needed to drive improvements in energy efficiency."

The third year of the BEES project has continued to work towards supporting these international and national goals. The work programme has focused on implementing data collection, initial analysis and establishing international linkages.

[1] Available from: www.iea.org/G8/2008/G8_EE_recommendations.pdf

Achievements and outputs from the third year include:

- Obtaining web-search and street-search data on approximately 2,000 buildings, including location, floor area, foot plate etc, which has allowed the production of simple 3D computer models
- Planning, specifying and undertaking a national telephone survey from approximately 1,000 Strata 1 to 5 Building Records
- Obtaining energy and water revenue records for the positively responding premises and undertaking preliminary analysis
- Interviewing a number of building resource managers
- Installation and monitoring of approximately 60 premises and undertaking preliminary analysis
- Completion of an investigation into the availability of data on energy and water use in educational and health buildings
- Development and initial testing of a range of building performance computer models, including generic model templates that cover the range of typical non-residential building types identified in the web-search
- Incorporation of aggregate survey data into the EERA (Energy End-use Resource Assessment) model
- Participation in the IEA SHC Task 40 'Near Zero Energy Building' international research activity
- The signing of a formal research collaboration agreement between BRANZ, Victoria University of Wellington and The Bartlett Faculty of the Built Environment, University College London
- Agreement to use the BUS instrument for the social research component of the project. This included an evaluation of the cost of creating a BEES survey instrument and calibrating it compared to using existing options.
- Preparation and delivery of research papers to three conferences – Sustainable Building 2010 (SB10) in Wellington, 'The Business of Energy Management 2010' in Wellington; and 'Construction in Building' (CIB2010), in Manchester, UK. BEES supported papers were awarded 'Highly Commended' in both the open and student paper categories of the SB10 conference
- Preparation and submission of a paper to an international peer reviewed journal
- In addition to work funded through this contract, through the FRST contract BEES also provided scholarships for research related to BEES goals to three PhD students and three Master of Building Science students. The scholarships awarded in 2008/09 to one Master of Building Science and three Bachelor of Building Science (Honours) students were successfully completed. The work of these students has permitted a range of topics to be explored in far greater detail than would have normally been the case, and provides support for a new generation of researchers.

Further information is provided on each of these achievements or outputs in this report.

1.3 BEES people

BEES is supported by a multi-disciplinary team from the six organisations listed below, with the team leader followed by the other team members in alphabetical order:

BRANZ Ltd – Nigel Isaacs, Dr Michael Babylon, Dr Michael Camilleri, Duncan Moore, Johannes Roberti

CRESA Ltd – Kay Saville-Smith, Ruth Fraser

Energy Solutions Ltd – Rob Bishop

Centre for Building Performance Research, VUW – Dr Michael Donn, Alexandra Hills

John Jowett, Consulting Statistician

CRL Energy Ltd – Dr Pieter Rossouw, Dr Tony Clemens (deceased), Dr Tana Levi.

The overall BEES project is financially supported by:

Building Research Association of NZ (BRANZ)

Department of Building and Housing (DBH)

Energy Efficiency and Conservation Authority (EECA)

Foundation for Research Science and Technology (FRST).

It is with sadness we record the untimely death of Dr Tony Clemens of CRL Energy Ltd, and acknowledge his involvement from the earliest days in the BEES research.

Members, and their substitutes, of the Governance Group appointed under the BEES Research Programme Agreement between BRANZ, DBH and EECA:

- **DBH** – David Kelly, Adrian Bennett, Louise Slocombe, Nick Lock
- **EECA** – Robert Tromop, Xanthe Howes
- **Building Research** – Wayne Sharman
- **BRANZ observer –** Lynda Amitrano
- **FRST observer** – Joseph Stuart
- **Statistics NZ observers** – Stephen Oakley, Martin Brown-Santirso
- **Ministry of Economic Development observer** – Simon Lawrence
- **Ministry for the Environment observer** – Chris Woods
- **Electricity Commission observer** – Jenny Walton.

Members of the Steering Group appointed under the FRST contract (BRAX0703) to provide input from key stakeholders into project design and operation:

- **Jason Happy** – Kiwi Income Property Trust
- **Professor George Baird,** School of Architecture, VUW
- **Associate Professor Deborah Levy**, Department of Property, University of Auckland
- **Norman Smith**, Rocky Mountain Institute (NZ)
- **Kees Brinkman**, Enercom.

It has been our practice to hold the full meetings of the Governance Group and the Steering Group at the same time.

1.4 Further information

Further information on the BEES research is available from the BRANZ website www.branz.co.nz under ‘Current Research’.

2. COMPONENT A – AGGEGATE RESOURCE USE PATTERNS

Component A has two primary functions in the BEES study.

First, it is designed to provide data to address three of the BEES study's eight research questions (Table 1). These are:

1. What is the aggregate resource (energy and water) use of non-residential sector buildings?
2. What is the average area energy use (kWh/m²/yr) of the non-residential sector?
3. What categories of non-residential buildings contribute the most to the aggregate energy/water consumption of this sector?

The second function is to accumulate building and premise-based data that allows for the robust selection of buildings for other components. In particular, these will be used to help establish the determinants and patterns of end-use of energy and water, as well as the relationship between the use of these resources and building dynamics.

To establish a robust sample for BEES, Component A has involved the compilation and validation of the building sample frame from which representative samples can then be drawn. This has been developed by:

- Drawing and analysing PropertyIQ and Auckland City Council valuation data
- Validating this data through web-search and street-search
- On-site building and premise validation.

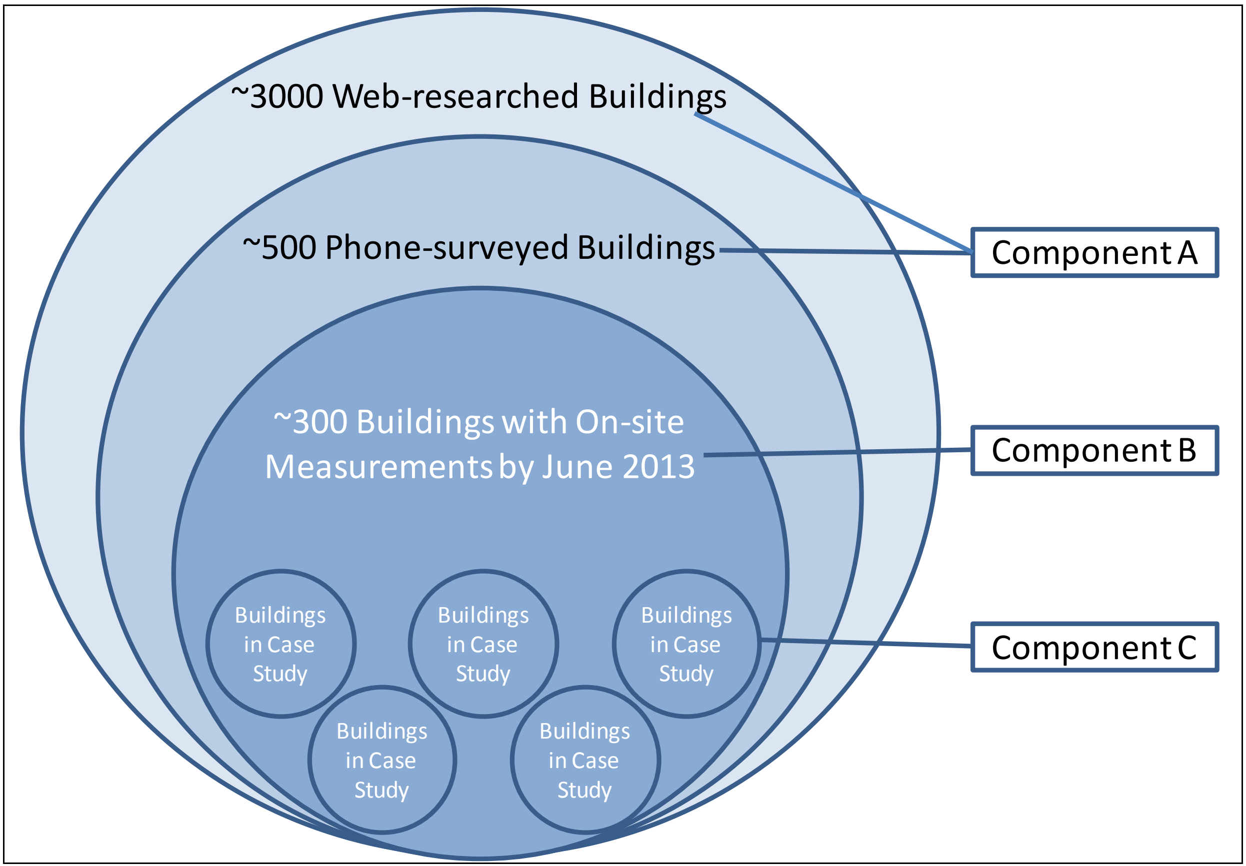
Surveying of eligible premises and buildings was then carried out to document:

- Occupancy and use
- Energy and water supply
- Tenure conditions
- Building characteristics.

The survey has also been used to identify those premises and buildings directly billed for reticulated energy and/or water and to initiate a consenting process to access those premises' use and billing data. This is directly relevant to addressing the substantive questions for Component A as well as supporting the other BEES components. The remainder of this section reports those activities and emerging findings.

In this 2009/10 year, Component A was designed and intended to produce: a national estimate of water and energy consumption in the non-residential building sector; an estimate of the average kWh/m²/yr of the sector; and a clear description of the buildings in this sector (e.g. floor areas, number of buildings, number of businesses, types of occupants etc). Figure 1 sets out the planned relationship between the samples used for Components A, B and C.

Figure 1: Hierarchical sample structure for Components A, B and C



As Figure 1 shows, the database created by Component A is then used for activities in Components B and C. Within Component A, the database provides both a base for analysis of non-residential buildings by size, location etc, as well as the essential list of premises for use in the Component A telephone survey.

The Component A database was planned to be a representative sample from a target of 3,000 non-residential buildings, which would then be used for the phone survey with a goal of achieving positive responses for about 500 buildings. This would enable the production of: a national estimate of water and energy consumption in the non-residential building sector; an estimate of the average kWh/m²/yr of the sector; and a clear description of the buildings in this sector (e.g. floor areas, number of buildings, number of businesses, types of occupants).

Although the unit of measure for BEES is the 'building', it is the individual premises within the building, plus any overall building activities (e.g. central heating, ventilation and air-conditioning (HVAC), elevators etc) which consume energy and water.

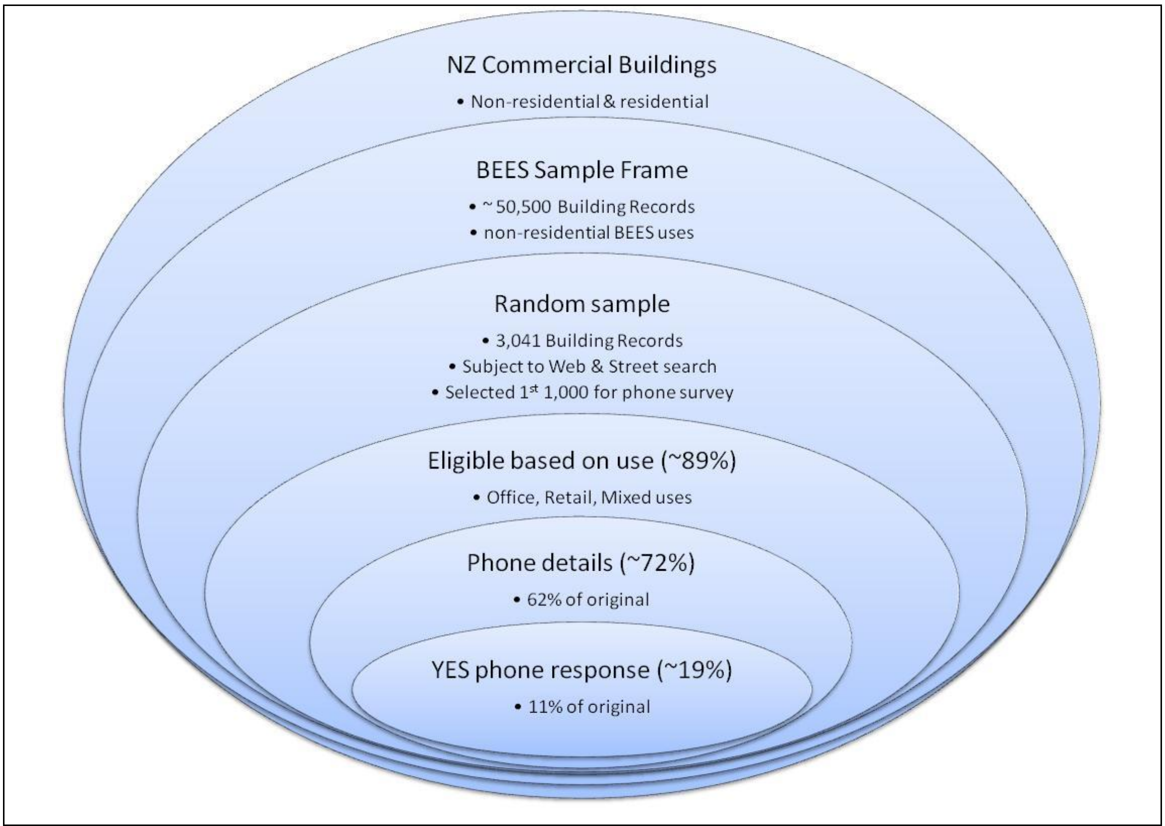
Figure 2 provides a graphical overview of the Component A activities in 2009/10. As discussed in the Year 1 & 2 report (Section 4, Isaacs et al, 2009), the purchase of valuation records from PropertyIQ and the Auckland City Council was based on use categories that were considered to be of potential interest. The individual valuation records were first grouped into Building Records, giving approximately 50,539 such records. It should be noted that a Building Record is not definitely about an actual building until confirmation has been found from the data collection process.

A random sample of 3,041 Building Records was then taken and subjected to web-search and street-search. As a result of this, a number of Building Records were found not be eligible based on their use. Phone numbers were then sought for each identified premise, and these were provided to the phone survey company. Those premises that responded positively, providing answers to the phone survey and permission to access their energy and water revenue records count as YES phone responses.

It was recognised that Strata 5 (Building Records over 9,000 m²) was likely to be different to the other strata, in particular because of the comparatively small number of buildings. Strata 5 consists of a total of some 564 buildings. After preliminary exploration, it was recognised that buildings of this size would most likely be occupied by a number of premises. Further exploration looking at a small number of Strata 5 buildings identified a sizable number of businesses likely to have their premises managed from a central head office.

It was decided that in order to proceed as quickly as possible with the phone survey, the Strata 5 buildings would be treated as a second part of the phone survey. The premises in the selected Strata 5 buildings were then identified, and those likely to have a central head office separated out. Contact is being made with these head offices and, at the time of reporting, we are awaiting the responses.

Figure 2: Overview of 2009/10 Component A activities



The following sections describe the various processes, the new knowledge obtained and the lessons learnt for the 2010/11 year.

2.1 Web-search and street-search

The web-search process was described in the Year 1 & 2 report (Section 4, Isaacs et al, 2009). In brief, web-search uses internet search engines and online databases to trace any businesses located at a given street address. In addition to the information available from the valuation record, resources of particular importance included Google Earth, Google Map, Google Street View and online phone directories (*White Pages* and *Yellow Pages*).

Web-search provided the first information on the actual number of buildings in the sample. Of the 3,041 Building Records, 2,085 have had the web-search completed.

Assuming the uncompleted Building Records have one building, then 6.1% of the Building Records had more than one building:

- 4.4% (133) of Building Records have two buildings
- 1.2% (35) of Building Records have three buildings
- 0.4% (13) of Building Records have four buildings
- 0.1% (3) of Building Records have five buildings
- 0.0% (1) of Building Records have six buildings.

Thus the 3,041 Building Records represent a total of 3,226 buildings.

For the first phone survey, the first 1,000 Building Records were selected and the street-search was applied for Strata 1 to 4 (801 Building records) (see Table 3). The Strata 5 Building Records were not fully analysed in Year 3 and will be reported in the Year 4 report.

Street-search involves a person visiting the site with a list of the business premises expected to be in that building. The names are checked against the building directory, removing the names of businesses that are no longer in the building and adding the names of new businesses.

A Building Record is 'eligible' only if:

- the building 'exists'
- the premise(s) 'exist'
- the premise(s) are occupied by a valid BEES use
- a phone number can be found for the occupant of that premise(s).

The following reasons would exclude a Building Record i.e. make it not eligible (see Table 8):

- **Building Record**: All Vacant; Duplicate; Incorrect Site; No Building Located; Site Not Located; Vacant Site
- **Premise Record**: Business Unknown; Duplicate; Not A Business; Not Evident; Not Present; Residential; Vacant
- **Not Eligible use category**: Carpark; Industrial; Ineligible; Residential; Unclear; Warehouse
- **Phone numbers:** phones were *not* found for 74 premises in 27 Building Records

Of the Building Records from Strata 1 to 4 selected from the first 1,000 Building Records (Strata 1 to 5), 62% were found to be either eligible or possibly eligible.

Although the Category Strata was based on five categories from the PropertyIQ database, it was not expected that all Building Records would be found to be eligible for inclusion in the BEES sample. The BEES 'Commercial Retail' category used here is the combination of six PropertyIQ categories:

- Commercial Liquor outlets including taverns etc (CL)
- Commercial Motor vehicle sales, service etc (CM)
- Commercial Retail (CR);
- Commercial Service stations (CS);
- Commercial Tourist (CT); and
- Commercial Vacant land which will be developed to a commercial use (CV).

The other BEES categories are as used by PropertyIQ – the codes are given in Table 4. The table shows that while the majority of the 'Commercial Office', 'Commercial Retail' and 'Commercial Mixed' were found to be eligible, almost the opposite was found for 'Industrial Service' and 'Industrial Warehouse'. The consequence of the different eligibility proportions shown in Table 4 is that the proportions in the final sample might change.

Table 4: Strata 1 to 4 proportion of original selection eligible by use category

Uses	Total #	Eligible	% Eligible
Commercial Office (CO)	117	101	86%
Commercial Retail (CR)	238	181	76%
Commercial Mixed (CX)	130	113	87%
Industrial Service (IS)	152	56	37%
Industrial Warehouse (IW)	163	42	26%
TOTAL	800	493	62%

Table 5 compares the proportions found to be eligible in the use groups. For example, the Commercial Retail category was 28% of the Building Records in the original sample, but after eligibility had been assessed it increased to 37%, a rise of 9%.

Table 5: Strata 1 to 4 proportion of original selection eligible by category

Uses	Eligible	Eligible	Original	Difference
Commercial Office (CO)	101	21%	16%	4%
Commercial Retail (CR)	181	37%	28%	9%
Commercial Mixed (CX)	113	23%	17%	6%
Industrial Service (IS)	56	11%	18%	-6%
Industrial Warehouse (IW)	41	8%	21%	-12%
TOTAL	492	100%	100%	

Thus the proportions for the floor area and regions in the 'eligible' category prior to the phone survey are very close to the original proportions. The use category is clearly different, with a reduction in the proportions of the 'IS' and 'IW' category Building Records. However, it is not considered necessary to alter the sample structure as a consequence of this change in the proportions of the use category, as these were originally only descriptive terms used by PropertyIQ.

It is expected that BEES will need to create its own, well-documented use categories, and to provide a basis for their comparison to the PropertyIQ database to permit national estimates to be prepared. This will be further examined by the BEES team in Year 4.

Table 6: Strata 1 to 4 average number of premises per Building Record

Size Strata	Building Records	Count of Premises	Average Number Of Premises
1	136	229	1.7
2	119	251	2.1
3	121	403	3.3
4	117	668	5.7
Total	493	1551	3.1

Table 6 calculates the average number of premises per Building Record by size strata. Although the average is just over 3 (3.1) premises per building, this increases from just under 2 (1.7) for the smallest Size Strata to just under 6 (5.7) for the largest.

Table 7: Strata 1 to 4 Building Record floor area ranges by size strata

	Size Strata	Mid m²	Building Records	Total Floor Area m²	%	Average m²/bldg	Min m²	Max m²
1	5 m² to 649 m²	328	136	42,359	4%	311	40	636
2	650 m² to 1,499 m²	1,076	119	114,708	11%	964	650	1,494
3	1,500 m² to 3,499 m²	2,501	121	269,671	26%	2,229	1,507	3,472
4	3,500 m² to 8,999 m²	6,252	117	600,656	58%	5,134	3,507	8,930
Total			493	1,027,395		2,084	40	8,930

Table 7 provides descriptive statistics for the floor area by size strata. Floor area data was obtained from PropertyIQ and is subject to correction once the data collection work is complete. For each of the floor area ranges (Size Strata) Table 7 gives the: simple floor area average; number of building records; total floor area and percent this is of all the floor area in Strata 1 to 4; average floor area; and range (minimum and maximum).

The average floor area for the 493 Building Records is 2,084 m² over a total floor area of just over 1 million m². The average Building Record floor area for Strata 1 is 311 m², which compares to the average of the Strata 1 range of 328 m², while for Strata 4 it is 5,134 m² and 6,252 respectively.

Table 8 provides a summary of the results in the preparation of the sample for the phone survey for the first group of buildings selected from Strata 1 to 4. The process is read from left to right – the number in the initial selection reducing in steps to the final number of premises to be surveyed.

Table 8 shows that 801 Building Records were initially selected, and as each building record can have one or more premises there were a total of 2,685 premises identified. A combination of web-search and street-search identified 2,543 premises as existing, with 142 of the expected premises found not to exist for a range of reasons: the building was vacant; there was no building found on the site; the site which had been matched to the title was not correct; the premise was a duplicate of another already identified premise; the building was not located; and the site was not located or the building had been incorrectly allocated to the strata. The result was only 709 buildings (89%) were confirmed to exist out of the original 801 Building Records.

The 2,545 identified premises were then checked, with 2,052 confirmed as existing. The buildings and premises were then checked for eligibility, further reducing the number to 1,722 premises. Where possible, phone numbers were then found for each premise, further reducing the number of valid premises to 1,647. The final list provided for the phone survey had 1,551 premises believed to be eligible with a further 96 for which the eligibility was unclear.

Table 8: Strata 1 to 4 buildings and premises counts for initial phone survey

Building Record Check		Check Premises Occupied		Check Premises Eligible		Phone number		To be surveyed	
Status	**Count**	**Status**	**Count**	**Status**	**Count**	**Status**	**Count**	**Status**	**Count**
Exists	2,543	Exists	2,011	Eligible	1,621	Known	1,648	Eligible	1,551
Vacant bldg	60	Vacant premises	23	Unclear	103			Unclear	96
Vacant site	15								
Incorrect site	6								
Duplicate	5								
Bldg not located	2	Premises not found	508						
Site not located	50	Not business	3	Not eligible	328	Not known	74		
Wrong strata	4								
TOTAL Premises	**2,685**		**2,545**		**2,052**		**1,722**		**1,647**
% OK of original	100%		95%		76%		64%		61%
% OK of previous			95%		81%		84%		96%
TOTAL Buildings	**801**		**709**		**695**		**500**		**494**
% OK of original	100%		89%		87%		62%		62%
% OK of previous			89%		98%		72%		99%

However, Table 8 also shows that premise data was obtained on 709 buildings (89% of the original sample). This will be used to develop an understanding of the non-residential built environment, providing an opportunity that has not been possible before. There is no other resource giving an overview of the location, construction and use of non-residential buildings in New Zealand.

