



**STUDY REPORT SR 277/4 [2012]**

**BEES** INTERIM REPORT  
Building Energy End-Use Study – Year 5

**ESTIMATING WHOLE BUILDING ENERGY  
USAGE**

Rob Bishop, Andrew Pollard and Nigel Isaacs

# **BEES (BUILDING ENERGY END-USE STUDY) YEAR 5: ESTIMATING WHOLE BUILDING ENERGY USAGE**

## **BRANZ Study Report SR 277/4**

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## **Reference**

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# PREFACE

Understanding how energy and water resources are used in non-residential buildings is key to improving the energy and water efficiency of New Zealand's building stock. More efficient buildings will help reduce greenhouse gas emissions and enhance business competitiveness. The Building Energy End-use Study (BEES) is taking the first step towards this by establishing where and how energy and water resources are used in non-residential buildings and what factors drive the use of these resources.

The BEES study started in 2007 and will run for six years, gathering information on energy and water use through carrying out surveys and monitoring non-residential buildings. By analysing the information gathered, we aim to answer eight key research questions about resource use in buildings:

1. What is the aggregate energy and water use of non-residential buildings in New Zealand?
2. What is the average energy and water use per unit area per year?
3. What characterises the buildings that use the most energy and water?
4. What is the average energy use per unit area for different categories of building use?
5. What are the distributions of energy and water use?
6. What are the determinants of water and energy-use patterns e.g. structure, form, function, occupancy, building management, etc?
7. Where are the critical intervention points to improve resource use efficiency?
8. What are the likely future changes as the building stock type and distribution change?

Understanding the importance and interaction of users, owners and those who service non-residential buildings is also an important component of the study.

For the BEES study, non-residential buildings have been defined using categories in the New Zealand Building Code, but in general terms the study is mainly looking at commercial office and retail buildings. These vary from small corner store dairies to large multi-storey office buildings. For more information on the building types included in the study please refer to BRANZ report SR224 Building Energy End-use Study (BEES) Years 1 & 2 (2009) available on the BEES website ([www.branz.co.nz/BEES](http://www.branz.co.nz/BEES)).

The study has two main methods of data collection – a high level survey of buildings and businesses, and intensive detailed monitoring of individual premises.

The high level survey initially involved collecting data about a large number of buildings. From this large sample, a smaller survey of businesses within buildings was carried out which included a phone survey, and collecting records of energy and water use and data on floor areas. The information will enable a picture to be built up of the total and average energy and water use in non-residential buildings, the intensity of this use and resources used by different categories of building use, answering research questions one to four.

The detailed monitoring of individual premises involves energy and indoor condition monitoring, occupant questionnaires and a number of audits, including: appliances, lighting, building, hot water, water, and equipment.

This report presents the method for estimating whole building energy usage data using the data collected in BEES. As BEES data is primarily collected on a per premise basis this method will be used to estimate the whole building energy use which includes premises and central services (or common area) energy use.

This report is intended to be used for discussion. If you have any comments or feedback on the methodology suggested here please get in contact with the BEES team- [BEES@branz.co.nz](mailto:BEES@branz.co.nz)

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# GLOSSARY

## **Aggregate Monitoring**

A high level survey collected data about a large number of buildings. From this large sample, a smaller survey of businesses within buildings was carried out which included a phone survey, and collecting records of energy and water use and data on floor areas.

## **Annual Energy Use Intensity (EUI)**

Annual EUI in kWh/m<sup>2</sup>. Sometimes referred to as the Energy Use Index, the EUI is a measure of building energy use per square metre of floor area.

## **BEES Buildings**

BEES is studying non-residential buildings where the building can impact on the energy and/or water use. In broad terms, these uses are office and retail uses. It was decided to use the NZ Building Code definitions, as these are consistent and uniformly used. Based on NZBC definitions, BEES will investigate Commercial buildings and Communal Non-residential Assembly-Care buildings.

## **Building**

An enclosed physical structure intended for human occupation.

## **Central services**

Services that are provided by the landlord for all tenants of the building such as HVAC, common area corridor lighting, exterior lighting, shared bathrooms etc.

## **Detailed Monitoring**

Monitoring energy and environmental conditions (temperatures, relative humidity, CO<sub>2</sub> and light levels) at an end-use level for 2-4 weeks.

## **Energy Purchase Data**

Meter readings that are provided by the power company.

## **Floor**

A floor in a multi-storey building.

## **Non-BEES Spaces**

Spaces that are outside of the scope of the BEES study such as car parks, residential, educational spaces and warehouses.

