Australian Government
Department of Resources, Energy and Tourism

ENERGY EFFICIENCY OPPORTUNITIES

REPRESENTATIVE ASSESSMENT GUIDE

National Framework for Energy Efficiency

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Energy Efficiency Opportunities guide to Representative Assessments

ISBN 978-1-921516-73-3 (hardcopy)
978-1-921516-74-0 (electronic pdf)

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Important notice – please read

This guide does not replace or modify any of the requirements in the *Energy Efficiency Opportunities Act 2006* or the Energy Efficiency Opportunities Regulations 2006.

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1 INTRODUCTION

1.1 ABOUT THE ENERGY EFFICIENCY OPPORTUNITIES PROGRAM

The Energy Efficiency Opportunities (EEO) program applies to corporations or corporate groups that use more than 0.5 PJ of energy per year. These corporations are required by legislation to undertake a rigorous and comprehensive assessment of their energy use, identify cost-effective savings opportunities, and report publicly on the outcomes. Corporations must assess 80% of their group's baseline energy use during the first five-year program cycle, and 90% in following cycles, and also assess any site that uses more than 0.5 PJ per year. Corporations must meet the 19 key requirements of the program's Assessment Framework to ensure they have completed an effective assessment. They must also submit an assessment plan – the Assessment and Reporting Schedule (ARS) – outlining how they will undertake their assessments and report on the outcomes.

1.2 OPTIONS FOR CONDUCTING ENERGY EFFICIENCY OPPORTUNITIES ASSESSMENTS

Companies with large, complex sites that use more than 0.5 PJ per year will need to assess each of these individually. For companies with a population of similar sites, fleets, technologies or processes using less than 0.5 PJ per year, the Energy Efficiency Opportunities Regulations 2006 give companies the option of seeking approval to undertake an assessment on a sample that is reasonably representative of the population – a representative assessment (RA). Results from a detailed assessment of the sample can then be applied to the wider population.

Companies must state in their ARS whether they intend to use the RA approach, detail the entities and sites which the RA will cover, and demonstrate that using this approach will not diminish the accuracy and comprehensiveness of the assessment. RAs can cover a range of 'energy use processes' (see Section 2.2.2) across all industries including, but not limited to, vehicles, retail outlets, telecommunications equipment or manufacturing processes. If a company has already submitted an ARS, and later decides to conduct a representative assessment, it must submit a revised ARS to include this information. Section 2.1.1 outlines the requirements for RAs in the regulations.

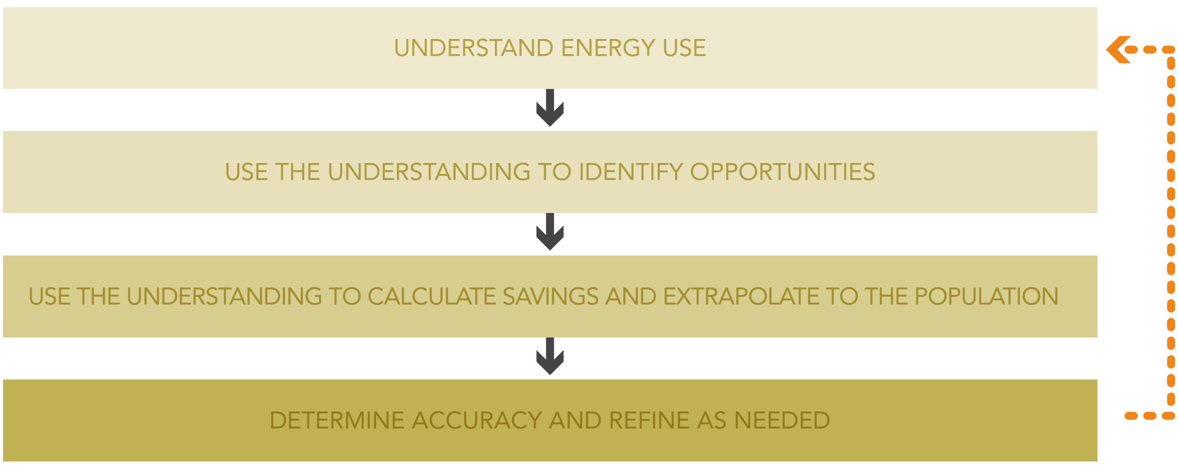
1.3 PURPOSE OF THE GUIDE

The purpose of this Representative Assessment Guide (the guide) is to:

- assist organisations to determine whether an RA is appropriate for their circumstances; and
- provide advice on how organisations can undertake an RA to meet the requirements of Key Elements 3 and 4 of the program's Assessment Framework.

1.4 USING THIS GUIDE

This guide aims to help companies establish whether a representative assessment is appropriate for their circumstances, and provide them with guidance on how to how to conduct an RA to the level of accuracy required by the Energy Efficiency Opportunities program. Like assessments of individual sites or processes, the broad aim of an RA is to build an understanding of energy use, and to use this understanding to identify and quantify energy efficiency opportunities.



This guide will step you through:

- deciding whether an RA would be appropriate for your company's circumstances;
- determining which energy use processes could use an RA approach;
- what kinds of data, and the level of skills, a company will need to undertake an RA;
- understanding the variations in energy use between and within energy use processes;
- how to sample a population of energy use processes, and the merits of different sampling methods;
- how to undertake a regression analysis and/or non-statistical modelling to examine the factors that have a greater or lesser influence on energy use;
- how to use an energy use model to identify and quantify cost-effective energy efficiency opportunities;
- how to progressively improve an assessment;
- how to build a business case to implement opportunities; and
- making sure the RA approach meets the program's accuracy and verification requirements.

This guide will be most useful for companies with a population of similar energy using processes, but it may also be useful for companies looking to gain a greater understanding of the complex interactions between energy systems, using a range of statistical and non-statistical methods.

1.5 WHERE DOES THIS GUIDE FIT WITH OTHER PROGRAM RESOURCE MATERIAL?

This guide is one of a number of resources developed by the Department of Resources, Energy and Tourism (the Department) to assist companies to undertake an effective Energy Efficiency Opportunities program assessment:

- The *Industry Guidelines* provide a plain English guide to the *Energy Efficiency Opportunities Act 2006* and regulations, with all of the regulated steps from registration to reporting.
- The *Assessment Handbook* provides a practical step-by-step guide to the assessment process, from planning through to implementation and reporting.
- Industry case studies demonstrate how organisations have approached energy efficiency assessments, including some of the outcomes, benefits and lessons learned from the process.
- Energy mass balance (EMB) case examples demonstrate how EMBs can be used as a data analysis tool in different industry sectors to understand how and where energy is used (Key Element 3).
- The *Energy Savings Measurement Guide* (*ESMG*) helps organisations to estimate, measure, evaluate and track energy savings, costs and benefits (Key Elements 3, 4 and 5).
- This document, the *Representative Assessment Guide*, assists organisations to determine whether a representative assessment approach is appropriate and beneficial for their business and provides a practical guide to RAs. (Key Elements 3 and 4).

All of these resources are available at www.energyefficiencyopportunities.gov.au.

The aim of this guide is to describe the procedures that are unique to assessing a large number of similar energy use processes (EUPs). Some companies may use more than one procedure to assess their energy use. This guide provides a brief description of other procedures (such as individual assessments) and refers the reader to the relevant documents for more detail.

2 ABOUT REPRESENTATIVE ASSESSMENTS

A representative assessment examines energy use and energy efficiency opportunities in a population of similar sites, vehicles or processes without the need for detailed investigation of each one. The obvious advantage of this approach is that it can reduce the cost, time and effort required for an assessment. An effective RA builds an understanding of energy usage that can be used to identify and quantify energy efficiency opportunities

For the purpose of this guide, all sites, vehicles or processes subject to a representative assessment are referred to as 'energy use processes' or EUPs.

An RA will be successful if the assessment of energy use and opportunities is sufficiently accurate for business decision making purposes and compliance with the program's requirements. More detail on compliance issues relating to RAs is provided in Section 5.

2.1 REPRESENTATIVE ASSESSMENTS FOR ENERGY EFFICIENCY OPPORTUNITIES

The central requirement of the Energy Efficiency Opportunities program is that rigorous and comprehensive assessment of energy usage[1] is carried out across a controlling corporation and its group members. The assessment must identify and publicly report those cost-effective energy savings and efficiency opportunities that will provide the business with up to a four year payback. To ensure that assessments are rigorous and comprehensive, the corporation and responsible entities must meet the 19 key requirements of the program's Assessment Framework.

In some organisations energy use is dispersed across a large number of relatively small energy using sites, vehicles or processes. Energy Efficiency Opportunities was therefore designed to enable participating companies with a large number of similar EUPs to focus their assessments on a sample which is representative of the whole group (or population) i.e. to undertake a representative assessment.

Companies that plan to conduct an RA of their energy use and opportunities, must include this information and their proposed approach in their ARS for Departmental approval.

BOX 1: REGULATORY REQUIREMENTS.

Paragraph 304 in Part 3 of Schedule 3 of the Energy Efficiency Opportunities Regulations 2006 states that the Assessment and Reporting Schedule must include:

A statement:

(a) stating whether the controlling corporation proposes, for sites, technologies or processes for which the annual use of energy is less than 0.5 PJ, to undertake assessments that can be shown to be reasonably representative of other sites, technologies and processes; and

(b) if the controlling corporation intends to undertake a representative assessment:
   (i) the entities or sites for which the representative assessment will be conducted; and
   (ii) information showing that the manner of undertaking a representative assessment will not diminish the accuracy and comprehensiveness of the assessment.

Examples

1 Assessing a sample of retail outlets that is representative of a larger population of outlets.

2 Assessing a sample of vehicles that is representative of a larger fleet of vehicles.

3 Assessing a machine or technology that is used in an identical fashion at other sites or within a site.

4 Assessing a commercial building that is representative of a population of commercial buildings.

1 'energy usage' means the way energy is used (by which equipment, when, etc.)

2.2 TERMS AND CONCEPTS USED IN THIS GUIDE

2.2.1 Terms

Terms, acronyms and abbreviations that have a particular meaning in the context of Energy Efficiency Opportunities and representative assessments are listed in the Glossary at Appendix A.

2.2.2 Energy use process

Companies participating in Energy Efficiency Opportunities cover a wide range of industry sectors and energy uses, including mining equipment, resource processing, manufacturing, communications, transport, and commercial buildings such as offices, accommodation, retail, and education.

Participants in the same industry sector may have different methods for segmenting and analysing energy use, for example by site, by technology, region or task. It is therefore necessary to find a term which applies equally to all participants and energy uses, and does not imply a particular way of segmenting energy use.

Throughout this guide the term 'EUP' is used to mean any 'energy use process', for example a single vehicle, a manufacturing plant or all the boilers in similar applications at dispersed sites. The meaning that is attached to the term will vary between industries and organisations.

2.2.3 Energy use model

Energy use assessments aim to progressively build an understanding of energy use. This includes identifying the factors that affect energy use, how those factors influence energy use and the extent of this impact. Understanding energy use is necessary both for establishing an energy use baseline, and to identify and evaluate energy efficiency opportunities.

This guide uses the concept of an energy use model to refer to the understanding of energy usage, and the analytical methods which can be used to build the model's detail, accuracy and usefulness. The energy model and its role are described in Section 4.5.

2.3 HOW TO USE THIS GUIDE

The guide aims to present material in a logical sequence so that it can be read sequentially. However, the material is divided into sections which stand alone, so the reader can go directly to the section which deals with the topic most relevant to the current stage of their Energy Efficiency Opportunities assessment. Where relevant, these are cross-referenced to relevant information elsewhere in this guide. The main sections of the guide are:

SECTION 1: INTRODUCTION

↓

SECTION 2: ABOUT REPRESENTATIVE ASSESSMENTS

↓

SECTION 3: WHEN IS A REPRESENTATIVE ASSESSMENT APPROPRIATE?

↓

SECTION 4: HOW TO CONDUCT A REPRESENTATIVE ASSESSMENT

↓

SECTION 5: HAS ENOUGH BEEN DONE TO MEET EEO REQUIREMENTS?

↓

SECTION 6: SUPPORT MATERIAL (APPENDICES)

3 WHEN IS A REPRESENTATIVE ASSESSMENT APPROPRIATE?

Key questions in this section:

- When is a representative assessment appropriate?
- When is a representative assessment not permitted?
- What is the alternative to a representative assessment?
- What are the benefits of a representative assessment?
- Are any special skills required?

3.1 WHEN IS A REPRESENTATIVE ASSESSMENT APPROPRIATE?

Using an RA rather than an individual assessment is appropriate where there is a reasonable expectation that Energy Efficiency Opportunities accuracy requirements can be met. That is, an RA will not diminish the accuracy and comprehensiveness of the assessment. There are two methods which can contribute to achieving this accuracy: statistical and non-statistical methods. These are described in Section 4.