Although only 11% of the initially selected buildings are currently considered to be included as 'YES' buildings, data is for the first time now available on the 89% of the sample which are eligible non-residential buildings office, retail or combinations of these and other uses. Note that the 11% 'YES' buildings is expected to increase as survey participation and/or data is obtained from head office and other centralised sources.

Year 4 will see the completion of analysis of the Strata 5 data and more detailed analysis of the patterns of New Zealand non-residential buildings.

2.2 National telephone survey

At the end of Year 3: the phone survey had been completed for the first group of Strata 1 to 5 buildings; the data had been cleaned and analysed; contact had been made to obtain permission to access energy and water revenue meter records; and the systems had been set up to obtain energy and water revenue data from the suppliers.

The questionnaire used in surveying was developed by BRANZ and CRESA, and revised by CRESA in the light of the 2009 pilot findings (see Section 6.3.3, Isaacs et al, 2009) and to better accommodate the needs of New Zealand Research Ltd's CATI (computer added telephone interview) technology.[2] New Zealand Research Ltd was provided with 1,647 business contacts believed to be associated with 494 buildings that appeared to be BEES eligible based on analysis of valuation data, web-based and business directory information, and on-site observation data.

The initial telephone survey was undertaken by New Zealand Research Ltd in February and March 2010.

A total of 268 businesses completed a questionnaire. The response rates are a little lower than, but consistent with, the pilot, ranging from the lowest response rate at 16% in Strata 4 building businesses to a response rate of 21% in Strata 3 building businesses.

[2] See: http://www.researchnz.com/fieldwork.html

Table 9 provides a preliminary analysis of the results from the telephone survey, grouping the buildings as 'All Buildings' (both 'YES' and 'Not YES' buildings); 'YES' buildings (buildings with enough premises replying YES to include the building in the analysis) and 'Not YES' buildings (buildings with none or possibly some premises that replied YES, but not enough to permit the inclusion of the building in the analysis).

Table 9 shows that of the 1,647 premises selected for the phone survey (cells highlighted):

- 268 (16%) provided a completed phone survey (YES)
- 70 (4%) have the potential to complete the survey (Maybe) but require further action by BRANZ e.g. make contact with head office
- 1,148 (70%) premises could not be contacted or refused to participate (NO)
- 161 (10%) premises were incorrectly included (Wrong) e.g. wrong phone number or building.

Table 9: Strata 1 to 4 phone survey responses

	Premises					Building			Premises		
Strata	Yes	Maybe	No	Wrong	Total	Any YES	Total	% Any YES	Yes Premises /bldg	Average Premises /bldg	Valid Premises % response
All Buildings											
1	43	3	172	25	**243**	35	136	26%	1.2	6.2	20%
2	51	8	194	23	**276**	40	120	33%	1.3	6.3	20%
3	80	4	313	39	**436**	48	120	40%	1.7	8.3	20%
4	94	55	469	74	**692**	49	118	42%	1.9	12.6	15%
Strata 1-4	268	70	1,148	161	**1,647**	172	494	35%	1.6	8.6	18%
YES buildings											
1	30	-	7	1	**38**	28	136	21%	1.1	1.3	81%
2	31	1	13	3	**48**	26	120	22%	1.2	1.7	69%
3	29	-	19	5	**53**	23	120	19%	1.3	2.1	60%
4	24	-	13	2	**39**	15	118	13%	1.6	2.5	65%
Strata 1-4	114	1	52	11	**178**	92	494	19%	1.2	1.8	68%
'Not YES' buildings											
1	13	3	165	24	**205**	108	136	79%	0.1	1.7	7%
2	20	7	181	20	**228**	94	120	78%	0.2	2.2	10%
3	51	4	294	34	**383**	97	120	81%	0.5	3.6	15%
4	70	55	456	72	**653**	103	118	87%	0.7	5.6	12%
Strata 1-4	154	69	1,096	150	**1,469**	402	494	81%	0.4	3.3	12%

The overall proportions are highly influenced by the larger number (402 vs. 92) of 'Not YES' (i.e. include 'Maybe', 'NO' and 'Wrong') buildings, as shown in the lower portion of Table 9. On average 19% of the buildings are in the 'Any YES' group, although this varies by strata. The smaller buildings (Strata 1 and 2) having a higher response rate than the larger buildings (Strata 3 to 4), but the sample size is not yet large enough to be confident there are any differences in the response rate by strata.

While there are 114 'YES' premises in 'YES' buildings, there are 154 'YES' premises in 'Not YES' buildings. These represent an opportunity to expand the numbers of 'YES' buildings by focusing on the 'Not YES' buildings and seeing if it is possible for them to become 'YES' buildings.

Table 10 gives the numbers of premises responding YES for the 'YES', 'Maybe' and 'NO' buildings. As shown in Table 9 there are 92 'YES' buildings, with 114 'YES' premises, but Table 10 shows there with a further 82 buildings (54 'Maybe' and 28 'NO' buildings) already with 156 (112 in 'Maybe' and 42 in 'NO' buildings) 'YES' premises that could become 'YES' buildings if time was invested to obtain enough premises.

Table 10: 'YES' and 'NO' buildings and 'YES' premises

Strata	YES Building			Maybe Building			NO Building		
	Bldg #	Yes Premises #	Avg Premises /bldg	Bldg #	Yes Premises #	Avg Premises /bldg	Bldg #	Yes Premises #	Avg Premises /bldg
1	28	30	1.1	5	8	1.6	3	5	1.7
2	26	31	1.2	9	14	1.6	5	6	1.2
3	23	29	1.3	18	41	2.3	8	10	1.3
4	15	24	1.6	22	49	2.2	12	21	1.8
Strata 1-4	92	114	1.2	54	112	2.1	28	42	1.5

2.2.1 Business characteristics of survey participants

(Prepared by CRESA)

Less than half (43.7%) of the premises participating in the Strata 1 to 4 interviews were multi-site business. They were also strongly dominated by the retail trade and the sectors of property and business services as well finance and insurance, as shown in Table 11.

Table 11: Business sector categories and participating businesses

Business Sector	Premises	% Premises
Retail trade	77	29.5
Property and business services	47	18.0
Finance and insurance	36	13.8
Health and community services	25	9.6
Not stated/Unclear	14	5.4
Accommodation, cafes and restaurants	12	4.5
Personal and other services	9	3.4
Education	8	3.1
Construction	7	2.7
Government administration and defence	7	2.7
Cultural and recreational services	6	2.3
Manufacturing/Other Manufacturing	6	2.3
Communications services	3	1.1
Wholesale trade	2	0.8
Electricity, gas and water	2	0.8
Total	261	100

The property and business services category is an extremely inclusive category which includes:

- Property operators and developers
- Real estate agents
- Non-financial asset investors
- Machinery equipment hiring and leasing
- Scientific research
- Technical services
- Computer services
- Legal and accounting services
- Other business services.

The finance and services category is somewhat narrower but includes all banking and financial investors as well as insurance of all kinds, including superannuation providers.

It also includes those businesses that provide services to the finance and insurance sector.

Clearly there is overlap between business sector categories and businesses and so the data must be treated with some caution.

However, the profile of businesses evident in Table 11 generates a particular mix of occupations among the employees working in the sampled buildings. The majority of businesses employ managerial, professional, clerical and administrative workers (Table 12).

Table 12: Occupations represented in participant businesses (n=261)*

Occupation	Business Premises	% of Premises
Managerial	237	90.8
Professional	155	59.4
Clerical and administrative staff	143	54.8
Sales workers	106	40.6
Technicians and trades workers	65	24.9
Community and personal service workers	23	8.8
Machinery operators and drivers	22	8.4
Labourers	10	3.8

2.2.1.1 Building characteristics

A total of 257 businesses provided information about the number of floors that they occupy. The majority of businesses (72%) report that they occupy around one full floor of their building. In relation to the building structure:

- 76.2% of businesses report that they occupy buildings with no double glazing
- 58.2% of businesses occupy buildings with centralised air-conditioned buildings
- 57.1% of businesses are in buildings with opening windows.
- 41% of businesses report that their building has a centralised central heating system.

While over half (53.6%) the businesses have undertaken some sort of refit of their space within their current building, the types of refit are clearly directed to cosmetic, appearance and spatial division rather than to energy or resource efficiency. Indeed, no businesses referred to refits designed to reduce energy or water consumption, although 14 businesses referred specifically to installing or changed their air-conditioning and/or heating system and addressing issues around lighting and plumbing.

2.2.1.2 Tenure, lease and management

Of the 261 businesses participating in the first wave of the Strata 1 to 4 survey, the vast majority are tenants with only a tiny number of sub-tenants, with the remaining businesses being owner-occupiers (Table 13). Additional analysis has found that a considerable number of the owner-occupier businesses share their building with tenant businesses.

Table 13: Tenure status of participant premises

Tenure	Premises	% of Premises
Tenants	211	80.8
Owner-occupier	47	18.0
Sub-tenant	3	1.1
Total	**261**	**99.9***

* Due to rounding

The businesses show a wide range lease arrangements. Fixed-term leases were widespread. A total of 168 of the tenants reported they had a fixed lease. Lease terms varied between 1-15 years. A considerable proportion of tenants reported that their tenure was governed by periodic tenancies, while other tenants were unclear about the tenancy mechanism and its conditions (Table 14).

Table 14: The lease arrangements of tenants

Lease Arrangements	Premises	% Tenanted Premises
Fixed-term lease	148	69.2
Periodic	29	13.6
Other	11	5.1
Unknown	26	12.1
Total	214	100.0

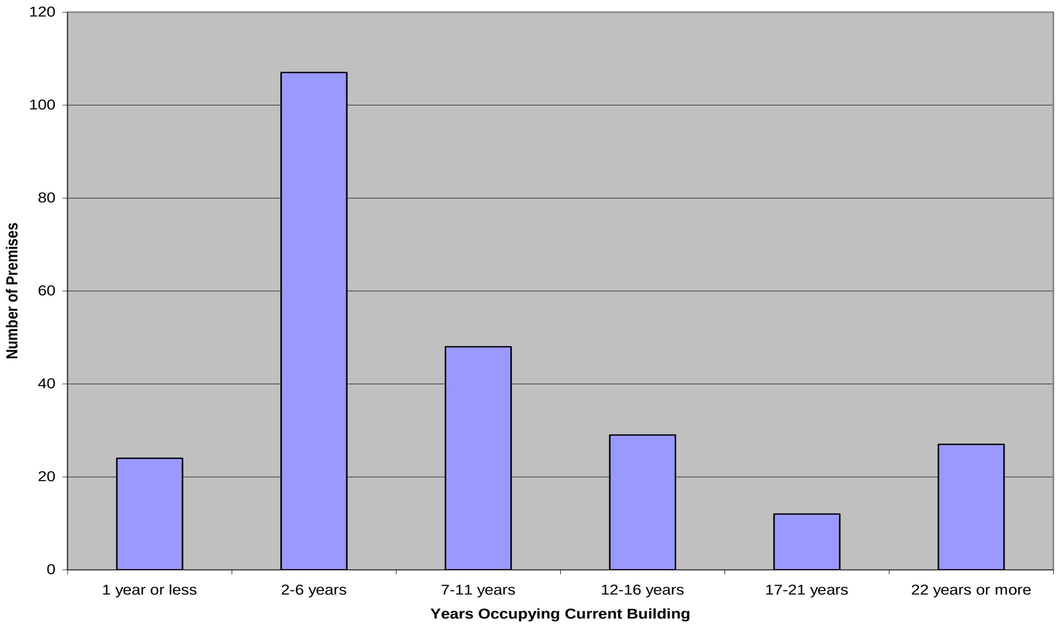
A total of 31.4% of businesses had been in their current building before the year 2000. Table 8 sets out the duration of occupation by participant businesses in their current building and the distribution is graphically portrayed in Figure 3. Table 15 gives the duration of occupation.

Table 15: Duration of occupation

Duration of Occupation	Premises	% Premises
1 year or less	24	9.7
2-6 years	107	43.3
7-11 years	48	19.4
12-16 years	29	11.7
17-21 years	12	4.9
22 years or more	27	10.9
Total	**247**	**100.0**

* 14 Missing cases

Figure 3: Distribution of business's occupation of current premises



As with lease arrangements, participant businesses reported a wide range of building management arrangements. Of participant businesses:

- 36.8% reported a building manager manages the building
- 36.8% reported a landlord manages the building
- 22.6% reported that no landlord or building manager manages the building
- 3.8% reported that both a landlord and a building manager manage the building.

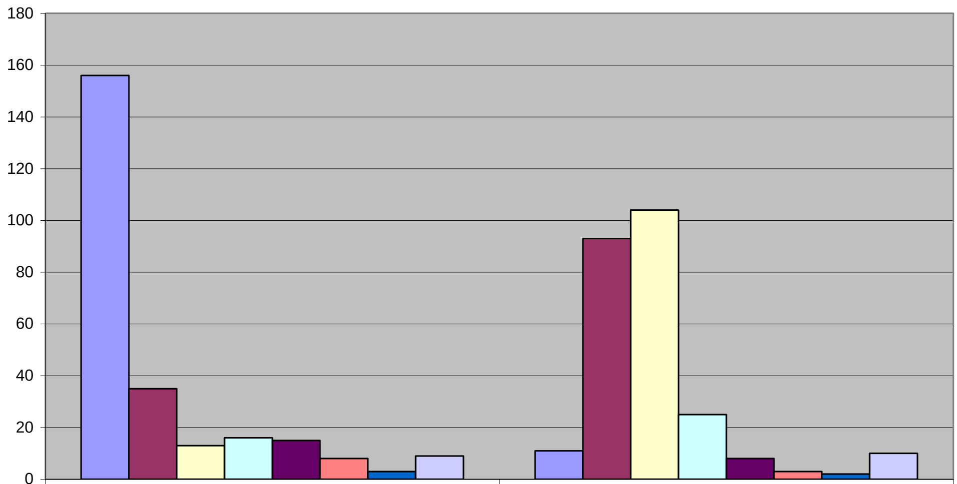
2.2.1.3 Occupancy characteristics

It has already been noted that typically businesses occupy around one building floor. However, occupancy ranges from operating out of an area less than one-quarter of a floor to occupying 10 floors.

The total number of employees represented by these businesses is around 3,900. On average, the participant businesses reported that 15 employees worked in the selected building. But like the floor occupancy, the range of employees across participant businesses is considerable, stretching from one person to 300 people.

Figure 4 sets out the distribution of business occupation for typical weekdays and typical weekends.

Figure 4: Hours with one or more employees on-site for weekends and weekdays

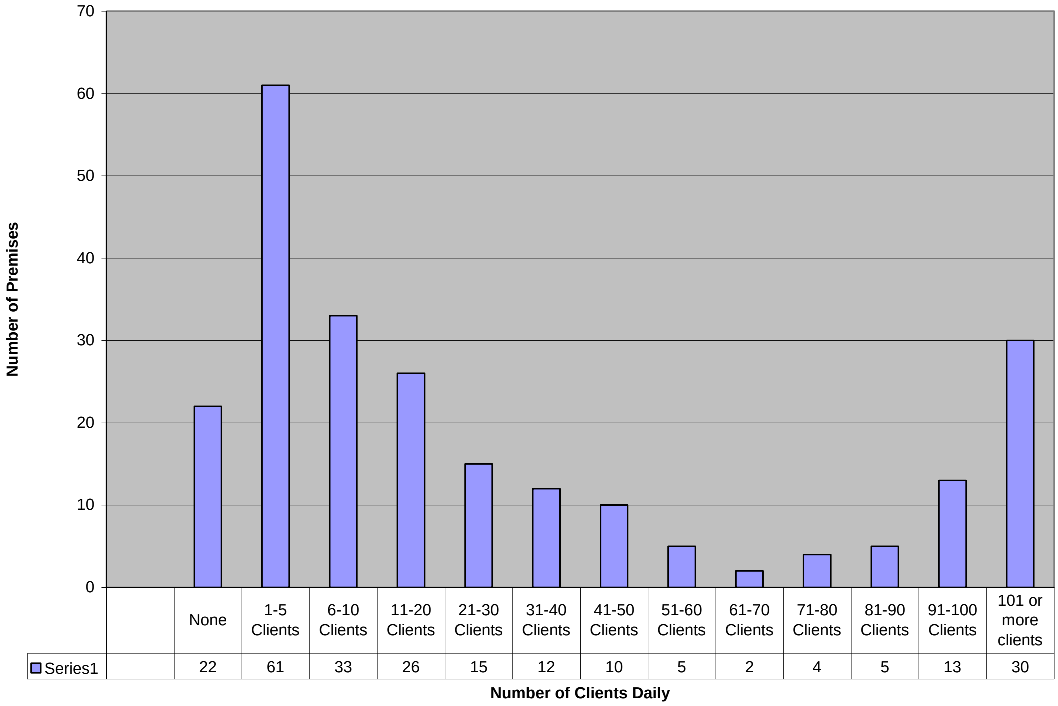


	Typical Weekend Hours	Typical Week Day Hours
5 hours or less	156	11
6-8 hours	35	93
9-11 hours	13	104
12-14 hours	16	25
15-17 hours	15	8
18-20 hours	8	3
21-23 hours	3	2
24 hours or more	9	10

Employees are typically on-site between 8-10 hours in a 24 hour weekday period. However, again the variability in the management and use of buildings in the non-residential stock is marked. Some businesses report that they only have employees on-site for an hour a day, while others have employees on-site for a full 24 hours on a typical weekday. That variability of building use during the working week is also characteristic of these business's use of their building during the weekend. A total of 60% of businesses report weekend occupation but that occupation involved some businesses in occupation of around an hour in weekends up to 24 hours.

In addition to employees being on-site, 91.5% of businesses have clients coming into the building. Not unexpectedly, given the mix of retail and more administrative and professional services that characterises the set of businesses in the Strata 1 to 4 buildings, the numbers of clients coming into the buildings occupied by participant visitors varied considerably (Figure 5).

Figure 5: Distribution of clients visiting premises on a typical day



2.2.1.4 Energy types

The primary energy source of these businesses is reticulated electricity. A total of 99.6% of businesses report consuming reticulated electricity with significantly fewer businesses consuming gas or diesel fuel (Table 16).

Table 16: Energy types reported by participant businesses (n=261)

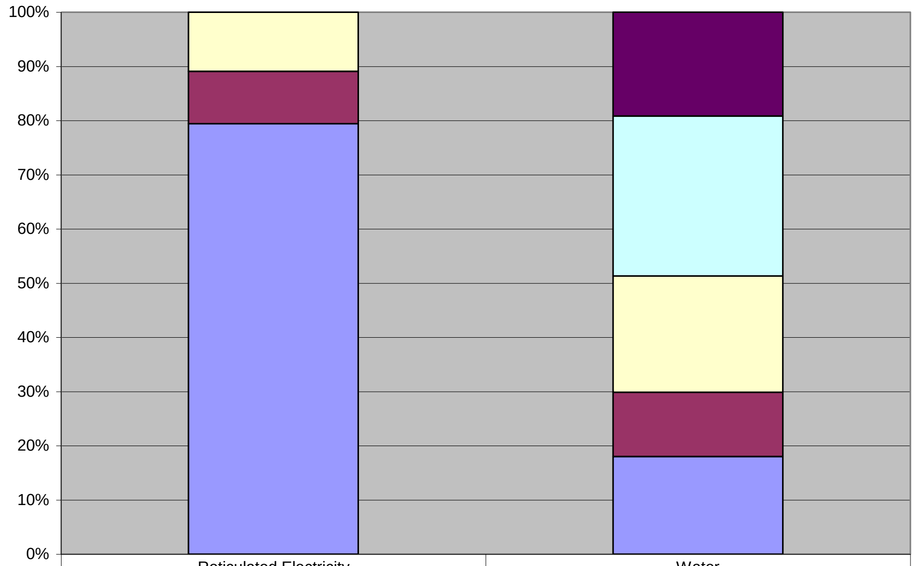
Energy Type	Premises	% of Premises
Reticulated electricity	260	99.6
Natural gas	28	10.7
Diesel or fuel oil	9	3.4
Wood, waste or biomass	5	1.9
Self-generated electricity	5	1.9
Coal	1	0.4

2.2.1.5 Energy and water purchase

Figure 6 provides a comparison of electricity and water purchasing. The majority of energy is purchased directly, but there is a considerable set of businesses that pay for water and/or energy as itemised or non-itemised components within their rental payments. Indeed, 14.8% of gas users and 10.5% of reticulated electricity users have these costs included and not differentiated from their rent. These businesses are, consequently, not exposed to energy pricing mechanisms and it may be expected that they have little awareness of their energy consumption and little incentive to reduce it. This will be explored in both Component B and the case studies.

Lack of exposure to pricing mechanisms is particularly apparent in relation to water. Whereas the majority of energy users buy their energy direct, only 18% of businesses report directly purchasing water. Also, 21.5% report that they pay for water in their rent, 29.5% claim that they do not pay for water at all, and 19.2% report that they do not know whether they pay for water.

Figure 6: Exposure of businesses to electricity and water pricing



	Reticulated Electricity	Water
Don't Know		50
Do not pay		77
Non-itemised in Rent	27	56
Itemised Paid to Landlord	24	31
Paid Direct to Supplier	197	47

2.2.1.6 Equipment and appliances

Business premises have a wide range of equipment and appliances that can be broadly divided between those which are business specific and those which provide for the needs of staff. In the first category are:

- Computers (reported in 92% of businesses)
- Printers (85%)
- Photocopiers (71%)
- Servers (69%)
- Fax machines (stand-alone – 52%)
- Projectors (29%)
- Electronic whiteboards (12%).

In the second category are:

- Refrigerators (92%)
- Microwaves (85%)
- Dishwashers (38%)
- Cooktops and/or ovens (30%)
- Water coolers (50%).

Clearly, there may be some overlap between these two categories. Certain types of business may require refrigeration and cooking facilities as a direct part of their service provision. This dynamic will be better understood through BEES Component B.

Table 17 sets out the total number of equipment and appliances accounted for by the 261 participant businesses, the mode of equipment/appliances per business, as well as the median and average numbers of these appliances and equipment.

Table 17: Equipment and appliance prevalence in participant businesses (n=261)

Equipment/Appliance	Total Number	Mode	Mean	Median
Computers	3074	2	11.8	5
Refrigerators/freezers	564	1	2.2	1
Printers	812	1	3.1	2
Microwaves	326	1	1.2	1
Photocopier	383	1	1.5	1
Computer server	315	1	1.2	1
Stand-alone fax machine	259	0	1.0	1
Water cooler	226	0	0.9	1
Dishwasher	154	0	0.6	0
Cooktop/oven	141	0	0.5	0
Projector	128	0	0.5	0
Electronic whiteboard	155	0	o.6	0

2.2.2 Implications of initial Strata 1 to 4 telephone survey

This data has been treated as a quota sample. It nevertheless demonstrates a number of important points in relation to non-residential buildings within the BEES project:

- The wide diversity of the businesses that inhabit the BEES buildings, evidenced by:
  - business sector and activities
  - staff numbers
  - client numbers
  - operating periods
- The heavy reliance of these businesses on reticulated electricity
- Variations around the exposure of businesses to pricing signalling in relation to both energy and water
- Variations in lease arrangements and exposure to landlords and property managers
- Sizeable, albeit minority, proportion of businesses who are owner-occupiers
- The range of, and mix of, appliances and equipment in these buildings.