## **Unoccupied premises**

Vacant premises at the time of surveying, In BEES they are assumed to use no energy (outside of those provided by central services)

## **Non-Residential Building**

The New Zealand Building Code Handbook (3<sup>rd</sup> Edition, 2010) identifies non-residential building stock categories, these include:

**“Communal Non-Residential:** Applies to a building or use being a meeting place for people where care and service is provided by people other than the principal users. There are two types:

**Commercial:** Applies to a building or use in which any natural resources, goods, services or money are either developed, sold, exchanged or stored, for example, an amusement park, auction room, bank, car park, catering facility, coffee bar, computer centre, fire station, funeral parlour, hairdresser, library, office (commercial or government), police station, post office, public laundry, radio station, restaurant, service station, shop, showroom, storage facility, television station or transport terminal.

**Industrial:** Applies to a building or use where people use material and physical effort to extract or convert natural resources, produce goods or energy from natural or converted resources, repair goods or store goods (ensuing from the industrial process, for example, an agricultural building, agricultural processing facility, aircraft hanger, factory, power station, sewage treatment works, warehouse or utility.)”

### **Peak Load**

The peak measured load of the energy assessed as contributing to that end-use. Note: this may be different from the installed load, as some equipment may never be observed to have operated during the monitoring period.

### **Peak Load Density**

The peak load was divided by the recorded floor area of the premise, to yield the observed peak load density, in watts per square metre.

### **Sample Frame**

Selected from Quotable Value (QV) property codes CL – liquor outlets including taverns, CM – motor vehicle sales or service, CO – office type use, CR – retail use, CS – service stations, CT – tourist type attractions as well as other amenities with an emphasis on leisure activities of non-sporting type, CV – vacant land or with low value of improvements which when developed is likely to have a commercial use, CX – other commercial uses or where there are multiple uses. This includes 50,539 building records nationwide.

# 1. INTRODUCTION

The aim of this report is to define the method of estimating the energy use of whole buildings from measurements of individual premises' energy use.

The design of BEES allows information to be expressed in various forms for different audiences and different needs. For example BEES buildings which are monitored in detail have in addition to energy totals, the peak (power) loads of premises and end-uses measured. This information can then be used to characterise spaces and end-uses in ways other than (annual or daily) energy totals. However, BEES monitoring can be for a period of less than a full year and for areas less than the whole building, so it is necessary to establish suitable assumptions and methods to permit the data to be used to develop national estimates for other relevant purposes.

Non-residential buildings are a collective of premises and corresponding services. For an individual business premise their primary focus is on their business outputs. A building owner, who necessarily has to provide for central services is more concerned by the performance of the whole building and its energy use.

Estimates of New Zealand's non-residential energy use can be calculated either by:

- A **premise level estimate** calculated by adding together all premises with each premise including a pro-rata share of the central services they use, or
- A **whole building estimate** where the energy use of a building is calculated by adding all premise and central service energy use together.

The premise level estimate can be used to calculate the sector wide non-residential energy use as it deals more effectively with the unavailability of data but as this report deals with entire buildings it is not considered further in this report. It will be reported on in the final BEES report.

Whole building estimates relate conceptually to something physical - a building. Whole building estimates can be used to benchmark buildings to identify energy efficient or inefficient buildings, this efficiency level may relate to either the building or the premises within the building,

This report focuses on how energy records can be applied to determine whole building estimates of energy use. These estimates will be simplified to measures such as standardised energy use intensity ( $\text{kWh/m}^2$ ) and peak load density ( $W_{\text{peak}}/\text{m}^2$ ).

There are several subtleties involved with translating the energy records of BEES premises to whole building estimates, as some parts of buildings were not measured during BEES, but still use resources. One of the most important aspects is that in many larger buildings some energy services are supplied to spaces directly, without metering the energy used by individual premises, such as heating, ventilation and air-conditioning (HVAC) and service hot water.

The spaces within a building can be characterised as follows:

- Premises that are being studied within the BEES sample frame, for which we have recorded data, either directly monitored, or from energy revenue meters.
- Similar premises that are within buildings in the BEES "sample frame", but which are not being directly monitored, so for which we do not have energy data.
- Spaces containing shared services which can be associated with non-tenanted spaces (lobbies, plantrooms, stairwells etc.)
- Unoccupied premises, which are intended to be tenanted, but were not at the time of the study.

- Spaces with uses outside the BEES “sample frame”, primarily residential spaces within mixed-use buildings. Many larger buildings in New Zealand’s main urban areas have some spaces devoted to apartments, and these spaces have been specifically excluded from this study. Carparks are another category that comprises significant floor area in buildings, which was intentionally not examined.