3.2 WHEN IS A REPRESENTATIVE ASSESSMENT NOT PERMITTED?

A representative assessment is not permitted for any site, technology or process which uses more than 0.5 PJ of energy per year. An organisation that has a mix of sites and processes above and below this threshold may be able to meet its Energy Efficiency Opportunities obligations using a mix of RAs and individual assessments. For further information refer to paragraph 304 in Part 3 of Schedule 3 of the Energy Efficiency Opportunities Regulations 2006, as presented in Section 2.1.1.

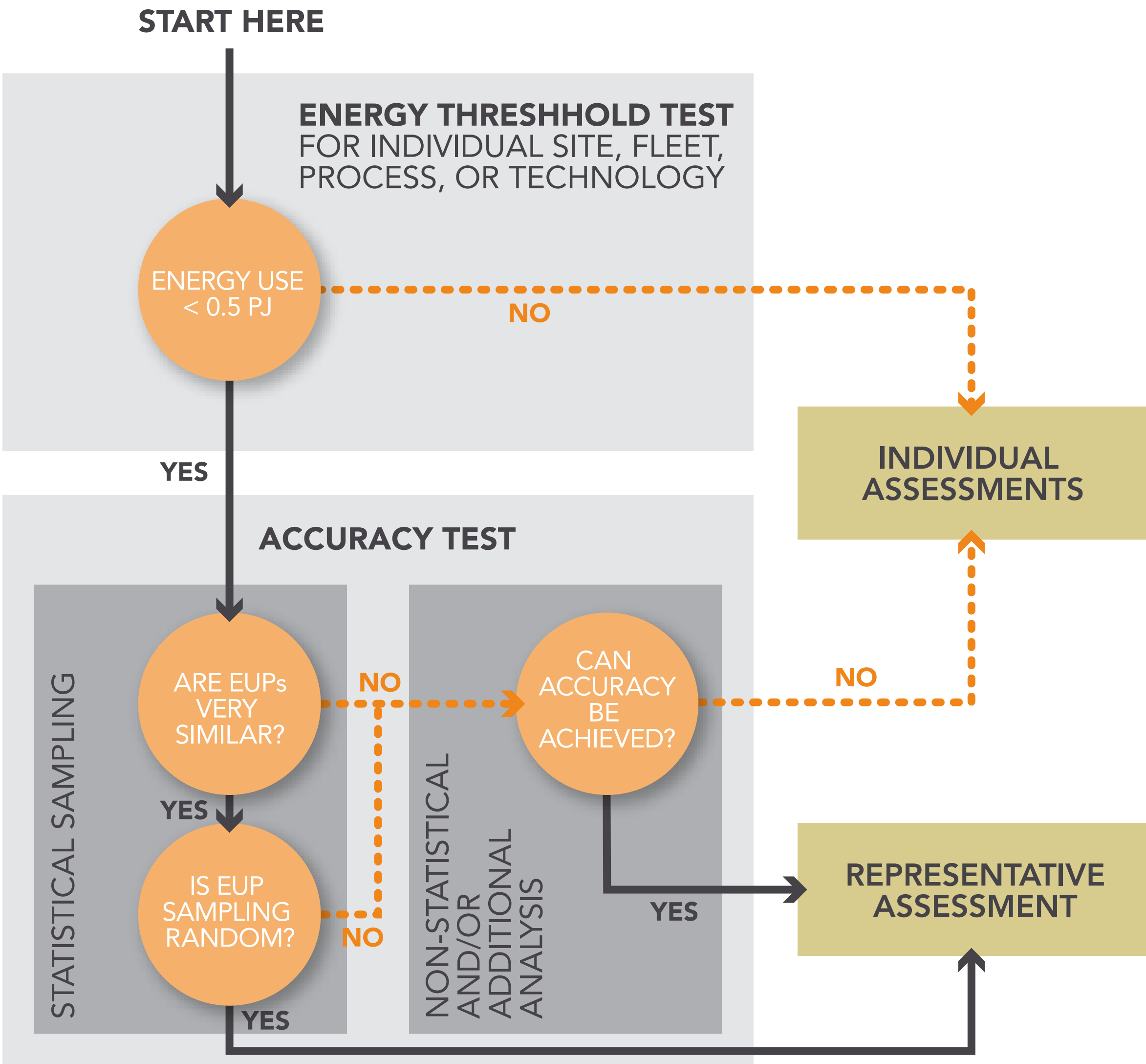
3.3 WHAT IS THE ALTERNATIVE TO A REPRESENTATIVE ASSESSMENT?

The standard approach to conducting assessments is to assess energy usage for every EUP by measuring energy consumption, inputs and external conditions for that EUP, identifying energy saving opportunities for the EUP, and assessing those opportunities. For the purpose of this guide, such an approach is called an individual assessment. Under some circumstances the Energy Efficiency Opportunities program does not permit an RA, so an individual assessment must be undertaken.

3.4 DECIDING WHETHER OR NOT TO CONDUCT A REPRESENTATIVE ASSESSMENT

The overall decision making process is shown in Figure 1. Key decisions and processes are described in the following sections.

Figure 1: Decision tree – representative assessment or individual assessments?



3.5 EVALUATING THE COSTS AND BENEFITS OF A REPRESENTATIVE ASSESSMENT

Providing that the energy consumption threshold test and accuracy criteria described earlier in this section are satisfied, the decision on whether or not an RA can potentially be used will be based on the costs and benefits to each Energy Efficiency Opportunities participant.

For some organisations, with hundreds or even thousands of similar EUPs, the large savings in time and money will clearly favour a representative approach. In such cases an RA will be chosen even if additional data, skills and tools must be acquired, as this will still be faster and less costly and time-consuming than conducting individual assessments.

For other organisations, even those with similar EUPs, it may be preferable to conduct individual assessments. For example, if a manufacturer has factories making the same food product in five different states, energy use might vary between the plants because of different climatic conditions. The factories may also be at various stages of developing an energy management plan. In this case the company might decide to use different consultants near each plant to work with the factory energy or environmental teams to undertake individual assessments, building on progress to date with their energy management plans.

Apart from comparing the costs of RAs and individual assessments, there are other possible advantages of RAs over individual assessments which need to be considered:

- *Economy:* RAs are more likely to achieve economies of scale in the design, purchase, installation of equipment, and, more generally, trialling and fine-tuning of energy efficiency improvements than individual assessments, which may recommend a variety different of energy efficiency improvements (even if the EUPs are similar).
- *Sharing the benefits:* RA tools and methods provided in this guide will help organisations to document and systematise the understanding of energy usage and the sharing of information. Even if an organisation has only two similar EUPs, it is very likely that there will be lessons from each one that can benefit the other. Sometimes these lessons are shared through informal contact between staff at the sites. However, formal approaches may be needed to ensure that lessons are documented and shared.
- *Quicker identification of opportunities:* An RA is likely to be a faster process for identifying some energy efficiency opportunities than a number of individual assessments. Earlier identification means the opportunities can be assessed, reported and implemented sooner.
- *Identification of additional opportunities:* An RA has the potential to identify opportunities that would not be identified using individual assessments because of the greater depth of analysis that is possible within the sample (to partially replace breadth of analysis) and insights provided by comparing energy usage between EUPs.
- *More accurate evaluation of opportunities:* The greater depth of analysis can increase the accuracy of opportunity evaluation for the sample, partly offsetting sampling error.

Once a company has evaluated the costs and benefits and decided to adopt the RA approach for particular EUPs, the approach must be included in the ARS and approved by the Department.

3.6 SKILLS REQUIRED FOR THE ASSESSMENT

RAs will require the same skills that are required for individual assessments, as well as some statistical skills and possibly modelling skills. Statistical skills should be easier to learn or hire than the engineering and other skills required for individual assessments. In any case, the cost of learning or acquiring these skills is likely to be much lower than the savings achieved by conducting an RA.

4 HOW TO CONDUCT A REPRESENTATIVE ASSESSMENT

4.1 OVERVIEW OF THIS SECTION

This section provides guidelines on conducting a representative assessment of energy efficiency opportunities, including:

- planning the assessment;
- understanding variation in energy use between EUPs;
- representative sampling;
- the energy use model;
- regression analysis; and
- progressive and iterative improvement.

4.2 REVIEWING THE SITUATION AND PLANNING THE ASSESSMENT

4.2.1 Assessment and Reporting Schedule

The first step is to review the planned assessment against the organisation's approved ARS. Are the methods that will be used to define the population of EUPs and assess energy usage and efficiency opportunities consistent with the methods previously approved by the Department through the ARS? If not, any proposed changes will need to be discussed with the Departmental Client Liaison Officer.

4.2.2 Population selection

For the energy use which is to be representatively assessed, consider whether it is best to define the population of EUPs as, for example; sites, technologies, vehicle types, or transport tasks. The viability of this choice will be influenced by existing data and the similarity of the EUPs and their energy usage.

4.2.3 Similarity of EUPs

It is important to consider the level of similarity between EUPs, and the level of similarity of their energy usage. Energy use may vary significantly between seemingly identical EUPs because of their different tasks, operating conditions, human operators, and raw materials. For example:

- It might be assumed that all automatic teller machines of a certain model have the same or very similar energy consumption, regardless of climate and number of transactions.
- Vehicles of the same make and model might carry different loads over different routes, and so have very different energy consumption.
- Manufacturing machines might have an identical design but energy use may differ between the machines because of product or raw material specifications, ambient conditions, or operating methods.
- Supermarkets' energy use might be expected to vary widely, because of known differences in design, size, climate, trading hours, or installed equipment.

The degree of similarity between EUPs and their energy usage, and the ability to quantify and correct for the effect of any differences will influence how the RA is conducted, for example:

- selection of methods for investigating and understanding energy use;
- whether to segment the population of EUPs into smaller, similar groups;
- the role of sampling, deciding the sample size and selecting the sample; and
- the steps and iterations required to identify and quantify energy efficiency opportunities with the required level of accuracy.

4.2.4 Data availability

The availability of data on energy consumption and the factors thought to affect consumption is important. Energy consumption data on individual EUPs may vary from 15 minute electricity data for petrol stations with interval billing meters, to non-existent data for individual vehicles which are refuelled at a depot, or for individual machines within a factory.

The following questions will help to analyse the availability and quality of data:

- How easy is it to obtain data on energy consumption and on the factors thought to affect energy consumption (e.g. building size, number of customers, vehicle payload, driver identity)?
- How accurate is the data? Has it been validated or tested?
- How current is the data? If the data is old, is it still accurate, or have the EUPs changed since the data was collected?
- What previous energy investigations have been conducted, and are the results available and still applicable?
- What energy efficiency improvements have been previously evaluated, trialled or implemented? What data is available on these?

The availability and quality of this data will affect the effort and time required to assess energy usage. It may also influence the selection or scheduling of the analytical methods described in this guide.

4.2.5 Planning the assessment

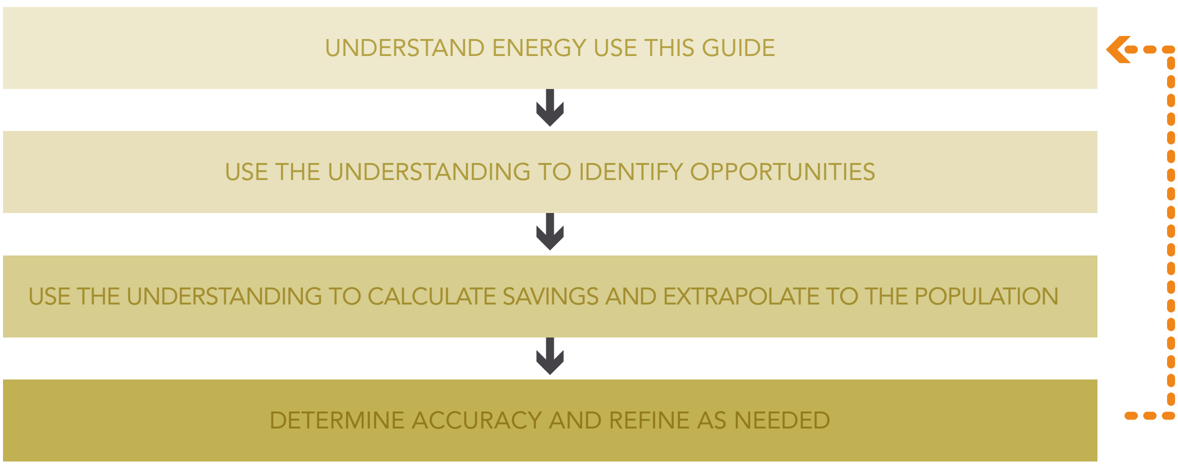
At the planning stage it is therefore necessary to decide:

- how the EUPs will be defined;
- whether the population will be divided into smaller groups for assessment, and if so, how;
- which investigative and modelling methods will be used to understand energy usage; and
- how accuracy will be measured and which refinements might be needed to reach the required accuracy.