In regard to the latter, the demise of the once universal stand-alone fax machine (now in only 52% of premises), and the rise of the water cooler (in 50% of premises), are notable. Notable too is the mix of effectively ‘domestic’ and ‘work-related’ appliances and equipment in these businesses.

Ultimately this data is intended to illuminate the aggregate energy and water use of these businesses and buildings. The number of businesses and buildings out of the set of businesses subject to this preliminary analysis that will contribute to establishing average aggregate energy and water use at a national level will depend on successful access of supplier data, and the extent to which processes to raise the building yield from this set of businesses are successful.

That will obviously take some time. However, the current data provide a rich dataset amenable to considerably more analysis. In particular, there are two steps that will allow for a greater amplification and understanding of these businesses and the buildings in which they reside.

First, this data will be matched using their unique compound identifiers to data in other datasets. It is critical that this is done in a carefully managed process in which the baseline of the resultant meta-database is established and understood. This will allow a much broader analysis of businesses and their buildings.

It will also allow us to establish whether the hierarchy established for data collection is adequate to BEES analytic needs. It has, for instance, become apparent during the analysis of the data that establishing the number of storeys in a building is not fully covered by the valuation or StreetView data as expected. Consequently, a minor amendment has been made to the telephone interview for Strata 5 and for replacement interviews to record the total number of floors in the buildings in which businesses are operating.

Secondly, even without matching to other data at this time, there are opportunities to explore the way in which businesses and buildings relate to each other. A preliminary analysis of the 261 businesses in these 171 buildings suggests that the relationship between building and businesses is complex and cannot simply be understood by understanding the tenure status, activities and consumption of individual businesses.

For instance, while only 18% of the businesses are owner-occupiers, 47 (27.5%) of the buildings have an owner-occupier residing in them. This raises a number of questions. Are these buildings managed differently from other buildings? To what extent do owner-occupiers attempt to reduce resource use in their building compared to property managers, facilities managers or landlords who are not occupying their building? Do owner-occupiers buildings have a different range of activities and businesses undertaken in them or do they occupy different sorts of buildings? And, if so, does this have any impact on resource use?

Other analysis of this dataset of 261 businesses and 171 buildings may help illuminate the extent to which building uses are mixed or tend to be homogeneous in character. If building use tends to be homogenous, strategies to manage resource use would be very different from buildings which are mixed. Similarly, do some buildings tend to have stable business occupation while others show significant turn-over in terms of duration of business occupation? Is there any impact on the profile of resource use in these different types of buildings if, in fact, they exist?

Exploring those and a myriad of other questions may provide not only fruitful ground for broader analytic activities in Component A and Component B, but perhaps also a way in which case studies may be focused in the future.

2.3 Energy- and water-record data

By the end of Year 3, all of the phone survey respondents who had indicated they would be happy to provide access to their energy and/or water revenue data had been contacted. Requests for those who had responded have been sent to the energy or water supply company, and the relevant records requested for as long a time period as they were being held. Water data is likely to be quarterly revenue records, electricity data a mix of monthly and half-hourly meter records, and gas data monthly revenue records. The data analysis will be reported in the Year 4 report.

3. COMPONENT B – DETERMINANTS OF RESOURCE USE

Component B – Determinants of Resource Use randomly selected and recruited about 50 buildings from which on-site measurements of indoor environments and energy use were gathered. The sample size is smaller than for Component A because on-site measuring is many times more costly per building (see Figure 1). As many as possible of the buildings for on-site monitoring will be recruited from the buildings which participated in the Component A phone survey.

In addition, Component B involved the design and undertaking of five case studies which are also reported in this section.

3.1 Interviews

(Prepared by CRESA)

The buildings recruited thus far for data collection into Component B cannot be taken to fully represent the sample frame, as during 2009/10 it was necessary to independently recruit them (see Section 3.2). As a consequence the sample was not sufficient and insufficient data had been collected to support the undertaking of matched data manager interviews.

This has meant that 2009/10 interviews have been refocused to a set of interviews with building managers and owners not necessarily linked to recruited buildings. A case frame for the interviews was developed around three types of building manager and property managers that emerge as potentially critical on energy and water consumption in New Zealand's non-residential buildings. The focus of these interviews is to assess the following:

1. Whether there is active recognition of energy and water consumption issues in the way in which buildings are managed and/or operated.
2. The extent to which resource optimisation is a component of building acquisition and investment decisions.
3. The mechanisms property portfolio managers, facilities managers and property managers use, if any, to incentivise or enforce occupant behaviour that optimises resource performance.

Table 18 sets out the case frame for and the focus of the interviews. Three groups have been identified.

First, those involved with facilities management within which four different types of facilities managers have been identified. An in-depth interview is being undertaken with individuals in each of these types. They are:

- Landlords who directly undertake facilities management in multi-tenanted buildings
- Landlords who undertake facilities management in buildings that they themselves occupy as well as being occupied by tenants
- Providers of facilities management on contract to landlords
- Facilities managers of high-end complex buildings.

The second set of managers who influence and have a stake in buildings are property portfolio managers. That is, those who acquire and manage property portfolios for companies owning significant property portfolios such as ING, AMP or similar businesses.

Table 18: In-depth interview case-frame management of non-residential buildings

Sector	Number of Interviews	Focus
A. Facilities Management • Hands-on landlords/multi-tenant building • Owner-occupier landlord with tenants • Provider of facilities management on behalf of landlords • High-end complex building facilities management	4	• Extent/intensity of management and scope of work • Focus of facilities management in particular building • Engagement with tenants • Key priorities for facilities manager • Mechanisms used to define facilities managers' performance • Mechanisms to measure building performance
B. Property Portfolio Managers	2	• Priority given to resource (energy and water) optimisation in investment, acquisition and disposal choices • Mechanism for ensuring resource optimisation in building design, build • Mechanisms to manage tenant resource use • Extent of control over facilities management in buildings and focus/priorities for facilities management
C. Property Managers for Green/Social Responsibility Companies	2	• Extent to green brand drives building selection and operation • Criteria for building selection • Extent of management to optimise resource use • Management tools and user education

The third set of stakeholders in non-residential buildings who may have a particular interest in the resource use and performance of the buildings from which they operate are businesses who brand themselves as 'green'. The issue here is the extent to which business branding of that nature is tied in with resource minimisation strategies associated with their building selection and management.

This is a qualitative activity involving eight in-depth interviews. Interviewing will be completed and reported early in the 2010/11 year.

3.2 Monitoring

(Prepared by BRANZ)

The main survey instruments[3] used in the targeted survey are:

1) Monitored energy and environmental data
2) Appliance audit
3) Lighting audit
4) Building audit
5) Hot water audit

[3] "Survey instrument" in this context means a method for collecting information or data.

6) Water audit
7) Equipment audit (e.g. HVAC, lifts etc)
8) Occupant details questionnaire.

The survey instruments developed in the pilot were deployed in the full survey, and as practical issues or improvements came to light were evaluated and implemented. In most cases, this has not resulted in any substantial change to the data collected by any survey instrument.

Due to the late start of the Component A telephone survey, the targeted survey buildings were initially recruited independently. Only when the Component A telephone survey was completed was a list of ‘hot contacts’ available and used.

Procedures have been developed to manage the recruitment process, such as tracking calls and contacts, recruitment scripts, information packs, standard email templates etc. The recruitment process takes considerable time and effort, even for the ‘hot contacts’ from the completed telephone survey.

3.2.1 Monitoring equipment

A range of monitoring equipment has been used to obtain data on the different aspects of supply and end-uses.

3.2.1.1 Energy

The two types of circuit electricity monitoring equipment used in the BEES project are:

1) Multivoies (www.omegawatt.fr)
2) Energy Logger Pro (www.onsetcomp.com/data-logger).

These are installed by a registered electrician under the instructions and supervision of a BEES team leader. An installation manual has been developed for electricians to allow them to become familiar with the system before the time of their first installation.

The targeted survey now mainly uses the Multivoies system, with the Energy Logger Pro being usually used only for longer term monitoring and case study work.

The Multivoies equipment has proven to be reliable and easy to use. Data collection has proven to be reliable with very low rates of data loss from the Multivoies system. Only one set of data from one circuit channel was unreliable due to damage to a sensor coil. Data loss is more likely to occur due to operator error than equipment faults, and the installation and downloading processes have been improved to minimise such loss.

Additional Multivoies circuit monitoring equipment was purchased in early 2010 to enable a larger number of buildings to be monitored simultaneously, and to allow for potentially very large installations in the large buildings and shopping malls in Strata 5 (see Table 3).

In 2010 GPRS cellphone communication modules were added to the Multivoies product range. One was obtained for trial, and following a successful trial a total of 41 were purchased. These allow remote downloading hourly or daily from anywhere in New Zealand. There are several benefits of using this system:

1) Ability to check monitoring while in progress
2) Ability to reconfigure loggers from anywhere in New Zealand if there are problems

3) Ability to reuse monitoring equipment without sending it back to the base for data downloading
4) No need to download data at BRANZ or in the field (saving time and money)
5) Able to record at 1 minute intervals due to larger onboard memory
6) Increased data collection reliability (data can still be recovered even if the GPRS module fails to communicate).

The Multivoies system does have the capability to monitor, store and also remotely download readings from other sensors (e.g. temperature, humidity, plug-in appliances); however that monitoring equipment is not being used in BEES. One reason for not using it is that the range of the wireless communication would often not be sufficient to cover an entire premises, or to go between floors.

Plug-in electrical appliance monitoring was started using the Plogg system, as initial trials were very successful. Unfortunately, these proved to be unreliable, with software and data connection problems and failed Ploggs in the second batch. In 2010 Plogg issued a recall/repair notice due to an electrical design fault. All 11 Ploggs were withdrawn from service. Forty Enerplug appliance monitors (part of the Multivoies system) have been purchased and are now used.

The forms for recording the monitoring equipment set-up have been modified based on experience to improve their usability and usefulness, and to minimise the incidence of set-up and configuration errors that could result in data loss.

3.2.1.2 Water and gas

Where water and gas meters are found, attempts are made to monitor them.

During the pilot, electronic water meter reading trials were undertaken using a range of nine different sensors to cover the various meter types. In practice, as the full targeted monitoring proceeded, more and more different types of water meters were found. In the field, it turned out to be too difficult to carry a sufficient range of water meter reading sensors. The process of identifying which sensor to use, then following the detailed instructions for installing equipment that is only occasionally used, would give a slow and unreliable field monitoring method. Connecting and wiring sensors with data loggers in the field would also significantly increase the time needed for installation. The decision was made to rationalise down to one type of water meter sensor for the Elster (Kent) meter, which is the one most commonly used in New Zealand.

The monitoring is performed using Onset micro-logger stations rather than the BRANZ logger used previously (so as to have the same software and data procedures as the Hobo loggers, and avoid making wiring connections in the field as well as to ensure proper watertightness). This process is working well, and the installation of the reading sensors and loggers usually only takes about 10 minutes.

For those water (and gas) meters for which the reading head does not fit, time lapse cameras are being used instead. This builds on the experience of trying to use optical methods to capture and read images of meter displays, which did not lead to a reliable and practical field data collection method. Brinno “GardenCam” time lapse cameras are used, at a cost of about $350 each (www.brinno.com/html/product02a.html). These are designed for outdoor use to capture images of gardens and plants. They have been modified slightly by setting the focal distance to ~5 cm for clear close-up images, and by having LEDs fitted to provide light at night or in dark water meter holes. This gives us almost identical lighting conditions during the monitoring period and further processing using an OCR method could be implemented (data entry is manual at present). Development and early use trials have been successful.

3.2.1.3 Environmental data

The environmental data monitored is:

1) Temperature
2) Humidity
3) Lux level
4) CO_2 concentration.

The equipment selected for temperature, humidity and lux level is the Hobo U12-012 logger. These are small, battery-powered loggers that are easy to conceal. Several U12 loggers are installed per premises.

The CO_2 concentration is measured by a Telaire meter connected to a Hobo logger. It measures CO_2 concentrations up to 2,500 ppm (which is very high and unlikely to exceeded often in buildings). Only one CO_2 meter is available for each set of installation equipment, so only one location can be monitored in each building. This is selected to be a typical space in the main area (e.g. office, retail floor) (www.microdaq.com/telaire/).

Forms have been developed and tested to record the equipment and what was monitored so that the data can be correctly identified in processing, and so that there is traceability to the equipment inventory and calibration.

In addition, 100 Hobo U10-003 temperature/humidity loggers were purchased, with the intention of leaving one in each building for an entire year, logging the above-mentioned parameters in 30 minutes intervals (due to memory limits). This will provide long-term monitoring of indoor conditions, to enhance and correlate with the long-term energy meter data.

3.2.1.4 Equipment calibration

Calibration processes have been developed for all the measurement equipment used in the targeted survey. All temperature and humidity loggers have been calibrated to a reference traceable to the National Standards Laboratory at IRL. Lux loggers have been calibrated relative to each other to give consistent readings. Electrical power (Multivoies) monitoring equipment has been checked against a unit calibrated by the National Standards Laboratory, and all units perform within the manufacturers specifications. CO_2 loggers are sent to an independent laboratory for calibration.

3.2.1.5 Monitoring equipment

The monitoring equipment now being used by BEES is illustrated below:

- Energy Logger Pro H22-01 + interface modules (Figure 7)
- Hobo Current Transformers (Figure 8)
- Hobo Environmental Loggers (Figure 9)
- Multivoies logger with different size Rogowsky coils (Figure 10)
- EnerPlug electricity logger (Figure 11)
- Brinno Garden Watch Cam modified with LED light source (Figure 12)
- Multivoies logger (Figure 13)
- Multivoies clamp Rogowsky coil (current transducers) (Figure 14)
- Telaire 7001 CO_2 Sensor (Figure 15)

Figure 7: Energy Logger Pro H22-01 + interface modules

Figure 8: Hobo Current Transformers

Figure 9: Hobo Environmental Loggers

Figure 10: Multivoies logger with 25 mm & 130 mm Rogowsky coils

Figure 11: EnerPlug electricity logger

Figure 12: Brinno Garden Watch Cam with LED

Figure 13: Multivoies logger

Figure 14: Multivoies Rogowsky clamp current coils

Figure 15: Telaire 7001 CO2 Sensor

Robust Pelican 1560 protective cases (Figure 16) have been purchased and fitted out with the monitoring and installation equipment. The cases permit the equipment to be safely and securely shipped as luggage on planes, boats, trains or cars.

Figure 16: BEES monitoring kit

3.2.2 Building audits

A range of audits are carried out on-site as part of the monitoring installation process. All field data is collected on several printed paper forms to allow multiple people to work on different forms at any one time. The data entry process from these forms takes around 30 minutes per premises.

BRANZ is using a digital pen system for the 2010 BRANZ *House Condition Survey*. Once this is fully operational its use for the BEES targeted survey will be re-evaluated.

3.2.2.1 Appliance audit

The appliance audit has been successfully deployed, and provides a practical and rapid audit process that causes little or no disruption to the occupants. The list of appliances audited has had a few additions to reflect the types of appliances commonly found (e.g. electronic whiteboard has been added to the list).

The appliance tally information is being used to randomly select which appliances to monitor, according to a predetermined selection scheme implemented by an Excel spreadsheet and macro. This is similar to the selection process used in HEEP.

3.2.2.2 Lighting audit

Lighting has been identified as one of the major energy end-uses in non-residential buildings, and considerable effort is being put into the monitoring and audit to measure and characterise lighting.

Lights are identified to a location in the building (matching the building audit floor plans) and to a switch control. Data is collected on each type of lamp in each light fitting with the wattage and total number recorded. The lamp type is selected from a list, as is the control type. The wattage is either read off the lamp (if readable) or estimated from a table of typical values. This audit data enables room-by-room or area-by-area calculations of lighting stock and lighting power density to be made.

Although it would be preferable to confirm which switch or circuit relates to a specific set of lights, it has not been found to be generally practicable to trace lighting circuits by turning lights on and off, a process which was trialled in the pilot. Some businesses do not want the lights turned off at all, and even if they are happy with the process, it takes too much time. Lights are only traced in this way if they cannot be identified from the distribution board. There is always a danger that the labelling on the distribution board is inaccurate, and instead of switching off a light it could be an important piece of equipment such as a computer or specialised instrument that is being switched off. It would be unreasonable to expect participating businesses to tolerate such potentially serious disruptions.

3.2.2.3 Building audit

The purpose of the building audit is to collect information on the physical layout and structure of the building so that characteristics of the buildings are known, permitting the creation of computer simulation models.

The first stage of the building audit is to copy or draw and annotate a floor plan, identifying each activity area, room height, floor coverings, glazing, doors etc. This is a time-consuming process, but with experience a floor plan of 1,000 m² with approximately 10 rooms can be measured, drawn up and annotated in about 30 minutes. The time taken depends more on the number of rooms than on the floor area.

Data on each elevation is matched to the floor plan.

Early versions of the building audit collected detailed information on the elevations. However, as most of that information is collected visually the photographs of each elevation are now used to collect the information (such as window areas, shading etc), for later coding and integration in the simulation models. This saves time in the field.

Some information that was desired has often turned out to be impossible to collect in practice, such as underfloor insulation for slab-on-ground floors. Some questions used in the pilot were dropped or simplified to reflect the quality of information that could be obtained.

There appears to be no other viable way to collect and annotate this type of information. If floor plans are available ahead of installation this saves time, so the occupants are asked to provide floor plans if possible. Obtaining plans from council records has been found to take too long and requires too much time to identify the correct plans in the available records.

3.2.2.4 Hot water systems audit

As was the case in the pilot, it is difficult to find hot water systems in many non-residential buildings as they are usually in out-of-the way places, and access is usually difficult or impossible. As the occupants do not normally own the building, and usually did not witness its construction, they often do not know where the hot water system is, let alone any information about it. In one building it was reported that when there was a fault in the hot water system, the plumber called to fix it could not even find the hot water cylinder and had to leave without fixing the fault!

As a result the amount of information collected on hot water systems has been reduced to a practicable minimum. However, in the worst case at least the temperature of hot water is obtained.

3.2.2.5 Water audit

The water audit collects basic information about water use in the building, including the number of water-using fixtures. The water meter is located (if it exists) and monitoring equipment fitted where possible.

3.2.2.6 Equipment audit

The equipment audit covers large equipment used for central services (such as HVAC systems and components, servers, lifts, boilers etc). As there is such a large diversity in the type of equipment and services provided, it has not yet been possible to develop a comprehensive checklist. This will be further developed in the coming year.

3.2.2.7 Occupant questionnaire

An occupant questionnaire is mostly conducted during the installation, or as a short telephone interview at the convenience of the responding occupant. The occupant questionnaire mainly covers occupancy and schedules. The BUS survey will be implemented in the 2010/11 year (see www.usablebuildings.co.uk).

3.2.3 Photographs

Digital photographs are taken of the following:

1) Photos of all exterior elevations
2) Photos of the surrounding buildings and terrain from all exterior elevations
3) Adjacent buildings
4) General photographs of the interior
5) Photographs of all distribution boards where equipment is installed
6) Photographs of environmental logger locations
7) Photographs of all major equipment (e.g. hot water systems, HVAC, chillers).

The photographs serve several purposes. Some are a record of the installation to assist in recall and identifying any problems later. Some are to record information that will be extracted and coded later (e.g. exterior elevations to identify glazing area, site shading etc). Using photographs particularly for the exterior elevations greatly reduces the amount of time required on-site. They are stored electronically with other material and data relating to the building.

3.2.4 Logistics

3.2.4.1 Field staff

Field staff are often used to assist with the installations, mainly undertaking the audit tasks. In some locations BRANZ has field staff that we use regularly. In less frequented locations, field staff might be recruited on a one-off basis, from staff used by BRANZ on other projects, personal contacts, or support staff supplied by the electrician. As the audit work is well prescribed most field staff learn it very quickly and do a good job with minimal supervision. A field training manual is being developed to support the training of temporary staff before the actual installation.

Using field staff both reduces costs by reducing the time spent by BRANZ staff, and also reduces the duration of the installation, an important factor as some businesses do not really want people working in their building for too long.

3.2.4.2 Installation

The pilot was conducted using a team consisting of an electrician and two or three other people. The full targeted survey is being done with a smaller team consisting of the BEES team leader and electrician, and when possible to organise an audit assistant to do the lighting, appliances and building audit.

The roles identified are:

1) BEES team leader. Install electrical monitoring equipment with electrician. Install all data loggers. Supervise installation.
2) BEES auditor. Conduct all the audits, with assistance from BEES team leader as required.

For smaller installations, or remote areas where getting an audit assistant is sometimes difficult, the BEES team leader may do all the audit work. This makes the installation longer.

On-site, the time required for each of these tasks has been roughly the same. In some cases the BEES team leader has finished before the auditor and can assist the auditor.

Some audit tasks need to be done in a specified order so that information can be transferred to the team leader to assist with the monitoring equipment installation.

In order:

1) Floor plan for building audit
2) Lighting audit
3) Appliance audit
4) Other audit tasks in no particular order.

The floor plan needs to be done before the lighting plan so that rooms or locations can be allocated to lighting circuits. The floor plan and lighting plan assist in identifying and tracing circuits. The appliance audit is needed before the appliance for monitoring can be selected.

The time required for installations have proved to be similar for the full monitoring when compared to the pilot study. In practice the time taken varies depending on the size and complexity of the installation. A small shop or office (50 to 150 m^2) usually takes about 1½ hours with three people. A large shop or office (~1,000 m^2) takes about 3-5 hours with three people. The time taken does not scale in proportion to the floor area, but to the complexity of the installation in terms of the number of circuits, distribution boards, rooms, and equipment.

The most uncertain part of the installations is the time taken to install the Multivoies electrical monitoring equipment. This depends on:

1) The number of distribution boards requiring monitoring (as many as five)
2) The number of circuits on each boards (ranges from 6 to ~60)
3) How well labelled and organised the boards are

4) The physical condition of the boards (some are very old and potentially dangerous)
5) The physical size and location of the boards (some are hard to work on)
6) If the electrician knows the building and boards
7) The skill of the electrician.

The number of boards and circuits is not easy to predict. Even a small premises (<150 m²) could have two or three boards, and might have as few as six circuits or as many as 40. The time taken can therefore be unpredictable.

To mitigate these issues the electrician who works on the building is normally used (as they usually know the distribution boards and how they are wired), and the number of boards and circuits is obtained by asking the electrician or the occupant before the site visit. This enables a better estimate of the time required for the installation and monitoring to be completed.

At this stage it is proving difficult to install more than one premise or building per day, as the time required is unpredictable. Also with the targeted survey installation being spread out over the year according to a preset schedule (time and geographic location) it is uncommon to have a large group of buildings installed in one location at one time. Only on one occasion have two installations been completed during one day, and at least one installation has taken more than one day, needing to be completed the next morning.

3.2.4.3 Removal

The equipment removal is done by the electrician, following a checklist of all the installed monitoring equipment. The checklist is prepared using the monitoring installations record. This saves a lot of time and money for BRANZ staff, especially for locations outside Wellington. This is usually done on a schedule, and all equipment is retrieved. Occasionally something is left behind requiring another visit, or a follow-up to the occupants. The equipment is taken by the electrician and stored in the provided equipment cases or packed in boxes. It is either held by the electrician for the next installation, or returned to BRANZ by courier.