## 1.1 Monitored Data vs. Energy Revenue Data

One key principle is to use the energy purchase data (e.g. meter readings) as the primary source of building and premise energy use information. For the majority of premises BEES has collected at least two years worth of energy purchase data. Data of at least one year allows the seasonality (or temperature dependence) of many buildings' usage to be interpreted. BEES monitoring is only for a short period – typically two weeks – and for individual premises rather than for entire buildings so although this gives good detail for individual end-uses it does not show the seasonality of energy usage through the year.

BEES continuously monitored individual electrical circuits in the chosen premises' electrical distribution boards, as well as the feeders to the premises' main electrical switch. Where possible premises use of used water, natural gas, or solid fuel was monitored as a time series.

The results of this monitoring gives an indication of both how much energy was consumed during the time of the monitoring, and what it was used for. These results are compared to the records of energy purchases to reconcile and confirm the validity of the monitoring. However, because building usage and occupancy are changing so constantly, purchase energy data will not necessarily match monitored data, unless they are for the same time period.

Also, this data only describes the energy use of the individual monitored premise, and are used to infer the energy use of the entire building. BEES monitored data is useful for assigning the total energy used to the individual end-uses that were operative during the monitoring. It was not always possible to measure all end-uses in the premise and as the heating and/or cooling is seasonal it is not always possible for the monitored use to be used directly for predicting annual consumption.

## 1.2 Methodology and Assumptions

Relatively few large buildings have adequate data to completely characterise the energy use patterns of the entire building, so a series of assumptions have been chosen to estimate whole-building energy use from the information we do have.

The basic method is to assume that the monitored premise(s) are representative of all the occupied, unmonitored premises in the building, excluding any non-BEES spaces.

The total energy used by the building would therefore be the sum of the energy use in these areas, the centrally provided services, and assumed energy use of unoccupied spaces and non-monitored spaces within the building.

The assumptions about the energy use of unoccupied and non-BEES spaces are as follows:

- Unoccupied premises are assumed to use no energy (outside of those provided by central services). This is not necessarily true, as lights, etc. may be left on even when a part of a building is vacant, but as we know of no better information, this is the assumption chosen.
- Central services energy use for unoccupied areas is the same as for occupied areas. This is an approximation, as the actual use can easily be more, or less. For example, the amount of energy expended in delivering centralised HVAC services depends on the nature of the HVAC system, its control, the demand for conditioning and the time of year. So, if a part of a building is left unoccupied in winter and HVAC is not switched off, then this area will require more heat than other areas, as it has no lighting, equipment and people heat gains to reduce its heating needs. Conversely, the unoccupied part of a building in summer would require less cooling for the same reason.
- Some areas within mixed-use buildings have been specifically excluded from this study. This particularly applies to residential areas in a building, and car parks. Both of these spaces have different patterns and amounts of energy use compared to BEES non-residential spaces. Rather than defining some buildings as being smaller than they actually are (to exclude the floor area

devoted to “non-BEES” activities), simple approximate values for energy use intensities have been assigned to these spaces. The suggested values are 200 kWh/m<sup>2</sup> (23 W/m<sup>2</sup> continuous) for spaces regularly occupied by people (i.e., residential spaces), and 100 kWh/m<sup>2</sup> (11.5 W/m<sup>2</sup> continuous) for spaces not regularly occupied by people (i.e., carparks which have people only passing through).

- Central services energy use for non-BEES areas is the same as for occupied areas. (In other words, the central services energy is distributed evenly across all building spaces.)

In reality, none of these assumptions can be supported by measured data from real buildings, but we believe they are justified, necessary, and adequate to estimate the energy use of whole buildings from measurements on premises. The uncertainty of this method is unknown at present, but evidence based analysis will be completed and reported on in the final report.

## 2. METHOD

The following are the formulae to be used to calculate the whole building's annual EUI and annual energy use. They each apply to electricity, solid fuel, gas and water, though they are most commonly applied to electricity.

For individually monitored premises:

$$(1) \quad EUI_{mp} = E_{mp}/A_{mp}$$

For averaging individually monitored premises in a building:

$$(2) \quad EUI_a = (\sum EUI_{mp} \times A_{mp})/(\sum A_{mp}) = (\sum E_{mp})/(\sum A_{mp})$$

For central services energy use:

$$(3) \quad EUI_c = E_c/A_c$$

For non-BEES spaces:

If a space is regularly occupied by people (i.e. a residential space), then

$$(4) \quad EUI_{on} = 200 \text{ kWh/m}^2$$

If a space is not regularly occupied by people (i.e., a carpark which has people only passing through), then

$$(5) \quad EUI_{un} = 100 \text{ kWh/m}^2$$

For vacant premises:

$$(6) \quad EUI_v = 0 \text{ kWh/m}^2$$

For entire buildings:

$$(7) \quad E_b = EUI_a \times (\sum A_{mp} + \sum A_{up}) + EUI_{on} \times \sum A_{on} + EUI_{un} \times \sum A_{un} + EUI_c \times A_c$$

$$(8) \quad EUI_b = E_b/(\sum A_{mp} + \sum A_{up} + \sum A_{on} + \sum A_{un} + A_v + A_c)$$