4.3 REPRESENTATIVE PROCESS AND METHODS

Like individual assessments, the overall aim of an RA is to build an understanding of energy usage and to use this understanding to identify and quantify energy efficiency opportunities. Figure 2 shows the assessment process.

Figure 2: The Energy Efficiency Opportunities assessment process



The main distinguishing feature of RAs is the task of identifying and quantifying energy efficiency opportunities for all EUPs, without conducting detailed investigations of every EUP. This, in turn, involves two activities which are not a part of an individual assessment:

- ***understanding*** how energy use varies between the EUPs in the population being assessed; and
- ***adjusting*** the predicted energy savings of each opportunity identified, for each of the EUPs in the population, to the extent required by differences in the variables influencing energy use.

The ***adjustment*** of calculated energy savings relies on first ***understanding*** the variation in energy usage between the EUPs in a population. The remainder of this section includes a description of the methods which can be used to achieve this understanding and adjustment.

4.3.1 Responses to variation in energy usage

Table 1 describes the three categories of variation in energy usage between EUPs, and possible responses to help identify and assess energy efficiency opportunities with the required level of accuracy.

Table 1: Responses to variation in energy usage

Variation in energy usage	Response
1. The variation is thought to be small enough that accuracy can be achieved by assessing a sample. EUPs which might have sufficiently similar energy usage include ATMs, public phones and computers.	Check the variation in energy usage between EUPs. If the variation is small enough that the required accuracy can be achieved, assess energy usage and energy efficiency opportunities in a sample. Sampling is discussed in Section 4.4. Extrapolation of the energy savings from the sample to the population is the simple multiplication from the sample results to the population.
2. Energy usage is thought to vary only according to one or a few well-defined characteristics.	Either: • divide the population into groups with very similar energy usage (this is known as segmentation, or stratification), then treat each segment as a homogenous group as described for the population in the previous row; or • create an energy use model for the entire population which describes mathematically the variation in energy usage between the EUPs (see the next row). The parameter values for each EUP in the population should then be entered into the model and summed to determine population energy use. The choice between these methods will depend on a comparison of the costs, benefits and accuracy of each approach for these EUPs.
3. The variation in energy usage between EUPs is wide and dependent on several variables, so that the population is not homogenous. Segmenting the population is likely to require many segments and assessments of the EUPs in each one.	Progressively build an energy use model which: • quantifies the effect of the differences between the EUPs on their energy usage; • assists in identifying energy efficiency opportunities; and • provides a means of adjusting the calculated or piloted energy savings for each EUP according to the differences in their characteristics or operation. Energy use models are described in Section 4.5.

4.3.2 Estimating variation in energy usage

It is necessary to understand the variation in energy usage between the EUPs so that appropriate analytical methods can be selected. This might be informed by, for example:

- applied logic, such as "we expect all our Type XYZ computer servers to have very similar energy usage because they are all the same brand, model and age, and appear to be performing very similar tasks";
- manufacturer's data;
- previous testing, energy audits, sub-metering, etc; or
- billing data showing that the energy consumption of all EUPs is the same (note that the consumption could be the same but energy usage profiles could be different and so the energy savings from some opportunities may vary between EUPs).

4.3.3 Methods for dealing with variation in energy usage

The following table summarises the methods of dealing with variation in energy usage between EUPs. Some of these tools may also have application in individual assessments.

Table 2 outlines the methods which are unique to RAs or have a unique application in RAs.

Table 2: Methods of dealing with variation in energy usage

Method	Use in individual assessments	Additional or unique use in RAs
Stratification (in sampling)	None	Creating smaller groups of similar EUPs in which there is lower variation in energy usage than in the population, and so assessment accuracy is increased.
Modelling	Understanding energy usage in a single EUP, and explaining the variation in energy use e.g. with changing time.	Understanding the variation in energy use between individual EUPs, by relating the variation to the EUPs' variables. Adjusting the calculated energy savings of an efficiency opportunity to the parameter values of different EUPs, to take account of difference in energy usage of the EUPs.
Regression analysis	Revealing the relationship between the energy use of an individual EUP and the independent variables, e.g. weather, operator behaviour, raw materials or production volume.	Revealing the relationship between the variation in energy use between EUPs, and the values of variables thought to influence energy use.

4.4 REPRESENTATIVE SAMPLING

Key questions in this section:

- What is representative sampling?
- What is the role of representative sampling in an RA?
- How is a representative sample selected?
- How big does the sample need to be?
- How do you undertake representative sampling in an RA?

4.4.1 What is representative sampling?

A representative sample is a small subset of a population whose characteristics represent those of the entire population with sufficient accuracy.

Representative sampling for the purposes of the Energy Efficiency Opportunities program is a type of sampling where an attempt is made to select EUPs which are representative of a larger population of those EUPs.

The premise underlying the ability to do a representative sample is that the population is sufficiently similar that only a fraction of the population needs to be studied (assessed) to be able to understand energy usage and evaluate opportunities with the required accuracy.

Representative sampling has these main steps:

- deciding whether the population is sufficiently similar that it can be assessed as a single group;
- if not sufficiently similar, dividing the population of EUPs into groups which are expected to have sufficiently similar energy usage (stratifying the population into segments);
- selecting a sample of EUPs from the population or segment;
- detailed assessment of energy usage and energy efficiency opportunities of the sample EUPs (as would be done with individual assessments); and
- extrapolation of the results of the assessment of the sample to the population.

There are two possible ways to generate a representative sample:

- The first and most rigorous method is to select the sample of EUPs using random sampling. In this statistical sampling, data is gathered from a small group and the results are extrapolated to make statistical generalisations about a larger group.
- The second and considerably less rigorous approach is non-statistical sampling, using methods such as *convenience sampling* and *quota sampling*. Convenience sampling[2] occurs when samples are mainly selected on the basis of their convenience, such as selecting a factory because it has an enthusiastic sustainability manager. Quota sampling selects the sample based on objective, logical criteria (e.g. one of each store type, or from each state or company operating division). Quota sampling is more likely to be representative than convenience sampling, but like convenience sampling it is non-random. Truly representative sampling is extremely hard to accomplish where non-statistical sampling techniques are used. Non-statistical methods would be required to extrapolate from the sample to the population and to assess the accuracy of this extrapolation process.

4.4.2 Simple and stratified sampling

There are two random statistical sampling techniques which can be used:

- Simple random statistical sampling techniques can be used where the total population consists of one similar EUP.
- Stratified random sampling techniques are required where the total population can be divided ('stratified') into segments of the same or similar EUPs. Within each segment the variation in energy usage is expected to be small enough to allow energy efficiency opportunities to be assessed with sufficient accuracy. This means that the assessment of energy usage and energy efficiency opportunities applies equally and accurately across all EUPs in that segment. Stratification is required when there are different groups of homogeneous EUPs that need to be investigated separately, such as refrigerated trucks, courier vans and semi-trailers.

Both random statistical sampling techniques are summarised in the program's Energy Savings Measurement Guide. They are also well documented in statistical textbooks, and are included in most statistical software packages.

4.4.3 How to stratify the population

The steps in stratification are:

- deciding on the variable(s) which will be used to divide the EUPs into groups with similar energy use; and
- using this variable(s) to divide the population into groups.

2 'Convenience sampling' and 'quota sampling' are defined in the Glossary at Appendix A.

For example, the only two variables affecting energy usage in a population of 1200 fast food restaurants of a standard design might be:

- cooking equipment supplier (i.e. 'brand A, brand B, or brand C'); and
- inclusion of a coffee shop (i.e. 'with or without a coffee shop').

The objective is to minimise variation within each segment and to maximise variation between segments. The simple classification for the fast food restaurants and the number of stores in each segment are shown in Table 3.

Table 3: Example of a simple classification system for fast food restaurants

Coffee shop included? → Cooking equipment supplier ↓	With coffee shop	Without coffee shop	Total
Brand A	100	175	275
Brand B	250	0	250
Brand C	275	400	675
Total	**625**	**575**	**1,200**

Classification variables can be:

- binary variables (i.e. which can only take only two possible values, such as 'with or without a coffee shop');
- discrete variables (e.g. equipment brand A, or brand B, or brand C), with a known number of possible values, either numerical or non-numerical; or
- continuous variables (e.g. process time) with no limit to the number of possible numerical values.

For example, a supermarket chain might decide that floor area is a useful classification variable. Floor area is a continuous variable which can have many values, so a further step is needed to select ranges of values of that variable for classification, for example:

- small supermarkets: < 2,500 m^2
- medium supermarkets: 2,500 m^2 to 5,000 m^2
- large supermarkets: > 5,000 m^2.

> The selection of classification variables should be based on the reasonable expectation that all EUPs within the group will have very similar energy usage and the variables are known or believed to influence energy use.

Classification variables could include factors such as process type, process throughput, process location, process duration, process technology, boiler fuel source, feedstock type, quarry type (hard or soft rock) or the number of lines in a communications network.

Most EUPs, even where energy usage may seem to vary little between members of the population, could require at least three classification variables. If each classification variable has just two values, the classification and stratification will result in six segments from which samples will be drawn. Energy usage and efficiency opportunities must then be investigated for each of these segments.

More classification variables will result in:

- more population segments and more samples for assessment; but
- less variation in energy use within each segment, and therefore fewer members of the segment will be needed to accurately represent energy usage in segment.

4.4.4 Sample design

The design of the sample, i.e. selecting a sample of the population to represent the population, might be based on random selection or non-random selection.

Statistical sampling is based on the random selection of a sample. This is an unbiased sampling technique in which every member of a population has an equal and known chance of being included in the sample. It is possible to estimate the required sample size to deliver the required statistical accuracy for a randomly selected sample.

For a random sample that is normally distributed, the required sample size for a given level of accuracy can be estimated using:

$$n_0 = \frac{z^2 \times C_V^2}{e^2}$$

where:

Cv is the coefficient of variance (the ratio of sample standard deviation to the sample mean) which can be assumed to be 0.5 in the first instance. Alternatively, test measurements or previous data can be used to obtain values for Cv;

e is the precision requirement, such as 0.05;

z is the normal distribution value for the desired confidence level, taken from the t distribution Table using an infinite sample size. The value of z for a 95% confidence level, consistent with the National Greenhouse and Energy Reporting System (NGERS), is 1.96.

Once a suitably sized sample has been analysed, the required sample size can be refined by adjusting the value of Cv.

For example, analysis of a sample of 10 out of 253 courier vans gave a mean fuel consumption of 10.9L/100km, with a standard deviation of 2.6L. The company estimated that an accuracy level of ±10% would be required to evaluate a major capital investment in liquid petroleum gas conversions. At the 95% confidence level, the required sample size to deliver an accuracy level of ±10% can be estimated at:

$$n = \frac{1.96^2 \times (2.6/10.9)^2}{0.1^2} = 22$$

This indicates the need to increase the sample size to 22 before undertaking the representative assessment.

Non-random selection may introduce an (unmeasured) bias which may reduce the representativeness of the sample. It also makes it difficult to quantify the accuracy of the sample-to-population extrapolation process. The size and type of this bias cannot be determined easily.

The challenge with any non-random selection is ensuring (or determining whether) the selection process generates a sample that is truly representative of the underlying population that the sample has been drawn from.

An organisation that uses non-random selection must be able to explain how the selected sample is representative of the underlying population, in order to obtain ARS approval. Reasons should be documented for verification purposes.

Non-random statistical sampling techniques

There is no simple (or established) statistical process to establish that a sample selected using a non-random sampling technique is representative of the population. A strong logical argument will be needed to support the contention that the selected sample is representative of the energy use profile of the population.

Sampling ratio

The sampling ratio is the percentage of the population (or segment of the population) which is selected for further assessment. There is no absolute rule on the sampling ratio required. The governing principle is that the overall RA must:

- identify the energy efficiency opportunities in the population; and
- accurately[3] quantify the savings and costs of these opportunities.

The sample ratio required to achieve these requirements will depend on:

- the variation in energy usage expected in the segment of the population, for example energy usage in supermarket lighting systems of the same design might be expected to vary little around Australia, while supermarket cooling systems might be expected to vary significantly with climate and sales volume;
- the extent and appropriateness of the stratification of the EUPs into sub-populations for sampling; and
- additional methods, data and investigations undertaken to refine the understanding of energy usage and efficiency opportunities;
- trialling and piloting of energy efficiency opportunities.

It could be that a sample of two or even one is sufficient where non-statistical modelling is used, providing that it can be demonstrated that the accuracy requirements have been met.[4]

Sample selection based on the energy model

If there is a significant variation between the actual energy consumption of some EUPs and the energy consumption predicted by the energy model[5], it would be sensible to select EUPs for further investigation with:

- close to the predicted energy consumption as it could be argued that these EUPs are more representative;
- higher than predicted energy use, as this might reveal opportunities at this individual EUP and/or reveal other important independent variables that have not been included in the model; and
- lower than predicted energy use, as this might reveal opportunities for all other EUPs and/or reveal other important independent variables that have not been included in the model.