The removal process is much quicker than the installation – typically taking less than one hour to remove the electrical equipment from the distribution boards and return the board setting to the original condition, and 5-10 minutes to retrieve the environmental loggers and appliance loggers.

3.2.4.4 Downloading and primary processing of data

Data from equipment that is returned is downloaded by BRANZ. The monitoring installation forms allow the data to be correctly identified.

Equipment that is held by the electrician is either downloaded remotely, downloaded on-site before being installed in the next building, or is swapped for fresh equipment and taken back to BRANZ for downloading.

The GPRS cellphone modules which are now being used with the Multivoies electricity monitoring equipment communicate data to a central FTP server once per day.

The data from all the monitoring equipment are downloaded, checked and stored in named files in the appropriate location. The monitoring set-up sheets are used to check that all data loggers have been retrieved and all files downloaded.

All data is visually checked before being stored. Where problems occur they are fixed if they can be, otherwise the files are stored. Strict naming and filing conventions are applied to ensure that data is stored in the correct place ready for processing.

The processing of data is done using the S-Plus statistical package. This package was used for HEEP, with modifications made for the BEES project. Building on the existing HEEP platform has saved an enormous amount of effort in developing software.

To reduce the processing time and improve reliability the data files are usually not altered once they are downloaded. For example, as some data loggers are not stopped when they are retrieved there is data from after the removal, and this needs to be removed from the processing. This process is handled by a master monitoring set-up file which stores the name and location of every data logger, the start and end-time for monitoring, and other related information such as the location, descriptor of the data, and other information used for processing.

There are several major benefits of this system:

1) Most data processing is done by making entries in a spreadsheet rather than editing or processing files
2) The downloaded data files are not altered
3) No extra copies of the data files are needed
4) No chance of making irreversible changes to data files
5) No chance of corrupting data files
6) Much faster than editing thousands of individual files
7) Master processing list is the record of processing
8) Can be done as a batch process.

3.2.4.5 Importing data into S-Plus

The data are imported into S-Plus using a custom set of importing and processing functions. The raw data files consist of multiple separate files for the Multivoies logger(s), temperature/humidity/light loggers, and any other data loggers. All this data needs to be combined into a single file for processing and analysis.

For each data file:

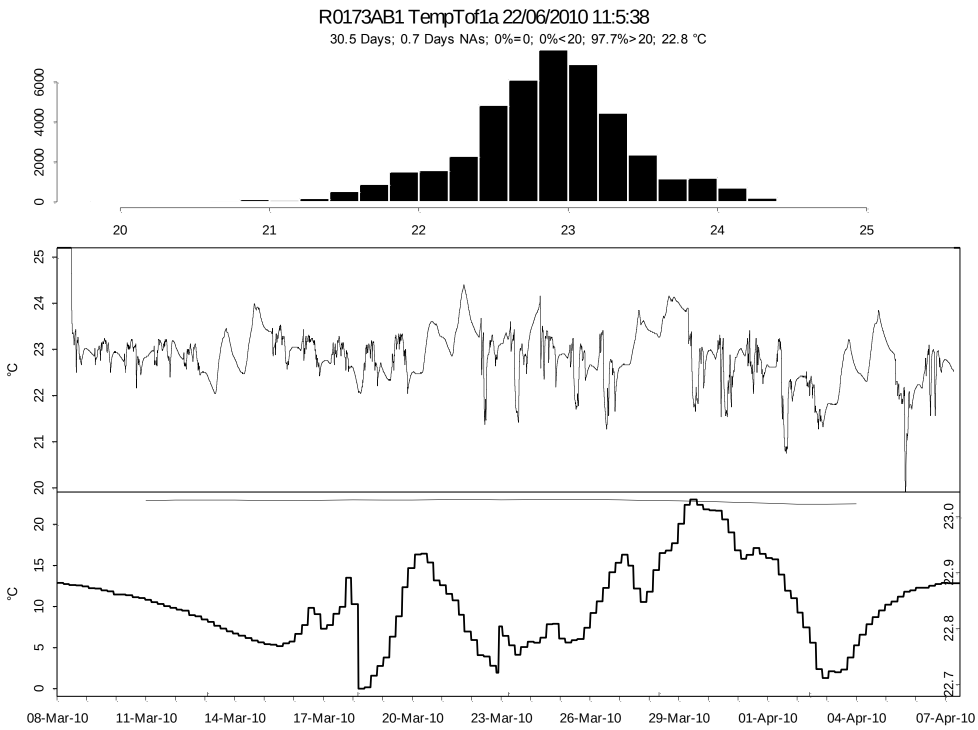
1) The data is imported
2) Known problem data is removed automatically (e.g. start-up values)
3) The time base is aligned to 1 minute interval, and data interpolated if needed
4) Names are assigned to each item of data from the monitoring set-up
5) Start and end times are applied to each item of data from the monitoring set-up
6) Calibration corrections are applied.

The data from all files are then combined into one data object:

1) All data are trimmed to the start and end times for the premise(s)
2) Totals and other processing done (e.g. add all air-conditioning units (aircon) to give air-conditioning total)
3) Data object is stored.

After the data is imported all the data is visually inspected using Exploratory Data Analysis (EDA) plots. An example is provided in Figure 17 for a temperature sensor located in an office. The label ‘TempTof1a’ means the Temperature end-use (Temp), data type temperature (T), located in office number 1 (of 1), with “a” indicating the first sensor in office number 1. The EDA plot has a description of the data and basic statistics in the title. The upper plot is a histogram of the data, from which extreme values, zeroes, negative values and other potential problems can be readily identified. The middle plot is the time series of the data, in this case at 10 minute intervals. The lower plot has the average by time of day (midnight to midnight) and the seven-day moving average. By inspecting this plot an experienced analyst can identify any problems very quickly, and identify any interesting or unusual patterns. For this case the time of day profile is unusual as it is maintained within a very narrow band (average only varies between 22.7°C and 23.0°C) and shows evidence of tight active control (at 8 am the temperature drops, presumably when the air-conditioning system starts on a timer). Any data problems detected from the EDA are then traced, fixed and the data re-imported.

Figure 17: Example of EDA plot for temperature



3.2.5 Status of targeted monitored buildings

Table 19 provides summary statistics on the BEES Installations completed between 1 June 2009 and 30 June 2010.

Table 19: BEES monitoring 2009/10

Activity	Count
Premises	42
Buildings	34
Distribution boards	~58
Electrical circuits	~1,200
Temperature/humidity/light loggers	~160
Water meters	36
Time lapse cameras on water meters	2
Plug-in appliances	~30

In almost all cases all distribution boards and all electric circuits were monitored in the participating premises. In a few cases where several floors were occupied by one premise a sub-selection of floors was monitored.

To give some perspective on the complexity and amount of work involved a comparison with HEEP is useful (see Isaacs et al, 2010).

Once HEEP reached full-scale monitoring, 100 houses were monitored in each year. Installations were undertaken by one of three teams, each led by a trained BRANZ staff team leader. The work required for the HEEP audit (everything excluding monitoring equipment installation) is comparable to the BEES audits. The monitoring for HEEP was less complex (three-quarters of houses had only total and hot water monitored) with fewer distribution boards (usually only one) fewer circuits (usually ~10).

In comparison, the BEES monitoring installations over the 2009/10 period have completed 42 premises in 34 buildings. Electrical monitoring equipment has been installed on 58 distribution boards, monitoring ~1,200 electrical circuits. This is comparable to the entire electrical monitoring undertaken in one year of HEEP installations. For BEES there is only one BRANZ installation team leader (not three) with a back-up, so to achieve this amount of monitoring is a major achievement.

3.2.6 Preliminary analysis

Preliminary analysis of some targeted monitoring data is given to demonstrate what type of information and analysis the data can support. As the data is not yet a full statistical sample, and is on the basis of premises, **this analysis does not represent the national building or premises stock**. No inference can, or should, be drawn from this analysis.

Note that all the reported analysis is preliminary and subject to change.

3.2.6.1 Major electricity end-use totals and breakdowns per premise

The major electrical end-uses in the surveyed buildings are:

- Premises total
- Lighting
- Air-conditioning
- Plug loads
- Hot water.

The full report on this work provides for each premise the approximate breakdown of end-uses, where the data was available for processing. Note that as each premise is only monitored for a short period (typically 2-4 weeks) these breakdowns do not represent the annual end-use breakdown on an annual basis. As more premises are monitored, statistical analysis will be used to infer the overall annual energy use breakdown.

Based on the monitored buildings, the daily electricity use varies widely, from 7.1 kWh/day for a small shop to about 1,500 kWh/day for a large office building.

The sample is too small to make useful breakdowns by business type or size; however there appear to be some obvious patterns in the data.

The smaller shops are usually small suburban or provincial town shops, which often have no dedicated heating or HVAC system. Their energy consumption is usually very low (10-30 kWh/day). For these types of business the lighting is often the dominant end-use, and is often a high percentage of the total electricity consumption. One small shop had 97% of the electricity used for lighting. This proportion was verified, as the shop had no hot water system, no heating, and only a handful of small appliances.

Air-conditioning is present in only some premise. Some are central HVAC systems, but most are single or multi-split systems. As the time of year monitoring was done varied, the energy consumption for air-conditioning does not represent a full year. Consequently the air-conditioning electricity consumption for the short periods monitored is highly variable, ranging from 1% to 58% of total electricity consumption.

Power point (plug load) electricity consumption appears to be slightly more consistent, ranging from 21% to 70% of total electricity consumption.

Hot water appears to be a minor end-use. For those premises where a hot water system existed and was monitored separately the consumption was usually about 1% to 2% of the total. Some premises had hot water systems that were turned off or disconnected.

Computer servers are difficult to monitor as occupants often refuse to allow monitoring equipment to be installed due to concerns over possible power interruptions (which we note is unlikely with the BEES monitoring equipment). For the three servers monitored so far, consumption ranges from 3.2 kWh/day to 48.1 kWh/day. These are typical business sized servers – there is one large server farm in a monitored BEES building, which consumed 160 kWh/day (~60,000 kWh per year) for one of two server rooms, excluding the room HVAC. These preliminary results could suggest that server electricity consumption might be larger on average than hot water energy consumption in commercial buildings.

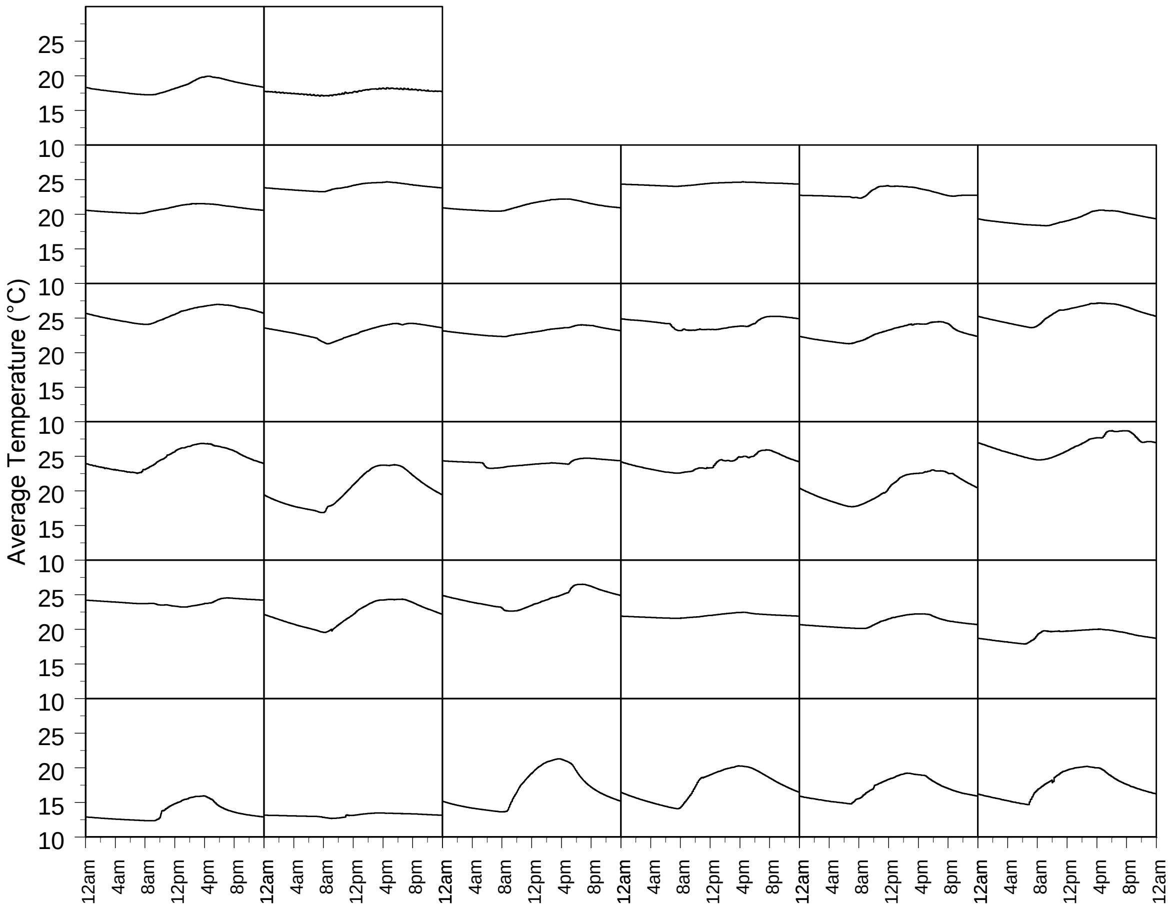
The monitored electricity data already shows the wide variation of electricity consumption between premises and between end-uses. Even in the small selection so far, the range from lowest to highest electricity consumption is a factor of 200.

3.2.6.2 Temperature, humidity and light

Temperature, humidity and light are monitored in several locations within each of the premises. Examples of average daily temperature profiles are given in Figure 18 for 32 rooms in monitored premises. It is again stressed that the monitoring is for a short time period (usually 2-4 weeks) so does not represent an annual average.

One of the early findings from HEEP was that winter indoor temperatures were low, and often poorly controlled. In the BEES premises monitored so far the indoor temperature profiles usually do not show evidence of tight control of the internal temperatures. Most premises seem to be left free-running after hours, and only a few show evidence of being conditioned 24 hours a day to a controlled set-point temperature within a band of a couple of degrees Celsius. It seems that many non-residential premises are not well controlled, possibly due to a lack of a centrally-controlled HVAC system, insufficient capacity or poor control. The belief that non-residential buildings in New Zealand are operated to a well-controlled set-point and schedule might not reflect the actual operation of many buildings. This result can be expected to change as increasing numbers of different building sizes and uses are monitored.

Figure 18: Temperature profiles from 32 rooms in monitored premises

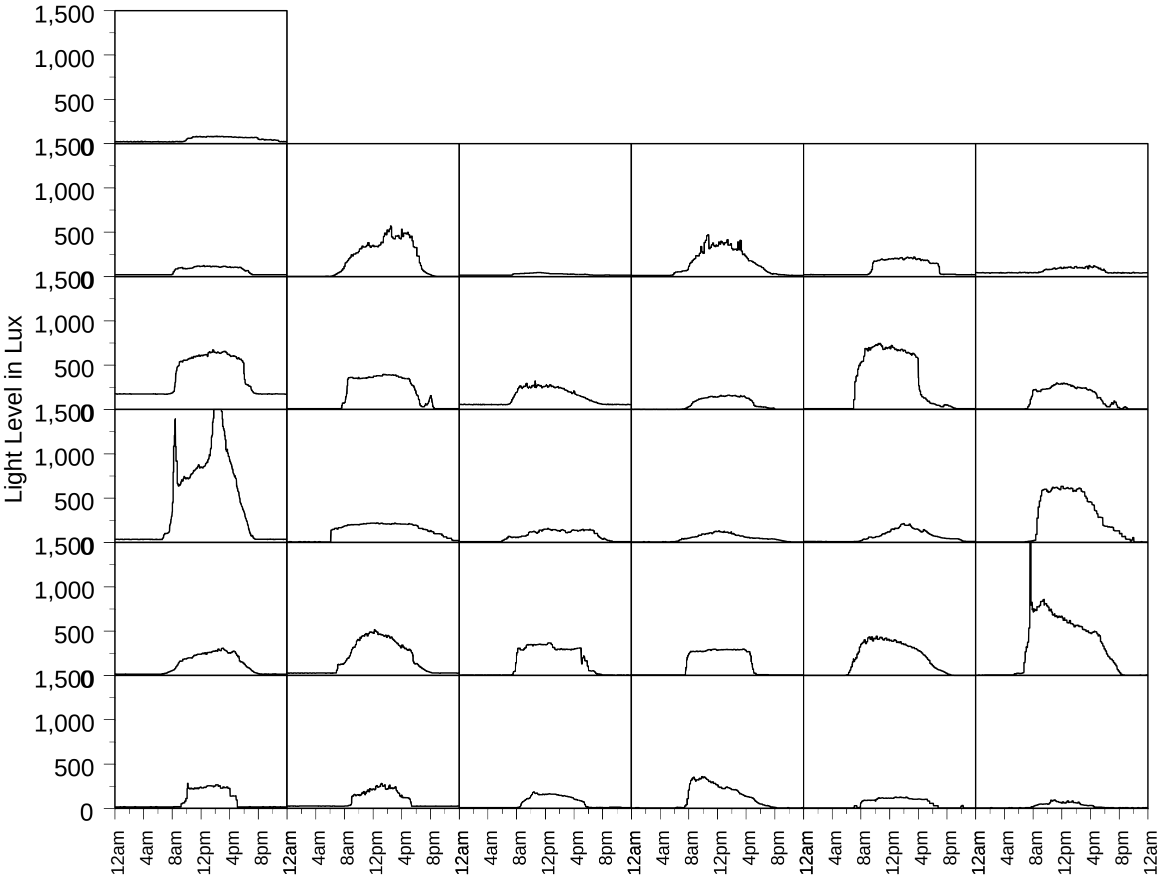


Light levels are also monitored in the BEES premises using a lux sensor. This gives non-colour corrected light levels in units of lux. Average daily profiles of this data are given to explore lighting patterns. Examples are presented in Figure 19. The monitoring is for a short period of time (usually 2-4 weeks) so does not represent an annual average.

Most of the lighting profiles show a distinct period of lighting during the day with a reasonably rapid increase and decrease in light levels. For some the light levels are stable for most of the day, probably indicating the sensor is mainly illuminated by artificial light, and that the lights are left on continuously during business hours. For others the light levels vary during the day, possible due to partial daylight illumination. Typically the lighting levels are around 200-400 lux during the day.

When further analysis is done on the BEES data it will be possible to compare the monitored lighting levels with the lighting audit information to determine how much installed lighting is being used to achieve the lighting levels.

Figure 19: Lighting profiles (lux) from 31 rooms in monitored premises



3.2.6.3 Baseload and standby

The baseload and standby was analysed for HEEP houses, and provided very valuable information on standby and other constant loads such as lights left on and faulty refrigeration appliances. A full description of the method can be found in the HEEP Year 10 Report.

So why is this important for BEES? The baseload and standby is made up of appliances or equipment that are constantly on (e.g. exit lights, security systems), standby power of appliances and systems, overnight lighting, etc. By removing the energy used by appliances and equipment when it is cycled on and off, some assessment can be made of how much other energy they are using. This gives potentially useful information which could be used to identify savings or efficiency improvements.

One BEES case study has already started to examine baseloads, and there is potential for developing this into practical procedures that could be applied to metered interval data to provide new information to consumers. Using the 10 or 1 minute interval data from BEES could help to determine what information can be gained at the 30 minute intervals typically used for metering.

Baseload and standby analysis is attempted for the monitored BEES premises. The analysis methods are still under development as there are several features of the premises and the data not seen in the HEEP houses. These include:

1. Much higher prevalence of cycling appliances such as refrigerators and HVAC systems

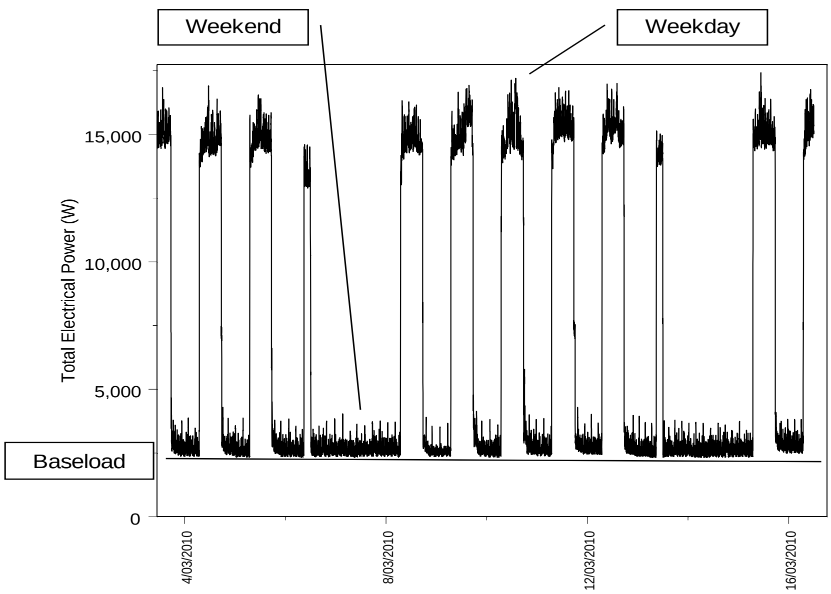
2. Much higher numbers of appliances and systems

3. Often pronounced differences between the after-hours loads during the week and weekend.

As a result, the electricity consumption is less likely to reach a stable minimum after-hours as often as in houses, as there are more appliances and particularly cycling appliances. Most early targeted survey premises were monitored at 10 minute intervals, with later ones (and all future ones) at 1 minute intervals, which gives a much greater ability to filter out the cycling equipment and appliances.

An example of the data for the total electricity consumption of a premise is given in Figure 20 below. This premise shows a distinct pattern of use across the week, with five days of full operation and several hours of operation on Saturday. The load never drops below about 2,500 W, as indicated by the baseload line. For this premise the HVAC system appear to be running 24 hours a day. The relatively stable baseload suggests that all HVAC equipment and major cycling loads are often simultaneously off, otherwise the minimum value on the graph would vary widely, giving a “ragged” bottom edge. While for this premise the load never dropped below ~2,500 W, what makes up this load has not yet been determined.

Figure 20: Example of baseload data



The baseload was estimated for all the monitored premises with data available. On average the baseload was ~1,100 W, and ranged from near zero to 6,700 W. In HEEP the average baseload was 112 W. What makes up this baseload still needs to be determined. At this stage analysis of overnight lighting electricity consumption can be done for some premises, and this ranged from 5 W to 2,900 W, with an average of 368 W. It seems that some lights are left on overnight, and this might account for ~1/4 of the baseload. Further work is needed to better understand and quantify the baseload of non-residential buildings, and identify what end-uses contribute to it.

3.2.6.4 Conclusion

The targeted survey is now running at full-scale, with enough equipment to monitor about 10 buildings at any one time, and enough trained staff to install a maximum of about 10 buildings per month. A robust set of survey instruments, forms, equipment, procedures and processes is being used. The scale of the task has been determined and appropriate resources (personnel, equipment and money) allocated so that the planned number of buildings can be monitored.