Where  $EUI_{mp}$  = Energy Use Intensity for individual monitored premises (kWh/m<sup>2</sup>)

$EUI_c$  = Energy Use Intensity for central services (kWh/m<sup>2</sup>)

$EUI_{om}$  = Energy Use Intensity for occupied non-BEES spaces (200 kWh/m<sup>2</sup>)

$EUI_{un}$  = Energy Use Intensity for unoccupied non-BEES spaces (100 kWh/m<sup>2</sup>)

$EUI_v$  = Energy Use Intensity for vacant spaces (0 kWh/m<sup>2</sup>)

$EUI_a$  = Energy Use Intensity for average monitored premises (kWh/m<sup>2</sup>)

$EUI_b$  = Energy Use Intensity for whole building (kWh/m<sup>2</sup>)

$E_{mp}$  = Annual energy purchases for monitored premises (kWh/year)

- $E_c$  = Annual energy purchases for central services (kWh/year)
- $E_b$  = Annual energy purchases for whole building (kWh/year) (estimated)
- $A_{mp}$  = Floor area for monitored premises ( $m^2$ )
- $A_{up}$  = Floor area for un-monitored premises, covered by BEES ( $m^2$ )
- $A_{on}$  = Floor area for occupied non-BEES spaces ( $m^2$ )
- $A_{un}$  = Floor area for unoccupied non-BEES spaces ( $m^2$ )
- $A_v$  = Floor area for vacant spaces ( $m^2$ )
- $A_c$  = Floor area for central services ( $m^2$ )

Similarly:

- $E_{mp1}$  = Annual energy purchases for the first monitored premises (kWh/year)
- $E_{mp2}$  = Annual energy purchases for the second monitored premises
- $E_{mpn}$  = Annual energy purchases for the  $n^{th}$  monitored premises
- $EUI_{mp1}$  = Energy Use Intensity for first monitored premises ( $kWh/m^2$ )
- $EUI_{mp2}$  = Energy Use Intensity for second monitored premises ( $kWh/m^2$ )
- $EUI_{mpn}$  = Energy Use Intensity for  $n^{th}$  monitored premises

### 3. EXAMPLES

The following examples illustrate the use of the above formulae in calculating whole-building energy use and Energy Use Indices, for increasingly complex situations.

#### 3.1 Single Premise Building with No Landlord Use



Figure 1: Single Premise Building with No Landlord Use

This is a building with one single premise of 1,500 m<sup>2</sup>, which uses 273,000 kWh/year, and there is no landlord energy use or area.

Table 1: Single Premise Building Details

Premise	Floor Area	Energy Use
Monitored Premise	1,500 m <sup>2</sup>	273,000 kWh/year

This is the simplest case.

$$EUI_{mp} = E_{mp}/A_{mp}$$

$$(9) \quad EUI_{mp} = 273,000 \text{ kWh/year}/1,500 \text{ m}^2 = 182 \text{ kWh/m}^2$$

The energy use for the building is the same as for the premises: **273,000 kWh/year**. The annual EUI for the premise and the building is **182 kWh/m<sup>2</sup>**.

#### 3.2 Single Premise Building with Landlord Energy Usage Known

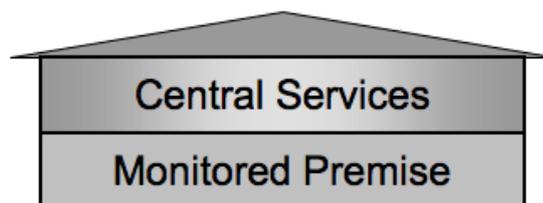


Figure 2: Single Premise Building with Landlord Energy Usage Known

The monitored premise again is 1,500 m<sup>2</sup>. Landlord has an additional 30 m<sup>2</sup> of plantroom, lift lobby and toilets. Landlord supplies service water heating, mechanical ventilation for toilet exhausts, lifts and lobby lighting. Landlord energy use is known, at 18,000 kWh/year.