Sample extrapolation to the population

Once the EUPs have been described and modelled, and various energy saving initiatives have been proposed and evaluated (and most likely piloted), these results need to be extrapolated from the sample EUPs to all EUPs in the population.

4.5 THE ENERGY USE MODEL

Key questions in this section:

- What is an energy use model?
- What is the role of the energy model?
- How to build the energy model?

3 The benefits and costs must be evaluated to within ±30%, and should be within ±10%, where significant capital expenditure is required.

4 This would only be the case if the model applies across the population. For example, a pipe flow model should apply to any piping system once fluid characteristics, temperatures, piping materials, minor flow restrictions, phase changes etc. are taken into account for each EUP. What matters is that the model is accurate and appropriate within the required range of values (e.g. for a pipe flow model, that the relationships applying to the appropriate flow regime are used).

5 The energy use model is described in the following section. The model might be derived from regression analysis, described in Section 4.7.

4.5.1 What is an energy use model?

The energy use model is a description (including a mathematical description) of the way energy use varies with respect to the input or independent variables.

4.5.2 What is the role of the energy use model?

The main role of the energy use model in RAs is to quantify the effect of independent variables on the energy consumption of individual EUPs, so that the value of predicted or measured energy savings can be calculated for any other EUP.

The energy use model also assists in identifying energy efficiency opportunities by providing insights into the effect of the differences in the independent variables between EUPs. For example, an initial regression analysis of electricity consumption in Coles supermarkets produced an energy model which suggested that the presence of an air-lock at entrance reduced annual electricity use by 719,103 kWh (see the case study in Appendix D).

Other potential benefits and roles of the energy model include:

- a visual representation of inputs, influences and outputs (energy and mass) to aid collaborative discussion of possible energy efficiency opportunities;
- a comparison between the modelled effect of some variables on energy consumption and the effect predicted by engineering calculations (where this can be calculated). For example, if modelling suggests that increasing feedstock moisture content increases energy use significantly more than predicted by engineering calculations, this points to a potential inefficiency and therefore an area to investigate for possible savings actions (e.g. is the dryer efficiency much lower than was believed?);
- the ability to quantify the effect of proposed changes in the EUP (e.g. equipment changes, control changes);
- the ability to compare alternative EUPs (e.g. different transport modes); and
- adjusting opportunity baseline energy consumption records for changing conditions, so that the true underlying effect of implemented energy efficiency actions can be measured. For example, this would be necessary if a petrol retailer changes lighting in order to reduce electricity use, but electricity varies significantly throughout the year because of store air-conditioning and refrigerated displays.

4.5.3 How to build the energy use model

Components of the energy use model

The energy use model normally has two main components:

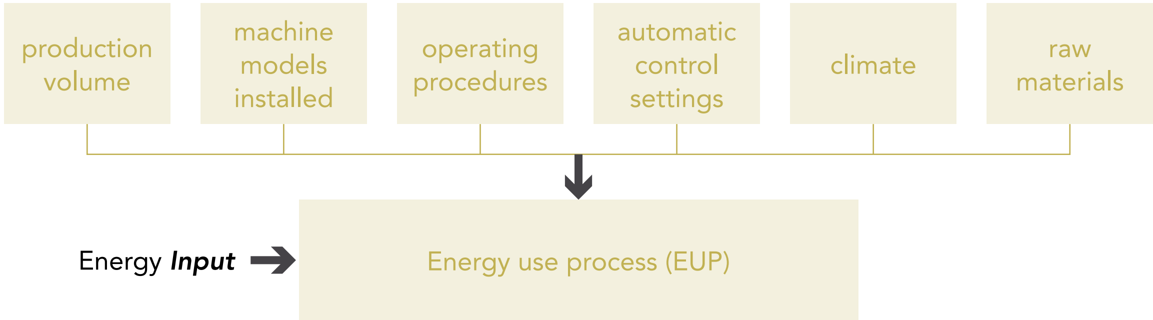
- a diagram, to assist in visualising the model and listing the independent variables; and
- a mathematical equation (or set of related equations) for each energy source, showing how energy consumption changes with changes in the independent variables.

The energy use model diagram

The diagram shows the variables which influence energy consumption. It could also show outputs (e.g. production) and material flows as shown in Figure 3.

Figure 3: Energy use model, independent variables influence energy use

Influences, or independent variables, e.g.:



The independent variables which are important for a type of EUP are determined by the analysis conducted in constructing the model.

Developing and refining an energy use model diagram is a brainstorming process that assists in determining which variables to include in the energy use model.

Constructing the energy use model

The first step is to create a list of all the variables likely to have some influence on energy consumption. Experienced and knowledgeable staff in an organisation will be the best starting point in listing these variables. Of course, some analysis is required to determine the extent to which each variable influences energy consumption and so the initial list will only be an educated guess.

Table 4 shows examples of types of variables that could be expected to significantly affect energy consumption in a range of EUPs. A more extensive listing of types of EUPs and variables is provided at Appendix B.

Table 4: Examples of variables which might affect energy use

Variables which might affect energy use
Raw material characteristics
Products manufactured/services provided
Equipment type, model, age, maintenance, or condition
Energy source
Automatic control settings
Operator/manual control settings
Ambient conditions (e.g. temperature, humidity)
Production volume and rate/time
Ambient weather conditions
Operating hours
System size, area, capacity, etc.
Total turnover
Air-conditioning temperature and humidity set-point
Location

The initial aim is to construct an energy model that incorporates approximately five to ten of the most significant variables that impact upon energy use, as this should be sufficient for at least the initial analysis. Further variables can be incorporated later to improve accuracy or assess more marginal opportunities.

From the list of all variables likely to influence energy consumption:

- select the five to ten variables which are expected to have the most impact on energy consumption;
- quantify how the independent variables influence energy use, for example using methods such as:
  - statistical methods such as regression analysis (see Section 4.7); or
  - non-statistical methods such as sub-metering, energy mass balances, engineering calculations, experiments etc[6].

The energy use model equation

The generic energy usage equation is shown in Figure 4, and may be developed by either statistical or non-statistical methods, or a combination of both.

Figure 4: The energy use model equation

y = a + b[f(x1)] + c[f(x2)] + d[f(x3)] + e[f(x4)] .....

where:

- ***y*** is energy consumption (the dependent variable).
- ***a*** is a quantity of energy used by all EUPs, regardless of the value of the independent variables.
- ***f(x1), f(x2), f(x3), etc.*** are the functions of the independent variables, the value of which changes from EUP to EUP and may take various mathematical forms.
- ***b, c, d, e, etc.*** are the coefficients which quantify the degree to which changes in the value of the independent variables affect the energy consumption of an individual EUP.

There will be an energy use model equation for each energy type. The energy use model equations quantify the extent to which each of the independent variables influence the consumption of each energy source. The energy use model equations 'open the lid on the energy consumption black box', and so enable the identification and quantification of efficiency opportunities for individual EUPs.

4.6 RELATIVE MERITS OF SAMPLING, STRATIFICATION AND MODELLING

4.6.1 Methods of dealing with energy usage variation

Table 2 described two methods of dealing with variation in energy usage in EUPs:

- sampling, which relies on stratification to remove variation within segments of the population; and
- modelling (to quantify and explain the variation between EUPs).

This section discusses the factors that need to be considered if deciding between sampling and modelling.

4.6.2 Sampling

The default method for an RA is statistical sampling. The inclusion of RAs in Energy Efficiency Opportunities assumed similar EUPs and a sampling process sufficiently representative of the population. This allows a text book statistical analysis to be undertaken, including statistical sampling and extrapolation from the sample to the population, which will make it possible to evaluate energy efficiency opportunities to an accuracy of ±30% across the population.

Variation in energy use, and accuracy requirements

Variation of energy use across the population of EUPs can be addressed by stratification as part of the statistical sampling process. Each segment would require a sample of EUPs and analysis of energy use and opportunities within that stratum.

6 These methods are presented in more detail in the Energy Savings Measurement Guide.

Number of variables

Some EUPs are built to a common design (e.g. some brands of service stations, vehicles of a particular model, industrial boilers, some manufacturing machines) but the design of many EUPs varies from individual to individual. For example, it would be very difficult to identify two identical office buildings from the tens of thousands in Australia. Even in a single organisation's portfolio of buildings it would be rare to find two buildings that are substantially similar.

Table 5 outlines some of the variables which are likely to affect energy use in an office building. Note that this is not a definitive list, but a collection of possible variables to illustrate the variation in design configurations and so the difficulty in being able to accurately select a sample to represent a population.

Table 5: Variables affecting energy use in office buildings

Variable	Possible values	Comments
Size	3	Floor area (size categories)
Location	5	Climate zone
Economy cooling	2	Binary: yes or no
Car park	2	Binary: yes or no
Air-conditioning system type	4	e.g. dual duct, fixed volume or VAV
Heating type	2	e.g. electric heat pump or gas
Reheat type	2	e.g. electric resistance or gas heated water
Lighting type	2	Category (any value)
Working hours	2	Standard or continuous
Low rise / high rise	2	Number of floors
Possible Combinations	**7,680**	

Even in the case of devices which are manufactured to a standard design, other factors can lead to very large variation in energy consumption and energy usage. Some examples are shown in Table 6.

Table 6: Variables affecting energy use in devices with standard design

Standard design of:	Energy consumption and usage affected by:
Vehicle (truck, train, aircraft)	Load Operator (driver) Terrain and gradients Route (traffic congestion, stoppages) Weather (e.g. wind)
Service station	Hours of operation Ambient temperature (affects store air-conditioning and refrigeration)
Network exchange	Ambient temperature (cooling energy) Ambient humidity (efficacy of cooling system)
Bank branch	Location (weather) Floor space
Fast food restaurant	Location Number of customers Food sales
Manufacturing plant or machine	Production volume Feedstock type or quality Product variation Ambient conditions Production method

Combinations and segments

In order to have similar EUPs in a sample, the EUPs (e.g. supermarkets) would need to be divided into segments. For example, supermarkets could be divided into stand-alone supermarkets and those inside shopping centres; small, medium and large supermarkets; those with and without heat recovery, or with and without bakeries. If the number of possible combinations of design and other classification variables is large, the number of segments will also become very large.

Even with a large number of segments, there is likely to be significant variation in energy usage within each segment because there are other independent variables which are not used in the stratification. This is likely to require sampling and detailed analysis of several EUPs in each segment. The numerous segments and samples within each segment will result in many samples (and therefore energy efficiency opportunity assessments) within the population.

Continuous variables

Stratification relies on having classification variables that can be used to segment the population. Discrete variables are more suited to this role, such as:

- car engine type – petrol or diesel;
- supermarket refrigeration – with or without heat recovery for store heating.

Many factors affecting energy use vary continuously, rather than falling neatly into discrete categories. In these cases, stratification must rely on arbitrary setting of categories so that the individual EUPs fall into one segment. Examples of continuous variables and the way the categories might be formed in order to create discrete groups are listed in Table 7.

Table 7: Continuous variables and arbitrary categories

Continuous Variable	Possible values	Arbitrary categories.
Floor area	Any	Small < 1,000 m^2 Medium 1,001 to 10,000 m^2 Large > 10,000 m^2
Operating hours	35 – 168 hours/week	Standard working hours Continuous (24/7)
Location	Anywhere in Australia	States and territories, regions
Weather	Varies by locale and time	Climate zones 1, 2, 3, 4, 5

If these continuous variables have a significant influence on energy usage and consumption, assigning individual EUPs with similar values for that variable to a different segment based on thresholds could lead to a loss of accuracy or a loss of insight into how energy is used.

4.6.3 Modelling

Modelling can:

- Quantify variation in energy usage between EUPs with a single energy model for each energy source.
- Increase accuracy by being able to accommodate more variables at less cost than if those variables were used to stratify the population into segments each requiring investigation.
- Achieve greater accuracy than sampling, if continuous variables have a significant influence on energy consumption.
- Enable the use of a smaller representative sample, where it can be demonstrated that the mathematical model applies to the entire population and can be evaluated using the specific parameters for each EUP.

4.7 REGRESSION ANALYSIS

Key question in this section:

- What is regression analysis?
- What is the role of regression analysis in an RA?
- How do you undertake regression analysis?

4.7.1 What is regression analysis?

Regression analysis is a statistical method which attempts to quantify the influence of the value of *independent variables* on the value of a *dependent variable*.

The dependent variable is often referred to as the 'Y' value. In most regression analyses undertaken for Energy Efficiency Opportunities RAs, the dependent variable is energy. The independent variables are often referred to as the 'X' values.