The full system for downloading, processing, applying calibration corrections and assigning in a central database is operational. Data are processed quickly (usually within 1-2 weeks) after downloading, ready for analysis. These processes ensure that good quality, reliable data is collected and stored in a form that is traceable and searchable, and can be analysed on a consistent basis.

While the number of premises and buildings is currently insufficient to provide national or grouped analysis, the monitored data is beginning to reveal patterns of energy use and indications of the levels of energy consumption and service in non-residential buildings.

Patterns of temperature suggest that temperatures in many non-residential buildings are not well-controlled, and that they are not operated to well-defined set-points or schedules.

Patterns of lighting (lux) suggest that lighting is used mainly during the day, and that light levels (and perhaps lighting energy consumption) are reasonably stable throughout the day.

Humidity and CO_2 levels are also being monitored, and will be reported on in subsequent analysis.

Electricity consumption varies widely in the premises monitored so far, with a range of 200 times from lowest to highest. The wide range in the floor area is probably the main reason for this range, so this and other drivers of energy consumption will be explored in future analysis. The fraction of total electricity used for lighting varies widely. It seems that in some small retail premises lighting is the dominant energy end-use. Water heating appears to be a very minor end-use (maybe a few percent). Servers are fairly common and it seems that their energy consumption might be larger than for water heating.

3.3 Case studies

(Prepared by Energy Solutions)

Five trial case studies were designed and carried out to explore what drives the variation in energy use in non-residential buildings. The results of this work also provided the opportunity to examine the value of case studies to the overall research. The case studies are summarised in this section. The full case study reports are available from the BRANZ website (www.branz.co.nz) . Note that building names or other identification are not provided in order to ensure confidentiality.

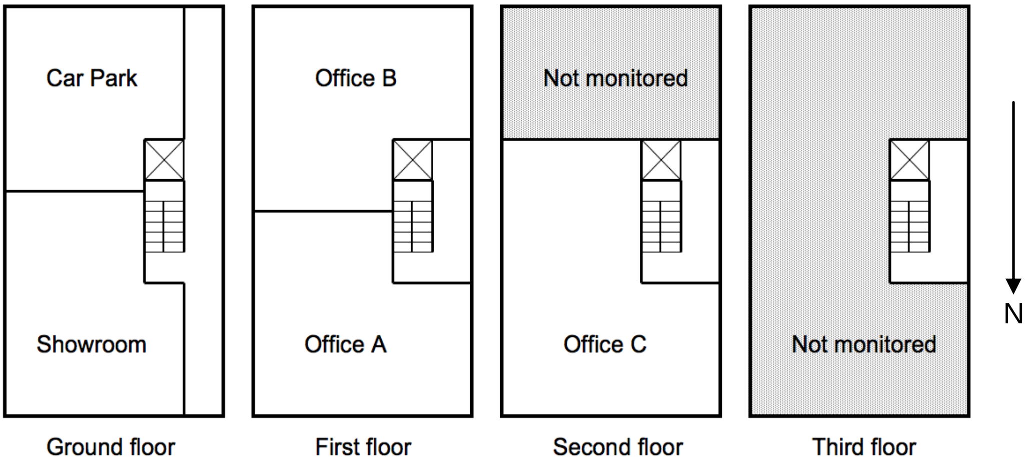
3.3.1 Case study 1: Comparison of measured results for similar premises

Four premises in a Wellington, mixed-use non-residential building were monitored during December 2009 to January 2010, three in sufficient detail to document all of the end-uses.

The four-storey building has several office premises and a retail showroom on the ground floor. It is approximately 80 years old. There is a passenger lift and stairwell, enclosed car park at the rear, and corridor through the building on the ground floor.

A simplified plan view of the building is shown in Figure 21 below. The street frontage, facing north, is at the bottom of this plan. The showroom and three offices were monitored, as well as much of the common areas.

Figure 21: Case study 1 – schematic floor plans



The monitoring yielded some interesting results, showing the similarities and differences in energy end-uses between premises in the same building. The premises were similar in size and annual usage (especially on an area basis), but differed markedly in their patterns of use.

There were both winter-peaking (south-facing) and summer-peaking (north-facing) premises in the building, and one that peaked in both summer and winter, with slightly lower use during swing seasons.

Office B, on the south side of the building, has by far the highest heating loads with an AUEI (Area Energy Use Index– the annual energy use divided by the floor area) of 61 kWh/m²/yr, comparable to other buildings with predominantly electric resistance space heating. The showroom had by far the highest lighting energy use, both in terms of installed lighting density (22 W/m²) and usage.

Office C had all the apparent electrical circuits on its distribution board monitored, but these accounted for less than half of that premise's energy use. For two of the premises, the individual circuits exactly matched the power use to the premise. For another, the total premise use was only within about 10% of the sum of the individual circuits. This was somewhat confused by other circuits, not connected to that premise that were monitored on the same logger, and not clearly distinguished.

Office A showed a significant decline in energy use – over 30% in the past two years. It would be interesting to determine what caused this reduction.

One important lesson learned from this is the need to prepare a "single line diagram" during the monitoring of complex buildings, so that the circuits running from each distribution board can be fully identified, and individual circuits linked to each premise.

Finally, one premise, (the showroom) had its energy purchase account with an address different to its street address. This might indicate that they are being charged for someone else's electricity use, although the data did not show this.

The end-uses for the three premises where these were completely measured are summarised in Table 20. The first three columns list the energy use, floor area and AEUI. The next columns list the peak season, and lastly how much below the normal usage the energy use is in the month of January.

Table 20: Case study 1 – energy use and seasonality

	Energy use kWh/y	Area m²	AEUI kWh/m²/y	Peak Season	January low
Office A	21,537	262	82	Summer	- 40%
Showroom	28,952	276	105	Winter	- 20%
Office B	29,944	258	116	Winter	similar
Office C	50,046	437	115	Summer & winter	- 30%
Common areas	38,324	~2,000	19	Consistent	- 10%

Table 20 shows for this case study building there is extreme variability in the season of peak energy use. The January (summer) energy usage is unusually low for most of the premises, due to low occupancy, showing that the month of January is not a representative time to monitor building energy use patterns. Some of this is due to the large numbers of holidays during this period compared to others (which can be accounted for), but there may have also been unusual occupancy effects during this period.

Table 21 compares the end-uses for the three premises where these were completely measured and the results of the previous case studies (a single-storey office building, a tower block office building, and a mixed-use [industrial/non-residential] office building).

Table 21: Case study 1 – area energy use and power indices by use

		Lighting		**Plug loads**		**HVAC**	
	kWh/m² y	**W/m²**	**AEUI**	**W/m²**	**AEUI**	**W/m²**	**AEUI**
Current case studies							
Office A	82	16	29	14	21	20	32
Showroom	105	22	62	15	11	24	21
Office B	116	9	19	25	35	(~30)	61
Previous case studies							
Single-storey office	*120*	*14*	*34*	*2*	*5*	*25*	*68*
Tower block office	*168*	*16*	*44*	*15*	*37*	*35*	*39*
Mixed use office	*122*	*13*	*24*	*30*	*29*	*124*	*81*

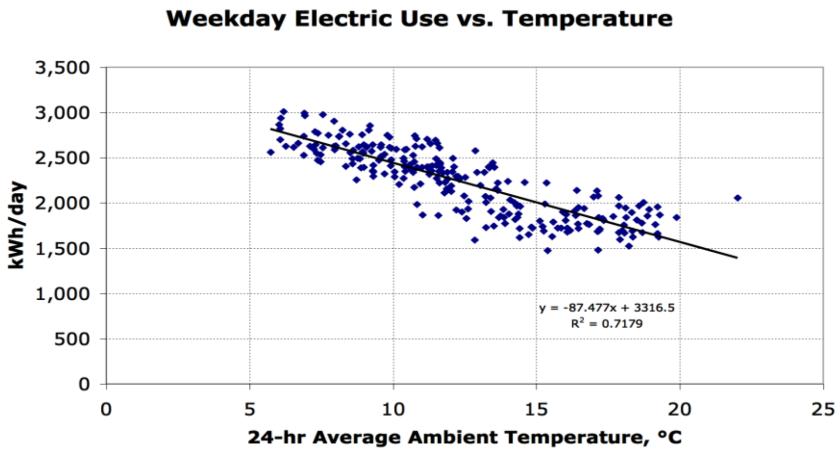
3.3.2 Case study 2: Measuring temperature-dependent building energy loads

The energy use of non-residential buildings is characterised by a temperature-independent 'baseload' use occurring every day of the year, and a temperature-dependent load that can be caused by either, or both, heating and cooling.

This temperature-dependent load is usually expressed as a linear function of outside air temperature. This follows from the normally accepted (simplified) physics of building heating loads, where the heat loads from conduction and ventilation are linearly related to temperature difference between inside and outside.

An example of this is the daily (weekday) energy use of a set of buildings with electric resistance heating and little refrigerative cooling, shown as the individual points on the graph below, for an entire year. The temperature response (sometimes called the 'performance line') is shown as the regression line through those points. Figure 22 provides an example, where the outside temperature explains 72% of the variation in the building's energy use.

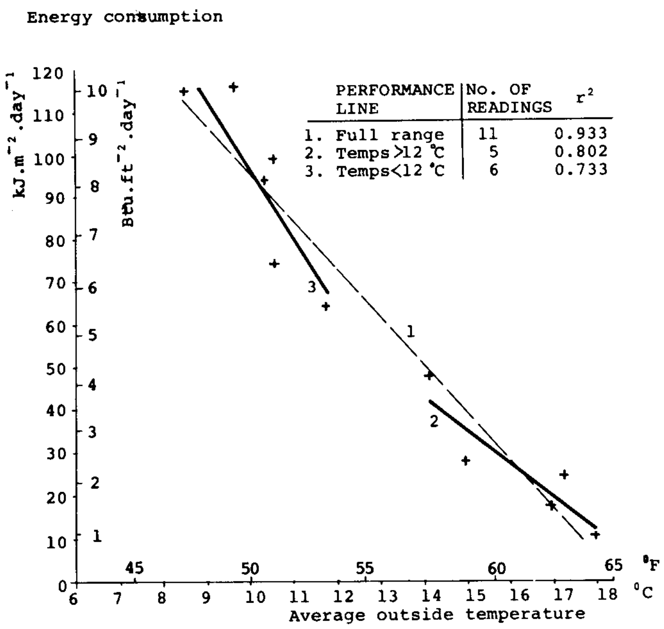
Figure 22: Case study 2 – weekday electricity use vs. temperature



This technique analyses the whole-building daily total electricity or gas energy use (midnight-midnight) as a function of 24-hour average ambient dry bulb temperature, as measured at a local weather station (or on-site).

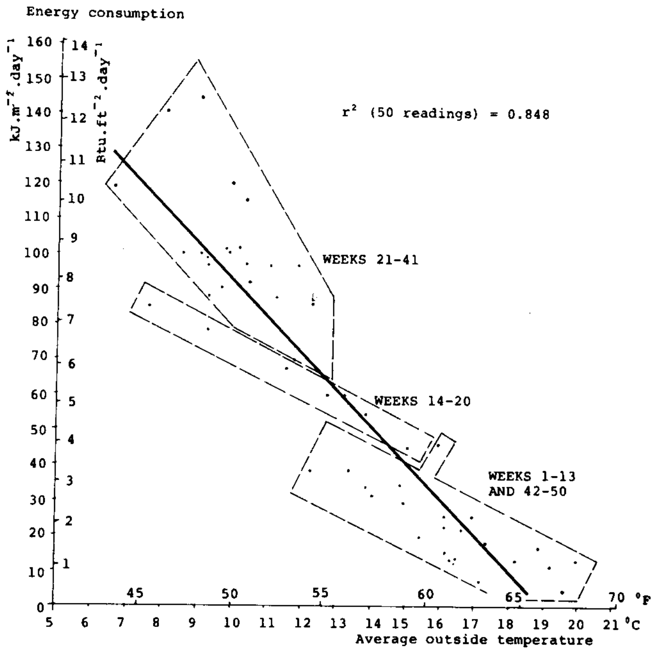
The use of energy performance lines to help understand energy use is not new. For example, Brander (Baird et al, 1984), analysed building performance lines, noting that they tend to vary in different seasons, even within the same year. Also, for example, Figure 23 plots the monthly energy use of a building heating system against the average outdoor temperature. Temperatures either above or below 12°C show different performance line slopes – higher (indicating a larger heat loss coefficient) when temperatures were lower.

Figure 23: Performance line analysis of a heating system based on monthly readings



Performance line analysis using weekly energy measurements showed similar results (Figure 24), with the data from weeks 21-41 showing a significantly higher slope than the other three sets of weekly data.

Figure 24: Performance line analysis of a heating system based on monthly readings



More recently, researchers at Texas A&M University and elsewhere have made use of a wide range of temperature-dependent load shapes to characterise building energy use. An 'International Performance Monitoring and Verification Protocol' (IPMVP) has been developed to support the verification of energy savings and is now widely used.[4]

The variation in these temperature-dependent load shapes suggests that characterising building energy use by a simple performance line may be oversimplifying the situation. This was explored by this case study in order to better quantify the monitoring procedures to be used by BEES.

It was concluded that the main reason that the annual temperature response (performance line) of a building cannot be determined from short-term measurements is the likelihood of different heating and/or cooling operating regimes in the different seasons of the year.

It may be possible to infer the performance line of a building from measurements made when the energy use is most strongly responding to outside temperature. That is, a building with a winter peak energy load caused by space heating could have its response approximated by measurements made during the peak of the heating season.

However, for the case study Wellington example it was found that even in the winter period some of the performance lines based on fortnightly data had opposite slopes to the overall annual performance line. The analysis suggests it is possible that Christchurch, or in other climates with higher temperature variability, will prove more amenable to this type of extrapolation. It may be possible to infer a performance line if measurements are taken at times of both high and low temperatures (on an annual basis). However, this will require two sets of metering installation and removal from each premise.

[4] International Performance Monitoring and Verification Protocol, US Department of Energy (December 1997). See http://www.evo-world.org/

Alternatively, measurements made on the heating or cooling systems only could show higher resolution than whole-building measurements, and thus avoid the scatter caused by non-heating or cooling energy use variations.

Finally, the existence of different operating regimes at different times of the year, probably mean that a simple linear function is inadequate to explain building temperature-dependent energy loads.

3.3.3 Case study 3: Understanding long-term changes in building energy use

The energy use of non-residential buildings is characterised by a temperature-independent ‘background’ use occurring every day of the year, and a temperature-dependent load that can be caused by either (or both) heating or cooling.

This case study separates the temperature-independent and temperature-dependent loads for a large New Zealand non-residential office building in order to support the development of the BEES monitoring protocol.

It was found that the variations in temperature-independent electrical energy use over time appear to be mostly correlated to the increase in background electrical load of the building,

The variations in temperature-dependent electrical and gas energy use over time appear to be mostly correlated to the consistency of control of the HVAC (the main temperature-dependent load) and the external temperature.

With a more detailed and complete dataset, these correlations could be made more conclusive. This may be an option in the future, as the building has now moved to recording its half-hourly gas and water consumption.

3.3.4 Case study 4: Energy savings opportunities from BEES monitoring

A potentially important outcome from the BEES work would be to illustrate potentially cost-effective energy saving opportunities. This case study documents some of the opportunities found from the first stages of monitoring during the 2009/10 year.

Almost all of the savings opportunities identified are instances of equipment being left running when it is not required. These all came from the monitoring of individual electrical circuits within a building, which is not common outside this research study. The examples found were:

- HVAC plant running when not required:
    - Air-conditioning runs more when unoccupied
    - Retail showroom cooling system left running over Christmas holidays
    - After-hours heating running continuously
    - Gas boiler always starting early
- Lighting
    - Lighting left on permanently (building not continuously occupied)
    - Lights occasionally or accidentally left on
    - Unrealised daylighting potential
- Plug loads
    - Hidden electric heaters.

The case study concluded that almost all of the identified energy savings opportunities are instances of equipment being left running when it is not required.

Examination of the results suggested that a further case study could look at whole-building or whole-premise energy load profiles (both 24-hour and 12-month) to determine what (if any) savings opportunities could be inferred. The case study provided examples of a business showroom premise over the Christmas holidays, and of whole-building gas purchase profiles. Both of these could be considered as being more revealing of larger savings than the individual circuit examples.

The wider value of the results of this case study is that whole-building or whole-premise load profiles are routinely generated during energy billing, and especially energy management activities, and so have a much wider potential application than results based on individual circuit monitoring.

3.3.5 Case study 5: Circuit label accuracy

This case study could not be fully completed in the 2009/10 year without adversely disrupting a host site's operations. As part of case study 1 (Section 3.3.1), it was found that one premise had an additional set of fuse circuits installed that had no electrical distribution documentation. Surprisingly, these circuits appeared to use over half of the energy flowing through that premise's revenue meter.

In one of the pilot monitoring installations undertaken in 2008/09, it was observed that one of the main HVAC plant was connected through the neighbouring building occupant's electrical distribution and metering.

In both these cases the extra effort of the case study identified an energy use issue that had not previously been considered by the building occupants. Although the circuit labelling in the other buildings investigated during the pilot stages of monitoring generally appears to be reasonable, these discoveries do raise a potentially important issue.

As a result of the case study it is recommended that during monitoring installations details are recorded of any unclear or mis-labelled circuits. This data will be support to ongoing consideration during the rest of the BEES monitoring. In particular, this shows the importance of completing an inventory of the loads and equipment on each electrical circuit, and then comparing to the label on each circuit. This will help inform further work on this in subsequent years, to determine how much uncertainty there is in what is measured on distribution board circuits.

4. COMPONENT C – BUILDING DYNAMICS

Component C – Building Dynamics was not commenced in 2009/10. It will commence in 2010/11, when focused case studies will be developed based on the Component A and B results from the 2009/10 year (see Figure 1).

5. COMPONENT D – FACILITATING IMPROVED RESOURCE MANAGEMENT

Component D – Facilitating Improved Resource Management was designed to allow the BEES data to be used and/or applied successfully. In 2009/10 this study reviewed attempts to influence resource use in non-residential buildings through a 'systematic review' (after the fashion of the Cochrane Collaboration). Component D also used data from existing sources to produce an analysis of energy and water consumption and expenditure in New Zealand's public education and public health sectors.

This component will include the systematic review of a set of attempts to influence resource use in the stock of non-residential buildings, and an analysis of resource consumption decision-making in high public cost non-residential buildings (education buildings and hospitals).

5.1 Systematic review

(Prepared by CRESA)

Systematic reviews are a method by which the results of different evaluations dealing with the efficacy of particular practices, techniques or programmes are compared. That comparison is used to assess the overall weight and direction of evidence arising out of the body of current research.

Systematic reviews provide: "an overview of primary studies which contains an explicit statement of objectives, materials and methods and has been conducted according to explicit and reproducible methodology." The relative strengths of traditional forms of reviewing research literature compared with the strengths of systematic reviews are concisely summarised by Petticrew (2001) in Table 22.

Traditional reviews, or narrative reviews, are not merely a matter of 'poor' review practice. They are a practice of review embedded in academia, the limitations of which are well recognised across disciplines. Petticrew's description of the narrative or traditional review is well accepted – see Davies (2000), Young et al, (2002) and Torgerson (2003) which all note the relationship between narrative review techniques, thesis writing, 'opinion' pieces and 'expert' reviews. Petticrew points out that systematic reviews require practitioners to actively engage with the substance of the literature in a way characterised by narrative reviews and promote the relevance of narrative or traditional reviews in the process of conceptual engagement with research problematics.

Table 22: Systematic reviews and traditional reviews compared

Comparison Parameter	Good Quality Systematic Reviews	Traditional Reviews
Deciding on review question	Start with clear question to be answered or hypothesis to be tested	May also start with clear question to be answered, but they more often involve general discussion of subject with no stated hypothesis
Searching for relevant studies	Strive to locate all relevant published and unpublished studies to limit impact of publication and other issues	Do not usually attempt to locate all relevant literature
Deciding which studies to include and exclude	Involve explicit description of what type of studies are to be included to limit selection bias on behalf of the reviewer	Usually do not describe why certain studies are included and others excluded
Assessing study quality	Examine in systematic manner methods used in primary studies, and investigate potential biases in those studies and sources of heterogeneity between study results	Often do not consider differences in study methods or study quality
Synthesising study results	Base their conclusions on those studies which are most methodologically sound	Often do not differentiate between methodologically sound and unsound studies

The interrogative method is based on implementing a standard process of research interrogation that involves six key specifications and steps:

- Review goal and scope
- Critical review questions
- Literature selection criteria
- Literature search method
- Data extraction instrumentation
- Analytic approach and reporting (Pawson et al, 2001a & b).

Such an approach was broadly used to develop the method for the systematic review of the research and evaluation related to the efficacy of interventions to optimise energy and/or water resource use in non-residential buildings.

The disadvantage of systematic reviews are that they still require a body of data which does two things. First, it must be clearly evaluative of practices, policies, programmes or interventions. Secondly, that data has to be research-based. It must have an experimental or other empirical foundation, it cannot be entirely theoretical modelling nor merely an untested opinion no matter how expert.

The method for a systematic review on the efficacy of energy optimisation policies, practices and programmes was developed with BEES. However, in applying the systematic review template to the body of literature reviewed in the BEES project (see Isaacs et al. 2009), it became clear that the research base was still very limited and continuing would add little materially to the work already undertaken by the United Nations Environment Programme's review of buildings and climate change (UNEP, 2007). For that reason, the focus of activity shifted to: distilling the best practices around optimising energy efficiency in the building stock; and comparing those practices with those that prevail in New Zealand.

5.2 International practice to optimise non-residential building efficiency

Table 23 below summarises the range of tools and policy instruments used in varying jurisdictions to optimise energy efficiency of non-residential buildings. These are categorised as: mandatory/regulator; economic/market-based; financial; and support, information and voluntary action instruments.

Table 23: Tools and policy instruments by type and examples of countries

Measure/Policy Instrument	Examples of Countries	Type of Measure
Appliance standards[5]	EU, US, Japan, Australia, Brazil, China, NZ	Mandatory/regulatory
Building codes[6]	Singapore, Philippines, Algeria, Egypt, US, UK, China, EU, NZ	Mandatory/regulatory
Procurement regulations[7]	US, EU, China, Mexico, South Korea, Japan	Mandatory/regulatory
Mandatory labelling and certification programmes[8]	US, Canada, Australia, Japan, Mexico, China, Costa Rica, EU, NZ	Mandatory/regulatory
Energy efficiency obligations and quotas[9]	UK, Belgium, France, Italy, Denmark, IE	Mandatory/regulatory
Utility demand-side management programmes[10]	US, Switzerland, Denmark, Netherlands, Germany, Austria	Mandatory/regulatory
Energy performance contracting[11]	Germany, Austria, France, Sweden, Finland, US, Japan, Hungary	Economic/market-based
Co-operative procurement[12]	Germany, Italy, UK, Sweden, Austria, Ireland, Japan, Poland, Slovakia, Switzerland	Economic/market-based
Energy efficiency certificate schemes[13]	Italy, France	Economic/market-based
Kyoto Protocol flexible mechanisms[14]	China, Thailand, Central and Eastern Europe	Economic/market-based
Taxation (on CO_2 or household fuels)[15]	Norway, Germany, UK, Netherlands, Denmark, Switzerland	Financial
Tax exemptions/reductions[16]	US, France, Netherlands, KO	Financial
Public benefit charges[17]	Belgium, Denmark, France, Netherlands, US	Financial
Capital subsidies, grants, subsidised loans[18]	Japan, Slovenia, Netherlands, Germany, Switzerland US, Hong Kong, UK, China, Russia, India, Indonesia, Iran, South Africa, Venezuela, Kazakhstan	Financial
Voluntary certification and labelling[19]	Germany, Switzerland, US, Thailand, Brazil, France, NZ	Support, information and voluntary action

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5 IEA (2005); Schlomann et al (2001); Gillingham et al (2004); ECS (2002); World Energy Council (2004); Australian Greenhouse Office (2005); IEA (2003a); Fridley and Lin (2004) cited in Levine et al (2007) – see reference list at the end of this report.