**Table 2: Single Premise Building with Landlord Energy Usage Known Details**

Premise	Floor Area	Energy Use
Monitored Premise	1,500 m <sup>2</sup>	273,000 kWh/year
Landlord	30 m <sup>2</sup>	18,000 kWh/year

This is only slightly more complicated.

$$EUI_{mp} = E_{mp}/A_{mp} = \mathbf{182 \text{ kWh/m}^2} \quad (\text{refer Equation 9})$$

$$(10) \quad EUI_a = (\sum EUI_{mp} \times A_{mp}) / (\sum A_{mp}) = EUI_{mp} \quad (\text{only one premise})$$

$$(11) \quad EUI_c = E_c/A_c = 18,000 \text{ kWh/year} / 30 \text{ m}^2 = \mathbf{600 \text{ kWh/m}^2}$$

$$(12) \quad EUI_b = \{EUI_a \times (\sum A_{mp} + \sum A_{up}) + EUI_c \times A_c\} / (\sum A_{mp} + \sum A_{up} + A_c)$$

$$= \{182 \times (1,500 \text{ m}^2) + 600 \times 30 \text{ m}^2\} \div (1,500 + 30 \text{ m}^2)$$

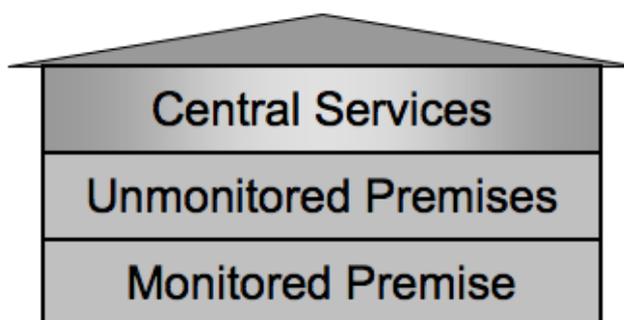
$$= \mathbf{190 \text{ kWh/m}^2}$$

$$(13) \quad E_b = EUI_b \times (\sum A_{mp} + \sum A_{up} + A_c)$$

$$= 190 \text{ kWh/m}^2/\text{year} \times (1,500 + 30 \text{ m}^2) = \mathbf{291,000 \text{ kWh/year}}$$

The landlord's effective annual EUI is **600 kWh/m<sup>2</sup>**. The annual EUI for the building is **190 kWh/m<sup>2</sup>**. The total energy use for the building is **291,000 kWh/year**.

### 3.3 Multiple Premise Building with One Monitored Premise



**Figure 3: Multiple Premise Building with One Monitored Premise**

The monitored premise is as above. Other tenanted premises comprise 1,800 m<sup>2</sup>. Their energy usage is unknown. The landlord's assessed area and energy use are known, and as above.

**Table 3: Multiple Premise Building Details**

Premise	Floor Area	Energy Use
Monitored Premise	1,500 m <sup>2</sup>	273,000 kWh/year
Landlord	30 m <sup>2</sup>	18,000 kWh/year
Other Tenanted Premise	1,800 m <sup>2</sup>	?

In this case, the unknown tenanted premises are assigned the same annual EUI as the known tenanted premises. Then the overall annual EUI and energy use is calculated as follows:

$$EUI_{mp} = E_{mp}/A_{mp} = 182 \text{ kWh/m}^2 \quad (\text{refer Equation 9})$$

$$EUI_a = \sum(EUI_{mp} \times A_{mp}) / (\sum A_{mp}) = EUI_{mp}$$

$$EUI_c = E_c/A_c = 600 \text{ kWh/m}^2 \quad (\text{refer Equation 11})$$

$$(14) \quad EUI_b = \{EUI_a \times (\sum A_{mp} + \sum A_{up}) + EUI_c \times A_c\} / (\sum A_{mp} + \sum A_{up} + A_c)$$

$$= \{182 \times (1,500 + 1,800 \text{ m}^2) + 600 \times 30 \text{ m}^2\} / (1,500 + 1,800 + 30 \text{ m}^2)$$

$$= 186 \text{ kWh/m}^2$$

$$(15) \quad E_b = EUI_b \times (\sum A_{mp} + \sum A_{up} + A_c)$$

$$= 186 \text{ kWh/m}^2 \times (1,500 + 1,800 + 30 \text{ m}^2) = 618,600 \text{ kWh/year}$$

### 3.4 Multiple Premise Building with Two Monitored Premises

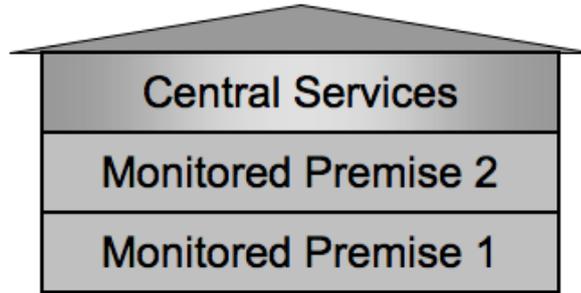


Figure 4: Multiple Premise Building with Two Monitored Premises

There are two premises, both monitored: one with 1,500 m<sup>2</sup> floor area and 273,000 kWh/year premise energy use, and the other with 1,800 m<sup>2</sup> floor area and 201,600 kWh/year premise energy use. The landlord's assessed area and energy use are known, as above.