Regression analysis will attempt to fit various linear and non-linear regression models (equations expressing the dependent variable as a function of independent variables) to see which independent variables make a difference to energy use, and identify how closely results predicted by the model fit the actual data.

If successful, this will indicate the probable relationship between the variables and energy use. The analysis will also produce a *coefficient of correlation* (R^2) which indicates how good the fit is. R^2 ranges from:

- $R^2 = 0$ (no relationship could be found); to
- $R^2 = 1$ (the regression model derived explains 100% of the variation in the dependent variable).

An R^2 value of 0.75 indicates that the equation explains 75% of the variation in the dependent variable.

4.7.2 What is the role of regression analysis in a representative assessment?

The strength of regression analysis is the ability to (at least partly) reveal what is happening 'inside the black box' of energy use. For example, the aim might be to determine how a service station's electricity consumption varies with the quantity of fuel dispensed.

Regression analysis of total store fuel sales and total electricity consumption has the potential to reveal the relationship providing enough data records are available and if the other independent variables are included in the analysis. This analysis of high-level, historic data can complement more detailed analysis of individual EUPs (e.g. measurement at one site, for one vehicle or one machine).

When regression analysis reveals a relationship between an independent variable and energy use, this means that the independent variable is a predictor of energy use, but it does not mean that the independent variable *caused* the variation in energy use. For example, a heated public swimming pool will have more patrons on a hot day, and will use less gas for water heating on a hot day, but the additional swimmers did not cause the observed reduction in gas use. Both the increase in swimmers and the reduction in gas use were caused by the increase in ambient temperature.

Regression analysis can be used to:

- better understand the relationship between independent variables and energy use at multiple EUPs. For example, with records from many similar retail outlets, it is also possible to investigate the differences between stores, such as store size, location and air-conditioning type;
- select individual EUPs for closer assessment, on the basis that they are:
  - on the line of best-fit from the regression model (where the difference between the predicted energy use and actual energy use is minimal) and can be considered a reasonable representation of the population;
  - well above the line (higher energy consumption than predicted based on the value of the independent variables) and so there could be more opportunities for energy savings at this particular EUP; and
  - well below the line (lower energy consumption than predicted) and could indicate how to save energy at other EUPs.

Strengths and limitations

Regression analysis relies on variation in the variables being analysed. It will not reveal the potential influence of a variable if there is too little variation in the data set being analysed. Variation in the data is necessary for the regression model to be able to quantify or explain variation in energy use.

Regression analysis will be more successful where there is an underlying relationship between the independent variables being tested and the dependent variable. In searching for an underlying relationship between the independent variables and energy, a statistical analysis program assumes that the effect of each variable is independent of the others. This may or may not be the case, but it is an acceptable accommodation in order to facilitate the analysis, provide reasonable quantification of the effect of each variable, and to assist the RA and the search for opportunities. Regression analysis will work better where there are many data points.

The regression relationship might only be valid within an appropriate range. For example, changing fluid flow rates may change a flow regime, in which case different relationships would apply.

4.7.3 How to undertake regression analysis

The basic statistical analysis process is to assemble all of the data (independent and dependent variables) for all the EUPs into a large table, with one row for each record, and one column for each variable including energy.

This table is then uploaded into a statistical analysis program (such as Minitab[7], Matlab[8] or Excel[9]) which will attempt to find the equation containing the independent variables that best fit (predict) the variation in energy consumption.

For example, the analysis could start with the hypothesis that energy consumption in an EUP is strongly related to a single variable such as tonnes of product manufactured, as shown in Table 8.

Table 8: Values of a single independent variable and a dependent variable

Dependent 'Y' values Energy used	Independent 'X' values Tonnes of product
21.21	0.92
17.00	0.76
17.94	0.33
14.51	0.10
12.70	0.32
17.27	0.97
18.43	0.98
17.31	0.53
12.41	0.15

In this example only nine records are shown in order to save space. However, regression analysis would normally be based on many more records, probably hundreds or thousands.

After uploading the data into a statistical program, designate the dependent variable (left column in the table above) and the independent variable(s) (right column), and start the analysis. The program will generate:

- an equation relating energy use to the independent variable; and
- the correlation coefficient, R^2, indicating how well the equation represents actual energy consumption.

7 www.minitab.com/products/minitab
8 www.mathworks.com/products/matlab
9 See Appendix C: Using Excel for regression analysis.

The results from Excel for this example are shown in Table 9.

Table 9: Regression analysis results from Excel

Regression Statistics	
Multiple R	0.457197
R Square	0.209029
Adjusted R Square	0.171364
Standard Error	2.144107
Observations	23
	Coefficients
Intercept	14.45504
X Variable 1	3.726012

The last two rows of the table show that the linear equation with the best fit that the analysis produced is:

Energy consumption = 14.45 + 3.72 x (where x=production volume in tonnes)

The R^2 figure indicates that only 21% of the variation in energy consumption is explained by the current linear equation.

In order to improve the understanding of energy usage and to identify and quantify the opportunities to an accuracy of ±30%, it is necessary to be able to explain the variation in energy use to **at least** ±30% ($R^2 > 0.70$) even before other inaccuracies and uncertainties are introduced. Additional uncertainties include the uncertainties of extrapolation from the sample to the population and the predictive accuracy of the model. In practice, this means that R^2 should be a lot higher than 0.7, perhaps 0.85-0.9, to provide the explanatory power necessary to meet the required accuracy for opportunities.

The low R^2 value in Table 9 indicates that while production volume appears to be correlated with energy use, there are other variables which are influencing energy consumption.

In Table 10, three more independent variables were identified and data was collected.

Table 10: Values of four independent variables and a dependent variable

Dependent 'Y' values Energy used	Independent variables 'X' values tonnes of product	'd'	'e'	'f'
21.21	0.92	0.07	0.54	0.25
17.00	0.76	0.49	0.37	1.00
17.94	0.33	0.20	0.57	0.38
14.51	0.10	0.65	0.84	0.10
12.70	0.32	0.96	0.43	0.01
17.27	0.97	0.76	0.96	0.75
18.43	0.98	0.45	0.33	0.07
17.31	0.53	0.55	0.82	0.70
12.41	0.15	0.84	0.37	0.21

The analysis was then re-run. Some of the results are provided in Table 11.

Table 11: Regression analysis results from Excel for four independent variables

Regression Statistics	
Multiple R	0.961568
R Square	0.924613
Adjusted R Square	0.874355
Standard Error	0.928762
Observations	11
	Coefficients
Intercept	15.12931
Variable 1	4.274324
Variable 2	-5.93985
Variable 3	3.604548
Variable 4	-0.14244

The last five rows of the table show that the equation with the least squares best fit is:

Energy consumption = 15.13 + 4.27 × (production) -5.9 × V2 + 3.6 × V3 – 0.14 × V4

The R^2 figure indicates that 92% of the variation in energy consumption is explained by the equation.

4.8 OTHER METHODS

An organisation is likely to need to employ a range of techniques in order to understand energy use, and to identify and evaluate energy efficiency opportunities. These techniques are described in the Energy Efficiency Opportunities *Assessment Handbook* and *Energy Savings Measurement Guide*, and their application in RA is described in Table 12. The choice of modelling approach or approaches will depend on EUP characteristics plus data/measurement systems (see *ESMG* Section 1).

Table 12: Assessment techniques and application to representative assessments

Assessment technique	Reference	Application to representative assessment
Regression analysis	*Assessment Handbook* Section 12	More useful where the following conditions apply: • high level data; or • a large population and large variation in the population.
Benchmarking	*Assessment Handbook* Table 6 and Section 11	Comparing energy use with similar EUPs, design performance, past performance etc, after adjusting for differences in services delivered by the EUPs.
Sampling		Detailed investigation of energy usage in a subset of the population, and extrapolation of the results to the population. Requires appropriate stratification of the EUPs and random sampling.
Energy mass balance	*Assessment Handbook* pp 60-64 *ESMG* Part 3	Assists in building the equations underlying the energy use model to determine the energy baseline for opportunities and to identify and evaluate energy efficiency opportunities.
Engineering calculations/custom spreadsheets/ software simulations	*ESMG* Section 1	Helps to build the equations underlying the energy use model to identify and evaluate energy efficiency opportunities.
Sub-metering direct measurement	Key Requirement 4.3 *ESMG* Section 2.1	More useful where energy use is not expected to vary significantly between EUPs. For example, a direct measurement of the energy use of lighting is more likely to be applicable across the population of EUPs than that of cooling equipment.
Interval metering	*ESMG* Section 2.4 *Assessment Handbook* p 54	Identifying how energy use varies with time of day and day of the week helps to identify the components of the load, and so build the energy use model.
Pilot	*ESMG* Section 4.3.2	Trial implementation of an opportunity, measuring the change in energy use, and extrapolation of the results to other similar EUPs.

4.9 REVIEW AND REFINE

4.9.1 Achieving accuracy

Assessment of energy efficiency opportunities needs to be accurate to within ±30%.

The overall accuracy achieved in the assessment of an opportunity will depend on factors such as:

- the variability of energy usage between EUPs,
- how well the component of energy use being targeted can be quantified (e.g. it will probably be easier to accurately determine the energy consumption of a constant load). The quantity of energy used might be estimated with sampling and modelling, and the estimates refined with engineering calculations, sub-metering, etc;
- the level of confidence in the opportunity being assessed, for example an opportunity which is a concept or experimental will be lower than one which is well proven;
- testing, piloting, etc. to quantify the energy savings; and
- any inaccuracies present in individual assessments (described in the *ESMG* Section 3).

The assessment of each opportunity must include quantifying the accuracy of the assessment, based on the accuracy of the measurements, data, assumption, modelling and calculations which the assessment is based on.

4.9.2 Why is 'progressive and iterative' improvement valuable?

Energy Efficiency Opportunities program requires a rigorous and comprehensive search for and evaluation of energy efficiency opportunities. Large energy-using processes may provide significant potential savings in return for large capital investments. These opportunities will require detailed and accurate business case analyses. In turn, this will require sufficient time and the appropriate skills to collect and analyse the data effectively. Adequate financial and human resources also need to be allocated to opportunity evaluation.

Organisations should aim to achieve progressive and iterative[10] improvements in the quality of their Energy Efficiency Opportunities assessments. This approach can limit the resources dedicated to the RA to the amount required to achieve the required level of accuracy at each stage of the program.

Progressive opportunity implementation

The aim of the RA process is to gradually build understanding of energy use, document data gaps and arrange for these to be reduced. It is important to use the data and analysis available early in a company's Energy Efficiency Opportunities process to identify immediate opportunities. Implementation can then focus on opportunities that need little or no investment and will generate clear savings or that have other (non-energy) drivers. This early implementation provides financial benefits to the organisation, and positive feedback to those involved, early in the assessment process.

The next step is to document and organise the additional data, investigation, tasks (e.g. arrange supplier quotations) and analysis needed to produce businesses cases for the opportunities which can not be evaluated with existing data. Often this further investigation can be conducted in conjunction with implementation of identified projects.[11]

For RAs, the additional value of progressive and iterative refinement is that it:

- limits the complexity of the conceptualisation and data collection early in the process;
- allows the organisation to get started, and to test the early assumptions, data sets, data collection capability and energy models; and
- allows the organisation to schedule a few iterations of sampling, modelling, and piloting early enough in the assessment process to allow for improvement of the RA processes, within the timetable in the approved ARS.

How to refine the representative assessment energy use model over time

To refine the energy use model over time, first list the independent variables that are expected to explain most of the variation in energy use. Assess the accuracy of the model by testing how well it predicts energy consumption. This could be done, for example, by evaluating how well it predicts energy consumption for one of the EUPs if conditions change in the future, or as the independent variables are deliberately changed (i.e. through a controlled experiment). Another option is to test the model using historic energy consumption data for other EUPs in the population. (Section 4 of the *ESMG* discusses estimation methods.)

The level of accuracy of potential energy savings needs to be within ±30% to meet program requirements (Key Requirement 4.3) and for business decision making. The accuracy for business decision making will depend on the predicted energy saving for the opportunity being tested. For example, a more accurate model will be required to test the effects of minor truck aerodynamic improvements which are expected to reduce fuel use by 2%, than the model required to test a low mass trailer which is expected to save 10%.

The required level of accuracy will also depend on:

- how close the estimated return on investment is to the organisation's hurdle rate of return. For example, if the hurdle rate is 20% per year, a savings action with an estimated return of 22% per year will require more accurate assessment than one with an estimated return of 100% per year;

10 In the context of an Energy Efficiency Opportunities assessment, 'progressive' means completion of larger tasks or projects by breaking them into smaller, more manageable steps, which are repeated, usually according to a documented rule or routine. The overall iterative process is often seen as a loop or cycle.

11 Note that while the accuracy of energy models can be refined over time, the required accuracy level should be considered prior to installing any additional metering.