6 World Energy Council (2001); Lee and Yik (2004); Schaefer et al (2000); Joosen et al (2004); Geller et al (2006); ECCP (2001) cited in Levine et al (2007).

7 Borg et al (2003); Harris et al (2005); Van Wie McGrory et al (2006) cited in Levine et al (2007).

8 World Energy Council (2001); OPET Network (2004); Holt and Harrington (2003) cited in Levine et al (2007).

9 UK Government (2006); Sorell (2003); Lees (2006); Collys (2005); Bertoldi and Rezessy (2006); Defra (2006) cited in Levine et al (2007).

10 IEA (2005); Kushler et al (2004) cited in Levine et al (2007).

11 ECCP (2003); OPET Network (2004); Singer (2002); IEA (2003a); World Energy Council (2004); Goldman et al (2005) cited in Levine et al (2007).

12 Oak Ridge National Laboratory (2001); Le Fur (2002); Borg et al (2003) cited in Levine et al (2007)

13 OPET Network (2004); Bertoldi and Rezessy (2006); Lees (2006); Defra (2006) cited in Levine et al (2007).

14 ECS (2005); Novikova et al (2006) cited in Levine et al (2007).

15 World Energy Council (2001); Kohlhaas (2005) cited in Levine et al (2007).

16 Quinlan et al (2001); Geller and Attali (2005) cited in Levine et al (2007).

17 Western Regional Air Partnership (2000); Kushler et al (2004) cited in Levine et al (2007).

18 ECS (2001); Martin et al (1998); Schaefer et al (2000); Geller et al (2006); Berry and Schweitzer (2003); Joosen et al (2004); Shorrock (2001) cited in Levine et al (2007).

Measure/Policy Instrument	Examples of Countries	Type of Measure
Voluntary and negotiated agreements[20]	Mainly Western Europe, Japan, US, NZ	Support, information and voluntary action
Public leadership programmes[21]	Mexico, Philippines, Argentina, Brazil, Ecuador, NZ	Support, information and voluntary action
Awareness raising, education/ information campaigns[22]	Denmark, US, UK, Canada, Brazil, Japan, NZ	Support, information and voluntary action
Mandatory audit and energy management requirement[23]	United Sates, France, NZ, Egypt, Australia, Czech Republic,	Support, information and voluntary action
Detailed billing and disclosure programmes[24]	Ontario, Italy, Sweden, Finland, Japan, Norway, California	Support, information & Voluntary action

An evaluation carried out by Levine et al (2007) of a wide range of instruments showed that they can achieve significant energy and as well as CO_2 emission savings, although cost-effectiveness differed considerably:

- Appliance standards, building codes, labelling and tax exemptions achieved the highest reductions
- Appliance standards, energy efficiency obligations, demand-side management programmes, public benefit charges and mandatory labelling were among the most cost-effective (they all achieved significant energy savings at negative costs)
- Investment subsidies were the least cost-effective
- Tax reductions for investments in energy efficiency were more effective than taxation
- Labelling and voluntary programmes can lead to large savings at low-costs if they are combined with other policy instruments
- Information programmes can achieve significant savings and are a useful addition to most policy measures
- Economic instruments, information programmes and regulation effectiveness can be substantially improved if appropriately combined into policy packages that take advantage of synergistic effects (Ott et al (2005) cited in Levine et al (2007) e.g. co-ordination of energy audit programmes with economic instruments.

The Energy Service Company (ESCO) industry can grow when public procurement legislation accommodates Energy Performance Contracts (EPCs) and focuses on energy-efficiency or renewable energy provisions, or in the presence of an energy-saving obligation.

Despite the demonstrated effectiveness of these instruments, the energy consumption in buildings is still increasing in most developed countries, given growing demand for amenities and increased comfort (IEA (2004f) cited in Levine et al (2007)) and despite the increased efficiency of major energy-consuming appliances.

Factors identified as limiting the effectiveness of policy instruments include: slow implementation processes; no regular updating of building codes; and insufficient enforcement and barriers within the building sector (e.g. lack of integrative design and practice). The implementation of a diversity of policy instruments is needed, in tandem

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[19] OPET Network (2004); Word Energy Council (2001); Geller et al (2006); Egan et al (2000); Webber et al (2003) cited in Levine et al (2007).

[20] Geller et al (2006); Cottrell (2004) cited in Levine et al (2007).

[21] Borg et al (2003); Harris et al (2005); Van Wie McGrory et al (2006); OPET (2004) cited in Levine et al 2007.

[22] Bender et al (2004); Dias et al (2004); Darby (2006); Ireland A (2005); Lutzenhiser (1993); Ueno et al (2006); Energy Saving Trust (2005) cited in Levine et al (2007).

[23] World Energy Council (2001) cited in Levine et al (2007).

[24] Crossley et al (2000); Darby (2000); Roberts and Baker (2003); Energywatch (2005) cited in Levine et al (2007).

with programmes that increase consumer access to information, awareness and knowledge (although there is only medium evidence of the need).

Effective application of the wide range of measures available is likely to require an integrated, multi-stakeholder approach. The United Nations Environment Programme (UNEP, 2007) has identified the stakeholders and their roles and actions that they believe necessary to implement such an approach. The stakeholders are: government; investors; developers; owners; commercial tenants; research and education; designers; facility managers; real estate brokers; operations and maintenance; manufacturers and suppliers; builders; users/occupants; professional associations; regulators; the media; and the public as shown in Table 24.

Table 24: Stakeholders by roles and responsibilities

Stakeholder	Role	Actions
Government	Policies and regulations	Establish policies; enabling mechanisms; financial dis/incentives; lead by example as client
Investors	Source of capital	Reduce risk by specifying high performance; lead by example as client
Developers	Project initiation and management	Increase level of innovation; responsibility and environmental consciousness
Owners	Asset management	Life-cycle thinking
Commercial tenants	Management of firms	Demand sustainable building for rental space as policy
Research and education	Knowledge generation and dissemination	Knowledge generation and dissemination
Designers	Creating potential performance	Improve knowledge of new methods and technologies; educate clients; adopt and promote sustainability principles
Facility managers	Operations and maintenance	Operate building in an environmentally-conscious way; monitor performance and share
Real estate brokers	Influence the market	Improve level of knowledge; then advocate high performance
Manufacturers and suppliers	Provide products and services	Life-cycle view; aware of systems integration; broaden networks
Builders	Construct the building	Respect environmental factors while following client requirements; educate and add value
Users/ occupants	Use the building	Ask for manual; respect sustainable operation needs; participate
Professional associations	Influence work of individual members of firms	Ensure that members improve knowledge and skill; adopt, enable and promote sustainability principles in their field; promote cross-disciplinary action
Regulators	Risk management	Receptive to new approaches that support sustainability
The media	Agitate or enthuse	Demand sustainable building
The public	Agitate or enthuse	Demand sustainable building

Source: UNEP (2005) cited in UNEP (2007).

5.1.4 New Zealand policy and operational instruments

The measures adopted internationally include: a mix of regulatory requirements, which set the legislative context; financial mechanisms; non-regulatory measures such accreditation, training and information provision; and voluntary action. There is no strategic plan in New Zealand for achieving energy efficiencies in office buildings despite their considerable consumption of energy. As a whole the commercial sector in New Zealand (which also includes retail, banking, hotels and motels and hospital) uses around one-third of total electricity consumption. Measures to promote or facilitate energy efficiency tend to be non-regulatory, ad hoc and lacking in co-ordination.

Identified barriers to the establishment and implementation of energy efficiency measures in office buildings include:

- A lack of strategic direction, with little co-ordination between agencies responsible for implementing different measures
- A general government focus on deregulation and reduction in compliance costs, in tandem with a general perception that New Zealanders are resistant to regulation
- A general government retreat from the concept of sustainability, including in legislation such as the Building Act 2004
- That there is no explicit market value given to the energy performance of buildings
- A lack of technical knowledge about energy efficiency amongst building design and construction professionals. While most architects will have completed an energy efficiency module as part of their training, it is unlikely to have been presented or perceived as a priority. Other professions (e.g. builders etc) may not have been given any technical training
- Lack of building commissioning in New Zealand (and therefore a lack of focus on energy efficiency)
- Poor compliance with the NZBC, given lack of knowledge of parts of it by builders, consent officers and building inspectors
- Business drivers that are unlikely to include energy efficiency
- A lack of energy price signals to encourage consumers to take cost-effective measures, especially at times of peak demand
- An absence of appropriate incentives (e.g. for architects, builders and landlords) to adopt energy efficiency measures
- Lack of access to capital for energy efficiency investments
- Inconsistent incentives for utility providers. On the one hand, they are encouraged to promote energy savings and efficiencies. However, they are also required to return dividends to shareholders (e.g. through increased sales).

Despite a number of factors undermining any co-ordinated or strategic approach to improving energy efficiency in new and existing office buildings in New Zealand, there are a range of measures currently in place. These include some aspects of the Building Act 2004 and the NZBC that address sustainability in general, building construction, building management, and efficiencies in equipment and appliances. These are listed in Table 25.

In addition there are a number of government agencies with functions that relate to energy efficiency. These agencies include: the Energy Efficiency and Conservation Authority (EECA), the Electricity Commission (EC), the Ministry of Economic Development (MED), the Ministry for the Environment (MfE) and the Department of Building and Housing (DBH). It is the Government's intention that EECA be the primary service delivery agency for energy efficiency programmes

The general roles and responsibilities of these agencies are outlined below:

- The **Energy Efficiency and Conservation Authority (EECA)** has been established to help people in the commercial and domestic sectors to become more energy efficient, including using more renewable energy. Its goal is to maximise cost-effective energy savings and the co-benefits for all New Zealanders, and stimulate the uptake of both large and small-scale renewable energy by assessing the potential for cost-effective energy savings and emissions reductions. It provides: information and advice, business support, funding and incentives, setting and monitoring of standards and ratings, and research and monitoring. Its work also contributes to a secure energy system for New Zealand.

- The **Electricity Commission (EC)** is a Crown entity set up under the Electricity Act 1992 to oversee New Zealand's electricity industry and markets. It is funded through the electricity levy. It regulates the operation of the electricity industry and markets to ensure electricity is produced and delivered to all consumers in an efficient, fair, reliable and environmentally sustainable manner. It also promotes and facilitates the efficient use of electricity. The Commission carries out research and information activities as well as providing programmes to promote energy efficiencies. The Commission's focus on end-use has the potential to create energy efficiencies in office buildings through: providing financial incentives for investment in electricity efficiency; seeking innovative ways to enable consumers to respond to pricing incentives to use electricity more efficiently; facilitating the introduction of advanced/smarter meters; encouraging and facilitating demand-side participation in retail markets; and promoting the efficient use of load management.

  Both the EECA and the Electricity Commission have a common objective: to promote the use of electricity in an efficient and environmentally sustainable manner. Their activities are based on the premise that electricity efficiency and demand side management help reduce demand for electricity. Pressure on prices, scarce resources and the environment is therefore reduced. From October 2010, the energy efficiency functions of the Electricity Commission will be transferred to the EECA.

- The **Department of Building and Housing (DBH)** has responsibility for implementing the Building Act 2004, which applies to the construction of new buildings as well as the alteration and demolition of existing buildings. The 2004 Act has repealed the Building Act 1991 and introduces a number of changes to the law governing building work, some of which relate to climate change and energy efficiencies. In particular, as outlined in Table 25, changes have been made to the NZBC relating to achieving efficiencies in heating and cooling systems and lighting. The Department is responsible to the Minister of Building as well as the Minister of Housing.

- The **Ministry of Economic Development (MED)** works directly for the Minister of Energy and Resources, with a focus on improving the quality and reliability of key infrastructural services. MED's Energy and Communications branch leads the Ministry's strategic priority of improving the quality and reliability of key infrastructural services, including energy.

- The **Ministry for the Environment (MfE)** is the Government's principal adviser on the New Zealand environment and on international matters that affect the environment through: environmental management systems (i.e. laws, regulations and national environmental standards); national policy direction; guidance and training on best practice; and information. It has specific functions under the Resource Management Act 1991, the Hazardous Substances and New Organisms Act 1996, the Ozone Protection Act 1996 and the Climate Change Response Act 2002 that could relate to commercial buildings.

Focus and actions in place in New Zealand, as summarised in Table 25, are broadly those policies and actions that can be categorised as sustainable development related, building construction, building management, and efficiencies in equipment and appliances.

Sustainability: Some principles of sustainable development are included in Section 3 of the Building Act 2004. One of the four purposes of the Act is to ensure that "buildings are designed, constructed, and able to be used in ways that promote sustainable development" (p.25). The Act also lists 16 principles to guide its interpretation and implementation. Four relate to energy efficiency and/or reduction in CO_2 emissions during and post-construction. These four principles note the need to facilitate or promote: efficient use of energy, energy conservation and renewable sources of energy; efficient and sustainable use of materials in construction; the efficient use of water and water conservation; and a reduction in the generation of waste during construction. These principles contained in the Building Act 2004, coupled with some specifics of the NZBC and other abatement measures (see Table 25 for details), largely align with the principles of energy efficiency outlined in Levine et al (2007). However, most of the measures focus on increasing the efficiency of appliances, heating and cooling equipment and ventilation and, to a lesser extent, the development of some aspects of quality control processes, mainly with respect to building operation. There are few measures that encourage or facilitate the utilisation of active solar energy and other environmental heat sources and sinks, seek to change the behaviour of occupants and owners, or encourage integrated design processes.

Building construction: Measures include requirements related to: the thermal envelope in new buildings and retrofits (e.g. in some instances, improvement of building windows) to reduce heating and cooling energy use; encouragement to reduce embodied energy through use of wood products and reduce operating energy through the use of wood products (for heating); improving the performance of heat pumps; increasing inclusion of performance-based regulations in the NZBC (e.g. for HVAC systems); certification and labelling systems; and education, training and audit programmes for businesses and local and central government organisations. See Table 25 below.

Building management: Measures include approaches and technologies for ongoing control of a building's energy consumption pattern. New Zealand examples include: some encouragement of passive solar and other space heating systems, especially in local and central government organisations; energy efficiencies in HVAC systems through the application of energy-efficient HVAC design principles; and reducing the cooling and heating load, to some extent, through the choice of building materials. It seems that there are few measures to address building shape and orientation and other design factors that reflect climate conditions. Details of specific measures are summarised in Table 25 below.

Equipment and appliance energy efficiency: These measures are the most commonly implemented. Measures to improve the energy efficiency of equipment and appliances installed or used in office buildings include: voluntary and regulatory/mandatory standards and labelling; financial incentives; research and development programmes; and information tools. See Table 25 below.

Table 25 was initially based on a table in the Ministry for the Environment's 2009 document*: New Zealand's Fifth National Communication Under the United Nations Framework Convention on Climate Change*. It includes only those measures and parts of measures that relate to commercial buildings, in particular office buildings. It also includes details and amendments supplied by the DBH, the EECA, the Electricity Commission and the MED.

Note Table 25 spreads over four pages.

Table 25: New Zealand policies and actions for energy efficiency in office buildings

Principles of Energy Efficiency	Measure	Objective	GHG focus	Type of instrument	Implementing Entity(ies)
Measures in place					
Increase efficiency of appliances /equipment	Efficient Products Programme (See also Product labelling and Minimum Energy Performance standards)	Allows New Zealand and Australia to align energy efficiency standards and labelling, and develop joint energy efficiency measures for products where appropriate.	CO_2	Mandatory/ Regulatory, voluntary, information	EECA
	Efficient Lighting Strategy[25]	Provides subsidies and information for efficient lighting products.	CO_2	Fiscal, information	EC
	Product labelling – aligned with Australia	Requires manufacturers and suppliers of whiteware appliances and heat pumps to provide energy efficiency information to consumers at point of sale, through displaying a product's average annual electricity use, and a comparative star rating (to show its efficiency relative to similar models).	CO_2	Mandatory/ Regulatory	EECA
	ENERGY STAR® international programme	An endorsement mark to promote high efficiency products (typically the top quartile of models on the market). ENERGY STAR partners (manufacturers, suppliers, retailers) can use the mark to promote products that meet ENERGY STAR specifications. Products under ENERGY STAR in NZ include (but are not limited to): computers, monitors/ displays, heat pumps, fridges, imaging equipment (e.g. copiers), televisions and compact fluorescent lamps.	CO_2	Voluntary	EECA
	Minimum energy performance standards (MEPS)- aligned with Australia	Aims to increase the average efficiency of products entering the market - leading to increased productivity growth and lower energy costs. Products are tested and registered as meeting a minimum standard for energy efficiency before they can be sold. MEPS coverage includes (but is not limited to): air conditioners/heat pumps, distribution transformers, fluorescent lamps and ballasts, and three-phase electric motors	CO_2	Mandatory/ Regulatory	EECA

25 For more details see New Zealand Efficient Lighting Strategy 2008-2010: http://www.electricitycommission.govt.nz/pdfs/advisorygroups/pjtteam/LESG/ELS.pdf; http://www.electricitycommission.govt.nz/opdev/elec-efficiency/programmes/lighting/current/index.html and www.rightlight.govt.nz

Principles of Energy Efficiency	Measure	Objective	GHG focus	Type of instrument	Implementing Entity(ies)
Implement quality control in construction, operation and maintenance of building	Green Star NZ	This is an industry-led environmental rating scheme (coupled with training modules) that evaluates the attributes and performance of new and refurbished buildings, looking at design, construction and operation.		Voluntary Information and training	New Zealand Green Building Council
	Waste Minimisation Act 2008	Aims to reduce damage to the environment from waste generation and disposal by encouraging more efficient use of materials. It will also contribute to reducing GHG emissions from the waste sector.	CH_4	Mandatory/ Regulatory	MfE
	Financial assistance to commercial sector	Aims to improve business's electricity efficiency through part-funding efficiency projects such as upgrades of building management systems, lighting replacements, replacement of inefficient chiller systems, and installation of monitoring and targeting systems.	CO_2	Fiscal, information	EC
	Advice to businesses[26]	Identifies energy management opportunities; assists in development of energy management action plans; and encourages new or under-used technologies that make processes more efficient. For instance energy audits to assess energy use, identify energy and cost-saving opportunities and highlight potential improvements in energy use. Design audits. Grants to fund energy specialists for new building design teams.	CO_2	Information	EECA
Adopt integrated design systems	Increasing the use of wood as a construction material	A range of initiatives designed to increase the use of wood as a construction material, such as: funding full life-cycle analysis research, professorship positions, and funding demonstration buildings.	CO_2	Research, information, education	Ministry of Agriculture and Forestry

[26] For more information see: http://www.eecabusiness.govt.nz/services-and-funding/audit-grants

Principles of Energy Efficiency	Measure	Objective	GHG focus	Type of instrument	Implementing Entity(ies)
Reduce heating, cooling, ventilation and lighting loads	New[27] Clause H1.3.6 in the NZBC set out in *Schedule 1* of the Building Regulations 1992[28]	Amendment aims to facilitate efficient use of energy by requiring HVAC systems to be located, constructed, and installed to: limit energy use, consistent with the intended use of space; and enable them to be maintained to ensure their use of energy remains limited, consistent with the intended use of space.		Mandatory/ Regulatory	DBH
	Revised Acceptable Solution for the NZBC Clause H1.3.5	Improve the energy efficiency of new lighting installations in large non-residential buildings.		Regulatory	DBH
Reduce heating, cooling and lighting loads Implement quality control in construction, operation and maintenance of building	Business programmes	Provides information on new technologies and energy management, grants for energy audits and demonstrations of new technology, and one-on-one support for energy-intensive businesses. Grant funding is available for new or under-utilised technology improvements.	CO_2	Voluntary, information, fiscal	EECA
Utilise active solar energy Implement quality control in construction, operation and maintenance of building	Crown Energy Efficiency Loans Scheme	This scheme supports central and local government to implement energy efficiency initiatives and renewable energy projects within their own operations such as energy audits of designs, funding for more insulation, high-efficiency lighting and a low-loss ducting system for ventilation, heating and air-conditioning.	CO_2	Fiscal, information, education	EECA
Minimize halocarbon and other emissions	New Zealand Emissions Trading Scheme	The scheme will cover all sectors and all gases, and will reduce emissions by making emitters pay for any emissions covered under the Kyoto Protocol.	CO_2 CH_4 N_2O HFCs \PFCs SF_6	Economic, Mandatory/ Regulatory	MED, Ministry of Agriculture and Forestry, and MfE

[27] For more information see: http://www.dbh.govt.nz/energy-efficiency.

[28] The Building Code is in the first schedule of the Building Regulations 1992, which were made under the Building Act 1991. They are now treated as if they were regulations made under the Building Act. 2004 (most of the 1992 Regulations were revoked in 2005 by the Building (Forms) Regulations 2004).

Principles of Energy Efficiency	Measure	Objective	GHG focus	Type of instrument	Implementing Entity(ies)
	Winter Supply Shortage Campaign	This campaign set a 15% electricity savings target for the government sector to provide leadership in electricity savings (the public was asked to achieve savings of 10%).	CO_2	Information	Government sector, electricity industry's Grid Security Committee and Winter Power Group
	47-agency Govt programme[29]	To provide the government sector with the opportunity to show leadership in implementing energy efficiency measures in buildings through loans to government departments, district health boards, Crown owned companies, territorial authorities, regional councils, universities, polytechnics and public and integrated schools**.**	CO_2	Information and role modelling	Government sector
	Energy end-use data study for commercial buildings[30]	Part-fund the six-year Building Energy End-Use Study (BEES) that aims to: – quantify and characterise the energy use in NZ non-residential buildings; – help identify efficiency potential for business and government; – enable improved policy development and implementation, including the NZES and the NZEECS.		Information	BRANZ
Measures to be implemented					
	Increase professional energy management services	Accreditation scheme for auditors and training for energy management specialists.		Training/ information	EC
	Building performance rating scheme for new and existing commercial buildings	Possible introduction of a building energy rating tool for new and existing commercial buildings, coupled with information to facilitate the most cost-effective solution (based on recent MED study).		Information	DBH
	Electricity efficiency training programmes for commercial buildings	Development of a range of training programmes designed to improve capability and skills in efficient technologies and their application for commercial buildings.			EC

29 For more information see http://www.eecabusiness.govt.nz/services

30 For more information see http://www.branz.co.nz/current_research#BEES

5.3 Energy and water use and expenditure in education and health

(Prepared by CBPR)

This task utilised data held by third parties e.g. Ministry of Education, Ministry of Health, District Health Boards, EECA etc to produce an analysis of resource consumption in education buildings and hospitals. It did not attempt to collect data from individual educational or health facilities.