Table 4: Multiple Premise Building with Two Monitored Premises Details

Premise	Floor Area	Energy Use
Monitored Premise 1	1,500 m <sup>2</sup>	273,000 kWh/year
Monitored Premise 2	1,800 m <sup>2</sup>	201,600 kWh/year
Landlord	30 m <sup>2</sup>	18,000 kWh/year

In this case, the annual EUI of the two tenanted premises are averaged, then the tenancy and landlord Annual EUIs are averaged for the whole building.

The overall annual EUI and energy use is calculated as follows:

$$EUI_{mp1} = E_{mp1}/A_{mp1} = 182 \text{ kWh/m}^2 \quad (\text{refer Equation 9})$$

$$(16) \quad EUI_{mp2} = E_{mp2}/A_{mp2}$$

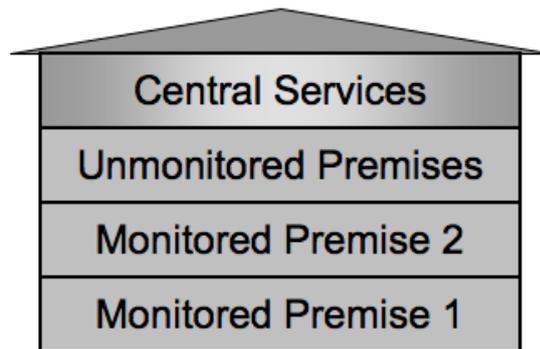
$$= 201,600 \text{ kWh/year} / 1,800 \text{ m}^2 = 112 \text{ kWh/m}^2$$

$$\begin{aligned}
 (17) \quad EUI_a &= \Sigma(EUI_{mp} \times A_{mp}) / (\Sigma A_{mp}) \\
 &= (182 \times 1,500 + 112 \times 1,800) / (1,500 + 1,800) = \mathbf{144 \text{ kWh/m}^2} \\
 EUI_c &= E_c / A_c = \mathbf{600 \text{ kWh/m}^2} \quad (\text{refer Equation 11}) \\
 (18) \quad EUI_b &= \{EUI_a \times (\Sigma A_{mp} + \Sigma A_{up}) + EUI_c \times A_c\} / (\Sigma A_{mp} + \Sigma A_{up} + A_c) \\
 &= \{144 \times (1,500 + 1,800 \text{ m}^2) + 600 \times 30 \text{ m}^2\} / (1,500 + 1,800 + 30 \text{ m}^2) \\
 &= \mathbf{148 \text{ kWh/m}^2} \\
 (19) \quad E_b &= EUI_b \times (\Sigma A_{mp} + \Sigma A_{up} + A_c) \\
 &= 148 \text{ kWh/m}^2 \times (1,500 + 1,800 + 30 \text{ m}^2) = \mathbf{492,600 \text{ kWh/year}}
 \end{aligned}$$

In this case, where the records of all the energy used in the building are available, the energy use can be simply totalled, and the annual EUI calculated directly:

$$EUI \text{ Total} = \{273,000 + 201,600 + 18,000 \text{ kWh/year}\} / (1,500 + 1,800 + 30 \text{ m}^2) = \mathbf{148 \text{ kWh/m}^2}$$

### 3.5 Multiple Premise Building with Monitored and Unmonitored Premises



**Figure 5: Multiple Premise Building with Monitored and Unmonitored Premises**

In this case, there are three premises, two of which are monitored, with energy use and floor areas as above. There is also a third premise, with unknown energy use, but a floor area of 3,000 m<sup>2</sup>. The landlord's assessed area and energy use are known, as above.

**Table 5: Multiple Premise Building with Monitored and Unmonitored Premises**

Premise	Floor Area	Energy Use
Monitored Premise 1	1,500 m <sup>2</sup>	273,000 kWh/year
Monitored Premise 2	1,800 m <sup>2</sup>	201,600 kWh/year
Landlord	30 m <sup>2</sup>	18,000 kWh/year
Unmonitored Premise	3,000 m <sup>2</sup>	?

In this case, the annual EUI of the two tenanted premises are averaged, this is applied to the monitored and unmonitored premises, and finally the tenancy and landlord EUIs are averaged for the whole building.