- how close the estimated payback period is to four years. (Energy Efficiency Opportunities mandates reporting of opportunities with paybacks of up to four years, so greater accuracy is needed for opportunities that are close to a four year payback.);
- the size of the investment required; and
- other risks/uncertainties with the proposed technology or change.

The gap between the achieved accuracy and the required accuracy will determine whether refinement is required. In order to refine the model, consider adding further variables, or using more accurate data for the variables already incorporated in the model (e.g. a closer weather station, or alternative measuring instrument). Other options include:

- using more data, i.e. covering a greater period;
- using more detailed data (e.g. monthly data instead of yearly averages, weekly production data instead of monthly data, hourly profile data from a 'smart' energy meter instead of monthly invoice data). Suitable data frequencies are discussed in Sections 1 and 2 of the *ESMG*;
- sub-metering at some sample EUPs to better determine the energy consumption of sub-systems;
- pilot studies and bench testing (varying some of the independent variables) in order to more accurately determine the relationship between that variable and energy use; and
- increasing the sample size used for data mining/statistical analysis.

How to incorporate data from trials and implemented opportunities into assessments

Even if the sample assessment is only for one EUP as part of a non-statistical modelling process, it will be important to measure the actual effect of implemented opportunities, to ensure that the predicted savings are being achieved. If the EUPs' total energy consumption has not been reduced as predicted, this could indicate that the implemented action is working but the energy consumption elsewhere in the EUP has increased.[12] Another possibility is that the implemented opportunity is not performing as expected, for example it has not been commissioned properly or supplier efficiency claims are not being achieved in practice.

With an RA, the potential to implement savings actions at multiple EUPs makes it even more important for the energy savings achieved to be quantified and optimised. This is detailed in Section 1 of the *ESMG*, and can be summarised as three steps:

1. Establish the energy baseline for the opportunity.
2. Estimate the effect of the opportunity or trial.
3. After implementation, adjust the baseline for measured factor variation and then determine measured savings.

To use outcomes and data from trials and implemented actions to improve assessment accuracy, consider which mix of the following is required:

- Measuring the energy consumption of a device, machine etc. For example, a project to change the lighting in a building could measure the power draw of a single fitting. Changes to a production machine may be best measured by permanently installing an electricity meter on the supply to that machine.
- Correcting the measured energy consumption at that EUP for changes in the independent variables that are expected to affect that consumption. For example, weather data would probably need to be factored into the analysis of changes to a heating system, but not to changes to lighting.
- Adjusting the expected energy savings at other EUPs, based on the differences between the independent variables at the EUPs and at the test installation EUP.
- Quantification of other benefits or effects found during the trial, such as improved process control, comfort, noise, maintenance, operational benefits or avoided problems.
- Incorporating refinements in the energy-saving actions that have been discovered during the trial.

12 Energy baselines from which savings are measured should be adjusted for changes in energy use factors so that savings calculations are based on the actual values of energy use variables.

5 HAS ENOUGH BEEN DONE TO MEET THE PROGRAM'S REQUIREMENTS?

Key questions in this section:

- What are the implications of the Assessment Framework for a representative assessment?
- What are the accuracy and coverage requirements?
- What are the reporting requirements for RAs?
- What documentation is required for verification purposes?

5.1 REPRESENTATIVE ASSESSMENTS AND THE ASSESSMENT FRAMEWORK

The RA needs to be evaluated against the key elements of the Assessment Framework to determine whether it meets the requirements of the Energy Efficiency Opportunities program. These elements, and their particular application to RAs, are described in Table 13. Note that an effective RA process addresses Key Elements 3 and 4, but is underpinned by the involvement of sufficiently skilled and knowledgable people (Key Element 2). All other key elements must be applied across the corporate group.

Table 13: The Assessment Framework and its relevance to a representative assessment

Key Element	Intent	How an RA can meet the intent
3: Information, data and analysis	Sufficient data, in suitable forms, is used to quantify and understand energy use, identify and quantify energy saving opportunities, and to track performance and outcomes (where actions are implemented). Energy data is analysed from different perspectives to understand relationships between activity and consumption, and to identify energy efficiency opportunities.	Analysis is required to understand energy use across all EUPs, to identify efficiency opportunities, and to evaluate the opportunities. Different forms of analysis to be explored. Strongly implies creation of an energy use model.
4: Opportunity identification and evaluation	An effective process is undertaken so that all potential energy efficiency opportunities are identified. This process is broad, open-minded and encourages innovation. Opportunity areas are documented and analysed to a level sufficient for informed evaluation up to a four year payback. A whole of business evaluation is undertaken to enable decision makers to make good business decisions about energy efficiency opportunities.	RA analysis (regression analysis, energy mass balance, calculations, sub-metering, etc) can be used both to identify opportunities, *and* to quantify opportunities identified by other means. Preliminary analysis can be used in opportunity identification workshops, and progressively refined to achieve the accuracy required by EEO and for investment decisions.

5.2 ACCURACY AND COVERAGE

An organisation's analysis of energy usage is required to be comprehensive and with sufficient rigour to:

- quantify EUPs' energy use to within ±5% (Key Requirement 3.2a) – in most cases this will be possible with existing records, for example utility billing and vehicle refuelling data. This level of accuracy will generally require the aggregation of billing data for each EUP;
- quantify energy and material flows through the EUPs to within ±5% for sufficient energy uses which must be studied to achieve compliance with the coverage rule[13] (Key Requirement 3.2d)—it is most likely that achieving this accuracy requirement in an RA of multiple EUPs will require a combination

13 At least 80% of baseline energy use must be assessed in the first 5 year cycle, and at least 90% of energy used in subsequent five year periods. All sites with energy use ≥ 0.5 PJ must be individually assessed.

of techniques such as regression analysis, sub-metering, engineering calculations and energy mass balance. To achieve ±5% for energy inflows for each energy source will generally require the aggregation of billing data for each EUP;

- identify energy efficiency opportunities for all the energy uses which must be studied (Key Requirement 4.1);
- evaluate opportunities with sufficient accuracy to quantify implementation costs, benefits and energy savings to ±30% (Key Requirement 4.3);
- evaluate the whole-of-business costs and benefits for opportunities in order to calculate a payback period, with an accuracy of ±10% for opportunities requiring major capital investment (Key Requirement 4.4). It is advisable to adjust the model for the values of the independent variables for each EUP where major capital investments are involved; and
- produce a business case with the information and accuracy required by your organisation, in order to decide whether to proceed with the opportunity (Key Requirement 5.1). This accuracy requirement may exceed program requirements, especially for larger investments.

For verification purposes companies need to be able to demonstrate that they have met these EEO requirements.

5.2.1 Checking the accuracy of regression analysis

Checking whether the data is sufficient requires testing the effect of the independent variables on energy use, until at least 70% of the variance of energy savings, costs and benefits for an opportunity can be explained. If the unexplained variance exceeds 30%, it will be very difficult or impossible to use the model to assess opportunities with an accuracy of ±30%. As discussed in Section 4.7.3, this implies an R^2 value much larger than 0.7, perhaps 0.85-0.9.

5.2.2 Checking the accuracy of representative sampling

The following information needs to be provided in detail in order to demonstrate that a representative assessment is sufficiently detailed and accurate:

- Population stratification: define how the EUPs are similar and can be grouped together for RA purposes. Define the classification variables that were used to divide the total population into segments.
- Sampling ratio: define the sampling depth (ratio) required and why you think this sample ratio is sufficient to generate a representative sample.
- Sample selection: define how the sample was selected, whether the sampling method was random or non-random, and why the sampling method is representative of the underlying population or segment.
- Sample-to-population extrapolation: Define how the sample results can be extrapolated to the underlying population or sub-population and what error is calculated or estimated to result from sample extrapolation to the population or sub-population, or how the accuracy has been tested.
- Non-statistical modelling: outline the assumptions behind the model, the circumstances in which the model should apply and the estimated variation in accuracy that will result from extrapolation of the model from a sample to the entire population.

In addition to these specific points, for verification purposes it is advised that all companies maintain documentation to address the key requirements of the Energy Efficiency Opportunities Assessment Framework.

5.3 DOCUMENTATION FOR VERIFICATION

The Department is responsible for overseeing the Energy Efficiency Opportunities program. This includes undertaking verification of registered companies' levels of compliance with Energy Efficiency Opportunities legislation by addressing the six key elements and 19 key requirements of the Assessment Framework.

Companies selected for verification will be required to contribute to both desktop and full verifications (which include a site visit). Where requested, companies will need to demonstrate their compliance by providing documentary evidence of the methodology and data underlying their representative assessment. Specifically, this will be covered through verifying Key Elements 3 and 4, which will be undertaken with the assistance of an energy expert (appointed by the Department). Therefore it is necessary to maintain comprehensive records of the RA, including data survey and collection, assessment planning, sample design, data analysis, accuracy evaluation and procedures to achieve the required accuracy and comprehensiveness.

> The Energy Efficiency Opportunities Regulations 2006 stipulate that a controlling corporation must make and keep records of its compliance with the legislation for at least seven years and that these must be made available to the Department for inspection.

Further information can be obtained from the Energy Efficiency Opportunities Verification Handbook, your Client Liaison Officer or the Manager – Verification.

Hotline	Email	Post
1300 799 186	energyefficiencyopportunities@ret.gov.au	Attn: Energy Efficiency Opportunities GPO Box 1564, CANBERRA ACT 2601

Website:
www.energyefficiencyopportunities.gov.au

6 APPENDICES

6.1 APPENDIX A: GLOSSARY OF TERMS AND ABBREVIATIONS

Term	Meaning, as used in this guide
Accuracy, required	The benefits and costs of opportunities must be evaluated to within ±30%, or to within ±10%, where significant capital expenditure is required (other accuracy requirements are outlined in Section. 4.1.3).
ARS	Assessment and Reporting Schedule
Baseline energy use	To determine assessment coverage, the baseline energy use information should be provided for the trigger year. However, where this is not a typical year for energy usage, or systems do not facilitate collecting data in that period, participants may use any continuous twelve month period from July of the year prior to the trigger year to June of the year following the trigger year. For example, if the trigger year is 2005-06, the twelve month period can be any continuous twelve months between July 2004 and June 2007. This twelve-month period is referred to as the baseline year. For opportunities, the historical baseline energy consumption should be adjusted for changing conditions, so that the true underlying effect of implemented energy efficiency actions can be measured.
Convenience sampling	Convenience sampling occurs when samples are mainly selected on the basis of their convenience. Convenience sampling does not necessarily produce a representative sample. The obvious advantage of this type of sampling is its ease of use, but this sampling design is non-random and the sample may be biased. Examples of convenience sampling include selecting: • site X because it has the most enthusiastic and cooperative environmental manager; • store X because it is the newest and has the most reliable as-built documentation; • plant X because it adjoins the corporate management offices (and so gets more corporate visits than all other plants combined). See also: • random sampling • quota sampling
Data	Facts, usually a collection of numbers relating to the quantity of energy use, and observations/quantification of factors that affect energy use. See Information.
Data mining	Processes or techniques used to reveal meaning, trends and relationships that are not easily seen in the data.
Department (the)	Department of Resources, Energy and Tourism
Dependent variable	In this guide, the main dependent variable is energy use. The quantity of energy used depends on the value of the independent variables.
EEO	Energy Efficiency Opportunities
EMB	Energy mass balance
Energy efficiency idea	A documented energy efficiency idea.
Energy efficiency opportunity	An idea to be quantified and assessed.
Energy consumption	The quantity of energy used.