The task explored and commented on the literature on energy and water use in New Zealand hospitals and education buildings. Where possible, it gathered 'collected' data (preferably at a national level), and discussed the outcomes from analyses and the issues with using this data.

The following were commonly noted issues in the literature review, data collection and analysis stages:

- There is a lack of data collection and collation at a national level of the energy use in all the building uses considered in this report, except for universities:
  - Early childhood buildings
  - Private (independent) schools
  - Higher education buildings (except universities)
  - Hospitals.

  In some cases this data is available at a regional level.
- There is a national database of primary and secondary schools expenditure on Light, Heat and Water (LHW) maintained by the Ministry of Education for financial reporting reasons. Although the database is now updated annually, reporting variables have changed e.g. the use of student numbers and floor areas. The national database still does not permit analysis by expenditure on energy separately to water, and it still does not provide the necessary information to support analysis of energy use, which in turn could support improved energy efficiency.
- There is variability and inconsistency in how data is reported by different sources and for different buildings. The result is that apparently useful data from energy audits and other sources cannot be used for the purposes of comparison or planning.
- Further, with the exception of the Ministry of Education data for schools and the Tertiary Education Facilities Management (TEFMA) data for universities,[31] most data was collected intermittently and not consistently over a period of time.
- With the exception of four universities, no information is available on water consumption. While the Ministry of Education data for schools includes expenditure relating to water use, as discussed above, no accurate figures for just water consumption could be gained.

Overall, these points suggest, as other researchers have noted before, that the way both energy and water use is managed and reported needs to be improved. For example, Donn and Bruhns (1984) noted back then that the difficulty in obtaining energy consumption data is evidence that proper energy management practices are not in place in many schools and hospitals. This would still be a valid conclusion. This applies not only to schools but also to early childhood buildings, hospitals, and some higher education buildings.

[31] Tertiary Education Facilities Management (TEFMA). See www.tefma.com

The findings from this research in water and energy use in education and hospital buildings led to the following recommendations. Given the commonality of these issues across the different building types, these are intended for both education and hospital buildings.

A common thread to the recommendations is the long established, but yet to be implemented, need for a coherent data capture system. Given the necessary support from all the involved agencies, this could lead to the development and implementation of an energy and water performance framework.

The combination of data and framework will make it possible to optimise the overall performance in these largely government-funded sectors.

Without data and framework the ever-increasing energy and water costs seen over the past decades will continue.

5.3.1 Recommendations

1. There is a need for serious energy and water use data collection at a national level. As Bruhns and Baird recommended in 1986, “the long term benefits of the development of ongoing databases are even more important to the nation.”

   This national database could be based on the current financial database managed by the Ministry of Education, the system administered by TEFMA, an existing commercial database such as ‘eBench’ or a specific database developed by EECA or some other appropriate agency. The benefits of having such a database are that individual hospitals or education buildings can gauge how they are performing relative to similar others or a national benchmark. Without measurement there can only be limited management and the opportunity to reduce energy and water consumption.

2. For this to be successful, however, education and hospital-based organisations need to be encouraged to regularly collect and submit data to such a database. The importance of having an overall organisation or body to regularly remind, collect, update and report on the information is illustrated through the absence of the databases that were initiated in the 1980s (e.g. Bruhns and Baird (1986) for hospitals and other commercial buildings, and Isaacs and Donn (1987) for schools). This may be suited to an organisation such as EMANZ for example. Confidentiality issues with having such a database will also need to be addressed.

3. As highlighted from the difficulty the ETS study (2003; 2004b) and Donn and Bruhns (1984) had in establishing a formula to estimate schools’ energy use, it is important that actual monitored data from each individual building is provided to such a database as opposed to estimations from utility bills. That is, the reality is that “the subtle combination of people, site and building system makes each school unique and not amenable to statistics which seek to identify general patterns or influences” (Donn and Bruhns, 1984). A further breakdown of this energy and water consumption in terms of monthly consumption, fuel-type and end-uses would also be beneficial.

4. Some consistency and commonality in how these energy and water consumption figures are reported is needed so that consumption figures from different sources and buildings are comparable to each other. This could suggest that a recognised standard or system for reporting data is needed.

5. As Isaacs and Donn (1987) point out, each organisation (such as an individual school) needs to have a person assigned to the responsibility of energy management, possibly included in the tasks of the overall facilities manager. The benefit of having such a facilities manager is evidenced through the quality and extent of data that many hospitals and tertiary institutions can, and do, provide.

6. To achieve these recommendations, barriers need to be reduced and incentives provided for building/facilities managers to undertake this extra reporting work and for their authorities to allow them to do this. As Donn and Bruhns recommended in 1984, incentives and the incorporation of energy management with other functions of the organisation are important aspects to consider when developing an energy management plan.

This study has provided an improved understanding of the current situation surrounding the measurement and use of energy and water in education buildings and hospitals. It has illustrated as others before have concluded – for example Donn and Bruhns (1984); Bruhns and Baird (1988); Cory (2009); ETS (2004 a, b, c); Heap (2009); Isaacs and Donn (1987) – that there is insufficient data collection, reporting systems and management systems of the energy and especially water use in New Zealand education buildings and hospitals. What data is reported is inconsistent between sources in terms of the quality and the details what is collected and reported.

To conclude, the key point to take from this report is that there is a lack of standardised collection, reporting formats and management systems. This was found to arise across all sections of the report and was a common issue regardless of the type of building (with the only exception being universities) and whether it was energy or water consumption being measured. As a result the current data on energy and water consumption in the majority of education buildings and hospitals is disparate. There is a need therefore for a standardised data collection structure to be established, and support provided for the additional work that this would require, if an improved understanding of the use of energy and water in education and health buildings is to be gained.

These systems cannot be created by an ad hoc research project, even though such a project could collect, analyse and report on data. The history of energy management in the health and education sectors has been long on research projects and their recommendations, but short on their implementation. Will these sectors be looking back in 30 years times still wishing that they had the essential data and systems to permit them to efficiently and effectively use energy and water, or will they continue to be simply faced with ever-increasing costs?

6. COMPONENT E – MODELLING & FORECASTING

Component E – Modelling involved two sub-projects.

Firstly (Sections 6.1 and 6.2), BEES data was used to create thermal simulation models of the buildings documented in Components A, B and C. These models will use the computer programmes Google Earth, SketchUp, OpenDesign, Radiance, su2rad and EnergyPlus. The work explored the generation of building models in a standardised and quasi-automated manner. The goal of the work is to both improve the empirical basis of the models themselves, thus improving their accuracy at the individual building level, and (unlike EERA) generate scenarios that show the distribution of responses to a change (e.g. a single change in NZBC H1 might improve thermal performance of one part of the non-residential stock but decrease performance in another).

Secondly (Section 6.3), the BEES data was used to develop and update EERA (Energy Efficiency Resource Assessment), which is a computer-based tool for modelling scenarios of aggregate energy demand e.g. in response to changes in the numbers or types of non-residential buildings or changes in the NZBC Clause H1[32].

6.1 Simple building performance models

(Prepared by CBPR, VUW)

The original intention of this task was to model 50 BEES buildings within EnergyPlus from the Google Earth data within the BEES survey. When it came to implementing this plan, it was determined that to make an individual model of each building would be time-consuming and would not serve the long-term BEES goals. Instead, a set of modelling templates for constructing any non-residential building from the Google Earth base were developed.

This set of template files would include not just the building materials, but also the relevant occupancy schedules of energy loads such as lighting and equipment, and the temperature set-points, and in a radical departure from normal practice also a set of building geometry templates.

There were two starting points for the construction of these generic templates. The first was the 15 US Department of Energy benchmark buildings which represent most of the US commercial building stock (Torcellini et al, 2008). These models have been published and can be used for public use. They are published as EnergyPlus benchmark models. They were used to produce concept template files of New Zealand built forms, constructions, internal gains and building schedules. The second starting point was the paper 'A Classification of Built Forms' (Steadman et al, 2000) from which consistent detailing of the built form and the building geometry was developed.

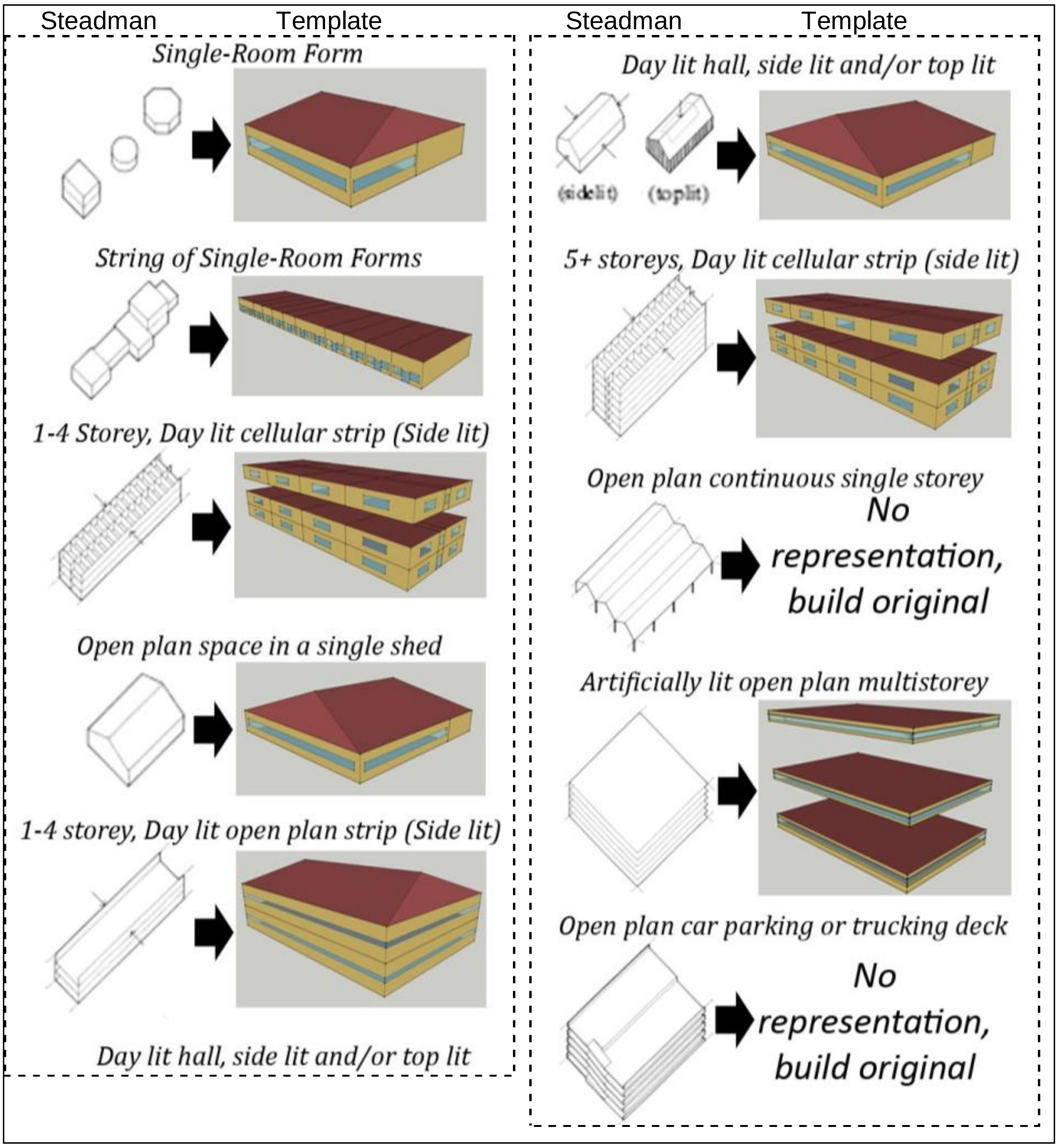
The goal was to have a standardised set of templates with simple standardised dimensions, and within the SketchUp Computer Aided Design (CAD) interface, to scale these dimensions to those found from Google Earth for the BEES buildings to be studied. This straightforward approach, if it worked, would scale to many hundreds of files which the one-by-one modelling could not.

The goal was also to prepare a set of standard EnergyPlus templates comprising New Zealand relevant construction materials; the material thermal properties data from *NZS 4214 – Methods of determining the total thermal resistance of parts of buildings* (SNZ,

[32] See http://www.crl.co.nz/climate_change/energyEfficiency.asp

2002) or '*CIBSE Guide A'* (CIBSE, 1999) . The construction layers were determined from common building constructions (Spence, 1998).

Figure 25: Steadman forms and Template files



A set of standard geometry templates was built from the US Department of Energy benchmark files and the 'Steadman forms'. Figure 25 displays the built forms and the corresponding benchmark buildings.

These templates were then evaluated within EnergyPlus; the major issue to be overcome for this approach was to establish a means of scaling the HVAC systems as the building geometry was scaled. A system of template file creation was developed where the buildings when scaled were found to perform in a credible manner.

6.2 BEES modelling – complex models

(Prepared by CBPR, VUW)

This research task developed and created the following models:

1. Five energy end-use and daylight availability computer simulation models based on datasets of specific premises within relatively well-documented buildings
2. Three energy end-use and daylight availability computer simulation models based on datasets of detailed building performance information.

The research component of this activity was to determine a process of model construction which would reduce the potential for error. Constructing each new thermal model from scratch with only the building geometry and building specification as input is a recipe for modelling disaster, as there is too great a potential for error in the data input as the many hundreds (if not thousands) of data-points are entered to create a full description of the building.

The approach adopted was to test the construction of the complex models using as a starting point the template file developed for the modelling of the simple buildings based upon the Google Earth data.

What was accomplished was:

- Eight EnergyPlus thermal simulation input files were constructed and the thermal simulations were run. These input files were based upon the separately developed template files, and the exercise of building the thermal simulations within SketchUp as developments of these templates was successful – standardisation of starting point did not compromise the model-making process
- The resulting files all ran successfully with the standard NIWA weather data for their location.

From this, a set of questions for future work was derived:

- Based on the results from the BEES monitored data, what are the HVAC system defaults and options that should be developed as part of these templates? At present the heating and cooling and ventilation system defaults for these templates are based upon the US 'Best practice' data incorporated into the US Department of Energy benchmarks
- What are the impacts upon performance prediction of selection of the actual weather data for a performance time period compared to the standardised weather data normally used for design purposes? Standard weather data is commonly used to permit comparison between different model variations, and to provide a standardised basis for compliance with mandatory or voluntary codes.
- If a simple, standardised method of model construction is adopted, as here, what is the relationship between predicted and actual energy use?
- What measures of building performance are relevant to the various building energy end-use measures being undertaken within BEES? We anticipate we will have detailed energy use for a maximum of 2-3 months and annual data at a much less detailed – disaggregated – level. What we need to evaluate with the eight models thus far constructed is whether breakdowns into Lighting, Heating, Cooling, Ventilation and Other are sufficient; and whether data on a monthly, hourly, daily or annual level is at all useful for the understanding of how these buildings are currently operating

- How to build from the modular, template-based starting point for these and for the simpler models to a point where standard building design changes can be applied in a standardised form to all models to test the impact of different building design or operational interventions. This last option may take two years to develop to its fullest extent. If it focuses on using design changes to understand which of the observed building design features are significantly affecting the current operation, it stays within the general purview of the BEES project.

6.3 Trial modelling of non-residential end-use energy demand

(Prepared by CRL Energy, Dr Pieter Rossouw)

This activity developed scenario-specific forecasts of resource efficiency, using data from Component A in the EERA model. A selected energy efficiency policy was trialled against a "business-as-usual" (BAU) scenario.

6.3.1 Modelling business-as-usual energy demand with EERA

This section is a summary of the EERA modelling methodology described in the previous CRL Report (Rossouw, 2008). Bottom-up scenario modelling of the end-use energy demand of non-residential buildings is useful for policy, planning and market analysis purposes. Such models provide information on the:

- Contributions of individual building types and end-use equipment to the energy demand, supply energy requirements and resulting GHG emissions
- Energy-use patterns
- Impact of energy efficiency actions.

A comprehensive and realistic bottom-up BAU base case scenario is essential for these models since the methodology for investigating the effects of energy efficiency actions consists of:

- Establishing an end-use energy reference scenario (base case) e.g. BAU, frozen efficiency or other type
- Creating an enhanced efficiency case by implementing energy efficiency actions on the base case
- Estimating the effect of the energy efficiency actions as the difference between the enhanced efficiency case and the base case.

The BAU scenario is defined as the situation which results from a BAU economic and energy efficiency development, *excluding* the effects of the actions described in energy efficiency scenarios.

Table 26 sets out the defined terms used in the development and application of the EERA model.

Table 26: EERA defined terms

ANZSIC	**Australian and New Zealand Standard Industry Classification**
Bottom-up models	Bottom-up models are focused on the physical or geographical details of the entity being modelled
Gross energy demand	Total energy demand delivered to a unit of equipment
Net energy demand	Total energy demand delivered to a unit of equipment minus the energy required to produce useful work
Scenario model	Model capable of building and investigating a number of scenarios to show how the future may unfold under a set of given assumptions
Stock model	Energy model where the energy demand is estimated from the energy consumption of a stock of equipment, each unit of equipment with a given energy intensity
Top-down models	Top-down models represent the overall energy-economic system
Vintage stock model	Stock model where the new annual stock retires at a rate determined by the lifetime of the equipment

Projection of the energy demand of end-use equipment is necessary for scenario modelling, and requires the use of appropriate drivers and methods of incorporating the drivers in the estimation of future energy use. The drivers involved in non-residential building end-use energy projections are:

- Building floor area as a measure of the energy use. This is a good measure for lighting, office equipment, and space heating, ventilation and air-conditioning (HVAC), and similar area-related activities
- Market forces that influence the stock of equipment
- Technological development in the form of changes to the specific energy consumption of equipment.

These drivers are incorporated into EERA, which uses the following expression for the net energy demand (NED) of a stock of equipment belonging to a given region, sub-sector, end-use, equipment and energy type:

$$NED = (RSA \times ED \times EI) / TE$$

Equation 1

Where:

RSA = Regional sub-sector activity i.e. a quantity measuring the economic activity in the region and sub-sector

ED = Equipment density i.e. the number of equipment of a given type and end-use per unit activity

EI = Energy intensity i.e. the gross energy consumption per equipment of a given type

TE = Thermal efficiency of the specified equipment in converting gross to net energy.

From Equation 1, the information required to calculate energy demand in non-residential buildings includes:

- Region and sub-sector, required since the space heating and cooling of a building are influenced by a building's geography

- Building type, thermal properties and time-series floor area. The building type and thermal properties are used to estimate space heating demand in varying climate regions
- Time-series equipment densities, energy intensities and thermal efficiencies of the energy-using equipment for each region, sub-sector and end-use. The equipment needs to be specified in sufficient detail to allow the modelling of energy efficiency actions at the single equipment unit level.

6.3.2 Overview of EERA

The EERA model and database (Rossouw, 2003) is a bottom-up model and database of energy-using equipment, containing energy consumption data and trends in the form of a BAU scenario for all economic sectors of New Zealand. Information on the implementation procedures, costs, barriers and uptake rates of energy efficiency actions are employed to calculate their impact on reference scenarios derived from the BAU scenario.

EERA estimates the contributions of individual end-use equipment to the sector energy demand, and converts this energy demand into supply energy requirements and resulting GHG emissions. EERA has three functions:

- Investigating the effects of energy use on energy supply resources and the environment
- Providing a compendium of energy efficiency actions available to influence energy use
- Investigating the effects of energy efficiency actions on energy demand and supply resources, and their economic viability.

6.3.3 Regions, sub-sectors, building types and floor areas

The geographic regions in EERA are defined by the boundaries of the 16 Regional Councils given in Table 27 (see p72) in terms of their Territorial Authority combinations.[33]

The non-residential sub-sectors used in the EERA database are given in Table 28 (see p73), with their associated economic activities. For all sub-sectors except Communication, the activity is the regional floor area of buildings of a given type in the sub-sector. For the Communication sub-sector, the activity is contribution to GDP since the floor area for this sub-sector is not known. Table 28 also gives the category codes of the PropertyIQ building types[34] allocated to the sub-sectors as activities.

PropertyIQ provides historical floor areas from 1980 to 2009 for the EERA sub-sectors, as well as a basis for projection to the year 2050. The PropertyIQ floor areas are grouped by decade of construction as well as by the following additional categories:

- Missing: Area for which no date of construction is available
- Unknown pre-1920: Constructed prior to 1920 but decade of construction unknown
- Remodelled: Remodelled from previous periods or previously used for other purposes.

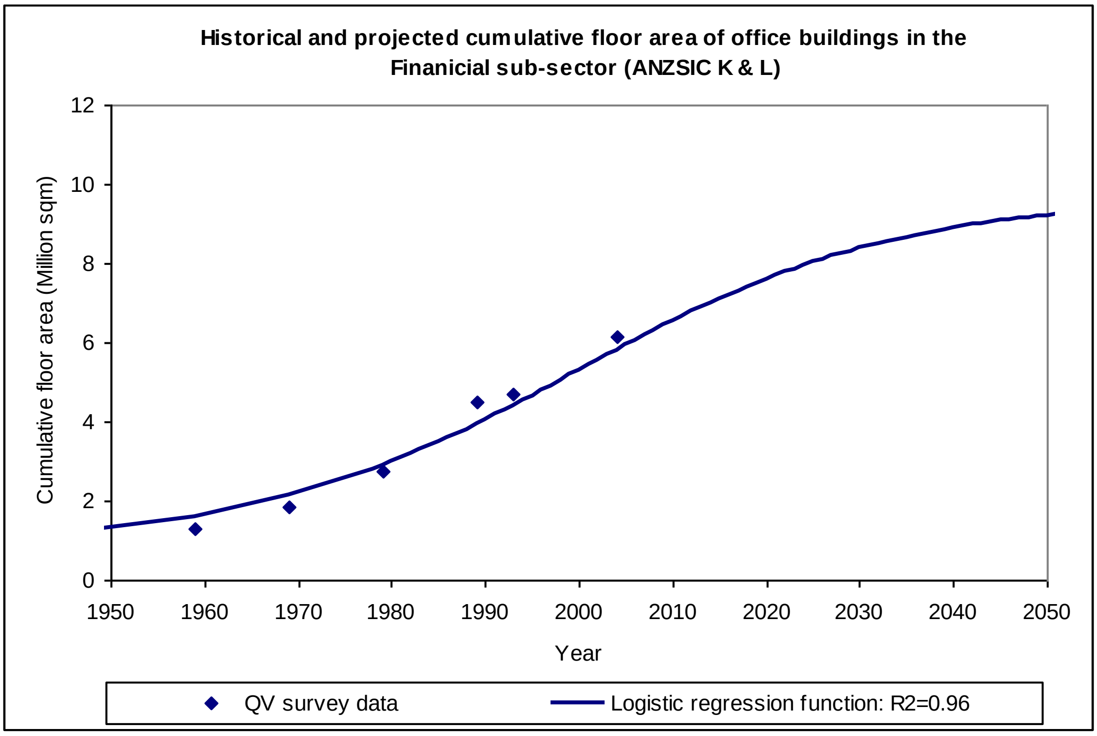
The Missing, Unknown pre-1920 and Remodelled decade areas are combined to obtain a pre-1920 base area. To this area, the areas from post-1920 decades are added sequentially to construct a plot of cumulative area growth, where it is assumed that all

[33] See Local Government New Zealand website:(http://www.lgnz.co.nz/lg-sector/maps/index.html)
[34] See PropertyIQ New Zealand: https://www.qv.co.nz/

remodelled areas originate from pre-1920 decades. Annual area changes for the 1980-1989 and 1990-1993 periods are provided by linear interpolation between the 1979, 1989, 1993, 2003 and 2009 areas.