The overall annual EUI and energy use is calculated as follows:

$$EUI_{mp1} = E_{mp1}/A_{mp1} = \mathbf{182 \text{ kWh/m}^2} \quad (\text{refer Equation 9})$$

$$EUI_{mp2} = E_{mp2}/A_{mp2} = \mathbf{112 \text{ kWh/m}^2} \quad (\text{refer Equation 16})$$

$$(20) \quad EUI_a = \frac{\sum(EUI_{mp} \times A_{mp})}{(\sum A_{mp})}$$

$$= (182 \times 1,500 + 112 \times 1,800)/(1,500 + 1,800) = \mathbf{144 \text{ kWh/m}^2}$$

$$EUI_c = E_c/A_c = \mathbf{600 \text{ kWh/m}^2} \quad (\text{refer Equation 11})$$

$$(21) \quad EUI_b = \frac{\{EUI_a \times (\sum A_{mp} + \sum A_{up}) + EUI_c \times A_c\}}{(\sum A_{mp} + \sum A_{up} + A_c)}$$

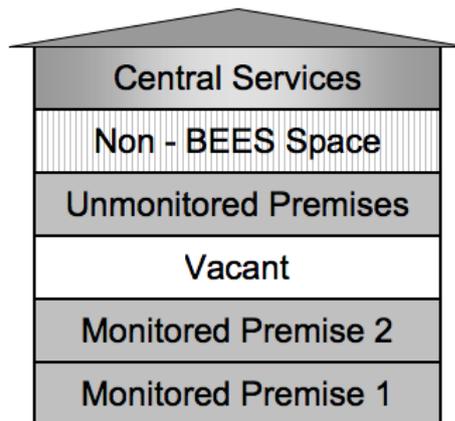
$$= \frac{\{144 \times (3,300 + 3,000 \text{ m}^2) + 600 \times 30 \text{ m}^2\}}{(3,300 + 3,000 + 30 \text{ m}^2)}$$

$$= \mathbf{146 \text{ kWh/m}^2}$$

$$(22) \quad E_b = EUI_b \times (\sum A_{mp} + \sum A_{up} + A_c)$$

$$= 146 \text{ kWh/m}^2 \times (3,300 + 3,000 + 30 \text{ m}^2) = \mathbf{924,055 \text{ kWh/year}}$$

### 3.6 Multiple Premise Building with Monitored and Unmonitored Premises, Vacant Premises and Non-BEES Spaces



**Figure 6: Multiple Premise Building with Monitored and Unmonitored Premises, Vacant Premises and Non-BEES Premises**

In this case, there are five premises, one of which is residential with a floor area of 1,000 m<sup>2</sup>, and outside of the BEES sample frame. Another premise is vacant, also with a floor area of 1,000 m<sup>2</sup>. Of the remaining three, two are monitored, with energy use and floor areas as in the above examples. The third premise has unknown energy use, but a floor area of 3,000 m<sup>2</sup>. The landlord's assessed area and energy use are known, as above.

**Table 6: Multiple Premise Building with Monitored, Unmonitored, Vacant and Non-BEES Premises Details**

Premise	Floor Area	Energy Use
Monitored Premise 1	1,500 m <sup>2</sup>	273,000 kWh/year
Monitored Premise 2	1,800 m <sup>2</sup>	201,600 kWh/year
Landlord	30 m <sup>2</sup>	18,000 kWh/year
Non-BEES (Residential)	1,000 m <sup>2</sup>	?
Vacant	1,000 m <sup>2</sup>	?
Unmonitored Premise	3,000 m <sup>2</sup>	?

In this case, the annual EUI of the two tenanted premises are averaged, this is applied to the monitored and unmonitored premises, and finally the tenancy and landlord annual EUIs are averaged for the whole building.

The overall annual EUI and energy use is calculated as follows:

$$EUI_{mp1} = E_{mp1}/A_{mp1} = \mathbf{182 kWh/m^2} \quad (\text{refer Equation 9})$$

$$EUI_{mp2} = E_{mp2}/A_{mp2} = \mathbf{112 kWh/m^2} \quad (\text{refer Equation 16})$$

$$EUI_a = \sum(EUI_{mp} \times A_{mp}) / (\sum A_{mp}) = \mathbf{144 kWh/m^2} \quad (\text{refer Equation 17})$$

$$EUI_c = E_c/A_c = \mathbf{600 kWh/m^2} \quad (\text{refer Equation 11})$$

$$(23) \quad E_b = EUI_a \times (\sum A_{mp} + \sum A_{up}) + EUI_{on} \times \sum A_{on} + EUI_{un} \times \sum A_{un} + EUI_c \times A_c$$

$$= 144 \times (3,300 + 3,000 m^2) + 200 \times 1,000 m^2 + 0 + 600 \times 30 m^2$$

$$= \mathbf{1,125,200 kWh/year}$$

$$(24) \quad EUI_b = E_b / (\sum A_{mp} + \sum A_{up} + \sum A_{on} + \sum A_{un} + A_v + A_c)$$

$$= 1,125,200 kWh/year / (3,300 + 3,000 + 1,000 + 1,000 + 30 m^2)$$

$$= \mathbf{135 kWh/m^2}$$

## 4. ISSUES

### 4.1 Annualising Energy Purchase Records

There are several issues around the assessment of annual energy purchases for buildings.