Term	Meaning, as used in this guide
Energy mass balance	A method of accounting for: • the materials and energy entering and leaving a site or fleet and its processes, systems or equipment; and • the energy and material flows, energy conversions and energy use within the site or fleet and its processes, systems or equipment. Note that to ensure appropriate coverage, an energy mass balance should define, to an accuracy of ±5%, at least 80% of a site's energy use and all processes not already included in the 80% that use at least 0.1 PJ of energy per year. An energy mass balance should provide a thorough understanding of: • the material flows and energy use through a site, its processes and systems, and items of equipment including items such as pipes and ducts; • the specific services and products the energy use delivers; • the energy conversion processes within a system, and quantifying the efficiency of those conversions; and • the identification of energy waste and energy efficiency opportunities.
Energy use	The quantity of energy consumed i.e. energy consumption.
Energy usage/energy usage profile	How energy is used (when, by what, purpose, factors affecting).
Energy use process (EUP)	One of a group of similar energy-using sites, facilities, machines, processes, operations, technologies, vehicles, services, etc.
ESMG	*Energy Savings Measurement Guide*
Independent variable	A variable that influences energy use but is not influenced by energy use.
Individual assessment (IA)	Assessing the energy usage and energy efficiency opportunities for each energy use process individually. Results of individual assessments are not extrapolated to the entire population of similar EUPs, although lessons from earlier assessments may be incorporated in later assessments. Thus there is not necessarily an overall analysis and comparison of data from multiple EUPs.
Information	Information is data (see Data) in context. Information conveys meaning, whereas data in isolation does not.
Model *(n)*	See the short description in Section 2.2.3, or detailed explanation of energy use models in Section 4.5.
PJ	Petajoule
Population	The set of N energy use processes that would be included in a representative assessment.
Quota sampling	A type of stratified (see Strata) sampling in which selection within the strata is non-random, but based on objective logical criteria related to energy use. Quota sampling ensures that there will be a representative sample of the population for specified criteria or strata. However, the actual sample may not necessarily be selected in a random manner, so the sample may not be representative for some other important criteria. The sample design for most representative samples will be quota sampling. The main argument against quota sampling is that it does not meet the basic requirement of randomness. Examples of quota sampling would be ensuring that the sample includes: • supermarkets with and without bakeries; • service stations with carwashes; or • manufacturing plants with 'type X' machines. See also: • Convenience sampling • Random sampling

Term	Meaning, as used in this guide
RA	Representative assessment
Random sampling	An unbiased sampling technique in which every member of a population has an equal and known chance of being included in the sample. Random sampling is the process of selecting and canvassing a representative group of EUPs from a particular population of EUPs in order to identify the attributes of the population as a whole. A related sampling technique is stratified sampling, in which the population is divided into segments, with random samples taken from each segment (or stratum). See also: • Convenience sampling • Quota sampling
Regression analysis	Any statistical tool or method used to analyse quantitative data, in order to develop an equation that will explain the way the *dependent variable* changes in response to changes in *independent variables*.
Representative assessment	Assessment of energy use and efficiency opportunities in a group (or population) of energy use processes, without investigating every individual member of the population. The chosen approach to representative assessment must be approved by the Department in the ARS.
Sample	A subset of the population which has been selected using a sample design.
Sample design	The formal documented process that outlines how a sample selection will be made from the population.
Segment	See Strata
Statistical analysis	Examination, description and summary of data in order to improve presentation and understanding.
Strata	A population may include a number of distinct homogeneous categories (or groups or segments) and these can be organised by these categories into separate 'strata'. A sample is then selected from each stratum separately, using a stratified sampling process. The reason to use a stratified sampling design is to ensure that particular groups within a population are adequately represented in the sample design, and to improve efficiency by gaining greater control on the composition of the sample.
Variable *(n)*	A parameter which quantifies a physical characteristic.
Vehicle	Any inanimate mobile device used for transport, whether by air, sea or land, e.g. aircraft, train, ship, car, or motorcycle.
Whole-of-business impacts	Energy and non-energy benefits and costs (capital and ongoing). Non-energy impacts may include productivity, safety, product quality etc.

6.2 APPENDIX B: VARIABLES LIKELY TO AFFECT ENERGY USE IN DIFFERENT EUPS

Example of EUPs	Variables which might affect energy use
Hospital	Number of beds Number and type of surgical operations, procedures, bed-nights Ambient temperature Ancillary services provided: • laundry central sterilising department • consulting rooms • offices Equipment age, technology and controls Fuel type
Manufacturing, mineral processing, food processing	Raw material quality, moisture content, type, variant Product type Recipe (the set list of ingredients and procedures for processing) Automatic control settings Operator/manual control settings Who is the operator/shift supervisor/manager Ambient conditions (e.g. temperature, humidity) Production volume Production rate (volume/unit time) Which production machine(s) or production line(s) is used Equipment age, technology and controls Fuel type
Mining	Mass of material extracted Vertical distance mass elevated Horizontal distance material moved Ore or material concentration Overburden Mine depth Water removal Temperature at working face Energy required for separating material from the surrounding earth Equipment age, technology and controls Fuel type

Example of EUPs	Variables which might affect energy use
Office building, bank branch, some retail premises, university building.	Ambient temperature Ambient relative humidity Operating hours Floor area Number of staff Air-conditioning temperature control set-point Air-conditioning equipment and controls design Equipment age, technology and controls Fuel type (e.g. for comfort heating and for water heating)
Supermarket, some retail premises	Ambient temperature Ambient relative humidity Strip shop, stand alone, large shopping centre Heat recovery on refrigeration equipment? Air locks/how other outside air and exhaust air are controlled Trading hours Length/surface area of refrigerated and freezer display cabinets and chests (with doors or covers, and without) Floor area of retail space Total turnover Number of customers Number of product lines stocked Air-conditioning temperature control set-point Air-conditioning temperature humidity set-point Equipment age, technology and controls
Telecommunications	Communications equipment load Ambient temperature and humidity (affects cooling equipment) Cooling equipment type Floor area (affects lighting load) Lighting type Lighting controls

Example of EUPs	Variables which might affect energy use
Transport operation	Location of origin and destination
	Route
	Time available for transit
	Vehicle speed
	What is to be transported (people, livestock, refrigerated food, etc.)
	Freight mass
	Vehicle mass
	Transport mode (air, rail, road, sea)
	Specific vehicle (engine, drag, freight capacity, ancillaries energy use)
	Conditions (wind, ocean currents, temperature, road surface)
	Conditions (traffic)
	Operator (driver, pilot, captain) inputs
Water pumping	Water volume pumped
	Volume flow rate
	Difference in elevation between source and destination
	Resistance of pipes and valves etc, valve settings
	Automatic control settings
	Which pump set used
	Equipment age, technology and controls

6.3 APPENDIX C: USING EXCEL FOR REGRESSION ANALYSIS

6.3.1 Overview

This appendix describes how to use Microsoft Excel to perform multiple regression analysis. Using Excel to perform this analysis is quite simple. The most demanding and time-consuming part of the process is collating the data (deciding which independent variables are important, deciding on the period for which data will be analysed, collecting and controlling the quality of data on energy and the independent variables). These steps are described in Section 4.7.

6.3.2 Software version

These notes are based on Microsoft Office Excel 2007 (12.0) with service pack 1, and Excel 2003.

6.3.3 Installation of 'Analysis ToolPak' add-in

In order to perform multiple regression analysis in Excel, the 'Analysis ToolPak' add-in must be installed. The procedure to check if the Analysis ToolPak is installed (and to install if necessary) is:

Excel 2007	Excel 2003
• Click the MS Windows logo at the top-left corner of the application window. • In the dialog box which opens, click the 'Excel Options' button at the bottom of the box (or press Alt+i). • In the dialog box which opens, in the left panel click the text 'Add-Ins'. • If 'Analysis ToolPak' is listed in the installed add-ins list, Excel can perform multiple regression analysis. • If 'Analysis ToolPak' is not on the list of installed add-ins, install it by following the steps described below. To install the 'Analysis ToolPak' • Go to the 'Manage' drop-down box at the bottom of the dialog box. • Select 'Excel Add-ins' and click 'Go'. • In the box which appears, ensure the top check-box: 'Analysis ToolPak' is ticked, then click the 'OK' button. You may be prompted for the MS Office installation disc.	• On the Tools menu, click Add-Ins. • If the add-in you want to use is not listed in the Add-Ins available box, click Browse, and then locate the add-in. • In the Add-Ins available box, select the check box next to 'Analysis ToolPak', and then click OK. • If necessary, follow the instructions in the setup program to install the Add-in.

In Excel 2007, to confirm that the Analysis ToolPak is accessible, in the menu bar select the 'Data' tab. The 'Data Analysis' icon should be visible (probably at the right-hand end of the tool bar ribbon).

6.3.4 Preparation of data

Variables can be:

- Continuous; the variable can have any value in a range
- Discrete; the variable can only have certain values
- Binary; the variable can only have one of two values

Binary variables

To include binary variables in multiple regression analysis, for each EUP, assign a value to the variable or either zero or one, depending on whether the feature is present or absent in that EUP.

Discrete variables

The best way of handling a variable which can have one of several (more than two) values is to create a variable for each possible value of that variable. For example, if analysing train fuel consumption for 100 trips where there were only four drivers, four variables would be created:

- Driver_Fred
- Driver_Harry
- Driver_Bruce
- Driver_Jane

For each record, one of these variables (corresponding to the driver for that trip) would be set to equal one, and all the other three variables would be made to equal zero. It would be prudent to include a column on the data input workbook to sum these four variables for each record, to ensure that the four variable add to a value of one. Two cells at the top or bottom of the table could be used to check that maximum and minimum value of all the cells in the total column are both equal to one.

Arranging the data

Create a table for all the data (independent and dependent variables) for all the EUPs, with one row for each EUP, and one column for each variable including energy.
The table will be easier to read if energy is in the left hand column.

In the top row of the table, include a row with a short label for each variable (this will make the results easier to read), as shown in Figure 5.

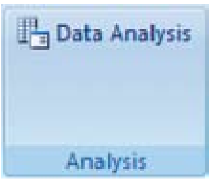
Figure 5: Data arranged in Excel for multiple regression analysis

	A	B	C	D	E	F
4		Site	Energy	production	moisture	control 1
5		NSW 1	9,970	1,167	0.54	25.29
6		NSW 2	10,617	1,247	0.37	35.00
7		NSW 3	10,910	1,290	0.57	26.20
8		NSW 4	9,882	1,157	0.84	42.03
9		NSW 5	10,263	1,196	0.43	34.67
10		NSW 6	10,665	1,251	0.96	39.35
11		NSW 7	9,192	1,062	0.33	38.15
12		NSW 8	9,124	1,036	0.82	27.24
13		NSW 9	10,483	1,225	0.37	28.98
14		QLD 1	9,080	1,038	0.93	36.81
15		QLD 2	10,423	1,229	0.06	41.27
16		QLD 3	9,815	1,148	0.49	28.16
17		QLD 4	10,435	1,243	0.84	41.06
18		QLD 5	9,673	1,124	0.55	40.86

In Excel 2007, Select the data analysis icon in the tool bar, as shown in Figure 6.

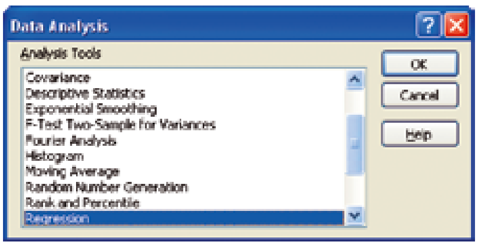
If using Excel 2003, go to the Tools menu and select 'Data Analysis', then select 'Regression' from the Data Analysis dialog box shown in Figure 7.

Figure 6: Excel data analysis icon



In the dialog box, select 'Regression Analysis' then 'OK'. This will open the Regression dialog box.

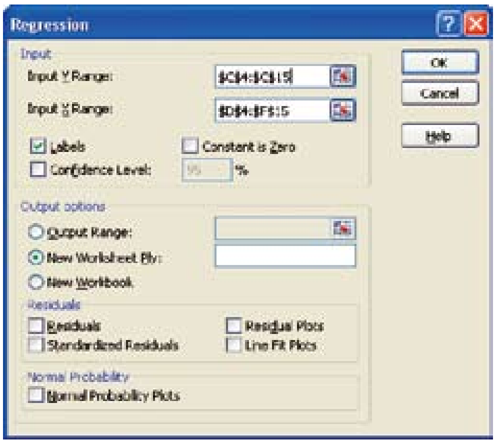
Figure 7: Excel data analysis dialog box



In the Regression dialog box shown in Figure 8:

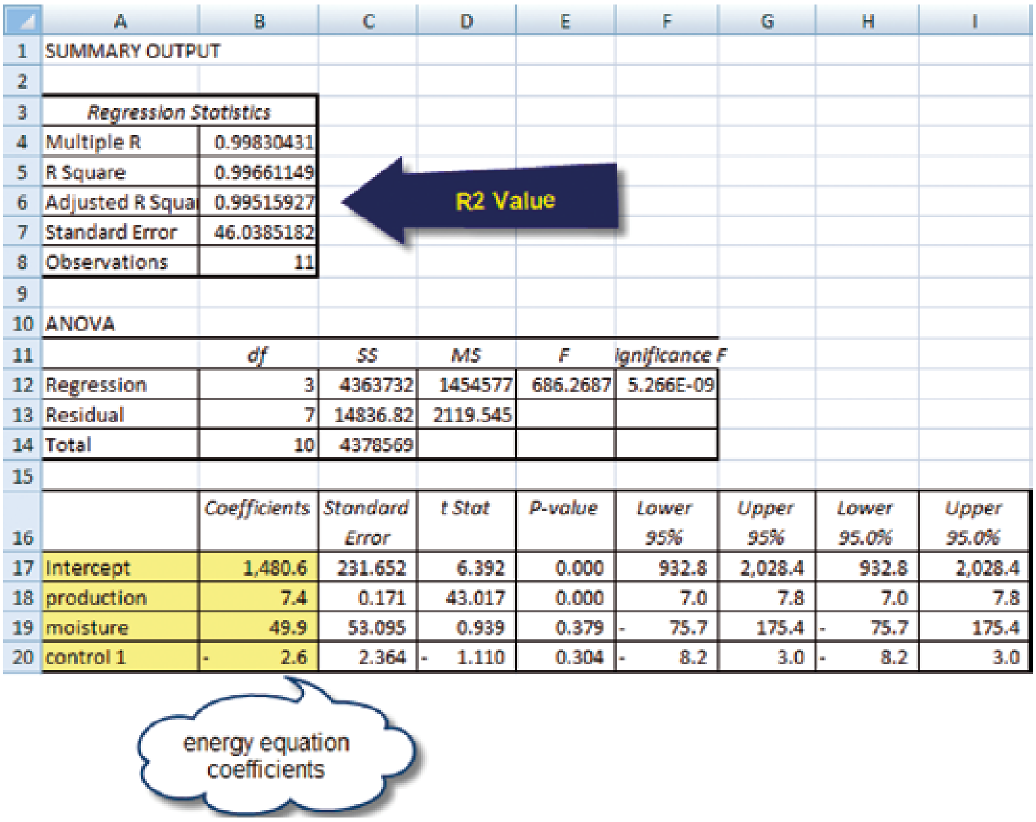
- mark the Energy column (including the header row) as the 'Input Y Range'
- mark all Independent variables columns (including the header row) as the 'Input X Range'
- select the 'Labels' check box
- turn the 'New Worksheet Ply' radio button on
- click 'OK' to start the analysis

Figure 8: Excel regression analysis dialog box



Excel will create a new worksheet with the results of the multiple regression analysis, including the R^2 value and the values of the coefficients of each of the independent variables, as shown in Figure 9.