As an example of projection based on the PropertyIQ survey data, the historical and projected PropertyIQ floor areas of the K&L financial and insurance sub-sector are given for the period 1950-2050 in Figure 26.

Figure 26: Historical and projected cumulative floor area of office buildings in the financial and insurance sub-sector (ANZSIC K&L: 1996)



Estimation of the heating load required to maintain the difference between a set temperature inside the building types listed above and that of the environment can be calculated with space-heating simulation procedures and models such as EnergyPlus[35] if the thermal properties, configuration of the building and heating regime are available. This methodology has not been employed in EERA due to a lack of such information. Instead, non-residential building space heating has been obtained from the EECA's Energy End-use Database (EECA, 2002).

6.3.4 Equipment density, energy intensity and thermal efficiency

In stock models the energy demand of a region and sub-sector is given by the energy consumption of a stock of equipment, each unit of equipment with a given energy intensity, as expressed by Equation 1. This equation does not specify the size of each unit of equipment, but the realism with which energy demand and the specificity of energy efficiency actions can be modelled is dependent on the detail with which the equipment stock is specified.

The main energy-using equipment in the sub-sectors of the non-residential sector, as provided by various sources (EECA, 2002; Merts and Cleland, 2004; Australian

[35] See US Dept. of Energy: *EnergyPlus Energy Simulation Software*: *Energy Efficiency & Renewable Energy* (http://apps1.eere.energy.gov/buildings/energyplus/about.cfm. accessed 23 Aug 2010).

Greenhouse Office, 2009), and used in EERA, are given in Table 29 (see p74). This selection provides scope for a wide range of energy efficiency actions aimed at the equipment level.

Commercial and industrial equipment sales data are collected by EECA for minimum energy performance standards (MEPS) control purposes (EECA, 2000-2004; 2003; 2004; 2005; MCE, 2007; 2007), and include information on air-conditioners, electric motors and refrigeration cabinets. EECA also maintains the Energy End-use Database (EEUDB) (EECA, 2002) and the New Zealand Heating Plant Database (US Department of Energy, 2005). Other surveys provide additional end-use and equipment energy consumption information (Merts and Cleland, 2004; Australian Greenhouse Office, 2009; PCNZ, 2000, 2005; Isaacs and Crocker, 1997), US Department of Energy, 2005; Energetics Ltd, 1994). The results of some of these surveys have been reported in EECA's *Energy-Wise Monitoring* quarterly publication (EECA 1993; 1995; 1996-2001; Aulakh, 1997, 2000).

However, for most commercial equipment the available equipment density data only cover a few disconnected years or a fraction of the period that is employed in the EERA model. A procedure is therefore needed to interpolate and extrapolate the available equipment density data to cover the period 1980-2050.

When available, sales data are used in vintage stock models to calculate historical equipment stock; alternatively historical equipment stocks are obtained directly from the above sources. These stocks are divided by the floor area to obtain the equipment densities of Equation 1, which are interpolated and projected with suitable regression functions. Due to the saturation and decay behaviour of equipment density trends, logistic regression functions are found to be the most suitable for projecting these trends. Alternative functions are only considered applicable where the historical data cover most of the period in question and better regression fits can be demonstrated.

The EECA and other sources listed above also provide information on the historical energy intensity of technologies. In cases such as the EEUDB database, where the equipment energy demand applies to the whole sub-sector, this demand is equal to the energy intensity of a sub-sector wide single equipment unit. Energy intensities of equipment units representing an organisation or company are also possible. EECA studies in support of MEPS proposals provide energy intensities of individual equipment units, as do some US Department of Energy databases. Some of the above sources also provide equipment efficiencies.

For the EERA BAU database, equipment densities, energy intensities and efficiencies were obtained or calculated as described above.

6.3.5 Using BEES data in EERA

The collection and processing of the BEES telephone survey, web-search survey and PropertyIQ floor area statistics were not finished during 2009 so the BEES data was only partially available to be included in the EERA model. The data were derived from:

- Administrative data sources:
  - Valuation data from PropertyIQ
  - Energy supply data from retail energy supply companies
- Existing non-administrative data:
  - Business directory data e.g. APN Ltd
  - Google Street View
- Reported from occupants/managers/owners of selected buildings

- Observed data through:
    - Direct monitoring of resource use
    - Direct on-site observation.

In view of the preliminary nature of the present BEES data, only aggregate BEES data from administrative and existing non-administrative sources were used in EERA. Of this data, the floor areas by region, building type and building age obtained from PropertyIQ are the most useful since the floor areas are used as main drivers for the projection of non-residential energy demand by sub-sector and region.

Building structure survey information collected by Google Street View is not at this stage useful for EERA since the model does not possess a building simulation model. Equipment saturation and density of appliances per premise from preliminary telephone survey analysis are not nationally representative and at this stage can only provide an estimate. It cannot be fully incorporated in EERA until the complete analysis is performed.

In view of these considerations, the regional floor areas by building type from PropertyIQ were combined in sub-sectors as shown in Table 28, and used as regional sub-sector activities for the BAU scenario of EERA.

6.3.6 Modelling energy efficiency scenarios

The methodology for investigating the impact of energy efficiency actions consists of:

- Establishing a reference scenario, usually the BAU scenario
- Creating an efficiency scenario by implementing energy efficiency actions on the reference scenario through modifying the activities (floor area), equipment stock or equipment energy intensity. This results in a modified energy demand which can be converted to supply energy requirements and GHG emissions
- Estimating the impact of the energy efficiency actions as the difference between the energy efficiency and the reference scenarios, usually the difference in energy demand or GHG emissions.

Since energy efficiency scenarios are usually policy-driven, the BAU regional, sub-sector, end-use and equipment differentiation must be adequate to allow the specification of policy-driven floor area, and equipment stock and energy intensity changes. This is possible for the EERA non-residential sector BAU scenario.

Energy efficiency actions can be applied over a specified period, starting at a given date and controlled by the level of funding over that period. The level of funding is expressed through the penetration rate of the action. Where the energy efficiency action is implemented through regulations such as the NZBC or MEPS, implementation occurs from a given date and the penetration rate is given by the rate at which new buildings are erected and by the sales of equipment respectively. In this case, once introduced, the level of funding does not influence the action.

The object of regulatory measures such as MEPS and the NZBC is to upgrade the new stock of equipment and buildings on an ongoing basis. Their impact starts small but continues to grow and can accumulate rapidly, depending on the growth rates of the affected appliances and buildings. These are the most cost-effective options, with a low maintenance cost once the regulations are locked into place. Due to the mandatory nature of MEPS measures, the lifetime of the equipment being affected does not influence the subsequent savings since no reversion to the previous type of equipment is possible.

Since EERA is based on a rich end-use energy demand structure with a relatively simple energy supply mechanism which cannot influence the energy demand, only the implementation of demand-side energy efficiency actions is possible. Supply-side changes have to be affected indirectly through the demand side.

6.3.7 Improved lighting scenario

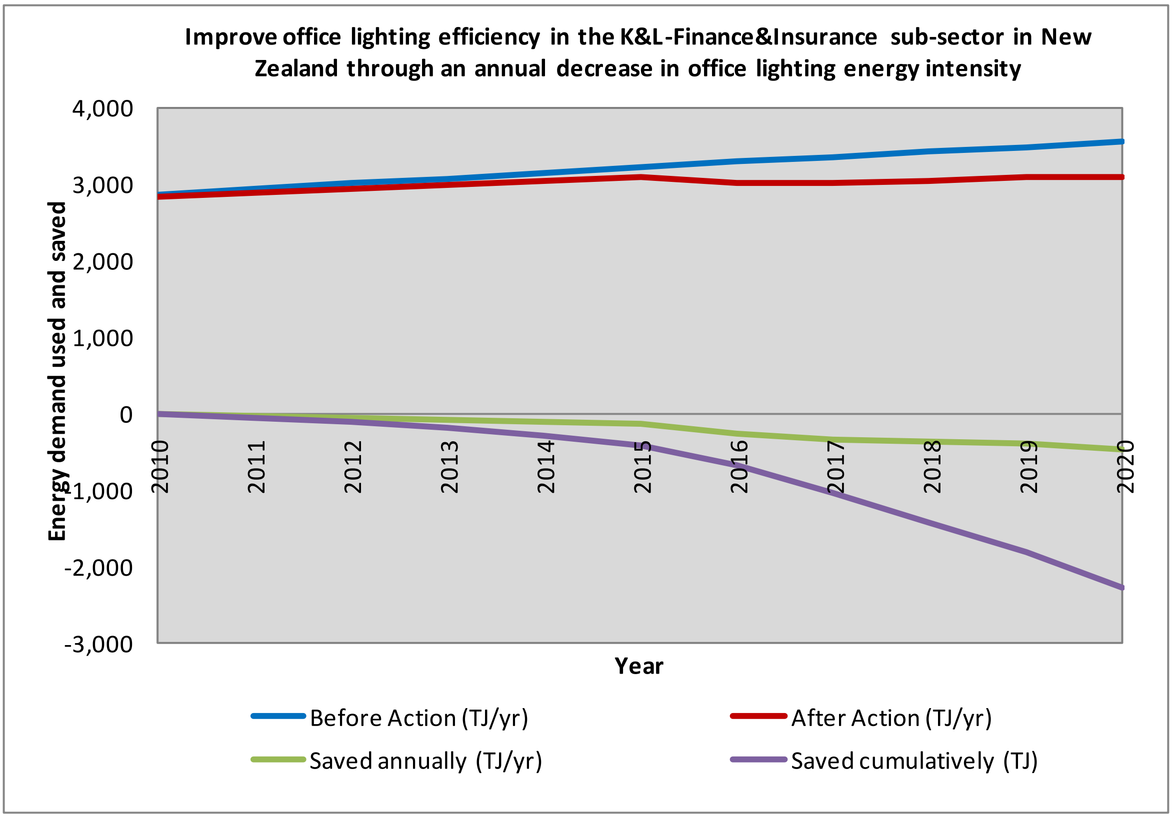
As a demonstration of the calculation of the impact of energy efficiency actions on the BAU scenario, the implementation of an action to improve the energy efficiency of office lighting is discussed.

In this action, the efficiency of the lighting of non-residential buildings in the finance & insurance sub-sector (ANZSIC Level 1 Divisions K & L) of New Zealand is improved by 1% per year from the year 2010 to the year 2020. This would be achieved by the replacement of conventional with low-loss lamps and ballasts in all non-residential office buildings.

In EERA this is achieved by improving 1% annually from 2010 to 2020, the energy intensity of the existing mixture of inefficient fluorescent ballasts and lamps from the K&L financial service sub-sector for the whole of New Zealand. The effect of this action on the lighting energy demand of the BAU scenario is shown in Figure 27.

Figure 27 illustrates that for energy efficiency measures that upgrade equipment and buildings annually on an ongoing basis, their impact starts small but continues to grow and can accumulate rapidly, depending on the growth rates of the affected equipment and buildings. Since these changes are equipment-based, their effect is secured once the changes are locked into place.

Figure 27: Effect of 1% annual decrease in office lighting energy intensity 2010-2020 for finance & insurance sub-sector



6.3.8 Conclusions

The BEES project can supply realistic and up-to-date data for the modelling of end-use energy scenarios in non-residential buildings and the impact of energy efficiency actions on these scenarios. The use of this information in the EERA model would assist in constructing reliable bottom-up scenarios that are useful for policy, planning and market analysis purposes.

Only aggregate BEES data from administrative and existing non-administrative sources could be usefully employed in EERA. Of this data, the floor areas by region, building type and building age obtained from PropertyIQ are the most useful since the floor areas are used as main drivers for the projection of non-residential energy demand by sub-sector and region.

The calculation of the impact of an energy efficiency action on the BAU scenario, consisting of improving the lighting in non-residential office buildings, illustrates that EERA can be used effectively to determine the impact energy efficiency policy actions.

6.3.9 EERA tables

Table 27: EERA geographical regions (Regional Councils and Territorial Authorities)

Region ID	Region name	Description
1	All Regions	All regions
2	Northland	Far North DC, Whangarei DC, Kaipara DC
3	Auckland	Rodney DC, North Shore CC, Waitakere CC, Auckland CC, Manukau CC, Papakura DC, Franklin DC (North)
4	Waikato	Franklin DC (South), Waikato DC, Hamilton CC, Waipa DC, Otorohanga DC, Waitomo DC (North West), Thames-Coromandel DC, Hauraki DC, Matamata-Piako DC, South Waikato DC, Taupo DC (West), Rotorua DC (South West)
5	Bay Of Plenty	Taupo DC (North East), Tauranga DC, Whakatane DC, Kawerau DC, Western Bay of Plenty DC, Opotoki DC, Rotorua DC (North East)
6	Gisborne	Gisborne DC
7	Hawkes Bay	Taupo DC (South East), Wairoa DC, Hastings DC, Napier CC, Central Hawkes Bay DC, Rangitikai DC (North East)
8	Taranaki	New Plymouth City DC, Stratford DC (West), South Taranaki DC
9	Manawatu-Wanganui	Stratford DC (East), Ruapehu DC, Wanganui DC, Rangitikai DC (South West), Manawatu DC, Tararua DC (North), Palmerston North CC, Horowhenua DC, Waitomo DC (South-East), Taupo DC (South)
10	Wellington	Kapiti Coast DC, Masterton DC, Carterton DC, South Wairarapa DC, Upper Hutt CC, Lower Hutt CC, Wellington CC, Porirua City CC, Tararua DC (South)
11	Marlborough	Marlborough DC
12	Nelson	Nelson CC
13	Tasman	Tasman DC
14	West Coast	Buller DC, Grey DC, Westland DC
15	Canterbury	Kaikoura DC, Hurunui DC, Waimakariri DC, Christchurch CC, Banks Peninsula DC, Selwyn DC, Ashburton DC, Timaru DC, Mackenzie DC, Waimate DC, Waitaki DC (North West)
16	Otago	Waitaki DC (South East), Central Otago DC, Queenstown-Lakes DC, Dunedin CC, Clutha DC, Chatham Islands
17	Southland	Southland DC, Gore DC, Invercargill CC

Table 28: EERA database sub-sectors with their activities and PropertyIQ category code

Sub-sector ANZSIC Code (1996)	EERA_EnergyScape sub-sectors	Activity	PropertyIQ	
			Property IQ Code	Purpose of building
F+G	Wholesale & Retail Trade	Floor area	IW	Warehousing
			CM	Motor vehicle sales, service etc
			CR	Retailing use
			CS	Service (petrol stations etc)
			CX	Numerous non-residential uses on one site
H	Accommodation, Cafes & Restaurants	Floor area	CA	Non-residential accommodation such as motels, hotels etc
			CL	Liquor outlets including restaurants, cafes etc
			CT	Tourist type attractions and non-sporting amenities
I	Transport and Storage	Floor area	CP	Parking buildings
J	Communication	GDP	N/A	Area not available
K+L	Financial (Including Finance, Insurance, Real Estate and Business Services)	Floor area	CO	Office type use
M	Administration and Defence (Central and Local Government Administration, Defence, and International & Extra-territorial Bodies)	Floor area	CO	Office type use
N	Education	Floor area	OE	Educational uses like pre-school, primary, secondary, tertiary and university
O	Health & Welfare	Floor area	OH	Health and medical uses like hospitals, medical centres, doctors' surgeries
			CE	Homes for the elderly
P	Cultural	Floor area	CC	Cinema, theatre and public hall type complexes
			OA	Assembly halls
			OM	Maori sites like marae, meeting houses and burial sites
			OR	Religious and places of worship
Q	Personal	Floor area	IS	Personal services; usually with interface to general public as clients

Table 29: Energy-using equipment by end-use

End-use by fuel type	Equipment
Electricity	
Space heating and cooling	Air-conditioners with or without heat pumps
Space heating	Space heaters with or without heat pumps
Water heating	Hot water cylinders with or without heat pumps
Lighting	Lamps of all types
Light electrical	Office equipment: personal computers, terminals, printers, photocopiers and fax machines
Heavy electrical	Electric motors used in lifts and escalators
Pumping	Electric motors used in pumps and packaged compressors, including reciprocating single-acting air compressors and rotary screw compressors with an input power up to 20 kW. Applications range from pneumatic tools to seasonal recreation services and for continuous medical uses.
Blast freezing/chilling	Blast freezer/chiller plants in which sub-freezing temperatures are maintained for the rapid freezing and storing of perishable items, especially food.
Remote refrigeration	Remote refrigeration systems where compressors and condensing equipment are separated from the cooled area e.g. for supermarket display cases or for large spaces, such as cool storage rooms.
Self-contained refrigeration	Self-contained refrigeration systems with integrated components, designed to plug into an available electricity supply. It can also be industrial refrigeration equipment such as that used in food processing, abattoirs and dairies.
Accommodation cooking	Ranges and tops
Process cooking	Process heaters and ovens
Coal	
Space heating	Custom-built boilers are not delivered as a complete assembly of a vessel, combustion equipment, insulation, piping and controls.
Space heating	Burners
Water heating	Custom-built boilers
Process heating	Custom-built boilers
Natural gas	
Space heating	Packaged boilers use an energy source, for example natural gas, oil or electricity, to generate hot water or steam. The term 'packaged' refers to the complete assembly of a vessel, combustion equipment, insulation, piping and controls that is factory-assembled and shipped as a single unit.
Space heating	Burners
Water heating	Packaged boilers
Water heating	Hot water cylinders
Process heating	Packaged boilers
Process heating	Burners
Accommodation cooking	Ranges and tops
Process cooking	Process heaters
Process cooking	Process ovens
LPG	
Space heating	Packaged boilers
Space heating	Burners
Water heating	Packaged boilers
Process heating	Packaged boilers
Process heating	Burners
Accommodation cooking	Ranges and tops
Process cooking	Process heaters, ovens
Fuel oil	
Space heating	Custom-built boilers
Space heating	Burners
Water heating	Custom-built boilers
Geothermal	
Space heating	Custom-built boilers
Water heating	Custom-built boilers

Sources: EECA, 2000-2004; MCE 2007, 2008.

7. CROSS-COMPONENT ACTIVITIES

(Prepared by BRANZ)

Cross-component activities are tasks focused on project management, international cooperation (especially through IEA Task 40), and technology transfer (including presentations, stakeholder consultations, and supervising FRST-funded Honours, Masters and PhD students).

7.1 International co-operation

We now have two formally signed agreements supporting the BEES research:

- International Energy Agency (IEA) Solar Heating and Cooling Agreement (SHC) Task 40 & Energy Conservation in Buildings and Community Systems Programme (ECBCS) Annex 52 ‘Towards Net Zero Energy Solar Buildings’. This Task will operate from 1 October 2008 to 30 September 2013.[36] BEES is a major contributor to Subtask C: Advanced Building Design, Technologies and Engineering. Victoria University of Wellington, New Zealand, is represented by Michael Donn, Subtask C Leader, with a Co-Leader from Université de la Réunion, France, represented by François Garde.
- The Bartlett Faculty of the Built Environment, University College, London[37] – a formal agreement was signed between BRANZ, VUW and The Bartlett.

These provide opportunities for researcher interchange, but most importantly ensure that the research is linked with current international best practice. These agreements serve to maximise the benefits from the BEES research to New Zealand, while minimising the duplication of effort.

7.2 Technology transfer

Papers have been presented on a range of activities resulting from the BEES research over the past year. These are cited in the references at the end of this report and include:

Non-peer reviewed published articles: Isaacs (2009a).

Peer reviewed conference papers: Bint et al (2009); Bint et al (2010); Camilleri and Isaacs (2010); Donn et al (2009); Hsu and Donn (2009), Isaacs et al (2010a).

Report (FRST required): Isaacs et al (2010b).

Non-peer reviewed conference paper and workshops: Camilleri (2010); Isaacs (2009b); Isaacs (2010a); Isaacs (2010b).

7.3 BEES scholarships

Table 30 lists the scholarships awarded during the 2008/09 and 2009/10 years to students at Victoria University of Wellington. The three Bachelor of Building Science (Honours) scholars completed their degrees at the end of 2009, two with first class and one with second class honours. Ms Lee Bint converted from a Master of Building Science to a PhD at the end of 2009. She was then awarded a BRANZ scholarship to support the completion of this degree. She continues to be supported by BEES with equipment and travel, as well as regular contact with the research team.

[36] See http://www.iea-shc.org/task40/index.html

[37] See http://www.bartlett.ucl.ac.uk/architecture

The following scholarship awards have been made in the 2009/10 year:

Chi-Yao (Henry) Hsu – BEES Scholarship for Master of Building Science looking at improving the performance of non-residential building facade design (full-time, one year) (Supervisor Michael Donn)

Quentin Heap – BEES Scholarship for Master of Building Science looking at lighting in retail stores (Otaki) (Supervisor Nigel Isaacs)

Shaan Cory – BEES Scholarship for PhD looking at obstacles preventing Net Zero Energy buildings being built in New Zealand (full-time, three years) (Supervisor Michael Donn)

Alexandra Hills – BEES Scholarship to develop a PhD proposal looking at using emerging web technology to understand resource use in non-residential buildings (partial assistance to develop full PhD proposal, one year) (Supervisor Michael Donn)

Claire Dykes – BEES Scholarship for Master of Building Science looking at user perceptions of buildings (Supervisor George Baird)

Table 30: VUW scholarships

Title	First Name	Last name	Degree	Completion
2009 Scholarships				
Ms	Lee	BINT	MBSc	Converted to PhD end 2009 (awarded 2010 BRANZ scholarship)
Mr	Shaan	COREY	BBSc(Hons)	Completed 2009
Mr	Quinten	HEAP	BBSc(Hons)	Completed 2009
Mr	Chi-Yao	HSU	BBSc(Hons)	Completed 2009
2010 Scholarships				
Mr	Shaan	COREY	PhD	Underway for completion 2013
Ms	Claire	DYKES	MBSc	Underway for completion 2011
Mr	Quinten	HEAP	MBSc	Underway completion Feb 2011
Ms	Alexandra	HILLS	PhD	Underway – topic to be defined
Mr	Chi-Yao	HSU	MBSc	Underway completion Feb 2011

The benefits to both the BEES research and the individual students from these scholarships have been considerable. For the BEES research, they have explored areas in detail that would not have otherwise been able to be considered. For the students the scholarships have helped them develop their research and communication skills, as early steps to successful careers. Scholarships will be re-announced for 2011 during 2010.

7.4 Project management

This activity included: day-to-day management and administration activities, as well as the holding of regular sub-contractor meetings: developing science design, programme and study design methodology; evaluating the data collection system; and establishing reporting and technology transfer activities.

Two meetings of the FRST Governance Group were organised by the BEES team (held on 10 November 2009 and 28 April 2010), and meetings of the Steering Committee were managed by the DBH.

Ongoing liaison was maintained with a wide range of stakeholders, including Statistics NZ, the Electricity Commission, the energy supply sector etc, to help reduce duplication of effort, and ensure lowest cost data collection and that the overall results from the work will be of maximum value to the widest range of possible users.

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