Ideally, the daily purchase records for the premises, up to and including the monitoring period would be analysed, and the 365 days of records prior to the conclusion of the monitoring would be summed to give the annual purchases. The choice of energy data BEFORE the monitoring period is to avoid the effects of changes to the site's equipment or operation (such as changing tenants) that take place after the monitoring is completed.

However, due to the vagaries of revenue metering, recording and energy supplier cooperation, daily records are not generally available, although this may change as smart metering becomes more widely used. Most premises evaluated in BEES investigations had some historical monthly electricity and gas purchase data available, usually for at least a year preceding the monitoring. Where possible we received at least two years worth of purchase data, however some sites have less than a year's data available, other sites have multiple years, and some sites have data that is not realistic (such as constant daily usage for many months in a row). In some cases there have been changes of use or not all of the building or space has been occupied for the entire period for which purchase data is available.

Of the sites with multiple years of energy purchase data, the most recent year's data will be taken as representative of the site as it was surveyed and monitored. Due to frequent changes in tenants it is not appropriate to take more than the previous years data, unless there are valid reasons for not doing so. For this purposes of this analysis it has been assumed that year on year climate variations are not significant.

### 4.2 Inexact Years of Energy Purchase Data

There is often some variation in month-to-month meter reading dates, so that the sum of twelve nominally monthly energy purchase records will not necessarily give the usage over a calendar year (365 days). To account for this, the data is converted to average daily values between true meter readings (the estimate readings every second month by some providers is ignored). The year is taken as 365 days.

Example:

*A site has been monitored between 12 June and 26 June 2011. The electrical revenue meter reading date following the monitoring was 30 June 2011. There are twelve monthly electrical energy purchase records available, stretching back before June 2010.*

*The intention is to assess the energy use between 1 July 2010 and 30 June 2011.*

*The oldest relevant purchase record is for the usage between the meter reading dates (i.e. not an estimated reading) of 24 June 2010 and 23 July 2010, during which time the site used 3,306 kWh. These purchases were over 29 days, so the average daily usage over that period was 114 kWh/day.*

*Thus for the period of 1 July through 23 July 2010, the assessed energy use is*

$$23 \text{ days} \times 114 \text{ kWh/day} = 2,622 \text{ kWh}$$

*This total should be used for the earliest month's use, and (presuming continuous metering), the sum of the twelve monthly purchase records should cover the equivalent of 365 days.*

### 4.3 Incomplete Years of Energy Purchase Data

If there is less than a year's worth of energy purchase records for a building, but more than six months, then the six month period that includes the highest and lowest average daily consumption (kWh/d) should

have its average daily use (kWh/d) calculated. This average should then be multiplied by 365 days/year to get an estimate of the annual consumption.

If the energy purchase records are less than six months in duration, the extrapolation becomes difficult, and probably this premise should not be used in the analysis. The decision not to use a particular premise's records will be decided on a case-by-case basis.

#### **4.4 The Effects of Working and Non-Working Days**

Originally it was intended to analyse the energy purchases for each site by occupied and unoccupied day (typically weekdays, weekend days and public holidays), but this was not found to be fruitful for various reasons:

Much of the electricity (and all of the gas) purchase data is aggregated into monthly or larger amounts, and cannot be separated into occupied/unoccupied days. Although our analysis has attempted to eliminate the effect of estimated meter readings, there are still visible effects showing in the data, including:

- *Sites sometimes showed unusual patterns of significantly higher or lower monthly purchases than would have been expected from temperature (seasonal) or occupancy effects.*
- *Sites occasionally showed large year-to-year variations in the patterns of daily purchases, trending either up or down by over  $\pm 50\%$ .*
- *Some retail food premises have several different daily schedules each week for example some days they are open for breakfast, lunch and dinner and others days open for only breakfast and lunch. A simple "occupied / unoccupied" signal does not adequately account for this effect.*

In summary, the amount of extra precision in the results (if any) that this adjustment would deliver is considered to be much less than the effort required to generate it.

## **5. SUMMARY**

This report defines the method of estimating the energy use of entire buildings from measurements of individual premises that will now be used in developing reports from BEES monitoring data. Comments and suggestions are invited.