Figure 9: Excel regressional analysis results



	A	B	C	D	E	F	G	H	I
1	SUMMARY OUTPUT								
2									
3	*Regression Statistics*								
4	Multiple R	0.99830431							
5	R Square	0.99661149							
6	Adjusted R Squa	0.99515927							
7	Standard Error	46.0385182							
8	Observations	11							
9									
10	ANOVA								
11		*df*	*SS*	*MS*	*F*	*ignificance F*			
12	Regression	3	4363732	1454577	686.2687	5.266E-09			
13	Residual	7	14836.82	2119.545					
14	Total	10	4378569						
15									
16		*Coefficients*	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
17	Intercept	1,480.6	231.652	6.392	0.000	932.8	2,028.4	932.8	2,028.4
18	production	7.4	0.171	43.017	0.000	7.0	7.8	7.0	7.8
19	moisture	49.9	53.095	0.939	0.379	- 75.7	175.4	- 75.7	175.4
20	control 1	- 2.6	2.364	- 1.110	0.304	- 8.2	3.0	- 8.2	3.0

The regression equation can be written by equating energy consumption to the sum of the product of the independent variables and their respective coefficients, and adding the error quantity.

Energy use = 1,480.6 + 7.4 x production + 49. 9 x moisture – 2.6 x control + error

Interpreting the regression formula is discussed in Section 4.7 and illustrated in Appendix D.

6.4 APPENDIX D: EXAMPLE OF A REPRESENTATIVE ASSESSMENT

6.4.1 Coles multiple regression analysis

In 2003-04 Coles conducted an initial multiple regression analysis to assist in understanding energy consumption and so inform the design of a new supermarket. Because the supermarket was to be built in Victoria, only Victorian stores were included in the first analysis.

Coles started by listing the variables expected to influence energy consumption as listed in Table 14.

Table 14: Coles initial list of variables influencing supermarket electricity use

x_1	Selling area
x_2	kWh/m²
x_3	Building type
x_4	Trading hours
x_5	Age of building
x_6	In store bakery
x_7	Average weekly customer count
x_8	Refrigeration length – cool with no doors
x_9	Refrigeration length – frozen with doors
x_{10}	Refrigeration volume – cool with no doors
x_{11}	Refrigeration volume – frozen with doors
x_{12}	Refrigeration breakdown costs
x_{13}	Back of house cool room volume
x_{14}	Back of house freezer room volume
x_{15}	Ceiling height
x_{16}	On-site meat room
x_{17}	Airlock at entrance
x_{18}	Lighting type

Coles realised that variable x_2 was a combination of two other variables (electricity consumption and floor area) and so should be excluded from the regression analysis.

Data on these variables and electricity consumption were collected for 30 Victorian supermarkets, and analysed using multiple regression analysis. This revealed that thirteen variables had a negligible effect on energy use and could be omitted. The resulting regression equation was:

Electricity use = (771,244 + 558 x_1 + 852 x_{10} + 922 x_{11} – 719,103 x_{17}) kWh/year

The R^2 value of this equation was 0.76, indicating that the estimated model explains 76% of the observed variation in energy consumption between stores.

The regression equation was rewritten to make the meaning clearer:

Electricity use = 771,244 (electricity use independent of variables tested)
+ 558 Selling Area (m²)
+ 852 Refrigeration volume – cool with no doors
+ 922 Refrigeration volume – frozen with doors
– 719,103 (if there is an entrance air-lock) kWh/year

This equation could be made clearer than the version produced by the statistical analysis software, by combining the first and last terms:

Electricity use = (771,244 – 719,103)
+ 558 Selling Area (m^2)
+ 852 Refrigeration volume – cool with no doors
+ 922 Refrigeration volume – frozen with doors
+ 719,103 (if there is ***no*** entrance air-lock) kWh / year

i.e.

Electricity use = 52,121
+ 558 Selling Area (m^2)
+ 852 Refrigeration volume – cool with no doors
+ 922 Refrigeration volume – frozen with doors
+ 719,103 (if there is ***no*** entrance air-lock) kWh / year

Accuracy of regression equation

The actual and predicted annual electricity consumption of the 30 Victorian stores included in the analysis is depicted in the following figure and table.

Figure 10: Coles stores' electricity consumption: actual and predicted by regression

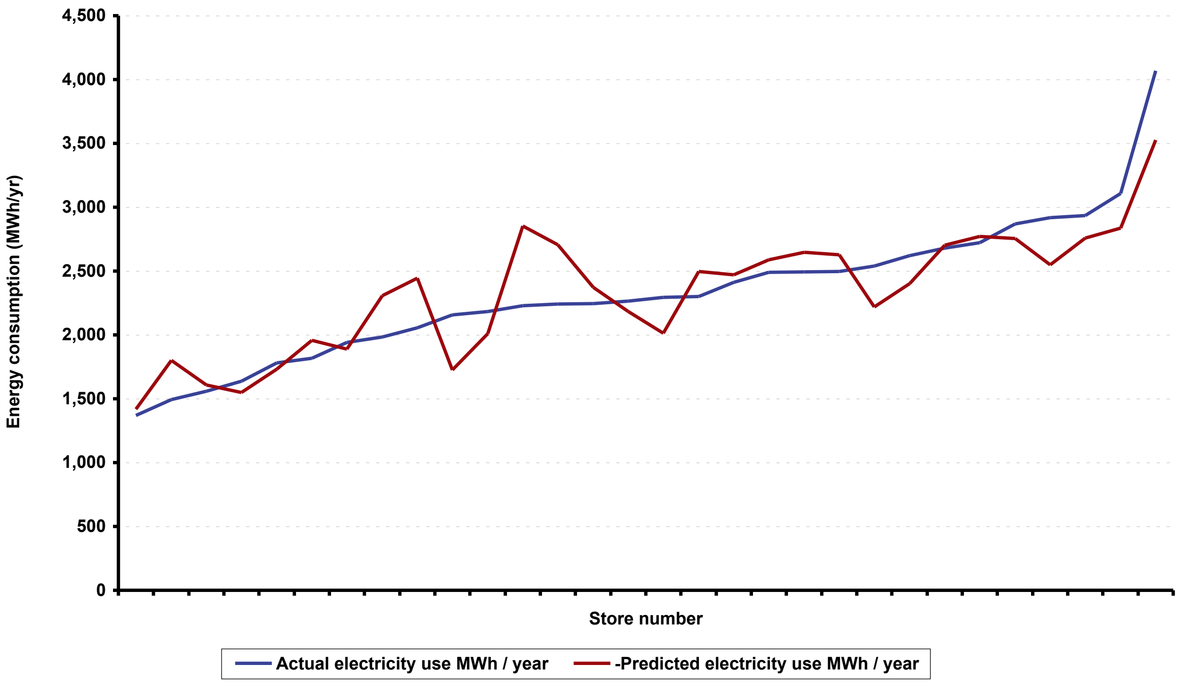


Table 15: Coles stores' electricity consumption: variation between actual values and those predicted by the regression equation

Store No.	Actual c.f. Predicted %
1	-3.7%
2	-20.4%
3	-3.2%
4	5.4%
5	2.8%
6	-7.7%
7	2.8%
8	-16.3%
9	-18.8%
10	20.1%
11	7.9%
12	-28.0%
13	-20.7%
14	-5.6%
15	3.5%
16	12.3%
17	-8.5%
18	-2.5%
19	-3.9%
20	-6.2%
21	-5.2%
22	12.6%
23	8.4%
24	-0.9%
25	-1.7%
26	4.0%
27	12.7%
28	6.0%
29	8.8%
30	13.3%

The two highlighted stores are the only two stores in the study which have an air-lock.

Analysing results

The initial regression analysis allowed Coles to concentrate on the factors which appeared to have the greatest influence electricity use, to spend less time on those which seem to have less influence, and to gain greater understanding of complex interactions between energy systems.

The influence of selling area on total electricity use was to be expected, but less expected was the extent of the following on total electricity use:

- the presence (or absence) of an air-lock; and
- the quantity of refrigerator and freezer display cabinets.

One surprise was the lack of influence of some variables, such as lighting type (whether a lighting efficiency retrofit has been completed) and the presence of a bakery.

Coles realised that the air-lock and refrigerator/freezer displays both have a large influence on electricity use because air-borne moisture entering the store condenses on cold display cases (giving up latent heat of condensation), increasing the heat load on the refrigeration system. This condensation has to be removed, often by electric heating to provide the heat for the phase change from liquid to vapour. This process adds to direct electricity use and further increases the load on the refrigeration system. In the case of freezers, the water vapour can go through two additional phase changes; from liquid water to ice, then back from ice to water. Each phase change is energy intensive.

Lessons and potential opportunities

Based on the initial analysis, it appears that keeping moisture from entering a supermarket with an air-lock has the potential to save over 700 MWh of electricity per store, per year (about a quarter of store energy use). Potential opportunities suggested by this early finding include:

- investigate installing air-locks at all stores;
- investigate whether air-lock design can be improved to achieve even greater savings;
- better control of outside air entering the store from sources other than the main entrance (e.g. loading docks, air-conditioning outside air make-up);
- removing moisture from incoming air, for example dehumidification coil in the air-conditioning outside air intake;
- removing moisture which has entered the store, for example dehumidification desiccant wheels or heat-pump drier;
- reducing water used in the store (e.g. cleaning or spraying fresh produce);
- zoning and separating areas with distinctly different temperature and humidity requirements; and
- examining how refrigeration systems collect and remove moisture and how this could be improved.

Further investigation

Further investigation suggested by this initial analysis and reflection includes:

- improving the accuracy of the electricity prediction model, such as by including additional stores and searching for other factors influencing electricity use;
- energy mass balance calculations to estimate the effect of air infiltration in a store;
- measurement of air flows into and from a store;
- examining some of the stores in which the model significantly underestimated or overestimated electricity use. It could be that some of these have a main entrance which is more exposed or more sheltered than the average store. A review of data held at headquarters or a quick visit to some of these 'outliers' may reveal an additional variable which should be included in the analysis; and
- including more stores in the analysis, such as:
  - more stores with air-locks; and
  - stores outside Victoria (it would be reasonable to expect higher savings in locations with high humidity and/or high ambient temperature).

Further activities

The Coles Energy Efficiency Opportunities assessment also included:

- preparing a background paper on the findings of this analysis;
- conducting a workshop with Coles staff and external people, with the aim of finding and evaluating energy efficiency opportunities with the potential to cut electricity use by 30% – 50%;
- extensive metering and monitoring of a newer Coles supermarket at Avondale Heights to explore further the relationship between food storage needs, humidity levels and overall customer comfort. While refrigeration was confirmed as the main energy user, there were some surprises. Energy usage was expected to be higher in Summer with greater refrigeration demands. However, Winter and Summer energy usage levels were similar. This suggested that more investigation was needed on inefficient air conditioning and cold air spillage from refrigerated cabinets; and
- designing and constructing a supermarket at New Gisborne in Victoria, incorporating more than 40 energy efficiency innovations, including daylighting, and airlocks at the main entrance and rear dock seals. Ongoing monitoring of the new store and incorporating the results in new stores' design process.

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